INTEGRATING FLOODPLAIN LIVELIHOODS INTO A DIVERSE RURAL ECONOMY BY ENHANCING CO-OPERATIVE MANAGEMENT: A CASE STUDY OF THE PONGOLO FLOODPLAIN SYSTEM, SOUTH AFRICA

Report to the
WATER RESEARCH COMMISSION

by

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WRC Report No 1299/1/08
ISBN No 978-1-77005-797-5

March 2009

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ACKNOWLEDGEMENTS

The following is a list of members of the reference group responsible for this project. We wish to thank them for their interest and helpful comments.

Dr Andrew Sanewe	Water Research Commission (Chairman)
Dr GR Backeberg	Water Research Commission
Dr M McCartney	IWMI (International Water Management Institute)
Dr R Fincham	University of KwaZulu Natal, Pietermaritzburg
Mr H Karodia	Department of Agriculture and Environmental Affairs, KZN
Dr R de Neef	Department of Agriculture and Environmental Affairs, KZN
Dr B Mwaka	Department of Water Affairs and Forestry, Pretoria
Mr Jerry Methula	Department of Water Affairs and Forestry, Pretoria
Mr Collin Zwane	Department of Water Affairs and Forestry, Durban
Dr SS Mkhize	National Department of Agriculture, Pretoria

Because participatory stakeholder workshops are a collective effort, names of the people responsible for the various roles in the stakeholder workshops component of the research are acknowledged in the relevant Chapters 4-7 and in the progress report submitted to the Water Research Commission (Jaganyi et al., 2003). We acknowledge greatly the contribution made by the following people:

(i) A special acknowledgement goes to Dominic Mitchell for the excellent professional approach taken to facilitate the sensitive issues expressed in all the stakeholder dialogue workshops and for enabling these stakeholder workshops to run smoothly.

(ii) Another special acknowledgement is to Dr Mark Dent for initiating stakeholder co-management training in stakeholder dialogue workshops.

(iii) Another special acknowledgement goes to Mr Zeph Nyati because without his support on the ground (at Mboza village) much of this work may never have happened.

(iv) To Clive Poultney, Charel Bruwer, Mike Coke, Donovan Kotze and Matthew McCartney, Beason Mwaka, Collin Zwane, and Jerry Methula and Kononani Khorrombi – thank you very much for supporting the stakeholder process.

(v) To Catherine Hanekom and Peter Conant – their enthusiasm and determination to save the floodplain for nature conservation will remain in my memory forever!!

(vi) To all stakeholders of the Pongolo river system who are affected by artificial flood releases from the dam (communities, private sector, government, researchers and various NGOs), thank you for the valuable contributions that have made it possible for certain aspects of this report to be produced. We thank you for your willingness to participate in the stakeholder process and the wisdom of realising and accepting the need to begin building a shared understanding of issues so that we can begin mapping the best way forward.

(vii) To all the students of the University of KwaZulu-Natal (UKZN), Pietermaritzburg who participated in the social survey on the Pongolo floodplain, and also to the seven students who participated by putting raw social survey field data into the computer.

(viii) To JK Gumede of the Malaria Control Programme, DoH Jozini: thanks a million for everything. JK made it possible for us to access communities at the local household level by attaching students from the University of KZN to the local community members of the Malaria Control Programme who then made it possible for students to get data at household level easily from various households. We also wish to thank Amos Malwane for making it possible to access areas that we may never have reached. God bless you.

(ix) To the WRC as the funders of this study, thank you. A special thank you to the Research Manager Dr Andrew Sanewe. Andrew, thank you for your patience. God bless you.

(x) A special thank you goes to Dr Doug Merrey and Dr David Molden of IWMI-CA. Thank you for providing additional funding resources that produced Chapter 5. Doug and David, thank you for your patience as well. God bless you.

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LIST OF ABBREVIATIONS

AEAM	Adaptive Environmental Assessment and Management
CA	Comprehensive Assessment of Water in Agriculture
CBA	Cost Benefit Analysis
CMA	Catchment Management Agency
DAEA	Department of Agriculture and Environmental Affairs KZN
DED	Department of Economic Development
DoA	Department of Agriculture
DoH	Department of Health
DTI	Department of Trade and Industry
DWAF	Department of Water Affairs and Forestry
EF	Environmental Flows
EIA	Environmental Impact Assessments
ES	Environmental Space
ESA	Environmentally Sensitive Areas
FAO	Food and Agricultural Organisation
FoE	Friends of the Earth
GWP	Global Water Partnership
Ha	Hectares
ICDP	Integrated Conservation and Development Projects
IDP	Integrated Development Plans
IFRs	In-stream Flow Requirements
ISCW	Institute of Soil Climate and Water
ISEW	Index of Sustainable Economic Welfare
ITQs	Individual Transferable Quotas
IUCN	International Union for the Conservation of Nature
IWMI	International Water Management Institute
LRAD	Land Redistribution for Agricultural Development
LWWP	Lubombo Water Ways Programme
MAB	Man and the Biosphere Reserves
MAP	Mean Annual Precipitation
MAR	Mean Annual Run-Off
MCA	Multi-Criteria Appraisal
MDBs	Multi-lateral development banks
MSY	Maximum Sustainable Yield
NIA	National Income Accounting
NWRS	National Water Resource Strategy
POWADETA	Pongola Water Association for the Development of Traditional Agriculture
RDM	Resource Directed Measures
RH	Relative Humidity
RSA	Republic of South Africa
SMS	Safe Minimum Standard
SO	Social Optimum
SSSI	Sites of Special Scientific Interest
SWML	Social Welfare Maximizing Level
TAC	Total Allowable Catch
TEV	Total Economic Value

TPTC	Tripartite Permanent Technical Committee
UNEP	United Nations Environmental Programme
UNESCO	United Nations Education and Scientific Cooperation
UNHDI	United Nations Human Development Index
WCD	World Commission on Dams
WHO	World Health Organization
WMA	Water Management Area
WRC	Water Research Commission
WUA	Water User Association

EXECUTIVE SUMMARY

APPROACH TO THE PROBLEM

The approach to integrating livelihoods into a diverse rural economy was understood through stakeholder dialogue workshops. The outcome from these studies was then linked to knowledge from literature reviews, underpinning certain aspects of the ecological, social and ecological economic thinking in order to, not only, illustrate the 'agriculture, water and the environment debate' within a 'water and society' context, but also, to identify knowledge gaps requiring further research.

To learn about how best we can go about integrating floodplain livelihoods into a diverse rural economy by enhancing co-management, requires us to think about the simple fact that, '*all people within a catchment depend on the river and all are affected by what others do*'.

This implies that we can only find effective solutions if we learn what people are doing in the catchment and how it is affecting others. This explains the fact that, although the study is about floodplain livelihoods, information from literature reviews is presented to illustrate the expected possible impacts that those other interest groups may have on floodplain livelihoods. This is a principal requirement for successful integrated catchment management.

Given the lack of capacity needed to implement catchment co-management and integration within water user association (WUA) structures in rural areas, and, in an attempt to contribute to capacity building, the projects title, goals and objectives are addressed in a manner intended to enable others to learn what integrating livelihoods into a diverse rural economy, by enhancing co-management, means in practice. Indeed, social anthropologists tell us that it is through learning and sharing of knowledge that humans can improve and make progress.

OVERVIEW OF THE REPORT STRUCTURE

Objective 1

"*Develop an understanding of the driving forces of the current situation and establish a shared vision for a preferred, achievable and sustainable state of the floodplain system*".

This objective is addressed in Chapters 1-7. The study is introduced through:

(i) Chapter 1 – motivation for the study,
(ii) Chapter 2 – location of the study area,
(iii) Chapter 3 – methods used in the study.

Understanding that the driving forces of the current situation was developed through a process of identifying key stakeholders affected by artificial flood releases from the dam and describing their dynamic histories by reviewing literature (Chapters 4 and 5), using scientific knowledge to develop a review of possible impacts (Chapter 5) and acquiring new knowledge through social surveys (Chapter 7):

(i) Chapter 4 – trends in stream flow which are linked to Pongolapoort Dam management interests,
(ii) Chapter 5 – ecological interests describing impacts of reduced stream flow on the floodplain wetland ecosystem,
(iii) Chapter 6 – the history of agricultural development interests,
(iv) Chapter 7 – floodplain natural resource use interests.

In order to begin establishing a shared or common vision for a preferred, achievable and sustainable state of the floodplain system, the diverse interests identified were presented and shared in facilitated stakeholder dialogue workshops in order to enhance a shared understanding of the various interests among stakeholders by attempting to answer the question of why others are behaving or acting in certain ways. This process contributed to building a shared understanding of the behaviour of others. It also led to the identification of shared or common or overlapping values between regulatory authority interests and community interests. The common values between regulatory authority interests and community interests formed the basis for initiating catchment co-management actions to solve the common problem. The key prioritised **common value identified** between regulatory authorities and communities for immediate catchment co-management actions was:

(i) Decision-making needs (management); the need for a formal decision making structure involved in development discussions, transparency, accountability, empowerment and an ability to help communities reach true consensus on divergent and conflicting issues. Specifically, all communities expressed the fact that they would not only like their voice to be heard within a formal structure in terms of the Water Act, but would also like to be empowered to make decisions and act upon those decisions themselves in order to have them met.

Implementation plan for the common value above was:

(i) The need to integrate water resource use for economic needs, social needs, and ecological needs in order to support a sustainable diverse economy.
(ii) The integration of economic, social and ecological needs requires a 'comprehensive reserve determination' on a catchment scale to be initiated so that a knowledge base is developed to support decisions taken to share water among the diverse interests on an equitable, efficient and sustainable basis.
(iii) Results of a 'comprehensive reserve determination' are intended to achieve integration, sustainability, equity and efficiency of use. However, it was highly likely that the results may not be implemented in the absence of co-management structures (CMAs, WUAs), which have not been empowered from the beginning to build a solid foundation for a decision making process that is healthy with good governance, consensus and with functional equity.

Short-term implementation goals with respect to decision making were to:

(i) Ensure that all affected groups were empowered to participate actively in the decision making process through co-management training materials, so that a culture of continuous learning to underpin co-operative governance and strategic adaptive management is instilled,
(ii) Initiate DWAF processes for setting up local formal co-management structures (WUAs),
(iii) Initiate building up a 'knowledge base' in accordance with DWAF reserve determination needs to support interest-based bargaining and effective decision making within these structures.

Objective 2

"Develop a strategic plan, founded on democratic processes and institutions, which facilitates decision-making that directs behaviour and endeavours towards attainment of the preferred state on the floodplain (define incentives that can encourage people to change behaviour so that equity, efficiency and sustainable use can be attained)".

This objective is addressed in Chapters 8-9. The key intention of this objective was to develop a strategic plan that can initiate a research programme that deals with providing decision-support to the various specific interests (Chapters 4-7), while providing insight into establishing co-management structures and processes that enable integration of livelihoods into a diverse rural economy (Chapters 8-9).

Objective 3:

"Mobilise parties (people, service providers and regulators, etc.) to initiate and sustain the processes required to transform patterns of behaviour (see ii above) so that they direct patterns of resource use towards sustainability".

This objective was largely achieved through stakeholder dialogue workshops and the knowledge obtained has been integrated in Chapters 4-9.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions reached and gaps identified within specific interests (Chapters 4-8) are listed in Chapter 9. The following is a summary of the conclusions and recommendations:

Trends in stream flow

A critical review of trends in stream flow, up to 2004, of the Pongolo River Floodplain is analyzed and discussed within the context of the South African water policy and water as a social good. The discussion attempts to provide clarity to the meaning of the reserve within the context of floodplain water requirements by linking the requirements of the new National Water Act No. 36 of 1998 with the state of stream flow, socio-cultural practices on the floodplain, ecological interests of wetland ecosystem, water

based developments, preliminary reserve determination results, hydraulics of artificial floods and other international studies of floodplain water requirements. The outcome of the analysis is (i) Gaps that require further research (ii) Improved clarity that can help managers and decision-makers to define a sustainable level of protection (economic, social, and ecological). (iii) Improved understanding of the driving forces of the current situation, which is needed to establish a shared vision for a preferred, achievable and sustainable state of the floodplain system. (iv) A conclusion is made that the floodplain is an aquatic ecosystem which must be protected by allocating adequate water requirements in order to secure ecologically sustainable development in the region.

Ecological interests: impacts of reduced stream flow on the floodplain wetlands ecosystem

A review of impacts of reduced stream flow (caused by upstream dams) on a downstream floodplain wetland ecosystem is discussed within the context of water as an ecological good stipulated in the new National Water Act No. 36 of 1998. While reduced flooding caused by holding flood peaks behind dam walls is beneficial for flood control, irrigation and hydropower production, reduced flooding can have catastrophic consequences on downstream alluvial wetlands. Reduced flooding causes wetlands to shrink, change vegetation structure and consequently the ecosystem goods and services produced changes. Key ecological values provided by wetlands are their cost free ability to absorb excess nutrient waste and sediments from economic growth (e.g. irrigation agriculture), pasture production, fertile soils for agriculture and wildlife and, their ability to regulate disease and disease vector populations. Under conditions of reduced stream flow, the impact of pollution on aquatic systems increases, which in turn increases their risk to ecological failure with subsequent negative impacts on social justice. A key concern of regulating authorities must be how to improve water quality and restore stream flow. Solutions lie in designing developments to enhance ecosystem services and in defining a desired level of wetland protection that achieves a balance between developments and maintenance of ecological integrity. Some suggestions are made and they include building an ecological knowledge base on a catchment scale as a first step. Ecological knowledge on its own cannot provide solutions to the problems and needs raised by the regulating authorities. Wise solutions and decisions can only be derived from integrated studies whose outcomes help to define what is equitable and efficient, and solve issues of representivity and sustainability. Therefore, it is necessary to strengthen co-management structures like Water User Associations and Catchment Management Agencies and enhance their capacity to invest in co-management initiatives.

History of agricultural development interests

Commercial farming on the Makhatini flats is limited by other competing needs for land and water resources (e.g. game reserves and game farms for eco-tourism and recreation; subsistence agriculture supporting a huge rural population who are largely poor and economic growth needs upstream of Pongolapoort Dam).

Striving to achieve sustainability, efficiency and equity among competing needs can be enhanced by diversifying the economy and by ensuring that the development policy takes into account ecological, biophysical and social justice factors. We found that, if implemented, policy statements suggested by

(Bembridge, 1991, 1993; Molden, 2007; Denison and Manona, 2007) can achieve the overall goal of fostering an appropriate economically viable and environmentally responsible irrigated and dry land agriculture, food production and rural development system that improves the quality of life of the people in the region.

Wise decision-making aimed at achieving the overall development goal should be informed through diagnostic institutional/organisational studies that improve the alignment of national government policies relevant to agricultural development to the goals and objectives within each local sub-system i.e. the socio-economic and cultural system in which farmers find themselves; environmental system; regional economic system, financial system, irrigation system, local agricultural production system-crops, livestock, irrigated pasture, aquaculture. The production system should be informed by farming systems research and adaptive on-farm research so that farming systems for both dry land and irrigation farming can be continuously improved.

Improvement of problem solving with respect to resource allocation will require that catchment-wide studies are initiated as per the DWAF reserve determination requirements so that a holistic knowledgebase can be built to enable stakeholders, managers and decision makers to locate and link individual problems within a catchment context. This implies that information from the six diagnostic studies should not only be aligned to national policies, but should also be linked and integrated into the hydraulic model of the catchment in order to inform decisions taken to improve resource allocation, improve systems, structures, strategies, and processes for achieving the desired developmental goals as well as fine tuning the reserve determination outcomes so that sustainability can be assured in the long term.

Floodplain agriculture and general natural resource use interests

The Pongolo River floodplain was the first system in South Africa for which water requirements (environmental flows) were determined with a view to sustaining the productivity of the natural environment so that it would continue to service the needs of people living nearby. The allocation of water from the Pongolapoort Dam was justified based on economic, social and environmental considerations, and was adopted for implementation by DWAF. Based on community perceptions in this study, it is clear that the allocation of water and its delivery since 1984 has not afforded the floodplain system the socio-economic and environmental protection envisaged. This does not mean that a decision should be taken to do away with flood releases because, even under the current reduced flooding regime, the floodplain has retained a small level of production that contributes to sustaining the basic needs of many people. Out of 247 people interviewed, 74% felt that the river and floodplain are important resources for drinking, bathing, crops, fishing, grazing, livestock watering and provision of other wildlife resources. The demographic data and the biophysical state suggest that decisions taken must not deny people access to the use of the floodplain resources without providing tangible workable alternatives because they could easily become highly vulnerable to the effects of droughts, hunger, poverty, and disease. The concern of managers and decision-makers should not only be focused on investing in agricultural irrigation developments but must also consider improving access to good quality water from Pongolapoort dam to promote the livelihoods of the huge subsistence economy. This implies that plans

must be put in place to restore some level of natural stream flow on the floodplain and to improve water quality.

Co-management actions for enhancing representivity and stability

The new water law is underpinned by the principles of ***equity, efficiency, sustainability and representivity***. An attempt to explain what representivity means in practice is made, particularly with respect to co-management and integration needed to achieve fair resource allocation within a catchment management context. We found that the new water law and the policies developed to implement the law are firmly grounded within the theory and principles that underpin the integrated perspective of community development. The law takes into account economic, social and ecological needs and requires that existing diverse human needs must be taken into account in decision-making about water allocations. It is presently ten years since the law was enacted, and although some water sectors perceive that they have not experienced the positive outcomes of the water law, it is premature to make conclusions that suggest a need to shift the law and the policies, because they have largely not been implemented to the full extent. There are many diverse conflicting values, strong self interests and consequent tensions. Resolving these conflicting values requires establishing suitable decentralized WUA units with: community, racial and gender representation; with legitimate governance; and empowered to practice community development principles required to build robust and resilient management systems that can resolve conflicts and enable fair resource allocation. Decentralized co-management institutions can in turn enhance the pace of development in the catchment through capacity building strategies that promote good leadership, good governance, and by finding resources to invest in new initiatives that promote new ways of doing things so that change can be experienced. A structure showing various levels of central and decentralized units is proposed together with actions for implementation.

Co-management actions and incentives for enhancing sustainability, efficiency and equity

The new water law is underpinned by the principles of equity, efficiency, sustainability and representivity. An attempt to explain what **sustainability, efficiency and equity** means in practice is made, particularly with respect to co-management and integration needed to achieve fair resource allocation within a catchment management context. The multi-value model or frontier provides a way of thinking about how best to make the necessary dynamic shifts, ranging from conservation on one hand to intensive production on the other, as we strive to achieve desired levels of ecological sustainability, equilibrium or balance. As production increases, impacts such as natural resource over-exploitation, environmental degradation, and increasing income differentials increase with increasing production in agriculture and industry. Market incentives increase production unless policies adjust incentives; production continues and can lead to ecological failure, and consequent social impacts. Notions of the ecological meaning of sustainability, equilibrium and balance should guide decisions and actions taken to achieve efficiency and equity of water resource allocations between economic growth and subsistence needs and the reserve. Decisions needed to make any necessary shift must be informed by results obtained from implementing the DWAF comprehensive reserve concept.

CHAPTER 1: INTRODUCTION

Rather than each government agency, private conservation organization, business, or individual landowner acting in isolation, ecosystem management envisions them cooperating to achieve common environmental conservation objectives
(Holling and Meffe, 1996).

1.1 MOTIVATION

Achieving water security for the sustainable production of food and the support of rural livelihoods while preserving natural resources and ecosystems is one of the key challenges of the early 21st century (Dialogue on water for food and environmental security – FAO, UNEP, GWP, WHO, IUCN, IWMI, CA, 2001). The challenge is to bridge the gap between the agricultural and environmental sectors and to forge agreed-upon, workable solutions (CA, 2002; Molden, 2007).

In South Africa, rural black communities are generally poor. In many instances, this leads to high levels of dependency on, and even the unsustainable use of natural resources. Although subsistence irrigation farming can contribute to poverty alleviation or reduction, Backeberg and Odendaal (1998) suggest there is a need for the development of a wide-ranging programme, which not only develops agriculture but also improves skills to earn non-agricultural income through the integrated development of the rural-urban link. A research programme should not only address the immediate needs of rural communities, but also initiate an ongoing process which creates awareness of viable alternatives. In addition, the complexity of the information needs of rural people require a multi-disciplinary or inter-disciplinary research effort (e.g. with co-operation between applied social and natural scientists and other scientists) if sound solutions for a sustainable environment are to be achieved. How can decision-support of rural people's water based activities (e.g. irrigation farming, fishing, tourism and recreation) be improved through research at various scales – farms, irrigation schemes or river catchments? The Pongolo River provides us with an opportunity to develop a research programme (as a pilot study) that meets such characteristics and provides insight into the establishment of co-management structures and processes.

The Pongolo River flood plain was the first system in South Africa for which water requirements were determined with a view to sustaining the productivity of the natural environment so that it would continue to service the needs of people living nearby. The allocation of water from the Pongolapoort Dam was justified based on economic, social and environmental considerations, and was adopted for implementation by the Department of Water Affairs and Forestry (DWAF).

To this day, DWAF continues to allocate water both to meet local subsistence needs (agriculture, fisheries, etc.) along the flood plain and those required by neighbouring Mozambique. The allocation of water and its delivery, however, have not afforded the floodplain system the socio-economic and environmental protection envisaged. In addition, there is widespread and growing concern in government and the private sector about the viability of the flood plain system and its ability to continue to supply the range of goods and services necessary for a diverse and sustainable local economy. The well-being of many people is at stake.

It is evident that, despite the scientific knowledge and technical skills required to manage the delivery of flows of water, which can sustain the diverse socio-economy, the management system has strengthened some sectors at the expense of others. Whereas in the past, there was an equitable distribution of access to benefits, some sectors now perceive that they are bearing costs and not gaining benefits. Agriculture on the floodplain has grown at the expense of fisheries, tourism potential and biodiversity conservation amongst others. Some stakeholders question the sustainability of agriculture as currently practised and express the view that new, more appropriate, agricultural systems are a prerequisite for social, economic and environmental sustainability.

The causes of the current inequitable situation are centred in our failure to achieve a co-operative; community-based approach to the management of the use of the goods and services associated with the floodplain system. Failure to apply scientific knowledge and the inability to effect corrective action with commitment in response to evidence of inequity and a move away from the desired state for the system.

In recent years, the methods of determining in-stream flow requirements (IFRs), also known as environmental flows (EF), have been refined (King et al., 2000, 2004) but our knowledge and understanding of the human system required to manage in-stream flow to achieve equitable and sustainable use of resources are still in their infancy. This lies at the heart of the problem on the flood plain.

The national water Act No. 36 of 1998 and improved technologies, such as those for determining IFRs, raise expectations for protecting and optimising the use of goods and services provided by rivers. Since evidence indicates that this can be achieved only when we have effective community based resource management, there is an urgency to develop our capacity to empower people to better manage the way they use resources.

The Pongolo River floodplain is a logical choice for research of this nature because, amongst other factors,

(i) The area has a very high potential for agricultural development expansion, with a good climate and suitable soils;
(ii) We have a very good understanding of how the ecosystem functions to deliver goods and services. This provides a good foundation for co-operation and trans-disciplinary endeavours;
(iii) We have failed to deliver equity and sustainability; this allows us to examine the real reasons for failure. These lessons will be relevant far beyond the Pongolo system;
(iv) The Maputaland Spatial Development Initiative (SDI) is promoting a diverse economy in the region in which the natural resource assets are highly regarded;
(v) Agriculture is being promoted on the flats which provide opportunities for “mainstreaming” subsistence agriculture on the floodplain, so that appropriate farming practices are introduced and supported;

(vi) We need to take the initiative to ensure that there is appropriate management of the river system, which has a high potential for contributing much to local socio-economic development.

1.2 AIMS AND OBJECTIVES

1.2.1 The aims of the pilot study were to

(i) Learn about promoting effective, co-operative governance around the sustainable use of river systems in rural areas;
(ii) Redirect the pattern of resource use on the Pongolo River flood plain towards a shared vision reflecting a diverse and sustainable economy;
(iii) Establish a confident and capable team of researchers drawn from previously marginalized sectors.

1.2.2 More specific objectives were as follows

(i) Phase I: Develop an understanding of the driving forces of the current situation and establish a shared vision for a preferred, achievable and sustainable state of the floodplain system. (*This objective is addressed in Chapters 1-7*);
(ii) Phase II: Develop a strategic plan founded on democratic processes and institutions which facilitate decision making that directs behaviour and endeavours towards the attainment of the preferred state on the floodplain (Define incentives that can encourage people to change behaviour so that equity, efficiency and sustainable use can be attained). (*This objective is addressed in Chapters 8-9*);
(iii) Phase III: Mobilize parties (people, service providers and regulators, etc.) to initiate and sustain those processes required to transform patterns of behaviour (see ii above), so that they direct patterns of resource use towards sustainability.

This will include:

(a) Promoting co-operative governance over resource use;
(b) Improving the leadership and management skills necessary to advance economic and social welfare;
(c) Providing access to the training necessary to enable people to accept and sustain new land-use practices;
(d) Protecting and rehabilitating natural resources through minimising destructive practices and the introduction of new systems;
(e) Instilling a culture of continuous learning to underpin co-operative governance and strategic adaptive management.

(*Objective iii was addressed through stakeholder dialogue workshops. The outcomes of the workshops have been integrated in Chapter 4-9)*

(iv) Phase IIII: Evaluate project activities to measure and quantify the extent of capacity building achieved from the beginning to the end of the project by monitoring, auditing and implementing corrective measures on a continuous basis. (*This objective was largely implemented through stakeholder dialogue workshops*).

CHAPTER 2: THE STUDY AREA

2.1 INTRODUCTION

A detailed description of the location, biophysical, ecological and socio-economic factors of the study area was reported in a technical report by Heeg and Breen (1982) entitled, '*Man and the Pongolo floodplain*'. The same study was later published in Heeg and Breen (1994), in an article entitled, '*Resolution of conflicting values on the Pongolo River and floodplain, South Africa*'. Other studies have also described the floodplain area in terms of hydrology/hydraulics, e.g. Pitman and Weiss (1979) and Basson and Beck (2002).

The following section describes the location of the floodplain and associated pans relative to irrigable lands adjacent to the floodplain on the Makhatini flats, and the extent of the river catchment from source to sea, showing the location points of DWAF stream flow gauge meters.

2.2 LOCATION

The Pongolo River has a catchment area of 7081 km^2. It arises in the Drakensberg escarpment at 2200 metres above sea level near Wakkerstroom (Fig 2.1). In the upper catchment, it passes through a region of extensive alien plantation forestry – a stream flow reduction activity (Le Maitre et al., 1997; Schulze et al., 1996; Taylor, 1997; Van Wilgen et al., 1997; Versfeld, Le Maitre and Chapman, 1998). It flows eastwards along the coastal plain and passes the Lebombo mountain range into the Pongolapoort Dam at an altitude of 75 metres (m) – a drop of 2000 m in a distance of 480 km, i.e. an average incline of 1 in 250 (Pitman and Weiss, 1979). The river then turns north, is joined by the Ingwavuma and Usutu Rivers and then continues northwards into Mozambique and becomes the Rio Maputo which enters the Indian Ocean at the Bay of Maputo. The floodplain covers a distance of 220 km from the dam to the sea and the bed gradient flattens to 1 in 3000 (Pitman and Weiss, 1979). This enables a reduction in flow rate, the deposition of some sediment load, and the flooding of extensive areas adjacent to the river course from the latitude of approximately $27^0 15'$S to form the Pongolo floodplain.

The first 25 km of the Pongolo floodplain in the south is narrow and almost restricted to the main river channel and its associated lower terraces. The pans (oxbow shaped lakes) Mayazela, Mfongozi and Nhlanjane, of significant proportion, found in the southern portion of the floodplain are sustained mainly by feeder streams, but only receive water from the Pongolo River during exceptionally high floods. The floodplain widens after 25 km, its width varying between 0.8 and 4.8 km, and averaging about 3 km over the 50 km distance to the Mozambique border (Fig 2.2). While some of the pans in this northern sector have local catchments, they are all under the direct influence of the Pongolo River, and dependent on its floodwaters for the bulk of their water supply (Heeg and Breen, 1982).

The area adjacent to the floodplain, beyond the reach of flood waters, is known as the Makhatini flats, where people's homes are situated (Fig 2.3); it is also where almost all the irrigable soils are available to the Makhatini irrigation canal system, downstream from the Pongolopoort Dam.

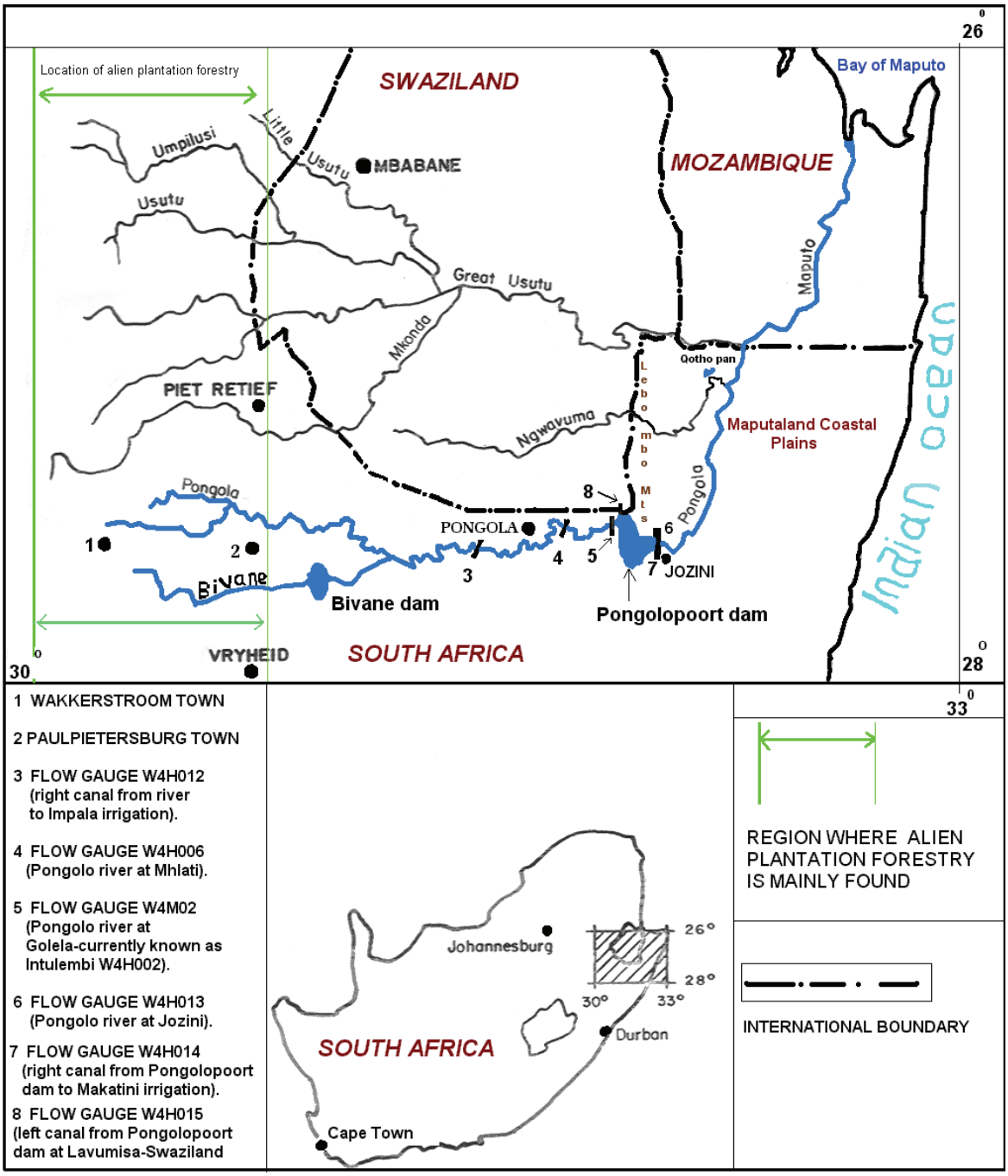


Figure 2.1: Location of the study area showing the Pongolo River from source to sea, and the major tributaries, the Usutu and NgwavumaRivers (Adapted from Pitman and Weiss, 1979).

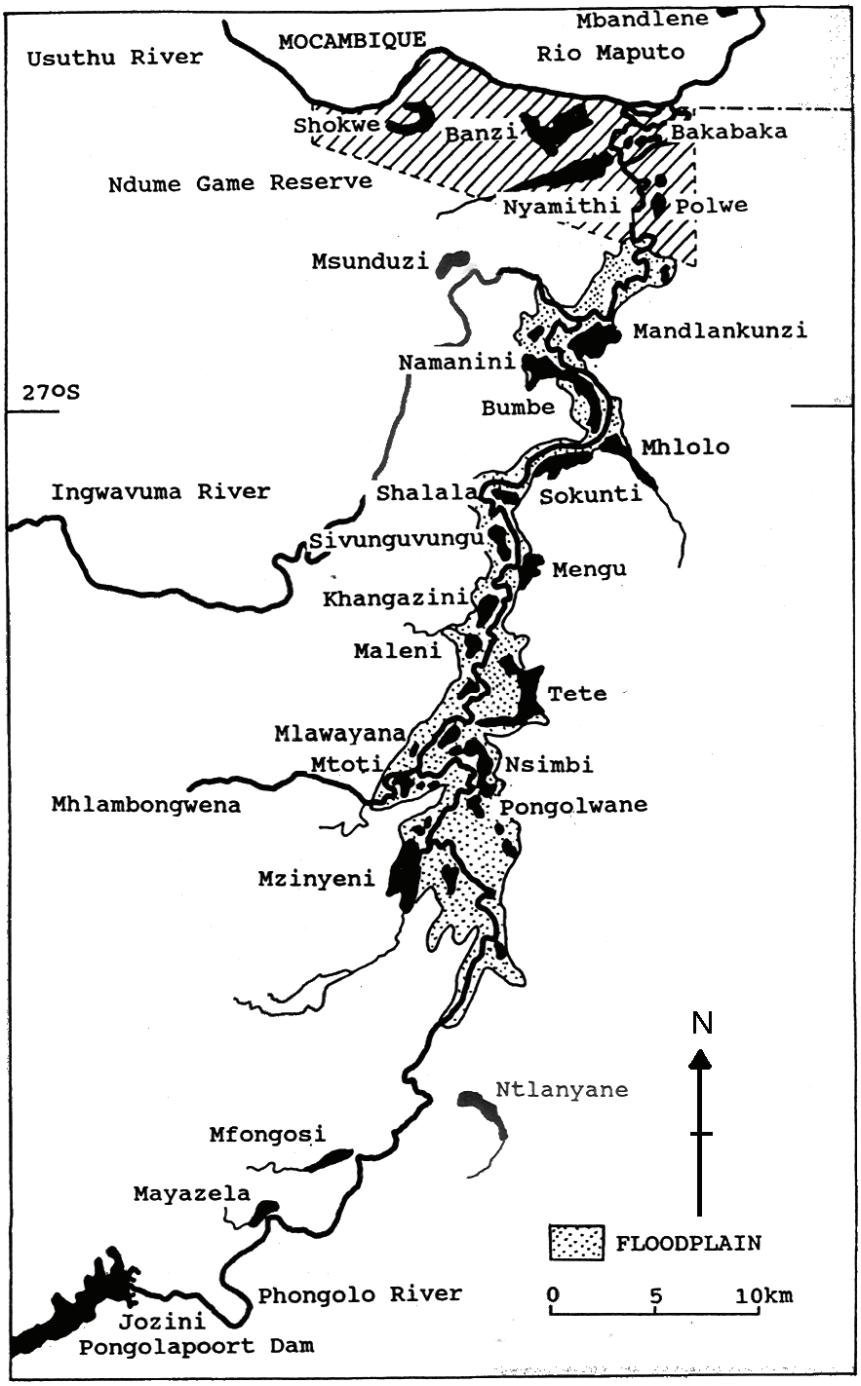


Figure 2.2: Pongolo River, showing floodplain pans and tributaries (from James, 1992).

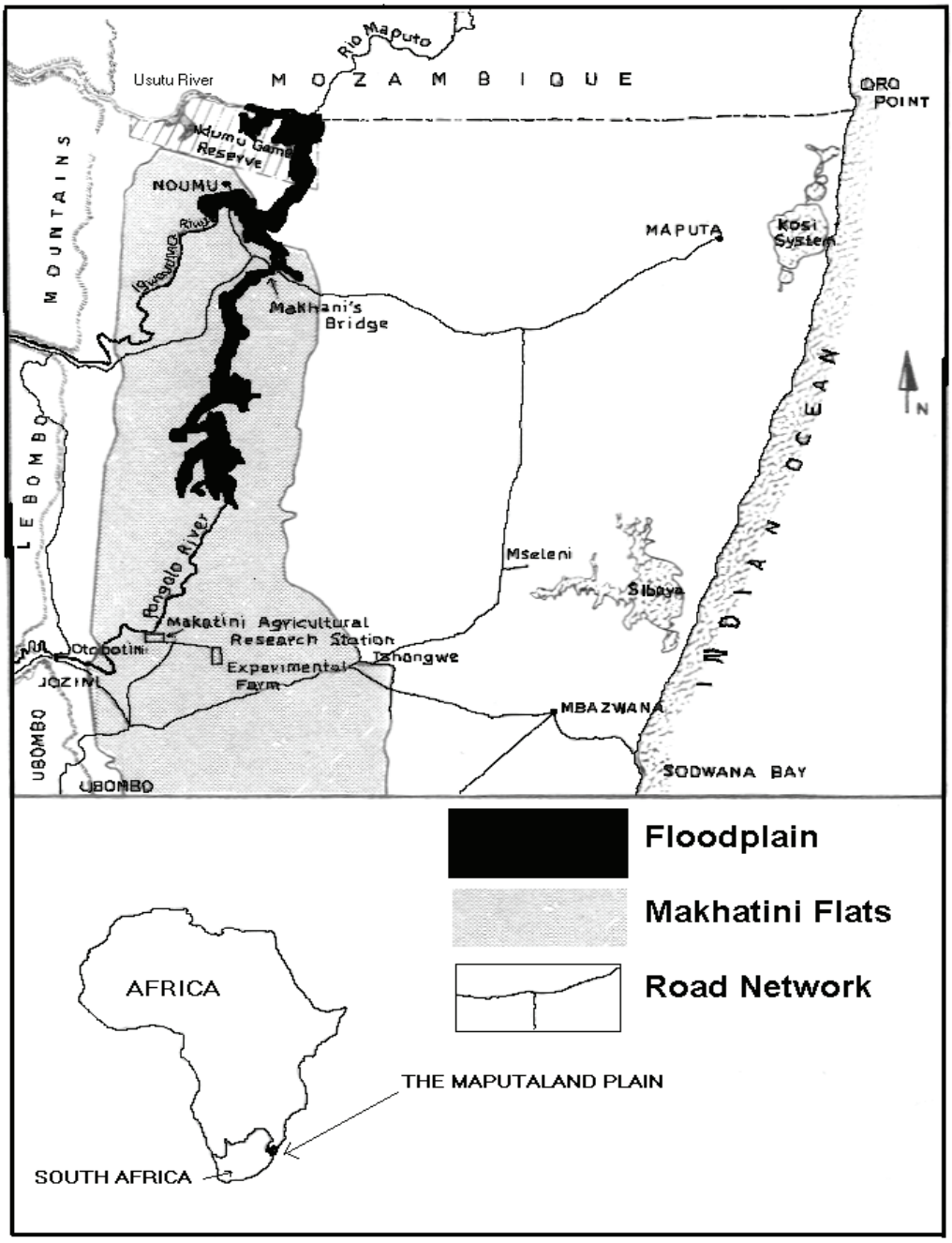


Figure 2.3: Location of the floodplain relative to the Makhatini flats as two distinct ecosystems. The Makhatini flats is the area adjoining the floodplain on both sides of the river and includes almost all irrigable soils available for agricultural development (from Heeg and Breen, 1982).

CHAPTER 3: METHODS

The following sections describe the approach to the problem of integrating floodplain livelihoods into a diverse rural economy.

3.1 LITERATURE REVIEW

A review of journal articles, relevant books and technical reports provided information on the theory and practice relevant to the relationship between biophysical and social issues and its dynamics; for example, the review covered the need to implement ecosystem management approaches and ethnographic studies of livelihoods so that the achievement of integrated sustainable development goals can be enhanced. A review of government technical reports, data from government sources on stream flow, soils, climate and disease, were used to describe the biophysical environment of the study area generally.

3.2 SOCIAL SURVEY OF FLOODPLAIN COMMUNITIES

A social survey of floodplain communities was carried out using the principles of ethnographic studies of livelihoods to identify the nature of floodplain resource use and various types of users, their perceptions and interests. Information was gathered through facilitated stakeholder workshops with communities affected by artificial flood releases from the dam, focus group discussions, review of minutes of DWAF annual flood release meetings with communities, field transect walks through the floodplain, a social survey at the household level using questionnaires. All these were supplemented with unstructured interviews with some key stakeholders who were interviewed more than once. Generally, information was gathered by living with the floodplain community for about three months, by becoming a presence, by entering into conversation, experiencing and doing what the community does (Chambers, 1981, 1983, 1997; Neuman, 2000).

3.2.1 Ethnographic studies of livelihoods

The approach to the social survey was supplemented by learning: research methods and principles underpinning 'ethnographic studies of livelihoods' and through a spiritual approach to community development'. This learning took place through personal communication and association with key leaders in the field of sociology (Prof Ari Sitas, University of KwaZulu-Natal, and Dr Gill Hart, University of California, Berkeley), in the field of anthropology (Dr David Szanton, University of California, Berkeley), and in the field of theology (Prof Gerald West, University of KwaZulu-Natal). Association with the various disciplines was made possible through the eSATI Research Cluster Programme (eSATI RCP 1999-2003). Amongst others, the following are some of the key principled methods that are required to implement social and anthropological research:

(i) Information should be gathered through ethnographic studies of livelihoods. This is a process of the reiterative gathering of information, continuously updating the key propositions, so that

the argument/key proposition can emerge in the way people's lives are played out. Information gathering in these studies requires that one becomes a presence, entering into conversation with the community, experiencing and doing what the community does.

(ii) The key forces and how they have been developed historically should be determined. How did these different forces get produced and how are they changing with time? Who are the stakeholders? Who are the individuals or organisations that may not have legitimacy? One needs to focus on the history of collective organisations. Who is dominant and who is subordinate? One needs to establish the structure of dominance, mapping out those who are excluded and those who are not; for example, how do the barons undermine the subordinates? Understanding these dynamics requires the need to be situated in the study area for some time. If tensions among self interests are high, public forums are not places to gather the real story. One needs to listen to stories outside of meetings as well.

(iii) An understanding of changes and relationships should be determined by repeated interviews (it is better to interview 6 people 60 times than 60 people at different times), engaging with people, doing things with/for people. This ensures quality research. Informal interviews tend to give good results as opposed to formal interviews. One should start by spending some time with the people being researched. One should understand what it means to be, for example, a cotton farmer. One should understand the constraints on, and propositions of, the people with whom one engages (Hendry, 1999).

(iv) One should desegregate (for instance, local structures) and look at how state and other elements in civil society make and re-make one another. One should look at power relationships, breaking open local structures and understanding changes over time. It is important to focus on the life histories of key people. What are the key pressures they experience? What was the organisational tenancy? Who was included and who was not, and what does that mean? Check for trends, for example, in the 'Order and the Manipulation of Chaos' (Mosko and Damon, 2005). For instance, critics of NGOs and poverty programmes point to the need to understand the role of intermediaries (special purpose vehicles) and power relations.

(v) Understanding poverty dynamics requires one to think in terms of access to resources. Levels of wellbeing are determined by demographic data.

(vi) The methods used must be reproducible (that is, someone else can repeat exactly what one did and get the same results).

(vii) The ways in which one draws general points of conclusions when making general claims/assumptions are important. Hypotheses should be matched to the scale of research. For example, one can make claims of issues at the global, or state level, but one must not forget what one set out to do at the local study sites. This is what is important for the study. One type of working with general claims is to use statistical indicators. One looks at relationships and connections in space and time in an attempt to understand the complex nature of livelihoods. One looks for linkages between many socio-economic variables. Generalisations are based on collections/clustering of variables instead of units. Connections about ongoing process become clear. For instance, it becomes easy to compare two environments in time and space. Within households, desegregate household interactions with

other households, groups, etc. 'How' are processes, histories, memories, and relationships happening?

3.3 STAKEHOLDER DIALOGUE WORKSHOPS

Stakeholder dialogue workshops were carried out in order to achieve the third objective of the study, "Mobilize parties (stakeholders, communities, service providers and regulators) to initiate and sustain the catchment management processes required to transform patterns of behaviour so that they direct patterns of resource use towards sustainability". Before transformation or change process(es) can be defined clearly, it is critical to understand the context in order to know how change can best be stimulated and sustained. The purpose of the stakeholder workshop was to bring all stakeholders together so that both stakeholders and project team researchers could build a shared understanding of perceptions and issues affecting the Pongolo River and floodplain system as a basis for the development of sound implementation plans. Therefore, the further purpose of the workshops was to promote dialogue among parties affected by artificial flood releases from the dam, namely, floodplain communities, dam property owners and regulation authorities, in order to begin building a shared understanding of the driving forces of the current situation and establish a shared vision for a preferred, achievable and sustainable state of the floodplain system. A facilitated workshop process was necessary for stakeholders to present their problem statements/concerns. As recommended in the methodological literature, actual words spoken by the stakeholders were captured verbatim in the dialogue process so that meaning and feelings could become explicit and easily shared and understood by others.

A facilitator as a "neutral party" can help people reach consensus and avoid getting bogged down in arguing about their respective interests. What is important is to get issues on the table. Designating them can come later. A professional facilitator, Mr Dominic Mitchell, carried out this function. His facilitation process is captured verbatim in Jaganyi et al. (2003). During these workshops, the project research team gave presentations as feedback of results arising from the research and the social survey. Participants also received training about the meaning of co-operative management. The message of the workshop helped participants to understand contrasting bargaining styles in the social process of water allocation, which is at the heart of integrated catchment management (Dent, 2003). This function was provided by the services of Dr Mark Dent who is a professional in management studies.

3.4 ECOSYSTEM MANAGEMENT APPROACH

The approach to implementing catchment co-management and integration comes from ecological or ecosystem management thinking. Christensen et al. (1996) explained the scientific basis of ecosystem management.

Grumbine (1994b, 1997) defined the ecosystem management approach, or thinking as, 'management that integrates scientific knowledge of ecological and biophysical relationships within a complex socio-political and values framework – towards the general goal of protecting native ecosystem integrity over the long term'. Holling and Meffe (1996) made suggestions about how ecosystem management can be put to action in the following statement, 'instead of each government agency, private conservation

organization, business, or individual landowner acting in isolation, ecosystem management envisions them cooperating to achieve common conservation objectives'. The design, analyses and interpretation of data and information in the study applied the thinking in the statements made by Grumbine (1994ab, 1997) and Holling and Meffe (1996).

Indeed, Yaffee et al. (1996) and Meffe et al. (2002) evaluated 100 ecosystem management projects in the USA and came to the conclusion that the ecosystem management approach is about creating better ecological outcomes and improved social dynamics among stakeholders (Yaffee et al., 1996). For example, in a large catchment along the coast, ecosystem management would link all owners and users from the tops of the hills at the source of the river to those at the seashore, including foresters, farmers, conservation biologists, hydrologists, business groups, townspeople, and the fishing industry (Miller, 1996; Primack, 1998a). Implied here is that, if water resources management on the Pongolo floodplain were to be successful at all, it would have to take into account all activities from source to sea.

3.5 COMMUNITY DEVELOPMENT THINKING

The approach to implementing catchment co-management and integration comes from ecosystem management thinking. Ecological thinking explains how nature functions and how it organises itself naturally. Ecological thinking is used to develop best practice values, principles and processes that underpin successful community development within catchment co-management structures. This view is strongly supported by the following studies: community development studies (Ife, 1991, 1999); social anthropology (Hammond, 1978); sociology (Haralambos and Holborn, 2000) and management studies (Senge, 1990; Senge et al., 1994; Senge et al., 1999).

The results of these reviews are linked to the Pongolo River floodplain co-management issues identified through the social survey and stakeholder dialogue workshops. In addition, a way of thinking about effective community development, and the actions needed to effect catchment co-management that can lead to creating diverse rural livelihoods is developed. The thinking developed helps to inform actions needed to implement (i) representivity and stability; and (ii) sustainability, efficiency and equity.

Other outcomes of these reviews are gaps that may need further research and key issues that managers and decision-makers need to be aware of to support effective decision-making on co-management and integration matters affecting floodplain livelihoods in a diverse rural economy.

3.6 ECOLOGICAL ECONOMICS THINKING

Some aspects of the ecological thinking and approach to environmental economics by Edwards-Jones, Davies and Hussain (2000) are reviewed and then related to the Pongolo River floodplain co-management issues. The purpose of the reviews is to inform thinking about sustainable economics and to help identify gaps that may need further research or key issues that managers and decision-makers need to be aware of in order to support effective decision-making on co-management matters affecting floodplain livelihoods in a diverse rural economy.

CHAPTER 4: TRENDS IN STREAM FLOW

4.1 INTRODUCTION

This chapter contributes towards the first objective of this study, "Develop an understanding of the driving forces of the current situation and establish a shared vision for a preferred, achievable and sustainable state of the floodplain system". The Pongolo River floodplain is an aquatic ecosystem, which requires protection by allocating an amount of water to sustain ecological and social needs according to the reserve requirements (DWAF, 1997, 1999, 2004). The challenge lies in defining quantity and quality of the desired level of protection. This chapter attempts to contribute towards defining the level of protection by describing the state of modified stream flow (up to 2004) and comparing it with virgin flows (i.e. stream flow before human developments like dams took place); the implications of this with respect to water based developments are then discussed.

4.2 THE FLOODPLAIN AS AN AQUATIC ECOSYSTEM

The floodplain as an aquatic ecosystem comprises the river course and those areas adjacent to it, the pans and land, which are seasonally flooded. Basson and Beck (2002) have illustrated a schematic river layout of inflows and outflows between the river and floodplain pans (Fig 4.1).

A cross section through the floodplain shows that it is characterised by a distinct vegetation structure (Fig 4.2). Each group of plants within this structure has built adaptation within itself that requires exposure to flood waters for a specific period in a year. This exposure to flood waters ranges from plants that live permanently in water (aquatic plants) to plants located at the high flood level margin that are exposed to flood waters for a short to rare period in a year. For example, fever trees (*Acacia Xanthophloea*) are exposed to floods rarely and hence form a distinct belt at the high flood level margin and are indicators of floodplain extent. Like any floodplain wetland, the vegetation structure along this moisture gradient (in-stream to dry land) can be characterized as aquatic communities→marshes→swamps→wooded swamps→terrestrial communities (Keddy, 2002; Gopal et al., 1990; Heeg and Breen ,1982).

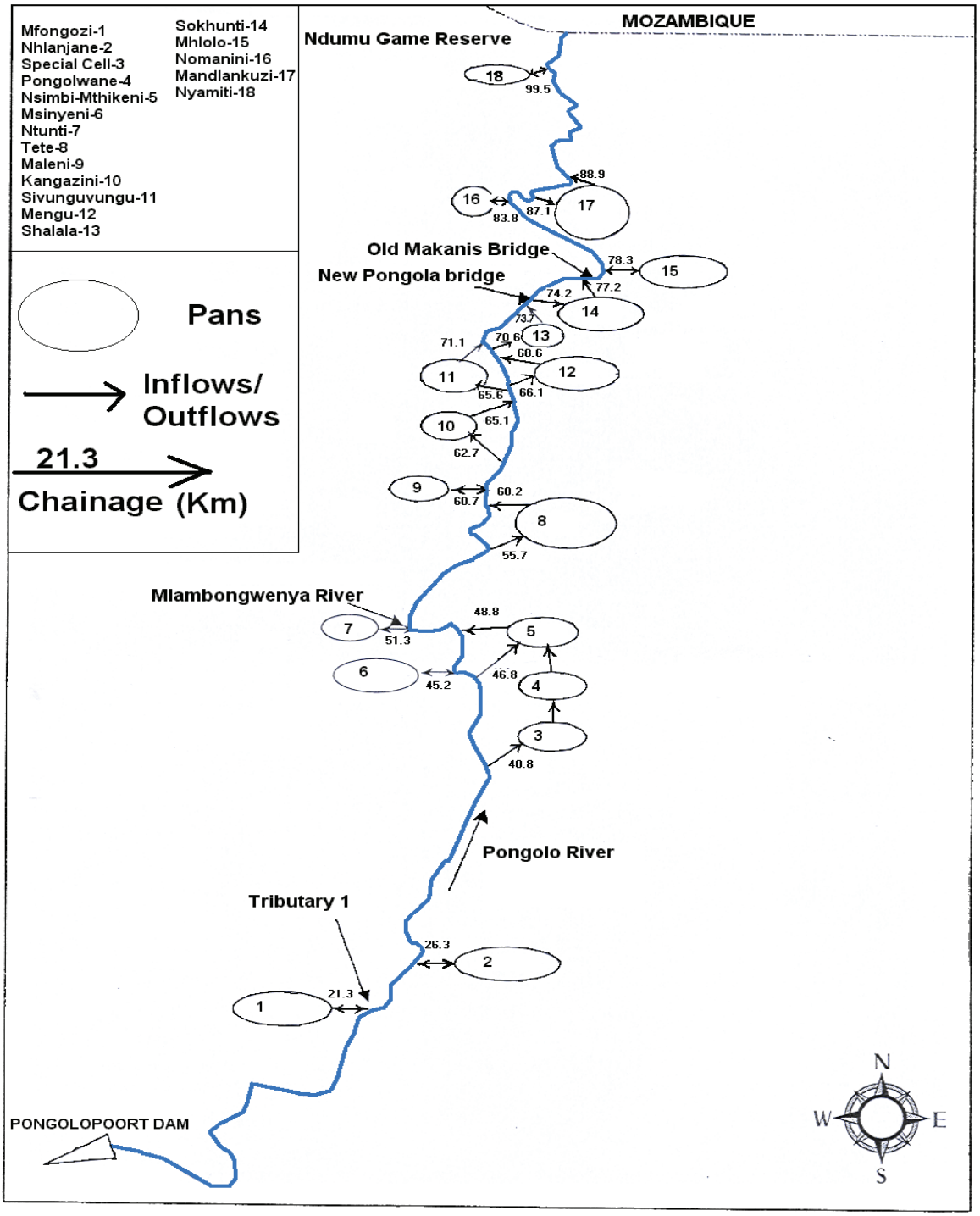


Figure 4.1: Pongolo River and pan layout: inflows (inlets) and outflows (outlets) (Basson and Beck, 2002).

Furness and Breen (1980) described in detail the distribution of plant communities of the seasonally flooded areas of the floodplain. The ecology of the floodplain system has also been described in detail by Heeg and Breen (1982); they cover key components of the ecosystem and their values with respect to plants (primary producers) and animals (secondary producers); the role that each one plays in maintaining floodplain production and nutrient cycling; and their response to a flooding regime. Plant terrestrial communities comprise trees, grasses and reeds. Aquatic plant communities comprise algal communities and hydrophyte communities (rooted plants). Animal communities comprise invertebrates, fish, crocodiles, birds, elephant, buffalo, rhino, antelope, hippo, livestock and man. Humans utilise these natural resources for fishing, crop growing, pasture, firewood, wild vegetables, medicine and bush meat. Sand forest is a dominant feature of the vegetation adjacent to the floodplain (Tinley, 1976; Pooley, 1993).

During periods of virgin flows, before Pongolapoort Dam was built between 1966 and 1972, it was estimated that there were some 65 named, and at least 25 unnamed, pans (oxbow lakes) within the 13 000 ha area which comprised the floodplain (Heeg and Breen, 1982). After maximum retention level, that is, immediately after the floodwaters of a flood sufficient to inundate the full extent of the floodplain had receded, the pans had an estimated collective area of 2 600 ha (Breen et al., 1978; Furness and Breen, 1980). The total flooded area, extending 10 414 ha (Heeg and Breen, 1982), became a huge fishery in summer (December, January, February). Flooding enabled the floodplain to receive an input of nutrient rich silt and energy into the aquatic system from terrestrial vegetation. Submerged terrestrial vegetation initiated various food webs while providing shelter for fish. Abundant food and shelter, coupled with warm water temperatures in summer, provided optimum conditions for fish production. Heeg and Breen (1982) estimated the potential production of this fishery to be between 500-750 tonnes per annum. Floodwaters receded slowly, exposing flood irrigated subsistence farmlands with soils that retained adequate moisture to sustain plant growth (crops, pasture) and wildlife during the dry winter season. Water level fluctuation from high flood level to maximum pan retention level was estimated to take a period of not less than two months (Fig 4.2). Seasonal floods carrying nutrient-laden silt provided flood irrigation and fertilization of subsistence farmlands. People planted crops on farm fields following the receding floods (Fig 4.3). While the floodplain became a huge fishery in summer, crops were grown on dry land ‘off’ the floodplain, and during the dry season in winter (periods of low stream flow), the floodplain retained adequate soil moisture to grow crops. Therefore, the livelihood strategy was diverse (farming, fishing, and hunting), and the effects of drought, such as crop failure and hunger, were reduced.

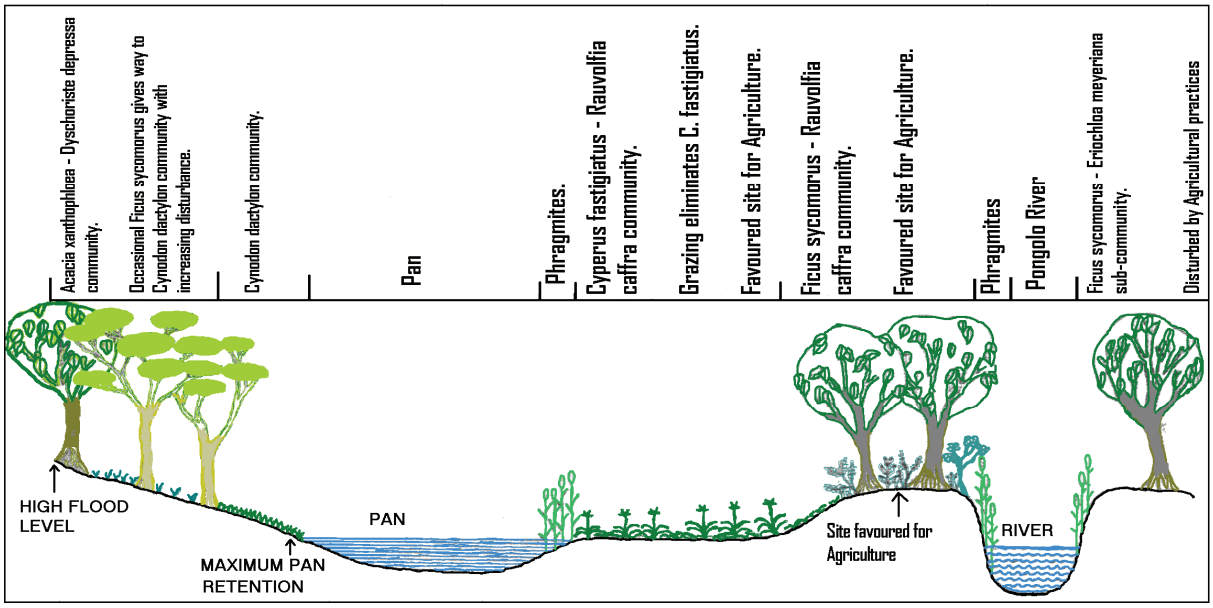


Figure 4.2: Cross section through the floodplain showing the distribution of typical plant communities (from Heeg and Breen, 1982).

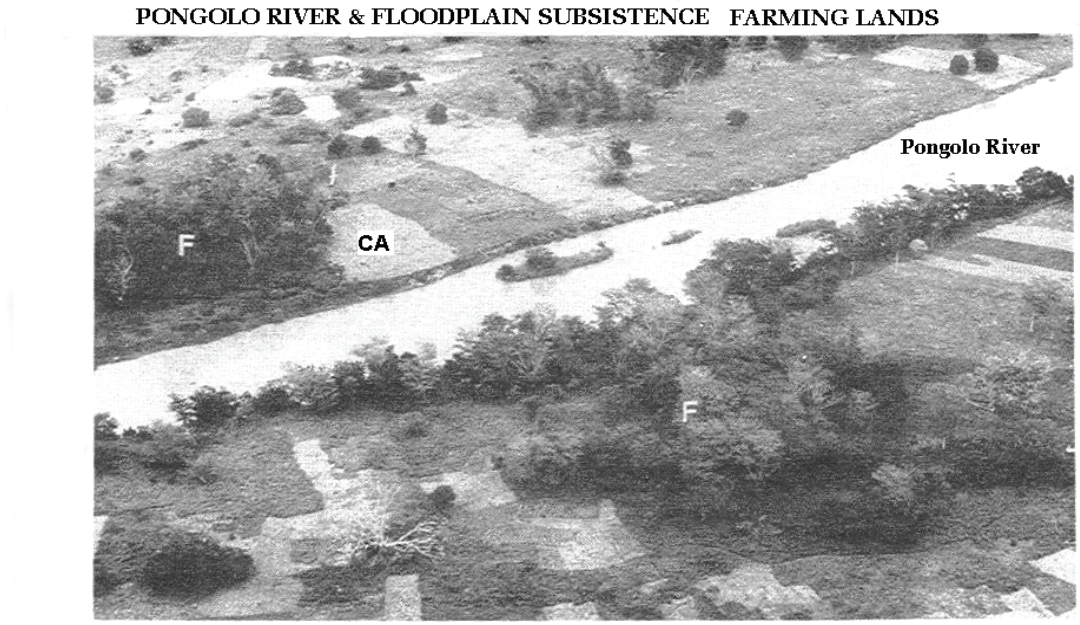


Figure 4.3: Aerial picture of subsistence lands on the floodplains that are seasonally flooded during the rainy summer season. Riparian forest (F). Cultivated fields (CA) (Photo by HD Furness in Heeg and Breen, 1982).

4.2.1 Estimating water requirements for the floodplain-period up to 1982

From a hydrology/hydraulics point of view, Pitman and Weiss (1979) developed a picture of what the natural flood peak looked like. According to them, accurate monitoring of the rise and fall of the river during flood started after 1949 (DWAF W4M02 gauge station). They analysed floods using maximum annual peak discharges over a 19-year reference period (1949-1961). Thirty-one hydrographs were analysed, and an average duration curve was derived and converted back to a hydrograph, which peaked at 690 m^3/s, with a typical time-to-peak of about 40 hours and a total flood volume of about 100 million m^3. The long-term mean annual peak, that is, the 2, 33 year event, was estimated at 540 m^3/s. Floodplain modelling, using the backwater cell model and manning equation to calculate flows showed that major floods inundate the floodplain, while minor floods hardly break out of the channel. The behaviour of two flood hydrographs was simulated in the model. One flood peaked at the rate of 690 m^3/s with a hydrograph volume of 100 million m^3 and an annual probability of occurrence of 32%. The other flood peaked at the rate of 345 m^3/s with a hydrograph volume of 50 million m^3 and an annual probability of occurrence of 62%. A third of all annual maxima were between these two values. Two simulations for each flood were made, one with all pans empty, and the other with water levels in the pans half empty (between bed level and maximum retention levels-MRL).

Results of the simulations showed that (i) pans that were completely recharged were initially overfilled – after peak stages were reached, the levels dropped slowly back to MRL. (ii) floods of the order of the mean annual event would recharge pans, even if at the start they were virtually dry. (iii) pans that were most difficult to fill were, in decreasing order, Mandlakunzi, Nyamiti, and Mhlolo. (iv) the quantity of water needed for a flood annually would amount to less than 10% (122 million m^3) of the mean flow of the Pongolo River (1220 million m^3). Further to (iii), Pitman and Weiss (1979) suggested that backwater from the Usutu River system when in flood could influence the behaviour of the lower reaches of the floodplain; for example, the Nyamiti pan could be recharged from the Usutu River, even with negligible flow in the Pongolo River. But, the fact that today the Usutu River has been impounded (for example, the Usutu-Vaal inter-basin transfer), the ability for the Usutu River effectively to recharge the Nyamiti pan is not known.

Pitman and Weiss (1978) noted the following limitations of the results of these simulations: (i) that the model was not adequately calibrated because it was based on MRLs determined by Breen et al. (1978) which were also preliminary (for instance they were related to pan bottom and not to mean sea level). (ii) The model was designed to handle only the short-term responses of the floodplain, that is, the behaviour during and shortly after the passage of a flood. Long-term responses such as soil-moisture requirement, that is, evaporation and seepage, which influence biological factors, were not modelled. Pitman and Weiss (1979) recommended that in order to permit model calibration and validation, field studies would need to be undertaken to monitor the rise and fall of water levels at key points throughout the plain during the passage of artificial flood release from the Pongolapoort Dam in the short term.

From a biological point of view, studies by Heeg and Breen (1982) described the natural flood regime and concluded that floodplain water requirements should mimic natural seasonal patterns in order to sustain and maximise diversity in the production of ecosystem goods and services. That is, any artificial flood

regime would have to mimic a pattern in which seasonal flows peaked with summer rains in December and February, with a higher flow rate in February, and occasional small peaks in July. In addition, it had been observed that pan margins, which flooded at very low flow rates (Table 4.1), therefore received floods more frequently, were very productive and very important for the people (for example, the Bumbe, Ngodo and Nomanini). These pans were very important for the production of crops, fish, and pasture as well as certain forms of wildlife. Because of this, it is necessary to know the duration of floodplain inundation, which maximized production during the natural flood regime.

To estimate the number of days a pan is in contact with the river in a year, as a measure of the duration of floodplain inundation, Heeg and Breen (1982) analysed flow intensity exceedance records and estimated the probabilities for the major pans of the system. One in two year events ranged from 7-118 days, and one in four year events ranged from 5-120 days. Unfortunately, these figures did not include pan marginal area flooded at every pan intensity, yet this is vital information if one needs to imitate natural flows and enhance the natural resource regeneration in the system. Breen et al. (1978) came up with terms such as low pan retention level (LRL), that is, pan levels during the dry season; maximum pan retention level (MRL), that is the level below which a pan loses contact with the river; high flood level (HFL), that is, pan marginal areas, beyond MRL. In their flood simulations, Pitman and Weiss (1979) equated MRL to weir sill elevation in their model, yet HFL, from a biological point of view is more important for natural resource regeneration on the floodplain than MRL. Therefore, if the floodplain has to be conserved, hydraulic engineers would need to consider HFL, and equate HFL instead of MRL to weir sill elevation in their models that estimate environmental flow requirements for the floodplain.

Generally, pans in steep-sided depressions required flow rates in excess of 85 m^3/s before receiving water, and were flooded less frequently, and for a shorter duration. Pans, which have extensive floodable margins, due to the flatness of the surrounding marginal land, were all flooded at a river flow rate of 85 m^3/s or less, and were inundated for 5 days or longer, 3 years in 4, and in excess of 40 days once in 4 years (Heeg and Breen, 1982).

Table 4.1: Flow rates of water released from the dam, at which individual pans are in contact with the river (based on data from Heeg and Breen, 1982). * pans with feeder streams originating from the Lebombo mountains west of the Pongolo River. Pan area, 25.8 ha.

	Flows (m^3/s)	**300**	**198.2**	**141.5**	**84.9**	**56.6**	**28.3**	**7**	**Total**
1	Mayazela* (25.8)	1	0	0	0	0	0	0	1
2	Mfongozi* (20.5)	1	0	0	0	0	0	0	1
3	Nhlanjane (37.9)	1	0	0	0	0	0	0	1
4	Ebugubugwini (8.8)	1	1	0	0	0	0	0	2
5	Pongolwane (9.9)	1	1	0	0	0	0	0	2
6	Shalala (49.2)	1	1	0	0	0	0	0	2
7	Matutwana (27.1)	1	1	1	0	0	0	0	3
8	Stutshanene (9.6)	1	1	1	0	0	0	0	3
9	Nsimbi (15.7)	1	1	1	0	0	0	0	3
10	Somtshatsha (11)	1	1	1	0	0	0	0	3
11	Mlawanyana (17.7)	1	1	1	0	0	0	0	3
12	Ntunte*(23.5)	1	1	1	0	0	0	0	3
13	Mhlolo (56)	1	1	1	0	0	0	0	3
14	Singulugwane (14.1)	1	1	1	0	0	0	0	3
15	Nhlanjane (16.8)	1	1	1	0	0	0	0	3
16	Nzila (14.2)	1	1	1	1	0	0	0	4
17	Mthikeni (45.4)	1	1	1	1	0	0	0	4
18	Pokolo (14.2)	1	1	1	1	0	0	0	4
19	Subane (59.7)	1	1	1	1	0	0	0	4
20	Tete (115.9)	1	1	1	1	0	0	0	4
21	Tetemcani (23.9)	1	1	1	1	0	0	0	4
22	Ndugozabo (14.5)	1	1	1	1	0	0	0	4
23	Ulusundu (50.4)	1	1	1	1	0	0	0	4
24	Maleni (46.5)	1	1	1	1	0	0	0	4
25	Kangazini (74)	1	1	1	1	0	0	0	4
26	Mengu (32.2)	1	1	1	1	0	0	0	4
27	Sivunguvungu (40.4)	1	1	1	1	0	0	0	4
28	Sokunti (101)	1	1	1	1	0	0	0	4
29	Mandlakunzi (255)	1	1	1	1	0	0	0	4
30	Ulujwe (37.5)	1	1	1	1	0	0	0	4
31	Polwe (22.9)	1	1	1	1	0	0	0	4
32	Nyamiti (183.4)	1	1	1	1	0	0	0	4
33	Bakabaka (23.2)	1	1	1	1	0	0	0	4
34	Bumbe (58.4)	1	1	1	1	1	1	0	6
35	Ngodo (22.1)	1	1	1	1	1	1	0	6
36	Namanini (63.4)	1	1	1	1	1	1	0	6
37	Mzinyeni* (74.2)	1	1	1	1	1	1	1	7
Totals (pans receiving water)		**37**	**34**	**31**	**22**	**7**	**4**	**1**	

Heeg and Breen (1982) concluded their studies by estimating the volume of water (from a biological point of view) required to sustain the floodplain, in its natural form, to be 126 million m^3. This value was broken down as follows: (i) 26 million m^3 per year as the amount of water required to maintain the

floodplain pans at MRL, based on an estimated annual evaporation of 2000 mm and a rainfall of 600 mm per year, allowing for seepage losses. (ii) an estimated amount of 100 million m^3 as the amount of water required for flood irrigation of subsistence lands; that is, to inundate the area between the levees and the adjoining high-lying areas (HFL) for reasonable periods (because productivity of the floodplain pans and floodplain lands results from floodplain inundation).

In order to make more water available for irrigation, Heeg and Breen (1982) suggested that the floodplain water requirements of 126 million m^3 could be optimised and reduced to 41 million m^3 by using a system of inflatable weirs, installed so that they could hold floodwater on the floodplain for longer periods to achieve the desired biological effect. With such a system, the water levels on the floodplain could be selectively raised and maintained without the wastage of a flow-through system; the saved water could then be made available for irrigation. Heeg and Breen (1982) felt that if such flood volumes were implemented according to an artificial flooding regime aligned to natural seasonal rhythms, they might meet environmental, economic and social needs. That is they would support a diverse economy in which ecological processes are sustained to support subsistence agriculture, fishing and irrigation.

4.2.1.1 Lessons learned

Lessons learned from this analysis shows that, recommendations made by Heeg and Breen (1982) to achieve a diverse economy suggested relocating some people into irrigation schemes, providing employment in irrigation schemes and urbanizing others and, in the short term, leaving a few people on the floodplain to ease exploitation pressure. In the long term, Heeg and Breen (1982) envisioned that the level of development would be such that the use of the floodplain for subsistence needs would be outlived and the floodplain would become purely a conservation area.

Today (25 years later) the floodplain is still an important natural resource (crops, fish, wildlife), supporting the basic needs of a huge rural population (Chapter 7) and cannot become purely a conservation area without providing the population with sound alternatives. Even at that time, Heeg and Breen (1982) carried out a cost benefit analysis of various livelihood scenarios 'on' the floodplain (subsistence agriculture, fisheries, tourism and recreation) and 'off' the floodplain (irrigation). Results of the cost benefit analysis showed that conservation of the floodplain as a development option was only justified if the water lost by irrigation agriculture to the floodplain could be greatly reduced and optimised through engineering solutions (installing a system of inflatable weirs) and by using the floodplain for a diverse combination of uses such as subsistence agriculture, fisheries, tourism and recreation.

The following section describes subsequent events (after 1982) that influenced Pongolapoort Dam management and also points to the fact that what was eventually implemented in terms of irrigation developments (Chapter 6) has benefited very few people, and hence the majority of the inhabitants still require the floodplain for subsistence needs. The vision of having the floodplain purely as a conservation area is still far from being achieved, unless a new plan, like that suggested by Backeberg and Odendaal (1998), is put in place. The plan put in place should recognise the fact that, irrigation farming can contribute to poverty alleviation in rural areas, but, it must be supplemented by the development of a

wide-ranging programme which not only develops agriculture but also improves skills to earn non-agricultural income through integrated development of the rural-urban link.

It is therefore very important that before decisions are made which assume that the use of the floodplain for subsistence needs has been outlived and that the floodplain should became purely a conservation area, or used for something else, decisions should be informed by cost-benefit scenarios that determine the most likely industries in the non-agricultural business sector of the South African economy that could contribute significantly to providing job opportunities to supplement subsistence agriculture and commercial irrigation in the region, while ensuring that an adequate amount of water (as a reserve) is left in the river and floodplain pans to absorb waste (effluents and nutrients) from these developments.

4.3 THE HISTORY OF PONGOLAPOORT DAM MANAGEMENT

4.3.1 Introduction

The stream flow required to sustain the floodplain depends on deliveries from the Pongolo River catchment commanded by Pongolapoort Dam. The fact that the Ingwavuma and Usutu Rivers are impounded means that the total water requirements of the floodplain have to be provided from the Pongolapoort Dam. It is therefore important to understand trends in dam levels because they not only influence artificial flooding requirements, but also downstream irrigation requirements.

The dam was built between 1966-1972. It is the fourth largest dam is South Africa with a capacity of 2445 million m^3. Analysis of trends in dam level data on an annual time step (Fig 4.4) shows four distinct periods. (i) 1970-1983: the dam could not be filled because there was no agreement with Swaziland, (ii) 1984-2000: the highest volume recorded (106%) during this period was in Feb 2000 and lowest in Feb 1993 (29%), and (iii) 2001-2004: since 2000, the dam's capacity has not dropped below 63% (1540 million m^3).

Analysis of the dam's level on a weekly time step showed that the highest dam drawdown could be linked to irrigation during the crop-growing season, October to March. Weekly time step data also shows clearly that drawdown for artificial flood releases, which frequently happen in September from 2002 onwards, are very small when compared to irrigation drawdown. A full socio-economic and political dynamic history of dam management is discussed below.

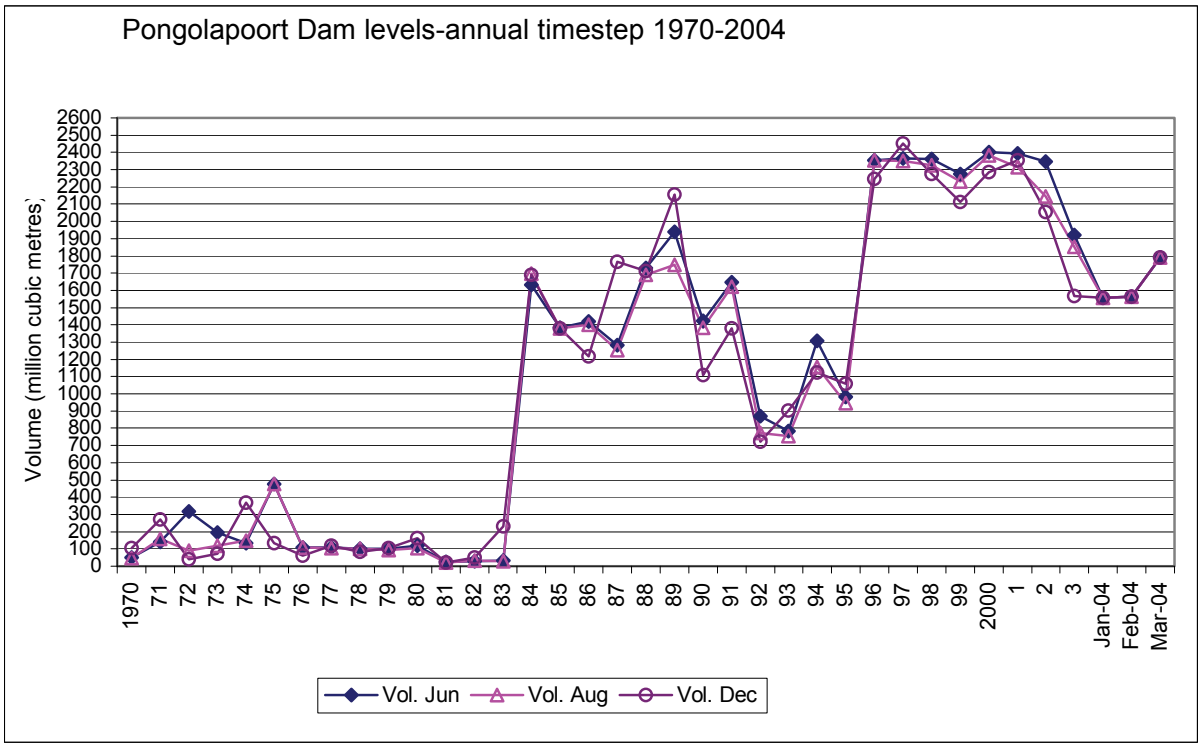


Figure 4.4: Dam level trends at Pongolapoort Dam – annual time step trends (Source data: DWAF database).

4.3.2 Management period with no stakeholder involvement (1970-1983)

The dam was kept low for the first 13 years of its life, because when the dam levels rose to above 30% full, it would inundate Swaziland territory and there was no official agreement between Swaziland and South Africa (Perkins and Arendse, 2002). An agreement was only reached in 1982 with Swaziland in return for a pumping scheme to supply water to a balancing dam at Lavumisa. The only way to keep the dam to below 30% full was to open the valves because the spillway gates on the side started operating after the dam reached 30% full. Releases of up to 85 m^3/s were made, which were some 10% of the peaks, which would have occurred naturally. Because all inflows were immediately released to keep the dam below 30%, prolonged releases of up to 90 days would happen (Perkins and Arendse, 2002). This interfered with downstream human activities such as crop losses and an inability to cross the river. In addition, during the period 1970-1983, plant species, not adapted to prolonged flooding, died, e.g. fever trees that characterize the edge of the floodplain are adapted to short periods of exposure to flooding (Bruwer, Poultney and Nyati, 1996).

In 1982 and 1983, severe drought occurred in the whole of South Africa and Pongolapoort Dam had less than 2% of its water capacity at the beginning of the 1983/84 summer season in December 1983. In February 1984, cyclone Domoina hit the catchment. Inflows peaked at 18 000 m^3/s and lasted approximately 24 hours. The dam being at 17% capacity prior to the event rose to 85% within 2 days.

Indeed, the dam played a major role in attenuating the flood, not only saving thousands of lives downstream but also saving the maize crop on the floodplain which was about to be harvested because it remained above water. On the other hand, containing Domoina in Pongolapoort Dam resulted in increased erosion of some pan inlets and outlets downstream of the dam, especially those with their own small catchment areas. According to Bruwer, Poultney and Nyati (1996) increased erosion of pan inlets was because these waters did not meet the Pongolo River backwaters, as would have been the case had the dam not existed. In addition, the Pongolo River cut new courses, where log and debris jams occurred.

There was a warning that a second cyclone (Imboa) was approaching, just after cyclone Domoina had struck in 1984. The radial gates were opened, releasing 1 480 m^3/s to create space for the additional inflows. Weather patterns changed and the second cyclone missed the catchment. This flow augmented the subsiding water level from cyclone Domoina. Floodplain water levels rose by up to 0.8 m inundating and rotting the maize crop, resulting in total crop failure for the floodplain communities and thereby enhancing poverty and hunger among the communities who had just experienced severe hunger over the previous two years of severe drought (1982, 1983). The release of water from the dam had not been communicated to the communities. As Bruwer puts it, "the release came as a great shock and caused confusion among the communities".

4.3.2.1 Lesson learned

Dam design and irrigation development took into account the interests of sugar investors (33 000 ha) located 'off' the floodplain on the Makhatini flats and ignored completely the interests of downstream floodplain communities by altering the natural stream flow which impacted negatively on the ecosystem services produced by the floodplain to support subsistence needs (crops, pasture, fisheries).

When the world prices of sugar fell in the mid 1970s, investors simply pulled out leaving behind a huge dam that had altered the natural flow of the river downstream, destroying a strong subsistence economy enjoyed for centuries. Had the dam design and irrigation development taken into account subsistence needs, perhaps the limits to irrigation development would have been set for the whole catchment area from the beginning. The dam wall would have been built higher so that it could effectively control floods, while ensuring that natural patterns of stream flow (at least in terms of timing) are maintained downstream. Fish ladders would have been installed to allow natural seasonal migration of fish and other forms of wildlife along the river. The dam wall would have been designed to release sediment with floodwater. The use of engineering solutions such as inflatable weirs would have been installed to optimise water used for flood releases by ensuring that smaller quantities achieve the desired ecological effect (by enabling appropriate seasonal water level fluctuations), so that more water can be saved for irrigation and other livelihood strategies.

4.3.3 Management period when operated by DWAF national (1984-1999)

This was the period when Charel Bruwer operated the dam.

Based on research carried out by natural scientists (Heeg and Breen, 1982) and hydraulic engineers (Pitman and Weiss, 1979), recommendations were made specifying an artificial flood regime, which could meet environmental, economic and social needs. The first artificial flood happened at the end of September 1984. From then onwards flood releases to maintain environmental needs on the floodplain and those of Mozambique were carried out by DWAF annually. DWAF also managed water releases from the dam for irrigation and for flood control.

A review of implementation of developments and recommendations suggested by researchers, e.g. Heeg and Breen (1982), showed that the development interventions in the area in terms of nature conservation schemes, agricultural irrigation development and floodplain water requirements that were eventually implemented, made things worse for the floodplain communities (Bruwer, Poultney and Nyati, 1996; Bembridge, 1991, 1993). Details are discussed under section 4.4, 4.5 and Chapter 6.

4.3.3.1 Lesson learned

Lesson learned from the experience above shows that all developments implemented in terms of dam developments, nature conservation reserves and irrigation schemes left a feeling of anger and bitterness among the local population (Chapter 6 and 7). Both nature conservation schemes (game reserves) and irrigation schemes relocated people from productive areas into unproductive areas and then denied them access to the use of natural resources they had enjoyed for centuries by putting up fences and by not providing people with alternative means of supporting their livelihoods. See detailed discussions in section 4.4, 4.5, Chapter 6 and 7).

A future practice of implementing development in the area should be guided by a good conceptual development framework, which takes into account interests of local communities. Development frameworks should be conceptualised using community-based principles (Chapter 8). Clearly the long term vision put forward by Heeg and Breen (1982) that the level of irrigation developments would be such that the use of the floodplain for subsistence needs would be outlived and the floodplain would became purely a conservation area had not been achieved by 2004. It shows that development goals should take into account the importance of the floodplain for local livelihoods and should therefore try to arrive at scenarios that balance floodplain conservation with development. It is therefore desirable to put in place alternative plans by implementing ideas suggested by Backeberg and Odendaal (1998). This argument is discussed further in (section 6.4.12 – industry, GDP and jobs).

4.3.4 Management period when operated by DWAF national and regional (1999-2004)

4.3.4.1 Introduction

The new National Water Act No. 36 came into effect in 1998. The purpose of the Act is underpinned by the principles of equity, efficiency, sustainability and representivity. The outcome expected from implementing these four principles is a balance between developments for economic growth and environmental stability. The implication is that the new National Water Act (No. 36 of 1998) and the National Environmental Management Act (NEMA) (No. 107 of 1998) should always be implemented together through water policies (e.g. DWAF water protection policy 1999) and environmental management policies (e.g. Environmental Impact Assessment-EIAs).

It is hoped that, if both policies are implemented, the outcome should be water allocated to all stakeholders in order to balance developments for economic growth with environmental stability in the long term.

4.3.4.2 The new National Water Act and National Environmental Management Act (NEMA)

According to the DWAF water protection policy (1999), a water resource is seen as a large and complex ecosystem made up of not only water, but also the physical aquatic habitats (in stream and riparian), the aquatic biota, the physical, chemical and ecological processes which link water-to-landscapes-to-living things in the catchment areas (Grumbine, 1994ab, 1997; Christensen et al., 1996; Holling and Meffe, 1996; Yaffee et al., 1996; Miller, 1996; Primack, 1998; Meffe et al., 2002; Keddy, 2002). It is this larger ecosystem, which provides us with goods and services. Water as a commodity for economic and social use: irrigation; industrial use; waste dilution; waste purification; waste transport; supplies of fish; recreation and eco-tourism; water storage and retention; in stream transport of floods; maintenance of species and habitats in landscapes and domestic use. These services rely on hydrological, biological and ecological processes, which can only function within certain limits. As long as a water resource is disturbed within these limits, it retains a certain amount of resilience, (i.e. the ability to bounce back and to continue providing ecosystem goods and services). However, if a water resource is overutilized or allowed to degrade too far, (i.e. too much water is taken out, too much nutrients and waste is put in, or the natural shape and structure are modified too greatly by erosion, sedimentation or habitat degradation), then the water ecosystem loses resilience and risks ecological failure and the ability to meet people's economic and social demands for use.

The National Water Act (No. 36 of 1998) uses the concept of the ‘reserve’ to protect the resilience of water resources, in terms of quantity, quality and assurance and defines it as the quantity and quality of water required to: (i) satisfy basic human needs by securing a basic water supply, for people who are now or who will, in the reasonably near future, be relying on or taking water from, or being supplied from the relevant water resource; and (ii) protect aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant water resource.

Implied here is that the quantity of water allocated for ecological sustainable development should adequately absorb pollution waste from economic growth (irrigation and industries). The levels of pollution from economic growth should not destroy the water resource to the extent that it cannot be used for other desired economic and social developments.

For example, high concentrations of saline water or acid mine water cannot be used for irrigation, livestock watering, or basic needs. Excess nutrients in water bodies cause excessive plant growth, which rots and requires advanced purification before it can be used for basic needs. Therefore, the type of use (irrigation; domestic purposes; livestock watering; nature conservation and fishing, tourism and recreation; and industrial use) informs decisions on what the reserve should be in terms of quantity, quality and assurance in order to protect the ecological resilience of that particular water resource.

Therefore, the primary purpose of the reserve is to absorb pollution effluents from economic growth while retaining some level of quality that can still sustain biological functions in plants and animals (crops, livestock, wildlife, fish, and man). In addition to absorbing pollution effluents, a reserve in rivers, pans and dams can provide secondary functions such as fish and wildlife production and improve the value of the landscape in terms of aesthetic beauty, which enhances the potential for tourism and recreation.

In the case of the floodplain as an aquatic ecosystem, seasonal flooding leads to water level fluctuations, which stimulate nutrient, cycling processes through plant and animal growth, hence contributing to enhancing the capacity of the reserve to absorb waste effluents with respect to excess nutrients. Ecological sustainability is enhanced through both aquatic (in stream) and terrestrial processes. Secondary functions arising from the use of the reserve for flooding are crop production, in addition to fish and wildlife production and improvement of the value of the landscape in terms of aesthetic beauty, which enhances the potential for tourism and recreation.

But because climate limits the amount of water available for use in a catchment per annum, water is therefore a limiting factor, as there is not enough water available to maximise economic production to full potential without risking ecological failure and consequently social injustice. Water is therefore a renewable, natural resource with a limited amount of resilience to the pressures and demands of use. In terms of sustainability, the implication is that water can only be used at the rate at which it can be replenished; input of waste should be limited to the level at which it can be adequately absorbed or purified, etc. Some of the implications are: (i) developments in a catchment should be maintained at the level where their impacts do not cause aquatic systems to loose resilience (ecological failure) with social injustice consequences. (ii) the level of developments in the catchment that reduce stream flow, e.g. irrigation and alien (exotic) plantation forestry should be controlled. (iii) only a certain number of people in a catchment can be allowed to irrigate so that sustainability can be maintained. Indeed, this thinking is strongly supported by the National Environmental Management Act No. 107 of 1998, which requires that, through environmental impact assessment (EIA), developers should show that their developments have taken into account economic, social and ecological factors before approval is granted.

A procedure for implementing the reserve, in accordance with the DWAF Water Resources Protection Policy (1999), is through management class guidelines, which determine the level of protection of a

particular water resource. A reserve determination for an entire catchment should contain delineated water resource units; each unit should have a management class (e.g. A, B, C, or D), each with a respective quantity of water and quality objectives (quality specifications and monitoring to ensure compliance). For example, a river with very high ecological importance and sensitivity is given management class **A –** often with large quantities of water allocated to imitate natural stream flow regimes and to ensure that ecological processes are functioning at full potential. A river given class **A** and high **B** (class I) can serve as special water resources to be used for basic human needs with minimum treatment. Class **B** and high **C** (class II) can serve as general water resources to be used for basic human needs with treatment. Class **D** and high **E** can be used as hard-working water resources, and can be allowed to retain at least some ecological function and integrity (D), safe for some non-contact recreation and some water uses; advanced treatment may be required for basic human needs.

The Pongolo River floodplain is an aquatic ecosystem, which requires protection by allocating an amount of water to satisfy the requirements of the reserve. The challenge lies in defining a desired level of protection for the floodplain by dividing the amount of water available on an equitable and efficient basis for ecological sustainability, for social use through satisfying basic human needs and for economic growth through developments (irrigation, industries).

4.3.4.3 State of stream flow

The following section describes the present state of stream flow and then links that knowledge to the challenges facing implementation of the 'reserve concept' for the river reach covering the extent of the Pongolo River floodplain.

4.3.4.3.1 Calculated stream flow volume for Pongolapoort Dam

Stream flows required to sustain the floodplain depend on deliveries from the Pongolo River catchment commanded by Pongolapoort Dam with a virgin MAR of 1070 million m^3 and also from the numerous small tributaries draining the eastern slope of the Lebombo Mountains, which make up a virgin flow of 40 million m^3 (Pitman and Weiss, 1979). The Pongolapoort Dam has enormous potential to affect stream flows downstream. This is because the dam's potential full supply capacity of 2445 million m^3 is more than twice the virgin MAR of the entire river catchment (1220 million m^3). In the past 88% (1070 million m^3) of the virgin waters of the Pongolo River were held by the dam (Pitman and Weiss, 1979).

Rainfall seasonality

Rainfall was analysed for the area downstream of the Pongolapoort Dam in the lower catchment using data from the DWAF database – Jozini at Pongolapoort Dam, reference period 1962-2004. Using the median statistic, the month with the highest run-off is February. Rainfall concentrates in summer with 44.22% (Dec, Jan, Feb), then spring 29.41% (Sept, Oct, Nov), then Autumn 22.94% (Mar, Apr, May) and winter has the least rain concentration 3.43% (Jun, Jul, Aug). Mean annual precipitation (MAP) (mm) is 690; max MAP-1341; min MAP-376.3. MAP trends based on data over 100 years (1900-2000) shows

that rainfall appears to be increasing (Dent, Lynch and Schulze, 1989; Lynch, 2003). It is important to note that during periods of virgin stream flow, flooding of the floodplain coincided with summer rainfall.

Annual rainfall

On a catchment scale, the area downstream of the Pongolapoort Dam (lower catchment) has a lower MAP (400-600) when compared with the mid-catchment upstream of the Pongolapoort Dam (600-800) and the upper Pongola-Bivane catchment (800-1000) (Schulze, 1997; Dent, Lynch and Schulze, 1989).

Simulated run-off

Simulated run-off in the catchment was quantified on a regional scale (Schulze, 1997). The run-off in the lower catchment located downstream of the Pongolapoort Dam is much lower when compared to that from mid and upper catchments (Table 4.2). Schulze (1997) points out that South Africa is generally a semi-arid region. Average run-off (stream flow) constitutes 9% of the total rainfall, with 91% of all precipitation evaporating again (Whitmore, 1971). This compares poorly with the world average run-off to rainfall ratio of 35%. Schulze (1997) points out that, 'not even a relatively wet province such as KZN with a 16.5% run-off ratio generates close to world average'. To exacerbate the run-off problem, its spatial distribution is highly uneven and the year-to-year variability very marked (Schulze, 1997).

Table 4.2: Mean annual precipitation (MAP) (Dent, Lynch and Schulze ,1989). Median annual simulated run-off (Schulze, 1997)

	Upper-catchment (mm)	Mid-catchment (mm)	Lower-catchment (mm)
MAP (mean annual precipitation in mm)	800-1000	600-800	400-600
Median annual simulated run-off (mm)	150-200	100-150	40-60 (upper area) 60-80
Driest year in 10 (mm)	100-150	40-60	20-40
Coefficients of variation (% of annual simulated run-off)	60%-70%	90%-100% (some areas) 80%-9%0	100%-120% (upper area) 80%-90%

Evaporation

In South Africa, it has been estimated that evaporation constitutes 91% of MAP, compared to 65% worldwide (Whitmore, 1971). Evaporation trends measured at Pongolapoort Dam are highest in summer. Evaporation mean monthly values (mm) are (mean 124.7, max 160.4, min 104.6, median 120). Evaporation annual totals values (mm) are (mean 1496.4, max 1924, min 1255.7). When rainfall (precipitation) and evaporation values are compared, evaporation is much higher than precipitation. Evaporation is high due to high wind speed, arid surroundings and high temperatures (e.g. mean highest maximum is 40.3 in January). Pitman and Weiss (1979) estimated that water levels in floodplain pans could be lowered by about a metre a year by evaporation alone. During periods of low flows, saline seepage water from underground

becomes concentrated and lowers the water quality for agriculture and domestic use. Indeed most pans dry out between seasons if not recharged. Therefore annual flood release of good quality water from the Pongolapoort Dam is required to dilute the salts in the pans so that the freshwater qualities can be sustained. The high evaporation rates can also influence availability of good quality water from Pongolapoort Dam for artificial flood releases and good quality water for downstream irrigation.

Calculated dam yield

Data from DWAF database gauge WR001 Pongolapoort reservoir at Jozini was analysed for trends over the reference period 1986-2004. The mean annual calculated stream flow volume for Pongolapoort Dam was found to be 795 million m^3, maximum value being 1746 million m^3 in 1996 and minimum value being 97.25 million m^3 in 2003. Calculated stream flow volume for the dam started decreasing dramatically from 2000 onwards.

To what extent has the dam yield decreased relative to the yield from the whole catchment, i.e. the virgin mean annual run-off (MAR) of the Pongolo River? Basson and Rossouw (2003) reported a value of 1 344 million m^3 (which includes an amount of 213 million m^3 contributed by the Pongolo and Ngwavuma Rivers in Swaziland). According to Midgley, Pitman and Middleton (1994), the virgin mean annual run-off into the Pongolapoort Dam is 1 293 million m^3. The DWAF WR90 uses a figure of 1160 million m^3.

Therefore, it can be said that the Pongolapoort Dam yield has decreased from a virgin value of 1060 million m^3 to a modified value of 785 million m^3 over the reference period 1986-2004. Dam yield figures reported by hydraulic engineers are 630 million m^3 (Hughes, 2000) and 645 million m^3 (DWAF Report No. PB WMA 06/000/00/0304, 2004). It is highly likely that these calculated values have taken into account factors such as rainfall, run-off and evaporation losses.

It is also highly likely that the decrease in dam yield from a virgin value of 1070 to a modified value of 645 can be attributed to upstream developments that reduce stream flow. Such as Bivane Dam, built in 1995 to supply sugar irrigators with water and increase the assured yield to Impala irrigation scheme, located 100km downstream. Impala irrigation scheme had an area of 17 000 ha in 2002 requiring about 170-200 million m^3. Alien commercial plantation forestry was using about 200 million m^3 in 2002. Other un-metered direct abstractions from the river may be taking place. Continued reduction of inflows into Pongolapoort Dam limits downstream development opportunities.

4.3.4.3.2 Abstraction trends

Trends in water abstractions from the Pongola River for upstream irrigation at Impala and downstream irrigation at Makhatini show that annual abstractions are increasing (Fig 4.5).

For example, in 2003, abstractions for irrigation upstream at Impala irrigation scheme were much greater (211 million m^3) than downstream abstractions at Makhatini irrigation scheme (57.5 million m^3). There were un-metered abstractions observed, particularly during periods of low flows in winter and early

spring (Chapter 7). Field observations downstream of the dam revealed the presence of some engine pumps in the river and there were no gauge meters to quantify how much is abstracted. For example, it was observed that water was being pumped from Ngondo Pan in late June 2004 to irrigate a field dominated by a cotton crop adjacent to the pan. It is highly likely that many people are putting un-metered pumps in the river, particularly during periods of low flows (July-September). Actual quantities abstracted from the full extent of the Pongolo River are therefore not known.

Highest abstractions happen over crop growing season, late spring, over summer to early autumn (October to March), and then they decrease over autumn to early winter (April, May, June) and then increase slightly during late winter to early spring (July, August and September). This trend indicates that both summer and winter crops are cultivated.

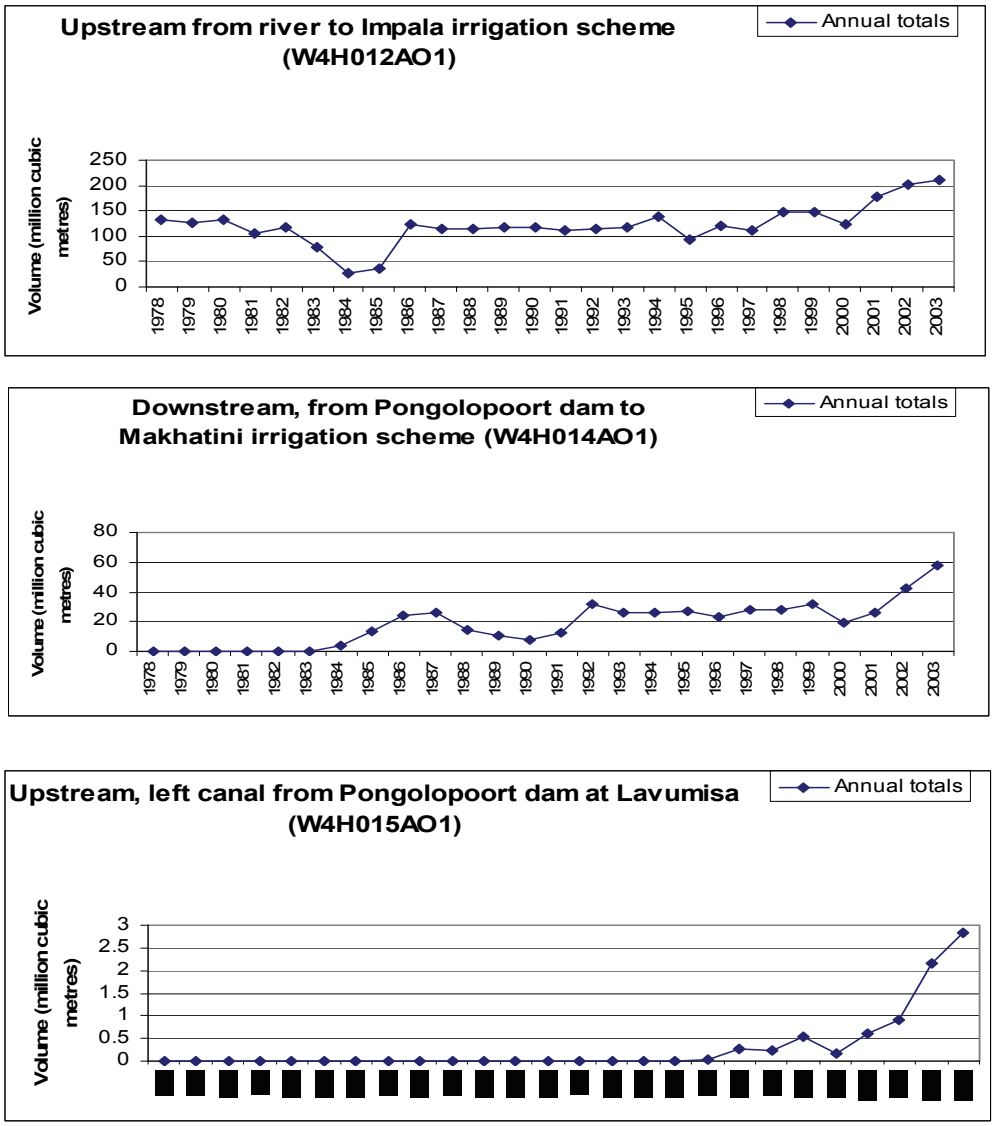


Figure 4.5: Abstraction trends (Source data: DWAF database)

4.3.4.3.3 Dam inflow and outflow trends

Maximum flows are important because they determine the ability of the stream to overflow the main channel and to flood the floodplain.

Analysis of trends shows that maximum annual outflows from Jozini (1986-1999) displayed variability and magnitude similar to that observed in natural flows (pre-dam patterns). This natural variability in pattern changed from 1999 onwards to a trend that is not natural by eliminating variability and hence stabilizing the flows (Fig 4.6). Maximum annual inflows then decreased dramatically from 2000 onwards, after the Bivane Dam development (Fig 4.6). Analysis of mean annual inflows and outflows (rate and volume) from 1986 onwards showed that the inflow into the dam was roughly equal to the outflow. Mean inflows and outflows started declining dramatically from 2000 onwards. Analysis of minimum annual inflows and outflows show that what is flowing out from Jozini is less than the amount flowing in from upstream and this is in turn much less than minimum virgin stream flow (1930-1969).

Seasonal stream flow patterns of dam inflows and outflows in terms of rate (m^3/second) were compared with seasonal rainfall patterns (Fig 4.7). Because of the fact that normal patterns should show a linear relationship between rainfall and stream flow, it is clear that patterns of downstream outflows from the dam at Jozini are abnormal when compared with rainfall. Virgin stream flow, before dam development at Golela and modified upstream flows at Mhlati, can be considered normal due to the linear relationship observed between rainfall and stream flow. Although modified stream flow at Mhlati may have reduced in magnitude, this can be considered normal in terms of seasonal timing, which matches rainfall.

In terms of flow rate (m^3/second), the summer peak shown in virgin flows at Golela (Dec-148, Jan-161, Feb-251) is held behind the dam wall for irrigation and this is shown by the low peak in artificial stream flow at Jozini over the same months (Dec-15, Jan-23, Feb-97). Similar trends are observed in terms of maximum volume (million m^3) of the summer peak at Golela (Dec-353, Jan-315, Feb-656) and at Jozini (Dec-200, Jan-182, Feb-452).

The normal natural seasonal flow trend is such that flows decrease from summer through to winter, i.e. summer max flows (Dec, Jan, Feb) are much higher than autumn max flows (Mar, Apr, May) which are in turn higher than spring max flows (Sept, Oct, Nov) and winter has the least max flows (June, Jul, Aug). In terms of quantities, the natural stream discharge over the reference period in terms of rate (m^3/s) were summer (560), autumn (311), spring (307), winter (123). Quantities in terms of volume (million m^3) were summer (1324), autumn (1246), spring (727), and winter (504).

The abnormal artificial seasonal flow (rate and volume) at Jozini has shifted in timing when compared to natural patterns in terms of timing; summer flows are experienced in spring (316 m^3/s), autumn flows are experienced in autumn (216), spring flows are experienced in winter (154) and winter flows are experienced in summer (135). Artificial volumes (million m^3) are spring (854), autumn (775), winter (551) and summer (834). Spring has the highest stream discharge (m^3/s) because artificial flood releases from the dam normally happen in late September to early October. Summer has the least stream

discharge because summer is the period when irrigation demands are very high. Artificial winter stream flow is much higher than natural winter stream flow.

A summary of the extent of change between virgin and modified flows from the trends above is illustrated in (Fig 4.8) and key statistics are shown in (Table 4.3).

Based on scientific evidence available (Welcomme, 1979, 1986; Keddy, 2002**),** this abnormal shift in stream flow pattern (timing, reduced volume, stabilizing flows), has great potential (i) to affect the effectiveness of flood irrigation of subsistence lands on the floodplain for crops and pasture production. (ii) to influence germination, growth and abundance of seasonal floodplain wetland plants and animals (fish, livestock, wild animals and man) that depend on these plants for food. (iii) to influence disease and disease vector populations (section 5.3.7). Results of a social survey (Chapter 7), based on community perceptions, confirmed that indeed the ability of the floodplain to produce natural resources had decreased, although the actual extent of reduction in production has not been quantified.

It can be concluded that reduction in stream flow, observed in artificial stream outflow from Pongolapoort Dam, has taken into account irrigation interests and the use of the dam for flood control but has completely ignored floodplain ecological interests (i.e. in terms of reduced magnitude and shifted seasonal timing of artificial flood releases).



Figure 4.6: Dam maximum discharge rate of inflows and outflows before and after dam development. Dam inflows (1930 to 1968 – Pongolo River at Intulembi W4H002 and 1969 to 2004 Pongolo River at M'Hlati – W4H006). Dam outflows (Pongolo River at Jozini 1986-2004 W4H013). Data missing 1947, 49, 50, 59 and 61; 1983,84,85. (Source data: DWAF database).

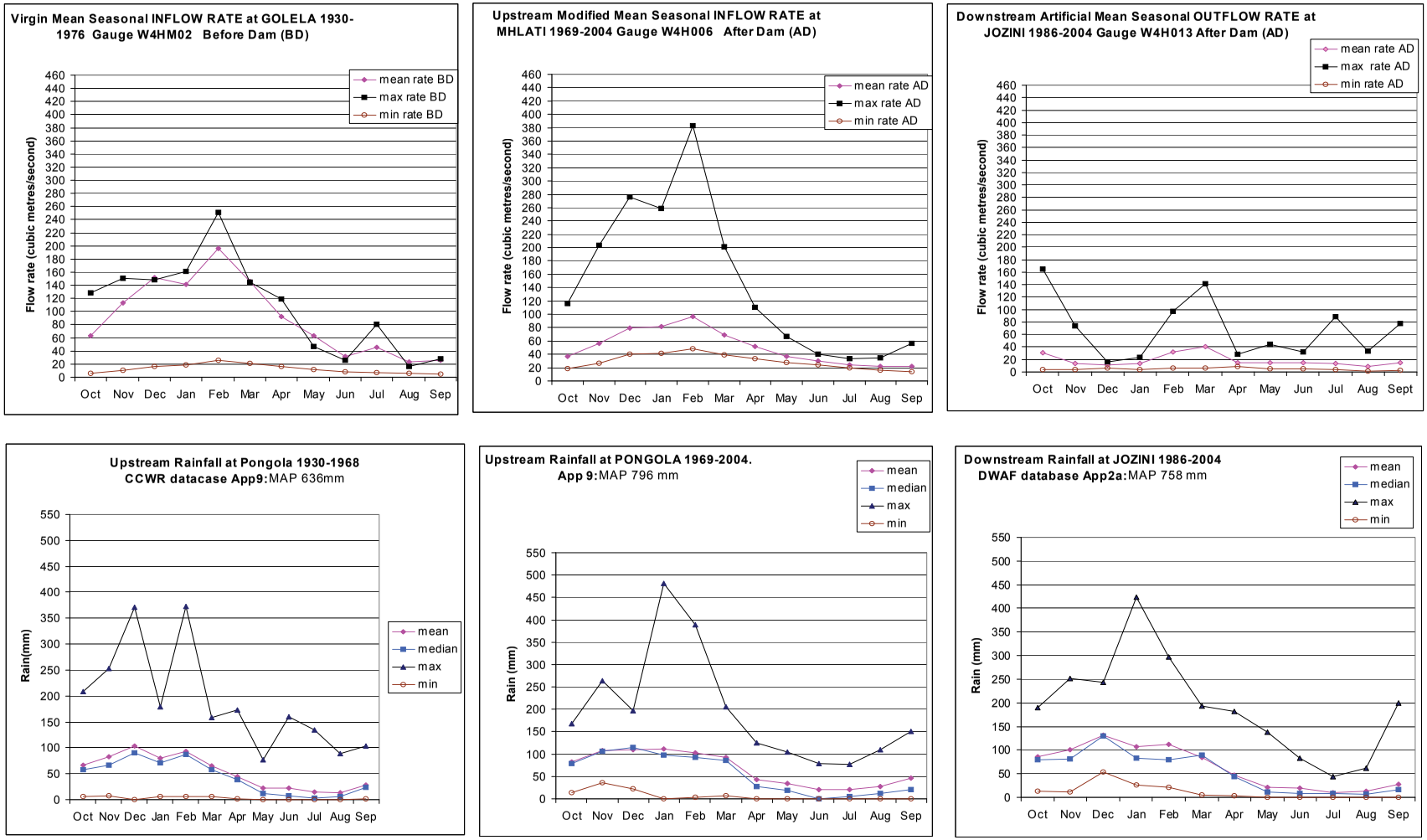
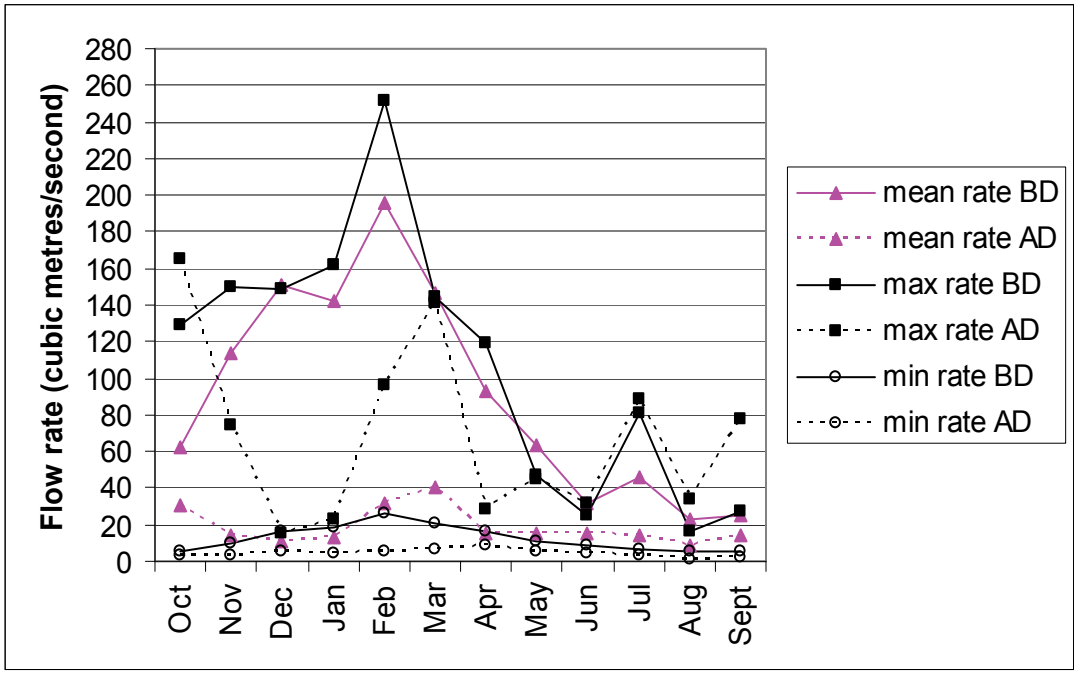


Figure 4.7: Seasonal patterns of Inflows and Outflows in terms of discharge rate First column-downstream **virgin** stream discharge and rainfall at Golela. Second column-upstream **modified** stream discharge and rainfall at Mhlati. Third column-downstream **artificial** stream discharge and rainfall at Jozini. (Source data: DWAF database).



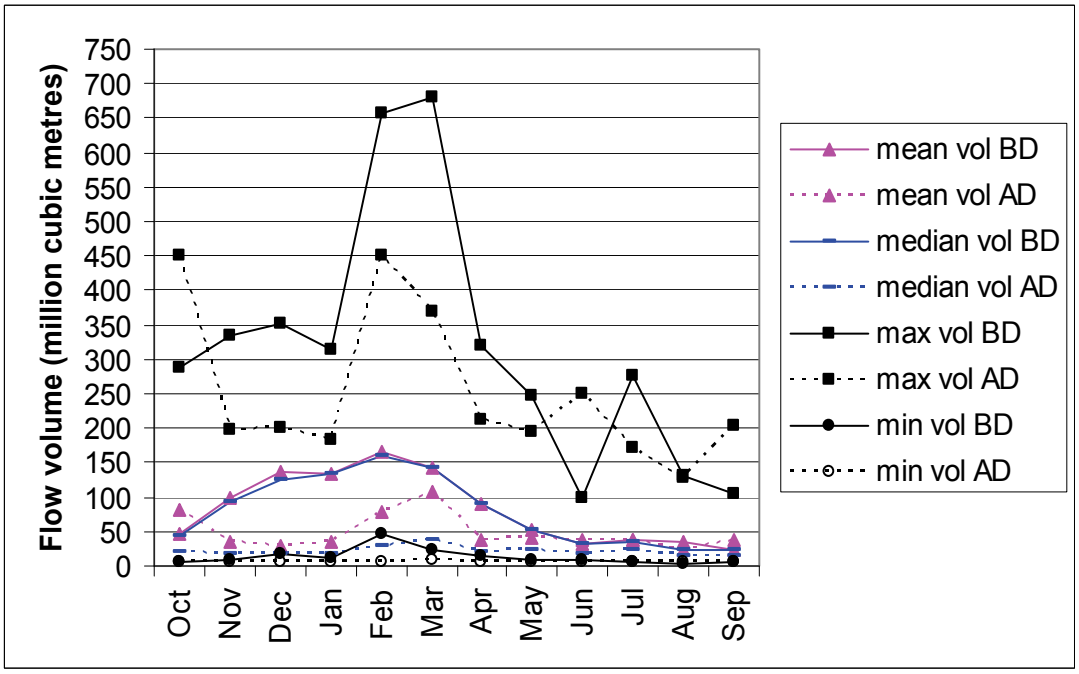


Figure 4.8: Summary of the extent of change between virgin and modified stream flow on the floodplain. Virgin Flows – Before Dam (BD) 1930 to 1968-Pongolo River at Intulembi (W4H002) with a MAP of 470 mm. Modified Flows – After Dam (AD) 1986 to 2004 – Pongolo River at Jozini (W4H013) with a MAP 796mm (source data: DWAF database).

Table 4.3: Key statistics of flow changes from virgin flows to modified flows (Raw data was sourced from the DWAF database)			
	Virgin flows 1930-1968. Makhatini agric. sta. Golela W4h002. (before dam development)	Modified flows 1969-2004. Upstream at Mhlati W4h006 (after dam development)	Artificial flows 1986-2004. Jozini W4h013 (after dam development)
Rainfall (mm) MAP	470	796	758
Volume (million m^3)			
Annual totals			
mean	937	1520	581
median	937	1067	533.8
max	2544	4397	1548
min	308	157	180
Mean Monthly			
mean	78	128	48
median	78	89	44
max	212	366	129
min	26	13	15
Flow rate (m^3/second)			
Mean stream discharge	GOLELA W4H002	MHLATI W4H006	JOZINI W4H013
mean monthly mean	87	49.46	18
median monthly median	51	36.17	8
mean monthly mean max	217	142.7	50
Mean monthly min	26	4.272	6
Maximum stream discharge			
Annual Max mean	448	500	476
Annual Max median	310	426	505
Annual Max max	1975	1438	767
Annual Max min	107	59	52
Minimum stream discharge			
Annual Min mean	3	10.32	0.241
Annual Min median	3	0.821	0.162
Annual Min max	11	47.09	0.568
Annual Min min	0	0.016	0

4.3.4.3.4 Use of hydraulicity index to quantify stream flow changes

The hydraulicity index is a measure of the relationship between rainfall and stream flow (Kuper et al., 2003). Rainfall increase should result in stream flow increase. This relationship between rainfall and stream flow is shown using a rainfall index (ratio of mean rainfall of a given year and the mean rainfall

over the entire reference period) and a hydraulicity index (ratio of the mean flow of a given year and the mean flow over the entire reference period) (Kuper et al., 2003). If the hydraulicity index of a river declines largely than the rainfall index over the same period, such a non-linear relationship may mean that any of the following is happening in the upper catchment: droughts, depletion of groundwater reserves, dams, extensive irrigation, or extensive alien plantation forestry or other stream flow reduction activities. For example, using such an analysis, Olivry (1995) was able to attribute the non-linear relationship between rainfall and flows to the depletion of groundwater reserves in the upper catchment of the inland delta of the Niger River in Mali. Much later Kuper et al. (2003) attributed the increasing non-linear relationship to dams in the upper catchment of the Niger River in Mali.

Hydraulicity based on mean stream discharge

Analysis of the relationship between rainfall in the upper catchment at Pongola (DWAF gauge W4E002) and downstream – managed mean outflows from Pongolapoort Dam at Jozini (DWAF gauge W4H013) 1986-2004, was compared with virgin flows at Intulembi\Golela (gauge W4H002) 1930-1968 (Fig 4.9).

Virgin flows on the Pongolo River system appear to have occurred from 1930-1968 because there is a linear relationship where flows increase or decrease with rainfall, except for the periods 1934, 1941, 1948, and 1955-1958. It may be that these were periods of drought. Although rainfall was frequently less than the mean (59.4 mm) for the reference period, resultant flows were frequently higher than the mean (69.03 m^3/second) for the reference period. Generally deviation of mean flows from the mean of the reference period fluctuated frequently around the mean, negatively (i.e. less than the mean) and positively (i.e. higher than the mean), indicating natural variability (Fig 4.9).

Modified flows began with the building of Pongolapoort Dam 1966-1972. Modified flows appear to start from 1969 to 2004. Although there is a linear relationship between mean stream flow and rainfall 1986-1995, it appears to have stabilized because there is no fluctuation around the mean such as the one observed in virgin flows (1930-1968). A distinct non-linear relationship between rainfall and mean flows appears after the Bivane Dam development from 1996 onwards up to 2004, despite increasing rainfall. Reduction in flows from the mean (67 m^3/second) increases steeply from 1999 onwards, reaching a 90% reduction from the mean by 2004.

Hydraulicity based on maximum stream discharge

Maximum stream discharge determines the ability of a river to overflow out of the main river channel and flood adjacent areas. Analysis of rainfall and upstream inflows at Pongola town and subsequent maximum outflows from Jozini based on annual maximum stream discharge (Fig 4.10) shows that annual maximum outflows from Jozini appear to have stabilized and reduced in magnitude greatly, despite increasing rainfall from 1999 onwards when compared with virgin flows from 1930-1976 and to modified flows from 1986-1998. Therefore, artificial flood releases between 1986-1997 increased with increasing rainfall. However from 1999 onwards, although artificial floods are increasing with increasing rainfall, they have not only reduced in magnitude but have also stabilized. It is necessary to find out whether they are really meeting environmental requirements (see Chapter 7). Mean maximum flow for the reference

period is 430.52 m^3/second and despite increasing rainfall, annual maximum flows have only increased from the mean by between 37.8% and 45% from 1999-2004.

Hydraulicity based on minimum stream discharge

Analysis of minimum stream discharge showed that mean annual outflows from Jozini reduced from the mean of the reference period (2.17 m^3/second) by 74% in 2000 and reached an 84% reduction by 2003.

The absence of flow gauge stations and rain gauge stations downstream from Jozini at Pongolapoort Dam means that actual flow patterns relative to rainfall are not known, although these values have been simulated (Table 4.4) by Dent, Lynch and Schulze (1989) and Schulze (1997).

From the above analysis, it is clear that outflows from the Pongolapoort Dam have been greatly modified due to irrigation dams (Bivane and Pongolapoort). It would be interesting to know to what extent rainfall in the region downstream of Jozini contributes to flows and whether rainfall alone can adequately sustain the natural resource regeneration (crop and wildlife growth), particularly in the floodplain after the current annual DWAF flood releases which appear to have more recently stabilized and reduced. It is important that gauge stations be installed in appropriate places to measure stream flow and rainfall.

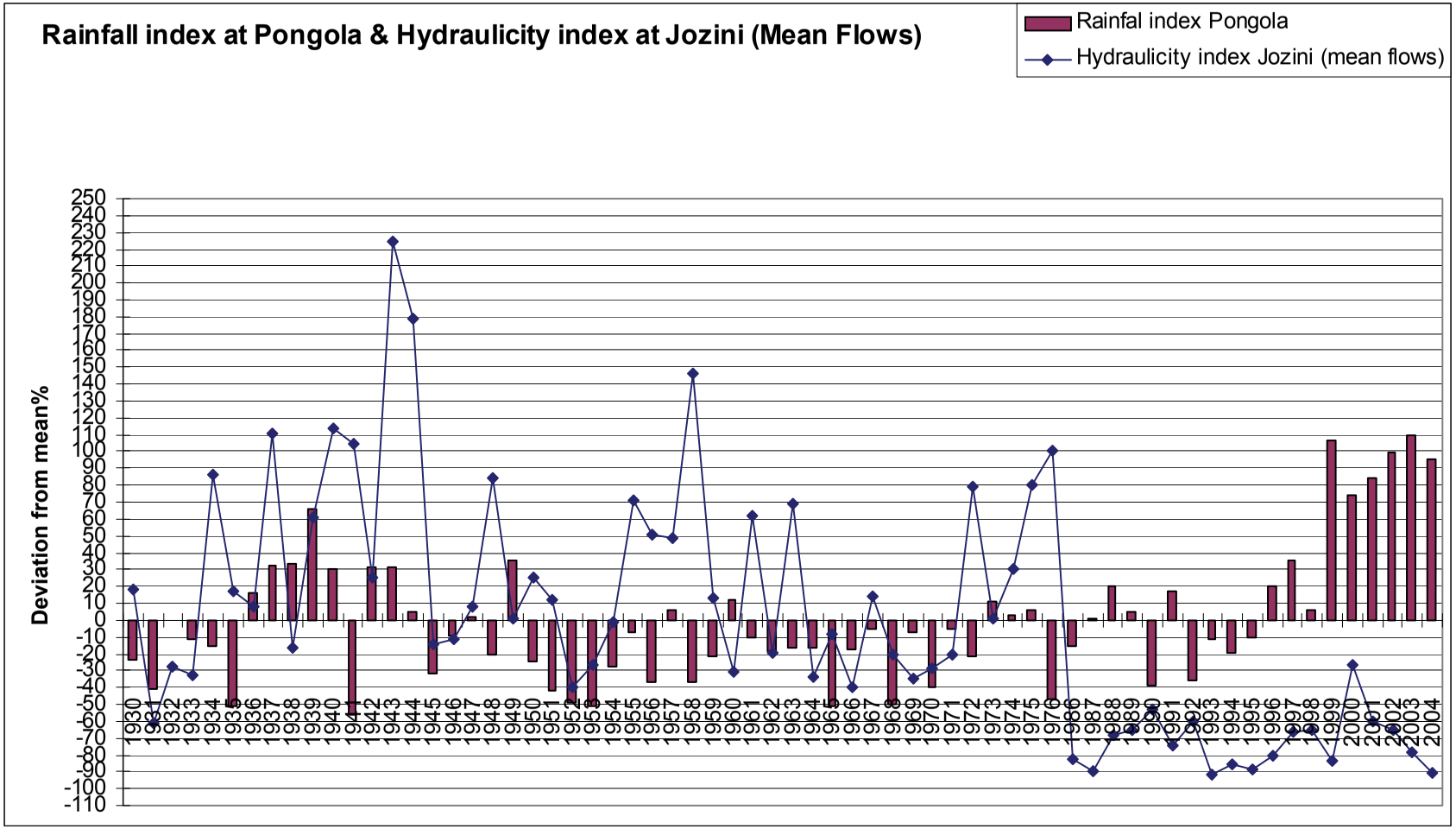


Figure 4.9:Hydraulicity index of mean flows at Intulembi-Golela and Jozini-mean stream flow (Source data: DWAF database). Data missing 1977-1985.

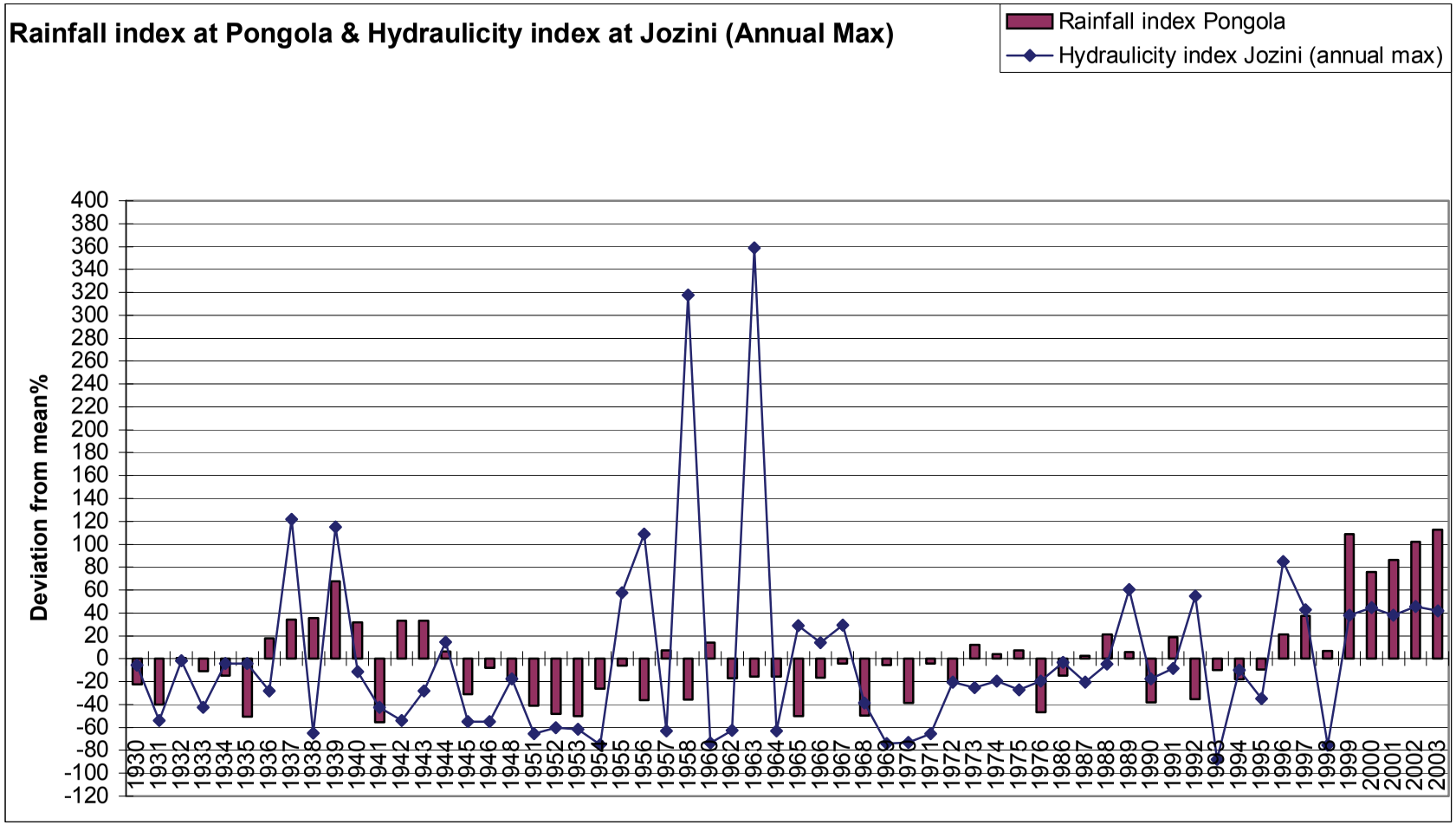


Figure 4.10: Hydraulicity index of maximum flows at Intulembi-Golela and Jozini-maximum stream flow (Source data: DWAF database)

4.3.4.3.5 Trends in flood peaks (annual max)

To compare trends and changes between virgin floods and artificial floods released from Pongolapoort Dam, analysis of annual maximum stream discharge from 1930-2004 shows distinct periods that can be linked to the following events (Fig 4.11): (i) 1930-1968, virgin flood peaks at Golela (W4M02/Intulembi W4H002), before the Pongolapoort Dam development. (ii) 1969-1977, modified flood peaks that were stabilized (no variability) when the dam was being built. (iii) 1986-1999, artificial flood releases from the dam at Jozini (W4H013). The flood peaks during this period had a variability and magnitude similar to that observed in natural flows (pre-dam patterns). (iv) 2000 onwards, stabilized artificial flood releases from the dam at Jozini (W4H013), which can be linked to the Bivane Dam development, expanding irrigation upstream and other stream flow reduction activities. (v) 1969-1995, upstream max peaks at Mhlati (W4H006), before construction of Bivane Dam and peaks that appear to be decreasing dramatically from 2000, after construction of Bivane Dam.

Standard deviation measures how widely values are dispersed from the mean value and was used to measure the degree of variability in annual max flows between virgin and modified flows. Fluctuation of annual max is greater in virgin flows than in artificial flows at Jozini. Upstream variation at Mhlati reduced after the Bivane Dam development (Table 4.4).

Table 4.4: Summary of mean and standard deviation statistic of annual maximum flood peaks (Raw data was obtained from the DWAF database)

	Annual Max (m^3/s)	Volume for the month (million m^3)
Virgin flows Golela W4M02/W4H002		
1930-1968	372 ± 246	193 ± 129
Artificial flows Jozini W4H013		
Before Bivane Dam 1986-1995	400 ± 182	168 ± 86
After Bivane Dam 1996-2004	571 ± 199	229 ± 95
Upstream flows Mhlati W4H006		
Before Bivane Dam 1969-1995	540 ± 374	289 ± 174
After Bivane Dam 1969-2004	381 ± 362	187 ± 122

The outcome of research carried out by Pitman and Weiss (1979) and Heeg and Breen (1982) led to recommendations made specifying an artificial flood regime which could meet environmental, economic and social needs. The first artificial flood was implemented at the end of September 1984. The following analysis supports the community perceptions in Chapter 7, that the flood regime that was implemented did not meet environmental and social needs.

It has been shown scientifically (Welcomme, 1979, 1986; Keddy, 2002; Kuper et al., 2003) that high floodplain natural resource regeneration is highly correlated with natural (virgin) patterns of seasonal stream flow through summer, autumn, winter and spring.

Although artificial flood releases from the dam at Jozini (W4H013) during the period 1986-1999 showed variability and magnitude similar to that observed in natural flows (pre-dam patterns), overall seasonal stream flow patterns (i.e. summer, autumn, winter and spring) differed greatly from natural seasonal patterns, hence influencing natural resource production.

For example, analysis of seasonal flows shows that one can discriminate between flows from a wet year, average year and dry year in virgin flows at Golela (i.e. a wet year has big flood peak and a dry year has a small flood peak). However, looking at artificial flows at Jozini, one can not make such discrimination because the biggest peak occurs at a different time (month) from that observed in natural seasonal patterns (Fig 4.12 and Fig 4.13). The same observation applies to upstream-modified flows at Mhlati. Within a specific reference period, the wettest year did not automatically have the highest flood peak nor did the driest year automatically have the lowest flood peak. Analysis of seasonal trends in years with a high, average and low flood peak for virgin flows at Golela, artificial flows at Jozini and modified flows at Mhlati showed that seasonal trends at Jozini were the most greatly modified when compared with virgin flows at Golela. At Jozini, there is a distinct single peak occurring at a different time (month) from that observed in natural seasonal patterns, while flows for the rest of the year are not only stabilized but greatly reduced in magnitude in comparison with virgin flows or with flows upstream at Mhlati (Fig 4.12 and 4.13).

Therefore, seasonal trends at Jozini over the period 1986-1999 or 1986-2004 are highly unlikely to meet environmental flow requirements because they are not only greatly reduced but also tend to stabilize after a distinct flood peak, which appears one month in a year. The natural flood season was characterised by several peaks of relatively short duration, rather than a constant flow and sudden shut down. Seasonal flows peaked with summer rains in December and February with a higher flow rate in February and occasional small peaks in July. These were the months within which the river was likely to break out of the main channel and flood the floodplain because inundation of the floodplain depends upon rate and duration of flows as well as the volume of water carried by the river (Pitman and Weiss, 1979).

After 2000 onwards, the same pattern as that observed pre-1999 is evident, except for the year 2000, a wet year with a very high flood volume (375.8 million m^3) in October that peaked at 700 metres/second (Fig 4.12). The distinct stabilized flow in 2000 that characterises the majority of other years is absent. It is important to note that in February, 2000 the dam was 106% full resulting in dam overspills, which contributed to increased downstream flows, resulting in seasonal flows with high peaks in October and February, which is closely similar to natural flow patterns. Indeed, floodplain farmers have never forgotten the year 2000 because crop harvest yields increased dramatically. One farmer reported that, for the first time, he earned R70 000 from a sweet potato crop that year. Ironically, these stream flow patterns may have influenced the sharp increase in malaria cases experienced in 2000, which peaked at 37 000 cases (see section 5.3.7.1). This can be expected because while fertile soils of floodplains have high primary production, they are also the source of immense human suffering from diseases such as malaria (Keddy, 2002).

Implied here is that environmental flow requirements on the floodplain, in terms of primary production, can only be met with a system that enables the floodplain to receive adequate water during periods similar to natural rhythms.

After 2000 onwards, the volumes reduced, stabilized and are out of line with natural seasonal rhythms.

It is highly unlikely that artificial flows from 1986-1999 met environmental requirements, due to a single distinct peak in a year. Indeed, during DWAF annual flood release meetings, this view is supported by floodplain communities who have always expressed the fact that annual artificial flood releases were not meeting their needs in terms of crops, fish, and drinking water (Chapter 7).

It is highly likely that the change in seasonal water level fluctuations at Jozini over the years from virgin to artificial has greatly influenced the ability of the floodplain to produce ecosystem goods and services.

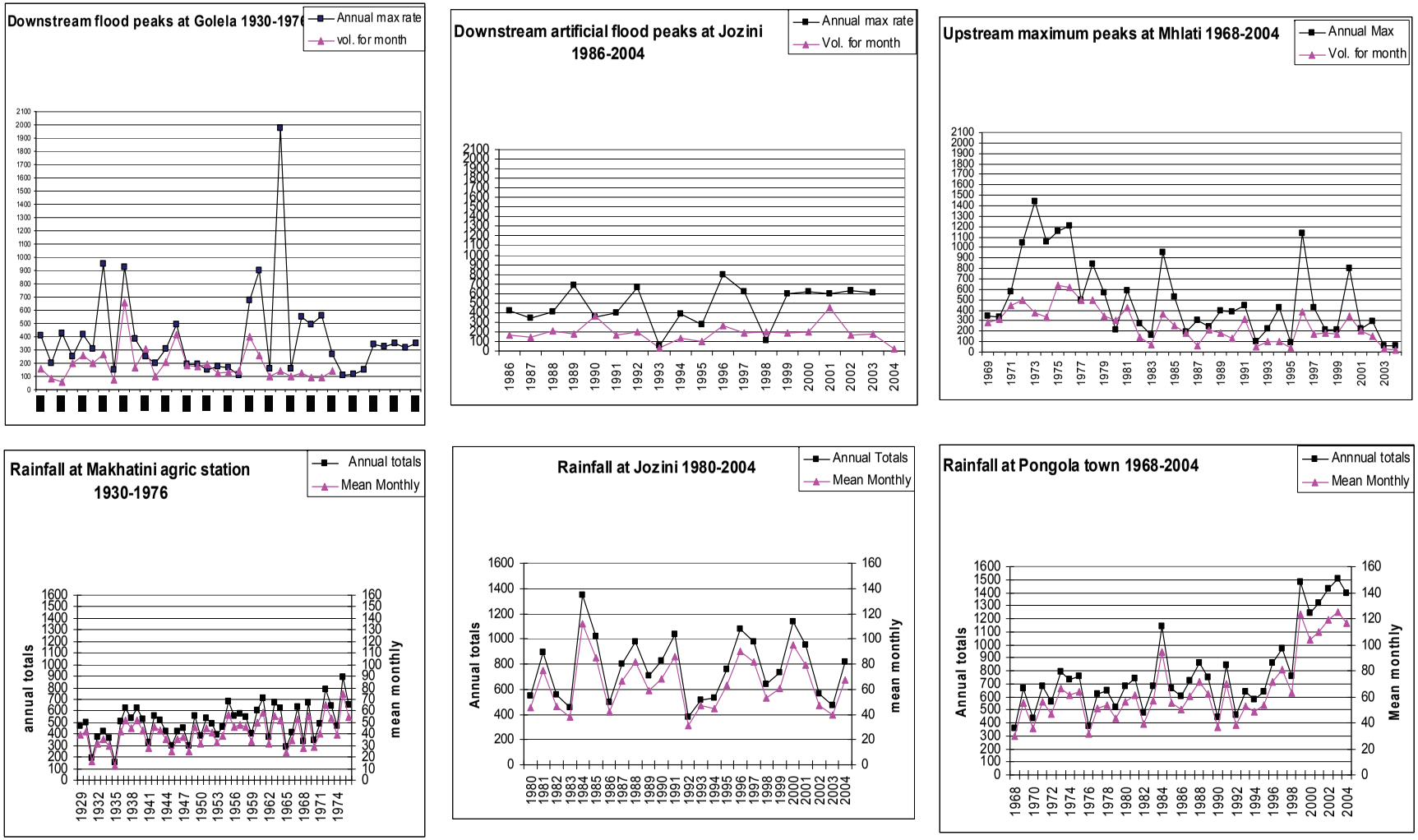


Figure 4.11: Trends in flood peaks (annual max). First column-downstream virgin flood peaks and rainfall at Golela. Second column-downstream artificial flood peaks and rainfall at Jozini. Third column-upstream modified flood peaks and rainfall at Mhlati (Source data: DWAF database).

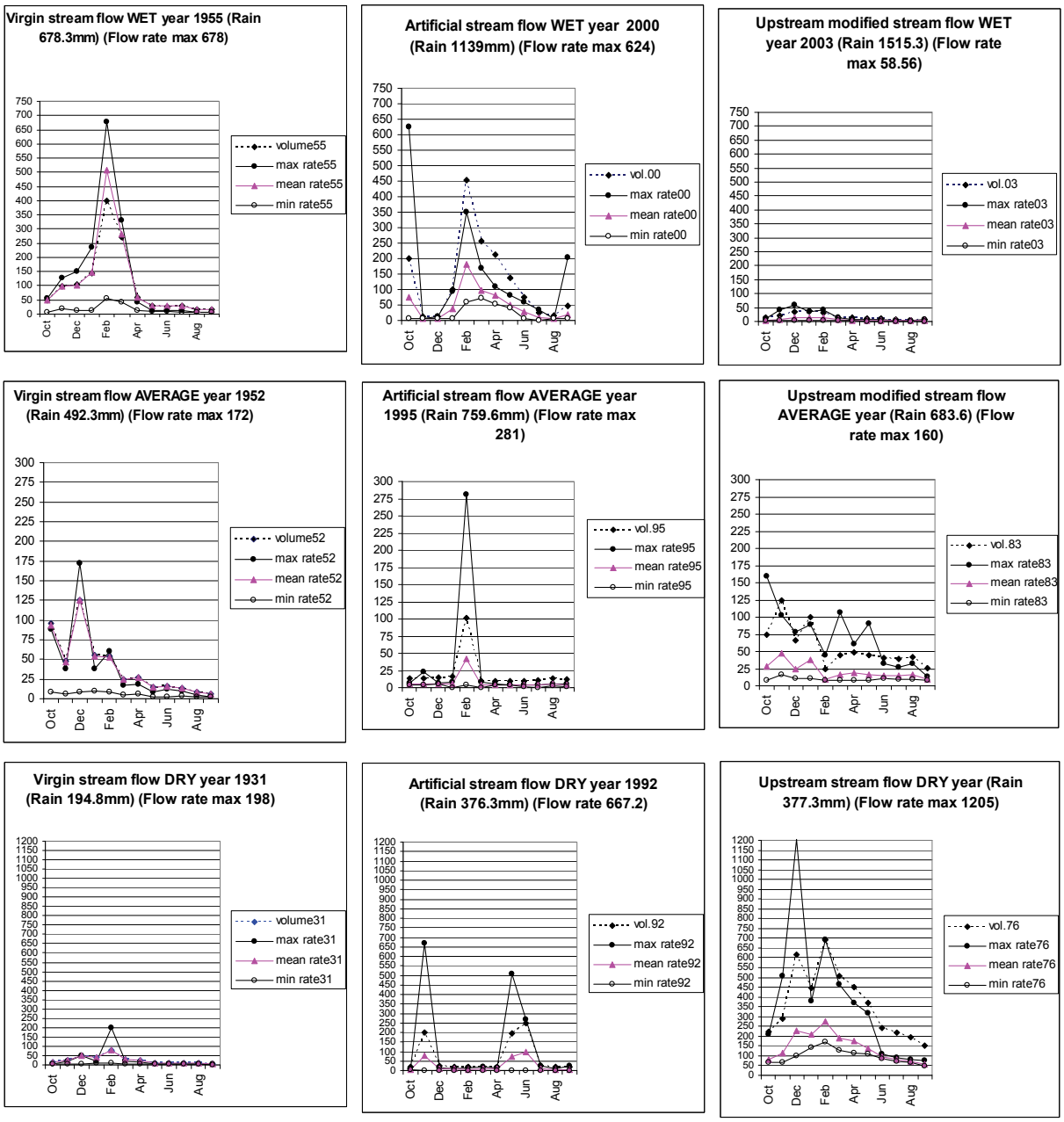


Figure 4.12: Trends in seasonal stream flows between wet, average and dry years. First column-virgin stream flow at Golela. Second column-downstream artificial flows at Jozini. Third column-upstream modified flows at Mhlati (Source data: DWAF database).

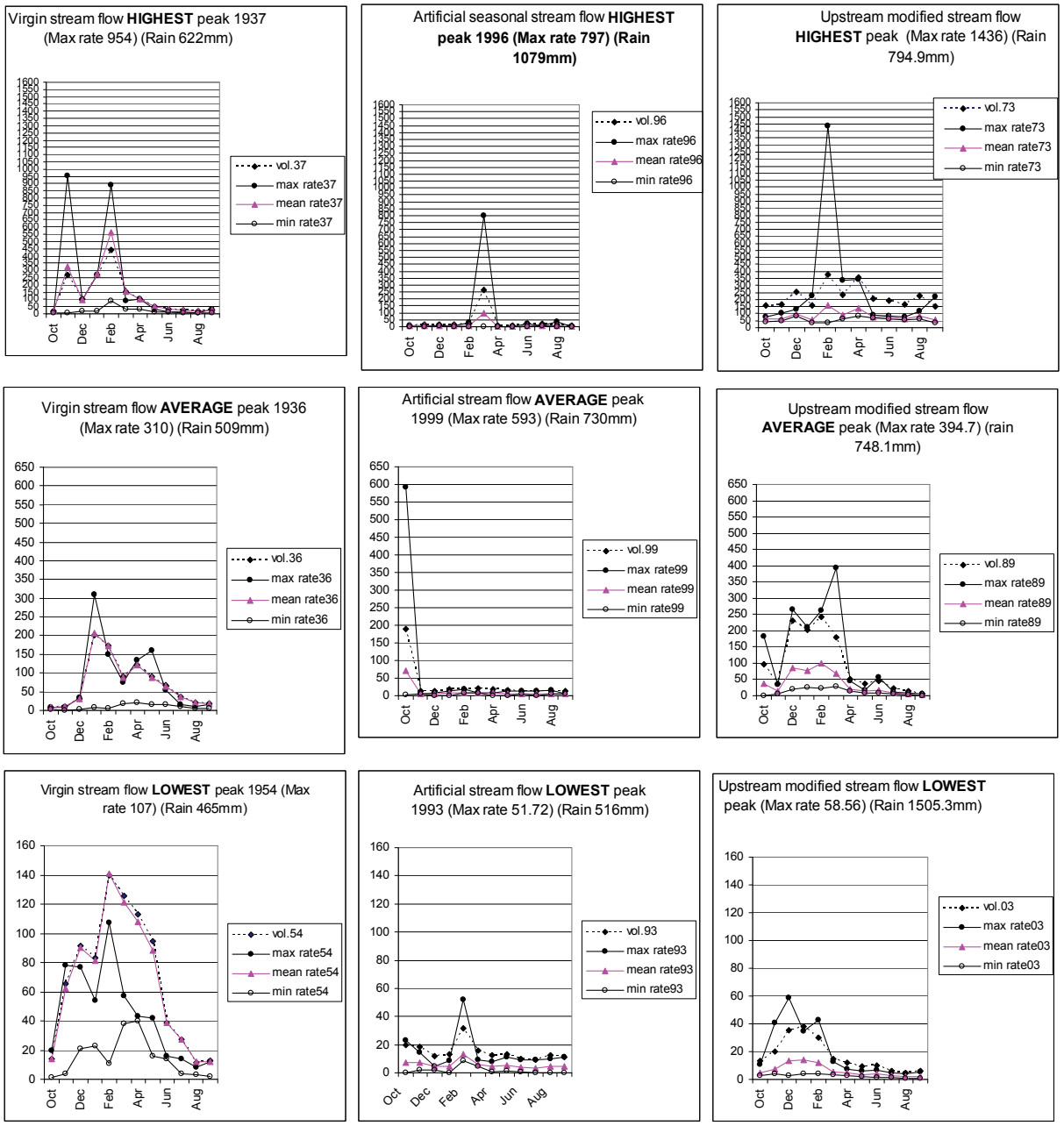


Figure 4.13: Trends in seasonal stream flows between years with high, average and low flood peaks. First column-virgin stream flow at Golela. Second column-downstream artificial flows at Jozini. Third column-upstream modified flows at Mhlati (Source data: DWAF database)

4.3.4.4 Trends in flood releases and the reserve

4.3.4.4.1 Trends in flood hydrographs (1999-2003)

A review of trends in the nature of floods implemented was carried out using data from flood hydrographs (1999-2003). It should be pointed out that data for the period 1984-1998 was not accessible. However, Hughes (2000) reported on volumes released during this period.

For example, when trends in an artificial flood hydrograph (1999-2003) were compared with a simulated flood hydrograph of average shape (Pitman and Weiss (1979), flood time to peak in artificial floods is much longer than the typical time of about 40 hours of an average flood peak and the flood volumes are much greater than 100 million m^3 (Table 4.5). Indeed, the flood volumes are far greater than the water requirements for flooding as determined by Pitman and Weiss (1979) (122 million m^3); Heeg and Breen (1982) (126 million m^3); Hughes (2000) (173-222.2 million m^3)

Table 4.5: Trends in the artificial flood hydrographs (Source data: DWAF regional office Durban).

Year	Month	Flood duration days (hours)	Peak discharge (m^3/s)	Time to peak (hours)	Flood volume (million m^3)	Dam capacity start	Dam capacity end	Dam capacity released
2003	Sept	15 (333)	800	147	200.16	75.7	67.7	8
2002	July	21 (476)	800	75	162.2	95.6	89	6.6
2001	Oct	20 (456)	500	168	269.57	93.8	82.8	11
2000	Oct	19 (432)	700	216	375.8	97.3	76.24	21.06
1999	Oct	7 (152)	800	34	218.1	90.04	80.87	9.17

In a social survey (Chapter 7), communities reported that 2000 was the only year, which they felt that floods had supported the natural resource regeneration of the floodplain. Indeed, the huge flood volume (375.8 million m^3) in 2000 is an important feature that stands out in these hydrographs. This large flood volume led to a situation where flood protection measures failed in Mozambique. While the matter was being sorted out between the two governments, no large managed flood release happened in 2001, i.e. water did not break out of the main river channel to flood adjacent areas (personal communication – Dr B Mwaka, DWAF, Pretoria). Subsequently extreme, dry conditions were experienced on the floodplain and increasing pressure from the communities led to a request for a flood release in July 2002. It is important to point out that, although Mozambique was distressed by the flood in 2000, floodplain farmers in South Africa were very happy that year because crop yields and fish yields increased greatly due to dam overspills. Results of the social survey in Chapter 7 showed that majority of floodplain farmers prefer to have dam overspills.

According to DWAF regional offices (2002), water allocation to meet flood releases from the Pongolapoort Dam operates on a 7-year flood cycle with the goal of making 244 million m^3/ annum available for 5 years and during the remaining 2 years to carry out 2 releases/year of 244 million m^3. According to the DWAF regional office, the large flow rates required for flooding the floodplain can only be achieved when the dam is more than 60% full. Clearly, as use of the Pongolapoort Dam increases, the

average water level of the dam can be expected to drop and the frequency of flood releases that can be achieved will decrease. Indeed, trends in stream flow show clearly that flood release volume is less than 244 million m^3/annum from 2002 onwards and dam levels have not dropped below 63% (1540 million m^3) from 2001. Full dam capacity, i.e. 100%, is (2445 million m^3).

4.3.4.4.2 Review of a preliminary reserve determination study (1983-2000)

Note that discussions of this review are considered in section 4.4 – reconciling conflicting needs.

In 2000, DWAF commissioned a reserve determination study at 'Desktop level'. The purpose was to determine the water quantity component of the reserve and the resource class for the Pongolo River downstream of Pongolapoort Dam, to comment on the likely impact on the yield of satisfying the requirements of the reserve and to compare the results with historical patterns of spills and releases from the dam. Hughes (2000) carried out the study, using data for the period 1983-2000 in the analysis. He found that (i) between 1983-1999 the dam had been operated, or had spilled in such a way that would closely satisfy the reserve as determined by the methods used for either a B or C class. (ii) the overall reserve determination was based on a broad regionalisation of past IFR workshop results, and reserve estimation procedures used in the National Water Balance Model, and it was highly likely that this estimate may therefore not have accounted for the requirements of the Pongolo floodplain. (iii) that there was sufficient water available to operate the dam to satisfy the demands, as well as the reserve but recommended that this be confirmed by a revised yield analysis of the Pongola basin system.

4.3.4.4.3 Estimating the ecological component of the reserve

Note that discussions of this review are considered in section 4.4 – reconciling conflicting needs.

Hughes (2000) used RDM methods (1999) to calculate the water quantity component of the reserve and the resource class for the Pongolo River downstream of Pongolapoort Dam. The total annual maintenance requirement as a % of the MAR (1102) was found to be 30.2% for B (333.3 million m^3) and 20.2% for C (222.2 million m^3). The mean annual long-term estimated requirements, based on a 70 year period incorporating wet, normal and drought periods were found to be – B (312.6 million m^3) and C (217.3 million m^3). In terms of a preliminary resource management class, the area was assigned present ecological status equivalent to management class C (222.2 million m^3) (representing a moderately modified state) (Table 4.6).

Table 4.6: Summary of in stream flow requirement estimates (IFR) (million m^3) for outflows from quaternary catchment W44E (From Hughes, 2000).

	MAR (for a 1:50 drought year)	Low flow (Maintenance)	Low flow (Drought)	High flow (maintenance)	Total flows (maintenance)
Ecological class B	1102	226.4	64.5	106.9	333.3
Ecological class C	1102	132	64.5	90.5	222.2

After an allowance for present day upstream abstractions was taken into account, Hughes (2000) reported a dam yield estimate of 630 million m^3. He pointed out that yield reduction estimates of the reserve used by the regional office were 244 million m^3 for ecological management class B and 173 million m^3 for ecological management class C and that these figures were probably still applicable as they were only dependent upon the critical drought duration and not the actual total yield estimate.

When reserve results are compared with historical patterns (1983-1999) of spills and releases from the dam, the mean annual volume of released water was 544 million m^3 compared to the reserve requirements of 313 million m^3 for a B class and 217 million m^3 for a C class. Hughes (2000) points out that a major part of this volume appeared to have occurred as uncontrolled spills during wet years.

4.3.4.4.4 Estimating basic needs component of the reserve

Note that discussions of this review are considered in section 4.4 – reconciling conflicting needs.

The basic human needs reserve (i.e. water for drinking, food preparation and personal hygiene) was calculated to be 0.001 million m^3/annum based on a lifeline amount of 25 litres/person/day for a population of 100 people. The total population figure in the quaternary catchment W44E was used to calculate the basic human needs reserve (Table 4.7). Hughes (2000) reported that the population data used was based on population water requirements provided by the Chief Directorate, Water Services and Directorate and Community Water Planning and was based on the 1991 census data and an extensive field verification project, initiated in 1994.

Table 4.7: Preliminary basic human needs reserve for Quaternary W44E (From Hughes, 2000).

Quaternary	Population (current requirement)	Per capita need (litres/day)	Basic Human Needs Reserve required (million m^3/annum)	% of virgin mean annual runoff (1102 million m^3)
W44E	100	25	0.001	0

4.3.4.5 Conclusions on state of stream flow

The Pongolapoort Dam yield had decreased from a virgin value of 1060 million m^3 to a modified value of 785 million m^3 over the reference period, 1986-2004. The official dam yield, reported by DWAF, was 645 million m^3 in 2004. Reduction in dam yield can be attributed to upstream:

(i) Bivane Dam development for irrigation at Impala utilizing about 211 million m^3 by 2004; and
(ii) Stream flow reduction caused by commercial forestry utilizing about 200 million m^3.

Irrigation demands for water upstream at Impala irrigation scheme (211 million m^3) were higher than irrigation demands at Makhatini irrigation scheme (57.5 million m^3) by 2004.

There were un-metered abstractions directly from the river channel observed particularly during periods of low flows in winter and early spring. Not all abstraction data was available and it was therefore difficult to quantify exact volumes abstracted.

Generally artificial stream flow downstream of the dam had reduced greatly when compared with virgin stream flow. Specifically, stream flow data in terms of inflows and outflows, hydraulicity index, flood peaks and flood hydrographs showed that:

(i) The period 1984-1998, artificial flood releases from the dam tried to mimic natural patterns in terms of magnitude only. However, trends in seasonal timing did not match natural rhythms and were characterised by an annual, single, distinct, sharp peak in October, instead of two gradual peaks in December and February that characterise natural seasonal patterns.

(ii) After the upstream Bivane Dam development in 1995, inflows into Pongolapoort Dam reduced and mean outflows decreased dramatically from 2000 onwards, while maximum outflows in terms of artificial floods reduced in volume, then stabilized.

From a biological point of view, if floods released are not aligned with natural seasonal rhythms, they can never meet environmental requirements of a floodplain wetland ecosystem in terms of maximizing ecological functions needed to enhance natural resource regeneration or production (Keddy, 2002; Welcomme, 1979; 1986). Because floods released between 1984-2004 were not aligned with natural seasonal timing, big flood volumes did not add any value in terms of natural resource regeneration. The reason why the big flood in 2000 supported production was due to the fact that the dam was so full that it over-spilled in such a way that made it possible for the floodplain to receive adequate amounts of water at the right time of the season.

Clearly, the volumes of water released were large enough to imitate the natural flooding of the floodplain and hence meet the goal of floodplain water requirements and the reserve. However, the state of stream flow indicates that they may have met the requirements of the reserve in terms of in stream flow requirements (IFR) but they certainly did not meet the floodplain water requirements due to technical reasons, as it requires engineering solutions to achieve this in modified river systems.

Therefore the findings of Hughes (2000), which conclude that reserve estimates may not have accounted for the requirements of the Pongolo floodplain, are strongly supported and that although there was sufficient water to meet the demands, as well as the reserve, a revised yield analysis of the Pongola basin system would need to be confirmed.

4.4 RECONCILING CONFLICTING DEMANDS ON THE AVAILABLE WATER

4.4.1 Introduction

According to the requirements of the new National Water Act No. 36 of 1998, of the total amount of water available for use in a catchment a certain amount should first be set aside to serve the purpose of a reserve (ecological and basic human needs), before allocations can be made for economic growth in order to achieve long-term sustainability. The challenge lies in defining reserve requirements for a floodplain ecosystem.

The following sections attempt to provide clarity to the meaning of the reserve within the context of floodplain water requirements by linking (i) the requirements of the new National Water Act No. 36 of 1998 with the state of stream flow results in section 4.3. (ii) results of the social survey (Chapter 7). (iii) reviews of ecological interests (Chapter 5). (iv) review of agricultural developments (Chapter 6). (v) reviews of preliminary reserve determination by Hughes (2000). (vi) studies of the hydraulics of floods by Basson and Beck (2002), and other international studies of floodplain water requirements.

4.4.2 The reserve and floodplain water requirements

For the river reach downstream of the Pongolapoort Dam, it is important to distinguish between the reserve in terms of in stream flow requirements (IFR) and floodplain water requirements. The following section shows that although reserve requirements (IFR) may have been met, floodplain water requirements have not.

4.4.2.1 Comments on the preliminary basic human needs reserve determination

The first component of the reserve is the basic human needs reserve, defined as the quantity and quality of water required to satisfy basic human needs by securing a basic water supply for people who are now or who will, in the reasonably near future, be relying on, taking water from, or being supplied from the relevant water resource.

The implication for the basic human needs reserve requirement is that, the level of developments and the waste effluents that they produce, may end up in water resources (rivers and pans). The effluents produced should be at a level, which allows people who rely on, take water from or are supplied from the relevant water resource to use it for basic needs, but with treatment. Note that management class ratings and subsequent requirements for water treatment are: minimum treatment is required for a river with management class A or B; treatment is required for a river with management class C; advanced treatment is required for a river with management class D or E (DWAF, 1999).

A preliminary reserve determination carried out by Hughes (2000) gave the Pongola River reach, downstream of the dam, an ecological management class C, representing a moderately modified state with water requirements making up between (173-222.2 million m^3) or 16%-20.2% of the MAR (1102). his rating should therefore be managed as ‘a general water resource’ used for basic human needs, with treatment (water for drinking, food preparation and personal hygiene). (DWAF, 1999).

In calculating the basic human needs reserve, Hughes (2000) used a value of 100 people. Yet, based on census data (Statistics SA 1991, 2001) (Chapter 6), the population living adjacent to the floodplain downstream of the dam should be about 80 000-100 000 people. This figure takes into account the population living adjacent to the floodplain and the fact that there are people living very far away from the floodplain but own pieces of land on the floodplain (Chapter 7). Therefore, quantities of water secured for basic needs are inadequate.

Furthermore, the basic human needs reserve (i.e. water for drinking, food preparation and personal hygiene) was based on a lifeline amount of 25 litres/person/day. According to the water services, policy on the human right to 'free clean basic water' this amount translates to free clean water of 6000 litres/month/household of 8 individuals. The social survey results in Chapter 7 show there are households with individual sizes (>8) and many have no cash incomes. Data from Statistics SA Census 2001 (Chapter 6) also supports the fact that many individuals in the region have no cash incomes. It is highly unlikely that such individuals can afford to pay for extra clean water and may have no alternative but to draw untreated water directly from the river channel and floodplain pans for drinking, food preparation and personal hygiene.

It is important that a risk to health assessment is carried out and simulated under various stream flow regime scenarios to determine the best stream flow regime in terms of human health. The outcome of the risk to health assessment must be linked to the development of a public health strategy. The public health strategy should take into account, among other things, the relationship between disease and various stream flow regime scenarios. According to studies by Coetzee and Bourne (1996), water related diseases endemic or prevalent in northern KZN where the Pongolo River and floodplain is located are malaria, bilharziasis, cholera, typhoid fever, dysentery, diarrhoea, polio, yellow fever, hepatitis, river blindness, parasitic worms, scabies and trachoma.

Poverty, coupled with a lack of access to adequate quantities of clean water and unhygienic living conditions, reduced stream flows and increased toxic input from developments, can enhance infection rates of these diseases causing epidemics and poor health. The current socio-cultural system practiced among floodplain communities (Chapter 7) implies that people will utilize the floodplain pans and the river directly for basic needs for a long time to come; indeed until such time that the government can adequately deliver safe water and sanitation to all (WRC Report No 1379/1/05; Jacobson, 2005).

Clearly, the implication for managing the Pongola River, as a C is that municipalities will provide treated, clean water to all households. It will be interesting to find out to what extent this has been or can be achieved in order to determine the risk posed to human health by managing the river as a C under the current socio-cultural system. It is also important to predict the level of risk to human health under conditions where developments in the catchment increase to the level where the river has to be managed as a D or E.

4.4.2.1.1 Gaps limiting the implementation of the basic human needs reserve

In determining a basic human needs reserve, the following knowledge should be factored into short and long-term plans that inform decisions on a reserve regime and management class:

(i) Accurate demographic data should be used;
(ii) The degree to which a population stops using water directly from the river for basic needs (i.e. the ability to pay for clean, treated water for drinking, food preparation and personal hygiene) should be determined;

(iii) Risk to health assessment should be determined and simulated under various stream flow regime scenarios. Specifically, prevalence of water related diseases and how they influence risk to health should be determined (e.g. malaria, bilharziasis, cholera, typhoid fever, dysentery, diarrhoea, polio, yellow fever, hepatitis, river blindness, parasitic worms, scabies, trachoma, etc.). The outcome of such studies should be factored into a holistic public health strategy for the region.

(iv) The ability of local municipalities to provide treated clean water to all households should be determined.

4.4.2.2 Comments on the preliminary ecological reserve determination

Hughes (2000) rightfully recognises that the ecological reserve requirements he estimated may not have taken into account the requirements of the Pongolo floodplain as an aquatic ecosystem. Indeed, results of the social survey in Chapter 7 point to the fact that we need to recognise that there are two economies existing in the area downstream of the Pongolapoort Dam, which require water allocation:

(i) a cash economy largely supported by commercial irrigation developments, located 'off' the floodplain on the Makhatini flats and tourism and recreation offered through E-KZN Wildlife and the private sector.

(ii) a subsistence economy supported by largely the natural resources produced 'on' the floodplain (crops and livestock watering, pastures, fisheries and wildlife) (see demographic data in Chapter 6 and 7).

According to reserve requirements, once water has been allocated to support these two economies, waste effluents arising from both, which end up in the water bodies, should be kept to a level, which allows the water to be used, with treatment, for downstream basic needs as well as other downstream economic uses (irrigation, livestock watering, fishing). Note that the ratings are minimum treatment A and B; treatment C; advanced treatment D and E (DWAF, 1999). The 'non-point source' nature of pollution coming from these two agricultural economies obviously makes it difficult to quantify and to implement the polluter pays principle, but it can be assumed that more pollution is likely to come from intensive commercial systems through run-off or underground seepage that ends up in water bodies on the floodplain pans and the river.

According to the description of the floodplain given in section 4.2, it is clear that it is an aquatic ecosystem made up of the main Pongola River channel, floodplain pans and the land between the river and pans that is seasonally flooded. Whereas the cash economy, supported largely by commercial agriculture on the land 'off' the floodplain, requires an adequate amount of irrigation water to produce mainly goods (food and fibre), the subsistence economy, supported by the land and water bodies on the floodplain, requires an adequate amount of flood irrigation water to produce both goods and services (excess nutrient regulation used for growing crops, pasture, fish and wildlife which enhances the value of the landscape by increasing opportunities for tourism and recreation). Therefore, it appears that the floodplain has more value because it has the potential to meet the basic needs of more poor people in a

subsistence economy and should not be destroyed by allowing flood releases to cease in the absence of alternatives.

Results of the social survey on the floodplain shows clearly that according to the perceptions of floodplain communities, artificial flood releases from the dam since 1983-1999 have so far reduced the subsistence economy perceived through a reduction in natural resource regeneration, even though according to the findings of Hughes (2000), the volumes of water released were big enough to satisfy the requirements of a class B river and exceeded a class C river. Trends in artificial flood hydrographs after 2000 onwards show that the river is currently being managed as a class C, with an annual flood volume of about 173 million m^3. A key concern from the community's point of view is that the total area flooded since 1983 to present has continued to decrease over the years and that the floods recede too fast and the soils do not absorb adequate moisture to support crop growth well and production of pasture, fish and wildlife had also decreased (Chapter 7).

Therefore, water requirements for the floodplain would have to be aligned with both ecological needs and community needs to support the subsistence economy. On the basis of the huge historical releases of volumes of water from the dam reported by Hughes (2000), it appears that, from a community perspective and from an ecological point of view, any volume of water released from the dam (big or small) cannot meet floodplain water requirements under the current reduction in stream flow trends shown in section 4.3 above, as long as the dam is in place. It should be pointed out that the releases may have met reserve requirements in terms of in stream flow requirements (IFR), but they did not meet floodplain water requirements. Indeed, many floodplain communities feel that they have to walk long distances most of the year to reach a fresh water source on the main river channel, due to the bad quality water found in floodplain pans. Therefore suggestions by Heeg and Breen (1982), requiring an artificial system to be put in place (e.g. inflatable weirs) as a means of optimising water use to achieve the desired ecological effect while saving water for other uses, is highly supported by the results of this analysis.

On this basis, recommendations by Hughes (2000) to revise the yield analysis and improve the reserve determination for the floodplain is also greatly supported because the volumes implemented appear to have been decreasing from 2000 onwards, yet nothing has been put in place to optimise water use. Under such conditions of reduced stream flow, if alternatives are not put in place, the risk of destroying the agricultural based subsistence economy is very high and the health risk posed is likely to be very high. For example, based on the knowledge from the social survey (Chapter 7) the river cannot be managed as class D or E because very many poor people still depend on the river resource directly for basic needs. Many floodplain communities do not have cash incomes, so food is grown freely on the floodplain. Currently agricultural irrigation expansion is threatening to reduce the reserve for downstream communities further (Chapter 6). Balancing water allocations between irrigation and floodplain agriculture will require optimisation techniques to be put in place, such as weirs (Heeg and Breen, 1982) supplemented by the promotion of water conservation techniques, e.g. rainwater harvesting for infield and domestic uses (Smith, 2003; Beukes et al., 2003; Van Rensburg et al., 2003).

To enhance implementation of the reserve concept, some studies have reported principles and processes for supporting stakeholder participation in integrated river management (Van Wilgen et al., 2003 and

Breen et al., 2006). These studies support the thinking that the reserve as a concept intended to enhance water conservation and long-term sustainability should not be perceived as a 'wasteful amount of water for the environment', which limits water use for profitable commercial ventures. Rather, a reserve should be perceived as a 'state of the water resource needed to serve people's needs' in the present, the future and for future generations. Implied here is that there is no absolute or ultimate value of the 'reserve' that can be objectively determined by engineers. It should be linked to the achievement of a particular state of the water resource and will depend on what state the water resource will benefit stakeholders most (irrigation, industries and waste dilution, fish, wild life, riparian vegetation, socio-cultural uses -drinking, bathing, livestock watering, religious purposes, tourism and recreation, etc.). This is therefore a value-based decision that should reflect the full spectrum of societal needs, perceptions, beliefs, values and norms (Breen et al., 2006).

Basson and Beck (2002) have been investigating only the hydraulics (and not the biological nor the socio-economic links) of the annual flood releases from Pongolapoort Dam since 1999 as part of a WRC project, "The hydraulics of the impacts of dam developments on the downstream river morphology". Basson and Beck (2002) simulated and monitored the July 2002 flood hydrograph with a volume of (162.2 million m^3). They pointed out that the July 2002 hydrograph resembled a natural hydrograph more closely than previous flood releases. Basson and Beck (2002) also simulated the water levels in pans to rise by between 2-5 metres taking between 1-5.5 days to reach their highest water levels.

However, Basson and Beck (2002) do not specify whether the 'highest pan water levels' they refer to are the same as high flood levels – HFL (Fig 4.2), which from a biological or ecological point of view is important for natural resource regeneration on the floodplain. Studies by Heeg and Breen (1982) led to the suggestion that generally an acceptable drop in water level from HFL to MRL should not be less than 2 months. The degree of water level fluctuation between HFL and MRL determines the success of biological processes that enhance ecosystem service provision (crop, pasture, fish and other forms of wildlife). It is not known to what extent pan water level fluctuations, prescribed by Basson and Beck (2002), support such production processes. For instance, during the July 2002 flood, they report that the, "water level rose by 2.9 metres to the highest water level in 6 days at Tete pan. The water levels then reduced from highest water level by 2.6 metres in 13 days. Pans that are most difficult to fill are Mandlakunzi, Nyamiti and Mhlolo. At Mandlakunzi pan, water level rose by 3.4 metres to the highest water level in 9 days. The water levels then reduced from highest water level by 1.3 metres in 10 days".

The success of such water level fluctuations can only be measured in terms of ecosystem service production of biological benefits, which in turn support socio-economic gains.

Wetland scientists (Keddy, 2002) have shown that natural hydrology which translates into soil moisture and stream flow determines the ability of wetlands to sustain production of goods and services through ecological processes, which are influenced by the following variables, in order of importance: fertility/nutrient gradients; salinity; disturbance (seasonal water level fluctuations, erosion, grazing, fire, ice, waves); competition; herbivory; sedimentation. Suppressing natural dynamics in wetland and riverine systems through the effects of dams, dyking, and draining reduce wetland ecosystem resilience and persistence through time (Keddy, 2002). Therefore, the dynamic interaction of these variables and

how they influence ecological processes should be understood and incorporated into hydraulic models to help managers and hydraulic engineers design and optimise systems and structures that imitate nature more closely, thus causing less negative impacts on natural processes that produce ecosystem services in floodplain wetlands.

Clearly hydraulic studies (Basson and Beck, 2002) need to be linked to biological and socio-economic components to measure the extent to which artificial floods and IFR are supporting ecologically sustainable development (subsistence and commercial). It is highly unlikely that flood releases from Pongolapoort Dam are meeting socio-economic and biological benefits on the floodplain because the number of days the floodplain is inundated after a flood release is becoming less than 10 days per annum in recent years. This is far removed from a natural duration of floodplain inundation estimated to be at a degree of flood waters receding at a rate not less than 2 months from HFL to MRL (Heeg and Breen, 1982).

This view is further supported by the analysis of flood peaks, which showed that, although annual artificial flood releases after dam development from 1986-1999 imitated natural patterns to a greater extent in terms of timing and magnitude, seasonal trends during this period were still out of line with natural seasonal rhythms. Flood peaks reduce and stabilize almost immediately after a flood release and the seasonal natural variability, which is important for biological or ecological activity, is lost (Figure 4.11, 4.12, 4.13). This leads to a situation where the floodplain soils experience severe drought most of the year. It is therefore highly unlikely that artificial flows from 1986-1999, with high magnitudes, met environmental requirements.

After 2000 onwards, artificial flood releases have deviated greatly from natural rhythms by shifting timing, reducing in magnitude greatly and by having seasonal trends that have stabilized. It is highly likely that flood volume will continue to decrease with increasing developments (irrigation, commercial forestry). Such reduced stream flows will increase drought conditions on the floodplain. Indeed, results of a social survey on the floodplain (Chapter 7) show that severe drought conditions are experienced most of the year, forcing communities to increase environmental degradation by cultivating in ecologically sensitive areas (ESAs), such as pan inlets, outlets and pan beds where soil moisture is more likely to be retained to support crop growth. Under these conditions, it is even more unlikely that artificial stream flows will meet environmental requirements. Therefore, innovative measures (e.g. engineering solutions) will have to be put in place to optimise available water use on a sustainable, equitable and efficient basis because the river system is now artificial and the stream flow can never be natural as long as the dam is in place.

4.4.2.2.1 Gaps limiting implementation of the ecological reserve

Whereas reserve requirements (IFR) may have been met, floodplain water requirements have not.

Based on the review of artificial floods above, it can be concluded that the recommendation made by Heeg and Breen (1982) to put in place an artificial system, e.g. engineering solutions, such as inflatable weirs installed to optimise water use by holding flood water on the floodplain for longer periods to

achieve the desired biological/ecological and socio-economic effect, is strongly supported as the only way the floodplain can receive water to meet its environmental requirements, while supporting a diverse economy in terms of irrigation, subsistence agriculture, fishing, tourism and recreation, etc. The water levels on the floodplain can be selectively raised and maintained without the wastage of the current flow-through system. Indeed, such a system has been used elsewhere. For example, Rosenberg et al. (1995) reported impacts of reduced flooding in the Peace-Athabasca delta in Canada. When the Bennet Dam was completed 1200km upstream, the removal of the annual peak in floodwaters that occurred each June led to a rapid change in the vegetation in the delta through short-term succession. Within two years, the total wetland area had decreased by 28%, and the numerous ponds and lakes of the delta were drying up at the rate of 20% per year. To mitigate these negative impacts weirs were constructed to hold back floodwaters and recreate natural periodic flooding, and although this did not protect all wetlands, it made the best out of a bad situation (Keddy, 2002).

The success of such a system can only be judged by way of monitoring the evolution of the floodplain ecosystem with respect to natural resource regeneration:

(i) Through monitoring variables that influence ECOLOGICAL processes (e.g. hydrology, stream flow, soil moisture; fertility/nutrient gradients; salinity; disturbance (seasonal water level fluctuations, erosion, grazing, fire, ice, waves); competition; herbivory; sedimentation).
(ii) Through monitoring variables that influence SOCIO-ECONOMIC, benefits (e.g. crop production, fish production, pasture production and production of other forms of wildlife). Output of data from ecological and socio-economic monitoring programmes should be linked to HYDRAULIC MODELS of the systems to enhance model calibration and optimisation of water use.

In determining the ecological reserve (both IFR and floodplain water requirements), the following knowledge should be factored into short and long-term plans that inform decisions on a reserve regime and management class:

(i) The floodplain is an aquatic ecosystem, which produces both goods and services cheaply and should be protected by allocating an amount of water that makes it possible for it to continue producing maximum quantities of goods and services that society needs.
(ii) Knowledge of the proportion of the population supported by a cash economy from commercial ventures. Type and quantity of pollution produced from commercial ventures and source (point source, non-point source) in order to implement the polluter pays principle fairly.
(iii) Knowledge of the proportion of the population supported by a subsistence economy. Type and quantity of pollution produced from a subsistence economy and source (point source, non-point source) and whether the polluter pays principle can be implemented fairly.
(iv) Build a knowledge base that links stream flow to ecological, social and economic factors in order to compare various scenarios of levels of goods and services that the environment can sustainably produce.

4.4.3 Dynamics of water requirements for economic growth

4.4.3.1 Initial water based developments

A review of the implementation of water-based developments and interventions in the area between 1982-1994 was carried out. The developments include nature conservation schemes, agricultural irrigation development and floodplain water requirements in terms of artificial flooding regime from Pongolapoort Dam needed for floodplain ecological processes to produce benefits that support a subsistence economy. It was found that the planning phase of these developments, did not take into account knowledge obtained through a holistic approach to community development (Ife, 1999). As a result, the developments made livelihoods more difficult for the majority of the population (Van Rooyen, 1983; Bruwer, Poultney and Nyati, 1996; Bembridge, 1991, 1993). Even since 1994, agricultural developments that are being implemented have not taken into account holistic thinking, and it is highly likely that long-term sustainability cannot be assured (Chapter 6) (Denison and Manona, 2007).

For example, when world prices of sugar fell in the mid 1970s, sugar irrigation investors simply pulled out of the area leaving behind this huge dam that had altered the natural flow of the Pongola River downstream, destroying a strong subsistence economy enjoyed for centuries (Poultney, 1980; Bruwer, Poultney and Nyati, 1996; Perkins and Arendse, 2002). A holistic approach to development would have ensured that dam design could provide water requirements to meet economic, social and ecological needs.

Nature conservation schemes or game reserves, e.g. Ndumu and Tembe relocated people from productive areas into unproductive areas and then denied them access to the use of natural resources they had enjoyed for centuries by putting up fences and by not providing people with alternative means of supporting their livelihoods (Bruwer, Poultney and Nyati, 1996). Many of the communities that were moved out of these areas (i.e. areas adjacent to rivers) had to travel long distances from their new homes in order to reach a fresh water source, the Pongolo River, which previously had been close to their homes. These issues exacerbated rather than alleviated the subsistence livelihoods of these floodplain communities (Bruwer, Poultney and Nyati, 1996).

Irrigation schemes also relocated people from productive areas into unproductive areas, hence limiting areas available for subsistence farming and pasture fields for livestock grazing. Very high farmer failure on irrigation schemes was because local, poorly resourced, unskilled farmers were settled on irrigation schemes designed for big commercial business, with a centralized management structure run by a managing agent who also owned farming interests, inappropriate land tenure systems and high interest rates (Bembridge, 1991, 1993; A'Bear and Louw, 1994). To make matters worse, communities were allocated land holdings that were uneconomically feasible (<10 ha) (DoA, 1994) and unskilled application of irrigation water contributed to irrigation inefficiency and the lack of adoption of the recommended technology leading to low yields and a vicious cycle of increasing debt loads (Van Rooyen, 1983; DoA, 1994). Under these conditions, many farmers failed to make a success of irrigation farming.

The natural resources of the floodplain were the only available alternative means of survival for some of farmers who had failed to make a success of irrigation farming. However, the nature of the artificial

flooding regime implemented annually from the dam caused drought conditions on the floodplain for most of the year, causing communities to increase environmental degradation by cultivating in ecologically sensitive areas, which retain adequate moisture, needed to support crop growth (pan inlets, pan outlets, inside pan beds and on river banks). A lot of effort was exerted for little gain in terms of crop production and fishing (Chapter 7).

Therefore, future practice of implementing developments in the area should be guided by a good conceptual development framework, which takes into account the interests of local communities. Development frameworks should be conceptualised using community-based principles (Ife, 1999). Indeed, the National Environmental Management Act (NEMA) No. 107 of 1998 expects developers to ensure that impacts of developments are predicted so that their negative effects can be mitigated in the planning and implementation of the development. Environmental impact assessments (EIAs) carried out for economic developments should show clearly the extent of impact expected in the social and ecological spheres. Often (EIAs) carried out for economic development is considered alongside financial and economic criteria. A good EIA ensures that decision makers have available information that is as informed as possible in the economic, social and ecological spheres of the environment when considering projects for implementation.

For instance, it has been shown that the use of the floodplain for subsistence needs has not been outlived (Chapter 7). Before decisions are taken to do away with floodplain water requirements, cost benefit studies would need to quantify the impacts of such a decision in the ecological, social and economic spheres. Plans for new developments would need to carry out cost benefit scenarios (to inform decisions), which include opportunities outside primary industries (agriculture, forestry, fishing), i.e. from the non-agricultural sector of the South African economy, which require skills development to earn non-agricultural income.

4.4.3.2 Water as a limiting factor to economic growth

If we look at how the available water has been historically partitioned for use in the whole catchment, it can be seen that in 1994, initial proposals for water allocation from the Pongolapoort Dam was based on a nett assured dam yield of 920 million m^3 (DoA, 1994). Out of this amount, 430 million m^3 was reserved for upstream use in the Republic of South Africa and 490 million m^3 was provisionally allocated for KwaZulu-Natal (downstream of the dam). Of the total allocation for Mozambique, 50% was supplied from the KwaZulu-Natal allocation and the other 50% from South Africa's allocation. The total allocation for flooding floodplain pans consists partly of the 32.5 million m^3 released for Mozambique (126-32.5 million m^3) (Table 4.8). It was estimated that the water available for irrigating downstream of the dam (333 million m^3) could irrigate some 25 000 ha after allowing for 30% losses in conveyances, evaporation and irrigation efficiency. Potential irrigable area could drop to 19 500 ha if cropping was confined to sugar alone (DoA, 1994).

Table 4.8: Water Allocation from Pongolapoort Dam before 1994 (values in 10^6 m^3) (DoA, 1994)					
	Net assured	Total Downstream (KwaZulu-Natal)	Division of KwaZulu-Natal allocation	Division of RSA allocation	Total Upstream (RSA)
Mozambique		65	32.5	32.5	32.5
Floodplain pans		126	Consists of the 32.5 released for Mozambique (126-32.5)	0	0
Irrigation		333	0		
Household and Industrial purposes		31	0		
Total Water Available	920	490			430

By 2004, the dam yield had reduced to 600-645 million m^3/year at an assurance of 80% (DWAF Report No. PB WMA 06/000/00/0304, 2004).

Factors influencing reduction in runoff and dam yield can be attributed to upstream developments: dam, irrigation, and commercial alien (exotic) plantation forestry, and invasive alien vegetation (DWAF Report No PB WMA 06/000/00/0304, 2004). For instance, commercial alien (exotic) plantation forestry, which is a stream flow reduction activity, has been increasing over the years in the upper catchment (Schulze, 1996; DWAF report on commercial timber resources 2002; 2003; 2004). Between 1995-1999, Bivane Dam was constructed in the upper catchment with a full supply capacity of 113 million m^3 to increase the area under irrigation and the assurance of supply to sugar irrigators 100 km downstream at Pongola town (Impala irrigation board estimated at 17,000 ha in 2002) (Schulze, 1996; DWAF regional office, 2002). For example, water abstractions by the upstream Impala irrigation scheme in 2003 were so much higher (211 million m^3) than water abstracted by the Makhatini irrigation scheme (57.7 million m^3) located downstream of the dam. A plan was then put in place to expand agricultural development downstream on the Makhatini flats.

In 2002, the Department of Agriculture and Environmental Affairs, KwaZulu-Natal (KZN) rolled out its agricultural expansion plan known as 'the green revolution' – Makhatini Development Plan (DAEA, 2002). The principle underpinning the green revolution plan is that, if all high potential agricultural land in KZN were to be farmed to the intensity it is farmed in the existing commercial sector, overall agricultural production could quadruple over the next 20-year period. For example, total land with potential for irrigation on the Makhatini flats area is 106 000 ha. Out of this total area the Makhatini irrigation scheme comprised 11 200 ha and only 3 900 ha was under irrigation in 2002. According to the Makhatini development plan very good irrigable land beyond the Makhatini irrigation scheme was 76 600 ha (DAEA, 2002).

Worst case scenario is that if irrigation and all other stream flow reduction activities, such as commercial forestry, are not controlled in the whole catchment they could utilize more than the virgin mean annual run-off 1 344 million m^3 of the Pongolo River catchment. For example, considering the Makhatini flats alone, 106 000 ha can use 1060 million m^3 of water if the crop is sugarcane or half 530 million m^3 if it is cotton. The implication for the worst case scenario is that all water would go to support economic growth and there would be none left to serve the purpose of the: ecological reserve (IFR), basic needs reserve and

floodplain water requirements for a subsistence economy leading to environmental degradation, ecological failure and social injustice. This fact has been clearly illustrated in section 4.3. Therefore, a key constraint to achieving full agricultural potential of some 106 000 ha of land on the Makhatini flats is water availability which depends on allocation from the Pongolapoort Dam.

The view that water is a limiting factor is reflected in the increasing opposition to flood releases from affected parties in the agricultural irrigation sector within the catchment, which is always expressed during DWAF annual flood release meetings.

The view of water as a limiting factor is also reflected in the document presented by the Department of Agriculture during the launch of the agricultural development plan on the Makhatini Flats to initiate the green revolution plan (DAEA, 2002). The exact quote reads:

"*Sustainable development is a balancing act. It is a marrying together of the natural resources and the human resources in an area in such a manner that the ecological balances are not so disturbed that the whole ecological system implodes. This is the dilemma that faces us on the Makhatini. We talk about the floodplain. In reality, there is no floodplain because Pongolapoort Dam ensures that flooding no longer occurs, and so we are dealing with a residual or historical floodplain rather than an active floodplain. Our challenge is to manage what we have in such a manner that while the natural resource base is optimally utilised for the benefit of the people in the area, the whole environment can function sustainably.*"

It is argued generally that the floodplain does not really exist. This argument is intended to find more water for economic growth by destroying the floodplain wetland ecosystem. What is worrying is that this perception appears as if it is being implemented by DWAF, as shown in the reducing stream flow trends downstream of the dam (section 4.3). Yet there is no plan to ensure that the floodplain receives adequate floodwater requirements to satisfy community needs often expressed at the DWAF annual flood release meetings and in the social survey (Chapter 7).

It is argued here that the perception by the DAEA to stop floods, destroy the floodplain wetland ecosystem completely in order to find more water for economic growth is simplistic, short sighted and uninformed. This argument is strongly supported by existing scientific literature on impacts of dams used for irrigation and hydropower production worldwide (Welcomme, 1979, 1986; IUCN wetlands programme newsletter No. 12, 1996; Barbier and Thompson, 1998; Adams, 1992, 1993, 1995, 2000; WCD, 2000, 2000a; Keddy, 2002). Yet for some reason, this phenomenon (destroying wetlands) is common worldwide.

On a global scale, existing and projected future increases in water demands have resulted in a complex conflict between the urgent need to develop rivers as renewable sources of freshwater for various off-stream uses and the need for their conservation as biological ecosystems (King et al., 2000). Water-resource developments (e.g. dams, dyking, draining, levees, water abstraction and other hydraulic manipulations) are responsible for a number of large-scale physical disturbances to riverine ecosystems (rivers and wetlands). The most significant impacts are a change in the natural flow regime which

influences a change in water quality, biological communities and biophysical factors, consequently changing ecosystem services produced (Keddy, 2002; WCD, 2002).

For example, Costanza et al. (1997) and Zedler (2003) named some of the key ecosystem services produced by wetlands:

(i) Wetlands filter out excess nutrients from agricultural and urban runoff preventing eutrophication of downstream waters;
(ii) Wetlands purify water and are often referred to as the planet's kidneys;
(iii) Wetlands absorb rainfall and storm flows thereby mitigating the negative impacts of floods;
(iv) Wetlands trap loads of sediment that might otherwise degrade vital waterways;
(v) Floodplain wetlands and deltas of major rivers in Sub-Saharan Africa play a central role in the rural economy of the region by providing fertile agricultural land of exceptional productivity, particularly in comparison with the surrounding arid and semi-arid rangelands where the dry season is long and arid. The floodplains also yield valuable supplies of fish, timber, and other natural products and provide an essential habitat for wildlife, especially migratory birds. Floodwaters bring essential moisture and nutrients to the soil. As floodwaters recede, crops are grown and some soil moisture persists into the dry season to provide essential grazing for livestock and other forms of wildlife. Floodwaters provide breeding grounds for large numbers of fish. Water, which soaks through the floodplain recharges the underground reservoirs and supplies water to wells downstream and beyond the floodplain (Adams, 1992, 1993, 1995; Hollis et al., 1993; Barbier et al., 1991; Wesselink and Drijver, 1993; Horowitz and Salem-Murdock, 1990; Heeg and Breen, 1982; Bruwer et al., 1996; IUCN Wetlands Programme Newsletter No 12, 1996).

According to Costanza et al. (1997) and Zedler (2003), wetlands cover only 1.5% of the planet's surface, but contribute nearly 40% of the global renewable ecosystem services, worth US$33 trillion per year. Others point out that biodiversity and ecosystems, our natural capital, are beyond price, even at the marginal level; that they are the basis of life itself; without them there would be no place for people on earth, so their loss could not be compensated (Keddy, 2002; Perrings, 2005, 2006). It is argued that US$33 trillion per year is a serious underestimate of infinity and the values that matter to conservation are ethical and moral; that humanity's concerns should be to conserve these ecosystems, and therefore their valuation is largely irrelevant (Perrings, 2005). Despite the enormous value of these vital ecosystems, they have been regarded as unproductive areas to be lost or reduced, drained, dyked and filled (Keddy, 2002). According to Wetlands International, about 50% of the world's wetland area has been lost since 1900. If this is true, something needs to be done to restore and protect wetlands. Hence, in this study, we argue and make justification for the need to protect the Pongolo floodplain wetland ecosystem by ensuring adequate water requirements to sustain its existence because it has enormous potential to contribute to enhancing the capacity of the reserve by absorbing excess nutrients from economic developments, while providing social benefits to support a subsistence economy.

The Makhatini Agricultural Development Plan (DAEA, 2002) must take into account the fact that, under the current reduced stream flow regime (shown in section 4.3), it can be wrongly argued that the use of

the floodplain for subsistence needs has been outlived. The truth of the matter is that under reduced stream flow, the floodplain has become so unproductive that a lot of effort, in terms of agriculture or fishing, is made for little gain, forcing many communities to migrate to very crowded, poor living conditions in urban, informal settlements. This simply shifts the poverty problem elsewhere instead of addressing it by allocating adequate amounts of water to a subsistence economy or providing alternatives in the non-agricultural sectors of the economy to enhance the social well-being of a majority of the rural poor and stop unnecessary migration to face (in most cases) inhuman living conditions elsewhere.

It should also be realized that the whole environment (ecological, social, and economic) is unlikely to function sustainably in the long-term, under a scenario where, the floodplain is destroyed and the goods and services it produces are lost. According to the requirements of the Water Act, a reserve should ensure that waste effluents from economic growth, which end up in the water resources, do not pollute these water resources to the extent that the quantity and quality of water left in rivers cannot meet the economic, social and basic needs of others. A good example in South Africa, which shows the extent of environmental degradation under such conditions, is the story of the Hartbeespoort Dam in the North West province. Communities have suffered greatly under the impact of excess nutrient loading in water resources from economic growth (urban, industrial and agricultural sources). Large amounts of money are spent annually to clean up the pollution waste physically, biologically and chemically, without much success (Du Plessis, 2004). Balancing the level of developments with the reserve in the whole catchment would have avoided such impacts.

Given a very high rural population of many poor people in the study area, it is highly likely that, in the absence of floodwater requirements and a floodplain wetland ecosystem, it will be very difficult to meet the basic needs of everyone.

It is true that under the current reduced stream flow regime, it can be argued that we are dealing with a residual or historical floodplain rather than an active floodplain. However, this should not form the basis for justifying complete floodplain wetlands destruction by doing away with floodplain water requirements because scientific studies have shown that floodplain ecosystems are highly resilient with enormous ability to bounce back when given adequate water (Welcomme, 1979, 1986; Keddy, 2002; Kuper et al., 2003). For example, Kuper et al. (2003) reported on studies carried out on a floodplain ecosystem of the inner delta on the Niger River in West Africa. The delta ecosystem was found to be resilient and well adapted to the inter-annual fluctuation in the availability of water. Natural resources were well adapted to these fluctuations. For instance, annual fish production tripled, after the abundant floods of 1994, from 1993, despite droughts in the 1970s and the 1980s. Traditional production practices (crops, pasture, and fishing) consider this variability, and people have developed different coping strategies. For example (i) greater mobility and making use of resources wherever they are available in the ecosystem; (ii) families have more than one professional activity, and are able to choose an activity that enables them to procure sufficient revenues or food (Kuper et al., 2003).

In addition, an IUCN wetlands programme newsletter, No.12 January 1996, reported an assessment of studies on the use of artificial floods from dam developments for floodplain restoration and management in sub-Saharan Africa (Nigeria, Cameroon, Senegal, South Africa, Zambia, Kenya and Tanzania). The

study covered floodplains of the major rivers, including Zaire, Senegal, Niger, Zambezi, which support floodplain wetland ecosystems of exceptional productivity, particularly in comparison with the surrounding arid and semi-arid rangelands where the dry season is long and arid. The assessment found that increasing human population, livestock and rising poverty have combined to put pressure on floodplain ecosystems leading to overexploitation of resources. Solutions have focused on major river engineering schemes such as dams, which provide an all year supply of water in a highly seasonal climate. Because floodwater is retained behind the dam, a reduction in floodplain flooding has had a disastrous effect on the rural economy downstream, which relies on wetland products and functions and dam development schemes have diminished rather than improved the living standards and the subsistence economy of the regions (Barbier and Thompson, 1998; WCD, 2002).

For instance, Barbier et al. (1991) compared economic returns (per 1000 m^3 use of water) from an irrigation scheme, with that from, natural floodplain wetlands in a river basin in Nigeria. They found that the natural floodplain made far greater economic returns per unit use of water (US$ 32) than the irrigation scheme (US$ 0.15 – excluding operational costs). Yet floodplain wetlands that had covered an area of 2000 km^2 before dam development in 1971 (Adams, 1992), had reduced to 300 km^2 after dam development (Hollis et al., 1984), thereby decreasing economic returns greatly (Barbier et al., 1991). The results informed relevant authorities (government, water boards, and researchers) and discussions were initiated and it was agreed that although yields from intensive irrigation schemes are higher per ha than from floodplain agriculture, the high operational costs of the schemes reduced the benefits substantially. It was agreed that artificial flooding should play a role in the maintenance of rice production, dry season agriculture, fuel wood, timber, fish, wildlife and ground water recharge. Studies carried out in other countries supported these views (Adams, 1992; Hollis et al., 1993; Barbier et al., 1991; Wesselink and Drijver, 1993; Horowitz and Salem-Murdock, 1990; Heeg and Breen, 1982; Bruwer et al., 1996). Appendix 1 summarises the actual issues in individual countries.

Clearly, few dams and irrigation schemes in Africa have ever realised their full potential and many have serious environmental, technical, administrative, socio-economic and political problems (Adams, 1993, 2000; Bembridge, 1991, 1993, 2004; WCD, 2000; Denison and Manona, 2007). Based on these studies, it is concluded that, the best strategy to ensure long-term sustainability where floodplain wetlands exist adjacent to a large rural population that is largely poor, is to implement water allocations that ensures diverse developments. Water should be allocated to areas used purely for nature conservation for tourism and recreation and to areas that combine environmental conservation and intensive and extensive floodplain and off-floodplain farming systems (dry land and irrigation) and of traditional and modern techniques. In order to do this, a hydrological model of the floodplain should be developed to assess the effect on re-flooding various extents of the floodplain and a socio-economic model should be used to determine the benefits of each option in terms of improved fisheries, agriculture, livestock, health, tourism and recreation and other options (Wesselink and Drijver, 1993).

Managing agriculture to enhance ecosystem services was one of the policy actions recommended in a comprehensive assessment of water management in agriculture worldwide (Millennium Ecosystem Assessment, 2003; Falkenmark, Finlayson and Gordon, 2007; Molden, 2007).

Lessons learned from the review above on the use of artificial floods from dam developments for floodplain restoration and management in sub-Saharan Africa show us that the problems experienced in the study area with respect to irrigation water requirements vs. artificial flood release water requirements can be expected.

For example, there was “very high local farmer failure” reported on the Makhatini irrigation scheme (Bembridge, 1991, 1993; Van Rooyen, 1983; DoA, 1994). One question to be asked is, “What happened to the local farmers that failed on the irrigation scheme?” As seen in the results of the social survey (Chapter 7), these farmers moved their cotton farming activities from the irrigation scheme to the floodplain causing huge problems for others with respect to flood release timing (specifically causing problems for downstream communities and DWAF as the regulating authority).

After world prices of sugar fell and investors left the area in the mid 1970s, plans were put in place to settle local black farmers on the Makhatini irrigation scheme (DoA, 1994). Bruwer, Poultney and Nyati (1996) reported that the plans in terms of settlement, intensification and expansion had been badly conceptualised since 1985 because they benefited largely settlers.

Bembridge (1991) reported that due to farmer selection criteria on the Makhatini irrigation scheme, many local farmers were excluded from participating in the irrigation scheme due to lack of farming skills. Only 30% of scheme participants were farmers from the area, and 70% were settlers from elsewhere, and had acquired some farming skills and some resources of their own, and this gave them an advantage and a head start over the local farmers.

Bembridge (1991, 1993) points out that the goal of irrigation scheme developments benefiting local farmers was achieved only to a small extent due to complex socio-economic, cultural and technical dynamics of allocating huge estate-run irrigation infrastructure to ill-trained, poorly resourced, subsistence farmers. Many local farmers failed to make a success on the irrigation scheme and instead moved their farming practice from the irrigation scheme on to their traditional lands on the floodplain. This event, in turn, interfered with not only the traditional farming practice on the floodplain carried out by communities who had not been allocated land in the irrigation schemes, but also the DWAF procedures for managing artificial flood releases from the dam.

For instance, DWAF officials in charge of dam management reported that in 1996 negotiations for the annual DWAF flood release were at an advanced stage when a new group of local farmers under the name "POWADETA" (Pongola Water Association for the Development of Traditional Agriculture) voiced a demand that there be no flood release. A group of local farmers who had been allocated irrigation plots on the Makhatini irrigation scheme in 1985 and by 1996 many had failed – led the association.

According to Bembridge, 1991, 1993 and A’Bear and Louw, 1994; farmer failure on the irrigation scheme was due to, among other things, (i) the technical design of the scheme. (ii) a centralized management structure with farming interests of their own, which may have influenced their ability to be concerned about the interests of other farmers on the scheme. (iii) non-adoption of new farming practices. (iv) high costs of farm inputs (e.g. electricity for pumping water, fertilizers, pesticides,

maintenance of irrigation equipment, inability to apply adequate water for crop requirements, land rentals and tenure lease requirements on the irrigation scheme which meant that farmers could not live on their farms. This led to an increase in farm management costs, an increase in absentee farmers, an increase in farmer debt, which continued to increase due to high interest rates (DBSA – Reserve Bank, 1993; Bembridge, 1991, 1993; A'Bear and Louw, 1994). Some of the farmers who failed sub-leased their irrigation plots and moved their farming activities from the irrigation scheme to their traditional lands on the floodplain because it was more cost effective (e.g. no water costs, no fertilizers, no land rentals, no central managing agent). Nature provided these goods and services freely. These commercial farmers started growing cash crops such as cotton that had not been grown traditionally on the floodplain. However, cotton requires more growing days (180-210) than a traditionally cultivated crop like maize (120-140) days (Schulze, 1997). This meant that when all crops on the floodplain were harvested, cotton was the only crop left standing, waiting to mature (Chapter 7). Usually annual floods were released after all crops on the floodplain have been harvested. For the first time in 1996, floods could not be released when needed because cotton was still on the floodplain. The community was divided between cotton growing households who did not want a flood release and non-cotton growing households who wanted a flood release to flood irrigate the land so that they could prepare the land for the next crop. According to Perkins and Arendse (2002), this conflict among the communities was intense and unpleasant.

In addition, the conservation agency, EKZN Wildlife is responsible for protecting species and habitats both inside and outside protected areas and they strongly advocated for the removal of all farming activity from the floodplain in order to ensure that the protected area downstream of the dam received annual artificial flood releases from the dam in line with natural seasonal timing. Firstly, it was argued that even though the genetically modified (GM) cotton variety that was being cultivated, and manufacturers claimed that it hardly required pesticides, it had been observed that pesticides were being used on the cotton crop. Secondly, not all farmers grew the GM variety and therefore required the use of pesticides. EKZN Wildlife was concerned that increased use of pesticides and fertilizers on the floodplain would enter water bodies directly enhancing pollution.

It turned out that POWADETA had the power to overrule the rest of the community members and to influence DWAF's decision not to release a flood in 1996. Their request was acceded to and for the first time in history the Pongolapoort Dam spilled naturally in March 1997, expelling (for once and for all) unfounded rumours that the dam could not be filled, owing to structural problems (Perkins and Arendse, 2002). This continued for some months, making life very difficult for local downstream residents, as flows were such that the river could not be crossed. Soon afterwards, DWAF received a request for a flood release from the communities.

Drought conditions on the floodplain experienced over most of the year due to reduced stream flow because most water was held behind the dam wall, led to an attitude change among floodplain communities. Drought conditions led them to cultivate crops in ecologically sensitive areas (ESAs) – pan inlets, outlets and pan beds where soil moisture is highly likely to be retained to support crop growth. This practice enhanced environmental degradation greatly through over-exploitation of resources, increasing erosion and sedimentation (Bruwer, Poultney and Nyati, 1996). The findings reported by

(Bruwer, Poultney and Nyati, 1996) are strongly supported by the results of the social survey carried out on the floodplain in 2003 (Chapter 7).

Analysis above shows clearly that social, economic, cultural, technical and environmental/ecological cause and effect relationships have operated in the area as a whole causing rising economic benefits for some people. It is highly likely, rising poverty and a reduction in the social wellbeing for others (Chapter 7), hence reducing the economy of the region from an environmental economics point of view (Edwards-Jones, Davies and Hussain, 2000; Parkin, Powell and Matthews, 2000). Environmental economics requires external costs to be factored into economic accounting so that resources can be truly allocated equitably and efficiently. The question is, "Who are the beneficiaries and who is paying the social and ecological costs?"

The local dry-land farmers had for centuries practiced a farming system on and off the floodplain, which was synchronised with seasonal patterns of flooding. Agricultural risk was minimised by operating a combination of floodplain and off-floodplain fields. Livestock management was also linked to the flooding regime in that floodplain and off-floodplain grazing requirements were synchronised. Summer rainfall in Nov-Feb and the subsequent runoff and river flows enabled the river to overflow its boundaries and flood agricultural lands adjacent to it, enabling flood irrigation of subsistence lands. Flooding also enabled the filling up of pans (small lakes) adjacent to the river with fresh water. Annual river flooding provided goods and services for the benefit of the environment and floodplain communities. The natural system used seasonal timing of stream flow changes to allocate water resource use equitably between agriculture, fisheries and the environment and efficiently by maximizing ecosystem services produced (crops, fish, pasture and other wildlife). This enabled sustainable livelihood strategies such as:

(i) Flood irrigation of lands which enabled floodplain communities to grow crops when floods receded;

(ii) The area under floodwaters (i.e. the floodplain) became a huge fishery in summer. It covered an area of about 10 400 ha and produced approximately some 750 000 tons of fish per year (Heeg and Breen, 1982). Fish breed best in the warm summer waters. Floodplain pans were inundated up to high flood level in order to submerge pan marginal vegetation. Submerged vegetation provides both shelter and food (plants and insects) for young fish thereby enhancing production and harvestable yields;

(iii) During the dry season months and hence periods of low flows in autumn and winter, the floodplain soils retained adequate moisture which enabled the growth of grasses for livestock grazing. The growth of other natural resources which were not only used by the local communities, but also enabled the normal ecological functioning of the terrestrial and aquatic system (e.g. the aquatic macrophyte *P.crispus* provided food for birds and regulated the nutrient cycling of phosphates in the environment). Excess phosphates in water systems are a key pollutant;

(iv) Seasonal water level fluctuations on the floodplain (ranging from flooded to non-flooded) sustained floodplain ecosystem structures, processes and functions needed to maintain maximum floodplain productivity (goods and services for the benefit of the environment and floodplain communities).

For centuries, communities have utilised the floodplain without having to pay anyone to do so. The irrigation scheme requires a lot of money to sustain farming practices (e.g. modern agricultural practices such as fertiliser, pesticides and electricity for pumping water, land rentals and central control) and over the years became too expensive for local poor farmers to sustain. With time, many communities leased their plots on the irrigation scheme to people from outside the area and went back to utilizing the floodplain to grow valuable cash crops like cotton, which in turn caused problems for others.

Communities also realised that the dam had reduced the risk of losing crops through flooding on the floodplain. Nature (climate) was no longer controlling when the annual floods came; this was now controlled by Man. With time, communities learned to control DWAF managers to release floods based on their wants. For example, floods can only be released when crops grown on the floodplain have been harvested. A cotton crop stays much longer on the floodplain (through summer and autumn) than the traditionally grown crops, maize, beans, pumpkins, groundnuts, etc. This has meant that artificial flooding cannot be implemented in summer to imitate the natural patterns, and may be resulting in negative impacts on the natural functioning of the floodplain ecological ecosystem (structure, processes, and functions). According to literature, the outcome of this, coupled with reduced flood volume, is a reduction in floodplain productivity (nutrient cycling) and biodiversity (plants and animals). Consequently, reduced floodplain productivity impacts much more negatively on the livelihoods of floodplain households who do not grow cotton and are situated downstream of cotton farming households. Not everyone on the floodplain can afford to grow cotton, as one need to buy seed, fertilizers and pesticides. Non-cotton farming households depend heavily on the natural functioning of the floodplain ecosystem to sustain their basic needs (food crops, fish and water for drinking). Such households tend to prefer natural summer floods, which support high floodplain productivity.

On the other hand, households that grow cotton have higher annual incomes per year than those that do not grow cotton. These households do not depend so much on the food producing qualities of the floodplain because they can buy food from the shops using the income from cotton. Such households prefer flooding patterns that are not natural (winter and spring floods) to enable cotton to grow on the floodplain during summer (Chapter 7).

The Conservation agency (EKZN Wildlife) has the responsibility to protect species and habitats. EKZN Wildlife prefer natural summer floods and, during stakeholder meetings, they always express the desire for agriculture to leave the floodplain because farmers' summer crops are on the floodplain when flooding is needed for the sake of the environment. Yet farmers have no alternative as they cannot keep up with the irrigation scheme practices off the floodplain and the dry land farms are not as productive as the floodplain lands.

Fishermen prefer summer floods to enhance harvestable yields, as do the conservation agencies. However, while the conservation agency (EKZN Wildlife) has always expressed the desire for agriculture to be removed from the floodplain so that it can become purely a conservation area, fishermen express the desire to do both, i.e. fish and grow subsistence crops on the floodplain (Chapter 7).

After implementation of agricultural irrigation development expansion in the Ndumu area downstream of the dam, it was observed that tension over water needs between irrigation and fishermen started to crop up in 2004 (Chapter 7). To illustrate the shortage of water availability for various uses, a group of concerned local fishermen insisted that the venue for a focus group workshop in May 2004 be held inside a dry riverbed, with nil flows, on the Ingwavuma River downstream of the Qotho pan dam wall (Fig 7.24). This site is situated in the area planned for cotton development and expansion (i.e. see Fig 6.7 site 1 and 2 at Ndumu A and B). In addition, results of the social survey showed that communities utilizing other floodplain pans on the Pongolo River for fishing felt that the fish catches were very low and they wanted more water in the pans during summer to support fish production (Chapter 7). However summer is also the period when irrigation demands are very high. Generally, the fishermen felt that people owning irrigation plots were benefiting at their expense. In order to mitigate the problem of water sharing between irrigation and pan fisheries, the DAEA had initiated small-scale aquaculture technology research and development at the Makhatini agricultural research station. Pilot implementation projects were then initiated at Mboza village but the projects failed (see details in Chapter 6 section 6.6.3). Results of the social survey showed that communities perceived that aquaculture had been implemented in certain areas and had not been successful. They felt that natural production of fish in pans was a better option and therefore they wanted water rights for fishing.

The fishermen strongly felt that irrigation should be willing to share water with pan fisheries, because they (fishermen) had no access to fish on the Pongolapoort Dam, nor in nature reserves (Ndumu Game Reserve), nor to jobs in commercial irrigation ventures. However, the nature conservation agency (EKZN Wildlife) argued that the abundance of fish found in pans inside the protected area (Ndumu Game Reserve), served as a major source from where fish migrated and were recruited into other floodplain pans when the river was in flood after a flood release. Although such fish stocks were protected from exploitation pressure, EKZN Wildlife argued that fish stocks could only be maintained with frequent summer floods of adequate magnitude and with the timing aligned to natural seasonal rhythms.

The overall situation on the Makhatini flats is indeed a huge paradox with many contradictory statements but which contain the truth.

Therefore, key water demands identified from the discussion above are upstream demands for water (irrigation and commercial forestry); downstream water demands: irrigation, nature conservation, subsistence agriculture and fishing; and Pongolapoort Dam property owners who use the dam for irrigation, tourism and recreation.

Given the total area downstream of Pongolapoort Dam with potential for irrigation (106 000 ha) and a huge rural population (Statistics SA Census, 2001), clearly the demand will easily exceed the supply and competition between conflicting interests will increase.

The economic value of the potential yield from the development of irrigation farming on the Makhatini Flats is considerable and thus places an equally high premium on any water from the Pongolapoort Dam, which is used for other purposes like floodplain requirements through artificial flood releases to sustain ecological and social needs. However, the floodplain too has a current and potential monetary value,

which justifies its preservation, and Heeg and Breen (1982) suggested that research efforts should be directed at reconciling the conflicting demands on the available water.

A recent comprehensive assessment of water management in agriculture worldwide came up with eight key policy actions for decision makers in order to meet the ever increasing demands on a limited amount of water that the planet has had since creation (Molden, 2007):

(i) Change the way we think about water and agriculture,
(ii) Fight poverty by improving access to agricultural water and its use,
(iii) Manage agriculture to enhance ecosystem services,
(iv) Increase the productivity of water,
(v) Upgrade rainfed systems – a little water can go a long way,
(vi) Adapt yesterday's irrigation to tomorrow's needs,
(vii) Reform the reform process – targeting state institutions,
(viii) Deal with tradeoffs and make difficult choices.

4.4.3.3 Scenarios proposed to reconcile conflicting demands

In reconciling water requirements with available water, DWAF proposed two scenarios (DWAF Report No. PB WMA 06/000/00/0304, 2004). The first scenario is based on the National Water Resource Strategy (NWRS) DWAF, 2004), which excludes floodplain releases (that are currently supporting a subsistence economy), and the second scenario includes floodplain releases (Table 4.9).

Table 4.9: Reconciliation of water requirements and availability (million m^3/year) in the Pongolo River catchment (DWAF Report No. PB WMA 06/000/00/0304, 2004 pp 54).

Scenario 1 No floodplain releases: Based on the NWRS	Available water	Local yield	645
		Transfer in	0
		Total	645
	Water requirements	Local uses/requirements	255
		Transfer out	38
		Total	293
	Balance		**352**
Scenario 2 with floodplain releases	Available water	Local yield	645
		Transfer in	0
		Total	645
	Water requirements	Local uses/requirements	255
		Transfer out	38
		Floodplain releases	250
		Total	543
	Balance		**102**

On the basis of scenario 2 (with floodplain releases), the DWAF regional office in 2002 estimated that there was no longer enough water to irrigate 33 000 ha downstream of the Pongolapoort Dam on the Makhatini flats. As there was only about 100 million m^3 of water available for sugar irrigation

(10 000 ha), or, 20 000 ha for cotton because cotton uses less water. It is argued that the locatable surplus from the Pongolapoort Dam is difficult to quantify accurately due to uncertainties relating to the social and ecological requirements of the floodplains downstream of the dam and international requirements, and that the dam has remained under-utilised. This uncertainty would need to be resolved before large allocations were made from the Pongolapoort Dam. Therefore, a decision was made to make up to 100 million m^3 available for allocation subject to a detailed analysis of the catchment (DWAF Report No. PB WMA 06/000/00/0304, 2004).

This study has contributed to clarifying uncertainties relating to the social and ecological requirements of the floodplains.

It has shown that floodplain water requirements enable ecological processes (Chapter 5 – ecological interests), which in turn produce social benefits to support a subsistence economy (Chapter 7 – floodplain agriculture and natural resource use), as well as enhancing the functioning of the reserve as an excess nutrient pollution absorber (Chapter 5). However, the fact that the current stream flow regime has reduced and is not aligned with natural seasonal rhythms means that production of natural resources has decreased greatly (crops, pasture, fishing, poles and grasses for building houses and for making arts and crafts, wild vegetables, medicines, fruit and bush meat). Under the current reduced stream flow regime, it could be wrongly argued that the use of the floodplain for subsistence needs have been outlived. It is important that the DWAF national water resource strategy views Scenario 1 (with no flood releases) in this context before taking a decision to do away with flood releases.

Indeed, a key valid goal of national government is to grow the economy so that more jobs can be created for people. This view is reflected in the DWAF National Water Resource Strategy (2004), which uses the concept of integrated water resources management to achieve this goal.

In the National Water Resource Strategy (2004), it is stated that, "*integrated water resources management is intended to enable us to meet the needs of our people for water, jobs and economic growth in a manner that also allows us to protect and, where necessary, rehabilitate our aquatic ecosystems. Above all, integrated water resources management will make it possible for us to use our precious water to assist in addressing the overwhelming need to eradicate poverty and remove inequity in South Africa*".

The views expressed in the National Water Resource Strategy (2004) imply that Scenario 1 (with no flood releases) should only be supported if scientific data, in terms of cost benefit scenarios, is produced which shows that, should we destroy the floodplain so that it becomes a dry land, alternative uses of water saved from Scenario 1 (352 million m^3) will still be able to meet the basic needs of all floodplain people by eradicating poverty and inequity through jobs and economic growth, while ensuring that effluents ending up in the water resources from economic growth do not pollute the water resources to the extent that the quantity and quality of water left in rivers can not meet the economic, social and basic needs of others. The impact of Scenario 1 would be pans outside game reserves dry out killing subsistence fishing, marginal pasture, marginal crops, and wildlife. Pans inside game reserves dry out killing all wildlife, fish, and eliminate natural sources of drinking water and natural wetland vegetation grazed by game animals.

If Scenario 1 (with no flood releases) is implemented and the floodplain becomes a dry land, opportunities for making it productive through irrigation exist; however, it is highly risky building irrigation infrastructure on the floodplain under the present state of dam design. To reduce the risk of having irrigation infrastructure destroyed by floods, the dam wall may have to be higher than it is now so that it can effectively act as a flood control/protection against natural cyclone events frequent in the region (e.g. Domoina, February 1984 and more recently Favia, February 2006). Even though Favia missed the catchment, DWAF officials in charge of the dam remained on standby, ready to release water from the dam and create a buffer for new inflows from the approaching cyclone (Personal communication – Dr Beason Mwaka DWAF).

Scenario 2 (with flood releases) enhances the value of the landscape in terms of aesthetic beauty and is therefore a better option for promoting tourism and recreation (*holiday homes, hotels, lodges, restaurants and game reserves*) together with a subsistence economy. Indeed, a subsistence economy can also promote tourism because, very often, many international visitors would like to see and experience the traditional way of life of the local people.

Even if scientific data, in terms of cost benefit scenarios that integrate ecological, economic and social factors, show that Scenario 1 (with no flood releases) can be implemented, given the huge rural human population in the area, results should be tested first in stakeholder forums along the extent of the river before being implemented. This is because results of the social survey in Chapter 7 show that the floodplain is still supporting a subsistence economy and it is more sustainable in the short-term to implement Scenario 2 (with flood releases) and use artificial means (inflatable weirs) to optimise water usage for other purposes.

In building cost benefit scenarios, scientific data should be obtained using a holistic approach that looks at and links economic, social and ecological issues and activities in the whole catchment, from source to sea (Miller, 1996; Primack, 1998). This is because available water in the catchment is limited by natural processes in terms of (climate and nutrients) which in turn determine the existence of plants and animals, including humans on our planet. Therefore, best practice is to start by building scientific knowledge of the sustainability of the ecological and biophysical relationships of these factors under varying degrees of impact from human induced developments. This knowledge base is needed to inform decision-making on matters regarding acceptable levels and types of developments and the degree of acceptable socio-economic impact. The ecological and biophysical knowledge then forms the basis for developing various resource allocation policies to address issues of equity, efficiency, representivity and sustainability. The socio-political and values framework needed to make policy implementation more successful is decentralized community based management structures operating on community-based principles (Ife, 1999) (Chapter 8).

4.4.3.4 Tools for reconciling conflicting demands

King et al., 2004 reviewed three environmental flow assessment methods. The methods were Building Block Methodology (BBM) (King and Louw, 1998); Flow Stressor Response Method (FSR) (O'Keefe et al., 2002); and Downstream Response to Imposed Flow Transformation (DRIFT) (King et al., 2004). King et al., 2004 reported that, the BBM was found not to be useful for scenario development. All three methods were found

to meet the requirements of DWAF RDM approach, but DRIFT was more fully holistic and provided opportunities to develop scenarios by integrating four modules. Firstly, the biophysical module is described and then linked to the subsistence use module (social surveys, health issues, and compilation of economic data). The output is then used to build scenarios of various flows and their potential impact on rivers and the people at risk. The various scenarios are then compared in a compensation economic module to list compensation and mitigation costs and to inform wise trade-offs between various options and to arrive at the most viable option. We found that the thinking described in DRIFT is similar to that described by Heeg and Breen (1982).

A key factor found in all methods is that, compilation of scenarios used depends on availability of data and a knowledge base produced through good science by various specialists. This requires a structured, co-ordinated, multi-disciplinary data collection, monitoring and making predictions of impacts of various stream flow or environmental flow regimes on ecological, social and economic impacts of developments within a catchment. This is seen as the most appropriate means of enhancing understanding and increasing the confidence of predictions on environmental stream flow regimes and their consequences. The implications are that, currently there is little comprehensive data available, on a catchment scale, needed to inform wise decision-making between development options, e.g. DWAF Scenario 1 and Scenario 2.

One important factor that we found missing in these reviews is that they do not describe the socio-political and values framework needed to make policy implementation more successful. The study here attempts to fill that gap by defining values needed within a decentralized community based management structure operating on community-based principles (Ife, 1999) (Chapter 8).

4.4.3.5 Impacts of water for economic growth on the floodplain

The state of stream flow in terms of dam inflows and outflows, hydraulicity index and flood peaks showed that seasonal stream flow had decreased and timing of releases was not in line with natural seasonal rhythms since the Pongolapoort Dam development in the early 1970s. From 2000 onwards, there was a further dramatic decrease in stream flow linked to upstream expansion of developments that reduce stream flow (dam, irrigation, and commercial forestry). On the basis of knowledge from scientific studies on wetlands (Welcomme, 1979, 1986; Keddy, 2002), it is clear that such a stream flow regime cannot meet the environmental requirements of a floodplain wetland ecosystem; hence it can be said that the continued existence of the Pongolo floodplain ecosystem is under serious threat.

Consequently, the subsistence livelihoods derived from use of the floodplain's natural resources by a considerable local human population of rural people living adjacent to the floodplain is also threatened by a reduction in production of the following natural resources: crops, pasture, fishing, poles and grasses for building houses and for making arts and crafts, wild vegetables, medicines, fruit and bush meat (see Chapter 7).

Indeed, it has been reported that people have depended on the floodplain's natural resources for centuries, and the floodplain plays a key role in the subsistence economy, which is bolstered by earnings from migrant labour and from pensions (Poultney, 1980; Heeg and Breen, 1982; Bruwer, Poultney and Nyati,

1996). As a natural ecosystem, it is unique in South Africa and its biota, which includes tropical and other rare species, is adapted to the natural seasonal changes in water levels of the floodplain. The productivity of the whole system is dependent upon the annual summer floods and seasonal water level fluctuations across summer, autumn, winter and spring (Bruton and Cooper, 1980; Heeg, Breen and Rogers, 1980; Heeg and Breen, 1982; Bruwer, Poultney and Nyati, 1996).

In 1982, Heeg and Breen (1982) considered all possible floodplain ecological cause and effect relationships and on this basis made predictions about the possible impacts the Pongolapoort Dam and subsequent irrigation developments would have on the natural floodplain ecosystem and people's livelihoods downstream of the dam. They provided recommendations on how these negative impacts might be mitigated. Twenty-four years later, what Heeg and Breen (1982) predicted, with respect to increasing irrigation developments and possible impacts on the ecology of the floodplain ecosystem, is taking or has taken place. Yet nothing has been put in place to mitigate the negative impacts on the environment. It may well be that if Heeg and Breen (1982) had also predicted the social-cultural and political values, which they did not, planners may have done things differently. No wonder Grumbine (1994b) defines ecosystem management as management that integrates scientific knowledge of ecological and biophysical relationships within a complex socio-political and values framework towards the general goal of protecting native ecosystem integrity over the long term.

4.5 DEFINING DAM MANAGEMENT NEEDS – DWAF PERSPECTIVE

4.5.1 Introduction

According to community development principles (Ife, 1999), the best practice is for professionals to assist communities to define their own needs. Professionals should not define needs independently and then impose them on a community. Best practice is to integrate professionally defined needs (e.g. those identified above) with stakeholder-defined needs.

Community needs were defined through a stakeholder dialogue workshop where individual stakeholders presented and shared their problems. The process served the purpose of building a shared understanding of each other's problems, perceptions, values, beliefs and needs, and should form the initial foundation for developing a common understanding on which subsequent co-management initiatives can be built. In a dialogue process, the actual words spoken by the stakeholders should be captured verbatim so that meaning and feelings become explicit and easily shared and understood by others.

The outcome of this process was problem statement(s) based on stakeholder perceptions. Experience has shown that before groups can develop visions and goals, there should be a clear and widely recognised problem statement. The problem statement helps to establish a common understanding of the conditions and to prioritise initiatives needed to solve the problems on a catchment or sub-catchment scale.

The following sections cover what was shared from a DWAF perspective. Problem statements from other stakeholders are defined in other relevant chapters namely Chapter 5 – ecological values; Chapter 6 – agricultural development needs; Chapter 7 – floodplain community needs.

A summary of problems from all stakeholders affected by artificial flood releases from the dam can be seen in Chapter 8 and details of the actual dialogue process are in Jaganyi et al. (2002).

4.5.2 Dam management procedure relating to flood releases

The Pongolo River is shared between three countries, South Africa, Swaziland and Mozambique. At an international level, the Tripartite Permanent Technical Committee (TPTC) was formed to look at the water interests of the three countries. Due to the international implications, Pongolapoort Dam management is the responsibility of DWAF national and regional.

According to the managers responsible for managing the dam over the period 1999-2004 (Mwaka Beason and Zwane Collin – Personal communication 2004) the dam management process, with respect to artificial flood releases, is as follows:

Annual public meetings are held with stakeholders to discuss timing of an annual flood release event. Stakeholders from upstream and downstream are invited to attend. During these meetings stakeholders voice their proposals and constraints with respect to flood timing and volumes and impact on their needs. DWAF regional officials chair the meetings and record minutes. Negotiations take place among stakeholders and eventually consensus is achieved that attempts to balance the interests of all stakeholders. During the actual release, the flood co-ordinator and some hydrology staff from the regional office monitor the pan levels constantly, for water quality and silt loads. The staff remain stationed at the dam for the duration of the flood to deal with any queries/complaints or crisis and to accurately monitor the agreed outflow regime. After a flood event has happened, another public post-flood report-back meeting is held one to two months later to assess how communities perceived the impact of the flood. For the first time, in 2002, actual flows were measured at two new places, downstream of the dam; one at Pongola River new bridge, and the other on the border with Mozambique. Finally, the flood co-ordinator compiles a flood release report once all the monitored data has been retrieved and analysed. Subsequently, floodplain pan levels are monitored throughout the year, together with any community feedback.

4.5.3 Problem statement by Dr Beason Mwaka from DWAF – National (2002)

Beason Mwaka, is the Chief Engineer of Systems Operations.

To put meaning to the word ‘cards’ referred to below, note that in the dialogue workshop stakeholders were asked to write what they perceived as a problem per card. Cards were then ranked and displayed on the board.

"*I just want to make an observation. If you look at people's concerns displayed on the board, a majority agree that there are serious problems with respect to decision-making. This is simply due to the fact that there are many divergent views and interests, which enhance complexity in decision-making. The competition for water has been increasing and it continues increasing and the complexity of management is also increasing with time. If we take for example the issue of timing of flood releases. Based on the cards of concerns on the board now – one group is suggesting July, another August and another September. If I ask Peter Conant from the conservation agency EKZN-Wildlife here, I am sure he will say December or February. So that is the complexity of the management of decision making that comes with it. All of these things come to DWAF, and we at DWAF have to make a decision that attempts to fit in everyone's concerns. Charel Bruwer here, is lucky that he managed water some years ago (1984-1998), at the time when there was plenty of water and very few developments, he is now having praises from communities. Clive Arendse from the regional office and myself, are managing water now (from 1999 onwards), as developments are starting to increase, we are having problems. The person who is going to manage water 10 years from now is going to be even in more difficulties than we are. It is important that everyone understands these facts so that we can compromise better when we come to negotiate. When we come to negotiate, we should come with a win-win mind set. We know that we are going to lose a bit in order to accommodate other people. With the coming of the new Water Act, DWAF has plans and strategies in terms of the necessary institutions required at the local level to address these issues (CMA, WUAs) to implement equitable sharing of water resources---*."

4.5.4 Problem statement by Clive Arendse from DWAF – Regional Durban (2002)

Mr C.I. Arendse presented these problems in 2002, but since 2003 he is no longer an employee of DWAF. Mr Collin Zwane (dam control technician, northern KZN catchment management) replaced him.

(i) *The volume of the flood releases and the dam capacity at the end of a flood was questionable as to whether there was consensus on that. To expand on that, the upstream farmers and dam property owners want the dam as full as possible; the downstream people do not worry about that too much.*

(ii) *In 2000, the dam was full and over spilling occurred. Some stakeholders favoured natural spilling of the dam but this left no room for flood attenuation. Other stakeholders did not like the spilling because it made the life of local inhabitants downstream difficult as they cannot cross the river due to a lack of bridges. A certain amount of buffer or the absorption capacity left in the dam is important for flood control. If the flood buffer in the dam is inadequate and a big flood comes and destroys infrastructure or kills people, I would have a case to answer to the Minister.*

(iii) *Sometimes Mozambique's needs were in conflict with local community needs. For example, the big flood released in 2002 interfered with structures in Mozambique as the two governments were solving the problem; there was no flood release in 2001, leading to very dry conditions on the floodplain and a very unhappy local community.*

(iv) *Generally, stakeholder attendance is very erratic – as I said in some meetings we get a few people and in others we get very many people. This has implications on agreements reached. This fact has been linked to the fact that the location of the meeting venue is too far away for*

many community members who cannot afford to pay for public transport and so many people are forced to come only when there is a major crisis, e.g. when there was no flood release in 2001.

(v) Lastly, the region was inadequately staffed.

4.5.5 Needs statement – DWAF perspective

i. A broad needs statement, arising from the problem statement, can be summarized as: the need for a formal stakeholder decision-making structure involved in water based development discussions and implementations, which is transparent, accountable and empowered to make wise decisions.

ii. DWAF, as the regulating authority, are required by the National Water Act of 1998 to manage the dam to ensure equitable and efficient water allocations amongst all water users. DWAF also manages the dam for flood control; implied here is that the dam should be at a certain capacity to provide adequate space to hold back summer floodwaters. On this basis, DWAF prefers spring or winter floods. This basically means that should there be a situation where all local floodplain communities have been re-located and prevented from utilizing the floodplain, DWAF would still not be able to implement a natural summer flood regime, unless there was major re-engineering of the dam and the floodplain system to provide summer floods that enable conservation of the floodplain as a development option.

4.6 KEY LESSON LEARNED FROM RECONCILING CONFLICTING DEMANDS

(i) Even without doing a cost benefit analyses, a view emerging from this chapter is that the most sustainable option, in the long-term, is to protect the floodplain by allocating an amount of water that makes it possible for it to produce a diverse set of goods and services (ecological services, social goods and economic goods).

(ii) DWAF proposed two scenarios – Scenario 1 (with no flood releases) and Scenario 2 (with flood releases). When values in terms of goods and services from the two scenarios are identified and compared qualitatively, it becomes clear that the best option is to implement Scenario 2 (with flood releases) but put in place a system that makes it possible to use less floodplain water to achieve the desired ecological effect so that more water can be saved for economic growth. Therefore suggestions by Heeg and Breen (1982), requiring an artificial system to be put in place (e.g. inflatable weirs) as a means of optimising water use to achieve the desired effect, are strongly supported.

(iii) Subsequently, fine-tune the desired level of floodplain protection in terms of water allocations that balance economic growth, social development and ecological sustainability by building a knowledge base that links stream flow to ecological, social and economic factors in order to compare various scenarios of levels of goods and services that the water resource can sustainably produce.

(iv) Between 1982-1994, development interventions in the area in terms of nature conservation schemes, agricultural irrigation development and floodplain water requirements that were

implemented, ignored taking into account knowledge obtained through a holistic perspective and made livelihoods more difficult for many local communities. Even after 1994, agricultural developments that are being implemented have not taken into account holistic thinking, and it is highly likely that long-term sustainability cannot be assured.

Best practice should be guided by a good holistic conceptual development framework, which takes into account the interests of local communities. Development frameworks should be conceptualised using community-based principles and implemented within a decentralized community based management structure operating on community-based principles and values (Ife, 1999). For example, by 2004 the long-term plan envisioned by Heeg and Breen (1982) had not been achieved. They had hoped that the level of irrigation developments would be such that the use of the floodplain for subsistence needs would be outlived and the floodplain would became purely a nature conservation area, protected by EKZN Wildlife. The lack of implementation of a community-based approach to development is the reason why the long-term vision put forward by Heeg and Breen (1982) was not achieved. It indicates that development goals should take into account the importance of the floodplain for local livelihoods and should therefore try to arrive at scenarios that balance economic growth with floodplain protection for subsistence needs.

Due to the presence of a very large local rural population, it is very important that before decisions are made, which assume that the use of the floodplain for subsistence needs have been outlived and that the floodplain should became purely a conservation area or allowed to become a dry land as per Scenario 1(with no flood releases), it is important that such a decision is informed by cost benefit scenarios that determine the most likely alternatives, including industries in the non-agricultural business sector (i.e. opportunities outside primary industries such as agriculture, forestry, and fishing) that can contribute significantly to providing job opportunities to supplement or do away with subsistence agriculture on the floodplain. Therefore, ideas suggested by Backeberg and Odendaal (1998), which require that irrigation farming be supplemented by the development of a wide-ranging programme which not only develops agriculture but also improves skills to earn non-agricultural income through integrated development of the rural-urban link, are highly supported.

CHAPTER 5: ECOLOGICAL INTERESTS (IMPACTS OF REDUCED FLOWS ON THE FLOODPLAIN WETLAND ECOSYSTEM)

5.1 INTRODUCTION

This chapter contributes towards the first objective of this study, which is "*Develop an understanding of the driving forces of the current situation and establish a shared vision for a preferred, achievable and sustainable state of the floodplain system*".

Because the situation on the floodplain is characterised by reduced stream flow due to upstream dams and irrigation (Chapter 4), a review of the possible impacts of reduced stream flow on ecological processes of a floodplain wetland ecosystem is described. The outcome of this understanding becomes useful only when it is linked to other variables such as the biophysical state in terms of climate and soils (Chapter 6) and stream flow (Chapter 4). The three components (biophysical state, stream flow and ecological processes) then form the ecological knowledge base needed to inform decision-making on matters regarding the possible socio-economic impacts of the use of various resource allocation policies on equity, efficiency, representivity and sustainability (Chapter 8).

Ecological factors discussed here should inform many aspects of the reserve determination and the monitoring thereof. According to discussions in Chapter 4, a reserve for a floodplain ecosystem has two components, (i) in stream flow requirements (IFR) and (ii) floodplain water requirements. While DWAF as a regulating body ensures that water of good quality and quantity is allocated equitably and efficiently among users, the conservation agency EKZN-Wildlife is responsible for protecting species and habitats (aquatic and terrestrial) and the DoH is responsible for, among other things, water related disease and disease vector populations. Poor water quality influences its use for basic needs and economic growth, e.g. agriculture.

The following sections cover a review of possible impacts of reduced stream flow on ecological values of a floodplain wetland. The needs statements of key affected and interested authorities managing the floodplain's ecological values are also outlined.

5.2 THE NATURE OF ECOLOGICAL DYNAMICS

Understanding what drives natural ecological processes in wetland ecosystems, could help managers and hydraulic engineers design systems and structures that imitate nature more closely, thus causing less negative impacts on natural processes that produce ecosystem goods and services.

According to Krebs (1994), ecology is the study of interactions that determine the distribution and abundance of organisms. All ecosystems have two levels of production; primary producers (plants) that trap solar energy and secondary producers (animals and decomposer microbes) which depend on this

energy source (Krebs, 1994). The components of a floodplain wetland ecosystem are derived from terrestrial and aquatic sources (Keddy, 2002; Heeg and Breen, 1982, 1994). Floodwaters incorporate terrestrial components into the aquatic system. Productivity of the system (photosynthesis, growth, reproduction, decomposition) is governed by the processes, which occur under both flooded and non-flooded conditions. Hence, water level fluctuations are important for sustaining floodplain wetland processes. Some processes add biological material or biomass (photosynthesis, growth, and reproduction), and others remove them (fire, decomposition, herbivory\grazing and harvesting) (Keddy, 2002). Herbivores process less than 10% of the biomass in the vegetation (Deshmukh, 1986). A vast majority of plant biomass goes directly into the decomposer food web, where invertebrates and micro-organisms process it. Excess toxic pollutants, e.g. (pesticides, toxic effluents from sugar mills and other industrial effluents) deposited in wetlands can inhibit the decomposer food web process (invertebrates and microbes). According to Primack (1998), aquatic communities such as swamps, floodplains, lakes, rivers, tidal marshes, mangroves, estuaries, the coastal shelf and the open ocean, are able to break down and immobilize toxic pollutants (heavy metals, pesticides, and sewage) from farms, human settlements, and industries using largely, fungi and bacteria. When these systems are damaged or become degraded by human activity, e.g. dams and flood control measures, their waste cleaning abilities are greatly reduced, and these abilities are further reduced or destroyed when toxic input exceeds the level at which it can adequately be absorbed. When these ecosystems are damaged or destroyed, often, artificial expensive pollution management controls are installed to assume these functions (Young et al., 1985; Costanza et al*.,* 1997; Du Plessis, 2004).

Therefore, invertebrates and microbes largely determine wetland functions and structure, so it can be argued that wetlands are controlled from the 'bottom up'. Also the composition and structure of the vegetation determines the abundance and distribution of animals (Keddy et al., 1994). This has significant implications for managing wetland meadows for pasture (Tainton, 2000).

According to Keddy (2002), the relative importance of environmental factors that determine the properties of wetlands in decreasing order of importance are: hydrology\flows, fertility or nutrient gradients, salinity, disturbance (e.g. seasonal water level fluctuations, erosion, animal grazing, fire, mowing, ice, waves), competition, herbivory\grazing and sedimentation. This is supported by studies in the following areas: water level fluctuations (Heeg and Breen ,1982; Painter and Keddy, 1992; Toner and Keddy, 1997); fertility\nutrient gradients (Auclair et al., 1976); disturbance (Botkin, 1990; Pickett and White, 1985; Keddy, 2002); competition (Keddy, 2002); herbivory\grazing (Desmukh, 1986); and sedimentation (Keddy, 2002).

For example, it is now known that various combinations of water level fluctuations with various levels of increasing nutrient fertility produce various types of wetland communities. Gopal et al. (1990) showed that various wetland types (bogs, fens, marshes and swamps) can be produced along a gradient of varying water level changes (based on duration of flooding) with fertility (nutrient poor to nutrient rich). Bogs preferred nutrient poor (oligotrophic) and permanent water levels, while wooded swamps preferred nutrient rich (eutrophic) conditions with water level fluctuations ranging from long to short or rare. It has been shown that wetland vegetation patterns (zonation, succession and boundary clustering) and species composition (in terms of richness, dominance and rarity) are produced by multiples of environmental

factors acting simultaneously (Brinson, 1993a). Such knowledge can guide the determination of environmental flow regimes needed to protect and/or restore wetland ecosystems. This possibility provides opportunities to managers to create and recreate wetlands that we may never have seen in our lifetime. This understanding can improve our ability to predict changes in communities and ecosystems, our ability to manipulate them to achieve certain goals and the ability to chose those goals wisely (Keddy, 2002).

According to Keddy (2002), the conventional discipline of hydrology perceives wetlands from a mechanical perspective (ground water discharge, precipitation, and canal flows) and the hydrological functions of each class (donor, receptor, and conveyor), are like machines that provide services to humans (Brinson, 1993b). Management goals are achieved as long as these services are performed. To a hydrologist, the fact that there are different wetland types, marshes, swamps, fens, bogs with different plant and animals species, and different rates of disturbance and fertility, may be unimportant.

On the other hand, biologists perceive wetlands from an organic perspective. Primarily as natural communities of living organisms and strive to maintain patterns and processes within individual wetlands (Noss, 1995; Sinclair et al*.,* 1995). It is assumed that as long as bogs, fens, marshes and swamps retain their normal complement of species communities and processes (functions), they are providing the needed ecosystem services (e.g. groundwater recharges, nutrient regulation and transformation and recreation (Bardecki et al*.,* 1989; Richardson, 1995).

Keddy (2002) points out that, both the mechanical (with respect to flows) and organic perspectives are necessary to understand the multiple consequences of different management actions. Studies of functional ecology of species (e.g. the shape of bills in birds (Welty, 1982); food sources for fish such as carnivores (Keddy, 2002); and feeding mechanisms of insects such as shredders and parasites (Merrit and Cummins, 1984), shows clearly that the very presence of specific plants and animal groups can be treated as indicators that certain functions are occurring. The relative abundance of these functional groups is determined by changes in environmental factors (e.g. water and nutrients).

Quantitative models that link hydrology, ecology and human behaviour to predict not only the direction of change, but also the amount that is probable, are needed (Painter and Keddy, 1992; Toner and Keddy, 1997). The assumption is that if we appropriately manage wetland communities to maintain their natural composition by regulating multiples of environmental factors then we might achieve the desired structure and function and that function will persist through time (Keddy, 2002).

Suppressing ecological dynamics in wetland and riverine systems through the effects of human induced activities such as dams, dyking, and draining, reduces ecosystem resilience and persistence through time (Keddy, 2002).

Naturally induced ecosystem dynamics (e.g. seasonal water level fluctuations, erosion, grazing, fire, ice, waves) promotes ecosystem resilience; hence persistence through time. Indeed, persistence or sustainability of ecosystems and their communities is important for ensuring the persistence of human civilization (Holling, 1978; Christensen et al*.,* 1996; Keddy, 2002). Therefore designing artificial systems

that maintain naturally dynamic processes is key to ensuring persistence of the natural environment and of human civilization (Botkin, 1990).

Implied here is a need for different groups of scientists and managers to speak to one another to ensure that neither of these perspectives (hydrology and ecology and human behaviour) is neglected. This is because innovative solutions to the problem are urgently needed. A classic example in South Africa where this approach has been attempted is a case study of the Kruger Park Rivers Research Programme (Breen et al*.,* 1994, 1997, 2000).

Analysis of published articles (e.g. Carpenter and Lodge, 1986) points to volumes of research carried out by wetland scientists that lack purpose, goals, strategies and plans aimed at achieving successful conservation management (Keddy, 2002). These is coupled with the fact that many studies carried out have remained unpublished as technical reports in government departments, research institutes and universities and are therefore unavailable to the international community. In addition, fewer studies are conducted in southern hemisphere countries, compared to the northern hemisphere, yet this is where one finds a large number of relatively undisturbed wetlands. Keddy (2002) calls for more studies by wetland scientists to develop quantitative models linking wetland community structure to hydrological variables.

Another human problem that has hindered successful ecosystem management is the need to understand human social science and to link it with ecology and hydrology for successful implementation and management. Conservation and management of ecosystems comprises (i) developing priorities for action based on three goals (protection, management and restoration); and (ii) choosing indicators for those actions (based on selecting the appropriate factors to monitor, setting critical limits upon them and monitoring to ensure that management achieves it goals). Keddy (2002) argues that the need to protect landscapes should be the first priority for action because there is not much time left in which to protect relatively undisturbed landscapes. Management and restoration should be based on goals to maintain ecosystem function and values using ecological ecosystem management principles (Grumbine, 1994; Christensen et al., 1996; Grumbine, 1997; Haeuber and Franklin, 1996; Keddy, 2002), namely:

(i) Interconnectedness – the need for managers and researchers to appreciate the vast array of processes and inter-connections that underlie ecosystem function,
(ii) Managing ecosystems for sustainability while maintaining their natural dynamic character,
(iii) Recognising that ecosystems are connected and operate at local, regional, international and global scales,
(iv) Recognising that humans are part of ecosystems and incorporating human behaviour when developing clear goals to achieve the desired future state of the system and ensuring that human behaviour is included in models,
(v) Monitoring goals and objectives to ensure accountability (to enable comparison of expectations and forecasts), using indicators. Ensuring that someone monitors indicators, and that action is taken to alter management practices when indicators warn us of impeding problems.

The issue here is that even though ecosystem management principles are known, man continues to destroy the environment. Keddy (2002) points to the most important problem that wetland scientist's face – a limitation or lack of understanding of the external world, (i.e. their inability to relate to and communicate scientific facts to the human community so as to facilitate change). This calls for a need for scientists to have some basic training in psychology and social science and vice versa for non-scientists.

Ideally, long-term solutions should ensure that the entire human race understands basic concepts in ecology and hydrology, in addition to psychology and social science and ecological or environmental economics. This understanding may form a basis for reconstructing human beliefs, norms and values that enables a change in attitudes (people's thinking, practices, action and interactions) and subsequent decision making that supports the natural maintenance of ecosystem processes, structure and function. The fact that humans are part of ecosystems means that the rapid reduction in area and destruction of wetlands caused by human impact may eventually cause the human race to become extinct, just like the many plant and animal species that are already extinct (on local, regional or global scales) (Raup, 1992; Reid and Miller, 1989; Primack, 1998).

Indeed wetlands have always influenced humans; for instance, early civilization first arose along the edges of rivers in the fertile soils of floodplains. Wetlands are the cradle of human civilisation and giving them an economic value in monetary terms in order to justify their conservation is underestimating infinity (Millennium Development Ecosystem Assessment, 2003; Perrings, 2005, 2006). It is argued that wetland conservation should be based on ecological, ethical and moral values instead. That developments should strive to enhance ecosystem services (Millennium Development Ecosystem Assessment, 2003; Falkenmark, Finlayson and Gordon, 2007; Molden, 2007).

Yet the current obstacles to wetland research and conservation, as Keddy (2002) puts it, "exist in the heads of fellow citizens". Humans are not only failing to live in harmony with their environment but with each other (Ife, 1999). The factors influencing this behaviour are, among other things, ignorance, fear and greed (Senge et al., 1999; Ife, 1999; Keddy, 2002).

Indeed, management studies support the need to acquire learning skills that enhance overcoming such factors thereby enabling change in people's attitudes (Senge et al., 1999). They argue that, a key problem is that people do not resist change but people resist being changed. This phrase is supported by the fact that despite the presence of excellent technologies and laws that protect the environment, significant change in people's behaviour is not guaranteed and man has continued to destroy the environment.

Senge et al. (1999) points out that the way to achieve profound change is to ensure that people's inner values, aspirations and behaviour change with outer shifts in processes, strategies, practices and systems. It is not enough to change laws, strategies, structures and systems, unless the thinking that produced those laws, strategies, structures and systems also changes. Implied here is a need to align people's perceptions, beliefs, norms and values with the environmental policies that are in place.

The following review helps to contribute to this goal by identifying possible impacts of reduced stream flow on ecological values of a floodplain wetland.

5.3 THE IMPACT OF DAMS\IRRIGATION ON FLOODPLAIN WETLAND ECOSYSTEMS

5.3.1 Water level fluctuations

Dams and irrigation agriculture are a devastating combination for floodplain alluvial wetlands situated downstream. Irrigation requires water abstraction either directly from a stream or indirectly via dams or off-channel storage. Dams reduce downstream flows and flooding because seasonal floods are held behind the dam wall for irrigation use.

Depending on the nature of dam management, the effect of dams upon natural flow regimes downstream can be: stabilization of water levels, decreased or increased flooding, and shifted flood timing, where floods happen at times that are different from natural seasonal times.

Generally, an empirical pattern has been established around the world that dams reduce flooding and that reduced flooding stimulates a change in ecological processes causing wetlands to shrink and to change biological structure. An example is the encroachment by terrestrial species in which herbaceous wetlands are invaded by woody species, a conversion of wet meadows to woody plants, and the subsequent change in function, biological diversity and ecosystem services produced (Welcomme, 1979, 1986; Klimas, 1988; Nilsson et al., 1991; Johnson, 1994; Toner and Keddy, 1997; Poiana and Johnson, 1993; Rosenberg et al., 1995; Acreman, 1999; Keddy, 2002; Barbier and Thompson, 1998; Ehrlich and Ehrlich, 1981; Noss and Cooperrider, 1994).

Reduced flooding means that the floodplain remains dry for long periods between seasons which enhances the rate of change. For example, on the Pongolo floodplain areas of wetland grassland meadows utilised for pasture are converted to woody plants (bush) (Chapter 7) to the detriment of livestock health (Tainton, 2000).

On the Pongolo floodplain, Heeg and Breen (1982) found that the pasture grass, *Cynodon dactylon,* was well developed (away from marshy areas), around shallow pans with substantial margins subject to periodic flooding. Major localities were Nomanini pan (42 ha), Mthikeni-Nsimbi pans (27 ha) and Ngodo pan (32 ha). Total area covered by this grass on the floodplain was 171 ha. *Cynodon dactylon* played a significant role in primary production and nutrient cycling. A significant amount was inundated by floodwaters and utilised by aquatic herbivores or entered the decomposer cycle as detritus. Some was removed through cattle grazing. With respect to the response to a flooding regime, Heeg and Breen (1982) found out that *Cynodon dactylon* lawns need an annual period of flooding. Rate of soil moisture drying out is critical to the productivity of the system (Furness, 1981). They recommended a rate of exposure to flood waters be a drop in water level between high flood level and maximum pan retention level of not less than 2 months. If the floods receded too quickly, early water stress, coupled with grazing pressure from cattle, decreased productivity of the lawns. A sudden, complete shutdown after a simulated flood can cause rapid drying out of soil moisture. Results of analysis of trends in artificial seasonal flood peaks showed patterns characterised by a single distinct peak in a year, indicating that rapid drying out is

taking place (Chapter 4 – Fig 4.12 and Fig 4.13). Therefore, it is highly likely that its productivity and area covered by this valuable pasture grass has also decreased (Chapter 7).

In addition, other pasture communities *Cyperus fastigiatus* and *Echinochloa pyramidalis* occupied marshy areas (Heeg and Breen, 1982). Extensive stands were found in Ndumu game reserve and west of Tete and Nsimbi pans. Total area covered by these pasture communities on the floodplain was found to be 2471 ha. The herbivorous fish *Tilapia rendalli* and terrestrial grazers, cattle and hippo, graze *Echinochloa pyramidalis*. Both plants contribute to aquatic secondary production when flooded. Two months annually was considered the maximum tolerable period of submergence. It was observed that *C. dactylon* was replacing these communities in better-drained localities. Therefore, in order to preserve the pasture communities *Cyperus fastigiatus* and *Echinochloa pyramidalis* which occur in marshy areas, the flooding pattern should be such that the likelihood of marshy areas drying out between floods and summer rains should be minimal.

Because dams temporarily protect floodplain wetlands from natural seasonal flooding, the dry lands formed are frequently converted to intensive agriculture, which reduces the floodplain wetland area. For instance, the Mississippi River floodplain in the USA was estimated to be 85-95 million ha in 1990. Today only 2 million ha are left (Llewellyn et al., 1996). Similar trends are observed in African floodplains (Welcomme ,1976; Heeg and Breen, 1982; Horowitz and Salem-Murdock, 1990; Barbier et al., 1991; Hollis et al., 1993; Bruwer et al., 1996; Wesselink and Drijver, 1993; IUCN wetlands programme newsletter No. 12, 1996; Barbier and Thompson, 1998; Adams, 1992, 1993, 1995, 2000; WCD, 2000, 2000a).

In addition, modern agricultural practices tend to have negative impacts on native biodiversity because extensive areas of native vegetation are replaced by single species of crops, often under intensive management levels, using modern technologies, fertilizers and pesticides. Run-off containing excess nutrients and toxic organic compounds often accumulates in floodplain soils and river sediments. The scale and intensity of operations influences the extent of the impact on natural habitats, non-target organisms in the environment, in soils and in water bodies through run-off. Reduced flooding in terms of frequency and volume enhances these negative impacts through reduced ability to dilute and flush out pollutants, which impairs natural nutrient cycling processes leading to high nutrient loading in the environment and eutrophic conditions in water bodies causing anoxic conditions that kill fish and reduce water quality.

On the Pongolo floodplain, the presence of two upstream dams has meant that the floodplain remains dry for long periods between seasons. The dry lands formed are used for subsistence agriculture. As a result the once vast valuable pasture fields have been reduced greatly. The remnant pasture fields are overgrazed and are highly degraded (Chapter 7).

Impacts of reduced flooding in the Peace-Athabasca delta in Canada were reported by Rosenberg et al. (1995), as a further example. The removal of the annual peak in floodwaters that occurred in June, when the Bennet dam was completed 1200 km upstream, led to the rapid change of the vegetation in the delta through short-term succession. Within two years, the total wetland area had decreased by 28%, and the

numerous ponds and lakes of the delta were drying up at the rate of 20% per year. To mitigate these negative impacts weirs were constructed to hold back floodwaters and recreate natural, periodic flooding. Although this did not protect all wetlands, it made the best of a bad situation (Keddy, 2002).

5.3.1.1 Water level fluctuations – effects around the dam

A classic case of the impacts of dams and upstream effects (around the dam itself) was reported by Nilsson (1981). Management of the Gardiken reservoir in northern Sweden is such that water levels are the reverse of natural cycles (lowest in spring to begin storing water and highest in autumn and lowered progressively during winter to generate hydroelectric power). Water level fluctuates by as much as 20 metres, exposing 56 km^2 of shoreline. The combination of frequency and intensity is so extreme that no plants can tolerate the conditions over most of the shoreline. Further studies (Nilsson and Keddy, 1988) showed that the abundance of plants decreased with greater duration of flooding but increased with the number of floods. Species richness showed similar patterns but declined with the date of the last flood. The two best predictors of vegetation were (i) composition of vegetation the preceding year and (ii) the duration of the flooding the preceding year. If the duration of flooding was around 60 days, the vegetation remained more or less unchanged. If the duration of flooding was less than this, the abundance of plants increased, and if it was greater than this, the abundance of plants decreased. Species tended to shift into deeper water as the amplitude increased and responded to both duration of flooding and the timing of draw downs.

The role of models in predicting responses of ecosystems to change is important. Because variation in plant and animal communities can be explained by differences in hydrology, interacting with erosion and sedimentation (Junk, 1983), changes in hydrology associated with land developments such as dams, forestry practices, and agriculture may reduce the distribution of species or eliminate them completely.

It is therefore useful to know the duration of flooding that sets the upper and lower water fluctuation limits by exploring relationships among different components of hydrology and by relating them to vegetation. Tonner and Keddy (1997) showed that the probability of finding a wooded as opposed to an herbaceous wetland was caused by two factors, the end of the first flood and the beginning of the second flood. Therefore, the greater the period between the first and second flood, the higher the probability of the survival of trees and the occurrence of wooded wetlands.

Painter and Keddy (1992) developed a simple simulation model showing the response of wetland vegetation to changes in water level in the Great Lakes. Their objective was to predict the upper boundary of wet meadow and the lower boundary of the marsh. The model was used on projected water level scenarios to forecast the effects on wet meadows\marsh area. The model predicted losses of approximately 30% of the wetlands in Lake Ontario alone, if further reductions in amplitude occurred.

For the Pongolo floodplain ecosystem, a programme of monitoring and research has to be designed to collect data for modelling and for making predictions about the response of wetlands vegetation to change, which provides knowledge that informs a desired level of protection by setting upper and lower level water fluctuation limits. The monitoring programme must be designed in a way that local

communities take ownership and responsibility for monitoring within a community-based structure of management (e.g. WUAs, CMAs). This would cut monitoring costs and increase community awareness and self-regulation.

5.3.2 Fertility/nutrient gradients

Dams/irrigation reduces flows. Reduced flows lower a river, wetland or lake/dam's ability to dilute and control excess nutrients through natural processes. For instance, the use of fertilizers in agriculture leads to excess nutrient runoff and increased nutrient loading of water bodies causing eutrophication, i.e. rich nutrients that support growth of a dense plant population of usually a single species which shades out other species and the dense plant growth eventually kills animal life by depriving it of oxygen.

5.3.2.1 The relationship between wetland plants and nutrients

In a healthy body of water, with natural/pristine water quantity (stream flow) and natural/pristine nutrient loading, two types of plants have been found to co-exist by sharing available nutrient resources and regulating nutrient cycling processes. By doing so, they contribute to maintaining a balance in the nutrient loads of water bodies. The plants are: (i) algal communities**,** found free-floating, known as phytoplankton, comprising mainly blue-green algae (Cyanophyta) and algal communities attached to substrates like stone or larger plants, etc, known as epiphyton. Both have species known to fix atmospheric nitrogen, and (ii) macrophytes or rooted plants, such as permanent water lilies and water chestnut or seasonal ones, such as *Potamogeton crispus*.

Under abnormal conditions, e.g. low water quantities (flows), high pollutant input, induced through high level human activity (dams, irrigation, domestic and industrial effluents), this balance is disrupted, resulting in polluted water bodies. For instance, in eutrophic conditions associated with high nutrient loading, algal communities predominate; they increase in biomass, absorb light and shade out macrophytes. Under moderate nutrient loading conditions, macrophytes became dominant (Phillips et al., 1978). Carignan and Kalff (1980) established that the source of nutrients (particularly phosphorus) used by aquatic macrophytes during growth was mainly removed from sediments. Even under hypertrophic conditions, the sediments contributed nearly three-quarters of the phosphorus taken up during growth and a quarter came from the water column. Therefore, distribution and abundance of aquatic plant populations is determined by nutrient gradients in sediments just as in wetland and terrestrial plants (Keddy, 2000). Macrophytes have been reported to play a significant role in nutrient re-cycling. They regulate nutrient levels by removing nutrients from sediments, holding them during the growing season as organic matter and returning them to open water at the end of the growing season through decomposition (Barko and Smart, 1980).

Heeg and Breen (1982) provided justification for conservation of the Pongolo floodplain and recommended implementation of an artificial flooding regime that imitates natural seasonal patterns to optimise ecological processes and ecosystem services. For instance, unnatural flood timing could interfere with the growing season of the seasonal rooted macrophyte plant, *Potamogeton crispus,* upon which much of floodplain productivity depends because it provides significant energy input into the

system at the time of year, during periods of low flows in winter, when input from all other sources is minimal (Everson, 1980, Heeg and Breen, 1982). The seasonal rooted macrophyte plant, *Potamogeton crispus,* starts germinating from dormant, vegetative, reproductive parts known as propagules (turions) when water temperatures begin to fall during autumn in April. Within a short time, a dense growth of submerged plant is produced. Propagules are also extremely sensitive to desiccation, so *Potamogeton crispus* develops substantially in floodlain pans which do not dry out completely. Implied here is that reduced flooding of the floodplain (volume and frequency) caused by dams and irrigation has the potential to cause the drying out of huge areas of floodplain pans, subsequently leading to a reduction in the abundance of *Potamogeton crispus* and an increase in abundance of blue-green algal communities, causing eutrophic conditions.

A decrease in abundance of Potamogeton *crispus* is likely to lower the role it plays in nutrient regulation. For instance, *Potamogeton crispus* provides the base for various food webs (fish, birds, invertebrates, and mammals) in the dry winter period with naturally low flows (June, July, August, and Sept). These various food webs play a role in dissipating and hence regulating the nutrient concentrations. For instance, by late winter (July, August) propagules are produced. Huge flocks of ducks (*Dendrocygnus viduata*) invade the floodplain pans temporarily in winter to feed on *Potamogeton crispus* propagules. For instance, 8 000 ducks were recorded on an 86 ha floodplain pan (Tete) (Heeg and Breen, 1982). The fish, *Tilapia rendalli,* eats *Potamogeton crispus*. The snail (*Bulinus natalensis*) starts feeding on *Potamogeton crispus* when it stops growing and begins to degenerate and so plays a great role in the breakdown of the plant material. However, until then the alternative food for the snail is epiphyton algae, which grows on the leaves of *Potamogeton crispus* and other submerged plants. Epiphyton algae begin growing when *Potamogeton crispus* produces a dense growth which restricts wave action and reduces turbulence so that the water becomes progressively clear. Preliminary studies showed that epiphyton algae occurring on *Potamogeton crispus* had considerable nitrogen fixing potential: a maximum fixation rate of 23 mg of nitrogen/m^2/day, a total of 1.27g of nitrogen/m^2/4 months and it was estimated to add 1.14 tons to the nitrogen pool of Tete pan (86 ha). Epiphyton algae annual production was found to exceed that of *Potamogeton crispus* because its turn-over rate was higher (ranging from 14.4-2 days), despite the fact that it was consistently grazed by snails.

Potamogeton crispus was also found to directly increase the movement of inorganic nutrients through the system. Its roots are embedded in sediments at the bottom of the pan. For instance, phosphorus content in sediments at the bottom of Tete pan decreased as the standing crop increased. It was estimated that 0.17 tons of phosphorus was bound up in *Potamogeton crispus* in Tete pan (86 Ha). In September, the standing crop of *Potamogeton crispus* was 42.8g/m^2 which is equivalent to 34.95 tons of dry plant material, given that propagules remain dormant and do not decompose. Only 27.17 tons decompose and is put back into the system. Decomposition rate was found to be 1% per day so that at the beginning of summer in December, when the first natural flood peaks, this material has all been transferred to other components of the system (fish, birds, invertebrates, and mammals). The implication is that if floods occur before decomposition has taken place, there will be a loss of nutrients from pans (Everson, 1980, Heeg and Breen ,1982). Secondly, the abundance of this plant in subsequent years is likely to be affected by decreasing its yields or biomass (Phillips et al., 1978).

Auclair et al. (1976) showed that, fertilization alleviates nutrient limitation in wetlands (marshes and wet meadows) causing shifts in competitive ability that led to an increase in biomass (mass per square unit) but decreased species diversity. For example, large rhizomatous species such as *Phragmites communis* and *Typha angustifolia* were associated with high fertility (Auclair et al., 1976). Keddy et al. (1994), have also reported that competitive displacement of other species by the dominant species is higher in flooded and fertilized conditions. In aquatic situations, increased fertility causes eutrophication, resulting in diebacks of macrophytes and consequent anoxic conditions that kill fish. Excess nutrient loads reduced fish production in the Great Lakes (Christie, 1974; Vallentyne, 1974).

5.3.2.2 Impacts of excess nutrient loads on a dam

In South Africa, a classic example of impacts of excess nutrient loading in water resources from urban and agricultural sources is illustrated in the case of the Hartbeespoort Dam in the North West province (Du Plessis, 2004). The Hartbeespoort Dam is located in an up-market area where the rich and famous own multi-million rand homes dotted around the dam. The dam contributes greatly to the beauty of the surroundings and is very popular for recreational purposes. It was originally built for irrigation purposes as a job creation scheme to help alleviate poverty that prevailed after the First World War. Over the years, rapid urban developments upstream enhanced water pollution. For instance, 16 sewage works and many industries discharge wastewater effluents from high density Johannesburg and Pretoria cities into the Crocodile River flowing into the dam. The dam traps excess nutrients, rich in phosphorus and nitrogen commonly found in fertilizers, industrial wastewater, sewage effluent, soaps and washing powders. Excess nutrient loads stimulate eutrophication processes, which enhance growth of cyanobacteria and aquatic weeds. When the aquatic weeds (e.g. algae) die, they rise to the surface and start decomposing, forming a toxic cyanobacterial scum, which produces fumes and a foul smell. Decomposition processes deplete oxygen levels in the water and often under high temperatures, the nitrogen forms ammonia and methane, which is toxic to fish and birds.

Cyanobacterial blooms became a problem in the 1970s. However in April 2003, the problem increased to such a degree that three hectares of water close to the dam wall were covered with a 30cm thick sludge of rotting algae, which looked and smelled like raw sewage, which had a negative influence on prospective buyers looking to buy upmarket homes in the area. The taste and smell of water supplied from the dam for domestic purposes was also affected.

DWAF approved a budget for emergency clean-ups involving the physical removal of the cyanobacterial scum. For instance, to clean up scum accumulation, it took 10 days to pump out 3 ha of scum which was found to contain a ½ ton of phosphate. The cost of removing phosphate physically was R1 million/ton. The technique used was not effective because it pumped out a lot of water along with the algae. Optimising the pumping system was estimated at a cost of R1.2 million (Du Plessis, 2004).

It was estimated that 200 tons of phosphate per year was generated by industries in the catchment area, but only 20 tons was accounted for in inflows into the dam after filtration processes through wastewater works. Therefore, 180 tons must be carried into the dam in sediments through storm water or sewer blockages and leaks. Phosphate in the main water of the dam was estimated to be 25 tons, while dam

sediments contained about 140 tons. Significant reduction in algal growth would require a reduction in phosphate inflows into the dam of about 10 tons/year and a reduction in the phosphate levels in the dam itself from about 0.12 mg/litre to less than 0.05 mg/litre. On this basis, clean-ups put an end to fumes and the foul smell immediately, but do nothing to solve the real problem, the level of phosphates in the dam or outside the dam. In economic terms, the clean-up option is neither cost-effective nor efficient. Society is paying for the costs.

A national phosphate standard specification, used to regulate phosphate levels in water, was put in place in the 1970s. Since then, local governments have spent over R800 million implementing the phosphate standard, but the reality is that it has not achieved its goals. Many industries in the catchment meet phosphate specifications yet the phosphate load in the dam is very high. Within the catchment, chemical treatment in wastewater works costs R4-R6 million. The option of implementing a stricter standard required a huge cost of R100 million to upgrade the necessary infrastructure that could cope. Cost implications on a national scale are enormous, because the most abundant mineral ion in sewage sludge in wastewater works in all provinces of South Africa was found to be phosphorus, with concentrations of up to 10g/Kg (Jaganyi et al., 2005). These realities have triggered DWAF to supplement the phosphate standard by supporting research and development of alternative measures, such as integrated biological solutions (Du Plessis, 2004). Indeed, algal blooms are nature's way of bringing excess nutrients into balance. However, the biological system fails because the nutrient levels are just too high for nature to cope with. Clearly, if biological systems were put in place to clean up the environment, the costs saved could be diverted into projects that aim at improving the social wellbeing of the majority of South African people.

Although sewage sludges from sewage works were packaged and used as agricultural fertilizers, only 28% of the sewage sludge generated in South Africa was used for this purpose (Snyman et al., 2000). Although this was a productive way of recycling excess nutrients, non-point source pollution entering water bodies from agricultural sources is still a problem.

5.3.2.3 The role of wetlands in regulating excess nutrient loads from agriculture

In the USA, agriculture contributes about 65% of the nutrients that wash into the Mississippi River. In turn, when these excess nutrients reach the Gulf of Mexico, they cause eutrophication and a 'dead zone' of oxygen-poor water of up to an area of 20 000 km^2 (DeWeerdt, 2004).

Perhaps, exploiting the ecosystem services provided by wetlands can prevent such non point source pollution. For instance, ways could be found of integrating wetlands into agricultural drainage systems and designing such drainage systems in a way that helps wetlands to work more efficiently, like giant sponges that absorb huge amounts of nutrients (Zedler, 2001, 2000, 2003; DeWeerdt, 2004). The Department of Agriculture and Environmental Affairs and the Land Care programme, in partnership with DWAF and specialist wetland researchers (hydrologists and biologists), should lead such a project. Such projects have been initiated in the USA (Zedler, 2000, 2003; DeWeerdt, 2004). Local research must be carried out to improve local wetland functional efficiency.

Agriculture and reduced stream flow contribute significantly to destroying wetlands, and therefore goals to restore or create wetlands must aim to improve water quality and restore stream flow. Best approach is to start at the catchment scale and prioritise what to restore. Areas where the hotspots for habitat, water quality, and flood control overlap get highest priority for restoration. The approach has proved to be a powerful local planning tool. It has been found that a key factor to restoring effective wetlands is to create wetlands like those that characterize the native landscape.

Very often regulating authorities approve developments on condition that wetlands are restored to mitigate impacts. Zedler (2003) points out that managers must be aware of the differences between wetlands and ponds and avoid converting landscapes of diverse wetland types into a monoculture of ponds and the creation of generic wetlands where weedy, generalist species thrive and invasives crowd out native biodiversity. Restoring wetlands does not mean that if you build wetlands species will come. What makes an ecologically functioning wetland is a lot less straightforward. For instance, efforts to restore a coastal wetland failed to provide habitat for its intended bird resident as, even though the site looked like a healthy wetland, it lacked some subtler quality. Vegetation that the bird favours for nesting was planted but it did not grow (Zedler et al., 2001). After 10 years, the bird was still limited to small remnants of disturbed salt marsh habitat and the bird remains on the endangered species list (DeWeerdt, 2004).

An evaluation of twenty-five wetland restoration projects fell short of their goals in one way or another (DeWeerdt, 2004). Goals that used native species and pristine conditions achieved the best results. There is an ongoing debate within the field of wetland restoration concerning whether to invest time, energy and money in planting vegetation at restoration sites. Others argue that we simply need to restore the hydrology (stream flows) of the site and a wetland will develop of its own accord (Keddy, 2002, Kleijn et al., 2004); that nature knows best.

Indeed, under virgin or unmodified flow conditions, Heeg and Breen (1982) showed how the natural functioning of the Pongolo River and floodplain wetland ecosystem through water level fluctuations was able to achieve the goal of balancing agriculture and conservation. Floodwaters carried nutrient rich sediments from the catchment and deposited the sediment on the floodplain. Adequate water level fluctuations (volume and timing) enabled nutrients to dissipate in nutrient cycling processes through aquatic and terrestrial plants and animals, including man and his activities (fishing, pastoral zones, crop zones, harvesting and wildlife zones) and a balance in nutrient loads was sustained. Off-course other factors, like carrying capacity and level of resource exploitation, come into play; but generally, this optimised floodplain production in terms of biodiversity and food production. It is therefore important that managers develop a model of the present artificial system that makes it possible to define appropriate water level fluctuations needed to meet a desired level of protection and use.

The importance of hydrology\stream flows in mitigating excess nutrients in the environment is also supported by a study carried out to evaluate the ecological effectiveness of agri-environment schemes in the Netherlands (Kleijn et al., 2004). Because agriculture in Western Europe has greatly intensified, causing a dramatic decline in biodiversity, European Union countries spent about US$ 29 billion on conservation agreements between 1992 and 2003. Dutch conservation agreements pay farmers for

adopting agricultural practices intended to benefit nature. Kleijn et al. (2004) set out to find out whether conservation agreements really work. They evaluated botanical agreements and meadow bird agreements that prohibit changes in drainage and limit fertilizer and herbicide use and prohibit disturbing fields during bird breeding season. Comparisons were made for bird biodiversity and plant biodiversity between fields with and without agreements. Results showed that the agreements were not working and in some cases, they were harming target species. There was no difference in plant species diversity between fields with and without conservation agreements. Fields with meadow bird agreements had about 40% fewer wading birds (the target species) than those without agreements because they receive less fertilizer and so have fewer earthworms to eat. Specifically, the wading bird, the black tailed godwit-*Limosa limosa* has kept declining even though conservation agreements cover much of its habitat. About half the total population of this bird breeds in the Netherlands, which, historically, had a great diversity of meadow birds and grassland plant diversity that depended on high groundwater levels. More recently, groundwater levels have been kept low so that farmers can use their fields early in the spring, which enables them to gain a longer growing season, but it also makes the soil dry out faster and so decreases the population of worms and other soil dwelling prey available for wading birds to eat. Kleijn et al. (2004) concluded that conservation measures that require little adaptation of the farming system are unlikely to yield positive effects in intensively used agricultural landscapes. Simple conservation measures taken by farmers may not be sufficient to counteract the impact of factors that are often controlled at the landscape or catchment scale. Indeed, Keddy (2002) points out that key environmental factors determining species distribution and abundance are, in order of importance: hydrology\stream flows, fertility or nutrient gradients, salinity, disturbance (e.g. seasonal water level fluctuations, erosion, animal grazing, fire, mowing, ice, and waves), competition, herbivory and sedimentation.

On this basis, the view that hydrology (stream flows) is key is strongly supported. There is no point in approving funds for restoration projects or projects to assess water quality or vegetation integrity at sites where stream flows are severely altered from natural patterns; it is a total waste of money, time, energy and resources.

Implications of the study by Kleijn et al. (2004) and studies by Keddy (2002) for the Pongolo River floodplain are that piecemeal projects funded to enhance conservation targets (water quality or vegetation integrity) on the floodplain, without providing an adequate volume and flood duration and seasonal timing, are a total waste of tax payers' money and a waste of researchers time and effort since the environmental outcomes can never be achieved. Indeed over the years floodplain communities have become frustrated with the present artificial flood releases which have reduced production of wetland goods and services, making local communities very frustrated, and in turn blaming government for not meeting the needs of the environment and hence the basic needs for people. Hydrology (stream flows) on the floodplain is key and must be sorted out first.

5.3.2.4 The role of soil fertility and soil acidity on yields and excess nutrient loads

Studies of soil fertility and its relationship with soil acidity and nutrient cycling processes can provide information that not only improves production of crop yields, but can also improve the management of excess nutrient loads that are likely to lead to leaching into water bodies.

5.3.2.4.1 Nitrogen

Miles and Manson (2000) carried out a review of soil fertility studies in pasture management in South Africa and found that the natural processes in which soil micro-organisms mineralise nitrogen (N), by converting it from an organic form not available to plants to an inorganic form (ammonia and nitrates) available to plants, can contribute greatly to adding excess nutrient loads in cultivated, (tilled) fertilized fields which find their way into water bodies through leaching (Haynes, 1986; Whitehead et al*.,* 1990).

Factors determining production of pasture were found to be nitrogen availability, moisture and temperature. Sources of nitrogen supply can come from fertilizers, symbiotic nitrogen fixation by legumes, animal excreta and soil mineralization by micro-organisms.

It was found that under certain soil conditions, soil micro-organisms can either mineralise or immobilize nitrogen. Soil fertility measured on the basis of the clay content and its base status (i.e. soil chemical factors that make a soil acidic or basic) determines the rate at which nitrogen mineralises the soil. Acidic soils inhibit the nitrogen mineralization process (Adams and Martin, 1984). Soil disturbance (tillage) promotes soil aeration exposing organic matter to micro-organisms and enhancing the oxidation processes that lead to mineralization. The chemical composition of the decomposing litter influenced the direction of the process (mineralization or immobilization). Soil organic matter, rich in nitrogen (low C:N ratio <25:1, e.g. lugumes), was found to increase the mineralization process, whereas soils rich in carbon content (high C:N ratio>30:1, e.g. maize, straw and sawdust) immobilized nitrogen for prolonged periods leading to a temporary depletion of inorganic N reserves (the negative period). In soil organic matter having a C:N ratio between 25-30:1, immobilization of N dominated for the first few weeks of decomposition, after which there was net mineralization (Tisdale et al., 1985; Haynes, 1986: Whitehead, 1986). It was concluded that decomposing residues from pastures receiving high rates of N are unlikely, therefore, to bring about appreciable immobilization of N (Miles and Manson, 2000).

Tisdale et al. (1985) found mineralization increases sharply as temperatures increase over the range 5°C–35°C, and declined outside these ranges. High temperature and high moisture favour microbial growth and thus mineralization of soil N where the C:N ratio of the organic substrate is sufficiently low (Whitehead, 1986). As a consequence of moisture and temperature effects on mineralization, the availability of N from soil reserves peaked in the first half of the summer, particularly in summer rainfall climates (Sanchez, 1976).

Clearly the review shows that knowledge of the dynamics between soil fertility and its relationship with soil acidity, and nitrogen nutrient cycling processes and seasonal climate variables (temperature and moisture) can provide information that not only improves production of crop yields, but can also improve the management of excess nutrient loads which are likely to lead to leaching into water bodies. Such knowledge can contribute to improving environmental flows in terms of water quality relating to mitigating impacts of excess nitrates from non point sources.

5.3.2.4.2 Phosphorus

Like nitrogen, phosphorus is an essential macronutrient for all living organisms**.** Phosphorus nutrient cycling processes are similar to those of Nitrogen. It exists in organic and inorganic forms. Plant roots absorb phosphorus mainly as the monovalent di-hydrogen phosphate ion (H2PO4-).

Sutton (1969) and Barber (1980) reported a decrease in soil P availability with decreasing soil temperatures. Implied here is that, like nitrogen, seasonal temperature variations play a significant role on the availability of soil P to plants. Plants require more phosphorus during early growth than at maturity (Baylor, 1974; Kerridge, 1978; Mays et al., 1980). This fact has significant importance for seasonal patterns in plant response to phosphorous. For instance, in pasture establishment experiments, Beard (1973) found that adequate P at establishment promotes root growth and branching, thereby minimizing the effects of weed competition. Miles (1986) found Kikuyu grass (tropical species) has greater phosphorus requirements in spring/early summer than when growth is at its peak in mid-summer. Because plant response to P is often greatest during slow growth periods, the growth rate of the pasture during such growth periods determines stocking rate. In order to increase stocking rate, therefore, low soil P should not be allowed to restrict growth at these times. It is important to note that there are species differences in their ability to extract P from the soil and their overall P requirements for growth (Miles and Manson, 2000).

Miles and Manson (2000) reported that phosphorus is severely deficient in the majority of virgin soils in southern Africa, and particularly in the high potential dystrophic and mesotrophic soils of the humid eastern areas. Plant response to applied P on these soils is often spectacular, and correcting P deficiency enhances economic returns in pasture and cropping programmes (Miles and Manson, 2000).

Clearly studies of phosphorus nutrient cycling processes can provide information that improves production of crop yields by applying fertilizers at the appropriate time in the early stages of a crop growing season which enhances root growth and hence crop establishment, while improving the management of excess nutrient loads which are likely to lead to leaching into water bodies. Such knowledge can contribute to improving environmental stream flows in terms of water quality linked to mitigating impacts of excess phosphates.

5.3.2.4.3 Soil acidity

Soil acidity is a widespread limitation to plant growth, crop production and other forms of soil dwelling organisms. Soil acidity is a limitation in the higher rainfall areas of southern Africa. A chemical measurement of soil acidity is pH which reflects the amount of hydrogen ions present (H+). When pH is measured in water, the values obtained are generally 0.7-1.0 units higher than when pH is measured in KCl. The pH (measured in KCl) of soils having excessive acidity to plants usually lies between 3.9 and 4.5. Hydrogen ions are not toxic to plant roots. What causes acid soil infertility is aluminium whose solubility increases with increasing acidity. Aluminium restricts root growth in acid sensitive plants and limits the ability of the root to extract water and nutrients from a soil. In determining severity of a soil acidity hazard, pH alone is a poor indicator and methods that determine soluble Al in soils are used, e.g.

exchangeable acidity or acid saturation. Because high levels of Ca and Mg in a soil reduce the harmful effects of Al, percent acid saturation is a more reliable criterion for determining whether Al toxicity is a problem (Fey et al*.,* 1990; Miles and Manson, 2000).

Impoverishment of soil bases through leaching is the major factor in natural acidification. However, soil acidification can be greatly accelerated by human activity, e.g. alien plantation forestry and acid rain enhance soil acidification. Certain processes in agricultural systems accelerate soil acidification, e.g. cultivation enhances aeration and a more rapid bacterial oxidation of N containing organic compounds and a net production of acid; nitrification of ammoniacal fertilizers and the subsequent leaching of nitrates with Ca and Mg; the export of basic nutrients (K, Ca and Mg) in the harvest and symbiotic N fixation of leguminous plants (Haynes, 1983; Eckard, 1989).

Lime is used to alleviate soil acidity problems. Lime is any product whose Ca and Mg compounds are able to neutralize soil acidity. Carbonates, oxides, hydroxides, silicates of Ca and Mg are most widely used. The effects of lime on soil properties are: an increase in soil pH, a decrease in exchangeable acidity (Al+H), an increase in Ca and Mg levels, an increase in total cations, and a decrease in acid saturation. Lime has properties that can limit the leaching of nutrient cations in soils with low cation exchange capacity. Lime may also influence the availability of micronutrients to the plant and promote mineralization of organic N, P, and S (Miles and Manson, 2000).

5.3.2.5 The role of riparian buffer strips in managing water quality

The importance of managing water quality issues on a catchment scale is illustrated by a study that determined the extent to which riparian buffer strips effectively protect water quality. Riparian buffer strips are intended to protect water quality (excess nutrients and erosion) in water bodies. A study showed that simple conservation measures taken by farmers might not be sufficient to counteract the impact of factors that are often controlled at the landscape or catchment scale (Houlahan and Findlay, 2004). Wetland conservation policy and regulations around the world require narrow buffer zones or riparian strips around wetlands and rivers to protect water quality against excess nutrients from human activities such as agriculture, urbanization and industry. Many jurisdictions require narrow buffer strips greater than 20 metres. Houlahan and Findlay (2004) found most buffer strips ranged between 30-120 metres in Canada and then carried out a study to find out to what extent land uses beyond the narrow buffer zones could affect wetland water quality by measuring nutrient levels (nitrogen, phosphorus and potassium) in water and sediment samples for 73 wetlands. Adjacent land cover (forests, roads and a portion of wetlands) was assessed in areas up to 5 km from the wetland edges. Results showed that forest cover had the greatest impact on wetland nutrient levels because phosphorus and potassium was higher in wetlands that had little forest cover 2-4 km away. A loss of about 50% of forest cover led to an increase in phosphorus levels of up to 75%. Therefore, if riparian strips are to be an effective management tool, policy makers need to understand the distance at which adjacent land uses affect water quality. Within a catchment, less forest often means more agriculture and nutrient rich commercial fertilizers. Fertilizer run-off from fields 2-4 km away from a wetland affected downstream sediment nutrient levels. These findings suggest that small scale solutions such as narrow buffer strips around individual wetlands are

ineffective. Such measures, although important locally, must be supplemented with large areas of natural forest cover and wetlands within a catchment.

The findings of Houlahan and Findlay (2004) suggest the need to revise conservation policy and regulation intended to protect river\wetland water and sediment quality to ensure that an adequate proportion of natural forests within a river basin supplement the use of buffer strips intended to manage water quality.

5.3.3 Sediments

Rainfall and rivers continually erode the lands surface and carry sediments that are deposited in wetlands as water movement slows. It is estimated that the world's rivers deliver in the order of 10^{10} tons of sediment per year to their mouths, leading to the formation of large floodplains and deltas (Strahler, 1971; Milliman and Meade, 1983). The rate of sedimentation is controlled by gradient and water turn-over as measured by the ratio of flux to storage (i.e. from still water to very high flow rates) (Brown et al*.,* 1979).

Sedimentation is a natural feature of wetlands. In the long-term, many coastal and alluvial wetlands are dependent on sedimentation to create new habitats for biodiversity. For example, coastal shoreline wetland habitats created through processes of sedimentation can be: estuarine or submerged upland, fresh tidal or floating organic material, submerging coast with high marsh and low marsh or emerging coast (Stevenson et al*.,* 1986; Keddy, 2002). In inland deltas or alluvial wetlands, processes of sedimentation create characteristic vegetation structures. The erosion of land generates sediment, and wetlands are the sites where this sediment accumulates. The accumulation of sediment alters species composition. Plant adaptations to counter effects of burial by sediments shift towards species with deeply buried rhizomes (food storage organs) and strong pointed growing tips that penetrate through litter and sediment easily (Grime, 1979). The composition of invertebrates and fish also changes. Natural sedimentation rates enhance biodiversity resilience. Enhanced rates of sedimentation related to types of land use in the catchment decrease species resilience and enhance biodiversity loss.

5.3.3.1 Sedimentation effects on wetland plant and animal life

Three leading threats to fresh water ecosystems are sedimentation, exotic or alien species and impoundments such as dams and other hydraulic structures (Richter et al*.,* 1997). Agricultural non-point source is the primary cause of the unnatural sediment loads, a factor already seen to be a major cause of increases in nutrient levels as well. Another major source of sediment in catchments is road construction (Forman and Alexander, 1998).

5.3.3.1.1 Impact on plant life

Depth of burial by sediments is a key factor in determining germination and re-emergence of plants. A natural rate of sedimentation in terms of exact values is not clear. A measure of impact on biodiversity in the long and short term is more important. For example, sedimentation and competition intensity are

positively correlated, with sedimentation leading to increased soil fertility, which in turn leads to increased competition intensity (Keddy, 2002).

5.3.3.1.2 Impact on animal life

Richter et al. (1997) illustrated the extent of threat to animal life by sedimentation in fresh water ecosystems. Whereas terrestrial vertebrate extinctions are between 14-18%, the figures for aquatic organisms are much higher: amphibians and fishes 35%; crayfish 65%; unionid mussels 67% and 20% of fishes are extinct or in serious decline.

Sediments affect aquatic life in two ways. Firstly, fine layers of silt and clay smother aquatic invertebrates and fish eggs. Secondly, aquatic plants can be stimulated by the nutrients in the sediment, and when this excessive plant growth decomposes they can reduce oxygen levels, killing aquatic life (Vallentyne, 1974; Wetzel, 1975).

Studies of effects of both sediments and nutrient loading on aquatic life in a mountain stream showed that the following insect groups declined in richness, density and biomass with increasing sedimentation: *Plecoptera* (stoneflies), *Trichoptera* (caddis flies) and *Ephemeroptera* (mayflies). Many of the insects collected had their respiratory structures clogged with soil particles and fine sand and organic silt adhered to their body surfaces. The most sensitive groups to sedimentation were the filter feeding insect groups, e.g. *Diptera* (flies) and *Tricoptera* (caddis flies). Sediment loading appeared to be more detrimental than simple eutrophication. Other effects of sedimentation are the ability to shift competitive dominance. For example, Kirk and Gilbert (1990) showed suspended clay in aquatic communities shifted competitive dominance from *cladocerans* to *rotifers* by interfering with the feeding ability of *cladocerans*.

5.3.3.1.3 Impacts from human activities

Bormann and Likens (1981) compiled sediment yields of various human activities in catchments. Jurik et al. (1994) confirmed these sediment yields experimentally as follows: forested catchment (3-12 ton/km^2/year); clearcut catchment (300 ton/km^2/year); clear cutting followed by farming and pasture (3600 ton/km^2/year); and construction sites (49 000 ton/km^2/year). Studies by Lemly (1982) showed that logging or clear cutting, construction and grazing were sources of inorganic siltation and cattle provided sources of nutrients.

Effects of deforestation on streams were found to be even more serious, as, in addition to increased inorganic siltation, the water becomes warmer thereby reducing concentrations of dissolved oxygen. Consequently, tree leaves are the base of stream food webs; when trees are removed, the stream food web is removed along with them. On this basis, the amount of riparian forest was considered an important predictor of the biotic integrity of streams. Indeed, Steedman (1988) proved that biotic integrity of streams could be predicted from two watershed properties: % of land that is urban and % of riparian forest remaining. As the amount of urban land use in a watershed increases, increased amounts of riparian forest are needed to compensate. Steedman (1988) found that excellent biotic integrity values were only possible if riparian forest exceeds 75% and urban land use is less than 20%.

5.3.3.2 Sediment management and the role of models

Wise management of sediments in a catchment is possible if the sources of sediments are understood. Models help scientists and managers to clarify their thinking about environmental problems, and, if the models are successful, consequences of different management scenarios can be simulated, and the possible effectiveness of proposed changes in land use can be predicted (e.g. Starfield and Bleloch, 1991). Haith and Shoemaker (1987) developed the general structure of a sediment yield model. The model clarified thinking about the sources of sediments. Using such a model, Howarth et al. (1991) was able to explore the sediment yields that might arise out of different land use practices. They found out that forests and pasture had minimal contributions to sediment loading. The principal sources of sediment were the areas of intensive agriculture, in heavily populated catchments, and areas of urban-suburban landscapes.

In cases where human activities have stripped forests and ploughed fields, rainfall run-off increases with increasing flood peaks, which sometimes kills humans residing in floodplains. While reduced flooding caused by holding flood peaks behind dam walls is beneficial for flood control, irrigation and hydropower production, reduced flooding can have catastrophic consequences on downstream wetlands (Rosenberg et al*.,* 1995). Clearly, perceptions of benefits of developments must not lose sight of the importance of natural stream flows and erosion dynamics of catchments, on floodplain wetlands.

While, abnormally high levels of sediment are undesirable for vegetation types such as fens, or fish species such as salmon and trout, which inhabit mountain streams, high levels of fresh alluvial sediments produced in a moderately modified catchment are necessary for the normal establishment of vegetation species on floodplains, and consequently on animal species that depend on the vegetation for food (Welcomme, 1976; Goulding, 1980; Heeg and Breen, 1982). Examples of the importance of fresh alluvial sediments for animal and plant life range from the arid American west (Johnson et al*.,* 1976), the boreal forests of Canada (Nanson and Beach, 1977), the Amazonian rain forest in South America (Kalliola et al*.,* 1991), the heavily industrialised Rhine River in Europe (Schnitzler, 1995), to the African floodplains (Welcomme, 1976, 79, 86; Furness, 1981; Heeg and Breen, 1982). Clearly, damage is done to alluvial wetlands by reducing sediment loading in the lower sections of rivers and deltas, thereby risking the actual loss of coastal wetlands. Sedimentation is indeed a natural feature of wetlands (Keddy, 2002). Therefore ecologically sustainable developments imply that developments should be designed in a way that ensures seasonal deposition of sediments on downstream wetlands.

5.3.3.3 Sediments and time scale dynamics

According to Keddy (2002), burial, like fire, has two contradictory effects. In the short-term, it may cause immediate death. Nevertheless, in the long-term, it may create new habitats for the same organisms that were killed. In the short-term, one is inclined to view sedimentation as a negative factor, more so when sedimentation rates are increased by human activities, and particularly when small wetlands are filled in.

In the long-term, many coastal and alluvial wetlands are dynamic and are dependent upon eroded sediment to create new habitats. The cutting of new channels and depositing of new sediments is part of the natural dynamics of deltaic wetlands. The succession of saltmarsh vegetation from low marsh to high marsh is caused by the accumulation of sediment as well as peat (Niering and Warren, 1980; Fry and Basan, 1978).

Where sea level is rising, the rates of sedimentation must exceed rates of sea level rise, or else, saltmarshes will disappear. For example, in Jiangsu province, China, coastal recession of the southern Yellow River delta has occurred at 20 to 30 m annually and tidal land has sunk at rates of 5 to 10 cm/year over the past 50 years (Chung, 1982, Keddy, 2002).

The Mississippi River empties its waters in the Gulf of Mexico in Louisiana, USA. The suspended sediment load of the Mississippi River decreased by about one half from 1963 to 1982 due to the construction of levees, which restrict rivers from accumulating new sediment, and dams provide basins where sediment settles out and accumulates. The remaining sediment appears insufficient to counteract the effects of coastal subsidence and rising sea levels. As a result, 65 km^2 of wetlands are lost each year (Boesch et al*.,* 1994). Direct destruction of wetlands by draining or filling may account for less than 1/5 of the losses. Indirect effects from alteration of natural stream flows through dams and levees and overgrazing account for the rest of the losses (Boesch et al., 1994). Shaffer et al. (1992) showed that the intensity of overgrazing increased the sensitivity of vegetation to flooding which contributed to the loss of vegetation cover in the following seasons.

Generally, over longer time scales of centuries and millennia, the BALANCE between erosion, sedimentation, subsidence and emergence produces much of the physiographic diversity of coastal wetlands. This physiographic diversity provides the habitat template that generates biological diversity (Keddy, 2002).

5.3.3.4 Sedimentation in the Pongolo River and floodplain

In contrast to well-studied areas in the temperate zone, rather less is known about sedimentation in tropical rivers (Keddy, 2002). The role of sediment in the Pongolo River and floodplain has not been quantified. On the basis of scientific information from the studies above, one can qualitatively predict the effects of sediment on the Pongolo River; this was done by Heeg and Breen (1982). Virgin floodwaters before the Pongolopoort dam development deposited nutrient rich sediments on the floodplain, although, through the flushing out effect of floods, some sediment and nutrients absorbed into silt particles were lost.

The Pongolo River has a low sediment load, which is reduced further by storage in upstream dams, and it is therefore likely that a gradual decline in productivity of the system will result in a net annual loss of sediments and nutrients hence loss of biodiversity. However, the use of fertilizers in expanding irrigation schemes is likely to produce seepage water or run-off, rich in nutrients, which end up in the floodplain pans, rivers and patches of agricultural lands among native vegetation. It would be interesting to know whether such seepage water and run-off compensates for loss of silt-borne nutrients trapped in the dam, or

whether infact the nutrient loads from fertilizers are so high that they can cause eutrophication, e.g. favour the growth of phytoplankton-blue green algae instead of hydrophytes which are dominant in pristine states. During virgin flows, silt-borne nutrients in sediments deposited on the floodplain pans favoured the growth of rooted plants such as the aquatic macrophyte rooted in the sediments of floodplain pans, *Potamogeton crispus*, the meadow grass, *Cynodon dactylon,* found at the floodplain pan margin, i.e. between high flood level and maximum pan water retention and *Cyperus fastigiatus,* a grass grazed by cattle and hippo found in the marshy areas between floodplain pans and the main river channel. Sediments sustain these three key plants upon which so much of the floodplain productivity depends (Heeg and Breen, 1982).

Secondly, the Pongolo River flows from South Africa to the Indian Ocean in Mozambique at the Bay of Maputo. Its two main tributaries, the great Usutu and Ingwavuma, pass through Swaziland before joining the Pongolo River in SA which becomes the Rio Maputo in Mozambique. There is no data on the effects of sediment in the upper, mid and lower catchments. Effects of upstream sediment loads upon the lowland freshwater floodplain wetlands downstream of the Pongolopoort dam and the coastal delta at the bay of Maputo are not known.

5.3.4 Salinity

According to South Africa's National Water Resource Strategy (2003), water allocation amongst the various water use sectors was: agriculture (52%), nature conservation (20%), Domestic/Urban use (12%), Industry (8%), Mining (4%) and power generation (4%). Rising salinisation, caused by agriculture, industry and from natural phenomena, poses a profound threat to South Africa's water resources. Since South Africa's water resources are scarce and highly variable (Schulze, 1997), there is inadequate surplus capacity to dilute the salinity caused by these sources. Salinity is measured in terms of electrical conductivity (EC) or total dissolved solids (TDS) in Mg/L which makes up the non-toxic constituent of water quality, e.g. sodium, calcium, potassium, magnesium, chloride, bicarbonate, sulphate, silica, and total alkalinity (Dallas and Day, 1993; Palmer, Malan and Day, 2000).

The Pongolo River and floodplain is a freshwater ecosystem. However, naturally, the rivers of northern Kwazulu-Natal province in South Africa namely, the Pongolo, Mkuzi and Mfolozi, have high concentrations of dissolved solids during periods of low stream flows (Archibald et al., 1969), in July, August and September (Schulze et al., 1996). Expanding irrigation agriculture both upstream and downstream of the Pongolopoort dam is likely to reduce steam flows and hence decrease the diluting power of the river. Heeg et al. (1978) found salinization to be a potentially serious problem on the floodplain pans. Saline water seeps from the underlying marine cretaceous sediments, which then becomes concentrated due to evaporation. Nyamiti, Mhlolo and Tete pans were found to be affected in this way. Therefore, annual floodwaters are required to dilute the saline water for crop watering and livestock use as well as retaining their freshwater characteristics so that fresh water biological communities can be sustained. For instance, the aquatic plant macrophyte, *Potamogeton crispus*, upon which much of the productivity of the floodplain depends, stops growing at salt concentrations greater than 4 000 mg/L and the propagules (turions) do not germinate (Rogers and Breen, 1981). Oligochaete worms disappear at these salinities, and the Plankton community takes on a different composition

(Heeg et al., 1978). At concentrations of 11 500 mg/L, all zooplankton disappear (Kalk and Schulten-Senden, 1977). Fish species such as the Churchill (*Petrocephalus catastoma*) and the bulldog (*Marcusenius macrolepidotus*) rely on the production of an electric field around themselves in order to locate prey, usually aquatic larval insects (Kok, 1980). This mechanism does not work in water with a high electrical conductivity resulting from increased dissolved salts.

Clearly, in order to sustain biological functions needed to maintain species diversity characteristic of freshwater wetlands, the system must receive an annual or seasonal volume of flood waters to revitalize biological functions. In the absence of seasonal floodwaters the wetlands can either dry out or be converted to inland deltaic salt marshes.

5.3.5 Toxic constituents in water quality

Expanding irrigation agriculture both upstream and downstream of the Pongolopoort dam is likely to reduce flows and hence decrease the diluting power of the Pongolo River, particularly during periods of low stream flow (July, Aug, and Sept). Water quality problems and concerns are likely to be exacerbated during periods of low flows in winter from input of effluent from sugar mills (at Pongola) and a proposed mill downstream of the dam for bio-diesel production, increasing urban developments, and input of non-point source pollution of other toxic chemicals such as pesticides from agricultural sources as well as from the Department of Health malaria control programme, and from cattle dipping tanks. For instance, the impact of effluent from Pongola sugar mills on the water quality of the moderately modified stream flows of the Pongola River was shown in a study by Archibald et al. (1969). Downstream of the Pongola barrage (located upstream of the Pongolapoort Dam) dissolved oxygen in water was reduced to 28% saturation, aquatic animal life diversity was low, changing from 17 species above the barrage to four species of only Oligochaete worms which are tolerant of low oxygen concentrations. The river recovered from this pollution only after 30 km. Under current highly modified stream flows of the Pongolo River (Chapter 4), the impacts would be far greater. Heeg and Breen (1982) noted that, if such material from a mill were to find its way into floodplain pans which do not receive adequate flows, they would likely have a prolonged effect and would adversely affect use of the water for domestic and livestock watering purposes and impact on fish production by reducing the invertebrates populations which fish preys upon. It is important that the planning of developments that release toxic effluents into the river (irrigation and mills) must make sure that there is an adequate quantity of water available in terms of appropriate environmental stream flows needed to dilute and flush out or detoxify such waste with the help of bacteria and microbes.

5.3.6 Disease and flows

5.3.6.1 Malaria

While fertile soils of floodplains have high primary production suitable for both agricultural and wildlife production and are either drained or have natural stream flows severely reduced for this purpose, they are also a source of immense human suffering from diseases such as malaria. Although early human civilization arose along the edges of rivers in the fertile soils of floodplains, some may question how one

system can be both life giving and death dealing (Keddy, 2002). It is therefore important to understand the relationship between malaria cases and stream flow so that the knowledge can be used to influence decisions on disease management and artificial flood release timing.

Malaria mosquitoes are a threat to the health of humans because human malaria is transmitted from one person to another through the bite of a female Anopheles mosquito carrying malaria parasites. One third of all humanity lives in malaria zones where they are at risk of contracting it, and it was estimated that globally 2.7 million people per year die from the disease (Butler, 1997).

In Africa the most important malaria vectors are *Anopheles funestus* and *Anopheles gambiae*. A review of the malaria situation in South Africa (Sharp et al., 2000, Gumede, 2002) showed that before 1985, malaria case totals in the country were low. Chemical control of mosquitoes included use of the organochlorine pesticide DDT, which is one of the 12 toxic persistent organic pollutants (others being PCBs, dioxin and certain industrial chemicals), which persist in the environment for long periods of time and accumulate in the body tissues of living organisms through the food chain and therefore cause harm (e.g. cancer, developmental or growth defects), even in areas far away from the source of application. DDT is very persistent with a half life of 2-15 years. The Stockholm Convention on Persistent Organic Pollutants, to which South Africa is a signatory, required countries to phase out the use of these compounds. Given the health risks caused by malaria in Africa, and the fact that DDT is inexpensive, an exception was made that allowed its continued use in Africa for public health purposes until a more cost-effective alternative was developed.

In Kwazulu-Natal province, DDT was used to control mosquito populations in the malaria endemic areas of northern KZN, e.g. the former Ingwavuma and Ubombo districts. After irrigation development in the Makhatini area in 1987 malaria went from 3 to 5 cases per year to 7491 cases per year by 1995. According to Gumede (2002), irrigation increased malaria breeding sites through spillages and retainment of water on the ground. In addition, the phase out of DDT started in 1996. The phase out led to dramatic increases in malaria cases in KZN by 2000 (Fig 5.1). The dramatic increase saw up to 40,000 cases concentrated in the northern part of the country in provinces with international boundaries with Mozambique and Zimbabwe (Mpumalanga, Northern Province and KwaZulu-Natal). Death from malaria increased from 14 in 1992 to 423 in 2000. The increase was linked to several factors: irrigation schemes, increases in international border travel, the spread of HIV, and implementation of a policy requiring the phase out of DDT to synthetic pyrethroids for chemical control, and reduced coverage of the area sprayed. A decision was then taken to reinstate the use of DDT in 2000 and that application of DDT should be restricted to the interior walls of residential structures and eaves where humans are vulnerable to mosquito bites at night. Collaboration between two government departments (DoH and DoA) through the provision of resources that enabled employment of a large labour force to spray extensive areas was effected (Gumede, 2002). By 2001, there was a dramatic decline in reported cases which was attributed to the re-introduction of the use of DDT and the extension of the malaria control programme into Mozambique (Fig 5.1).

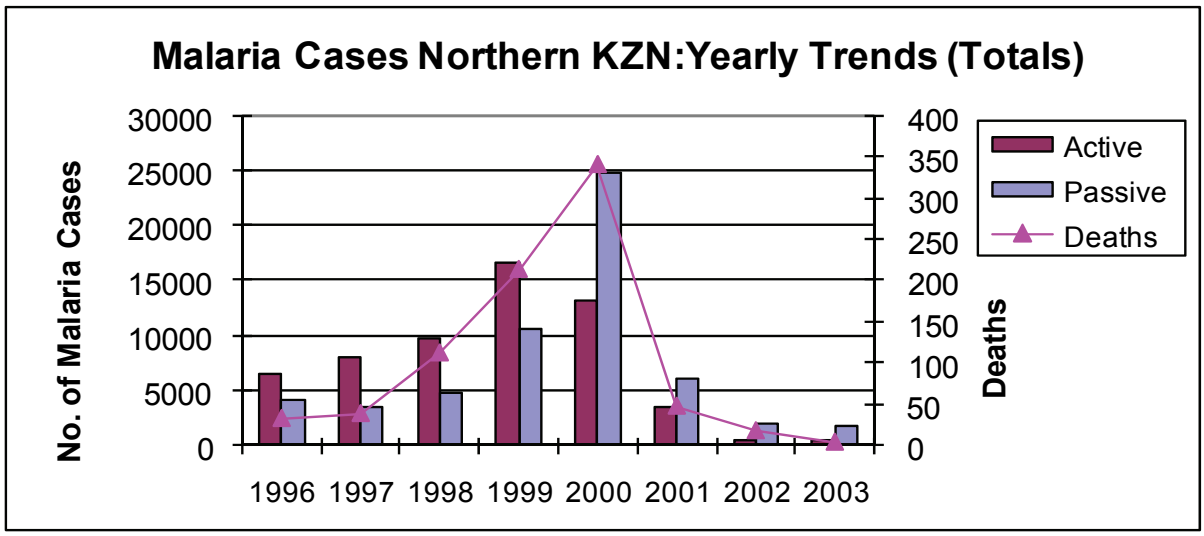


Figure 5.1: Yearly trends in malaria cases in Northern KZN province. Source data: DoH – Jozini Malaria Control Programme (Sharp et al., 2000; Gumede, 2002).

By 2003 DDT had brought malaria under control. However, from post-1994, major agricultural expansion in the area has been increasing with an increase in the use of pesticides. Specifically, irrigation developments supplied with water from the Pongolopoort Dam is concentrated on lands adjacent to the floodplain, the Makhatini flats irrigation scheme and Ndumo A and B irrigation schemes. Government support for agricultural development for emerging farmers in these former black areas is intended to alleviate poverty and enhance the social wellbeing of the population. Planned activities for expansion are cotton production, sugarcane, winter wheat, aquaculture and horticulture.

Given the increasing use of pesticides in agriculture coupled with pesticide use for malaria control in the area downstream of the Pongolopoort dam (Makhatini flats and Ndumo areas), it was feared that the risk of pesticide resistance in mosquito populations in the area was high. Resistance is a genetically inherited characteristic, which allows an insect to survive a dose of pesticide which would normally have killed it. While susceptible mosquitoes die, resistant ones survive and pass on resistant genes to the next generations. The mosquito population would eventually become fully resistant to a specific insecticide after several exposures and several generations, making the insecticide completely ineffective. Often huge resources are invested in research and development of pesticides. The impact of resistance means the life of a pesticide is reduced and the costs incurred during research and development may not be recovered, because mosquito vector-borne diseases re-emerge with consequent negative effects on the health and wellbeing of the human population, and the costs incurred by individuals to treat the disease increases. It has been shown that pesticide groups, such as organophosphates, carbamates and pyrethroids, control pests effectively; however resistance to these compounds has been detected in several medically important arthropods, among them Anopheles mosquitoes, possibly as a result of previous selection pressure from insecticides such as DDT. Miller (1988) showed how the knockdown resistance induced by selection with DDT confers inherent cross-resistance against the knockdown effect of pyrethroids and

vice versa. Cross-resistance can develop between DDT and pyrethroids (Malcolm, 1988, Hemingway et al., 1986).

Indeed, a study by Hargreaves et al. (2000) showed *Anopheles funestus* in the Ndumo area exhibited resistance to pyrethroids and to organophosphates in the Makhatini flats area (Mohloai, 2002). Sereda and Meinhardt (2003) reported the results of a survey to determine the status of pesticide residues in the water environment in Malaria endemic areas of northern KZN (Ingwavuma and Ubombo) with an active malaria chemical control programme and agricultural development supported by the DoA. The survey showed that the presence of pesticide residues representative of all chemical groups (organochlorines, organophosphates, carbamates and pyrethroids) in the water and sediments of rivers, pans, irrigation dams and irrigation canals was exerting major selection pressure for the enhanced development of malaria mosquito resistance which already exists in the area (Hargreaves et al., 2000; Sereda and Meinhardt, 2003).

The highest residues of pyrethroids were detected during the February 2001 cotton spraying season. DDT and its metabolites were detected more frequently in sediments than in water, often far away from household dwellings that have undergone DDT treatment. For instance highest residue levels were obtained in sediments near vegetable gardens in the Makhatini flats in the November and February samples. Generally, DDT residues were present in other irrigation farming areas on the Makhatini flats, Ndumu, and Ophansi area located southeast of the Makhatini flats. The floodplain pan, Nomanini, located adjacent to Ndumu A and B irrigation farms, had the highest concentrations of DDT and Carbamates in February. It is highly likely that the pesticides detected originated from both agricultural use as well as anti-malaria control. It is suspected that DDT residues may originate from illegal use of DDT in agriculture or misuse. Pesticide residues were also detected in game reserves at Ndumu and Tembe.

Clearly as irrigation expansion increases, pesticide use will increase. This is a major concern for the environment given the high contamination levels found in water and sediments (Sereda and Meinhardt, 2003).

Efforts to control vector-borne diseases have focused on the use of chemical pesticides but arthropod resistance (physiological, biochemical or behavioural) to pesticides is still a huge problem. The challenge lies in developing alternative management strategies that reduce mosquito resistance to selection pressure by diluting the resistance genes and causing resistant forms to revert to more susceptible levels (Croft, 1990; Sereda and Meinhardt, 2003).

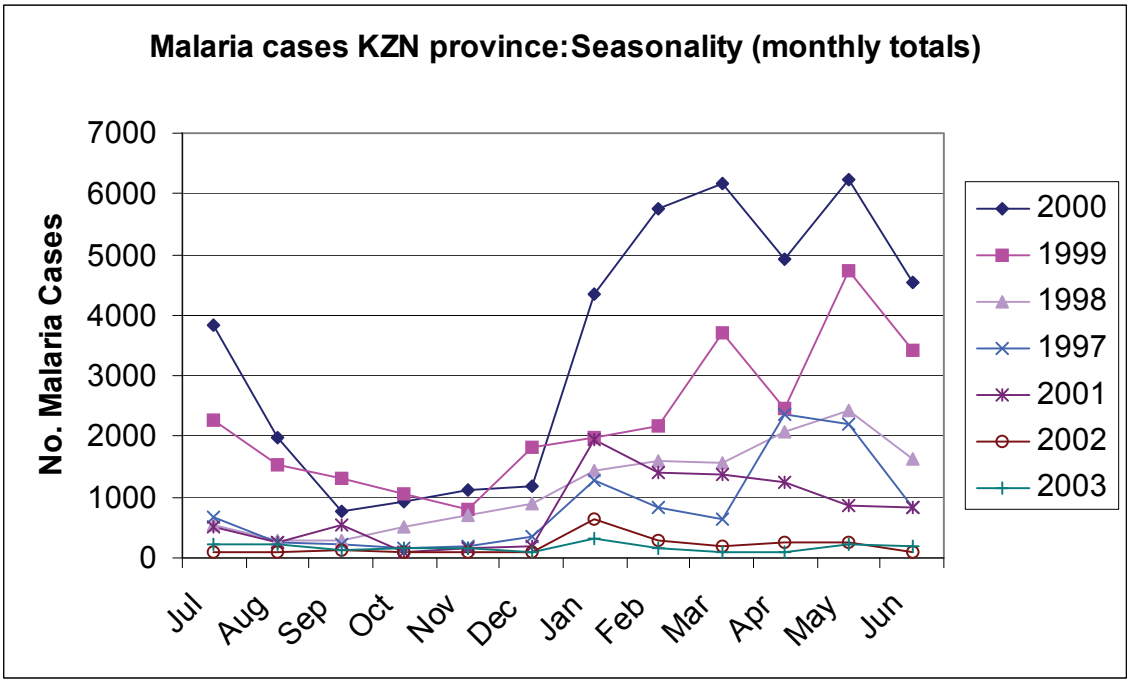
For instance, the behaviour and biology of the mosquito vector is linked to climatic factors such as rainfall and temperature, which is important in determining disease transmission (Sharp et al., 1988). Whereas moderate rainfall encourages *Anopheles* breeding, excessive rainfall flushes out mosquito larvae (Nethercott, 1974). Endemic malaria areas of northern KZN experience heavy summer rainfall (December to February) and moderate autumn rainfall (March to May) (Schulze, 1997). Stagnant pools of water, ideal habitats for mosquito breeding, increase during autumn. Hence, peak transmission is seasonal and peaks during the autumn months (Nethercott, 1974; Strebel et al., 1988; Sharp et al., 1988)

(Fig 5.2). During this time, irrigation also increases malaria breeding sites through spillages and retainment of water on the ground. Also very low water levels in floodplain pans and the river exposes extensive areas of muddy shores where animal hooves (livestock and hippo) form depressions of small pools of stagnant water that make a suitable habitat for mosquito breeding (Gumede, 2002).

It is also highly likely that the reduction in malaria cases shown from 2001 onwards cannot be attributed to DDT alone but to other variables such as the present artificial flood timing pattern which happens in spring (September) and reduced stream flow patterns (Chapter 4). The Department of Health officials have indicated to DWAF that when artificial flood timing happens in autumn (March, April and May) malaria cases increase greatly (Personal Communication – B. Mwaka DWAF).

It has also been observed that normal or high rainfall following prolonged droughts is associated with an increased prevalence of mosquito populations with a resultant upsurge in disease incidence (Strebel and Thompson, 1990; Hansford, 1993).

Freeman, (1995) showed that the malaria parasite (*Plasmodium falciparum*) has a highly correlated inverse curvilinear relationship with mean temperature. The mosquito has four stages in its life cycle: egg, larvae, pupa and adult. Egg, larvae, pupa stages occur in water while the adult is an active flying insect. Eggs are laid on the water surface of any stagnant sheet of water from lakes, dams, containers and temporary pools, caused by depressions in the earth. Eggs hatch into larvae within 1-3 days. The larvae feed actively obtaining their food from the water. The larva moults into a pupa after about 10 days and does not feed but comes to the surface from time to time for air. Optimum temperatures for a shorter larval development are 22°C-27°C (Gumede, 2002). The adult emerges from the pupa stage after about 4 days. The adult life span varies from a few hours to a few months. Malaria transmission can be prevented through methods targeting the aquatic stages or the adult mosquitoes' preferred habitat.



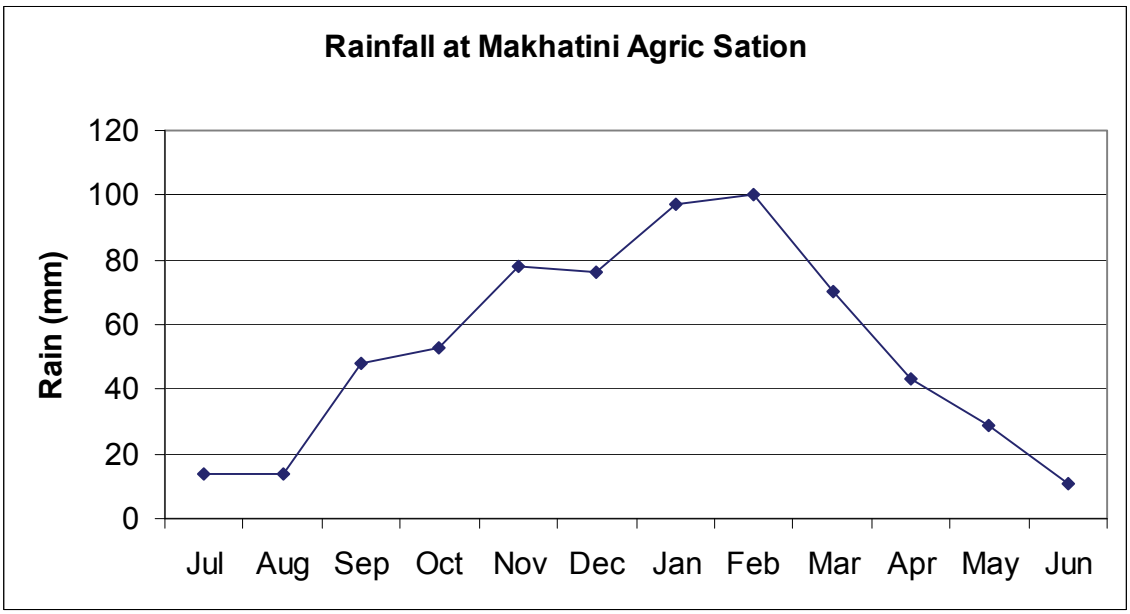


Figure 5.2: (Top graph) Seasonal trends in malaria cases shown relative to rainfall (Bottom graph) Malaria cases peak in autumn (Mar, Apr, May) when rainfall is decreasing. (Source data: DoH – Jozini Malaria Control Programme).

Stagnant waters of the Pongolo floodplain pans provide breeding sites for mosquitoes. However, Heeg and Breen (1982) reported that mosquito larvae occur in very small numbers in floodplain pans because invertebrates and fish prey upon them. The main breeding sites were discarded containers and pools of water around people's homes, small pools left by receding floods or filled by rainfall that were too small to harbour natural enemies of mosquitoes (fish and certain invertebrates).

Although this review identifies factors influencing malaria cases in the area which are known to peak in autumn as being pools of water created by rainfall over autumn, irrigation spillages and the use of DDT, it is highly likely that the current stream flow regime (a flood peak in September followed by extremely stabilized reduced flows for the rest of the year) plays a significant role in reducing malaria cases. However, studies that are more conclusive need to be carried out to provide more clarity on the relationship between malaria cases and stream flow so that the knowledge can be used to influence decisions that strive to achieve goals that balance malaria disease management, appropriate environmental stream flow regime and irrigation development designs that minimize the creation of preferred habitats for mosquitoes and other disease vector populations.

5.3.6.2 Schistosomiasis

Petr (1986) reported the impacts of altered hydrology on disease for Akosombo Dam on the River Volta in Ghana and found that stabilizing flows on the river increased the incidence of bilharzia disease (Petr, 1986). The dam has a surface area of 8 500 km^2 and annual draw downs of some 3 metres. Prior to construction of the dam, yearly flows cycled across four orders of magnitude, between 10 and $10^4 m^3 s^{-1}$ and after dam closure, flows stabilized at $10^2 m^3 s^{-1}$ throughout the year. River scouring was reduced and plant growth along the river banks exploded. A plant associated snail became more common, and schistosomiasis/bilharziasis is now endemic. Bilharziasis is a disease of man and livestock caused by parasitic worms (schistosomes). In its life cycle, the parasite uses aquatic snails as an intermediate host to develop to an infective larval stage, after which the infective parasite passes from the snail to water. Man and livestock are infected when they come into contact with infected water. The parasite lives and lays eggs mainly in the gut and urinary bladder, with the resultant symptoms of diarrhoea containing blood and mucus or blood in the urine. Reinfection of the snail population results from excretory products from infected persons and livestock being discharged into a water body where the host snails are present. Heeg and Breen (1982), found the intermediate snail hosts to be the dominant snail species in some Pongolo floodplain pans.

An analysis of artificial outflow trends from Pongolopoort dam in Chapter 4 showed a single flood peak in a year, which drops sharply and then stabilizes over the rest of the year. From literature, stabilizing flows on the River Volta in Ghana increased the incidence of bilharzia disease (Petr, 1986). It is highly likely that under the current stream flow patterns on the Pongolo floodplain (reduced and stabilized), the incidence of bilharzia disease among the population has increased.

Given the present socio-cultural practices, where sanitation infrastructure is absent and communities have frequent direct contact with the Pongola River and pans for drinking, bathing, washing, fishing, crop and

livestock watering, it is highly likely that the incidence of infection among the resident population is high. This was confirmed by medical staff at a clinic adjacent to the floodplain near Sokhunti and Mboza. Although all ages are affected, the peak prevalence of infection was found to be in children between 7-15 years of age (Schutte et al., 1977; Walker, 1977; Appleton and Bruton, 1979).

From literature, it appears that a natural flow regime, with appropriate seasonal fluctuations, is likely to keep the snail populations in balance. Whereas stabilizing flows would interfere with the ecology of the system, causing snail population explosion and enhancing disease transmission. There is need for data linking disease incidence, snail ecology and flows on the Pongolo River and floodplain system.

5.3.6.3 Other water related diseases

Coetzee and Bourne (1996) compiled an atlas of potential water related diseases in South Africa, such as cholera, typhoid fever, dysentery, diarrhoea, polio, yellow fever, hepatitis, river blindness, parasitic worms, scabies, and trachoma, etc. Analysis of the diseases, mode of transmission, prevention and trends, relevant to northern KZN, showed that all water related diseases are endemic or prevalent in northern KZN where the Pongolo River and floodplain is located.

Poverty, coupled with a lack of access to adequate quantities of clean water and unhygienic living conditions, enhance infection rates of these diseases, causing epidemics (Coetzee and Bourne, 1996).

For instance, transmissions of bacterial and amoebic diseases that cause epidemics (e.g. cholera, typhoid fever, amoebic dysentery, and diarrhoea) are prevalent in areas with poor or no sanitation facilities, so that, during periods of rainfall peaks in summer, run-off contaminates water bodies with infected faecal waste. Epidemics of these diseases are also linked to periods of low flows (July, August, September) when communities have to dig into dry riverbeds to obtain water for basic needs. At the municipality scale, epidemics occur when sanitation and water purification mechanisms fail and contaminate water bodies.

The most important solutions to these diseases are providing sufficient and safe water for basic needs, providing sanitation facilities for safe disposal of faecal waste, improving income and social wellbeing, controlling disease vectors, e.g. mosquitoes and rats, enhancing the health of domestic livestock, and monitoring industrial effluents and irrigation practices.

The socio-cultural practices on the Makhatini flats is such that people will utilize the floodplain pans and the river directly for basic needs for a long time to come, until such a time that government can adequately deliver safe water and sanitation to all (WRC Report No 1379/1/05; Jacobson, 2005).

Given a high human rural population, expanding irrigation, a sugar mill in Pongola town, a proposed biodiesel production mill downstream of the Pongolopoort Dam (DoA – Jozini Pers. Communication; Holtzhausen, 2005ab) and consequently reduced flows and increased toxic input into the water bodies of the Pongolo River and floodplain, the health of the human population and livestock is at risk. It is very important that an environmental flow regime, that enables good water quality, be sustained.

A high rural human population, coupled with reduced stream flows and increased toxic input caused by irrigation and effluents from existing and proposed industries, means that in addition to the need to implement an environmental flow regime that enables good water quality to be sustained, the DoH must put in place a public health strategy. The public health strategy should be a CO-MANAGEMENT activity between the Municipalities, DoH, DWAF, DAEA to ensure that, adequate water allocations for public health purposes are effected on the Pongolo floodplain and areas adjacent to it.

For instance, the public health strategy should ensure that public health officials make use of appropriate technologies to monitor the health of water bodies. For example, the HCT technology (human cell test), which can distinguish dirty water from dangerous water, (i.e. toxic effluents in the water in the (river and floodplain pans), which can cause chronic illnesses. The HCT test determines the extent to which toxic water impairs the oxidative ability of cells (Leukocytes – white blood cells) (WRC Water Wheel Magazine March/April 2003). Monthly tests would be a quick screen to identify problems that need further investigation, and to warn communities to stay away from identified toxic water bodies, particularly during periods of low flows in the dry season (July, August, and September). Alternative sources of water can either come from the effective implementation of the free basic water policy, increasing flows from the dam by reducing irrigation in the catchment, or supplementing free basic water allocations from national government by implementing rain water harvesting and conservation technologies to provide safe drinking water and increased food production with less water.

The public health strategy should ensure that municipalities as water services agents at the local level put in place and improve faecal disposal mechanisms, water purification systems, sewer systems, free basic water system and capacity to maintain these systems. For instance, an evaluation of the free basic water (FBW) policy (WRC Report No 1220/1/04) found implementation, especially in poor rural municipal areas, was inadequate. Yet these areas should be of high priority for FBW provision because they have very high incidences of water related diseases (Coetzee and Bourne, 1996). Problems hindering implementation was attributed to current institutional mechanisms, both at the district and local municipality level and at the community level. Problems were linked to financial, technical, political and logistical issues (WRC Report No 1220/1/04).

The public health strategy would need to recognise the fact that government alone may not efficiently reach out to everyone given the high numbers of poor people in South Africa. It is necessary to use the community-based approach within which relevant parties can be mobilized to actively participate in promoting the adoption of existing cost effective technologies, e.g. harvesting of rain water, the building and use of pit latrines and solar pasteurisation technology among others. Such an approach would go a long way in supplementing government subsidies and improving the social wellbeing of people.

A multi-sectoral approach involving local communities and the relevant regulatory authorities (Municipalities, DoH, DWAF, DoA, EA), co-ordinated through a co-management structure such as water user associations (WUA) or catchment management agencies (CMAs) is key to achieving sound sustainable solutions.

5.4 PROBLEM STATEMENTS AND NEEDS

5.4.1 Introduction

According to community development principles (Ife, 1999), the best practice is to integrate professionally defined needs (e.g. those identified above) with stakeholder-defined needs.

Community needs were defined through a stakeholder dialogue workshop where individual stakeholders presented and shared their problems. The process served the purpose of building a shared understanding of each other's problems, perceptions, values, beliefs and needs, and should form the initial foundation for developing a common understanding on which subsequent co-management initiatives can be built. In a dialogue process, the actual words spoken by the stakeholders should be captured verbatim so that meaning and feelings become explicit and easily shared and understood by others.

The outcome of this process was problem statement(s) based on stakeholder perceptions. Experience has shown that before groups can develop visions and goals, there should be a clear and 7widely recognised problem statement. The problem statement helps to establish a common understanding of the conditions and to prioritise initiatives needed to solve the problems on a catchment or sub-catchment scale.

The following sections cover what was shared from a DoH perspective and a nature conservation (E-KZN-Wildlife) perspective. Problem statements from other stakeholders are defined in other relevant chapters namely Chapter 4 – stream flow values; Chapter 6 – agricultural development needs; Chapter 7 – floodplain community needs.

A summary of problems from all stakeholders affected by artificial flood releases from the dam can be seen in Chapter 8 and details of the actual dialogue process are in Jaganyi et al. (2002).

5.4.2 Problem statement: Department of Health Perspective 2002

Problem statements from the DoH were presented by JK Gumede (DoH Jozini) and have been incorporated in section 5.3.7 above.

5.4.2.1 Needs statement: DoH 2002

The Department of Health are an interested party because stream flow in the river, pans and irrigation channels influences disease and disease vector populations (e.g. malaria, bilharzias). In addition, reduced flows have the potential to influence public health negatively by increasing water borne or water related diseases. Active public health multi-sector strategies involving local government, (Municipalities, DoH, DWAF and DAEA) would need to be put in place to help develop, monitor and mitigate these negative outcomes (see details in section 5.3.7).

It is very important that data relating to disease and disease vector populations be linked to a hydraulic model of the catchment in order to inform development of an appropriate stream flow regime that minimizes the negative impacts of disease.

5.4.3 Problem statement: Conservation Agency Perspective (EKZN-Wildlife 2002)

EKZN-Wildlife is a conservation agency responsible for protecting species and habitats inside and outside protected areas. Ndumu game reserve is a fenced protected conservation area located on the northern border with Mozambique and forms part of the floodplain. However, Municipal Integrated Development Plans or IDPs (2003), view the floodplain as a protected area because of it's high intrinsic biodiversity value and it's environmentally sensitive areas or habitats (ESAs). This is also the view of EKZN-Wildlife who prefers that the floodplain should be preserved and fully protected as a nature conservation area. The land use perceptions of municipal IDPs and those of the floodplain communities who utilize the floodplain for crop production and fishing (Chapter 7) are in conflict. These conflicting views on land use of the floodplain have been a constant source of disagreement between local communities and the conservation agency, EKZN-Wildlife (Chapter 7).

(Mr Peter Conant presented these problems in 2002, but he is no longer an employee of EKZN-Wildlife. Catherine Hanekom replaced him).

"EKZN-Wildlife is tasked by government with the conservation of biodiversity for the benefit of present and future generations, and for this reason, is legally bound to express concerns when biodiversity is threatened. It is important from a conservation perspective to conserve the Pongolo Flood Plain for the following reasons:

This flood plain is unique in South Africa. It is the only river flood plain with associated pans. There are a number of rare and important species found here. There are about 50 species of fish, many of which are dependent on appropriate flooding for their breeding. Many rare birds depend on the flood plain. It has large populations of duck and other waterfowl and South Africa's only breeding population of pelican seem to depend on it, flying here to feed during their breeding season all the way from Lake St Lucia on the East Coast of South Africa. A natural flood plain has great tourism potential.

EKZN-Wildlife manages Ndumu Game Reserve at the extreme north of the Floodplain. Because Ndumu is at the juncture of the Pongola and Usuthu Rivers it is somewhat buffered from some of the impacts of unseasonable and incorrect volumes of water being released as water from the Usuthu back floods into the Pongola system. Nevertheless, artificial floods do impact on Ndumu in the following manner:

The Pongola River and associated pans in the Reserve, are inundated at ecologically incorrect times of year, and not flooded when they should be. This caused numerous negative ecological impacts. These include aquatic animal and plant reproduction, feeding areas for aquatic birds, a lack of flushing out of alien aquatic plants. And flood plain productivity factors amongst many others.

Management activities can be impacted. This includes fences being washed away (which allows animals to escape and incurs considerable expenses to repair), aquatic anima1 counts to be ineffective due to sudden unexpected volumes of water, and interruption of animal capture activities.

Tourism at the peak season can be severely disrupted. Impacts of water pollution from agricultural activities on the floodplain, which is facilitated by unseasonable flooding. Impacts, which may affect Ndumu's status as a RAMSAR wetland.

It is important to understand that the whole flood plain depends on seasonally correct and regular flooding to achieve maximum productivity and prevent species loss. EKZN-Wildlife believes that if the flood plain can be allowed to function as naturally as possible that the greatest number of people will materially benefit from this productivity. For instance, it has been estimated that a sustainable fishery of some 750 tonnes per year can be realised, which translates into meeting the protein requirements of a great number of people not to mention the other opportunities of trade! barter, etc. Winter grazing for livestock would be greatly enhanced with a normal flood regime. And many tourism opportunities could be realised.

It is believed that current legislation from Departments of Agriculture and Water Affairs is not being applied correctly in the instance of decisions regarding flood releases and the consequent resulting human activities. Certainly, the Biodiversity Act, now nearly a reality, will have its provisions severely compromised by continuing to allow the system to operate in the current unnatural state.

Although Water Affairs presentation indicated that they achieve consensus in terms of water releases, this is certainly not the case as regards EKZN-Wildlife and we would welcome any new initiative to achieve this consensus".

5.4.3.1 Needs statement – EKZN-Wildlife (2002)

(i) Because EKZN-Wildlife is responsible for protecting species and habitats, preservation of the natural environment with diverse species and habitats and with a high potential for use in recreation and tourism is preferred. Natural patterns of stream flow can provide these goods and services; therefore, EKZN-Wildlife would prefer environmental flow regimes that enhance nature conservation benefits.

(ii) Floodplain communities should be removed from the floodplain so that it can become purely a conservation area.

CHAPTER 6: AGRICULTURAL DEVELOPMENT INTERESTS

6.1 INTRODUCTION

This chapter contributes towards the first objective of this study, which is to: "*Develop an understanding of the driving forces of the current situation and establish a shared vision for a preferred, achievable and sustainable state of the floodplain system*".

Specifically, the challenges of the interests of Agricultural Irrigation Development are described so that all other interests in the catchment can be aware of the challenges facing Agricultural development stakeholders. This process enhances the building of a stakeholder-shared vision at the catchment scale so that through holistic thinking (Chapter 8), the problems on the floodplain can be located within a catchment context. This understanding can enhance the processes of achieving positive outcomes through means of 'interest based bargaining which is needed to achieve fair trade-offs' among stakeholders (Dent, 2003), as they strive to attain a preferred, achievable and sustainable state, not only of the floodplain system, but also, a preferred state for the whole catchment system.

There are complex problems affecting agricultural production in the area downstream of the Pongolapoort Dam and the Makhatini flats. The interaction between various factors (economic, financial, technical, socio-political, infrastructural and institutional) has shaped the problems experienced on the Makhatini irrigation scheme, adjacent dry land areas and the floodplain. According to community development studies (Ife, 1999), for agricultural development or any other development policy decisions to be of benefit to the people downstream of the Pongolapoort Dam, the economy of the area has to be looked at not only from characteristics of farmers but also from a wider ecological (biophysical) and socio-cultural and political perspective.

To understand these dynamics, a review of local studies by Bembridge (1991, 1993); A'Bear and Louw (1994); Van Rooyen (1983); and the DoA (1994) was carried out. This was supplemented with knowledge from other relevant studies. Agricultural development on the Makhatini Irrigation Scheme since 1985 is described by assessing the management operation systems, farming practice, infrastructural components and support services. The intention is to understand what happened and how it happened and on this basis see how new development plans and the old processes can learn from these experiences so that mistakes are not repeated (Senge et al., 1999).

A review of farmer characteristics at the household/farm scale was also done to determine farmer problems, needs, perceptions and solutions. From these reviews, it is clear that on the basis of principles underpinning management theories (Senge et al., 1999), the inability of many irrigation scheme participants to make profit is not surprising (Bembridge, 2004; Denison and Manona, 2007), because the scheme shifted and changed over the years from white settler farmers, estate-run farming, small scale black farmers under central management to independent small scale commercial black farmers. The underlying physical irrigation design, land policies, management structures and relevant government

policies also changed, but have largely not been aligned to the shifting intentions of individual farmers, managing agent and the scheme design, hence making it difficult for local parties to address issues (Bembridge, 1991, 1993; A'Bear and Louw, 1994; Van Rooyen, 1983; DoA, 1994).

6.2 DESCRIPTION OF THE BIOPHYSICAL STATE

6.2.1 Climate

Climatic factors influence the growing efficiency of not only crop plants on the Makhatini flats, but also crops and wild plants on the floodplain. In order to enhance implementation of the concepts of integrated development plans (IDPs) and integrated water resources management, the dynamic interaction of these factors is described so that important issues are taken into account in the planning and promotion of a sustainable and efficient diverse economy.

Climate features measured at Makhatini agricultural research station are shown in Table 6.1. Generally, the climate of the region has been described as warm to hot humid sub-tropical, frost free with high summer temperatures (Schulze, 1965; Schulze, 1997).

Table 6.1: Climatic features measured at Makhatini Agricultural Research Station in 1980 (DoA, 1994).

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Mean	Total
Temperature ^{o}C (T)														
Mean T Max	28.3	29.2	31.4	32.4	31.5	30.8	28.9	26.8	25.1	25.1	26.3	27.6	28.6	
Mean T Min	16.7	18.6	20.1	21.3	20.8	19.7	16.7	12.9	8.6	8.6	11.5	14.9	15.9	
(T Max + T Min)2	22.5	23.9	25.7	26.9	26.1	25.3	22.8	19.9	16.8	16.9	18.9	21.2	22.2	
Range	11.6	10.6	11.2	11.2	10.6	11	12.2	13.9	16.5	16.5	14.8	12.7	12.7	
Highest monthly Max	38.1	37.3	38.6	40	36.9	36.2	34	32.7	31	31.5	34.2	35.7	35.5	
Lowest monthly Min	11.3	12.7	15.1	16.3	16.1	14.8	11	6.9	3.3	2.7	4.7	7.7	10.2	
Highest monthly Min	21.1	22.4	23.8	24.7	24.4	24.5	21.7	18.9	15.1	15.4	17.7	19.8	20.8	
Lowest monthly Max	19.3	21.1	23.5	24.4	24.6	23.8	22.9	20.4	18.9	18.5	18.6	19	21.3	
Extreme T Max	43.6	40.3	44.2	43.7	4.3	41.5	37.3	35.7	34.7	39.2	37.9	38.8	44.2 (Max)	
Extreme T Min	7.1	9.8	11.1	12.9	12.7	12.3	7	3	1.2	0.1	2	4.6	0.1 (Min)	
Humidity (Mean %)														
RH at 08h00	74	75	75	76	79	82	86	87	87	88	83	76	81	
RH at 14h00	52	56	54	53	56	56	53	50	43	44	47	47	51	
RH at 20h00	78	80	79	78	80	83	85	85	81	79	77	77	80	
Rainfall (Means)														
Precipitation (mm)	53	78	76	97	100	70	43	29	11	14	14	48		633
Thunder (no. of days)	3.9	5.3	3.9	6	3.6	3.8	3	1.4	0.5	1	1.5	2.9		36.8
Hail (no. of days)	0.3	0.4	0.2	0.3	0.1	0.3	0.1	0.1	0	0	0	0.1		1.9
Fog (no. of days)	0.3	0.2	0.2	0.1	0.3	1.5	0.8	3.1	1.4	4.4	1.5	1.1		14.9
Cloud cover (no of days)														
08h00	5.7	6	5.9	5.7	5.6	5.2	4.3	3.7	3	2.9	3.5	4.6	4.7	
14h00	5.3	5.8	5.5	5.6	5.7	5.5	5	4.2	3.2	3.4	3.7	4.3	4.8	
20h00	5.1	5.7	5.5	5.7	5.2	5	3.8	2.6	1.7	1.7	2.6	3.8	4	

Sunshine (hours/day)	6.6	6.6	6.9	7.4	7.2	7.6	7.3	7.8	8.1	8.0	8.2	7.4	7.4	
Evaporation (mm)														
A-Pan	218	224	261	261	215	200	162	139	120	138	178	199		2315
Wind (km/day)	231.6	238.7	233.3	190.2	211.4	180.5	150.1	168.7	127.0	149.3	190.4	240.8	192.7	

6.2.1.1 Temperature

Temperature is a basic climatological parameter used as an index of the energy status of the environment (Schulze, 1997). Temperature variables are: daily means, seasonal means, maximum values, minimum values and diurnal ranges (day and night). Temperature parameters have been used to estimate solar radiation, relative humidity, potential evaporation, heat units, chill units, frost zones, and agroclimatically optimum growth areas for crops (Schulze, 1997). Temperature limits the distribution of plants and animals in nature. Living organisms have optimum temperatures which assure the most rapid growth for a particular species and a range of upper and lower limits above or below which growth processes cease. These limits differ from species to species and in a given species from one stage of the life cycle to the next, e.g. germination, photosynthesis, and flowering stages have different optimum temperatures with lower and upper limits. For instance, generally photosynthesis of crops increases slowly from about 5°C to an optimum when leaf temperatures are about 30-35°C, then drops rapidly to 0°C when optimum temperatures are exceeded (Akin, 1991). Implied here is that plants in the field are usually below their optimum temperatures for photosynthesis for most of their growing season. Respiration, a physiological process that produces energy, takes place day and night and increases with temperature up to a varying maximum depending on the species.

Daily mean temperature has been used to distinguish between three broad thermal divisions of plants: (i) plants requiring mean monthly temperatures of 20°C or more for at least 4 months of the year (mega-thermal plants); (ii) plants that grow where mean temperatures of 10°C or less (micro-thermal plants) last for 8 months or longer ; (iii) meso-thermal plants of the mid-latitudes where the physiology of these plants is adapted to *strong seasonal rhythms,* as experienced over most of southern Africa (Schulze, 1997). Seasonal rhythms of mean temperatures show that there is a close relationship between the time for a life cycle to be completed and the temporal variation of the controlling climatic process, i.e. month-by-month variations of mean temperatures. For example, the aquatic macrophyte plant *Potamogeton cripus,* which plays an important role in regulating phosphorus in the Pongolo floodplain pans, starts germinating in April when temperatures begin to drop (Rogers and Breen, 1980; Heeg and Breen, 1982).

Heat Units: daily mean temperature is also used to calculate heat units. Schulze (1997) has explained the concept of heat units. Heat units measure total heat to which a plant or animal was subjected during its lifetime or a certain development stage. Heat units are measured in days-based degrees on a lower threshold value (below which development will not take place), accumulation of mean temperatures above this threshold, and below an upper limit. For example, if the threshold temperature is 10°C, and the mean temperature of a given day is 22°C, then 12°days, or heat units are accumulated for that day and added to a previous total. For example, the lower and upper threshold limits of maize (10-30°C), cotton ball worm (14-34°C), citrus and sugarcane (13°C). Heat units required by maize to ripen for the six

months growing season (October-March) are 1500-1700° days. Heat unit patterns on a catchment scale are shown in Table 6.2.

Table 6.2: Heat units (^{o}days) (Schulze, 1997).

	Upper-catchment	Mid-catchment	Lower-catchment
Summer growing season (Oct-March):	1800-2000	2400-2600	2600-2800
Autumn-Winter growing season	800-1000	1200-1600	>1600

Schulze (1997) reported that heat units (accumulated degree days) can be applied to the following: (i) the prediction of harvest dates of crops; (ii) the selection of crop planting dates after winter; (iii) the estimation of dry matter production (yield of certain crops); (iv) designating the switch from one crop phenological growth stage to the next (v) modelling the development of a crop canopy or an organism, e.g. sugarcane is considered to be at full canopy after 1200 heat units, (vi) modelling the development of an organism, e.g. one generation of the pest codling moth is 572 degree days; the codling moth can have >6 life cycles per annum in the lower parts of the Pongolo River catchment, 4-5 life cycles per annum in the mid-catchment and 3-4 life cycles per annum in the upper catchment; and (vii) estimating when to spray against pests; pest control advisers calculate at which stage of development a pest is by degree days (Zalom et al., 1983).

A temperature aspect, which influences use of the study area as a tourism destination, is the very high daily maximum temperature in summer (e.g. highest maximum value recorded in February is 40.3^{o}C). Humans experience serious to acute discomfort between December and March and only between mid-June and late July can the climate be described as comfortable (Heeg and Breen, 1982).

6.2.1.2 Relative Humidity (RH)

Winter crops can be grown on the Makhatini flats because winters are short, mild and frost free (DoA, 1994). However, it has been reported that during winter a riverine mist frequently occurs in the lower lying areas bringing along high humidity and cooler conditions in the morning. In late winter, very often very hot days can suddenly be followed by cool, overcast weather bringing higher humidity and the incidence of various fungal diseases that can be detrimental to crop production if precautionary measures are not taken (DoA, 1994).

In agricultural production, humidity can influence processes positively and bring benefits, or influence processes negatively and cause high costs. For instance, high humidity reduces rates of transpiration and hence water requirements of crops (Schulze, 1997). Photosynthesis rates have been shown to increase with RH (Baker, 1965), crop yields are often correlated positively with RH (Arkley, 1963) and water use efficiency tends to increase with RH (Chang, 1968). On the other hand, RH coupled with high temperatures favours conditions for the growth of crop diseases, pests, weeds and parasites in the fields and after harvest during storage and transportation of agricultural produce.

6.2.1.3 Evaporation

Water for irrigation development is stored in Pongolapoort Dam. Evaporation values from the dam have been shown to be higher than precipitation values (section 4.3.4.3). High evaporation rates can influence good quality water availability because salts tend to concentrate with the lowering of water levels and may limit irrigation use, particularly during periods of drought and under current reduced inflows from upstream, which are likely to be loaded with excess nutrient pollution from expanding upstream agriculture. Floodplain pans also depend on getting good quality water from the dam annually to flush-out accumulated salts coming from underground seepage (section 6.2.3).

According to Schulze (1997), all atmospheric moisture originates from evaporation from water surfaces and transpiration (water loss through plant stomata). Evaporation is controlled by three conditions: (i) the capacity of air to take up more moisture vapour which increases with temperature; the lower the RH, the more favourable conditions are for evaporation; (ii) the amount of energy available in solar radiation used for latent heat of the evaporation process; and (iii) turbulence from wind to replace the saturated air layers.

6.2.1.4 Wind

The Maputa land plain is subject to very high winds, particularly during the period September to December when the average daily run is 230–240 km/day. Annual wind patterns are similar to rainfall and temperature trends. Wind influences evaporation, turbulence in the pans, and wind erosion on the sandy soils (Hensley, 1966), which affects crops, sprinkler irrigation and influences pesticide application by enhancing drift to non-target areas. Wheat can be used as a rotational crop in winter; however, it is susceptible to wind and birds which makes it only partly suitable for the area.

6.2.2 Soils

The capacity of soil to absorb, retain and redistribute water regulates storm flow, base flow responses, drainage rates and associated water logging, suitability for irrigation, suitability for dry land farming and soil fertility which depends on the chemical base status and its interaction with the clay content (Schulze, 1997).

6.2.2.1 Soil texture on the Makhatini Flats

Soil texture influences the amounts of water that a soil can hold at critical levels. Critical levels used to measure soil content when all the soil's pore spaces are filled with water are: permanent wilting point (PWP), the lower limit of soil water available to a plant; its drained upper limit (DUL), also called field capacity and equal to the upper limit of soil water a wetted soil can hold after gravitational drainage has ceased; and saturation, also called porosity (PO), (Schulze, 1997).

Guidelines to the water retention characteristics of soils are based on soil texture classes according to the percentage of clay (Cl), silt (Si), sand (Sa) and on the basis of soil water content at saturation (PO, DUL

or PWP) and drainage rates (hydraulic conductivity). Eleven texture classes exist, namely Cl, Lm, Sa, LmSa, SaLm, SiLm, SaClLm, ClLm, SiClLm, SaCl and SiCl. A fine soil texture (Cl) would have the following characteristics: high soil water content at permanent wilting point (PWP) and at drained upper limit (DUL) but with relatively low plant available water (PAW) and slow release rates of soil water. A coarse soil texture (Lm) would have low soil water content at PWP and DUL, a low PAW, but release soil water rapidly. A medium soil texture (Lm) would generally have high plant available water (PAW) (Schulze, 1997).

Soil textures on the Makhatini flats area, i.e. areas covering the floodplain, the Makhatini irrigation scheme, Ndumu irrigation scheme in the north and the wider areas on the east and west side of the Pongolo River, are illustrated in Figure 6.1.

Most areas on the west side of the river have fertile soils and are targeted for commercial agricultural development expansion. All areas on the east side of the river have sandy soils except for the areas which form the floodplain, Makhatini irrigation scheme and Ophansi irrigation scheme. Soils found off the floodplain on the east side of the river where floodplain communities live are mainly sandy soil textures not suitable for growing many crops. The implication is that should floodplain communities be denied access to the use of floodplain resources, without providing workable alternatives, they can easily become highly vulnerable to the effects of droughts, hunger, poverty, and disease.

6.2.2.2 Soil forms and potential for agriculture on the Makhatini flats:

Soil classification systems group soils based on soil form and soil series (Macvicar et al., 1977; SCWG-Institute of Soil, Climate and Water). A soil form is an organized combination of soil horizons with the grouping of specific kinds of diagnostic horizons in specific sequences. The further subdivision of a soil form into soil series enables a more specific description of soils based on physical responses of soil texture, degree of leaching, calcareousness, surface crusting, cutan formation indicating the soils tendency to swell when wet and shrink and crack when dry and its degree of wetness.

A typical classification such as HU18 means that the soil form is Hutton (HU) and the soil series is Balmoral (18). Soil water content values in mm soil water per metre depth of soil at saturation are then assigned to the top soil horizon (A) and the subsoil horizon (B) at PO, DUL and PWP. These values have been used to calculate regional crop yields and other hydrological analyses (Schulze, 1997).

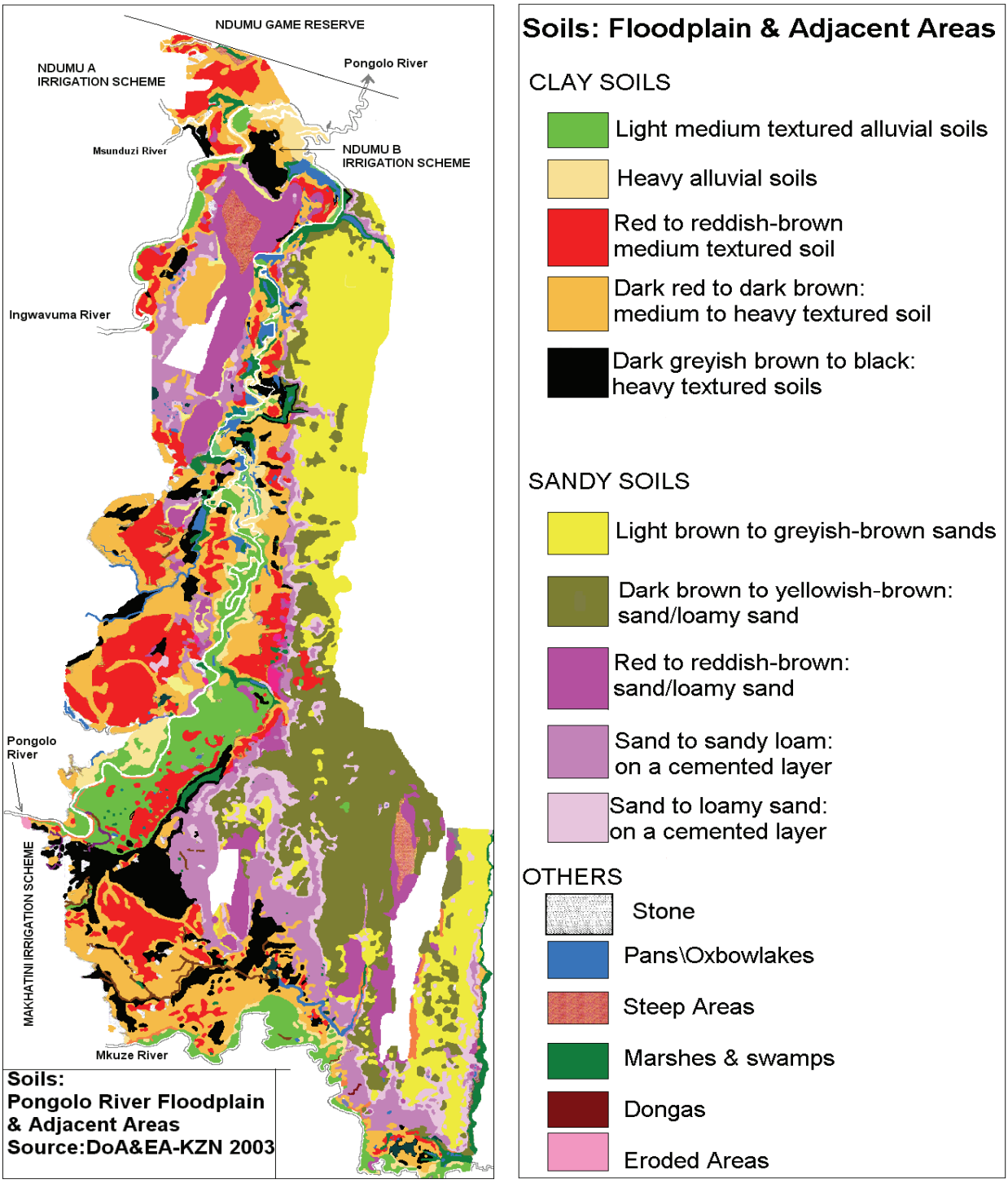


Figure 6.1: Soil distribution patterns (Source data: DAEA – KZN).

Soils considered being suitable for irrigation development on the Makhatini flats fall into three broad categories based on their permeability (Table 6.3). It is important to note that soils found in areas where floodplain communities live are sandy-coarse textured, where staple foods like maize may not grow well. Another important point to note is that Heeg and Breen (1982) showed results of trials carried out at the Makhatini Agricultural Research Station to test for the ability of crops to grow optimally in the area. Cotton was listed as having the ability to grow optimally. This fact influenced decisions taken to promote cotton development in the area (see section 6.2.2.7). Recent reports by (DoA, 1994 and Schulze, 1997) appear to suggest that cotton does not grow optimally in the region. This inconsistency needs to be clarified.

Table 6.3: Soil forms and potential for agricultural development on the Makhatini flats (Heeg and Breen, 1982).

Soil texture	**Soil form**	**Examples of Crops Optimally grown**
Clay-fine textured (slowly permeable)	Oakleaf Shortlands Bonheim	Rice, Sugarcane, Cotton, Sorghum, Wheat
Loamy-medium textured	Hutton Oakleaf Dundee Shortlands	Subtropical fruits, Sugarcane, Cotton, Winter Vegetables, Citrus, Wheat, Sorghum
Sandy-coarse textured	Clovelly Oakleaf Hutton Kroonstad	Groundnuts, Cassava, Tobacco, Citrus, Winter potatoes, Sugarcane (sugarcane can be sub-optimally grown due to widespread nematode infestation in sandy soils)

6.2.2.3 Soil fertility:

Nitrogen mineralization in soil is a natural process in which soil micro-organisms mineralise **nitrogen** (N) by converting it from an organic form not available to plants to an inorganic form (ammonia and nitrates) available to plants (Miles and Manson (2000). Under certain soil conditions determined by the relative interaction of environmental factors such as (soil moisture, temperature, decomposing litter and its chemical composition, soil acidity and disturbance-tillage), soil micro-organisms can either mineralise nitrogen (availability of inorganic nitrogen) or immobilize nitrogen (depletion of inorganic nitrogen reserves). Acidic soils inhibit nitrogen mineralization processes giving a low fertility score while basic soils enhance soil fertility and have high fertility scores (Sanchez, 1976; Adams and Martin, 1984; Tisdale et al., 1985; Whitehead, 1986, Haynes, 1986) (see ecological interests Chapter 5 for details).

On a regional scale, Schulze (1997) has reported soil fertility scores depending on clay content and the base status of the clay content, which determines the rate at which nitrogen mineralizes the soil (Table 6.4). On a soil fertility score of 0-10, the Pongolo River floodplain soils have a very high fertility score (8-9) and may mean that crops can be grown on the floodplain without addition of artificial fertilizers. The area adjacent to the floodplain in the east where the majority of floodplain communities live has a very low fertility score (1-2) and therefore requires artificial supplies of nutrients from fertilizers or may require lime treatment to enhance the base status**.**

Comparatively, the mid-catchment areas have an average fertility score of 4-5, while the upper catchment has a low fertility score of 2-3, which may result from soil acidification accelerated by human activity, e.g. extensive alien plantation forestry.

Table 6.4: Soil fertility score (Schulze, 1997).

	Upper-catchment (mm)	Mid-catchment (mm)	Lower-catchment (mm)
Soil fertility score (0-10)	2-3	4-5	8-9 (on the floodplain) 1-2 (area east of the floodplain)

Within the Pongolo catchment, primary production which is a quantitative expression of vegetative matter, e.g. harvestable yield which can be produced by the natural environment at a location over a given period of time (tons/ha/season or per year), is high and highly variable

Table 6.5: Primary production or harvestable yield of vegetative matter (Schulze, 1997).

	Upper-catchment (mm)	Mid-catchment (mm)	Lower-catchment (mm)
Primary production (tons/ha/season) CV% inter-annual variability.	10-12 CV% (20-30).	6-8 CV% (30-40)	6-8 and 8-10. CV% (30-40

6.2.2.4 Soil water stress in the study area:

Soil water stress is given as percentage days a plant is under water stress /month. Water deficits in plants affect photosynthesis, plant cell protoplasm dehydrates, leaf looses turgidity, and stomata guard cells close, preventing any further intake of carbon dioxide. Ability of a plant to withstand soil water stress depends on the species. Similarly, plants recover at different rates. Generally, plants experience more days of soil water stress in winter than in summer in the whole catchment (Table 6.6). In winter, the whole catchment experiences soil water stress, but the upper catchment experiences more stress. In summer, the lower catchment experiences more days of soil water stress when compared to the rest of the catchment (Mid and Upper).

Table 6.6: Soil water stress (Schulze, 1997).

	Upper-catchment	Mid-catchment	Lower-catchment
% days January (% days in summer)	50-60%	60-70%	70-80%
% days July (% days in winter)	>90%	80-90%	80-90%

6.2.2.5 Moisture growing season (soil water availability)

Soil water availability is determined by the hydrological or water budget at a specific locality, indices of the average start of the season date to the end of the season, and hence duration of the moisture-growing season is determined. The moisture-growing season measured by soil water availability days is lowest in the lower catchment (Table 6.7). It is important that the type of crops promoted in the lower region must be aligned with the growing season to ensure efficient growth.

Table 6.7: Moisture growing season – Soil water availability (Schulze, 1997).			
	Upper-catchment	Mid-catchment	Lower-catchment
Mean Start	September	September	October
Mean End	April	March	March
Duration of season (days)	200-225	175-200	150-175

6.2.2.6 Irrigation requirements

Crop production can be greatly enhanced through irrigation. At the national level, irrigation utilizes just over 50% of the available water resources. By 1986, it was estimated that 1.3 million ha was under irrigation in South Africa.

Irrigation requirements of crops can be determined if the following is known: crop water requirements, water losses, rainfall amounts (the amount of rain which replaces the soil water), and nature of soils. Models that integrate all these variables have been designed and computer routines developed and made user friendly for farmers (See Irrigation talk series in the quarterly magazine of the Water Research Commission, The Water Wheel, Pretoria SA). For example, Schulze (1995) describes the ACRU model. ACRU's irrigation water budgeting and scheduling routine options operate on a daily timestep and can consider different modes of irrigation scheduling which may be appropriate to prevailing climatic, crop, or farmer management conditions.

When the gross annual irrigation requirements of the upper, mid and lower catchments were compared (Table 6.8), the lower catchment downstream of Pongolapoort Dam has the highest irrigation requirements. It is important that this fact be taken into account when making decisions about water allocations in the catchment.

Table 6.8: Gross irrigation requirements on a regional scale (Schulze, 1997)			
	Upper-catchment (mm)	Mid-catchment (mm)	Lower-catchment (mm)
Median Annual gross irrigation requirements	900-1000	1100-1200	1200-1400
Driest year in 10	1100-1200	1200-1400	1400-1600

On a catchment scale, the lower catchment downstream of the dam has a lower MAP (mean annual precipitation in mm) (400-600) when compared with the mid-catchment upstream of the Pongolapoort Dam (600-800) and the upper Pongola-Bivane catchment (800-1000) (Schulze, 1997; Dent, Lynch and Schulze, 1989; Dent, 1999). Therefore, in the absence of irrigation, rainfall alone cannot ensure high crop yields on the Makhatini flats.

6.2.2.7 Farming practice on the Makhatini irrigation scheme

Knowledge of the interaction between soils, moisture and climatic factors can be used to estimate crop yields and to inform farming practice per crop grown, i.e. crop type, soil requirements, crop water requirements, growing season (days), planting time, climatic factors that limit efficient growth of a crop,

labour requirements, and agronomic risk. The following are important features that characterize crops grown on the Makhatini flats (DoA, 1994).

6.2.2.7.1 Field crops

Important features of field crops commonly cultivated on the irrigation scheme with respect to yields, growing season, water requirements, labour requirements, agronomic risk, market risks and potential markets are illustrated in Table 6.9.

Sugarcane: sugarcane thrives in the area due to a climate suitable for sugar production. The absence of local sugar milling facilities (the nearest sugar mill is situated at Pongola which is 85 km from the scheme), as well as the lack of production quotas and high transport costs had precluded the production of sugarcane. With the deregulation of the sugar industry, it would be possible for the Pongola and other sugar mills to subsidize transport costs. Provided this happens and sufficient quotas can be obtained, it is possible for this crop to be economically cultivated.

Table 6.9: Field crops – important features (DoA, 1994)

Crop	**Yield (Kg/Ha)**	**Growing Season (days)**	**Crop water requirements**	**Labour Requirement (Mandays/Ha)**	**Agronomic risk**	**Marketing risk**		**Potential markets**
						Formal sector	**Informal sector**	
Wheat	5 000	110-120	360	40	High	Assured Market (controlled product)	High	Wheat Board
Cotton	2 400	180-210	520	150-180	Moderate	Assured Market (controlled product)	High	Cotton Ginners Clark Cotton and Tongaat Cotton
Sugarcane	90 000	Perennial	1 400	180-200	Low	High nearest mill is about 95 km	High	Pongola Sugar Mills
Maize	7 000	120-140	470	40-60	Moderate to High	Assured Market (controlled product)	Moderate to High	Maize Board. Maize Millers, Retail outlets, Informal sector.
Dry beans	1 500	-	154	40-60	Moderate	Moderate to High	Low	Dry Bean Board, Grain merchants, Retail outlets, Informal sector.

Soya-beans	1 750	140	460	40-60	High	-	High	Oil Seeds Board, Grain merchants
Rice (paddy)	6 000	120-140	1 000	40-60	High	-	Moderate to High	Cereal manufacturers, Grain merchants, Retail outlets, Informal sector.

Cotton: a key comment to note on the cotton crop is that through many years of irrigation scheme management agents prescribing cotton practice, most farmers are familiar with production requirements and cotton companies are willing to finance production input for farmers and to provide assured markets. High yields go up to 3 tons/Ha. However, two factors found to inhibit cotton production are: (i) insufficient sunlight; the average number of sunshine hours per year is about 30% less than the optimum required; and (ii) ball damage through rain. Indeed the cotton-growing season is much longer (180-210) when compared with other field crops such as maize (120-140), rice (120-140), and wheat (110-120). Temperatures start falling before the cotton crop has effectively ripened. The growing season is October to March. According to Schulze (1997), ideal requirements for cotton growing are: a MAP of 500-700 mm rainfall; mean annual temperature >16°C; minimum sunshine, 2100; January mean temperature >22°C; boll development requires 27-32°C; ripening, RH 65%; soils should be freely drained, 0.9 metres in depth, ideally silty loam to clay alluviums but can tolerate a variety of textures. Water logging damages plants. The natural climate in the upper and lower catchments is climatically unsuitable for cotton growing. The mid-catchment can give yields of 1.5-2 tons/Ha/ season. Indeed the transfer of cotton farming practice from the irrigation schemes to the floodplain has interfered with traditional farming practices (maize and beans) because cotton stays longer on the floodplain and interferes with the timing of artificial flood releases. This causes conflict between cotton farming households and non-cotton farming households (section 7.3.3.3 in Chapter 7). A point to note is that cotton was listed as having the ability to grow optimally on the Makhatini flats (Heeg and Breen, 1982) which influenced decisions taken to promote cotton development in the area (see section 6.2.2.2). The reports above (DoA, 1994 and Schulze, 1997) and the results in Chapter 7 section 7.3.3.3 appear to suggest that cotton does not grow so optimally in the region. This inconsistency needs to be clarified.

Maize: maize is planted as a second crop with cotton. Maize growing is limited to the winter months due to high summer temperatures and incidence of disease. Maize is hand harvested and sold directly as green cobs or dried maize. Some farmers make use of the milling facilities at Thuthukani Co-op to mill their maize. Profit margins of maize sold as green cobs are high and marginal as dried maize. Optimum planting dates and correct cultivar choice determine whether high maize yields are achieved.

Dry Beans: dry beans are produced as a winter crop. Marketing is not a problem because the crops enter the market in spring at a time when stocks produced during the summer in the Free State and KwaZulu-Natal midlands have been depleted.

Rice: rice has a growth period of 120 days. Medium grain white rice was successfully cultivated on the scheme for a lucrative breakfast market. Harvesting is by hand, thrashed, dried, cleaned and polished by Thuthukani Co-op. Yields vary between 3.4 ton/ha and 5 tons/ha on upland conditions and up to 9 tons/ha on paddies.

Soya beans: profits from soybeans are modest. Although the bean has a high content of protein it is never eaten in KZN, owing to difficulty involved in cooking. It is an excellent rotation crop for maize, wheat and grain sorghum. Soybeans can be marketed through the Oil Seeds Board where a floor price is guaranteed or can be sold privately.

Wheat: wheat can be used as a rotational crop in winter. It is susceptible to wind and birds, which make this crop only partly suitable for this scheme

6.2.2.7.2 Horticultural crops

Potential horticultural crops include pineapple, citrus (grapefruit, Valencia oranges, and lemons), bananas, papaya, mangos, litchis, macadamia nuts, cashew nuts and spices. Limiting factors to production are the distance from markets and lack of processing and packing facilities for these crops. Winter vegetables include cabbage, tomatoes, onions, carrots, spinach and chillies. However, limiting factors to vegetable production are the short season, the distance from large outside markets and the small local market. Local processing of vegetables is important (DoA, 1994).

6.2.3 Ground water

During droughts, ground water is often the sole exploitable and reliable water resource for survival. However, subterranean water abstractions have to be recharged or replenished over a period by rainfall. A measure of recharge in the Pongolo catchment is illustrated in Table 6.10.

Table 6.10: Ground water – mean annual recharge (mm) (Schulze, 1997)

	Upper-catchment (mm)	Mid-catchment (mm)	Lower-catchment (mm)
Mean Annual Recharge of soil water (mm) into the vadoze zone (below the root zone)	60-70 40-50	20-30 10-20	10-20 40

However, studies have shown that the ground water resources in the Maputaland coastal plains are of poor quality due to high saline concentrations which take on the characteristics of sea water and may not be suitable for irrigation or domestic purposes in certain areas (Van Wyk, 1963; Du Preez, 1967; Orpen, 1972; Heeg et al., 1978). Ground water, associated with the Cretaceous beds of the coastal plains, is highly mineralized chloride water with total dissolved solids contents ranging from 1 000 to 24 000 mg/litre (Van Wyk, 1963; Orpen, 1972).

During periods of low flows, the Pongolo River takes on a high concentration of dissolved solids, whose composition is characterized by high concentrations of both sodium and chloride, thought to result from the entry of underground seepage water into the river (Archibald et al., 1969).

Studies of dissolved solids in floodplain pans showed salinization to be an even more serious problem than in the river channel (Du Preez, 1967; Heeg et al., 1978). Seepage water from sediments overlying the marine Cretaceous deposits on the Maputaland coastal plain resulted in several pans taking on the characteristics of dilute seawater, which becomes concentrated due to evaporation. Tete, Mholo and Nyamiti pans were particularly found to be adversely affected in this way. The very sandy soil structure within which these pans are particularly located may be the reason why salinity is a problem (Fig 6.1). These pans are therefore highly dependent on an annual dilution or flushing out by floodwaters of low dissolved solids in order to retain their freshwater characteristics (Heeg et al., 1978: Heeg and Breen, 1982).

Heeg and Breen (1982) warned that, in the planning of development of irrigation schemes, the geological formations that limit use of ground water for irrigation need to be taken into account. The long, gentle slopes on the Maputaland plains mean that considerable attention would need to be given to the drainage aspect. Because of the ability of salt to accumulate in the deeper layers of certain soils, salinity in the underlying Cretaceous rocks has the potential for enhancing water and soil salinization. In addition, the rapid permeability of the sandy soils can enhance the salinity of seepage water to the river and floodplain.

6.3 DEMOGRAPHIC PATTERNS IN THE CATCHMENT

6.3.1 Trends in population growth at the National Scale

The South African population increased from 40.5 million people in 1996 to 44.8 million people in 2001, a growth of 10% (Statistics South Africa Census, 2001). KZN province, within which the floodplain is located, had the largest population (9.1 million) and had the third largest population increase (12%) after the Western Cape (14%) and Gauteng (20%). These increases were attributed mainly to an internal migration of people from the more rural provinces to the more urban provinces. According to mid-2005 population estimates, the total human population in South Africa was estimated at 46.9 million and the overall rate of growth was reported to be declining steadily. For instance, the growth rate for 2004-2005 was estimated at 0.9%. KZN had the largest increase (20.6%), followed by Gauteng (19.2%). Gauteng, the Western Cape and KZN had positive net migrations with the largest number of persons expected to migrate to Gauteng. The Eastern Cape and Limpopo were expected to have the largest negative net migration, with the Eastern Cape expected to experience a negative net migration of approximately 320 000 for the period 2001-2006.

6.3.2 Regional and Local government boundaries

South Africa has nine regional provinces. The Pongolo River catchment is located mainly in KwaZulu-Natal province and partly in Mpumalanga province. Provinces are subdivided into District Councils

(DC). The Pongolo River catchment area falls mainly within Umkhanyakude and Zululand district councils in KZN and in one other district council in Mpumalanga province.

DCs are subdivided into local municipalities. Local municipalities in the upper Pongolo River catchment are eDumbe (KZ261) and Mkondo (Mp303), mid-catchment is uPhongolo (KZ262), and the lower catchment where the floodplain is located comprises Jozini (KZ272), located on the west side of the river and floodplain, and Umhlabuyalingana (KZ271) on the east side.

Local municipalities are further subdivided into wards, which form the lowest unit of governance. Democratically elected councillors represent local communities at this level. At the same time, section 211 of South Africa's constitution recognises the concept of traditional authorities (tribal authorities). Section 212 states that the National Legislature may provide for a role for traditional leadership, as an institution, at local level, on matters affecting local communities. Traditional leadership is made up of chiefs (*Inkosi*) and sub-chiefs (*izinduna*). Local councillors in municipalities can comprise up to 20% traditional leaders.

Therefore, two sets of wards have been delineated: (i) wards based on traditional leadership led by traditional chiefs and sub-chiefs who acquired their positions by inheritance (Fig 6.2); and (ii) wards for election purposes led by democratically elected councillors (see Fig 6.3 and Fig 6.4).

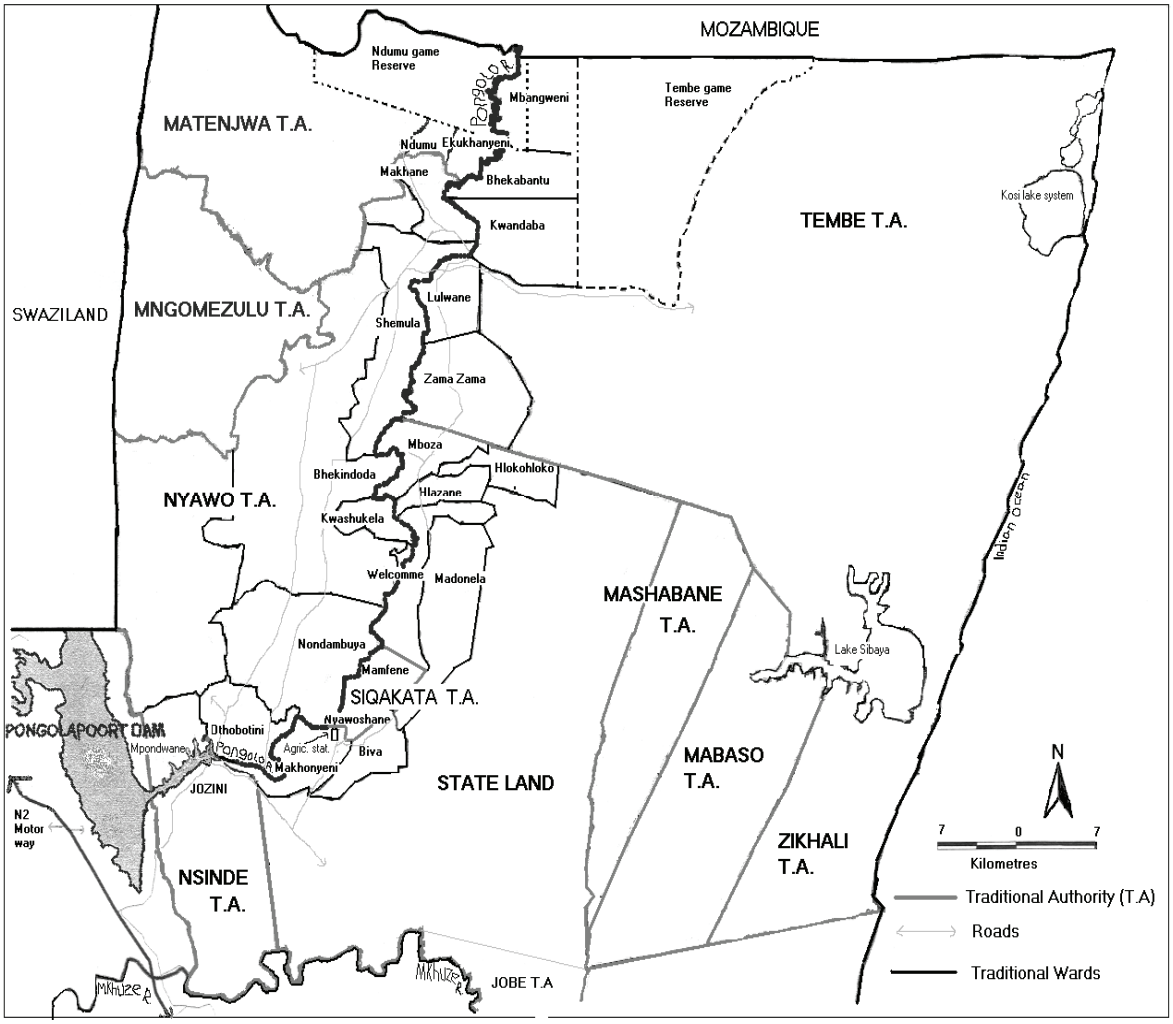
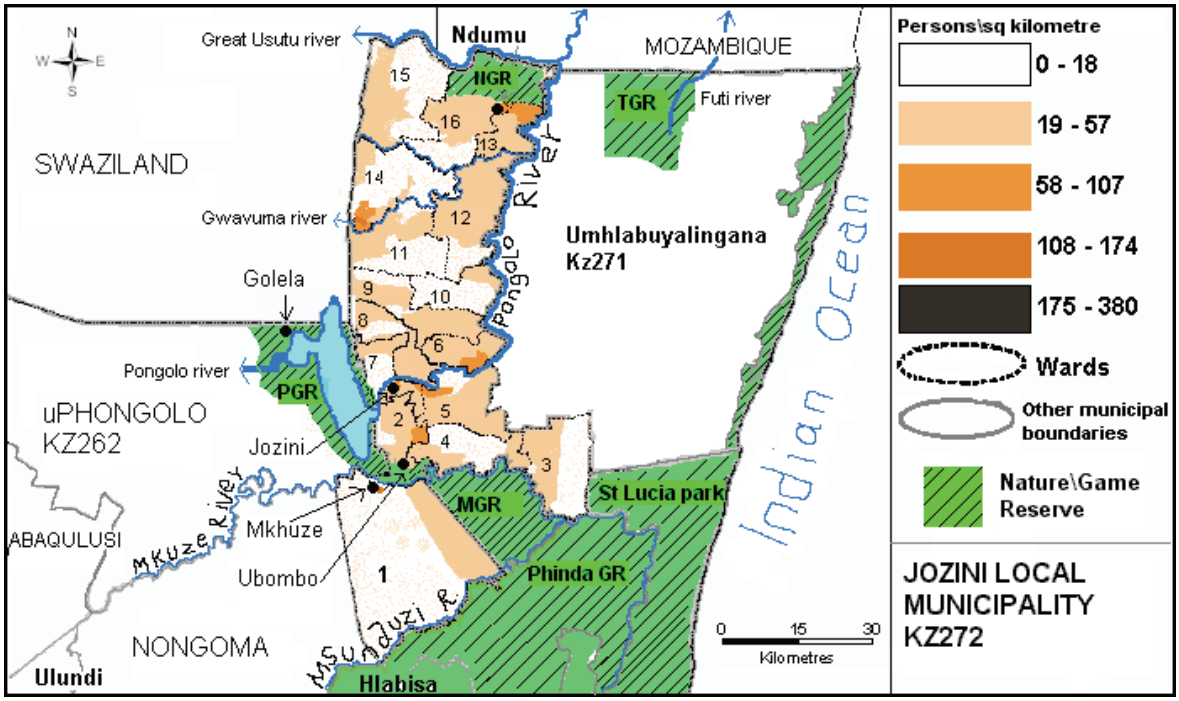


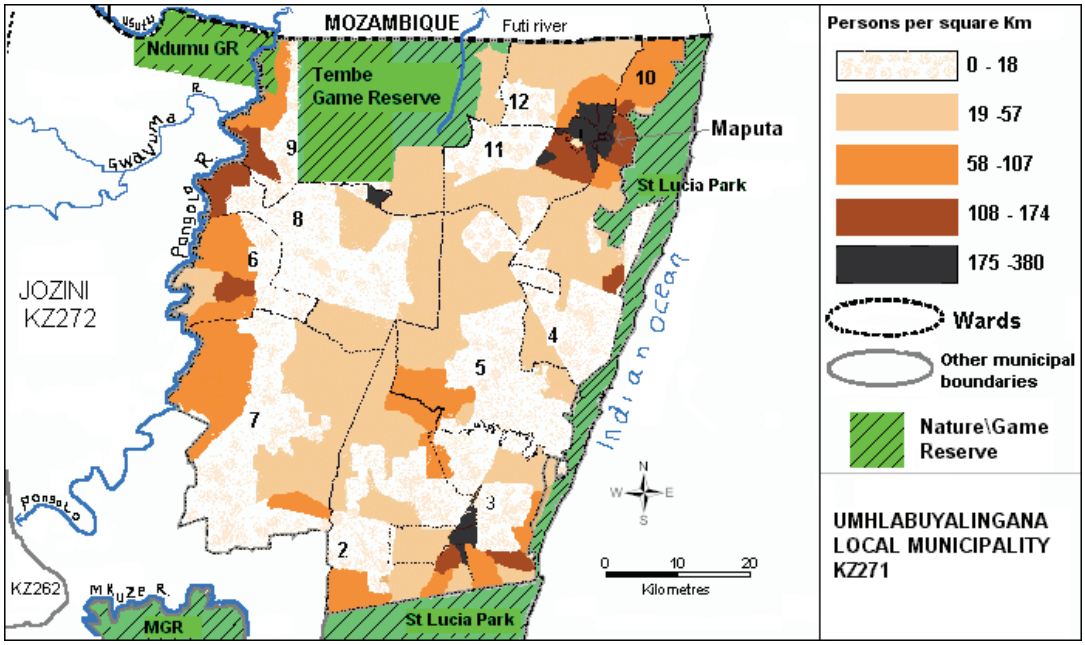
Figure 6.2: Local wards delineated, based on Traditional Authority leadership. Each tribal authority (TA) boundary is governed by a chief (*Nkosi*). TAs are sub-divided into wards governed by sub-chiefs (*iZinduna*). Only wards situated in the immediate vicinity of the Pongolo River and floodplain that are affected by artificial flood releases from the dam are shown (Source: Local government – Pietermaritzburg 2002)



Data for population distribution in Local municipality Jozini KZ272

MDB Ward No.	1996	2001	% Change	Area km^2	No. of Households
1	9057	11899	31.58	652.6898	2577
2	10334	9578	-7.32	128.5781	2355
3	9303	12836	37.98	196.3324	1947
4	5085	7908	55.92	139.1628	1242
5	9301	15813	70.01	161.6831	2514
6	6106	8001	31.04	71.0005	1233
7	8413	10120	20.29	98.9305	2271
8	5057	9740	92.6	107.7643	1524
9	11613	11272	2.94	164.06	1785
10	6397	7026	9.83	107.7182	1290
11	11285	10831	-4.02	195.1729	1974
12	14380	18630	29.55	222.4836	3336
13	11879	11634	-2.06	77.6854	2091
14	11328	13895	22.66	203.8594	2898
15	12846	14025	9.18	262.6373	2391
16	9305	10883	16.96	291.9743	2115
Totals	**151689**	**184090**	**21.36**	**3081.72251**	**33543**

Figure 6.3: Population distribution within the local municipality KZ272 – Jozini. Note: only data for Jozini is shown. (Source: modified from Municipal Demarcation Board/Statistics SA-Census, 2001).



Data for population distribution in Local municipality Umhlabuyalingana KZ271

MDB Ward No.	1996	2001	% Change	Area km^2	No. of Households
1	5466	4178	-23.56	14.4842	843
2	14625	17544	19.96	401.9627	2916
3	11704	12749	8.93	250.138	2109
4	7759	14441	86.12	324.2388	2943
5	9158	8946	-2.31	453.3821	1683
6	10440	10936	4.75	169.6729	1980
7	15754	20302	30.14	593.3678	3471
8	9884	13158	33.12	418.4066	2430
9	11326	10683	-5.68	623.8519	1983
10	10015	10155	1.4	70.6175	2121
11	8204	9644	17.55	205.1118	1881
12	8005	8227	2.77	168.1472	1608
Totals	122340	140962	15.22	3693.39445	25968

Figure 6.4: Population distribution within the local municipality KZ271 – Umhlabuyalingana. Note: only data for KZ271 is shown. (Source: modified from Municipal Demarcation Board/Statistics SA-Census, 2001).

6.3.3 Population distribution adjacent to the floodplain

Umkhanyakude district council DC27, made up of KZ271 and KZ272, comprised 325 052 people (SA Census, 2001). Estimation of the population adjacent to the floodplain shows that 28% of the population in Umkhanyakude district council, DC27, (92 369 people making up 16 581 households) live adjacent to the floodplain (Table 6.11). At the municipal level, Uhlabuyalingana KZ271, situated on the east side of the river, had a population of 140 962 making up 25 968 households. Out of this number, 39.09% (55 079 people making up 9 864 households) live adjacent to the floodplain. Jozini municipality, KZ272, located on the west side of the river had 184 090 people making up 33 543 households. Out of this number, 20.26% (37 290 people making up 6 717 households) live adjacent to the floodplain.

Table 6.11: Population in Wards adjacent to the Floodplain (compiled from Statistics SA-Census, 2001 database**)**

	Population – 2001	No. of Households
Umhlabuyalingana municipality		
KZ271 Ward No.6	10 936	1 980
KZ271 Ward No.7	20 302	3 471
KZ271 Ward No.8	13 158	2 430
KZ271 Ward No.9	10 683	1 983
Sub-total KZ271	55 079	9 864
Percentage of total population KZ271(140962)	39.07%	
Jozini municipality		
KZ272 Ward No.10	7 026	1 290
KZ272 Ward No.12	18 630	3 336
KZ272 Ward No.13	11 634	2 091
Sub-total KZ272	37 290	6 717
Percentage of total population KZ272 (184090)	20.26%	
Umkhanyakude District Council DC27		
TOTAL	92 369	16 581
Percentage of population in DC27 (325052)	28.42%	

6.3.4 Population distribution adjacent to the Pongola River in the whole catchment

Analysis of the population distribution patterns within the catchment showed that local municipalities located in the lower catchment downstream of the Pongolapoort Dam (Jozini KZ272 and Umhlabuyalingana KZ271) had a 'very high population density' adjacent to the river when compared with municipalities upstream of the Pongolapoort Dam, mid-catchment (uPhongolo KZ262) and the upper catchment (eDumbe KZ261 and Mkondo Mp303), with 'hardly any to no population density' adjacent to the river. Population density adjacent to the floodplain is particularly high from where the floodplain begins, which indicates a direct dependency on the river and floodplain resources.

6.3.5 Population distribution at the municipal scale within the catchment

Population in local municipalities increases as you move from the upper catchment to the lower catchment, i.e. municipalities in the upper catchments have less population when compared to those in the lower catchment (Table 6.12).

However, trends in population growth show an increasing gradient from lower catchment to the upper catchment (Umhlabuyalingana KZ271 – 15%, Jozini KZ272 – 21.36%, uPhongolo KZ262 – 21.83%, eDumbe KZ261 – 25.80%). These increases may be attributed mainly to internal migration of people from the less developed municipalities (Umhlabuyalingana KZ271 – 15%, Jozini KZ272 – 21.36%), to the more developed municipalities with more opportunities in agriculture, forestry and fishing (uPhongolo KZ262 – 21.83%, eDumbe KZ261 – 25.80%, Mkondo MP303 – 42.54%). Although Jozini KZ272 has the highest population (184,090), it is the least densely populated based on area to population ratio and has good soils with high potential for agricultural development expansion on the state lands.

Table 6.12: Population distribution at the municipal scale within the catchment (Statistics South Africa Census, 2001)

	1996	2001	% Growth	Area km^2
KZ261 eDumbe (upper catchment)	65 377	82 241	25.8	1 947.48422
KZ262 Uphongolo (mid-catchment)	98 314	119 780	21.83	3 235.10021
KZ271 Umhlabuyalingana (lower catchment)	122 340	140 962	15	3 693.39445
KZ272 Jozini (lower catchment)	151 689	184 090	21.36	3 081.72251
*MP303 Mkondo (*Note that only a small proportion lies within the upper Pongolo catchment)	100 245	142 893	42.54	4 868.15359

6.3.6 Trends in population growth in the lower catchment

It is important to note that pre-1994, areas previously known as Ubombo and Ingwavuma magisterial districts form a greater portion of the current municipalities of Jozini KZ272 and Umhlabuyalingana KZ271 respectively, which make up the district council DC27 – Umkhanyakude. Over a decade, the population growth rate increased by 13.6% in Ubombo and Ingwavuma districts, i.e. in 1960 – 95 929 people to 1970 – 108 964 people. More recently, population trends in this district show a growth rate of 18.6% over a period of 5 years (i.e. in 1996 – 274 029 people to 2001 – 325 052 people. Therefore, population growth is increasing in the lower catchment.

6.3.7 Trends in Household Size within the catchment

The distribution of the number of persons/households is characterised by a distinct pattern where many households have 10 individuals and over per household and one individual per household on both extremes of a normal distribution curve. The 'median statistic' shows that households downstream of the Pongolapoort Dam generally have larger household sizes (KZ271 Umhlabuyalingana and KZ272 Jozini –

7 persons/household) when compared to those upstream of the dam (uPhongolo KZ262 – 4 persons, eDumbe KZ261 – 5 persons, Mkondo MP303 – 6 persons) (Table 6.13).

Table 6.13: Trends in Household Size within catchment (Statistics South Africa Census, 2001)

	No. of Households				
Persons/Household	KZ272 Jozini	KZ271 Umhlabu	KZ262 uPhongolo	KZ261 eDumbe	MP303 Mkondo
1	5 361	3 901	4 969	2 229	3 958
2	3 164	2 416	3 654	1 699	4 152
3	3 022	2 496	2 550	1 467	3 829
4	3 669	3 176	2 512	1 589	3 849
5	3 824	3 113	2 360	1 564	3 160
6	3 631	2 935	2 133	1 475	2 511
7	2 965	2 267	1 754	1 186	1 787
8	2 314	1 747	1 417	1 053	1 398
9	1 828	1 200	998	768	955
10 and over	3 768	2 710	2 466	2 075	2 266
Total	33 546	25 961	24 813	15 105	27 865
Mean	3 354.6	2 596.1	2 481.3	1 510.5	2 786.5
Median	3 397.5	2 603	2 413	1 519.5	2 835.5
Max	5 361	3 901	4 969	2 229	4 152
Min	1 828	1 200	998	768	955

6.3.8 Water source

Trends show that the Pongola River is an important resource in many households in all the municipalities and rain water harvesting using rain water tanks is hardly practiced. Generally, municipalities upstream of the Pongolapoort Dam have more households with potable water inside yards than municipalities downstream of the dam (Table 6.14).

Table 6.14: Water Source 2001 (Statistics SA, 2001)

	No. of Households				
	%KZ272 Jozini Downstream	%KZ271 Umhlabu Downstream	%KZ262 uPhongolo Downstream	%KZ261 eDumbe Downstream	%MP303 Mkondo Downstream
Dwelling	2.75	1.62	5.37	4.59	17.75
Inside yard	8.96	11.35	35.14	29.71	18.42
Communal stand	11.46	3.68	6.93	11.80	12.15
Communal stand – 200 m	25.35	14.91	13.19	16.75	18.53
Borehole	6.14	27.08	4.25	6.06	5.02
Spring	4.58	8.67	5.79	1.56	3.84
Rain tank	1.59	1.48	1.09	0.84	0.56
Dam/stagnant	3.50	7.85	3.99	2.70	4.0
River/stream	30.61	18.92	20.09	21.87	14.91
Water Vendor	0.90	1.33	0.79	0.44	1.73
Other	4.16	3.11	3.37	3.66	3.07

6.3.9 Occupation and mode of travel

Trends shows that a great proportion of persons within the catchment have elementary skills, technicians or service workers. There are very few professionals. The majority of people within the catchment move about on foot.

6.3.10 Labour force

Trends show that municipalities upstream of the dam have a greater proportion of employed persons than municipalities downstream of the dam. Mkondo has the highest number of employed persons due to opportunities in forestry, followed by uPhongolo with opportunities in agriculture and game reserves, then eDumbe with opportunities in mainly forestry (Table 6.15).

Table 6.15: Labour Force

	%KZ272 Jozini	%KZ271 Umhlabuya	%KZ261 eDumbe	%KZ262 Uphongolo	%MP303 Mkondo
Employed	9.95	9.82	19.30	24.08	29.81
Unemployed	15.03	22.07	26.07	22.77	25.20
Not economically active	75.02	68.11	54.63	53.15	44.99

6.3.11 Income: individual monthly and annual household

The greatest proportion of persons with no individual monthly income is in the municipalities downstream of the dam (Table 6.16). On an annual scale, the proportion of households with an annual income increases for municipalities downstream of the dam. However, at the catchment scale, municipalities downstream of the dam have more households with no annual household income.

Table 6.16: Individual monthly and Annual household income (Source SA Census, 2001)

INDIVIDUAL MONTHLY INCOME					
	Persons				
Rands	%KZ272 Jozini downstream	%KZ271 Umhlabuya downstream	%KZ262 uPhongolo upstream	%KZ261 eDumbe upstream	%MP303 Mkondo upstream
None	86.00	85.01	73.41	80.93	75.89
R1-400	5.25	4.38	12.70	6.57	7.96
R401-800	5.12	6.90	8.60	8.45	9.18
R801-1600	1.24	1.35	1.94	1.51	2.94
R1601-3200	1.25	1.42	1.67	1.21	1.89
R3201-6400	0.75	0.59	1.06	0.78	1.29
R6401-12800	0.22	0.22	0.37	0.29	0.56
R12801-25600	0.03	0.03	0.12	0.09	0.14
R25601-51200	0.04	0.02	0.05	0.04	0.05
R51601-102400	0.03	0.03	0.04	0.03	0.03
R102401-204800	0.04	0.03	0.04	0.08	0.06
R204801 or more	0.00	0.00	0.00	0.01	0.01

ANNUAL HOUSEHOLD INCOME					
	No. of households				
None	47.28	44.86	16.59	35.81	27.09
R1-4800	10.64	8.21	23.65	10.93	12.24
R4801-9600	18.98	22.72	28.21	24.26	22.92
R9601-19200	10.22	10.65	16.16	13.91	17.58
R19201-38400	6.61	7.80	7.90	8.00	9.79
R38401-76800	3.88	3.55	3.95	3.84	5.31
R76801-153600	1.51	1.54	2.18	1.85	3.03
R153601-307200	0.41	0.30	0.74	0.61	1.231
R307201-614400	0.13	0.13	0.31	0.27	0.36
R614401-1228800	0.11	0.05	0.11	0.09	0.11
R1228801-2457600	0.17	0.12	0.14	0.30	0.25
Over R2457600	0.06	0.08	0.04	0.12	0.08

6.3.12 Industry – GDP and Jobs

Trends show that municipalities upstream of the Pongolapoort Dam have a greater proportion of opportunities in agriculture, forestry and fishing compared to those downstream of the dam (Table 6.17). It would be desirable to promote opportunities for employment downstream of the dam due to the presence of a huge labour force, as observed earlier in section 6.3.10.

Table 6.17: Industry 2001 (Source: SA Census, 2001)

Industry type	**Persons%**					
	%KZ272	%KZ271	%KZ262	%KZ261	%MP303	Total (%)
Communal/social/personal	36.46	41.52	16.32	14.21	11.37	119.88
Agric/forestry/fishing	10.63	5.34	41.16	26.46	31.35	114.94
Undetermined	16.84	16.93	7.16	17.57	7.48	65.98
Wholesale/Retail	11.43	11.77	8.61	9.53	12.32	53.66
Private households	8.45	6.63	9.17	12.12	8.25	44.62
Manufacturing	2.04	3.81	5.86	7.15	17.15	36.01
Construction	3.6	3.64	3.2	5.18	3.36	18.98
Financial/insure/Real estate/Business	4.95	5.03	2.99	2.45	3.18	18.6
Transport/storage/communication	3.61	3.71	2.46	3.57	2.63	15.98
Mining/Quarrying	1.49	1.17	2.1	1.2	2.51	8.47
Electricity/gas/water	0.46	0.45	0.97	0.55	0.4	2.83
Other	0.03	0	0	0	0	0.03

Based on income statistics (section 6.3.11) many floodplain communities are generally poor. In many instances, this leads to high levels of dependency on and even unsustainable use of natural resources of the floodplain to sustain basic livelihoods. Backeberg and Odendaal (1998) suggested that although subsistence irrigation farming can make a contribution to poverty alleviation in rural areas, it would have to be supplemented by the development of a wide-ranging programme which not only develops agriculture but also improves skills to earn non-agricultural income through integrated development of the rural-urban link.

In order to determine the most likely industries in the non-agricultural business sector of the South African economy that can contribute significantly to providing job opportunities to supplement subsistence agriculture and commercial irrigation in the region, data from Statistics South Africa, 2006 was analyzed.

According to national accounting trends (2001-2005), the contribution made by the agriculture/forestry/fishing sector to the Gross Domestic Product (GDP) was ranked 8 out of 10 (Table 6.18). A second significant feature in trends is that, while contribution to GDP from all other industry sectors was generally increasing, the contribution made by agriculture/forestry/fishing sector appeared to be declining (Fig 6.5).

Table 6.18: %GDP by industry at current prices, 2001-2005 (Source data: Statistics SA, 2006)

	2001	**2002**	**2003**	**2004**	**2005**
Finance, real estate and business services	19.13	19.24	20.07	21	21.12
Manufacturing	19.06	19.7	19.42	19.05	18.6
General government services	15.33	14.79	15.07	15.03	15.12
Wholesale and retail trade: hotels and restaurants	14.05	9.4	13.82	14.12	14.58
Transport, storage, communication	9.64	9.4	9.68	9.84	10.03
Mining and Quarrying	8.32	8.66	7.38	7.04	6.97
Personal services	6.07	5.89	6.12	6.15	6.27
Agric\forestry\fishing	3.51	4.15	3.58	3.05	2.55
Electricity and water	2.48	2.45	2.48	2.37	2.29
Construction	2.41	2.27	2.36	2.35	2.45

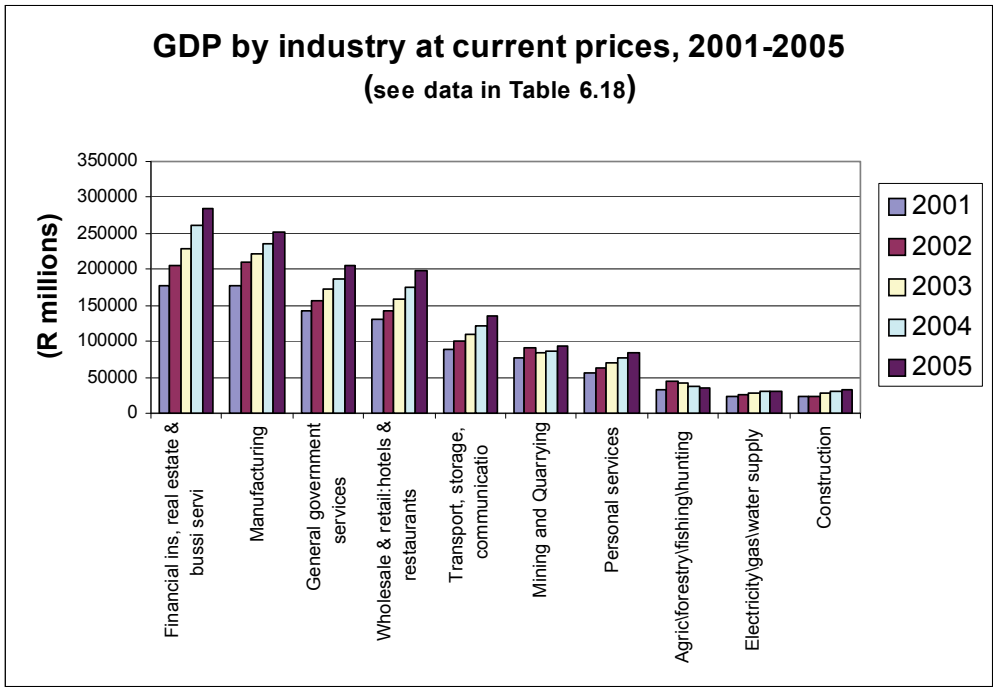


Figure 6.5: Trends in GDP per industry at current prices (2001-2005)

Therefore, in terms of contributions to GDP at the national scale, the five most important industries are: (1) finance, real estate and business services; (2) manufacturing; (3) general government services; (4) wholesale and retail trade: hotels and restaurants; and (5) transport.

What about industries that can contribute significantly to providing job opportunities? In the agricultural sector, the summer growing season ends in March and starts in September. The number of employees in the agricultural/forestry/fishing sector was compared with that from the non-agricultural sectors for the months of March and September. At the national scale, agriculture/forestry/fishing sector was ranked 5 out of 9 in terms of job opportunities offered (Table 6.19). In terms of contributions to job opportunities at the national scale, the five most important industries are: (1) community, social and personal services; (2) finance, real estate and business services; (3) wholesale and retail trade – hotels and restaurants; (4) manufacturing; and (5) agriculture/forestry/fishing/hunting.

Table 6.19: Number of employees (thousands) and gross earnings (R million) by industry in 2005 – National Scale (Stats SA, Quarterly employment statistical release P0277.1)

	March	September
Community, social and personal services	1793	1821
Financial intermediation, insurance, real estate and business services	1449	1524
Wholesale and retail trade, repair of motor vehicle, motor cycles and personal household goods; hotels and restaurants	1347	1381
Manufacturing	1176	1189
Agriculture\forestry\fishing\hunting	1170	925
Mining and Quarrying	449	444
Construction	375	439
Transport, storage, communication	312	322
Electricity\gas\water supply	44	45

The data in Table 6.19 was then analyzed to show variation in job opportunities (availability) (Figure 6.6). The agricultural sector had the greatest variation in job availability between growing seasons, whereby jobs decreased by 245 (thousands). In the mining and quarrying sector jobs decreased by 5 (thousands). On the other hand jobs increased in the following sectors, as follows: electricity\gas\water supply (1); transport, storage, communication (10); manufacturing (13); community, social and personal services (28); wholesale and retail trade, repairs, hotels and restaurants (34); construction (64); financial intermediation, insurance, real estate, business services (75) (Figure 6.6).

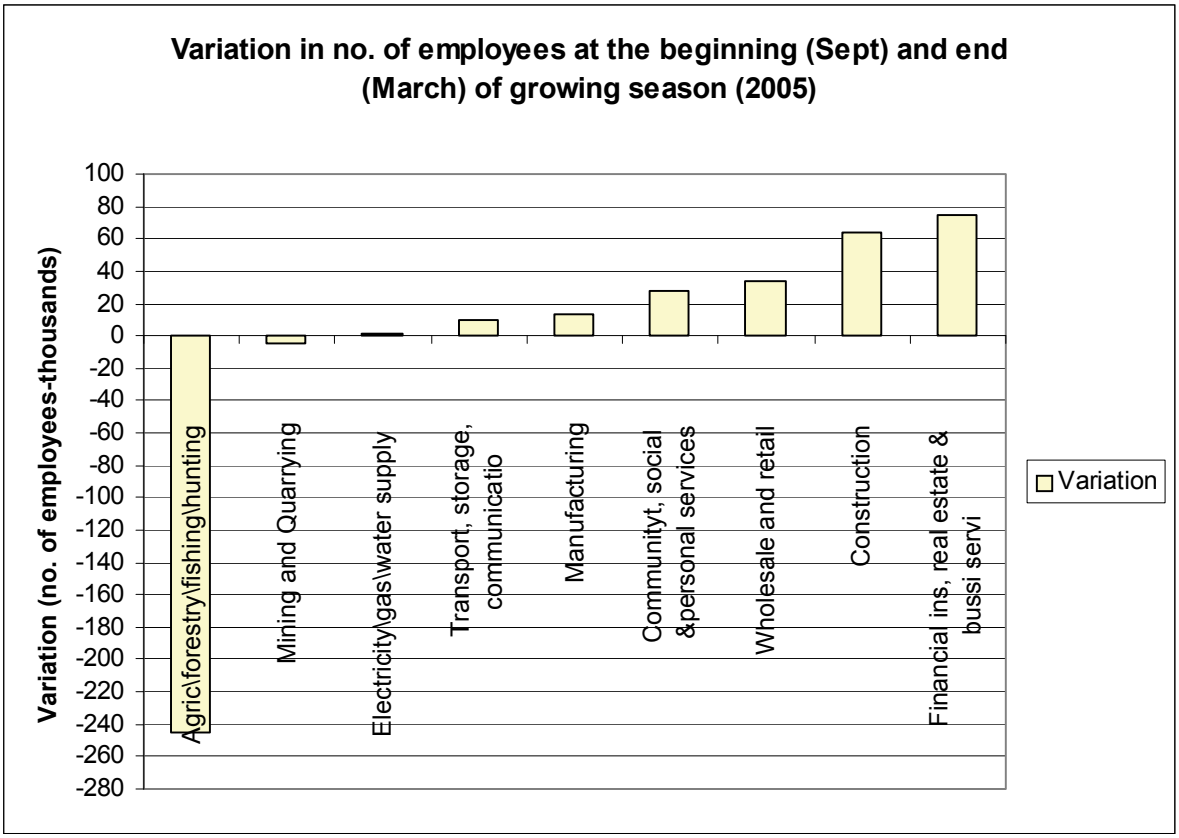


Figure 6.6: No. of employees by industry, 2005 (Source data: Statistics SA, Quarterly employment statistical release P0277.1)

The analysis (Figure 6.6) shows, that in the agriculture/forestry/fishing sector, at the national scale, many people (245 000) can only be assured of a job for six months in a year and thereafter they must find alternative means to supplement incomes needed to support livelihoods. Therefore, it is indeed desirable that industries in the non-agricultural sector of the economy be promoted to diversify sustainable livelihoods. Implications for the floodplain communities are, as shown in the results of the social survey in Chapter 7, that only a small proportion of the population have jobs as seasonal labourers on commercial irrigation farms owned by a few people and the majority have no jobs. For people with no jobs, the floodplain provides an alternative source of livelihood in terms of basic resources needed to sustain human life; food, water and materials for building shelters. Therefore, should the communities be denied access to the use of the floodplain resources without being provided with alternative sources of earning in the non-agricultural sector, many are likely to become more vulnerable to poverty.

To establish possible opportunities that can offer alternate employment, data from regional trends (2001-2005) were compared (Table 6.20). The agriculture/forestry/fishing sector ranked 4 out of 10 in terms of jobs offered on a regional scale, when compared to 5 out of 9 on the national scale. Overall, the three most important industries with more job opportunities in the non-agricultural business sector are: (1)

wholesale and retail trade; (2) community/ social/personal services; (3) manufacturing; (4) agriculture/forestry/fishing; and (5) private households.

Table 6.20: The employed (15-65 years) by main industry, 2001-2005 (thousands) (Statistics SA, 2006). *Due to small sample size, mining and quarrying estimates were excluded.

	MARCH					
	2001	2002	2003	2004	2005	Totals
Wholesale and retail trade	631	405	405	396	481	**2318**
Community/social/personal services	351	339	385	387	382	**1844**
Manufacturing	416	388	360	339	339	**1842**
Agriculture/forestry/fishing/hunting	341	248	207	239	242	**1277**
Private households	202	198	233	219	109	**961**
Financial insurance, real estate and business services	154	173	161	168	186	**842**
Transport, storage and communication	132	114	129	123	124	**622**
Construction	120	107	104	119	130	**580**
Electricity/gas/water supply	19	13	15	17	15	**79**
Mining and quarrying*	12					**12**
	SEPTEMBER					
	2001	**2002**	**2003**	**2004**	**2005**	**Totals**
Wholesale and retail trade	449	409	449	450	533	**2290**
Manufacturing	400	386	349	382	391	**1908**
Community/social/personal services	352	361	394	387	387	**1881**
Agriculture/forestry/fishing/hunting	165	333	239	209	209	**1155**
Private households	195	192	228	231	161	**1007**
Financial insurance, real estate and business services	187	162	182	161	186	**878**
Transport, storage and communication	125	128	115	130	140	**638**
Construction	105	108	116	120	139	**588**
Electricity/gas/water supply	19	17	21	14	21	**92**
Mining and quarrying*	0	0	0	0	0	0

Clearly the analyses above strongly supports the views of Backeberg and Odendaal (1998) that the agricultural sector must be supplemented by the development of a wide-ranging programme which not only develops agriculture but also improves skills to earn non-agricultural income through integrated development of the rural-urban link. From national and regional trends, it appears that the three most important industry sectors found to offer more job opportunities in the non-agricultural business sector and which should be considered for promoting in the study area are, in order of importance: the wholesale and retail trade; community/social/personal services; and manufacturing. Plans to promote such industries must be promoted, together with skills development strategies**.**

It must be noted that, although the agricultural, forestry and fishing sector is a primary industry and does not contribute as much to GDP when compared to finance, real estate, business services and manufacturing, it does provide jobs to many unskilled persons (farm labourers) while producing essential goods and services needed to sustain human life.

An interesting observation from the national accounting data is that, GDP trends (2001-2005) were declining in the agriculture/forestry/fishing sector, yet irrigation and commercial forestry were increasing (e.g. reduction in Pongolapoort Dam yield, section 4.5.1.1.5; increasing water abstraction trends, section 4.5.1.2; and expanding forestry, DWAF report on commercial timber resources 2001/2002; 2002/2003; 2003/2004). If we equate increasing water abstractions to increasing agricultural production, then why is the contribution to GDP declining? What is influencing this decline? Is the cause within irrigation, forestry or fishing? Is the decline due to economic dynamics, technical dynamics, social dynamics or ecological dynamics? It is important that the reasons for the distinct declining trend in contributions to GDP are investigated to determine the cause, so that measures can be put in place to ensure that sustainable production quantities are maintained (i.e. production that takes into account ecological, social and economic considerations).

Following is an account of the history of agricultural development interests in the area after the Pongolapoort Dam development and the subsequent planning and implementation of irrigation developments. Lessons from the history of agricultural development, in addition to the national accounting data above, fully support the views of Backeberg and Odendaal (1998), that profound poverty alleviation can only be achieved by diversifying the economy and enhancing skills.

6.4 THE HISTORY OF AGRICULTURAL DEVELOPMENT INTERESTS (PRE-1994)

6.4.1 Institutional arrangements on the Makhatini irrigation scheme

The following is a review of the agricultural development plan for the area since the early 1970s and is based on reports by (Van Rooyen, 1983; Bembridge, 1993; DoA, 1994; A'Bear and Louw, 1994) as well as other social and anthropology studies.

6.4.1.1 Farmer settlement on the Makhatini irrigation scheme

The Pongolapoort Dam was built between 1966 and 1972, with the intention of putting some 33 000 ha of sugarcane under irrigation on the Makhatini flats. Some water was also earmarked for irrigation use along the Mkuze River and Pongolo River.

In 1974, the original proposals for developing the dam and irrigation scheme was as a poverty upliftment scheme for white farmer settlement, and each farmer would be allocated a 20 ha plot. Implications for implementation meant that some 50 000 native inhabitants would have to be moved or displaced. The central government of RSA rejected this proposal and declared that the area east of the Ubombo mountain range, known as Maputaland, should remain a 'native area' and initiated new plans for the settlement of black farmers.

In 1977, the "Department of Native Affairs and Development" began plans for the settlement of black farmers after a feasibility study recommended that 28 000 ha of sugarcane be established, together with two sugar mills.

In 1978, the Department of Trade and Industry recommended that the development of the area under sugarcane be shelved due to a low world sugar price. New plans were then put in place for a mixed crop production programme; 15 800 ha and to utilize a canal design in this area to enable the production of sugarcane on some 13 000 ha, just in case sugarcane production became viable in the future.

In 1980, work on the scheme was discontinued through an order from Treasury due to lack of funds. The "Department of Co-operation and Development" through their agent "Corporation for Economic Development (CED) was then authorised to continue with the development and management of a much smaller project (3 000 ha).

In 1984, CED was disbanded and a new agent, the South African Development Trust Corporation (STK) was appointed to manage and implement the small project (3 000 ha) and begin the process of settling black farmers on the Makhatini Irrigation Scheme. The managing agent initiated the process by developing its own commercial farming interests first, on a 1 255 ha unit of estate-run cotton production. The agents argued that this was an important step because it would form a basis that could inform the development of small farming units for black farmers.

In 1985, 9 black farmers were settled on 5 ha plots during the cotton-growing season of 1985/86 (September-March).

In 1986, 37 black farmers were settled on 5 ha plots and another 47 farmers on 10 ha plots. In the two years from 1985 a total of 93 black farmers had been settled on 700 ha.

In 1987, 4 farmers were settled on 10 ha plots. New block 6A settled some 57 farmers on 598 ha.

In 1988, the Development Bank of South Africa (DBSA) financed the development and settlement of another new block, 6B. Settlement of 664 ha of the estate-run portion of the scheme (1255 ha) was settled to small farmers whereby the original settler holdings of 5 ha was expanded to 10 ha.

In 1994, the scheme comprised 5 pressurised irrigation blocks, each served by a separate pump station, flood irrigated paddies and vegetable lots. There were 259 registered irrigation plots with an average plot size of 10 ha. A total of 3 426 ha was under sprinkler irrigation from pump stations, out of which 2 788 ha was farmed by plot holders and 591 ha was the commercial section farmed by Mjindi Farming who also acted as managing agents for the whole scheme. Area farmed by non-commercial farmers was 33 ha. And 79 ha was paddy type flood irrigation for evaluation of rice cultivation.

6.4.1.2 The role played by the managing agent and other role players

The "Department of Co-operation and Development" changed to became the "Department of Development Aid" which provided short-term financing for farmers for 2 years from 1985/86 to 1986/87, after which STK took over this function and became the managing agent for the "Department of Development Aid" operating as Mjindi Farming Company (MFC). As a managing agent MFC was responsible for farmer settlement, services, and cropping units. Specifically, the functions of Mjindi Farming Company were: supply agricultural inputs to farmers; land preparation and harvesting services; pest control services; pressurised irrigation services to farmers; engineering and maintenance services; maintenance of underground irrigation equipment; pump stations and the comprehensive maintenance of own assets, namely commercial farming activities, crop processing and marketing services; extension service on the irrigation scheme and on "Trust Land" cotton areas in terms of dry land cotton; provision of training services at a fee in irrigation, pest control, chemical mixing and application, pest identification, budgets, community development services, and establishing the viability of new and alternative crops on trial/plot project basis.

In September, 1988 "KwaZulu Finance and Investment Corporation (KFC)" took over the production financing for small farmers. Up until the 1988/89 cotton season all actions and decisions with respect to land and crop production were carried out by Scheme Management, STK. KFC insisted that farmers should have some formal tenure (lease agreements) and that centralized scheme management decision making should cease.

In 1993, STK was phased out and Mjindi Farming Company (MFC) became a division of "Natal Trust Farms" but operated as separate companies. MFC was formed by an agreement reached between the Department of Agricultural Development, KFC and STK. Natal Trust Farms (NTF) (a subsidiary of KFC) were trustees of state land areas in KZN and oversaw development and maintenance of trust land. The goal of KFC was to develop commercial farming and to provide services to communal and other areas. KFC, NTF and MFC were parastatal organisations whose legal authority was the government.

Developing and implementing agricultural policy, such as research and extension services, is the responsibility of the Department of Agriculture. Other institutions involved were DWAF (develop and maintain main water supplies); cotton marketing companies; The Development Bank of South Africa (agricultural and rural development); The Industrial Development Corporation (IDC); private sector firms (Input supplies); and farmer associations (to provide a link between farmers and MFC and the DoA). Production inputs and commodities were obtained through MFC, Makhatini Farmers Co-operative and others.

In 1994 (post-apartheid era), the Republic of South Africa's trust lands (state lands) became the responsibility of the Department of Land Affairs who delegated responsibility of the majority of state lands in the area, including the Makhatini Irrigation Scheme, to the Department of Agriculture (DoA). The DoA appointed MFC to settle and develop farmers on the scheme.

6.4.1.3 Farmer selection criteria, land tenure, social infrastructure and transport:

The majority of communities in Maputaland are descended from the original inhabitants of the coastal plain, the Tembe-Thonga, a Tsonga-Shangaan speaking people (also known as Amathonga), whose distribution once extended from St. Lucia in the south to the Save River in the north (Levitas Ben, 1982; Torres, 1980). Early records show clearly that the Tembe-Thonga, an offshoot of the Karanga people, have been settled around Delagoa Bay for many centuries. Despite the political boundary, many people have maintained close contact with their kinsmen in southern Mozambique (Torres, 1980). The prevalence of nagana (sleeping sickness), caused by the tsetse fly, and malaria made the area unattractive to the Zulus and other colonial powers whose presence in the surrounding areas confined the Tembe-Thonga to the coastal plain where they have adapted to the physical environment in terms of their mode of subsistence agriculture (Poultney, 1980; Bruwer, Poultney and Nyati, 1996). They traditionally grew dry land crops with running cattle and goats and used floodplain and off-floodplain resources, crops, grazing and fishing (Bembridge, 1993).

Farming practice is synchronised with natural patterns of rainfall and happened off the floodplain on dry land during summer rains, as the floodplain was inundated with flood waters and could not be used for agriculture but was instead used as a fishery. During the dry season in winter and spring, floodplain soils retained adequate soil moisture to support crops and livestock grazing. This farming system was diversified and ensured food security throughout the year (Bruwer, Poultney and Nyati, 1996).

The Tembe-Thonga people have a strong clan structure (Poultney, 1980). Clan chiefs (Inkosi) usually appoint family members as district and sub-district headmen (*iziNduna*) who form the Tribal Authority (TA). This authority structure plays an important role in the lives of the people under their jurisdiction. In addition to being the most important judicial institution at the local level, they control access to natural resources such as land (Poultney, 1980).

The traditional authority system of land allocation is known as '*uku khonza*'. Settlers are introduced into the area by relatives or friends through this system, which means that the resident family stand security for the immigrant or settler family where they are obliged to abide by a code of conduct in the tribal authority ward in which they settle. In the second generation, after a period similar to that of probation, land allocated to the immigrant family can be inherited by the male heir in the immigrant or settled family (Bruwer, Poultney and Nyati, 1996).

The Tribal Authority (TA) did not recognise the fact that the lands had become state land because they continued to allocate land. This conflict of authority over land resources is a result of colonial rule, where colonial authority was imposed on traditional structures (Rubin and Weinstein, 1977). The problems of land tenure have persisted into post-colonial eras for many African countries that were colonised (Rubin and Weinstein, 1977; Toulmin and Quan, 2000). Today many African governments face the challenge of developing appropriate or best practice strategies (e.g. land reform) to address these problems, such as evolving new land rights, policy and tenure (Toulmin and Quan, 2000). In the Makhatini flats area, the TAs continued to allocate land based on Traditional Authority (TA) regulations and people's households are situated on state lands. Before the Pongolapoort Dam development, the availability of arable land

and grazing land attracted many settlers who brought their cattle with them. Allocation of arable dry land averaged 2-5 ha, with grazing land being available to all (communal) (Bembridge, 1991). Most people who moved into the area grew dry land crops, farmed cattle and goats using the floodplain and off-floodplain resources.

After the Pongolapoort Dam development and the subsequent development of the Makhatini irrigation scheme, land settlement on the irrigation scheme began in 1985.

An initial proposal of farmer selection criteria had been recommended based on nature conservation interests of the floodplain by biological researchers (Heeg and Breen, 1982). The criterion was that households who gave up land (on the floodplain) for the scheme would become eligible and would be given preference for irrigable land allocations. The aim of these nature conservation criteria for farmer selection was to enhance the conservation of natural resources on the floodplain and dry land areas by reducing over-exploitation of the natural resources by a growing human population.

However, during the implementation of farmer selection, the scheme-managing agents did not take into account the proposed nature conservation criteria for farmer selection. The selection committee was established by the scheme-managing agent and chaired by the "Department of Development Aid". Interested parties who got approval from the TAs and could prove KwaZulu-Natal citizenship and had some resources of their own were invited to apply. The applicants had to undergo a psychometric test to evaluate the skills needed to farm successfully. Farmer selection criteria, based on agricultural development management interests such as previous farming experience, meant that the majority of scheme participants (70%) were settlers who had come into the area from white farms in the Louwsburg/Ngotshe area adjacent to the Uphongolo municipality between 1976 and 1978 and had acquired some modern farming skills. Naturally, many local dry land farmers were excluded. Implied here is that nature conservation interests of the floodplain suggested by biological researchers, which had taken into consideration the interests of local farmers, never happened.

The nature of the land tenure system on the irrigation scheme that was implemented is a 20-year renewable lease agreement, which prevents farmers from physically settling on their irrigation stands. The impact of this arrangement is that poorly resourced farmers had to travel long distances (5-30 km on foot, bicycle, taxi or bus) in order to reach their lands and this had a negative influence on the management of their farming operations. Some farmers have made informal arrangements to use or lease land from inactive farmers. Some of the lessees came from as far afield as Nongoma and Johannesburg and were either sub-letting their land or using a surrogate to farm for them (A'Bear and Louw, 1994). This land tenure system means that land has no monetary value so cannot be used as collateral for credit. Many leases are due to expire in 2008. Therefore, mechanisms whereby market forces could effectively act as a sieve cannot happen. In the communal state lands adjacent to the scheme and those on the west side of the river, land tenure is an emotional issue and very much a political matter. For centuries the traditional authority leadership were the custodians of these lands with traditional property rights and ownership systems that have moral, social and legal concepts, which limit their use for economic value as local chiefs continue to control land allocations in these lands. Therefore, present land tenure arrangements on the trust land do not provide the necessary incentives and security for long term

improvements of agricultural production. This is a major constraint to future development of the scheme and the region as a whole (A'Bear and Louw, 1994).

Social infrastructure; six residential villages, schools, a clinic and purified water at standpipes were established by the state on the irrigation scheme for farmer settlement. However, pupils walk long distances to schools. Health and medical services are inadequate. These villages have grown to include people who are not irrigation farmers and problems exist relating to the cost of services, level of supply and land tenure (DoA, 1994).

Transport; the railway line is 40 km away at Mkuze and roads in and around the scheme are gravel. Potable water for domestic use is inadequately developed on the irrigation as well as the dry land areas.

6.4.1.4 Irrigation scheme operation

Irrigation water is distributed by a system of concrete canals, pump stations and pressure pipelines. The pressure provided is adequate for the direct connection of an overhead irrigation system. This is unlike most other government or irrigation schemes (Bembridge, 1993).

The DoA (1994) and A'Bear and Louw (1994) described the scheme operation process, summarized here, as follows: Farmers buy water from the managing agent. For a typical farmer, the travel distance to the MFC order point and the KFC office and back is some 30 km done on foot, bicycle and sometimes taxi or bus. Orders are placed on a weekly basis. All water order forms are given to the irrigation manager for deriving the required flows to be ordered from DWAF and supplied to each block. Control of actual irrigation taking place in the field is performed by water bailiffs. They unlock the hydrants of farmers who ordered water at the beginning of the irrigation period (Monday 07H00), inspect irrigation activities to ensure that farmers comply with the order that was placed (e.g. number of sprinklers used). When a farmer's water order has been met for the week, his hydrant is locked to prevent unauthorised use of water.

The fact that the scheme was converted to small-scale operation without modifying the designs is the greatest factor causing the various grievances between farmers and the managing agent. For example:

(i) A pump station supplies water to a group of farmers within a block. Farmers within a block do not always order the same quantities of water to be supplied at the same time. This theoretically means that the pump station may have to be started (switched on) for only one farmer, which is costly and inefficient.

(ii) Water payment is a constant cause of quarrels between the managing agent and farmers because farmers end up paying for water they did not order, because each farmer's water use is not monitored by a water flow meter. The managing agent also felt that farmers who did not order water can still tap illegally into the supply if they by-pass the locking device. This would force the agent to increase pressure by turning on another pump, which increases electricity costs. If pressure is not increased by turning on another pump, it causes farmers who ordered water to be under-supplied hence causing potential legal conflicts, since costs

can only be recovered from those who ordered. According to A'Bear and Louw (1994), installing water flow meters on each plot would only solve part of the problem because there would still be a need for central management to order water from DWAF and maintain central equipment, in addition to the fact that there would still be a need to re-design the scheme for small-scale operations.

6.4.2 Influence of land size and equipment use on economic feasibility

6.4.2.1 Land size and economic feasibility:

Studies by Van Rooyen (1983) and the DoA (1994) reported data, which showed the dynamics of the economic feasibility of a mixed crop production programme of cultivated crops (cotton, maize, dry beans, bananas and sugarcane) on the Makhatini irrigation scheme in the 1992/1993 season. Scenarios of possible profit margins attainable by farmers by varying cropping plans and plot size (ha) were explored (Table 6.21).

Variations of plot size consisted of plan **A** (20ha of cotton, maize and dry beans); plan **B** (20ha of cotton and maize); plan **C** (15ha of maize and cotton) and plan **D** (10ha of bananas and sugarcane). Average yields per crop per ha were used to calculate the total revenue (gross margin) obtained from each cropping plan per plot size.

Table 6.21: Cropping scenario plans based on average yields. Data for 1992/1993 season (Source: Directorate of Agricultural Economics in the DoA, 1994).**Banana establishment R10 872/ha @15.5% over 10 years = R2 207/annum. ***Sugar establishment R3 736/ha @ 15.5% over 10 years = R6 826/annum.

	A	B	C	D
Cotton (2 t/ha)	10 ha	10 ha	10 ha	
Maize (Green = 2.6 t/ha)	7 ha	10 ha	5 ha	
Dry Beans (1.2 t/ha)	3 ha			
Bananas (28 t/ha)				1 ha
Sugarcane (72 t/ha)				9 ha
Total	20 ha	20 ha	15 ha	10 ha
Crops per year	2	2	1.5	1.0
Gross Margins:				
Cotton @ R1 148/ha	11 480	11 480	11 480	
Maize @ R1 863/ha	13 041	18 630	9 315	
Dry Beans @ R550/ha	1 650			
Bananas @ R7 557/ha				7 557
Sugarcane @ R2 438/ha				21 942
Total Gross Margins	26 171	30 110	20 795	29 499
Less				
Rental @R120/ha	1 200	1 200	1 200	1 200
Water @ R500/ha	5 000	5 000	5 000	5 000
Other Overheads @ R200/ha	2 000	2 000	2 000	2 000
Total Overheads	8 200	8 200	8 200	8 200
Net Income before living and debt repayment	17 971	21 910	12 595	21 299
Less: Living expenses (say)	9 000	9 000	9 000	9 000
Available for debt repayment	8 971	12 910	3 595	12 299
Required for annual debt commitments (irrigation)	1 914	1 914	1 914	3 828
Required for annual debt commitments (banana establishment)**				2 207

Required for annual debt commitments (cane establishment)***				6 826
Available for arrear debt commitments	7 057	10 996	1 687	-562

Assumptions:

- Present scheme rentals are set at R120/ha.
- Water cost is set at a flat rate of R500/ha which is the negotiated flat rate for 1992/93 inflated by 11%.
- Other overheads set at R200/ha are considered to cover minimal sundry items such as vehicle costs, pipe repairs, administration, etc.
- Living expenses have been taken as R750/month for "Average" farmers.
- Amounts required for annual debt repayment under irrigation refer to a capital amount of R1 850/ha required to upgrade above ground equipment for the irrigation of sugar. This amount reflects in an annual debt repayment amount of R3 828 under column D.
- It has been assumed that half this amount will be required to renovate above ground irrigation sets on most farms for normal cropping. This is reflected as an annual debt repayment of R1 914 under columns A, B, C. There are farmers who do not require this renovation.
- In the four different cropping scenarios analysed, the assumption is made that the stand size is 10 ha and that farmers will be able to attain average yields. The gross margin for cotton, maize, dry beans, bananas and sugarcane was calculated separately taking into account the costs of seed, chemicals, mechanical operations, labour, etc. It is important to note that the high margin for maize is realized due to an assumed income combination of green cobs and dried maize.

The degree of profitability was determined by subtracting expenses from gross margin. The nature of expenses or costs incurred included: land rental/ha; water costs; overheads to cover sundry items such as vehicle costs, pipe repairs and administration, etc.; living expenses per month per farmer; upgrading above ground irrigation equipment of sugar; renovating above ground irrigation sets on most farms for normal cropping plans; and costs of seed, chemicals, mechanical operations, labour, etc.

Out of the four cropping scenario plans presented (**A, B, C and D**), scenario **C** represented the typical farmer situation as at 1992/1993.

Plan **A** and **B** were more profitable and were being executed by some scheme farmers, but according to economic dynamics, it was felt that increased adoption of either of these two cropping plans would effectively decrease local maize and bean prices to the extent that these two cropping options were likely to cease to be profitable. Cropping scenario **D,** comprising sugar and bananas, was not profitable due to the high establishment costs of sugarcane and the high transportation costs to mills 85 km away at Pongola town meant that sugarcane was not a viable crop choice, unless financial commitment could be obtained from the mill in terms of transport subsidisation (the budgeted figures on sugar represent a R33/ton transport cost). Bananas were suggested at 1 ha per farmer so as to attempt initially not to over-produce and negatively affect the national price of this supply sensitive crop.

6.4.2.2 Ability of farmers to repay debt

Because cropping scenario plan C represented the typical farmer situation, the ability of farmers to repay debt under scenario C was worked out (Table 6.22).

Table 6.22: Possible debt repayment period in years based on Cropping Scenario C (Average Yield) in Table 6.21. Source: After Directorate of Agricultural Economics DoA (1994).

Debt Range (Rands)	**Available Repayment =R168/ha/Annum**	
	Repayment Period in years	**Repayment Period in years**
	Including Interest @ 14.5%	**Excluding Interest**
1-500	4	3
501-1 000	14	6
1 001-1 500	Interest exceeds available funds	9
1 501-2 000	Interest exceeds available funds	12
2 001-2 500	Interest exceeds available funds	15
2 501-3 000	Interest exceeds available funds	18
3 001-3 500	Interest exceeds available funds	21
3 501-4 000	Interest exceeds available funds	24
4 001-4 500	Interest exceeds available funds	27
4 501-5 000	Interest exceeds available funds	30

An average yield would allow arrear debt repayment of R168/ha/year. For instance, for a debt range of R1-R500, a farmer would take 4 years to pay including interest at 14.5% or 3 years excluding interest. For a debt range of R1 001-R1 500, interest exceeds available funds, while repayment excluding interest is 9 years. Clearly, Plan C represented a gloomy picture with respect to financing for farmers! Indeed, the DoA (1994) reported that KFC would not refinance farmers who had not paid outstanding loans and had grouped farmers on the scheme into 3 categories (A, B, C). While category C was not entitled to any special financial facilities, category A and B were entitled to make cash draw downs, enjoy revolving credit facilities and maximum carry over debt of 21% for A and 6% for B. Yet category C represented the typical farmer situation. Based on these results it is no wonder that studies carried out by Bembridge (1991, 1993) to determine farmer characteristics on the scheme established that many farmers had failed to be successful on the scheme.

6.4.2.3 Irrigation efficiency can improve yields and economic returns

Van Rooyen (1983) and the DoA (1994) suggested that there was hope of improving the profitability of Plan C if farmers succeeded in producing maize crops at 8 t/ha. The question was, how could farmers manage this? Efficient irrigation of the farm can improve yields. Each of the irrigation plots used by farmers had been supplied with a full complement of pipes, valves, sprinklers, etc. to ensure efficient irrigation of the stand according to design parameters. However, a lot of pipes and sprinklers had since been lost or stolen and some farmers were unable to irrigate fully their plots. The wear on sprinkler nozzles results in a drop of operating pressure at the sprinklers, while simultaneously increasing flow through the nozzle. The effect is a reduced coefficient of uniformity, as the sprinklers do not operate

under design conditions. Inefficient irrigation leads to loss of income because crops grow unevenly and yields are lower (Van Rooyen, 1983; DoA, 1994). Replacement of worn or broken irrigation equipment is a regular maintenance item and should be budgeted for. Also, the correct model sprinklers, nozzles, etc. must be bought to ensure that the original design remains effective.

6.4.2.4 Profitability increases exponentially with increasing plot size

Data from Table 6.21 was then extrapolated and used to show how net income varies with utilization of available land (Table 6.23).

Table 6.23: Variation of income with use of available land. Cropping Scenario C used. The figures used were extrapolated from Table 6.21 and do not represent exact margins. The figures show that profitability increases exponentially with increased plot use. Source: After Directorate of Agricultural Economics (DoA,1994).

Stand size (ha)	Use	Gross Margin	Overheads*	Living Expenses**	Nett Income***	Nett Income/ha
10	50%	10 398	8 200	9 000	-6 802	-680
	75%	15 596	8 200	9 000	-1 604	-160
	100%	20 795	8 200	9 000	3 595	360
20	50%	20 795	15 400	9 000	-3 605	-180
	75%	31 193	15 400	9 000	6 793	340
	100%	41 590	15 400	9 000	17 190	860
30	50%	31 193	22 600	9 000	-407	-14
	75%	46 789	22 600	9 000	15 189	506
	100%	62 385	22 600	9 000	30 785	1 026

- *Overheads include land rental, flat rate water charge and other overheads at R2 000, R3 000 and R4 000 for 10, 20, 30 ha stands respectively.
- **Living expenses estimated at R9 000 per annum.
- ***Nett income after overheads and living expenses, before debt repayment.

It is clearly shown that profitability increases exponentially with increased plot utilization. Farmers who do not irrigate all 10 ha of their plots have an extreme burden to carry in terms of fixed costs and rent for each ha. Data also showed that a plot size of 20 or 30 ha could lead to reasonable incomes.

6.4.2.5 Operational costs of the managing agent and financial position of farmers:

Based on cash flow tables, the operational costs of the water supply section of Mjindi Farming were prepared by the Directorate of Irrigation Engineering at Silverton, Pretoria. The cash flow table showed that the operational costs for Mjindi Farming were found to be R1 825 000 for the 1992/1993 cotton season. The costs included water, power, overheads, labour, supervision, maintenance and management (but excluded costs of other functional divisions of Mjindi Farming). Another cash flow table of cultivation costs reflected the financial position of a 'representative farmer' throughout the season, using cropping plan C on a 10 ha plot, double cropping with maize and cotton. The table showed that the farmer's financial position was strongest directly after crop harvesting (March, June and July).

By 1993, the financial situation of scheme participants had deteriorated alarmingly, according to a report by DBSA, Reserve Bank (1993). Average farmer debt in terms of land rental and debt arrears at the end

of 1991 was R17 155. When the value of missing irrigation equipment (R5 895) and water costs was added, the average farmer debt rose to R31 158. Due to debt loads, only 65 farmers (25%) qualified for seasonal crop loans.

6.4.3 Comparison of expected and observed farmer performance

Using data from studies by Bembridge (1991, 1993), the actual farmer situation was compared with the expected farmer performance reported by the Directorate of Agricultural Economics (DoA, 1994). Analysis of farmer characteristics, with respect to cotton yields on the Makhatini Irrigation Scheme in 1988/1989 season, provided clarity on the limitations faced by farmers (Bembridge, 1993).

6.4.3.1 The recommended technology had not been fully adopted

The expected breakeven high technology yield of cotton production when recommended technology is applied, is about 2 000 Kg/ha and a potential of 3 000 Kg/ha. The actual crop yields produced by farmers was far lower (1 383 ± 591) than that expected, whereas dry land yields averaged 893 Kg/ha. Few farmers had a good knowledge of insect pests and did not scout regularly for pests.

6.4.3.2 Inappropriate land tenure system

Farmers did not live on their farms and could not adequately take care of many problems effectively. For example, poorly resourced farmers used bicycles, foot or bus to travel to their farms, some covering distances of >30 km/day. Land could not be used as security to obtain loans.

6.4.3.3 Inadequate agricultural extension services

Given that the farming labour was adequate, a strong and effective extension service could have easily overcome the limitations associated with literacy, such as technology uptake and general farm management training (calculating farming profit); and understanding their financial statements from KFC and the managing agent.

6.4.3.4 No incentive on financial returns

All farming decisions such as crop type and cropping programmes were made by the scheme management (MFC), while farmers provided the labour activities such as irrigation, weeding and harvesting. For example, the 1988/89 season showed that 2/3rds of cotton farmers were operating at a loss, with a gross income of R13 053 ± R6 817 on 10 ha plots and on properly managed plots, gross income was R14 541 in the 1991/92 season. The net income on a 10 ha cotton crop was only about R5000. Clearly, these observed values were far less than the expected values of production calculated by the Directorate of Agricultural Economics. This scenario did not provide a great incentive to farmers, and instead farmers tended to look to alternative economic activities as more profitable income sources, e.g. shops, taxis or work in Johannesburg, thus increasing the number of absentee farmers. Although the overall food

security position had improved in the area, especially during droughts, farmers with a high debt load perceived themselves as being worse off than before they started participating in the irrigation scheme.

6.4.3.5 Capacity building limitations relating to a rapid change in land holding

Capacity building limitations relating to a rapid change in land holding (from 2-5 ha to 10 ha): By 1994, many black farmers had failed. Only 30% of scheme participants (out of 259) had the necessary entrepreneurial ability to make a success of irrigation on their own (Bembridge, 1993). Farmer failure could not only be attributed to poor farmer selection, because local residents who were considered trainable by the management agents, had interest in farming, and some financial resources of their own were selected to participate in the scheme. However, these farmers found it difficult to adjust to such a rapid change in land holding and technology, in addition to the fact that they did not live on their lands, coupled with inappropriate irrigation design, and by 1990 many had failed. Clearly this showed that a 'person's proven ability to farm' as a selection criteria alone cannot determine success.

Worldwide experience had shown that, even if appropriate technology is provided and farmers live on their irrigation plots, it takes >10 years for large number of farmers in irrigation schemes to change from traditional farming practices to more modern, intensive farming techniques (Rogers and Svenning, 1969; Leagans, 1971; Chambers, 1981; Rogers and Kincaid, 1981; Rogers, 1983; Rogers and Kim, 1985; Underhill, 1984; Underhill, 1990; Bembridge, 1990). Bembridge (1993) suggested that innovations, such as the Makhatini irrigation scheme, should have an adoption span of up to 20 years. Based on management literature defining theoretical framework underpinning change, transformation and capacity building in individuals and institutional organisations (Senge et al., 1999), the views of Bembridge (1993) are highly supported. Effective, profound change in farming practice, on both irrigated and dry land, may take more than 20 years, when one takes into account social and economic influences of the apartheid past (pre-1994) coupled with the amount of effort needed to streamline structural and organisational learning challenges (Senge et al., 1999; Breen et al*.,* 2004). To overcome learning issues, a capacity building strategy must be put in place, supported by good leadership and resources for implementation.

6.4.4 Assessment of farming community perceptions and needs

By 1994, many black farmers had failed. Agricultural economic studies (Van Rooyen, 1983 and DoA, 1994) reported that farmer failure was linked to:

(i) inefficient irrigation application which reduced yields,
(ii) inadequate average plot size of 10 ha which was unprofitable, leading to,
(iii) an inability to meet loan repayments which was made worse by,
(iv) high interest rates leading to,
(v) farmers not getting refinanced due to lack of payment of outstanding loans.

Studies of farmer characteristics by Bembridge (1991, 1993) reported that observed farmer failure could be attributed to the following limitations:

(i) Inadequate adoption of recommended technology, leading to low yields,
(ii) An inappropriate land tenure system,
(iii) Inadequate agricultural extension services,
(iv) No incentive on financial returns,
(v) Capacity building limitations regarding a rapid change in land holding (from <2-5 ha to 10 ha).

What was missing from these analyses was how the farming community themselves perceived the problems. On the basis of a review of reports from workshops carried out by Bembridge (1991, 1993) and A'Bear and Louw (1994) the farming community perceptions were categorised into the following groups:

(i) Farmer perceptions of the irrigation scheme operation and management,
(ii) Farmer perceptions of dry land resource issues,
(iii) Irrigation scheme managing agent perceptions.

6.4.4.1 Farming perceptions

6.4.4.1.1 Farmer perceptions of the irrigation scheme operation and management

Assessment of farmer perceptions and concerns revealed a lack of interest and commitment towards the scheme due to lack of profitability resulting from high debt loads. Farmers felt that many of reasons that contributed to a lack of profitability were factors beyond their control. For example, there was only one source of farming credit (KFC). KFC and MFC did not ensure that farmers understood the terms of loans. Credit could not be obtained until the crop was 'knee high'. Loans took too long to process due to lack of collateral security, hence the requirement that a crop must be 'knee high' before loans were approved. Farmers argued that this requirement was ridiculous because money is required for initial inputs. Since land tenure was rental, it could not serve as collateral security for loans. Farmers perceived the period of financing to be too short and hail and drought conditions were not considered in terms of extending loan repayments. In addition to the fact that a large amount of irrigation equipment had been stolen, farmers were unhappy with the operation and efficiency of water distribution and management by MFC and raised a number of operational problems which can be linked to user needs, user participation, plot size, land tenure arrangement, cropping programmes and acceptable user rules scheme design. Specifically, farmers perceived that inefficient water distribution was due to a lack of flow meters to measure actual amounts used by an individual farmer, locking of taps, broken pipes, and high charges and not being able to obtain water when it was required. Farmers complained about the high costs of draught power for land preparation, aerial spraying of cotton and that there was no follow-up to ensure that the work had been done properly. Even on dry land plots draught power was a problem because oxen were often in poor condition when required for ploughing. Cotton farmers perceived the price to be too low, yet labour was very high and felt that there was only one marketing outlet for cotton and no formal marketing outlet for other crops and vegetables. Farmers wanted improved local markets where they could get a better deal for crops, vegetables and livestock (e.g. local processing on a co-operative basis).

6.4.4.1.2 Farmer perceptions of dry land resources

Farmers felt that dry land agriculture had been ignored, yet resources from dry land could be used to support irrigation activities, e.g. sales from livestock. The economy of the adjoining dry land area was based on cattle, goats, dry land cotton and drought resistant food crops. Cash income from agriculture in dry land systems was very low (Bembridge, 1991, 1993), with major part of household income derived from wages, pensions and other non-farming sources. Outputs from livestock in the area were low in terms of meat, milk and traditional uses of draught power and manure. Oxen were often in poor condition when required for ploughing. Livestock outputs were low due to over-stocking and the lack of application of veld management practices and principles (Bembridge, 1994). Deterioration of natural grazing areas occurred because the application of grazing management principles, including realistic stocking rates, was not compatible with attitudes of farmers towards livestock production. Constraints to livestock production are inter related by cause and effect relationships and constitute a system by which change in one element requires changes in other elements to achieve a stable farming system. Such constraints can be overcome by adequate institutional support, including improved technology development, local leadership and extension programmes.

6.4.4.1.3 Management agent perceptions

On the other hand, the concerns and point of view of the irrigation scheme management agent was that the reason why pump meters were not working was due to a lot of dirt in the water; many limitations were the result of scheme design that had been intended for large scale (estate-run) mono-culture, high technology systems. There was a lack of organisation and collaboration between cropping systems. Farmers did not understand the concept of water flow and pressure. The fact that farmers were not living on the scheme meant that communication with farmers was difficult.

6.4.4.2 The farming community interest groups

The interested parties identified had polarized views, such that farmer selection, according to any criteria, was bound to directly conflict with one or another set of vested interests. Broad categories of interest groups derived from these perceptions can be grouped into the following categories:

(i) Managing agent interests vs. farming community interests,
(ii) Land tenure interests between TAs and National Government,
(iii) Interest groups based on rich farmers vs. poor farmers.

6.4.4.2.1 The interest in a new irrigation design system

There was interest in the need for a new irrigation scheme design that allows for flexibility of use, for example mixed cropping, reduced water costs and enhanced water availability and flexibility of use, instead of the present scheme design intended for an estate-run mono-culture high technology system. Financial viability for farmers and the management agent was imperative because government subsidization would not be available in perpetuity. The overall objective of the irrigation scheme, and

hence that of the management agent, was realising profit on a per plot/farmer basis. To achieve this objective requires a scheme design system and a management structure with real financial accountability for profits and losses on individual plots. The management structure in place had concerns for, profits and losses on individual plots, but with little real financial accountability. On the other hand, farmers had real accountability for their profit and loss situation but no control over costs incurred in the management of the scheme. Hence, many poor farmers had failed, there were many absent farmers being tolerated on the scheme, management was blaming farmers and farmers were blaming management and the relevant authorities were not urgently addressing conditions pertaining to the financial viability of the scheme.

6.4.4.2.2 Land tenure interests between TAs and National Government

TAs were unwilling to move towards free-hold land tenure due to traditional beliefs. TAs argued that their communities are built on the shared ownership of land, and traditional leadership plays a role in their administration by allocating land to each of its members to meet his or her needs. That access to land ownership is not merely a property right, but a fundamental human right. That shared ownership of land is at the basis of a sense of human community embodied in the traditional social culture of '*Ubuntu*' and solidarity. A community and its land are united by a mystical relationship which ties together past, present and future generations and that traditional leadership is the final expression and custodian of this relationship (extracts from various speeches made to the Parliamentary Portfolio Committee of Land Affairs by Members of Parliament from KZN who are also Traditional Leaders, Chiefs or *Inkosi*).

The national government wanted to move towards ensuring security of land tenure so that land could operate as a market, enhance agricultural production and create jobs. Government's view was that the area should be developed for commercial farming operations and because it is an area where local black farmers were disadvantaged in so many other areas, due to apartheid policies, they could be offered the opportunity to become successful commercial farmers. Stress on the need to implement democratic strategies meant that the majority of farmer demands would have to be addressed by subsidization at tax payers' expense.

TAs feared that operating a land tenure system through a land market and the application of financial disciplines (e.g. shutting out poor farmers who default on loan repayments before ensuring that adequate capacity had been built into the local black farming community), would not achieve government's goal of providing opportunities to local black farmers to become successful commercial farmers. Settler farmers with capacity, ability and experience would take everything at the expense of local black farmers, thereby enhancing the status quo. TAs wanted appropriate land policies to be put in place to protect the interests of local black farmers.

6.4.4.2.3 Interest groups based on rich farmers vs. poor farmers

According to A'Bear and Louw (1994), the farming social structure had already split along the lines of 'poor farmers' and 'rich farmers' and this was clearly seen in the various farmer associations that had formed. For example: Makhatini Agricultural Producers' Union (MAPU) was made up of farmers that are more successful. MAPU was a commodity union concerned with promoting agricultural marketing

among members and other farmers. According to MAPU, free operations of markets principles were the only way to arrive at the goal of independent and stable producers. MAPU recognised that under the present scheme design, water would never be available to farmers on tap, as and when they needed it. MAPU wanted the scheme to be converted to bulk water supply to enhance water availability, reduce water costs and flexibility of use for a mix of crops, each with its own water requirements and management schedules. Ubombo District Farmers' Union (UDFU) was seeking to foster support for institutional and policy change with respect to the way the scheme was run. Makhatini Agricultural Advisory Committee (MAAC) represented the interests of TAs that lay claim to land on the Makhatini flats. MAAC operated in the Ubombo district and tended to be made up of less successful farmers with high accumulated debts, contributing to anxiety and uncertainty because they could not see their way clear to continuing their farming operations and consequently feared the loss of their land on the irrigation scheme.

6.4.4.3 Farming needs

Based on results from studies looking at institutional arrangements for the scheme, expected farmer performance, observed farmer performance, farmer perceptions and categories of interest groups, farming community needs were then derived. Bembridge (1991) summarized farmer perceptions and needs (Table 6.24).

Table 6.24: Farmer needs as at 1994 (Bembridge, 1993)

1) Irrigation farmer needs	**2) Dry land farmer needs**
A moratorium on outstanding loans	Water for irrigation
Markets for crops and vegetables	Water for livestock
Additional sources of credit	Camps for cattle
Farmer control of irrigation services	Farm inputs at lower prices
More food plots for women	Draught power
Improved extension services	Credit
Integrate cattle into the scheme	Extension services
Improve cattle marketing	
Hail Insurance	
3) Non-farm needs	**4) Community needs**
Domestic water supply	Job creation
Improved roads	Skills training
Clinics	Pre-school crèches
Electricity	Youth programmes
Schools	Shops
Telephones	Transport services
Low interest loans for home industries	

6.4.5 Policy statements required to address needs

Results from studies looking at institutional arrangements for the scheme, expected farmer performance, observed farmer performance, farmer perceptions and categories of interest groups and farming community needs, it was clear that the irrigation scheme had not come up to original expectations in terms of enabling local black farmers to be successful in terms of economic returns.

Key recommendations coming out of these studies were:

(i) Implement an integrated approach to rural development (Bembridge, 1993),

(ii) Initiate farming systems research and adaptive on-farm research so that farming systems for both dry land and irrigation farming can be improved, including the integration of livestock into the farming system (Bembridge, 1993),

(iii) Provide institutional support for escalating farmer debt due to high interests, hail damage and droughts (Bembridge, 1993),

(iv) Give land title and priority to present owners to acquire a piece of land which they occupy (Bembridge, 1993),

(v) The land tenure system should permit access to holdings of various sizes >20 ha to enable adequate profit and improve farmer incentives to continue farming (Van Rooyen, 1983; DoA, 1994),

(vi) Women food plots should became 1 ha instead of 0.1 ha so that they could be used for household food security as well as generating income (Bembridge, 1993). Bembridge (1991) had found that women participants with 0.1 ha plots preferred to sell vegetables to buy groceries than to use them for the household,

(vii) Farmers were the most important element in the whole scheme and must derive benefits from the scheme. Farmers' demands for participation in the management of the scheme were justified but required extensive training through an effective extension service. Government must be willing to invest in building farmer skills and capacity. This was part of investing in human capital and it would enhance scheme profitability, as the scheme costs of management would be greatly reduced (Bembridge, 1993). Costs would be saved in: mobilization of local human resources, improvement of maintenance activities, reduction of irrigation scheme staff, less loss and damage of equipment, improved resolution of disputes, and enhancing the provision of an organised means of extension and farmer training (Lowdermill, 1986; Underhill, 1990; Bembridge, 1993). Indeed, a report by DBSA, Reserve Bank (1993) had pointed to duplication in actions and services,

(viii) Farmer's participation in the scheme should take the form of "Irrigator Associations". Irrigator associations can be established and organised on a "Bock" or "Pump Station" basis to facilitate improved working relations with the managing agent (Bembridge, 1993),

(ix) Dry land Farmer Associations would form "extension committees" made up of farmers and extension staff to jointly set up objectives and implement extension programmes, participate

in development of suitable technology and farming systems, organise necessary services and farming inputs to support extension programmes (Bembridge, 1993).

This knowledge was then used to inform the development of a mission statement to guide the development of an overall agricultural development strategy, including an operational strategy for extension services to address these problems, improve the successful operation of the scheme and enhance production to full potential through an expansion programme of the Makhatini state land extension unit (Cedara Agricultural Development Institute, 1993).

The overall mission statement, which should be implemented in all the sub-systems through goals and objectives, was to foster an appropriate, economically viable and environmentally responsible irrigated and dry land agriculture, food production and rural development system for the Makhatini area aimed at improving the quality of life (Bembridge, 1993).

6.5 THE HISTORY OF AGRICULTURAL DEVELOPMENT INTERESTS (POST-1994)

6.5.1 Makhatini flats agricultural development plan (2002)

In 2002, the Department of Agriculture and Environmental Affairs – KZN rolled out its agricultural development plan for the Makhatini flats, known as 'the green revolution' (DAEA, 2002).

The plan is underpinned by a principle, which states that if all high potential agricultural land in KZN were to be farmed to the intensity it is farmed in the existing commercial sector, overall agricultural production could quadruple over the next 20-year period. For example, land with potential for irrigation development on the Makhatini Flats area is 106 000 ha. Out of this total area the Makhatini irrigation scheme comprised 11 200 ha and only 3 900 ha was under irrigation in 2002.

The agricultural development plan would be implemented through the following means:

(i) *Land redistribution for agricultural development (LRAD) policy framework*: (see summary of details in (Table 6.25). The programme caters for projects such as food safety net or security, equity schemes, production for markets and agriculture in communal areas. The intentions of the programme were to settle new farmers on state owned lands and create a new category of commercial farmers from the previously disadvantaged sectors. Such farmers would also be settled on existing commercial farmland on the willing seller, willing buyer basis.

(ii) *Intensification of production aimed at commercial and non-commercial areas,* e.g. small-scale sugar and timber operations in traditionally settled districts to be meshed with large-scale milling and provide a significant throughput for mutual benefit. Cluster development would be sought wherever possible.

(iii) *Development of agri-industries*: such as sugar, timber, tea, cashew nuts and cotton; plant processing for extraction of essential oils used in soaps and perfumes; cut flowers; and bio-diesel.

Table 6.25: Key features of the LRAD policy framework (LRAD – DoA, 2000).

The land **reform policy** has 3 components: restitution, tenure reform and redistribution programme. Within the redistribution programme, there are three components (i) redistribution for agricultural development – LRAD, (ii) redistribution for settlement (iii) redistribution for non-agricultural enterprises, e.g. eco-tourism projects.

The **goal** of the LRAD programme is to distribute 30% of land in the country over a period of 15 years. The aims of LRAD are: improve nutrition and incomes of rural poor who want to farm on any scale, de-congesting overcrowded former black homeland areas, and expand opportunities for women and young people who stay in rural areas. The objective is to empower beneficiaries to improve their economic and social wellbeing and promote environmental sustainability of land and other natural resources.

The **principles** that underpin these LRAD aims are that:

- conditions are flexible and beneficiaries define the project type and size according to their objectives,
- projects must be aligned to district Spatial Development Initiatives (SDI),
- beneficiaries make contributions in cash or kind according to their abilities,
- beneficiaries can access a range of cash grants depending on the amount of their own contribution in kind, labour and cash,
- beneficiaries must provide an own contribution of at least R5000. The grant and own contribution are calculated on a per individual basis, or people can apply as groups,
- women can apply for grants to acquire land individually or as groups and women – only projects are promoted because not less than a third of land must accrue to women,
- grant approvals are based on proposed project viability. Viability calculation takes into account total project costs and projected profitability,
- implementation is decentralized but ensuring inter-departmental collaboration at all spheres of government; local government plays a key role,
- district staff assist applicants but do not approve the application,
- ex-post audits and monitoring will substitute a lengthy ex-ante approval process,
- generally the mode of implementation is adopted in the interest of maximum participation of beneficiaries, speed of approval and quality of outcomes,
- acquisition of land by absentee owners for speculative purposes is not supported. People must be willing to live on or near the land and operate or work on it. People must be willing to purchase or lease land for agricultural activities,
- politicians and civil servants are not eligible for the grant,
- existing land holdings cannot be counted towards one's own contribution requirements,
- professional developers, land owners, communities, or individuals can initiate actions on their own, e.g. sub-divide, establish basic infrastructure and then sell to beneficiaries under LRAD,
- permission is not needed to sub-divide land under LRAD. But permission is required only if the land is to be re-zoned for agricultural use, i.e. from commercial or forestry or eco-tourism zones to agricultural zones,
- beneficiaries may choose to access land under forms of contract, e.g. lease contract with an option to buy at a later date,
- beneficiaries may choose to accept the assistance of a design agent. Payments to design agents, valuers and associated expenses with subdivision is taken out of a separate planning grant which is a maximum of 15% of the projected total capital costs of the project which are processed through banking institutions,
- project design may have unintended or unforeseen environmental impacts, e.g. irrigation from surface sources, therefore projects should undergo an environmental impact assessment.

LRAD **project types** are:

Food safety net projects – intended for poor families who can only mobilize a minimum contribution in cash, labour and materials.

Equity schemes – participants receive equity in an agricultural enterprise. The grant recipient is both a co-owner

and employee of the farm. The grant is intended for people actively and directly involved in agriculture.

Productions for markets – these farmers enter LRAD to engage in commercial agricultural activities. These farmers have more farming experience and expertise than those accessing land for subsistence or food safety net type activities. They access the grant and combine it with normal bank loans to purchase a farm.

Agriculture in communal areas – many people living in communal areas already have secure access to agricultural land, but may not have the means to make productive use of that land. Such people would be eligible to apply for assistance so as to make productive investments in their land such as infrastructure, or land improvements. These projects may take on the character of food safety net projects or may be commercially oriented.

The agricultural development plan intended to unleash the agricultural potential of the Makhatini Flats would be implemented in three phases (Table 6.26).

Table 6.26: Agricultural development objectives (DAEA Makhatini development plan, 2002)

Development phase	Objectives
Phase 1 Target the irrigated area using the following objectives	Plan expansion of the irrigation scheme, Maximise economic activity on the irrigated area, Advertise for a vegetable market to be located locally, Supply agricultural services to farmers on a cost basis, Lease and sell land via the LRAD programme, Restructure Mjindi Farming, Investigate partnerships for development.
Phase 2 Target the dry land part of the scheme using the following objectives:	Establish land rights for people living on the dry land area of the scheme, Determine the extent to which the scheme can be expanded, Design and expand the scheme, Advertise and dispose of plots of non-irrigable portions of expanded scheme to farmers.
Phase 3 Target the wider Makhatini Flats area using the following objectives:	Establish land rights for people living on the Makhatini state land, Survey state land using tribal boundaries and facilitate development within the surveyed area, Dispose of state land as development occurs.

6.5.2 Institutional arrangements for the agricultural development plan

According to the DAEA Makhatini development plan (2002), the following institutions will play a key role in the development plans.

The KwaZulu-Natal Development Trust (KZNDT) was established with the objective of facilitating the green revolution development in the area and to serve as a reliable channel for donor funding and the private sector to buy into the green revolution and for the private sector companies to earn profits from it. KZNDT considers projects for viability and sustainability to ensure that poorly managed development does not happen (unviable and unsustainable projects). KZNDT is a tripod mechanism made up of a partnership between the public sector (KZN DAEA), the private sector, through KZNDT, and farmers, through the KwaZulu-Natal Agricultural Development Forum (KZNADF). Management consultants, Deloitte and Touche, manage KZNDT and the company, Price Waterhouse Coopers, audits its accounts. KZNDT assists investors in accessing financial support from various donors. Investors apply with a business plan. Viability of the project is assessed. When the project is approved, a project champion

selected from the trustees is nominated. Funds are then deposited into the account of the organization that requested the funding.

The KwaZulu-Natal Agricultural Development Forum (KZNADF) is made up of farmers. It promotes the goals and the strategies of the DAEA by providing a means of communication between the DAEA, private sector and farmers. The forum promotes effective service delivery to farmers, e.g. when government wishes to raise service levels and keep costs within acceptable limits, and facilitate government's need to create economic growth in an efficient manner with consequent spin-offs of skills development and employment creation. Periodic meetings are held with stakeholders and training and focus group discussions take place.

Other organizations involved in supporting agricultural investment schemes are:

Department of Trade and Industry (DTI); Industrial Development Corporation (IDC); Foreign Investment Grant (FIG); Critical Infrastructure Programme; Export Marketing and Investment Assistance Schemes; Agro-Scheme; Small-Medium Manufacturing Development Programme; The Land Bank (provides a range of products to support the LRAD programme); Plant and Equipment Finance; Working Capital Finance; Agri-Business Division (Ithala Bank).

6.5.3 Implementation of the DoA green revolution plan

In 2002, the green revolution plan of the DoA was first implemented through a cotton investment company (Http://www.makcotton.co.za). According to the information obtained from the website, the cotton investment company is a black economic empowerment firm with a 65% black empowerment shareholding. The project has, since 2002, injected millions of Rands into an impoverished region, the Makhatini Flats, and created small medium enterprises (SMMs) and several thousand seasonal jobs, plus major opportunities as out growers for small farmers. Its vision is to stimulate rural development and reduce poverty on the Makhatini Flats by creating a world-class agribusiness through establishment of a cotton ginnery and other process industries in the heart of the area, and to attract investment in agricultural infrastructure and support services for smallholder farmers. For example, by 2002, the company had invested R50 million in a cotton ginnery in the heart of the area.

The investment company formed another company as its wholly owned subsidiary called Makhatini Cotton Farming (MCF). Its vision is to develop small farmers and the surrounding community by installing an irrigation scheme which will strive to maintain the highest possible returns and competitiveness through innovative planning and management of all resources available to it, with due care for the environment. MCF successfully negotiated with the government to lease 15 000 ha of state land on the Makhatini Flats and, in 2006, had obtained water rights for 4 000 ha. MCF had invested over R30 million in agricultural infrastructure, including pump stations, underground piping, overhead irrigation such as centre pivots and sprinklers. As at the end of 2004, 1 500 ha of land had been developed under irrigation. Additional loans had been obtained to develop up to 7 500 ha of previously under-utilised lands.

The overall land use plan of the Makhatini irrigation scheme is shown in Figure 6.7. Previously under-utilised lands that have been developed for cotton expansion are also shown.

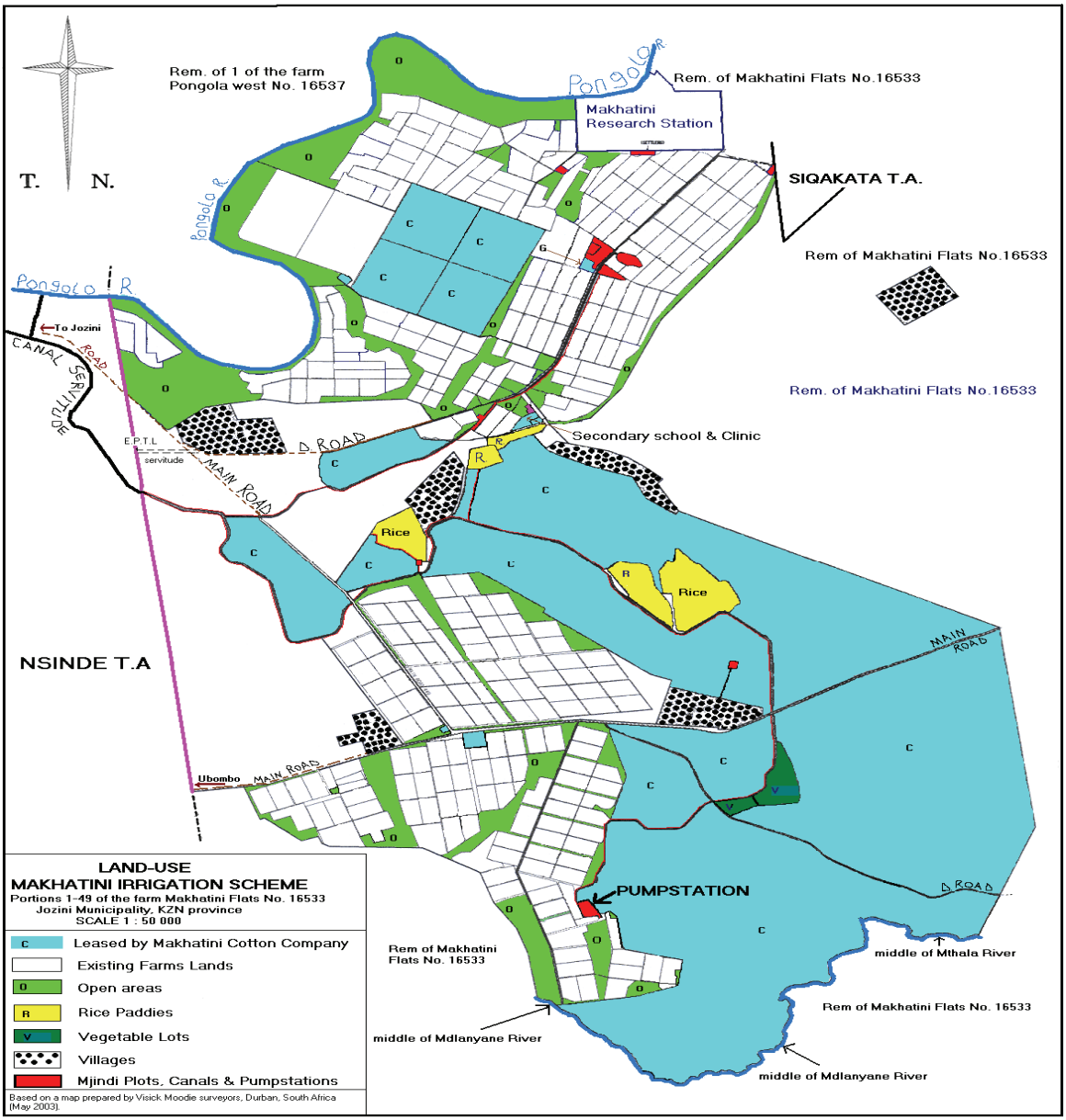


Figure 6.7: Land use plan of Makhatini Irrigation Scheme (11200 ha).

Currently 3 900 ha is under irrigation (276 plots). Potential for expansion exists (7 200 ha). Expansion is being undertaken by Makhatini Cotton Company who has built a cotton gin on site (G). There are also plans to build a sugar mill on site when the current area under sugar can justify construction of a mill. The scheme is managed by Mjindi Farming Company who is the service provider. They manage canals, pump stations and water delivery from the dam.

The total number of beneficiaries on the developed lands is 93 (Block No. 6 – 32 beneficiaries and first crop was due in 2003; Block No. 7 – 25 beneficiaries and first crop was due in 2005; Block No. 8 – 36 beneficiaries and first crop was due in 2005). See more details in (Table 6.27). Partnerships with food and seed companies have demonstrated the potential of dual cropping in the area and have broadened the commodity base to provide choice to farmers. It is envisaged that 20% of available lands could be utilised for food security during the winter season (wheat, maize and potatoes) (Http://www.makcotton.co.za).

Table 6.27: Trends in farmer settlement – cotton farming expansion Cotton season 2005 (Source: Http://www.makcotton.co.za)

Settlements	Remarks
Makhatini Cotton Farming (Pty) Ltd, successfully negotiated with the government to lease 15 000 ha of state land on the Makhatini Flats and obtained water rights for 4 000 ha. **Developed Lands***:* Block 6: Dedicated pump house built in 2003. Source of water – Mjindi Farming canal. 187 ha developed under centre pivot. 73 ha under pipes and sprinklers. First irrigated cotton crop 2003. No of beneficiaries in Trust – 32. Block 7**:** Extension to Block 6 pump house built in 2004. Source of water – Mjindi Farming Scheme Canal. 104 ha developed under centre pivot. 79 ha under pipes and sprinklers. First irrigated cotton crop due 2005. No of beneficiaries in Trust – 25. Block 8**:** Dedicated pump house built in 2004. Source of water – Mjindi Farming canal. 188 ha developed under centre pivot. 30 ha under pipes and sprinklers. First irrigated cotton crop due 2005. No of beneficiaries in Trust – 36. **Block 10and11** (Http://www.makcotton.co.za)	The Development Model of Makhatini Cotton (Pty) Ltd: The preferred ownership transfer model for each farm (typical size over 200 ha) is to form a limited company with a 51%-49% shareholding between Makhatini Cotton Farming and a Trust representing the local community in each area. All shares are transferable to the Trust once the investment has been repaid. The finance to pay for irrigational infrastructure will come from the Land Bank who will lend the money to the farming company. Makhatini Cotton Farming provides the leases and water rights as well as operational and management expertise to farm the land. Government grants will be used to train farmers

Location of the agricultural developments and expansion plan can be seen in Fig 6.8. The figure shows lands already developed on the Makhatini irrigation scheme and land to be developed situated in the north of the Makhatini irrigation scheme.

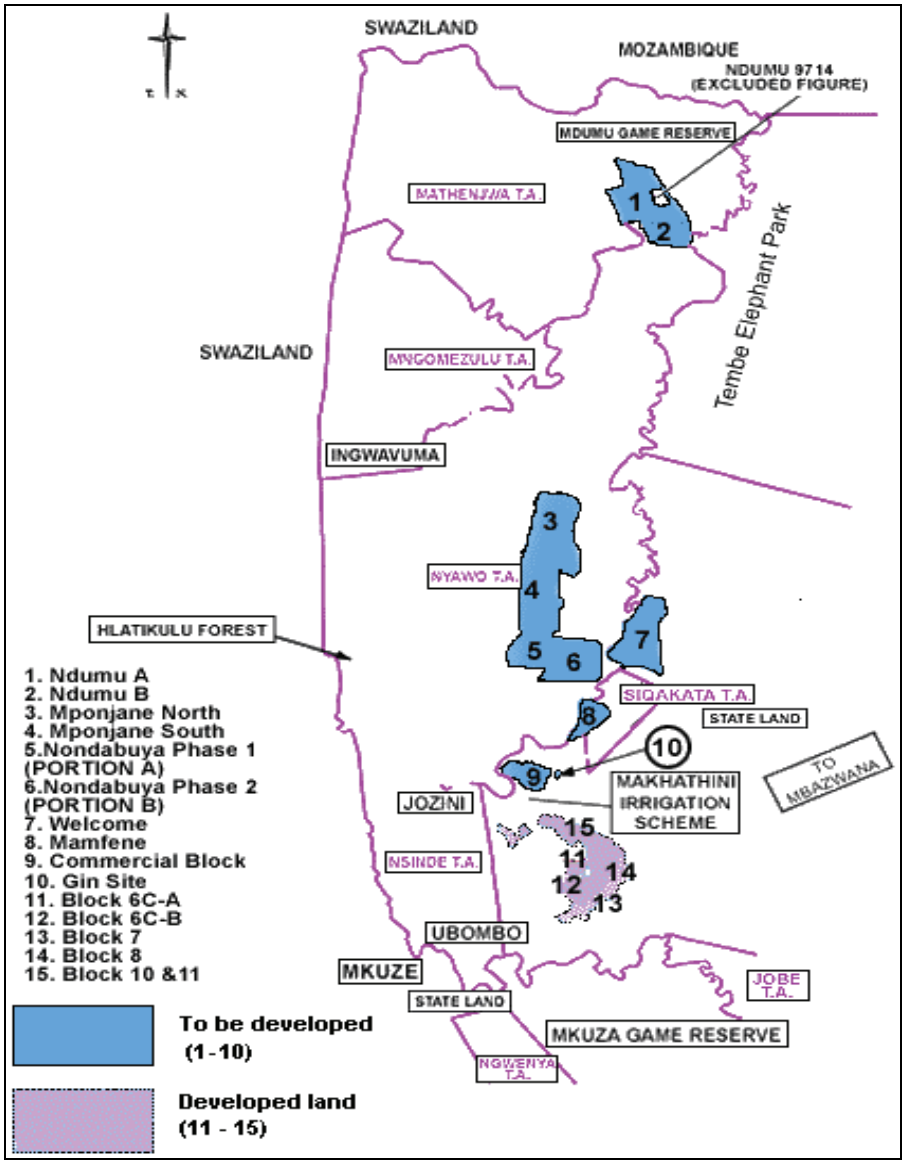


Figure 6.8: Agricultural irrigation development plans – cotton farming on the Makhatini Flats. Total area to be developed – 15 000 ha. (Source: Web site, January 2006, Http://www.makcotton.co.za).

6.5.3.1 The cotton investment company development model

The preferred ownership transfer model for each farm (typical size over 200 ha) is to form a limited company with a 51%-49% shareholding between Makhatini Cotton Farming (MCF) and a Trust representing the local community in each area. All shares are transferable to the Trust once the investment has been repaid. The finance to pay for irrigational infrastructure will come from the Land Bank who will lend the money to the farming company. Makhatini Cotton Farming (MCF) provides the leases and water rights as well as operational and management expertise to farm the land. Government grants will be used to train farmers in all aspects of commercial farming, including pump house and pivot/sprinkler maintenance, land preparation methods, creating crop budgets, tracking expenditures, and marketing in order to maximise the returns from a world-class irrigational infrastructure.

6.5.4 Opportunities:

The current state, as at 2002, in terms of irrigation infrastructure: pump stations (5), canals (32 km), pipelines (550 km), roads (25 km) and flow meters (290 meters). The current state as at 2002 in terms of production: sugarcane delivered to Pongola mill (1 500 ha); cotton delivered to new R100 million gin on site, owned by Makhatini cotton company, (1 600 ha); cotton grown off the scheme marketed through Vunisa Cotton (2 000 ha); vegetables (150 ha); bananas (20 ha); and maize (300 ha).

Opportunities for infrastructure expansion were: upgrading the existing irrigation scheme, estimated at R120 million, over 5 years. Specifically, extension of the existing irrigation to expand cotton through Makhatini Cotton Company (6000 ha), supported by a new gin on site that would enable provision of 80 jobs and many seasonal ones by extending the irrigation canal to the following tribal authority areas, Kwa Jobe, Siqakhata, Wasbank and Ndumu. Expand irrigation canal to enhance production of sugarcane, fruits and vegetable farming and processing and promote processing of raw materials. Expand irrigation canal to promote R40 million essential oils production (600 Ha).

Key opportunities are: Makhatini irrigation scheme pressurized irrigation system; and potential for agricultural development (106 000 ha) with high crop yields and income (Table 6.28).

Table 6.28: Agricultural potential based on yields for some crops on the Makhatini Flats 2002. The yield was estimated at 70% management level (Source: DAEA – KZN).

	Yield tons/ha	Gross Income/ha (SA Rands)
Field Crops		
Madumbe	±1.2	±37 500
Cotton (irrigated)	3.0-3.8	±8 250
Dry Beans (dry land)	0.1-1.1	±4 650
Groundnuts	0.7	±5 530
Soya beans (irrigated)	0.4 –2.2	±2 700
Maize (dry land)	4-6	±2 600

Sunflower (dry land)	0.4-0.8	±2 200
Sugarcane (irrigated)	89-138	±1 352
Horticulture		
Tomato	32.1-53.5	±92 500
Banana (dry land)	±20	±33 007
Carrot (hybrid)	26.7-33.4	±45 500
Table potato (dry land)	21.9-37.6	±29 250
Cabbage	29.2-40.5	±25 350

6.5.5 Constraints

6.5.5.1 Water availability

The DAEA Makhatini development plan (2002) recognizes two factors (land tenure and Makhatini irrigation scheme design) as being key factors that will limit agricultural development implementation in the area. It appears as if water availability is not viewed as a limiting factor.

Results of the social survey showed that conflict of water needs between irrigation farming and fishing had started to crop up. This site is situated in the area planned for cotton development and expansion (i.e. see Fig 6.8 site 1 and 2 at Ndumu A and B).

Ndumu A and B irrigation schemes in the north is mainly for small scale farmers. A tributary of the Ingwavuma River, called the Msunduzi River, has been dammed at Qotho pan where a small dam wall has been built on this pan to hold water for irrigating cotton, maize and vegetables on the Ndumu Estate A farms (6 000 ha). However, according to DAEA Jozini, (personal communication from Casper Nkabinde, 2004), water from this pan cannot meet the irrigation demands of Ndumu Estate A farms and additional supplies of water are obtained from the Pongolo River through Ndumu Estate B farms, who abstract water directly from the Pongolo River using an engine pump and pipes. Bush and forest is being extensively cleared to increase the irrigation area of Ndumu B farms.

The importance of water availability is discussed in Chapter 4, section 4.4, by comparing the implications of the proposed DWAF scenarios for water allocation in the catchment and arguments are presented that should be considered when reconciling water requirements with available water, by looking at the implications of water requirements for economic growth in the catchment and balancing them with water implications for the reserve requirements. It is argued that water availability is in fact a key constraint to achieving full agricultural potential of some 106 000 ha of land on the Makhatini flats area and that industries promoted in the area for economic growth (agricultural and non-agricultural) need to take into account water availability in the planning stage (by considering water needs to support subsistence agriculture) in order to ensure long term sustainability for all.

6.5.5.2 Land tenure issues

Land ownership boundaries are superimposed over traditional authority land boundaries to reveal the location of private land with title, communal lands under traditional authority control (no title) and state owned lands (Fig 6.9).

The governmental Department of Land Affairs has handed over state owned land parcels 3-4, 11-19, 21-29, 32 and 33 to the Department of Agriculture through a power of attorney so that they can be developed through the LRAD policy framework (Land Redistribution for Agricultural Development) (LRAD, 2000). Details of the LRAD framework are illustrated in (Table 6.25).

In addition to the LRAD programme, where state land could be transferred to emerging farmers, there was also the land restitution programme (Land Rights Act No. 22 of 1994), which led to the creation of the Commission for the Restitution of Land Rights. Within this Act, land that was removed from individuals and communities after 1913 may be reclaimed by the original owners and certain claims for land on the Makhatini Flats had been launched by various TAs on the Makhatini Flats, e.g. the Siqakhata community, Jobe community, Nsinde (Myeni) community and other TAs in the north and east of the Makhatini Irrigation Scheme.

Appropriate land rights for these communities will have to be established in order to enhance success in modern farming methods proposed through the agricultural development plan.

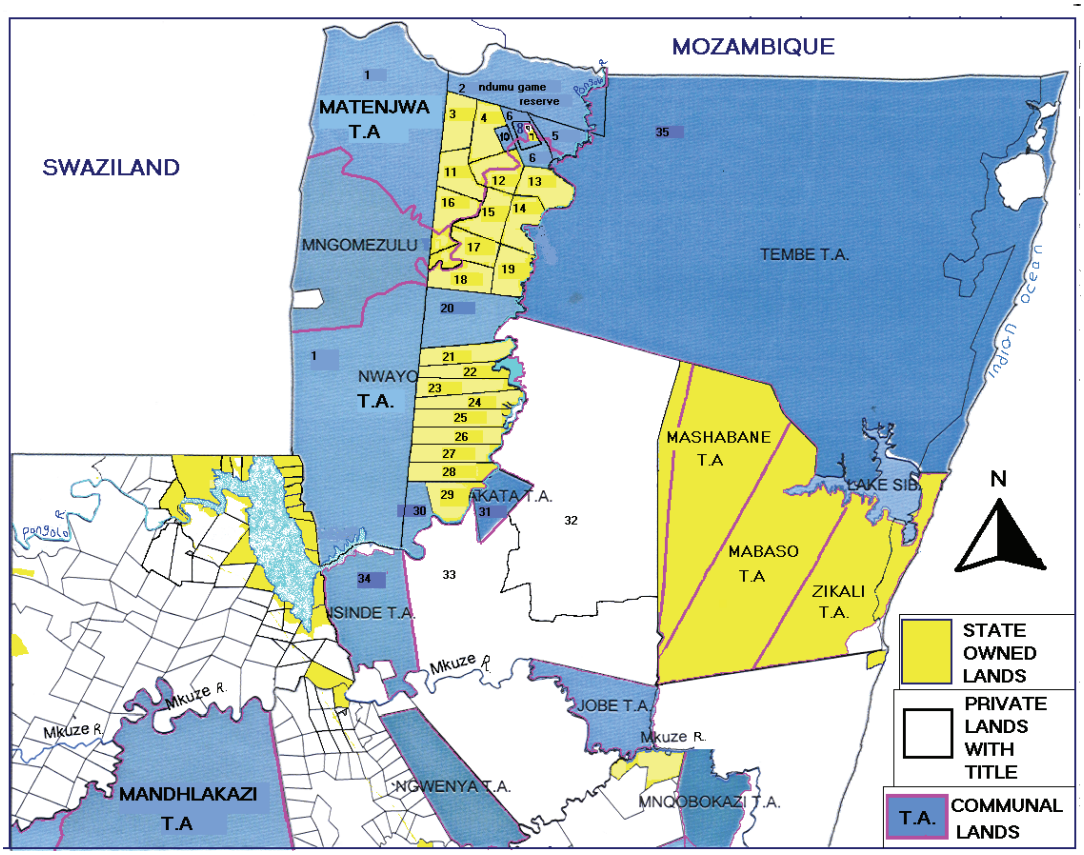


Figure 6.9: Cadastral information showing land ownership boundaries. The government's Department of Land Affairs has handed over land parcels 3-4, 11-19, 21-29, 32 and 33 to the DoA through a power of attorney to develop the land through the LRAD policy framework (Source: Local government, Pietermaritzburg, 2002)

6.6 KEY ISSUES ARISING FROM AN ANALYSIS OF INSTITUTIONAL ARRANGEMENTS AND PROCESSES

The following sections discuss downstream agricultural development plans.

6.6.1 Issues from institutional arrangements – Pre-1994

Apartheid policies influenced the movement of people into the area from upstream of the Pongolapoort Dam to enable development of vast areas into commercial forestry, irrigation and game reserves. This movement of people influenced the rapid increase in the rural human population in the area downstream of the Pongolapoort Dam since 1960 (see section 6.4). The planning of new developments in the area, which require use of vast areas of land resources, should take into account the needs of this huge human population that are currently using the land resources for subsistence needs. Projects requiring use of vast areas of land should not be approved until they can show clearly how the intended development will cater for the basic needs of the huge rural population. Projects should show how they intend to balance economic, social and ecological needs before approval is granted.

Cotton was promoted even though agro-climatic factors suggest that cotton growing is not very efficient in the area. Therefore, it is better that crops that grow efficiently in the area should be promoted.

The managing agents did not take into account other interests when making decisions about farmer settlement, although it can be argued that apartheid policies influenced their actions because they had to settle people displaced from elsewhere (upstream). Specifically, the interest of nature conservation and those of many local farmers were ignored. This fact has contributed greatly (in the negative sense) to the current problems experienced by DWAF and EKZN-Wildlife authorities in managing the natural resources of the Pongolo River floodplain (see section on reconciling conflicting needs in Chapter 4 and results of the social survey in Chapter 7).

The criteria for farmer settlement on the irrigation scheme proposed by nature conservation interests was that households who gave up land (on the floodplain) for the scheme would become eligible and would be given preference for irrigable land allocations. The aim of these nature conservation criteria for farmer selection was to enhance the conservation of natural resources on the floodplain and dry land areas by reducing over-exploitation of the natural resources by a growing human population. However, the complexities of the issues were such that even if these nature conservation criteria were implemented, the apartheid government would still have needed to find space to settle the displaced people from upstream. It is highly likely that many of the displaced people would have had to make use of the floodplain lands to support subsistence needs.

Therefore, apartheid policies are the cause of the current problems being experienced. The implication is that planned developments requiring the use of vast areas of the land resources should have a solid plan that shows clearly how the basic needs of this huge, rural population, who suffered greatly under apartheid, will be taken care of. Any approved development should not push people deeper into poverty.

The fact that the scheme was converted to a small-scale operation without modifying the designs is the greatest factor causing the various grievances between farmers and the managing agent e.g. farmers end up paying for services that they have not used, e.g. water and electricity.

Land tenure is by a 20-year lease agreement, which prevents farmers from physically settling on their irrigation stands. This, among other things, has influenced the farmers' inability to manage the farm effectively. Farmers should own their farms.

Observed farmer performance fell short of what was expected. Local farmer perceptions and concerns revealed a lack of interest and commitment towards the scheme due to the lack of profitability resulting from high debt loads. Local farmer failure was largely attributed to irrigation design intended for heavy commercial estate run businesses, suitable for the managing agent but unsuitable for poorly resourced local black farmers. Generally the central control nature of the management structure, failed to effectively transfer skills and capacity to many local black farmers. The managing agent felt that participation was going to place a high demand on their time. They wanted government to invest in training farmers by putting in place an effective extension service. Farmers were unhappy with the

management system and they wanted change. Local farmers felt that so long as all individual members could benefit, they would be willing to participate and take up responsibility.

6.6.2 Comments on the studies of the economic dynamics of irrigation farming

The fact that the scheme-managing agents owned commercial holdings on the scheme may have compromised their ability to act impartially when implementing their duties of managing the scheme. For example, it can be seen that up to the 1988/89 cotton season all actions and decisions with respect to land and crop production were made by the managing agents until KFC (the firm that provides financing for farmers) insisted that farmers should have some formal tenure (lease agreements) and that centralized scheme management decision making should cease. Ideally, the managing agent should have been made accountable (or report to) a committee made up of farmers owning plots and chaired by an elected farmer. Indeed this type of management structure is practiced on many white owned schemes (Irrigation Boards).

Indeed, many dams were built as poverty alleviation schemes for the poor white population pre-1994. Therefore, post-1994, irrigation developments intended for social development or upliftment of many poor black farmers should learn from the experiences of white irrigation boards. Irrigation boards played a significant role in South Africa's history of irrigation development and its contribution to not only infrastructural and economic development but also its contribution to social development (Jan du Plessis, 2003).

For instance, Jan du Plessis (2003) reported irrigation board experiences. Key lessons are that: (1) farmers themselves elect a chairman and board committee members to manage the shared water resource (2) and ensure that individuals with water-rights take their turn at the times allocated (3) money collected from farmers keeps the furrows in good repair, pays an occasional labourer to unblock the grids when litter and plant growth threaten to impede the flow (4) solving on-going problems with people stealing water (5) minutes are written well and kept as this provides (not only transparency) but also insight into the history of events (e.g. it can be seen in the records of the minutes that issues discussed did not only involve water sharing but also preventing fires, flooding and excess erosion), and (6) it is very important that newcomers understand the regulations.

Generally, it can be assumed that farmer failure or lack of profitability is not at the core of the concerns of irrigation boards (as it is in the black irrigation schemes), as it was not reported in the article by Jan du Plessis (2003).

Bembridge (2000) investigated small-scale irrigation schemes in the former black homelands in order to pinpoint major constraints and problems which could be used to improve designs, concepts, management and economic participation of farmers. For example, in the Eastern Cape province, Pedi district, Tyefu irrigation scheme was designed to provide bulk water to irrigate 5400 ha on the east and west banks of the Great Fish River. The scheme had 5 sectors, 29 commercial farmers with 4 ha plots. Food lot holders had units between 0.16-0.25 ha. It was found that the schemes were not economically viable from the onset due to the high costs of electricity for pumping water from the Great Fish River. The water supply system could not adequately sustain irrigation during periods of low stream flow (May-Oct) in addition to

the fact that, during this period, water presented a salinity problem. After 15 years, above ground irrigation piping and equipment was in poor condition. Consultants managed the scheme. Many farmers wanted to have greater participation in managing the scheme. The majority were illiterate (57%). Many plot owners were over 60 years of age (37%). Farming skills were poor due to ineffective extension services. The land tenure system was such that farmers did not own their plots. Many farmers were poorly resourced in terms of equipment and livestock. Monthly expenditure and savings were low. Income was largely derived from pensions and spent on buying food. Three out of 5 lived below the poverty line. Some farmers perceived that they had benefited while others felt that they had not. Leadership was weak and there was political rivalry between farmer unions. Bembridge (2000) concluded that rehabilitation of the scheme could only be justified as a poverty relief and food security measure, so long as the present development and rehabilitation costs were written off.

A clear distinction between the two types of irrigation schemes (i.e. irrigation board and small scale black irrigation) is that in the irrigation board, the management structure is made up of the farmers themselves; farmers own the plots, and plot sizes are economically viable (>20 ha) according to the findings of Van Rooyen (1983) and the DoA (1994).

It can be argued that, under the irrigation technology design with the following management system (estate-run for big business, where the managing agent owns farming interests, operating systems are centralized, land is rented – not owned, cropping programmes are controlled to sustain profitability of crops, and farmers do not live on the land and therefore costs cannot be saved through (less loss and damage of equipment, reduction of irrigation scheme staff, improvement of maintenance activities, improved resolution of disputes, enhanced provision of an organised means of extension and farmer training, and mobilization of local human resources); it was found that commercial plot sizes must be 20 ha or 30 ha or more to be profitable (Van Rooyen, 1983; DoA, 1994).

Is the figure of 20 ha-30 ha a standard which can be applied across the board, in other farming systems with decentralized management, e.g. irrigation boards and privately owned farms?

The answer to this question can only be obtained through studies that vary plot size with profitability under different cropping programmes, different irrigation technology design systems and by comparing centralized versus decentralized management systems, where farmers own the land or do not own it and where the managing agent has farming interests or no farming interests and the presence or absence of markets. For instance, there are privately owned farms in the country with a decentralized management system in terms of farm dams where water is abstracted directly from the river channel in to farm dams. Are such irrigation systems more cost effective in terms of irrigation production and profitability? Such comparative studies can provide the knowledge that helps to define the most appropriate irrigation technology, management system, plot size and type of land tenure needed to make the DoA – LRAD policy programme of land redistribution for agricultural development for black farmers more efficient and successful.

Plot size ideas are discussed further under co-management section 8.4.5.3.3. Denison and Manona (2007) suggest that plot size should generally be determined by the specific goals of farming and access to

markets. On the Makhatini flats, commercial farm size is limited by other competing needs for land (game reserves and game farms for eco-tourism, nature conservation and subsistence agriculture supporting a huge rural population). Farms size is also limited by competing needs for available water.

Bembridge (1993) argued that, no irrigation project however well-planned can be expected to contribute to the national economy unless it has the support of policy issues concerning land tenure, social and physical infrastructure, credit control, agricultural technology, research and specialist back-up, effective water supply delivery systems and an effective extension system as well as markets. He found that these factors had varying degrees of inadequacy on the Makhatini irrigation scheme.

6.6.3 Comments on agricultural development plan (2002)

According to the 2002 DAEA Makhatini development plan report it appears as if the situation on the Makhatini irrigation scheme in 2002 had not changed very much since the assessment carried out in 1993 (Van Rooyen, 1983; DoA, 1994; Bembridge, 1991, 1993).

The scheme was still under central control through a managing agent who also owned farming interests on the scheme. The agent was responsible for water supply and maintenance of water reticulation on the scheme and was subsidized by the DAEA to provide support to other farmers on the irrigation scheme. Over the years, the relationship between farmers and the managing agent grew to be one of dependency, due to the farmers failing to meet their financial obligations in terms of loans from KwaZulu Finance Corporation (KFC), which is currently known as Ithala Bank.

According to the 2002 DAEA Makhatini development plan, the situation had worsened so much over the years, to the extent that the managing agent was undergoing a process of restructuring whereby the DAEA began facilitating a three phased programme (Table 6.26) within the 'Green Revolution Programme' to administer debt repayment and sale of plots.

In the restructured plan, water provision and administration would continue through the previous managing agent (Mjindi Farming Company – MFC), but other new role players would be allowed to contribute towards development in the area (e.g. the new cotton farming company). It was also planned that pump station management structures, consisting of farmers attached to a pump station, would be established while MFC would provide administrative, financial and maintenance services to the pump station management structure.

It is important that an institutional study be carried out to evaluate the success of the 'restructured plans' – in terms of the degree to which they are meeting the needs of farmers. Management studies point to the fact that the only way profound change can be achieved is to ensure that people's inner values, aspirations and behaviour change with outer shifts in processes, strategies, practices and systems. It is not enough to change laws, strategies, structures and systems, unless the thinking that produced those laws, strategies, structures and systems also changes (Champy, 1995; Senge et al., 1999). Implied here is a need to not only align people's perceptions, beliefs, norms and values with the irrigation scheme system, structure, strategies and practices, but also to the intentions of the relevant government policies.

These ideas are supported by the results of a recent worldwide comprehensive assessment of water management in agriculture (CA Framework, 2002; Molden, 2007). The assessment came up with eight key policy actions for decision makers in order to meet the ever increasing demands on a limited amount of water that the planet has had since creation. Indeed, reforming the reform process was one of the policy actions recommended (Merrey et al., 2007). Doing thing differently would require the other seven policy actions to be taken into account (Molden, 2007) and they include:

(i) Changing the way we think about water and agriculture,
(ii) Fighting poverty by improving access to agricultural water and its use,
(iii) Managing agriculture to enhance ecosystem services,
(iv) Increasing the productivity of water,
(v) Upgrading rainfed systems – a little water can go a long way,
(vi) Adapting yesterday's irrigation to tomorrow's needs,
(vii) Reforming the reform process – targeting state institutions,
(viii) Dealing with tradeoffs and making difficult choices.

When this management thinking (Senge et al., 1999; Molden, 2007) is applied to the cotton investment company development model, it becomes easy to see the gaps, which would need to be addressed in order to ensure sustainability.

For example, the vision statement from the cotton investors, MCC, is to stimulate rural development and reduce poverty. The vision for the farming company on the ground, MCF, is to strive to maintain the highest possible returns. The vision statement for the trust representing the local community in each area for each farm (typical size over 200 ha) has not been mentioned. Yet the investors and the farming managing agents' expectations is that all investments will have to be repaid first before all shares can be transferred to the trust representing the local community in each area. Management studies have shown that long-term stability can only be achieved by taking into account and balancing the interests of all parties (investors, managing agents, local farmers, government policies and the environment/ecological interests). It is very important that the vision of local communities must be aligned with not only that of the farming managing agent and investors, but also with that of government and the environment, before the overall goal of stimulating development and reducing poverty can be achieved and sustained in the long term. This is a key gap that should be filled first, to prevent the situation where certain sectors benefit so grossly at the expense of others, hence destabilizing long-term sustainability. After ecological needs have been taken care of in terms of the reserve (Chapter 4), farmers were the most important element in the whole scheme and must derive benefit from the scheme. Implied here is that the needs of farmers must be kept central in all development discussions and addressed with immediate effect. Pre-1994, assessment of farmer perceptions and concerns revealed a big proportion of farmers lacked interest and commitment towards the scheme due to hardly or no profitability resulting from high debt loads (Bembridge, 1991, 1993). The result has been that farmers and society at large (as tax payers) have ended up paying the costs.

It is argued here that, even though investors will boost the economy and create jobs in the region, given the total human population in the area, only a small proportion of the human population can own these

ventures or be gainfully employed in these ventures. This fact is supported by the multi-value approach to agriculture ideas discussed in section 8.4 (Edward-Jones, Davies and Hussain, 2000).

For instance, studies illustrating the influence of land size on economic feasibility of irrigation plots carried out by the Directorate of Agricultural Economics, DoA, showed that net income and profitability increases exponentially with increasing plot size. Farmers who do not irrigate all 10 ha of their plots have an extreme burden to carry in terms of fixed costs and rent for each ha. Data also showed that a plot size of a minimum of 20 or 30 ha could lead to reasonable incomes. The implication for the Makhatini Cotton Company development model, which requires that the local community trust farm be >200 ha is that, economic feasibility can only be achieved if, for example, a 200 ha block is owned by 10 people x 20 ha plots, or 15 000 ha owned by 750 people x 20 ha plots, or fewer people if each person owns >30 ha.

According to Statistics South Africa Census 2001, population distribution in wards adjacent to the floodplain on the west side of the river within the Jozini municipality KZ272, where the Makhatini Cotton Company agricultural developments are planned, is 37 290 people comprising 6 717 households with an average household size of >8. For this community to farm economically or commercially on 20 ha plots (other things being equal), it would require 134 340 ha of land. This value is unachievable because the maximum available in the whole region (i.e. west and east side of the river) is 106 000 ha. To make matters worse, the population in wards adjacent to the floodplain on the east side of the river within the Umhlabuyalingana municipality KZ271, where soils are mainly sandy and marginal for agricultural development (excepts for soils in the south on the Makhatini irrigation scheme), and where the only soil resource available for growing crops for these people is found on the floodplain, are 55 079 people comprising 9 864 households with an average household size of >8. The total population in the wards adjacent to the floodplain on the west and east side of the river is 92 369, comprising 16 581 households, with an average household size of 8. Population distribution at the municipal scale (KZ272 Jozini) where the Makhatini Cotton Company developments are planned was 184 090, comprising 33 543 households with an average household size of 7 people. On the east side of the river, the KZ271 Umhlabuyalingana municipality has 140 962 people, 25 968 households with an average household size of 7). The total human population at district council level (KZ271+KZ272) is 325 052 people with 59 511 households (Statistics South Africa Census, 2001).

The implication of this population data, economic dynamics of farming reported by Van Rooyen (1983) and the DoA (1994) and water availability (Chapter 4 section 4.4), is that a very small proportion of any community can achieve direct benefits in terms of profits. Only a few people can gainfully own these agricultural irrigation scheme ventures. It also means that only a small proportion of the total population can work as labourers in these ventures. It must also be realized that, even if more farmers can benefit on smaller plot sizes (<20 ha), under different cropping programmes and management systems, water availability would still limit the number that could benefit from irrigation agriculture (Chapter 4 section 4.4). These ideas are strongly supported by the multi-value approach to agriculture (Edward-Jones, Davies and Hussain, 2000), and issues of what is efficient, equitable and sustainable (section 8.4).

The fact that only a few people can benefit from irrigation farming means that the rest of the population have to find alternatives for survival. This dynamic is reflected in the current tensions over the need for

water rights among floodplain fishermen who do both activities of fishing and growing crops on the floodplain; nature conservation agencies who want people to get out of the floodplain so that it can become purely a conservation area; downstream irrigation farmers who want to expand irrigation activities; and Pongolapoort Dam property owners who use the dam for irrigation, tourism and recreation. In addition, DWAF would like people to get out of the floodplain so that the dam can be safely managed for flood control due to the fact that cyclones are frequent in the area. The following section illustrates the issues.

The fishermen prefer summer floods to enhance harvestable yields, just like conservation agencies. However, while the conservation agency (EKZN-Wildlife) have always expressed the desire for agriculture to be removed from the floodplain so that it can become purely a conservation area, fishermen express the desire to do both, i.e. fish and grow subsistence crops on the floodplain (Chapter 7).

For example, after implementation of agricultural development expansion in the Ndumu area downstream of the dam, it was observed that tension over water needs between irrigation and fishermen started to crop up in 2004 (Chapter 7). To illustrate the shortage of water availability for various uses, a group of concerned local fishermen insisted that the venue for a focus group workshop in May 2004 be held inside a dry riverbed, with nil flows, on the Ingwavuma River downstream of the Qotho pan dam wall (Fig 7.24). This site is situated in the area planned for cotton development and expansion (i.e. see Fig 6.7 site 1 and 2 at Ndumu A and B). In addition, results of the social survey showed that communities utilizing other floodplain pans on the Pongolo River for fishing felt that the fish catches were very low and they wanted more water in the pans during summer to support fish production (Chapter 7). However, summer is also the period when irrigation demands are very high. Generally, the fishermen felt that people owning irrigation plots were benefiting at their expense. They perceived that aquaculture had been implemented in certain areas and had not been successful. They felt that natural production of fish in pans was a better option and therefore they wanted water rights for fishing (Chapter 7).

Indeed, the DAEA – KZN had tried to mitigate the problems of conflict of water use between irrigation and fisheries, through a study that looked at the status of the commercially exploited fish species of the Pongolo River floodplain, with a proposal for their management (James, 1992). The study found that fish populations had greatly decreased due to (i) modified and reduced stream flow associated with the building of the Pongolapoort Dam; (ii) agricultural practices close to pans and river banks had increased, leading to increased erosion and the silting up of pans; and (iii) increased fishing pressure. James (1992) recommended (i) aquaculture development by implementing and developing appropriate sustainable integrated aquaculture/agriculture systems, and (ii) education of the local communities of the importance of the planned regular and timeous natural flooding patterns.

On this basis, the DAEA – KZN initiated an integrated fisheries management plan by enabling research in small-scale aquaculture technology development and the building of an aquaculture facility at Makhatini Research Station for the following purposes: (i) to promote and demonstrate the new idea of fish farming; (ii) to provide fingerlings to the small-scale and subsistence farmers. Two indigenous fish species were chosen, namely: tilapia (*Oreochromis mossambicis*) and sharptooth catfish (*Clarias*

gariepinus); and (iii) train extension officers, farmers and communities in aquaculture for integrated and appropriate systems development and research.

According to researchers at the Makhatini Research Station, a pilot project was initiated at Mboza village. The integrated aquaculture project had fishponds with chicken cages above the fishponds. The uric acid from the chicken droppings falls into the water and fertilizes it. This enhances the growth of the things that fish feed on. The enriched water from the chicken manure, as well as from the fish itself, is used to fertilize vegetable gardens. Vegetable remains after harvesting, together with droppings from cattle, are thrown back into the fishponds to complete the cycle. The pilot project operated for some time and eventually failed. It was not operating as at 2003. The reasons why it failed would need to be investigated so that corrective measures could be put in place.

According to the results of the social survey on the floodplain (Chapter 7), communities perceived that aquaculture technology had been implemented in certain areas and had not been successful. They felt that natural production of fish in pans was a better option and therefore they wanted water rights for fishing in pans. They criticized the promotion of production of catfish. Communities felt that although it was the most abundant fish that survived when the water levels in pans were low and of poor quality most of the year, it was not a preferred fish for food. In addition, there are some traditional beliefs that prohibit eating catfish, but due to poverty and hunger, they are forced to eat whatever is available. Communities felt that, the only time they had access to other more preferred fish types was immediately after a flood release. Yet floods had reduced and water levels receded very quickly, causing poor water quality conditions most of the year (Chapter 7).

The fishermen felt strongly that irrigation should be willing to share water with pan fisheries, because they (fishermen) had no access to fish on the Pongolapoort Dam, nor in nature reserves (Ndumu game reserve), nor to jobs in commercial irrigation ventures. Although the nature conservation agency (EKZN-Wildlife) argued that the abundance of fish found in pans inside the protected area (Ndumu game reserve), served as a major source from where fish migrated and were recruited into other floodplain pans when the river was in flood after a flood release. Although such fish stocks were protected from exploitation pressure, the conservation agency (EKZN-Wildlife) argued that fish stocks could only be maintained with frequent summer floods of adequate magnitude and timing, aligned with natural seasonal rhythms.

In addition to irrigation farming, other economic alternatives that can provide jobs should be promoted because, very often, the social dynamic is such that people from elsewhere may end up taking irrigation jobs as farm labourers or owning irrigation ventures. In the short-term, it is highly likely that the rest of the local population will need to continue utilizing the dry land and floodplain systems for a livelihood of subsistence agriculture (crops, fish, pasture, wildlife, and tourism) that helps to diversify the economy by providing an alternative livelihood survival strategy. Hence, water provision from the dam to conserve the floodplain should not be allowed to cease to enable the irrigable area to increase. If the irrigable area is allowed to increase, without providing alternatives in the non-agricultural sector of the economy, poverty and hunger is likely to increase greatly among the rest of the population, because only a few

people can own plots in irrigation schemes. In addition, the irrigation scheme's key target is mainly to produce high value cash crops (instead of food crops) to pay off the investments quickly.

Also, if the floodplain is allowed to dry up in order to find more water for irrigation to expand high value crops, and its food producing quality is destroyed (crops, pasture, fish), people who are utilizing it and have no alternative means of survival (own irrigation plots or not employed in irrigation ventures), will be forced to start stealing food and other items from the irrigation schemes and crime is likely to increase in the area. For example, tension between fishermen and irrigation farmers was beginning to crop up near the Ndumu irrigation scheme in the north (see social survey Chapter 7). Therefore, if long term economic sustainability is the goal for the region, then social sustainability, supported by provision of floodplain resources (crops, pasture, fish, and wildlife) and other alternatives in the non-agricultural sector of the economy, is a key factor. Moreover, if long term social and economic sustainability is the key, then environmental/ecological sustainability must be the goal to enable production of crops, fish, pasture, etc. and if long term environmental/ecological sustainability is the goal, then adequate amounts of water must be allocated to sustain the environment/ecology in terms of a reserve (Chapter 4 section 4.6.2).

After ecological needs have been taken care of as a first priority in terms of, (i) a water reserve that is able to absorb waste from economic growth and (ii) biophysical sustainability in terms of soils and climate, the needs of farmers utilizing the floodplain and those on the irrigation schemes should be kept central in all development discussions and addressed, if the long term goal of government (which is to enhance the socio-economic wellbeing of rural populations) is ever going to be achieved, i.e. to reduce rural poverty and improve the social wellbeing of rural communities in this region. Since the Pongolapoort dam development and the subsequent farmer settlements on the irrigation scheme in 1985, the ecological (in terms of floodplain water requirements and not necessarily IFR-instream flow requirements) and commercial farmer needs on the irrigation scheme have largely not been addressed. The following story illustrates this fact. DWAF – KZN was in a process of putting in place the formal Water User Association structure for downstream communities (irrigation scheme participants and dry land participants) (Chapter 7). During one of these meetings, held at Mboza Village on 7th April 2005, a young man who is participating on the Makhatini Irrigation Scheme had serious concerns with the centralized scheme management structure. His concerns are quoted verbatim below. Note that these comments may be his perceptions, as they were not investigated, because the irrigation scheme was out of the scope of the social survey carried out on the dry land area adjacent to the floodplain – Chapter 7.

"My father participated in the Makhatini irrigation scheme since 1988.
My father is a very old man now so he asked me to take over from him.
I am experiencing problems buying inputs from MFC.
I do not want to buy inputs from MFC.
The costs are too high.
As farmers, we need to have more control of irrigation services ourselves.
We cannot take care of many things on the farm because we do not live on it.
So I can not take care of many things well.
I travel 8 km one way to get to my farm.
There is no water for drinking.
Sanitation facilities are absent.
So we travel 2 km from the farm just to get water to drink.

Access to water from MFC for irrigation is a problem.
We pay R16 000 per year for water and electricity, whether you used it or not.
This contributes to debt load for nothing.
You won't believe this –
I can show you my statements if you like –
I earned R30 000 from cotton and after all deductions of inputs, including transport,
I only received R5 000!
Transport of sugarcane is so high because we do not have a ready market on site.
So if you get R8 000, R7000 is taken away for transport and you end up with a mere R1000.
This is so demoralizing after all the hard work one puts in.
The lack of profitability and debt load is making me lose interest and commitment towards the scheme.
We need to engage government to provide solutions.
They keep saying that they want to improve the social economic wellbeing of rural people.
Many of us have not experienced any of this socio-economic wellbeing.
Because of lack of profitability many people have leased their farms to both black and white people from out of this area.
Farms are leased for R24 000/10 Ha plot/year.
Land tenure is a 20 year agreement which is renewable.
Many people are concerned that due to debt load many people will lose their plots when the lease expires in 2008.
I feel I can do better if certain things are corrected.
We hardly see extension officers both from MFC and from DoA.
They always say, "I am busy somewhere else".
When we see them, often they are looking for credit for MFC.
They do not see us at the start of the season.
They do not show us how to do things.
Cotton pests and diseases are a problem
I am about to give up and go to Jo-burg to look for a Job."

Clearly, the situation had not changed very much for some farmers on the irrigation scheme since the study carried out by Bembridge (1991; 1993).

For instance, the DoA was not in favour of a policy that allows people to live on their farms in this region (personal communication, 2006). It was feared that given the African social structure, e.g. many people have large families, and often live with or welcome many extended families and that the system of inheritance is such that farms are sub-divided among the sons, it was highly likely that several years down the line, good productive agricultural land will be converted to a residential area. This had already happened elsewhere and they did not want it to happen on the Makhatini Flats agricultural lands. We argue that the DoA needs to review this proposal because the younger African generation is continuously being modernized culturally within the current modern societies and this view is unlikely to be a reality in the present and near future. If, by allowing people to live on their irrigation plots increases production efficiency, reduces costs, and enhances profits, it should be allowed by all means. Laws can simply be put in place that prevent the property from being sub-divided for residential purposes.

Finally, there are lessons to be learned from the Makhatini irrigation experience. These problems must be taken into account in the planning and implementation of new developments to ensure that local farmers benefit. Problems experienced on the Makhatini irrigation scheme happened at a time when water availability was not a problem. With increasing water demand, problems will increase. Government is unlikely to continue subsidizing farmers in perpetuity. It is critical to address farmer needs through community-based, decentralized institutions because they have a higher chance of achieving equitable

and efficient allocation of resources among various sectors which diversifies the economy, hence promoting sustainability and social stability in the long term (Chapter 8, section 8.3). As discussed in Chapter 7, finding more water for irrigation while balancing ecological and social issues can be achieved by improving irrigation efficiency and installing inflatable weirs on the floodplain that optimise floodplain water requirements (Heeg and Breen, 1982), in addition to promoting soil moisture conservation techniques and rain water harvesting that enable communities to secure adequate water for drinking, crops and livestock (Smith, 2003; Beukes, 2003; Van Rensburg et al., 2003).

6.6.4 Defining downstream agricultural development needs – DAEA perspective

Generally, competing interests among the downstream floodplain communities and those upstream (irrigation and recreation) were clearly reflected during the annual stakeholder meetings to negotiate flood requirements chaired by DWAF (Minutes of DWAF annual flood releases for the Pongolo River and floodplain) and in the dialogue stakeholder workshop (Jaganyi et al., 2003).

On this basis, water use in the catchment will have to be subject to appropriate investigations and negotiations in order to achieve fair trade-offs through community-based decentralized structures (Chapter 8, section 8.3) due to these competing needs for water, namely:

(i) Irrigation,
(ii) Alien plantation forestry,
(iii) Water transfers to Mkuze and Swaziland,
(iv) Domestic and industrial use,
(v) Flood release for basic needs and the natural environment,
(vi) Shared river requirements with Mozambique
(vii) Any other use.

6.6.5 Needs statement of agricultural development (DAEA) perspective (2002)

In addition to the development objectives and challenges expressed in section 6.5.4 and 6.5.5, agricultural development needs and challenges include:

(i) Expand irrigation development to full potential (106 000 ha).
(ii) Specifically interested in expanding irrigation developments on available state land for poverty alleviation through private/public partnerships, thereby putting pressure on decision makers to find more water for irrigation, at the expense of floodplain agriculture and conservation. See arguments in Chapter 4 section 4.4.3, Chapter 5 and 7.
(iii) Based on the literature reviews carried out, it is highly likely that key constraints likely to limit achievements of these needs are: land tenure rights, water availability and institutional arrangements.
(iv) Promote small-scale aquaculture technology development to mitigate impacts of water requirements for irrigation (i.e. resulting in less water for floodplain fisheries) through research and development and initiate trials to investigate the viability of more intensive cage/pond fish culture systems on nearby irrigation balancing dams and canals.

(v) The Department of Environmental Affairs ensures (among other things) that environmental impact assessments (EIA) are carried out and approved before new developments can be allowed to take place. The EIAs should show that the new development would have minimal negative impact on the environment from a social, economic, environmental and ecological perspective. The EIAs should show that the economic benefits of developments outweigh the costs (social and ecological costs). The conflicting issue here is that sometimes development projects are approved without taking into account external costs to the environment, because it is difficult to put a monetary value to many environmental goods and services. Therefore, results of any cost benefit analysis should be tested in a public forum made up of affected parties before a project is approved and government should always intervene to protect ecological and social interests (see section 8.4).

For conclusions and recommendations to agricultural development see Chapter 9, section 9.3.

6.7 UPSTREAM DAM PROPERTY OWNERS – MKHUZE SUGAR ESTATES INTERESTS

Mkuze Sugar Estates is also known as Railway Valley Irrigation, owned by Charl Senekal (see location of the area in Figure 6.10 showing irrigation boards upstream of Pongolapoort Dam). Mkhuze Sugar Estates is directly affected by artificial flood releases from the dam because water is transferred from Pongolapoort Dam into the Mkhuze River catchment for sugar irrigation. According to the DWAF Report, No. PB WMA 06/000/00/0304 (2004), a Charl Senekal Suiker Trust pipeline was authorised to transfer 32.6 million m^3/annum into the middle reaches of the Mkhuze catchment from the Pongolapoort Dam for irrigation and domestic water supply to rural communities. A floating pump station abstracts water from the Pongolapoort Dam basin. Although the capacity of the pipeline is 90 million m^3, the Senekal Trust Licence is limited to 32.6 million m^3/annum. According to the DWAF report above, Mkuze catchment is characterised by large-scale commercial afforestation, irrigation and mostly rural water requirements. Transfers from Pongolapoort Dam improve water availability in the Mkhuze catchment greatly.

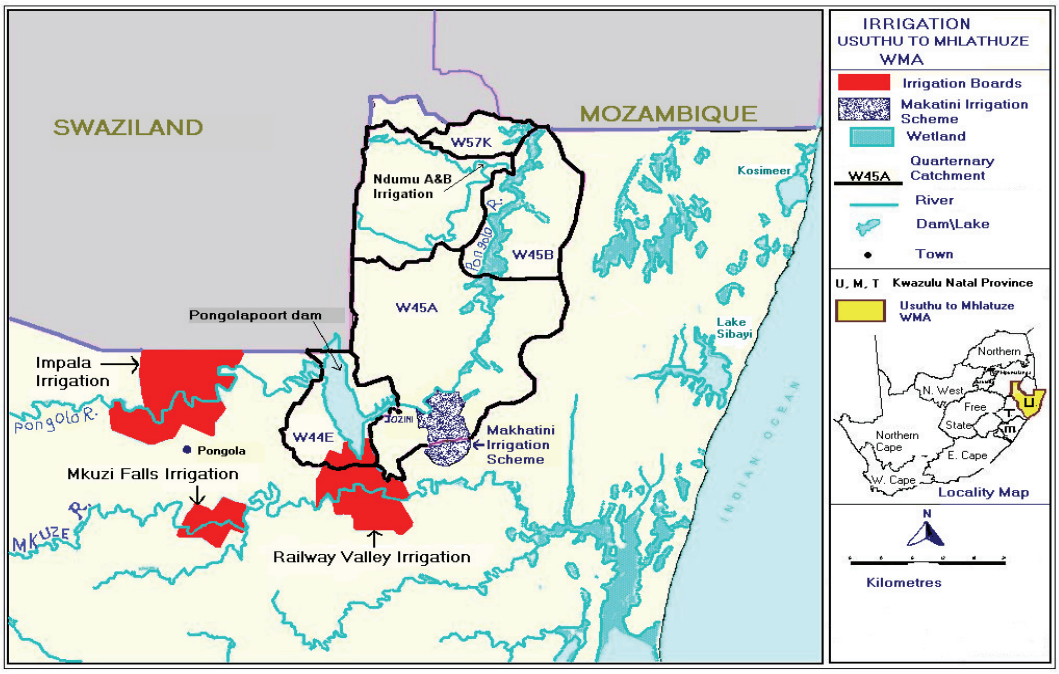


Figure 6.10: Irrigation developments along the Pongolo River system (Source DWAF, 2003).

6.7.1 Problem statement presented at the stakeholder dialogue workshop (2002)

A major concern is when the dam capacity is so low that the water level drops below the main irrigation pipe outlet. Because Mkhuze Sugar Estates has spent millions of Rands in investments and employs many hundreds of people in the Pongola area, it is also important that their concerns, and through them their employees, are also taken into account regarding the way the water is released.

6.7.2 Needs statement – Mkhuze Sugar Estates (2002)

Key interest is to maintain an assured steady flow of water for sugar production.

6.8 DEFINING NEEDS – GAME FARMING AND ECO-TOURISM, DAM PROPERTY OWNERS (2002)

Figure 6.11 shows land use around the Pongolapoort Dam, owned by EKZN-Wildlife and private land owners. Game reserve and lodge owners utilize the dam for tourism and recreation and have an interest in the way Pongolapoort Dam is managed for irrigation and artificial flood releases. Specifically, the quantity and quality of water in the dam affects tourism activities. According to the DWAF 2003 Pongolapoort Dam sustainable utilisation plan (DWAF directorate, social and ecological services), DWAF manages the dam as an irrigation and flood control dam.

DWAF has authority over the water surface area and state land immediately adjacent to the dam. Pongolapoort Dam basin, the water surface area and surrounding land was zoned by government in 1979, to be managed as a recreation park, nature and game reserve.

Economic development opportunities, e.g. public access management, commercial fishing, aquaculture programme and eco-tourism (comprising activities such as boat cruises, canoeing safaris, fishing, sport angling, houseboat experiences) are outsourced by DWAF through tenders, concessions, and management agreements.

A water user association that manages economic development and conservation activities according to the New National Water Act 1998 in this drainage region (quaternary catchment W44E) was formed in 2003.

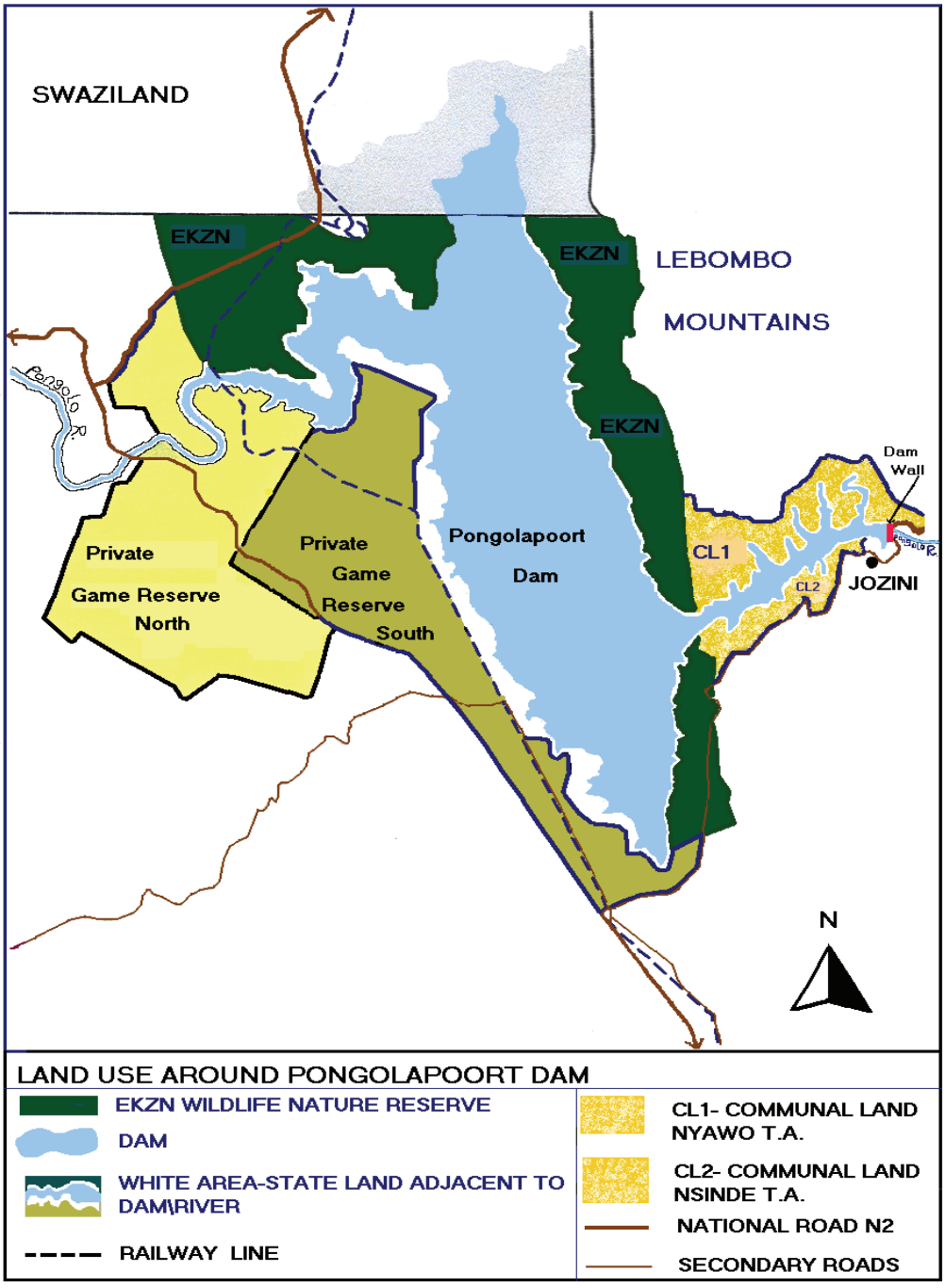


Figure 6.11: Land use around Pongolapoort Dam is mainly for public and private game reserves, for tourism and recreation (Source: DWAF database).

6.8.1 Problem statements – Game farming and Eco-tourism, Dam property owners (2002)

Peter Conant presented the following problem statement on behalf of owners of game reserves and lodges (Malcolm Thomson (EKZN-Wildlife), Brian Blevin, Koral Landman, Heinz Korse), during the stakeholder dialogue workshops (Jaganyi et al., 2003).

"*The parties located on the Pongolapoort Dam understand that the dam will regularly experience fluctuations in level due to irrigation needs, artificial flood releases, and flood attenuation. Their livelihood depends on a tourist industry. However, fluctuating dam levels do create certain problems for them.*

Fluctuating dam levels can make using the dam difficult, in terms of launching of boats, and accessing the shoreline for game viewing.

A winter release, whilst desirable in terms of creating a green lawn for grazing animals during dry periods, can be disastrous if it occurs too quickly in terms of valuable animals becoming mired in mud as they go to the water to drink, or in the case of hippo, trying to come out to feed.

While game owners understand that the dam is going to be drawn down, but there are certain times of the year that it is better for their business and for the animals that are part of the attraction for visitors. For example, the most favourable season for visitors is during the cooler months – Winter (Jun, Jul, Aug) and Spring (Sept., Oct., Nov.). Unfortunately, that is exactly the same time when there is no rainfall and no other water supply for animals except the dam. This is also the same time that downstream floodplain communities request for artificial flood release from the dam. Also the fact that the dam is managed for flood control by the dam authority – DWAF, means that the dam must be released during these months to ensure adequate capacity is left to hold back summer rains.

Because the animals depend on the dam for drinking, if the water draws down slowly during a flood release, the animals are able to continue to get to the water to drink.

But if the water draws down quickly, it exposes vast areas of soil and mud, the animals still must reach the water, but they've got a long distance of mud that they still have to go across, and many times, they get stuck in the mud, when they either have to be rescued, and in many cases they die. And this is no small matter to the game owners because some of the animals, like the white rhino, can be worth as much as R200 000-R300 000 per animal. They also depend on taking visitors on the dam in boats to look at animals, such as elephants, that are near to the edge of water and if the water is dropped quickly, they can't reach near enough for the visitors to see the animals properly.

Not only this, but in at least one case, a rapid and large release from the dam caused levels to drop to the point where animals escaped because they were able to go around fences which were not designed to accommodate such low levels.

There is also a very important sport, fishery, in the dam for tiger fish, which attracts anglers from all over the country. There are at least 2 major angling competitions each year specifically for tiger fish which attract hundreds of people who spend thousands of Rands. A release from the dam just prior to these events creates untold havoc when these people try and launch their boats and get stuck in mud. Consultation from the authorities would avoid this problem.

Timing and the rate at which a flood is released is the main issues for dam property game owners.

In summary, a release at any time of year is acceptable to these people, providing prior consultation is done, and large rapid releases are avoided at best, or prior consultation if this is unavoidable".

6.8.2 Needs statement – Game farming and Eco-tourism, dam property owners (2002)

(i) Prefer to have the dam as full as possible,
(ii) Dam water draw downs should be gradual.

6.9 UPSTREAM COMMERCIAL FORESTRY AND IRRIGATION INTERESTS

The upstream catchment is made up of the Pongolo-Bivane catchment and covers an area of 5789.79 km^2 (Schulze et al., 1996).

6.9.1 Introduction

Although the region upstream of the dam is not affected by artificial flood releases from Pongolapoort Dam and was not in the scope of the study, from a holistic perspective, it influences inflows into the dam. According to catchment management principles, activities happening in the whole catchment need to be known so that they can be accounted for in the planning of developments on a catchment scale. It is necessary to link all owners and users from the tops of the hills at the source of the river to the seashore, including foresters, farmers, nature conservationists, hydrologists, business groups, towns people, and the fishing industry (Primack, 1998). Implied here is that, if water resources management on the Pongolo floodplain is to be successful, it will need to take into account and link all activities from source to sea.

Specifically, the key challenges of the interests of upstream commercial forestry and irrigation are described, based on literature reviews, so that all other interests in the catchment can be aware of the challenges facing upstream stakeholders. This process enhances the building of a stakeholder-shared vision at the catchment scale so that through holistic linkages, the problems on the floodplain can be located within a catchment context.

6.9.2 Impacts of alien (exotic) commercial forestry and other invading species

The upper catchment of the Pongolo River falls within Southern Africa's timber belt which is climatically suitable for commercial afforestation of alien (exotic) species, mainly *Pinus*, *Eucalyptus*, and *Acacia* (Black Wattle) (Schulze, 1997). The trees are planted and processed for uses such as pulp for paper processing, saw logs, poles, mining timber, charcoal and firewood. The distribution is confined to high rainfall regions (>800 mm) of the coastal belt, mainly on the eastern side of South Africa. Hence, vast areas covering alien plantation forestry are mainly found in the source areas of the upper catchments of the Pongolo River and the Great Usutu (Fig 2.1).

DWAF have demarcated the timber belt into 12 forestry economic zones (DWAF report on commercial timber resources 2001/2002). On this basis, the catchment falls within Zone 4 – Mpumalanga South (Carolina, Eerstenhoek, Ermelo, Wakkerstroom, Piet Retief, and Waterval Boven) and Zone 5 Maputaland (Ingwavuma). In 2003, these economic zones became Mpumalanga South, Northern KwaZulu-Natal and Maputaland respectively.

Key forestry statistics with respect to area under forestry, ownership, new afforestation and conversion from forestry and other agricultural uses, is shown in Table 6.29.

Table 6.29: Commercial plantation forestry area, zones and ownership. Source: DWAF report on commercial timber resources (2001/2002; 2002/2003; 2003/2004)

	Area under afforestation (Ha)	Private sector ownership	Public sector	New afforestation (Ha)	Conversion from forestry to other agricultural uses (Ha)
2002					
National level of total commercial timber plantation area (Ha)	1,351,402 (had decreased by 0.0265% 358 Ha since 2001)	76%	24%	6 208 (increased by 12.28% 679 since 2001 5529)	3 517 (was 2 961 in 2001).
Economic Zone 4 – Mpumalanga South (Carolina, Eertenhoek, Ermelo, Wakkerstroom, Piet Retief, and Waterval Boven)	282,706 (area in 2001 270,331)	88.93%	11.07%	12,375	X
Economic Zone 5 Maputaland (Ingwavuma),	19,336 (19,247 in 2002)	0	100%	89	X
2003					
National level of total commercial timber plantation area (Ha)	1 371 625 (had increased by 1.5% 20 223 since 2002)	78%	22%	7 418	4 971
Zone 4:Mpumalanga South (Carolina, Eerstenhoek, Ermelo, Piet Retief, Wakkerstroom,	279 353 (was 282 706 in 2002)	90.8%	9.14%	0	

Waterval Boven)					
Zone 8:Northern Kwa-Zulu Natal (Dundee, Newcastle, Ngotshe, Paulpietersburg, Utrecht, Vryheid)	85 359 (was 82 382 in 2002)	96.5%	3.49%	2977	
Zone 5:Maputaland (Ingwavuma)	19 336 (was 19 336 in 2002)	X	100%	0	
2004					
National level of total commercial timber plantation area (Ha)	1 339 282 (was 1 371 625 in 2003). Area decreased by 31 342	77%	33%	1 995	4 585
Zone 4:Mpumalanga South	264 844 (was 279 353 in 2003)	90.07%	9.93%	0	
Zone: 8:Northern Kwa-Zulu Natal	91 573 (was 85 359)	96.84%	3.16%	6 214	
Zone 5: Maputaland	19 336 (was 19 336 in 2002)	X	100%	0	

The table shows that at the national level, the area under commercial afforestation was increasing from year to year until 2003. At the economic zone 8 level, in Northern KwaZulu-Natal, afforestation has continued to increase from year to year and this region lies in the upper catchment of the Pongola River.

Key environmental impacts of alien (exotic) commercial plantation forestry in South Africa are the reduction of native biodiversity and stream flow (Bosch and Hewlett, 1982; Jarvis and McNaught, 1986; Dye and Poulter, 1995; Smithers and Schulze, 1995; Le Maitre, Scott and Fairbanks, 1997; Versfeld et al., 1998). In 2001, commercial forestry in South Africa was estimated to have a consumptive water use equivalent of 7.5% of the country's water resources and expansion of the forestry industry has been regulated since 1972. Commercial forestry is liable to pay for water use as a stream flow reduction activity according to the New National Water Act 1998. Therefore, accuracy of estimation of water usage is a key factor. Using long term catchment afforestation experiments (>65 years) in the Western Cape, Scott, Prinsloo and Moses (2000) showed long term trends in water usage.

For example, the onset of significant flow reduction after planting varied depending on the structure of the competing native vegetation and the rate at which the catchment is dominated by the plantation crop. *Pine* plantations in tall native vegetation (*fynbos*) in the Western Cape and in the high altitude grasslands in the Drakensburg usually took longer to have an impact on stream flow (i.e. up to 6 years as opposed to 2-3 years without native vegetation). Once water reductions were significant, they become larger very quickly, reaching peak reductions early in the rotation, i.e. 15 years of age under *pine* and 10 years of age under *eucalyptus*. In a dry hydrological year, at one of the dry sites, flows ceased completely in the 4th year after planting.

In addition to commercial forestry, there are other terrestrial, woody alien invaders that cause the same environmental impacts on biodiversity and stream flow reduction (Table 6.30.)

Table 6.30: Top 10 alien plants found in the Sabie-Sand catchment arranged in order of decreasing invaded area. A distribution of all other alien species (33 in number) in the Sabie-Sand catchment can be seen in Versfeld et al. 1998.	
Species	**Common Name**
Solanum mauritianum	Bugweed
Lantana camara	Lantana, inkberry
Eucalyptus species	Gum trees
Psidium guajava	Guava
Pinus species	Pines
Rubus cuneifolius	American bramble
Caesalpinia decapetala	Mauritius thorn
Opuntia stricta	Australian Pest pear
Acacia mearnsii	Black wattle
Ricinus communis	Castor oil bush

Generally, effects of exotic species on native species can be devastating. Exotics outcompete native species and become abundant at the expense of native species. Exotic species displace native species through competition for limited resources; they may kill and/or eat natives to the point of extinction, or they may alter the habitat so that many natives are no longer able to persist (Macdonald, Kruger and Ferrar, 1986; Drake et al., 1989; Hengeveld, 1989; Primack, 1998).

In South Africa, the introduction of hundreds of species of alien trees has led to many populations of aggressive invaders that convert species-rich vegetation to single-species stands of trees, increasing biomass and decreasing stream flow dramatically (Macdonald, Kruger and Ferrar ,1986; Van Wilgen et al., 1997; Versfeld et al., 1998).

Models to calculate water-use have been developed, e.g.: ACRU model – Smithers and Schulze (1995); Scott and Smith (1997); Le Maitre et al. (1996); Le Maitre et al. (1997); Scott et al. (1998). Versfeld et al. (1998) reported that, on a unit area basis the incremental water use of dense alien invaders was equivalent to 1900 m^3 per hectare per year compared with 930 m^3 for commercial plantations. Invading species were found to occupy a greater land area and also consumed significantly more of the national water resource than the entire commercial forestry industry (Versfeld et al., 1998). For instance in the Sabie-Sand River catchment, it was estimated that alien plants used 146.4 million m^3 of water annually. This was more than the water use recorded in 1987 for commercial forestry (124.9 million m^3y^{-1}) or subtropical fruit irrigation (107.7 million m^3y^{-1}), and represented almost 20% of the Net MAR (732 million m^3y^{-1}) of the Sabie-Sand River catchment. During the simulation of alien plant water use, it was noticed that for several quaternary catchments water use exceeded MAR if the percentage cover of alien plants was allowed to reach 100% within the invasible area. In real terms, quaternary catchments can not sustain alien infestation at 100% cover, and the streams in these catchments would stop flowing before alien infestation reaches 100% cover. *Eucalyptus* and *Pinus* trees alone accounted for a 5% reduction in MAR within the Sabie-Sand catchment.

Current mitigation of environmental impacts of exotic plants involves (i) the physical removal of exotic invaders within catchments through a conservation project – WFW or "Working for Water Programme"

1997 implemented in 1995 under the auspices of the government DWAF, which seeks to maximize ecosystem service (the delivery of water), and to conserve biodiversity, by eliminating invading alien plants and restoring indigenous vegetation (Working for Water Programme, 1997; Van Wilgen et al., 1997). It also seeks to promote social equity through jobs and training for economically and socially marginalised people. For instance in 1998, 260,000 people in South Africa were employed by WFW programme (Hosking et al., 2002). (ii) Limiting the scale of commercial forestry expansion within catchments through the Afforestation Permit Policy Committees (APPC). In the New National Water Act, such activities will be enforced through catchment management agencies.

Hosking and Du Preez (2004) carried out a cost-benefit analysis of the WFW programme on six selected sites in the Eastern Cape province in South Africa, with the aim of assessing the economic feasibility of the programme and to establish whether it should enjoy preference above other government programmes. They found catchment management by WFW to be inefficient in all the six sites. However, they pointed out that non-water benefits were not evaluated and therefore not included in the analyses. Also known water benefits like fire damage reduction, preservation of biodiversity were not included in the calculations. However, in catchments where high consumptive demand existed, the projects became efficient if 30% cost savings could be achieved and when social discount rates were lowered, e.g. to 5%. List of costs and benefits in the study is illustrated in Table 6.31.

Table 6.31:Working for Water (WFW) programme – benefits and costs identified (Hosking and Du Preez, 2004)

BENEFITS	COSTS
Primary benefits	**Primary costs**
(i) Increased water yield (m^3/ha)	(i) Clearing, follow up operations, maintenance
Secondary benefits	**Secondary costs**
(i) Increased yield of agricultural products, e.g. increased yield of livestock carrying capacity, increased crop production for dry land and irrigated crops.	(ii) Reduction of firewood availability (alternative supplies could be obtained from indigenous sources)
(ii) Conservation and maintenance of indigenous biodiversity nurseries	
(iii) Improvement in water quality	
(iv) Secondary wood industry stimulation	
(v) Training	
(vi) Poverty alleviation	
(vii) Reduction of flood damage, fire damage and soil erosion	
(viii) Improved tourism attractiveness	

The major water users in the upper catchment of the Pongola River (Pongola-Bivane catchment) are commercial forestry and crop irrigation. No studies exist on water use by alien invaders species. These uses cause stream flow reduction which influences the water yield received for downstream users and further downstream water yield of the Pongolapoort dam.

6.9.3 Determining equitable water allocation between forestry and irrigation

Studies by Schulze et al. (1996); Schulze, Taylor and Pike (1996); and Taylor (1997) reported comparisons of water use between commercial forestry and irrigation. Models were used to show that these two land uses impact stream flow differently and impacts of irrigation were more severe than the case of afforestation especially during periods of low flows. For instance, Taylor (1997) showed that for every 1 ha of irrigated sugarcane, one needs to have 9.1 ha of *Eucalyptus grandis* plantation forest to have the same impact on stream flow reduction. The drier the catchment and season the higher the ratio.

Intensification of land use activities within a catchment that cause stream flow reduction (e.g. dams, commercial alien plantation forestry and irrigation), more so, during periods of seasonal low flows is a major concern in a water scarce county like South Africa (Schulze et al., 1996). The extent of stream flow reduction impact depends on the scale of operation; intensity of operation; physiographic factors of the land, e.g. marginality with regard to climate, soils; and location of development – upstream or downstream (Schulze et al., 1996).

For instance, the question of what can be considered equitable water allocation between commercial forestry and irrigation between upstream and downstream users (i.e. Impala Irrigation Board situated 100 km downstream) in the upper Pongola River catchment, i.e. the Pongola-Bivane catchment with a total area of 5788.79 km^2 was put to the test in a study by Schulze et al., 1996. The study was intended to add clarity towards decision making that would resolve conflict between irrigation farmers and the commercial forestry industry.

Irrigation farmers had the perception that increasing commercial afforestation in the upper Pongolo River catchment had over the years adversely affected the run off of the Pongolo River, reducing downstream flows. In 1995, DWAF approved proposals to build the Bivane Dam to enable irrigation development 100 km downstream at Impala Irrigation Board near Pongola town (Figure 6.9). DWAF then placed a moratorium on further commercial afforestation in the Pongola-Bivane catchment. On this basis, the Afforestation Permit Policy Committee (APPC) refused to grant an afforestation permit in the upper catchment but instead put a proposal to "forestry interests" to increase the capacity of the proposed Bivane Dam from 105 million m^3 to 118 million m^3 by contributing money (ten million Rands) in order to supplement the Pongola River at Pongola to provide for irrigation needs, particularly during periods of low flows. In return, irrigation farmers would withdraw blanket objections to new afforestation of up to 35,000 ha in the catchment (Bosch and Associates 1995). The Forestry Industry Association then commissioned Schulze et al. (1996) to undertake a hydrological impact study before making a decision.

Using the ACRU agro-hydrological simulation model technique (Schulze, 1995), impacts of various conditions on stream flow was assessed, particularly on low flows and baseline flows.

Schulze et al. (1995) concluded that impacts of the then present commercial afforestation on total and low flows within the Pongola-Bivane catchment, "while important locally, are masked and sometimes

overridden by impacts of other current land uses such as irrigation". At the total catchment scale, they concluded that proposed future afforestation expansion (50 000 ha) was unlikely to impact significantly on the then present stream flows.

However, they raised certain concerns that would need to be addressed before sound decisions could be made. For instance, in their study, there was little information on actual irrigation scheduling strategies on the ground, on crops irrigated or on irrigation efficiencies. Another point of caution was raised. Whether upstream land use practices existed or not, given the fact that the flow of the Pongola-Bivane system was highly seasonal (wet summers and dry winters), the storage of wet season flows in the Bivane Dam would be the only source of water to assure sugarcane yields and that these wet season flows were the only assured option available to the Pongola irrigators 100 km downstream.

Schulze et al. (1996) concluded that, even under normal climatic conditions, the then present irrigation demands could not always be met. On a long term basis, the abnormal climatic conditions, e.g. the severe El Nino-southern oscillation conditions of the early 1980s and again in the early 1990s, may have resulted in water shortages nearly every second year, as observed in the last 15 years of the 45 year simulation study, thereby enhancing the potential water crisis already found to exist for the irrigators. In addition, a water crisis for irrigators was likely to worsen given the new water laws which gives preference for the reserve (water needs for rural basic needs and for ecological needs).

If financial compensation was justified at all, it should not only be sought from the forestry industry, but also from upstream irrigators. Schulze et al. (1996) concluded that for sound decision making, many questions needed to be answered scientifically. For example, irrigation water demands, irrigation operating rules at farm and irrigation scheme scales in the light of the Pongola River's natural flow regime should be determined. In addition, the Bivane Dam's yield performance, under different operating rules at different risk levels of inflows and improved irrigation scheduling and water application efficiencies need to be determined.

6.9.4 Problems and needs statements – Pongola-Bivane catchment

Upstream was not in the scope of the study. Studies to identify water problems and needs should be initiated for the following sectors: commercial forestry, irrigation, and other relevant stakeholders.

6.9.5 Recommendations

Identify stakeholders and water related problems and needs.

Initiate catchment management processes by putting in place appropriate formal WUA structures.

CHAPTER 7: FLOODPLAIN AGRICULTURE AND GENERAL NATURAL RESOURCE USE INTERESTS

(*This chapter draws largely from results of the field research work by Salagae AM and Matiwane NF. The Masters thesis by Salagae (2007) contributed towards achievement of a Masters Degree in Environment and Development. Jaganyi J supervised both studies. Full funding for the studies came from this project. The approach to the studies and key outcomes are discussed here*).

7.1 INTRODUCTION

This chapter contributes towards the first objective of this study, which is to: "*Develop an understanding of the driving forces of the current situation and establish a shared vision for a preferred, achievable and sustainable state of the floodplain system*".

Downstream of the Pongolapoort Dam, there is a huge rural population that utilizes the resources of the Pongolo River floodplain for crops, pasture, fish and other wildlife resources (Heeg and Breen, 1982). Since 1984, the system receives annual artificial floods from Pongolapoort dam to maintain its environmental requirements, which include the support of basic human needs. To find out whether the flood releases were meeting the needs of the community and the environment, a social survey was conducted (Salagae, 2007) and supplemented by stakeholder dialogue workshops (Jaganyi et al., 2002) and focus group discussions. Community perceptions of the effectiveness of flood releases were assessed in terms of: general resource use, stream flow, water quality, subsistence agriculture and fishing.

7.2 SOCIAL SURVEY METHODS

Field research data was collected between 2002 and 2003. Therefore results captured in this chapter represent community perceptions of the system at that time. Any changes after this period can be measured against the perceptions captured here.

7.2.1 Patterns of floodplain land use

Patterns of floodplain land use for agriculture and perceptions of reduced stream flow on resource use was explored through stratified random samples of 247 households in six communities within traditional wards adjacent to the floodplain which were used as units of analysis (Fig 6.2). Sample size comprised 10% of the population in each traditional ward. Section labels relate to sub-divisions within wards assigned by the local Malaria Control Monitoring Programme of the DoH – Jozini. Location of sample sites along the river is such that Mboza is closer to Pongolapoort Dam, while Ekukhanyeni is nearer the border with Mozambique at Ndumu (Table 7.1; Fig 6.2).

Table 7.1: Social survey population sample size and location of area sampled in 2003						
Tribal Authority (TA)	**Community Name/Traditional Ward**	**Study area sample labels**	**Section labels based on DoH – Jozini**	**Population**	**No of households**	**10% of households**
Mashabane (east side of the river)	Mboza	S1	3	1114	244	24
		S2	4	996	162	16
		S3	5	617	247	24
Nyawo (west side of the river)	Mlambongwenya	S4	7	1721	295	30
		S5	9	1275	132	13
		S6	10	654	118	12
Thembe (east side of the river)	Zama-Zama\ Tete pan	S7	5	812	112	11
		S8	6	1380	316	32
	Lulwane	S9	3	976	112	11
	Bhekabantu\ Makanis	S10	5	1082	228	23
		S11	6	134	32	3
Mathenjwa (west side of the river)	Ekukhanyeni/Ndumu	S12	2	2798	448	48
Totals	**6**	**12**		**13556**	**2446**	**247**

7.2.2 Patterns of fish use

Patterns of fish use were explored through focus group discussions. The sampling size for each of the six focus group discussions was between 10-20 participants. Fishermen from the vicinity of six pans (Mzinyeni, Nsimbi-Mthikeni, Mengu, Hlanjwana, Mandlankunzi and Msunduzi) and from other pans adjacent to them participated in these workshops.

7.2.3 Transect walks

Transect walks were carried out on the floodplain during winter and summer to enable personal interaction with communities; observation of community field activities; degree of environmental disturbance to, e.g. vegetation, erosion and pan water levels. Ethnographic studies of livelihoods were used to identify the nature of resource use, various users and their perceptions and interests. This approach required the researcher to live with the communities being studied. The period of stay in the community was 3 months.

7.2.4 Stakeholder dialogue workshops

According to community development principles (Ife, 1999), best practice to 'need definition' is to integrate professionally defined needs with stakeholder-defined needs. Professionals should not define needs independently and then impose them on a community.

Community needs were defined through a stakeholder dialogue workshop where individual stakeholders presented and shared their problems (Jaganyi et al., 2002). The process served the purpose of building a shared understanding of each other's problems, perceptions, values, beliefs, needs, and should form the initial foundation for developing a common understanding on which subsequent co-management initiatives can be built. The outcome of this process was problem statement(s) based on stakeholder perceptions. Experience has shown that before groups can develop visions and goals, there must be a clear and widely recognised problem statement. The problem statement helps to establish a common understanding of the conditions and to prioritise initiatives needed to solve the problems on a catchment or sub-catchment scale.

What is reported here is the problem statements shared from a floodplain community perspective. Problem statements from other stakeholders are defined as Pongolapoort dam management concerns raised by the DWAF authority (Chapter 4); Ecological concerns raised by the conservation authority EKZN-Wildlife (Chapter 5); Water related disease problems raised by the DoH authority (Chapter 5); Agricultural development concerns raised by the DAEA authority (Chapter 6) and Upstream Pongolapoort dam property owners concerns (Chapter 6). A summary of problems from all stakeholders affected by artificial flood releases from the dam are outlined in Chapter 8 and a detail of the actual dialogue process is in Jaganyi et al. (2002).

7.3 RESULTS

7.3.1 Biographic status of communities

7.3.1.1 Age and Gender

Out of 247 respondents 151 (61%) were women and 96 (39%) were males. Respondents' ages decreased in the order of 56–65, 46-56, 26-35, 36-45, 15-25 and over 66 years (Table 7.2). More male respondents were interviewed at Tete pan (S8). The majority of respondents in the young category (15-25) were interviewed in Bhekabantu (S10).

Table 7.2: Age and Gender

Variables	**No.**	**Percentage (%)**	**Sample groups**
Gender	Male (96)	39	S1S2, S12, S7, S10, S9, S8
	Female (151)	61	S4, S6, S5, S11, S3
Age Class	15-25 (24)	9.7	S7, S8, S12, S10
	26-35 (43)	17.4	S8, S11, S12, S10
	36-45 (35)	14.2	S6, S2, S5, S1, S4
	46-55 (47)	19	S3, S9, S2, S5, S1, S4
	56-65 (73)	30	S6, S9, S2, S5, S1, S4
	> 65 (19)	7.7	S12, S10

7.3.1.2 Land allocation

Land allocation was mainly handled by the sub-chiefs (*Izinduna*) (38.1%) Once allocated, fathers can sub-divide it further to their sons (35.6%). Chiefs allocate land to people less frequently than sub-chiefs (26.3%). About 10% (25/247) of respondents indicated that they had allocated themselves land to use for cultivating crops without getting permission from anyone.

7.3.1.3 Period of residence in the study area

The length of stay of residents in the study area gives an indication of rates of migration or emigration. The overall majority of respondents (158\247) = (64%) have lived in the study area for more than thirty years. Those who have lived in the area for less than 5 years made up 5% of the responses, with the majority of these being located in S4 (Mlambongwenya) on the west side of the river. The rest have lived in the area for a period of between 6-20 years. This indicates a high rate of people moving into the area.

7.3.1.4 Distance between individual homes and the Pongolo River and pan

People's houses are closer to the pans than they are to the river. During periods when the pans are dry or too salty, they have to walk long distances (8-10 km return) to reach the river for fresh water (e.g. the majority in S3, Mboza section 3). Gender analysis revealed that on average more female respondents perceived the river and pans to be very far while men perceived it to be in the close-far range. This can be attributed to the fact that women frequently utilize these resources more often than men do. It was observed that women spent many labour hours per day collecting drinking water, bathing, and cultivating food crops.

7.3.1.5 Family size

Table 7.3 shows how the family size is distributed across the sample groups. Large families (> 16) reached maximum numbers in S12 (Ndumu), while small families (<3) were highest in S2 (Mboza section 2), which is closer to the dam where urban and agricultural irrigation developments are well established.

Table 7.3: Household size

Variables	**Percentage (%)**	**Sample groups**
< 3 (9)	3.64	S8, S4, S5, S3, S2
4-5 (57)	23.08	S6, S7, S11, S10, S12
6-10 (110)	44.53	S8, S4, S5, S3. S2, S1
11-15 (40)	16.19	S6, S7, S11, S10, S9
> 16 (31)	12.55	S10, S9, S12

7.3.1.6 Occupation

The structure of the total responses under this category indicates that the majority are subsistence farmers while very few are commercial farmers. Those who are unemployed outnumber those with jobs as farm labourers (Table 7.4).

Table 7.4: Occupation		
Subsistence farmers (103)	Health workers (8)	Security guard (6)
Unemployed (49)	Builders (5)	Drivers (4)
Farm labourers (32)	Temporary jobs (13)	Commercial farmer (4)
Scholars (30)	Fishermen (4)	Teachers (2)
Hawkers selling fish or sugar cane (13)	Shopkeepers (4)	Traditional healer (1)
Looking after cattle (11)	Game ranger (5)	Pastor (1)
Domestic worker (11)	Sand mining (6)	Policeman (1)

7.3.1.7 Income

Earnings from the informal sector depend on the season when crop produce is available, which means that in some months there is no income. Most (58) respondents' income is between R501-R1000, followed by those who earn less than R500 (34), then R1001-R2000 (21) and lastly those who earn R2001-R4000 (9). No one had a monthly income of more than R6000. Most respondents within communities sampled (Table 7.5) earn between R501 and R1001 per household. With respect to external sources of income, 46 respondents are pensioners, 35 have grants from the government and state welfare and 7 depend on relatives who are working.

Table 7.5: Income									
	Income						**Other source of income**		
	< R500	R501-R1000	R1001-R2000	R2001-R4000	R4001-R6000	> R6001	Pension	Relative grant	Government grant
Mboza	6	14	6	2	0	0	9	3	7
Mlambongwenya	9	15	5	1	1	0	8	1	6
Zama Zama	10	9	6	3	0	0	7	1	3
Lulwane	2	3	2	0	0	0	1	0	0
Bhekabantu	4	9	2	1	0	0	12	0	13
Ndumu	3	8	0	2	0	0	9	2	6
TOTALS	34	58	21	9	1	0	46	7	35

When communities were asked whether they have jobs, only a few (103) said they were farmers (see section 7.3.1.6). However, when asked if they grow crops, respondents indicated that most (210/247) grow crops for subsistence use, out of which 55 and 54 buy and sell what they produce (Table 7.3.8). Therefore, these results support the fact that the floodplain community is mainly dependent on a

subsistence farming economy. A smaller proportion of respondents indicated dependence on a cash economy.

7.3.1.8 Household roles

An analysis of roles and responsibilities based on gender shows that various household activities, such as collecting and gathering, looking after the house, crop growing activities and crop growing decisions, were undertaken by mainly women. Men mainly undertook making household decisions where money is involved.

7.3.2 Perceptions of general floodplain resource use

7.3.2.1 Use of floodplain resources

Three areas of the floodplain (river, pan and land) provide resources (Fig 4.2 and Fig 4.3). The perceived importance of use of floodplain resources is illustrated in Table 7.6. The results show that communities perceive the floodplain as a very important resource (74.34%). Overall importance in decreasing order of use is: agriculture (crops), drinking, firewood, fishing, bathing and washing clothes, livestock watering and grazing, medicine, harvesting grasses and reeds for building houses and crafts, wild starch food, bush meat, cultural ceremonies and sand mining. Field observations of the frequency of activities carried out on the floodplain were found to be generally similar to the importance rating of resource use based on perceptions.

Table 7.6: Perception of the general use of floodplain resources

	Don't Know	**Not important**	**Important**	**Very Important**	Totals
Cultivating crops	0	0	8	239	247
Drinking	0	5	15	227	247
Watering crops	0	5	15	227	247
Firewood	0	0	20	227	247
Fishing	0	5	15	227	247
Bathing/Swimming/washing clothes	0	5	25	217	247
Livestock grazing/watering	0	4	29	214	247
Wild fruit and medicine	0	3	30	214	247
Grasses and reeds harvesting	7	15	56	169	247
Water tubers (Madumbe)	5	9	90	143	247
Bush meat	26	37	54	130	247
Cultural ceremonies	33	67	44	103	247
Sand mining	124	59	14	50	247
Totals	**195**	**214**	**415**	**2387**	**3211**
Percentage %	**6.07%**	**6.66%**	**12.92%**	**74.34%**	

7.3.3 Floodplain land use for agriculture

7.3.3.1 Cultivation

Heeg and Breen (1982) reported that the floodplain covered 13 000 ha before dam developments, pre-1966. However, there are no records of the extent of cultivation on the floodplain during that period. Post dam developments after 1972, from 1970 aerial photographs, showed 1 344 ha was visibly disturbed by cultivation (Buchan, 1988). Furness (1988), re-mapped the area in 1985 and found 2 650 ha under cultivation (see aerial picture of farmlands Fig 4.3). Buchan (1988) meanwhile recorded 2 885 ha under cultivation in the same year, 1985. Therefore, the area under cultivation approximately doubled in 15 years. The 1985 values indicated that 41-45% of the floodplain that could be used for agriculture was being used, or had recently been cultivated. These figures were compared to the extent of cultivation trends on dry land areas within one kilometre 'off the floodplain', where an estimated 80% of other cultivation in the area occurs, and it was found that little change had taken place between 1970 (3 903 ha) and 1985 (4 251 ha). In total, land under cultivation on and off the floodplain was (1 344 + 3 903) =5 247 ha in 1970 and (2 885+ 4 251) =7 136 ha in 1985. Furness (1981) indicates that the ratio of the area cultivated on the floodplain to off-floodplain increased from 0.3:1 to 0.6:1 between 1970 and 1985 respectively.

A rough estimate of the extent of cultivation on the floodplain using 2001 aerial photographs found a value of 2 625 ha, which is close to that found by Furness (1988), 2 650 ha. This figure implies that between 1985 and 2001, all land that could possibly be used for agriculture on the floodplain was being used. The areas with the highest agricultural potential were being exploited to full capacity, i.e. between Mzinyeni to Pongolwane and Ngodo to Mandlakunzi (Table 7.7).

Table 7.7: Estimation of extent of cultivation based on interpretation of 2001 aerial photographs of the floodplain land cover.

Location	**Mzinyeni to Pongolwani area**	**Ntunte, Nsimbi and Mthikeni area**	**Lusundu, Tete, Maleni and Khangazini area**	**Mengu to Sivunguvungu area**	**Shalala to Bumbe area**	**Ngodo to Madlankunzi area**	**From Madlankuzi to Ndumu game reserve fence**	**Totals**
Cultivated area without trees (ha)	411	185	103	42	93	329	0	**1163**
Cultivated area with trees (ha)	380	185	165	125	165	380	62	**1462**
Totals	791	370	268	166	258	709	62	**2625**

In the 1979 aerial photographs, there were no visible fluvial deposits on the floodplain. In the 2001 aerial photographs, fluvial deposits had accumulated in some areas that used to be cultivated.

To investigate perceptions of cultivation, communities were asked to state where crops are cultivated. Out of 226 respondents, the majority (63.16%) stated that they cultivated both 'on the floodplain' and 'off the floodplain', followed by 28.95% that cultivated 'on the floodplain' and a small proportion who cultivated 'off the floodplain' only.

Communities were then asked how much land they cultivated. Plots cultivated on the floodplain ranged from between 0.1 ha-3 ha with about 357 ha cultivated by 210 respondents. Plots cultivated on dry land 'off the floodplain' ranged from 1 ha-5 ha with about 277 ha cultivated by about 162 respondents. The majority had cultivated these lands for a very long time.

Most of the land cultivated on the floodplain is between the river and floodplain pans. Due to the reduced stream flow that is experienced most of the year (Chapter 4), people cultivated in pan inlets, in pan outlets, inside some shallow pans, and very close to pan margins because these areas retained adequate soil moisture to support crop growth (Fig 7.1-7.2). For instance, the transect walk revealed that out of 43 cultivated sites: 54% were situated <10 metres from pans or rivers; 23% were at sites >100 metres, and 23% at sites between 10-100 metres (Fig 7.3-7.4).

Riparian forest, adjacent to rivers and pans, had been cleared and shifting cultivation practiced (Fig 7.5-7.6). Land was tilled using mainly animal power (137), followed by humans (128), and less frequently a tractor (63). No – till practised when crops were planted directly as floods receded (43).

When communities were asked to state where the source of water for watering crops came from many (72%) stated that it came mainly from rainfall, which is then supplemented by irrigation through DWAF artificial flood releases from the dam and by direct abstractions from the rivers and pans. Communities were then asked to prioritise what they felt was the most important water source for growing crops: 50% said the river, 33% DWAF artificial flood release and 17% said pans. The most frequent irrigation methods used, in order of importance, were: 53% bucket (a bucket is used to carry water from a river or pan on the head or in a wheel burrow to fill up a bigger container located adjacent to the garden from which crops are watered); 26% annual artificial flood irrigation from DWAF; 18% petrol pumps placed in the river or pans to drive sprinklers; and 3% furrows dug in the ground to direct water from rivers or pans to gardens (Fig 7.7-7.8).

Communities were asked whether they felt that every household cultivates on the floodplain. Out of 198 responses, 83% agreed, 10.6% disagreed, 5% were not sure and 0.15% did not know.

The majority (98) felt that cultivation was increasing. Communities were then asked to give reasons why cultivation of land on the floodplain was increasing. Of these respondents, 50% indicated that the increase was due to suitable conditions for crop production (soil moisture, fertile soil, water close by and access to land); 33% indicated that this was due to the high population growth, high unemployment, poverty and the need for food; 12% felt that cotton cultivation and good income returns from its production have prompted people to increase cultivation on the floodplain; 5% felt that they live close to the floodplain and that is why they are cultivating on the floodplain. People felt that the constraints of cultivating on the floodplain were such that young people were no longer interested in farming, droughts

were severe, competition between land for pasture and for crops was increasing, to the extent that animals frequently destroyed crops in the fields and that the floodplain was no longer as productive as it used to be in the past.



Figure 7.1: Cultivation inside pan beds (Ngodo – Bumbe pan, winter, June 2005). Note fever tree remnants in the background, which indicate the end of pan margins.



Figure 7.2: Cultivation of cotton in pan inlet and outlet, situated between the Pongolo River and Nsimbi-Mthikeni pan complex (February, summer 2003).



Figure 7.3: Cultivated land at Pongolwane pan. Note strip of grazing pasture left between pan and ploughed land (June, winter 2005).

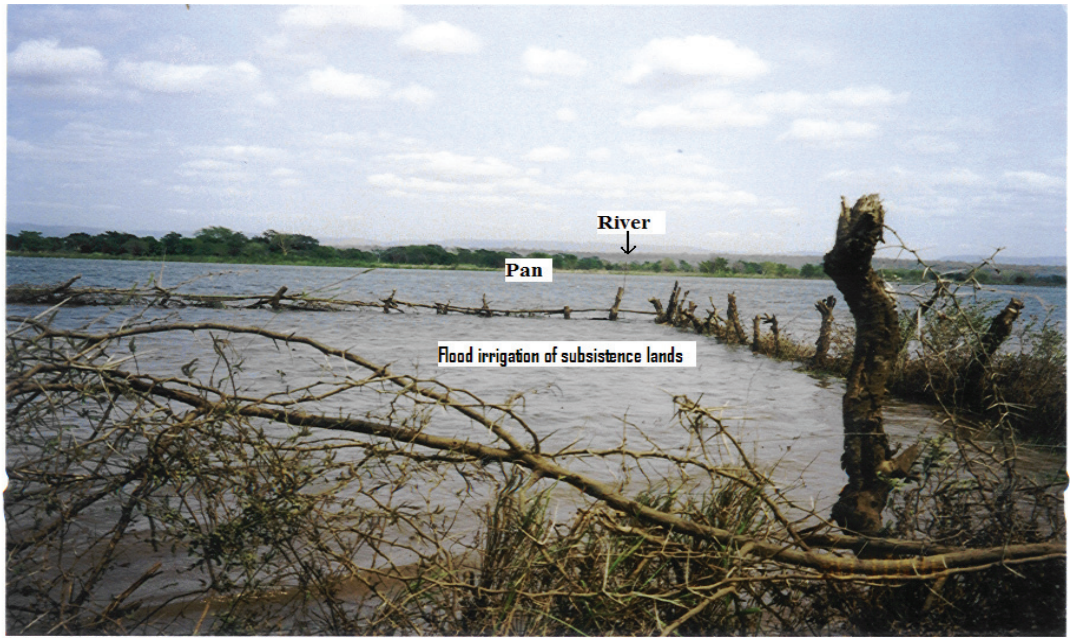


Figure 7.4: Flood irrigation of cultivated land after end of September artificial flood release from the dam (early October, spring 2005).



Figure 7.5: Undisturbed floodplain vegetation located in a protected area. Banzi pan in Ndumu game reserve showing undisturbed typical floodplain vegetation (riparian forest) in its natural form (May, autumn 2002).



Figure 7.6: Disturbed floodplain vegetation outside protected area. Pan margin vegetation found between the river and pans has been cleared to grow maize. Remnants of fever trees, which characterise floodplain vegetation, can be seen at the back of the picture (December, summer 2002).



Figure 7.7: Crop watering with a bucket is the most widely used method of irrigation (Ngodo – Bumbe pan, winter, June 2005).



Figure 7.8: Crop watering – furrows dug in the ground to direct water from rivers or pans to gardens (Ngodo – Bumbe pan, winter, June 2005).

7.3.3.2 Crop quantities and values

Crops grown on the floodplain are shown in (Table 7.8). The table shows that the floodplain has value in terms of crop production. Trends in perceptions, with respect to crop yields, show that almost all respondents (244\247) 99% felt that crop yields in the past were much higher than at present. They felt that crop yields would decrease in the future due to the fact that floods were decreasing. They felt that more recently soil moisture dries out very quickly after a flood. Many also expressed the opinion that insect pests were increasing over the years. Some of these insect pests were new to the communities, as they had never been observed before.

Crops found to be most frequently cultivated on the floodplain during the month of December were, in order of importance, maize, bananas, cotton, pumpkins, beans and sugar. Table 7.8 gives a rough guideline on quantities harvested and their values in SA Rands because few people responded to this question.

Most respondents consume all the produce that they grow. Some also sell and buy crop produce. Crop produce bought comes from within and from outside the floodplain. The crop produce from outside the floodplain is obtained from Jozini (13 respondents), home gardens (10 respondents) that are off the floodplain, Makhathini irrigation scheme and the Mjindi farms (8 respondents), and Ngwavuma, KwaNgwanase, Swaziland and Mozambique (especially maize) and Manguzi (2 respondents each).

Table 7.8: Crops grown on the floodplain and their values (2003). Madumbe and Mazibu are aquatic hydrophyte communities (e.g. Madumbe is water chestnut *Trapa Bispinosa* and Mazibu is a *Nymphaea* species)

	0-500 Kg/ha	**501-1000 Kg/ha**	**>1000 Kg/ha**	**Price/quantity (R/Kg)**
Maize	23	5	9	R100-R150\50Kg; R2\cob
Cotton	3	2	2	R500-R800\Bail
Sugar cane	6	1	3	R1\stick
Cabbage	10	1		R25\25Kg
Beans	7	2	1	R200\50Kg
Pumpkin	4	1		R2.50-R10
Sweet potatoes	3			R3-R5\Kg
Groundnuts	6		1	R150-R300\50Kg
Bananas	2			R30\50Kg; 50c each
Mangoes	4			R35\50 Litre
Tomatoes and onions	4			Tomatoes – R40\crate; Onions – R2.50\Kg
Others				
Cassava				
Spinach				R2.50/bunch
Pawpaw				R4.50/6
Madumbe				R12/5 litre bag
Mazibu				

7.3.3.3 Crop calendar

Maize is the main staple food. The extent of cultivation of the food crops maize and sweet potatoes is illustrated in Fig 7.9-7.10; bananas and pumpkins (Fig 7.11-7.12); and cash crops sugarcane and cotton (Fig 7.13-7.14). It was observed that cotton fields on the floodplain were mainly in fields that are located closer to the Makhatini Irrigation Scheme, specifically fields around Pongolwane-Nsimbi-Mthikeni areas. The Makhatini Cotton Company is located on the irrigation scheme and provides a cotton gin and a ready market for farmers. Floodplain fields in the mid reaches (Tete, Mengu, Shalala and Sokhunti) and lower reaches (Nomanini, Ngodo, Bumbe and Mandlankunzi) had no cotton fields on the floodplain. Cotton was cultivated off the floodplain in the lower reaches.

A crop calendar refers to the process of getting the seed, preparing the land, planting, applying fertilizers and pesticides, harvesting, and marketing of crops. A crop calendar chart for all crops showed that various crops are planted and harvested throughout the year. Crops are mainly planted in late winter and spring and harvested in summer. However, comparison of the crop calendar between the food crop, maize, and the cash crop, cotton, shows that cotton remains on the floodplain after maize has been harvested (Table 7.9), the reason being that cotton has a longer growing season (180-210 days) than maize (120-140 days) (DoA, 1994). Seasonal change also means that the cotton crop grows sub-optimally (Schulze, 1997), taking much longer to ripen.

Table 7.9: Crop calendar of maize and cotton on the floodplain

MAIZE	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Land preparation and planting	x										x	x
Application of pesticides	x	x										
Harvesting			x	x	x	x						
COTTON												
Land preparation and planting	x	x									x	x
Application of pesticides	x	x	x									x
Harvesting							x	x	x	x		



Figure 7.9: Food crop – maize fields covering an extensive area near Pongolwane pan (December summer 2002).



Figure 7.10: Food crop – sweet potato fields covering an extensive area near Pongolwane pan (February 2003).



Figure 7.11: Bananas and sugar cane fields. Pongolwane, June 2005.



Figure 7.12: Pumpkins grow freely almost everywhere on the floodplain. The three young men are undergraduate students from the University of KZN who participated in the floodplain household social survey and paused for a picture with a family.



Figure 7.13: Cash crop – sugarcane fields near Pongolwane (June 2005).



Figure 7.14: Cash crop – cotton fields grown near Pongolwane (June 2005).

7.3.3.4 Impact of cotton crop calendar on flood releases

The fact that cotton stays longer on the floodplain has brought about major conflict among floodplain communities over timing of DWAF annual artificial flood releases from the dam. Due to reduced flows and severe plant water stress that is currently experienced on the floodplain, which increases during periods of seasonal low stream flow (July, August, September) (Schulze, 1996), coupled with the fact that some pans dry up during these periods or reduce greatly in water level and quality, e.g. high salinity, communities in the mid and lower reaches of the floodplain usually request a flood release as early as July or August to flood irrigate subsistence lands in preparation for planting a new crop and to freshen up the pans for drinking, watering crops and livestock. On the other hand, floodplain communities in the upper reaches of the floodplain prefer flood releases in September after all cotton has been harvested. DWAF artificial flood release meetings with communities are held annually where all stakeholders affected by artificial flood releases from the dam meet to discuss and negotiate releases on the basis of their needs.

An analysis of minutes of these meetings, in addition to the information gathered while participating as an observer, revealed the following key points:

The distance from Pongolapoort Dam to the border with Mozambique at Ndumu is about 112 km. Meetings were held at Mboza village which is located halfway, about 60 km between Pongolapoort Dam and Ndumu. The implication is that because many floodplain communities are resource poor subsistence farmers, those living in the far reaches of the floodplain, where cotton is hardly found on the floodplain, and come from the following TA wards (Mbangweni, Bhekabantu, Kwandaba, Makhanis, Ekukhanyeni and Ndumu), require transport to get to the meeting venue. Unless transport was provided by DWAF, many people from the communities of the lower reaches of the floodplain, where cotton is not found, rarely made it to the meeting venue. Likewise, few people from communities in the middle reaches of the floodplain (Lulwane, Zama Zama and Shemula), where cotton is rarely found, made it to the meeting venue. However, many people in the upper reaches of the floodplain (Mboza, Hlokohloko, Hlazane, Kwashukela, Welcomme and Madonela), which are not only located closer to the meeting venue but also where cotton is mainly grown, were able to attend meetings easily and often dominated DWAF annual flood release meetings. The implication is that the voice of cotton growing households dominated the meetings. Hence, decisions made seem to be in favour of cotton farmers. For example, from 2000 onwards, DWAF annual flood releases have happened mainly in September, after all cotton has been harvested, while communities in the mid and lower reaches of the floodplain usually requested a flood release earlier in July or August during the seasonal periods, when stream flow is naturally very low (July, August, September).

The question of flood release timing needs among the various communities and perceptions of impacts of artificial stream flow was then explored under stream flow perceptions.

7.3.4 Stream flow perceptions

7.3.4.1 Flood timing perceptions

It was important to find out how communities perceive stream flow changes because resource productivity depends upon annual flooding of the floodplain system. The natural seasonal flooding patterns (timing, duration, and volume) were altered after the dam was built. Understanding changes in peoples' perceptions and their subsequent actions or attitudes will enable corrective measures to be put in place. To track changes in stream flow perceptions, communities were initially asked to state which months of the year they got rainfall. Responses for the various communities sampled showed similar patterns with measured rainfall, where 80% falls between October and March. Communities were then asked about timing of natural floods and the majority of responses showed that perceptions had mainly shifted from natural seasonal patterns (i.e. big flood in February followed by a relatively smaller flood in December) to more artificial trends that can be linked to flood release timing from the dam. However, there were still a few respondents, mainly from the older age group >55, who still remembered the natural flooding patterns. The implication is that communities will need to be educated about the benefits of seasonal flooding patterns.

Finally, communities were asked to state at what time of the year they desired (wants) to have artificial floods (Fig 7.15a). Overall results show that every month of the year was mentioned. Even within community sections, there were variations in desired months for floods. When sections within a community sample are grouped, results show that the majority of respondents in the Mlambongwenya, Zama-Zama, Bhekabantu and Ndumu communities want artificial floods in August (winter), whereas majority of respondents in Mboza and Lulwane want artificial floods in September (spring). Note that many respondents around Mboza grow cotton on the floodplain.

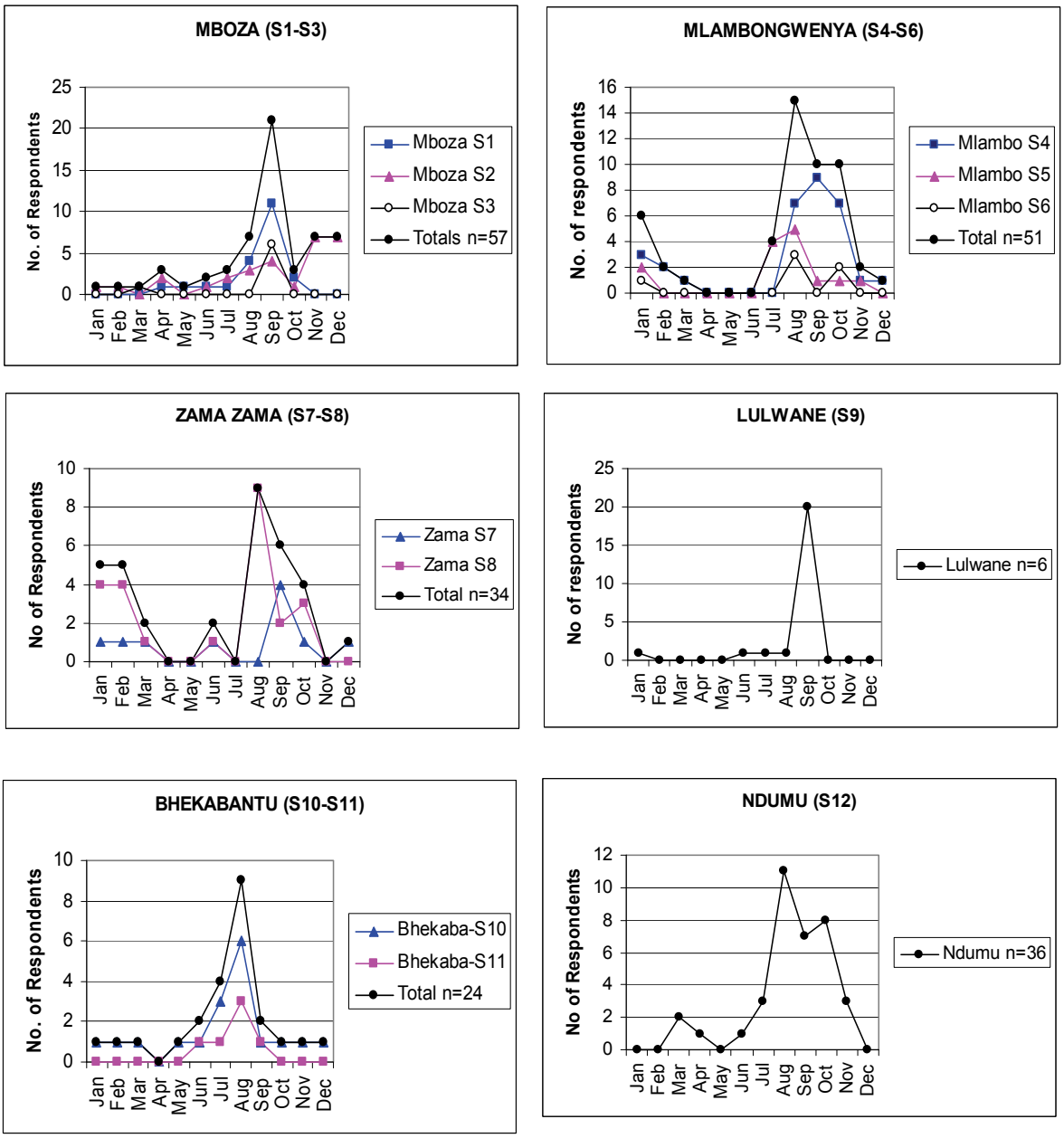


Figure 7.15a: Artificial flood release 'wants' Total N value=208.

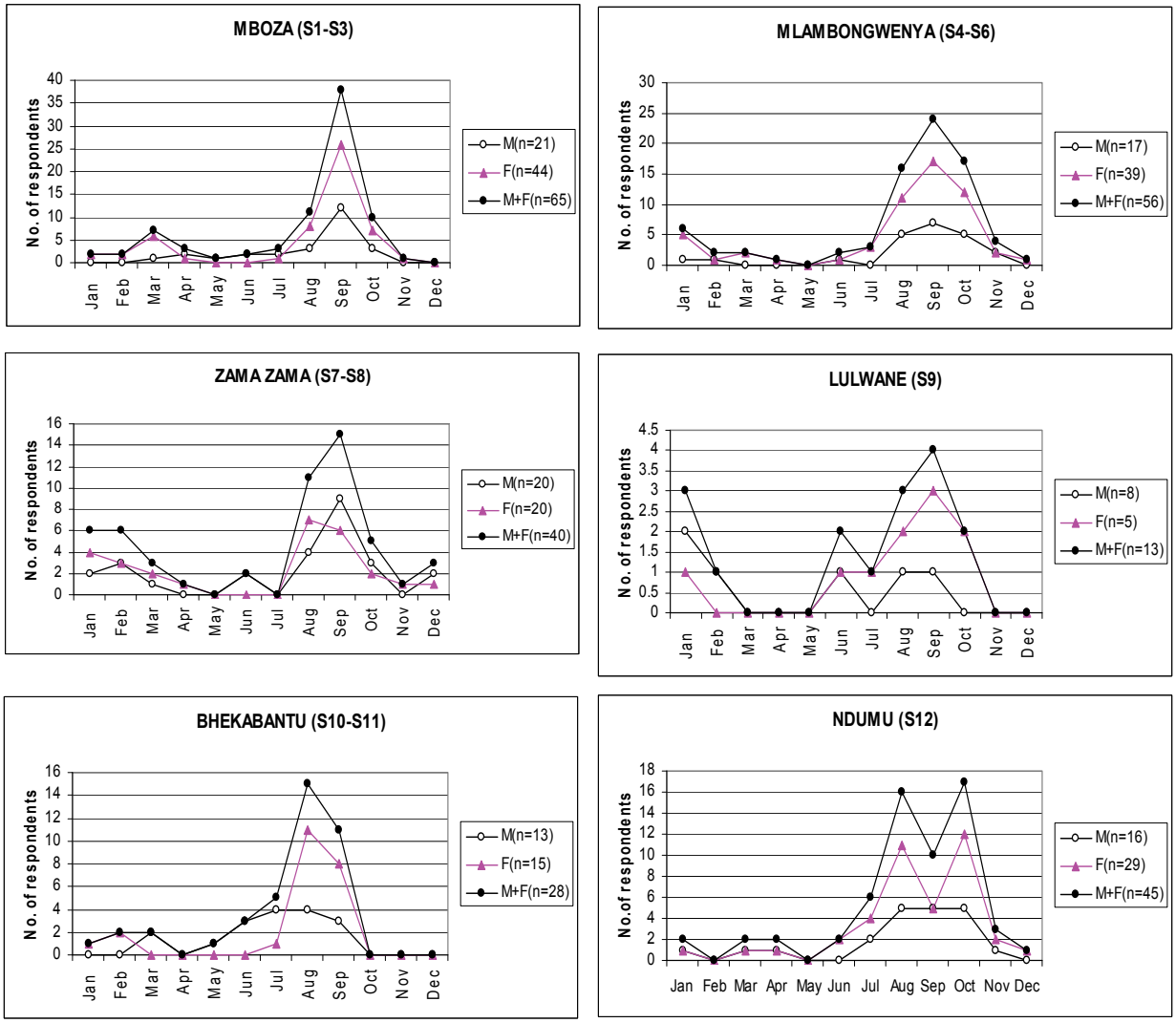


Figure 7.15b: Flood timing wants based on gender

At the overall floodplain scale, when respondents' artificial flooding 'wants' are grouped according to seasons (Table 7.10), spring 'wants' (from September to November) are the highest followed by winter (June to August), summer (December to February) and lastly autumn (March to May). Specifically, flooding 'wants' are highest in September, followed by August then October.

Table 7.10: When would you really like to have artificial floods released by DWAF? (**1**= want flood release; **0**= no flood release)												
	Spring			**Summer**			**Autumn**			**Winter**		
	Sept	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**
Mboza S1	1	1	0	0	0	0	0	1	1	1	1	1
Mboza S2	1	1	1	1	1	1	0	1	1	1	1	1
Mboza S3	1	0	0	0	0	0	1	0	0	0	0	0
Mlambongwenya S4	1	1	1	1	1	1	1	0	0	0	0	1
Mlambongwenya S5	1	1	1	0	1	0	0	0	0	0	1	1
Mlambongwenya S6	0	1	0	0	1	0	0	0	0	0	0	1
Zama – Zama S7	1	1	0	1	1	1	1	0	0	0	0	0
Zama – Zama S8	1	1	0	0	1	1	1	0	0	1	0	1
Lulwane S9	1	0	0	0	1	0	0	0	0	1	1	1
Bhekabantu S10	1	1	1	1	1	1	1	0	1	1	1	1
Bhekabantu S11	1	0	0	0	0	0	0	0	0	1	1	1
Ndumu S12	1	1	1	0	0	0	1	1	0	1	1	1
Months Total (1)	**11**	**9**	**5**	**4**	**8**	**5**	**6**	**3**	**3**	**7**	**7**	**10**
Months Total (0)	**1**	**3**	**7**	**8**	**4**	**7**	**6**	**9**	**9**	**5**	**5**	**2**
Seasons Total (1)			**25**			**17**			**12**			**24**
Seasons Total (0)			**11**			**19**			**24**			**12**

When artificial flood timing 'wants' are compared with natural seasonal flood timing, there is a distinct shift in attitude from natural seasonal summer floods to spring and winter flooding (Fig 7.16). Somebody wants a flood every month of the year. This fact is central to current conflicts within floodplain communities.

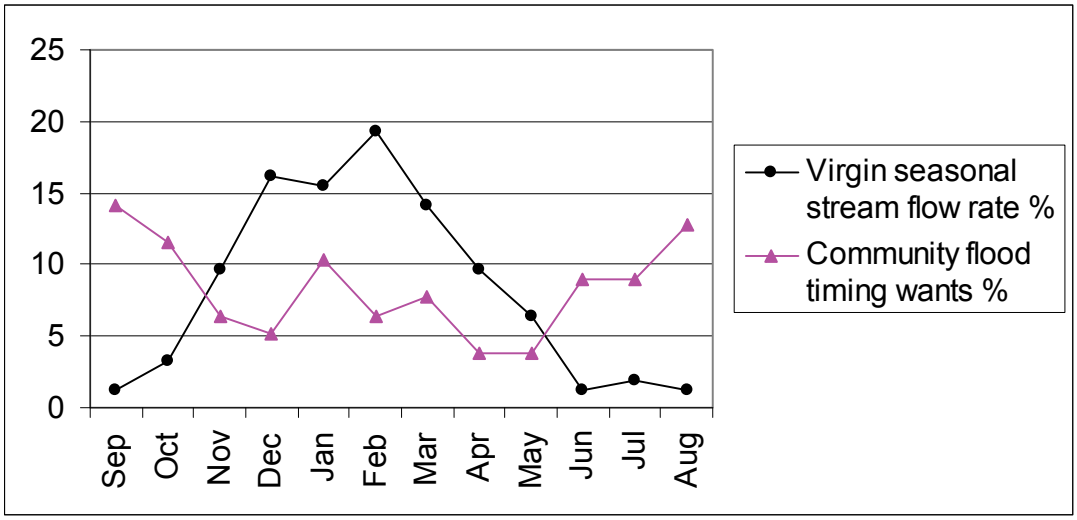


Figure 7.16: Artificial flood timing wants grouped according to seasons and compared with virgin stream flow rates. Sept-Nov (spring), Dec-Mar (summer); Apr-Jun (autumn); Jul-sep (winter).

7.3.4.2 Flood timing 'wants' based on user groups

Preferences of artificial flood timing 'wants' were then quantified based on various user groups, namely: gender, crop cultivators, livestock owners, fishing, and household activities (e.g., collecting water).

Gender analysis showed that flood timing 'wants' between men and women is the same for all the user groups (Fig 7.15b). However, flood timing 'wants' based on user groups was not easy to discern because the majority of respondents are involved in more than one activity so as to diversify food security strategy, with crop cultivation playing a central part. Communities felt that they wanted floods to stay on the floodplain for a period that did not interfere with the crop growing season. Those who fish and grow crops knew that the bigger the flood and the longer it stays on the floodplain the higher the fish production. Therefore, in order to balance the two activities, crops and fish, they felt that dam walls should be built around pans to hold water in the pans for longer periods. However, it must be pointed out that dam walls and many hydraulic structures have been found to cause more environmental problems than they solve (WCD 2002). If implemented at all, mitigating negative environmental impacts that they cause implies that they must be designed differently, so that they can imitate natural rhythms more closely (Rosenberg, 1995). From analysis of the data, crop cultivation was the main activity that determines flooding period. This is because where crop cultivation appeared there was a high peak of flood timing 'wants'. For other specific activities carried out on the floodplain, the majority of respondents indicate that they prefer flooding to be done around late winter (August) and early spring (September). These are periods of low flows and hence communities are desperate for floods to irrigate the land and to freshen up the pans. A few respondents, whose activities are mainly fishing, indicated that they would like flooding during natural flooding times, i.e. around summer (December, January and February) and early autumn (March). However, the majority do not want floods around this time because crops are still on the floodplain.

7.3.4.2.1 Summary of flow timing perceptions

Rainfall and seasonal flooding patterns perceived by communities generally mimic those of nature. However, the desired flood timing patterns, indicated by the majority of respondents, show significant shifts away from the natural seasonal flood timing patterns. For example, at the overall floodplain community scale, the majority (66%) of communities who are largely non-cotton growing households want floods in August (late winter). Cotton growers (30%) want floods in September (early spring). There were a few individuals who desire the natural summer flooding pattern, and these were found to be mainly fishermen (3%). At the individual community level, the majority want floods in September (spring), followed by August (winter). This pattern does not change within the various user groups (gender, crop farmers, livestock owners, fishing and domestic activities). Crop cultivation determines flood release timing because floods can only be released after all crops have been harvested.

7.3.4.3 Perceptions of impacts of dam hydraulics on the system

The majority of respondents, both at community section scale and at overall floodplain community level, agree that there are significant changes that they have observed before and after the dam was built. Overall impacts appear to be significant (Table 7.11). For example, pans are filling up with soil (140); productivity of cultivated land is decreasing (168); productivity of grazing areas is decreasing (158); the main river channel is becoming narrower (143); the river edge is becoming very steep (142); and the riverbed is becoming deeper (123). Such impacts have significant implications on flood volume released from the dam. For example, a deeper riverbed may mean that more flood volume is required annually to fill up the main river channel so that flooding can take place.

Table 7.11: Perceptions of impacts of dam hydraulics on the system

	Pan filling up with soil				**Pans drying up quickly**				**Productivity of cultivated land decreasing**				**Productivity of grazing areas decreasing**			
	Don't know	Disagree	Agree slightly	Agree	Don't know	Disagree	Agree slightly	Agree	Don't know	Disagree	Agree slightly	Agree	Don't know	Disagree	Agree slightly	Agree
Mboza	4	3	8	32	7	3	4	33	3	9	1	44	6	7	3	34
Mlambo-	4	9	0	38	0	7	3	43	0	7	7	39	2	3	8	40
Zama-	1	12	7	20	0	4	4	30	2	5	1	30	2	4	1	32
Lulwane	0	3	2	6	0	0	1	11	0	0	1	10	0	0	0	11
Bhekaba-	5	1	2	13	2	5	6	11	8	5	3	6	14	2	1	1
Ndumu	0	13	1	31	0	5	1	39	0	2	2	39	0	3	2	40
TOTAL	**14**	**41**	**20**	**140**	**9**	**24**	**19**	**167**	**13**	**28**	**15**	**168**	**24**	**19**	**15**	**158**

	Main River channel becoming narrow				**River edge becoming very steep**				**Riverbed becoming deeper**			
	Don't know	Disagree	Agree slightly	Agree	Don't know	Disagree	Agree slightly	Agree	Don't know	Disagree	Agree slightly	Agree
Mboza	5	8	2	26	5	7	11	24	7	8	6	19
Mlambo	4	4	4	39	8	3	4	35	10	8	2	32
Zama-	4	3	2	26	2	3	3	29	1	4	4	26
Lulwane	0	2	1	9	0	2	1	8	0	3	1	6
Bhekaba-	8	7	1	7	9	6	1	7	7	5	5	4
Ndumu	3	4	0	36	1	3	4	39	3	2	3	36
TOTALS	**24**	**28**	**10**	**143**	**25**	**24**	**24**	**142**	**28**	**30**	**21**	**123**

7.3.4.4 Perceptions of impact of flooding on pans, cultivated and grazing areas

When asked how long pans, cultivated and grazing areas should remain flooded or be in contact with the river in a year (Table 7.12), a large number of respondents for pans (25), cultivated areas (14) and grazing areas (11), indicated that in the past these areas were in contact with the river between 2 and 4 weeks. At

present, most respondents (19) indicated that, the pans are in contact with the river between 2 to 4 weeks per year. For cultivated areas and grazing areas, most respondents, (19) and (11) respectively, indicated that these areas are in contact with the river between 1 to 2 weeks per year. Regarding the future, most respondents indicated that they did not know how long these areas should remain flooded. However, among those who responded, most indicated that it should be less than 2 weeks.

Table 7.12: How long should the pans, cultivated areas and grazing fields remain flooded or be in contact with the river in a year?

PANS

	Past				**Present**					**Future**				
	1–2 weeks	2-4 weeks	3 months	6 months	<7 days	1-2 weeks	2-4 weeks	3 months	6 months	< 7 days	1-2 weeks	2-4 weeks	3 months	6 months
Mboza	-	6	0	1	2	1	7	2	2	-	0	0	-	0
Mlambo-	-	12	0	0	0	9	7	0	0	-	3	0	-	0
Zama-	-	2	0	0	0	0	2	0	0	-	0	2	-	0
Lulwane	-	1	0	0	0	1	0	0	0	-	1	0	-	0
Bhekaba	-	0	1	2	0	0	0	1	1	-	1	0	-	1
Ndumu	-	4	0	1	1	0	3	0	1	-	0	0	-	0
TOTAL	**-**	**25**	**1**	**4**	**3**	**11**	**19**	**3**	**4**	**-**	**5**	**2**	**-**	**1**

CULTIVATED AREAS

	Past				**Present**					**Future**				
	1-2 weeks	2-4 weeks	3 months	6 months	<7 days	1-2 weeks	2-4 weeks	3 months	6 months	< 7 days	1-2 weeks	2-4 weeks	3 months	6 months
Mboza	0	4	-	-	6	4	3	-	-	0	0	0	-	-
Mlambo-	0	8	-	-	0	8	5	-	-	5	0	0	-	-
Zama-	1	1	-	-	0	2	0	-	-	0	1	1	-	-
Lulwane	1	0	-	-	0	1	0	-	-	0	1	0	-	-
Bhekaba-	1	1	-	-	1	1	0	-	-	0	1	1	-	-
Ndumu	0	0	-	-	0	1	0	-	-	0	0	0	-	-
TOTAL	**3**	**14**	**-**	**-**	**7**	**17**	**8**	**-**	**-**	**5**	**3**	**2**	**-**	**-**

GRAZING AREAS

	Past				**Present**					**Future**				
	1-2 weeks	2-4 weeks	3 month	6 month	<7 days	1-2 weeks	2-4 weeks	3 months	6 months -	< 7 days	1-2 weeks	2-4 weeks	3 months	6 months
Mboza	0	1	-	-	3	3	3	-	-	0	0	-	-	-
Mlambo-	0	8	-	-	6	5	0	-	-	1	3	-	-	-
Zama-	0	1	-	-	1	1	0	-	-	0	1	-	-	-
Lulwane	0	1	-	-	0	1	0	-	-	0	0	-	-	-
Bhekaba-	1	0	-	-	0	1	0	-	-	0	0	-	-	-
Ndumu	0	0	-	-	0	0	0	-	-	0	0	-	-	-
TOTAL	**1**	**11**	**-**	**-**	**10**	**11**	**3**	**-**	**-**	**1**	**4**	**-**	**-**	**-**

When asked whether it is important for floods to fill up pans, reach cultivated areas and grazing fields, large numbers of respondents (pans – 195; cultivated areas – 187 and grazing fields – 156) in each of the sampled areas indicated that it is very important (Table 7.13) for floods to fill up these areas.

Table 7.13: Importance of floods to fill up pans, cultivated areas and grazing fields.

	Pans				**Cultivated area**				**Grazing fields**			
	Don't know	Not important	Important	Very important	Don't know	Not important	Important	Very important	Don't know	Not important	Important	Very important
Mboza	1	3	8	44	0	4	12	44	1	5	11	37
Mlambo-	0	2	4	43	0	0	3	51	0	2	4	41
Zama-	0	1	5	32	0	0	6	32	0	0	4	29
Lulwane	0	0	1	12	0	1	0	12	0	0	0	12
Bhekaba-	0	3	2	21	1	2	11	11	3	8	3	4
Ndumu	0	1	2	43	0	2	7	37	0	1	8	33
TOTALS	1	**10**	**22**	**195**	**1**	**9**	**39**	**187**	**4**	**16**	**30**	**156**

When asked whether artificial flood releases fill up pans or reach these areas, the majority of respondents (pans – 90; cultivated areas – 84; grazing fields – 80) indicated that DWAF flood releases rarely fill up these areas (Table 7.14).

Table 7.14: When asked whether artificial flood releases fill up pans or reach these areas

	Pan				**Cultivated area**				**Grazing fields**			
	Not at all	Rarely	Sometimes	Always	Not at all	Rarely	Sometimes	Always	Not at all	Rarely	Sometimes	Always
Mboza	0	24	16	11	0	20	16	13	0	19	14	4
Mlambo-	0	14	17	20	0	11	21	21	0	14	15	19
Zama-	0	11	14	8	0	13	11	8	0	11	12	6
Lulwane	0	5	4	2	0	5	4	2	0	6	3	2
Bhekaba-	1	17	5	2	0	14	7	1	3	7	1	1
Ndumu	0	19	14	6	0	21	10	7	0	23	9	6
TOTAL	**1**	**90**	**70**	**49**	**0**	**84**	**69**	**52**	**3**	**80**	**54**	**38**

The following are some of the reasons why respondents felt that it is important for these areas to be flooded:

Pans: are close to homesteads and we collect water for household use. We get fresh water for drinking and household use activities. Fish harvests increases. Pans are important for livestock watering and grazing, irrigation of crops cultivated close to houses and for additional natural resource harvesting, such as water lily tubers (Nymphaea) and water chestnuts (Trapa) known locally as *Madumbe* and *Mazibu* for food, reeds (Phragmites species) and grass for craft making. If the pan dries up or the water becomes

salty, we have to walk for three hours (about 5 km) to and from the river in order to get fresh water. Also sicknesses increase, such as cholera and diarrhoea.

Cultivated area: flooding soaks the land so that cultivation becomes easy. Soil fertility is replenished. With good flooding we are assured of good crop production.

Grazing fields: receding floods stimulate growth of meadow grasses (e.g. *Cynodon dactylon*), which is the pasture loved by cattle.

7.3.5 Pasture fields

As seen in Table 7.7, most land is under cultivation, yet grazing was observed to be an important activity. Overstocking was clearly evident because very many cattle were seen in very small fields, particularly around floodplain pan margins. Pasture quality was poor. Because the periods between annual DWAF artificial floods is long, often good quality pasture lawn around pan margins is shaded out by weeds and bush (Fig. 7.17-7.18). As seen in the needs analysis, communities would like government to initiate programmes that will enhance livestock production. A frequent conflict arising among communities is over livestock eating crops. Hence many crop fields have fences.

7.3.6 Water quality perceptions

7.3.6.1 Dissolved solids-salinity

Ground water associated with Cretaceous beds of the Maputaland coastal plains is highly mineralized chloride water with total dissolved solids contents ranging from 1 000 to 24 000 mg/litre (Van Wyk, 1963; Orpen, 1972; Heeg and Breen, 1982).



Figure 7.17: Pasture fields – fairly good pasture around pan margins. Most land is used for cultivating crops. Little land is left for grazing (Tete pan, February summer 2003)



Figure 7.18: Pasture fields showing bush encroachment; good quality pasture lawn around pan margins is shaded out by weeds and bush **(**Nomanini pan, June 2005).

During periods of seasonal low stream flow (Jul, Aug, and Sept), the Pongolo River takes on a high concentration of dissolved solids whose composition is characterized by high concentrations of both sodium and chloride, thought to result from the entry of underground seepage water into the river (Archibald et al., 1969).

Studies of dissolved solids in floodplain pans showed salinization to be an even more serious problem than in the river channel (Du Preez, 1967; Heeg et al., 1978). Seepage water from sediments overlying the marine Cretaceous deposits on the Maputaland coastal plain resulted in several pans taking on the characteristics of dilute sea water, which becomes concentrated due to evaporation. Tete, Mholo and Nyamiti pans were particularly found to be adversely affected in this way (Heeg et al., 1978). The very sandy soil structure within which these pans are particularly located may be the reason why salinity is a problem (Fig 6.1). These pans are therefore highly dependent on an annual dilution or flushing out by floodwaters of low dissolved solids to retain their freshwater characteristics (Heeg et al., 1978; Heeg and Breen, 1982).

To determine whether artificial flood releases were meeting this requirement, communities were asked to rate the level of monthly water saltiness on a scale ranging from salty to fresh as a perceived measure of dissolved solids in water in the pans.

At the overall floodplain community scale, most respondents felt that the most fresh water months were October (71) and June (69). The October response can be linked to the fact that most annual flood releases happened in late September, therefore during October the water would be the freshest, while the June response can be linked to the fact that modified stream flow regime from Pongolapoort dam had shifted from natural patterns. The shift is such that, although June lies within the natural period of low stream flow, modified maximum stream flow during June was much higher (Fig 4.8). Communities felt that the most salty water months were January (64) and February (63), despite the fact that these were periods of high summer rains. This response can be attributed to the fact that most of the summer rainfall flood peak was held behind the dam wall for use in irrigation (Fig 4.8).

Variations at individual community scales are also shown (Table 7.15). The communities in Ndumu and Mlambongwenya perceive the water to be mainly fresh, due to the fact that the pans in this northern sector have local catchments, the Ingwavuma River and Mlambongwenya River respectively. However, they pointed out that often there is a change in smell and colour indicating excess nutrient pollution from agriculture. Generally many people pointed out that there were some pans that were more salty than others (e.g. Tete and Mhlolo) and they became fresh for a few months after DWAF artificial flood releases. The majority agreed that pan utilization as a resource for various activities was greatly reduced when water became too salty. For instance, crops are generally watered between October and March. Many communities perceived that the salinity of water during this period was high and not suitable for watering crops because the summer peak is held behind the dam wall for irrigation (Table 7.15). Communities also felt that there was a tendency for very salty water to cause diarrhoea in people and livestock.

Table 7.15: Perceptions of water quality in terms of salinity												
Community name (Pans)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Mboza (Pongolwane, Nsimbi)			s	s	s	s	s	s	s	s		
Zama Zama (Tete, Mengu)		s	s	s							s	s
Lulwane (Mhlolo, Sokhunti)		s	s	s	s					s	s	s
Bhekabantu (Mandlakunzi)		s	s								s	s
Ndumu				s	s	s	s					
Mlambongwenya				s	s	s	s					

7.3.6.2 Water quality – chemicals from agricultural practices

Communities were asked whether they use fertilizers and pesticides to grow crops 'on the floodplain' and 'off the floodplain'. Table 7.16 indicates that pesticides are used on crops cultivated both on and off the floodplain. Crop spraying is carried out in September, October, November and December (spring and summer). Pesticides and fertilizer use, in addition to chemicals used in cattle dips situated off the floodplain, are sources of water pollution.

Table 7.16: Do you use chemicals on crops on and off the floodplain?				
Community sample	**Pesticide use on the floodplain**		**Pesticide use off the floodplain**	
	yes	no	Yes	no
Mboza	27	16	7	7
Mlambongwenya	27	9	22	25
Zama Zama	7	20	11	2
Lulwane	1	10	9	2
Bhekabantu	5	2	1	7
Ndumu	8	-	-	1

Chemicals used to control disease vectors are mainly used in spring and summer and peak in January. Spraying is carried out more frequently in houses than in rivers, pans and irrigation canals.

7.3.6.3 Water quality – diseases

The majority of communities were aware that cholera, malaria, bilharzias and diarrhoea are water borne diseases. Community perceptions of which months such diseases were more prevalent are shown at the overall floodplain community scale (Fig 7.19).

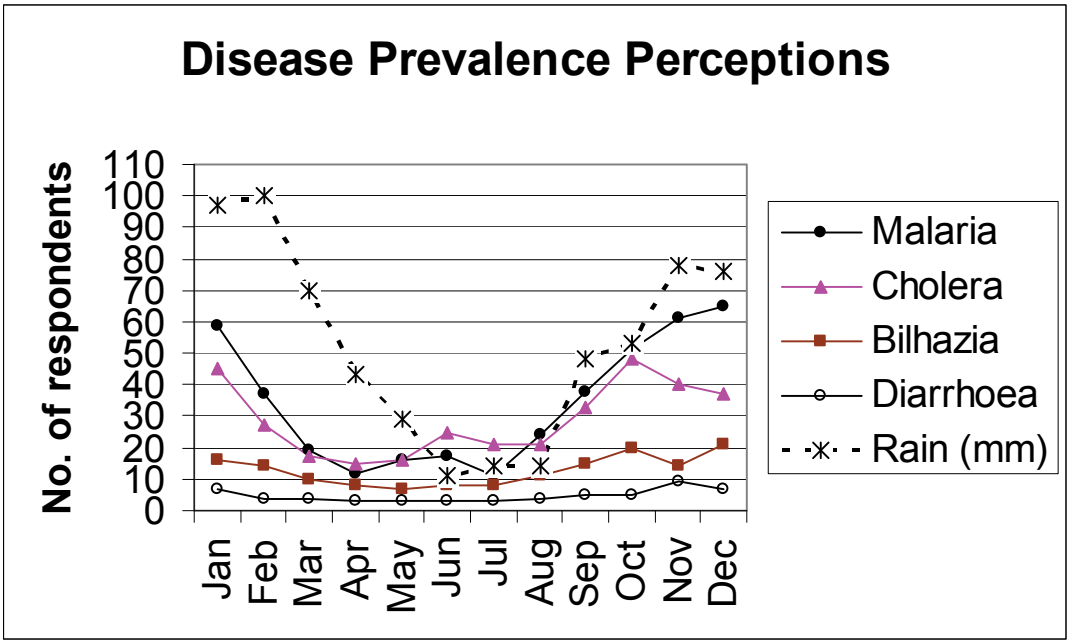


Figure 7.19: Perceptions of how water borne disease levels change with seasons – floodplain community scale.

Clearly diseases start increasing with increasing rainfall from early spring and peak in summer. Early spring (July, August and September) is a period of natural seasonal low stream flows, when pan and river levels are very low. Reduced stream flows from Pongolapoort dam enhance drought conditions on the floodplain greatly. Hence, winter crops do not grow well unless irrigated. Communities are readily infected with water related diseases during this period because water shortages mean that people dig in pan beds for water for basic needs (drinking and household use), hence increasing the rate of disease infection (Fig 7.20a). Rain tends to wash infected human waste from the land into the water and sediments, hence contaminating them and eventually causes infection rates to increase (Fig 7.19). Also rain creates habitats for disease vector populations and causes the diseases they transmit to increase (Chapter 5).





Figure 7.20a: Water Quality. The impact of a reduced stream flow causes pans to dry out quickly, reducing water quality for basic needs. Top picture – a pan bed in the Nomanini-Ngodo pan complex in June 2005. Bottom picture – a pan bed in the Nsimbi-Mthikeni pan complex in October 2002.





Figure 7.20b: Collecting water for domestic use from the main river channel. Women walk long distances from houses to the river (about 8 km return) to collect fresh water (2002).

People's houses are closer to the pans than they are to the river. During periods when the pans are dry or too salty, people have to walk long distances (about 8 km return) to reach the river for fresh water (Fig 7.20b). Therefore, pans are more frequently utilized than the river to save time. Recharging pans annually is therefore an important requirement for basic needs.

7.3.7 Floodplain land use for fisheries

7.3.7.1 Consumption level per household

Fishermen fish all year round. More fish are caught in summer than in winter. Fish is freely accessible to communities and provides a cheaper source of protein than chicken or beef. Most people only eat fish frequently after a flood release. A family of 8 can consume one big fish or six to seven small fish three times a day after a flood release. These numbers decrease greatly for the remainder of the year due to reduced stream flow from Pongolapoort dam (Chapter 4) and beans become the substitute for protein in diets.

7.3.7.2 Types of fish harvested

Based on fishermen focus group discussions, local names of fish types exploited for food from the pans are shown in Table 7.17. Because the main purpose of the study here is to initially track human perceptions, scientific names have not been assigned to each species. The local names are used here as human perceived 'morpho-types', i.e. as perceived by the local communities.

Table 7.17: Local names of fish types exploited for food from the pans. (1)=present. (0)= absent. The local names are used here as perceived 'morpho-types', i.e. perceived by the local communities.

Types of fish (morpho-types)	**Mzinyeni**	**Msunduzi**	**Mengu**	**Nsimbi**	**Mandlankunzi and Hlanjwana**
Barbul	1	1	1	1	1
Mbokwane	1	1	1	0	0
Mlomowokwenza	1	0	0	0	0
Mwesi	1	0	0	0	0
Sardin	1	0	0	0	0
Sinkonkonko	1	0	0	0	0
Sintinti	0	1	0	0	1
Skhwambi/Bream	1	1	1	1	1
Tigerfish	1	1	0	0	0
Umjozini	0	0	0	1	0
Malete	0	0	0	1	0
Total	**8**	**5**	**3**	**4**	**3**

Based on these perceptions, Table 7.17 shows that:

(i) Floodplain pans are an important breeding habitat for important fish species of the system,
(ii) On the basis of fish types, every pan is unique due to a high degree of pan endemism whereby certain fish species are found in certain pans and not others. This is an important feature to conserve in terms of biodiversity conservation so as to maximize biodiversity,
(iii) The most abundant fish in the whole system is the *barbul* (Catfish species) and *skwambi* (Tilapia species),
(iv) Most fish types are found in Mzinyeni followed by Msunduzi. This can be attributed to the fact that Mzinyeni and Msunduzi pans have independent catchments, supplemented by water from the Pongolapoort Dam. Pans that depend totally on water from the Pongolapoort Dam have few fish types, which may be attributed to the impact of reduced stream flows from Pongolapoort dam (Chapter 4),
(v) Communities felt that all fish types were highly valued although people preferred to eat some types more than others. They travelled to other areas to obtain the more preferred fish types. For example, in Fig 7.21a (top picture), a fisherman is showing a day's catch (one catfish caught in 24 hours) during the 'May 2004 fisherman focus group workshop at Mzinyeni pan'. Note that pan levels are very low in the background. According to the fishermen, this type of fish (common barbel) is most abundant when the volume of water is low and its quality poor. Communities prefer other fish types more than the catfish, and in addition there are some traditional beliefs that prohibit the eating of catfish, but due to poverty and hunger, they are forced to eat whatever is available. Fig 7.21a (bottom picture) shows a fisherman at Mandlakunzi pan in August 2004 (before the flood release). Pan levels are very low and a day's catch is poor <5. Again, the most common fish caught during this time are barbel. According to the fishermen, low pan levels and poor water quality was experienced most of the year. Annual artificial flood releases from the dam improved these poor conditions for awhile.

7.3.7.3 Fishing season

During natural or unmodified stream flows (pre-dam period) fish abundance was linked to summer floods (December to February). When in flood, the river provided a route for interpan migration, thereby supplementing the breeding stock of a pan by the recruitment of immigrants from other localities. Heeg and Breen (1982) reported having observed adult fish of all species that aggregate in the stilling pool below the dam wall, following cessation of a flood release. This observation suggested that upstream migrations occur in response to flooding. Therefore, the dam wall limits upstream migration of fish. Structures like fish ladders or fish bypasses are often installed to allow natural fish migration upstream and downstream. These structures are absent at the Pongolapoort Dam.

Communities indicated that fishing in pans was more productive than fishing in the river because many fish prefer still water. Responses obtained from communities linked fish abundance with artificial floods released in late September. They pointed out that fishing immediately after a flood release was difficult and not fruitful because of high levels of suspended solids (silt, mud and vegetation), which tended to ruin

fishing nets and fish eggs. Communities felt that artificial floods released from Pongolapoort dam come with such force that they scour the pans and wash out all the fish into Mozambique. For instance, the fish graze on a certain plant. When the floods come they wash out all the fish, plus the plant. When the floods get to Mozambique, they have less force. So the perceptions were that fish populations in Mozambique are far greater. Many respondents around Mandlakunzi-Bhekabantu said that they bought fish that came in from Mozambique.

Fishermen pointed out that the abundance of fish increases from 1-10 fish/day to 10-20 fish/fisherman/day for a period of 1-2 weeks after a flood release. Thereafter, the quantity of fish decreased sharply so that from December onwards, the catch per unit effort was about <5-10 fish/fisherman/day. For example, Fig 7.21b (top picture) shows very low pan levels at Bumbe pan in June 2005. Fish catches for the day (a 24 hour fishing effort) were only 10 small fish. The lady shown is buying the whole catch from the fisherman. She arrived on site at 8.00 am to wait for the catch. The fisherman brought in the catch at 12.00 am because the catch per unit effort was very low. Fig 7.21b (bottom picture) shows low pan levels at Sokhunti pan in May 2004.

The best time of the year for fishing was from October immediately after the flood release. After this period, fishermen felt that pan levels reduced very quickly exposing pan marginal vegetation which normally provides shelter and food for fish (Fig 7.22a). Note submerged vegetation after a flood release in September 2004 at Mzinyeni (Fig 7.22a). Communities pointed out that the abundance of fish in terms of a reasonable catch (10-20 fish/fisherman/day) lasted for approximately 1-2 weeks after a flood in Mzinyeni and less than a week in other pans. The picture was taken one week after the flood release. For increased fish production pan margin vegetation must remain submerged for longer periods than the current 2 weeks (Heeg and Breen 1982). Due to this fact, fishermen felt that a possible solution was for DWAF engineers to design some way of holding floodwaters on the floodplain for longer periods.

According to records by Heeg and Breen (1982), showing the area covered by various pans in ha (Table 4.1) and their locations (Fig 4.1), Tete pan (115.9 ha) is the third largest pan after Mandlakunzi (255 ha) and Nyamiti (183.4 ha). This may be the reason why there was a big catch of yellow fish in February (Fig 7.22b). Note that summer rains also peak in February and may have influenced the catch positively. Figure 7.23 shows women harvesting fingerlings (small fish) from Nsimbi pan in June 2005. Fish catches per day are low and are shared between the three families. Note that pan levels are very low, exposing extensive pasture lawns for livestock grazing.

7.3.7.4 Selling and buying fish

Table 7.18 indicates the value of fish obtained on the floodplain. Reduced flows have led to reduced fish production. The demand is always higher than the supply so hardly any is preserved or processed. The biggest buyers are local people within the floodplain. Other sources of fish are mainly from Pongolapoort Dam and from Mozambique.

Table 7.18: Showing prices of unprocessed and processed fishes in different sizes (2003-2004)						
	Unprocessed			Processed		
Sampled Areas	**Small**	**Medium**	**Large**	**Small**	**Medium**	**Large**
Mzinyeni	R5	R10-R15	R20-R70	R10-R15	0	0
Msunduzi	R6/kg	0	0	0	0	0
Mengu	R5-R25	0	0	0	0	0
Nsimbi	0	0	R20-R30	0	0	0
Madlankunzi/ Hlanjwana	0	R10	0	0	0	0



Figure 7.21a: Fishing in floodplain pans before artificial flood releases. Note reduced pan levels. Catch per unit effort decreases greatly. The most common fish abundant during this period is Barbel (cat fish). Top picture – Mzinyeni pan May 2004. Bottom picture – Mandlakunzi August 2004.





Figure 7.21b: Fishing in floodplain pans before artificial flood releases. Note reduced pan levels. Catch per unit effort decreases greatly. Top picture – Bumbe, June 2005. Bottom picture – Sokhunti, May 2004.



Figure 7.22a: Fishing in the floodplain pans after a flood release. Catch per unit effort increases greatly for up to 1-2 weeks after a flood release. Note submerged pan marginal vegetation that provides food and shelter for fish. Top picture – Mzinyeni pan, October 2004. Bottom picture – Mzinyeni pan, February 2003.



Figure 7.22b: Fish caught at Tete Pan in February 2003.



Figure 7.23: Women harvesting fingerlings (small fish) from Nsimbi pan in June 2005. Fish catches per day are low and are shared between the three families (bottom picture). Note that pan levels are very low exposing extensive pasture lawns for livestock.

7.3.7.5 Exploitation and the local management of fish

When the *Mzinyeni* fishermen were asked about utilization of fish in pans, they indicated that fish were scarce due to reduced stream flows and the change in flood timing from natural trends. Because fish was scarce due to modified flows, they felt that they were not over-exploiting the fishing. If this was the case then it was not their fault. They were continually experiencing a scarcity of fish from about one month after flood releases. They commented that fish should be released from the dam. They have a strong belief that the dam officials, during the dam construction, installed a net system on the dam wall, which prevents fish from being released downstream. Water was released from the dam throughout the year to keep the river flowing but they had observed that there were no fish in it. They felt that there should be some kind of system that allows fish to pass through freely and not only during annual flood releases.

The *Msunduzi* fishermen believe that there is reasonable exploitation of fish in the pans. They were very aware of the need for sustainable use of fish as an important and scarce natural resource. Despite such awareness, they had limited control on fish exploitation because it is the only survival strategy available to them. In order to sustain the pan water levels, they felt that walls should be built around pan margins to stop flood waters from leaving the pans quickly. They were very critical of the MQotho irrigation scheme, which was drawing out all the water from the pan. This negative feeling was aggravated by the fact that none of the fishermen owned plots in the scheme, yet they were paying the costs by not having fish freely available. It was also suggested that some of the fishermen should be given irrigation plots so as to create equal access to the utilization of the natural resources (Fig 7.24).

The *Mengu* fishermen responded to the question of exploitation and management of fish in the pans, by stating that the issue was not the over-exploitation of fish in pans but that there was already a scarcity of fish in the pans and the river due to reduced stream flows coming from the Pongolapoort Dam. They felt that even during periods of artificial flood releases, the flood water arrives with such force and pressure that it scours the pan beds and rivers and washes all the fish into Mozambique. The fishermen suggested that the floods should be released in a way that reduces scouring and enables the water to stay longer in pans. They also suggested that the water released should cover wider pan marginal area and should stay on the floodplain for at least two weeks because that way they are able to "kill three birds with one stone", i.e. they are able to irrigate the fields in preparation for ploughing and planting, improve pasture production and fish catches would increase.

The *Nsimbi* fishermen also felt that fish were scarce in the pans due to reduced stream flows from the Pongolapoort Dam, so they did not feel that they were over-exploiting the fish resource, and if this was the case, it was not their fault because they had to survive. They also believed that fish were deliberately not being released from the dam, because water was released throughout the year, yet there were no fish in it. They recommend that fish should be released from the dam. They also suggested that the water on the floodplain be preserved for longer periods than was happening, which would be favourable for fishing, and that there should be a well known market area where fish could be sold to everyone in the community.

The *Mandlankunzi* and *Hlanjwana* fishermen felt that there was no over-exploitation of fish but there was a scarcity of fish in pans. What they had observed is that the pans are becoming shallow and the fish are trying to find moderate to deep areas in pans. They suggested that some way should be found to make the pans deeper so that fish would be attracted to those pans.

7.3.7.6 Existing Controls and fishing committees or associations

The *Mzinyeni* fishermen said that there were no existing fishing controls. They felt that they did not want any fishing associations to exist because of the fear that such bodies would not only limit fishing but would also deny fishing access to many people who fish everyday as a survival strategy due to the absence of alternative livelihood means. They pointed out that fishing made it possible for them to support the household and to pay for their children's education. They also indicated that although they do not have associations and do not like associations, they know that forming an association would be a good thing because government does not fund individuals. The association committee could also negotiate with dam authorities to fish on the dam, to release water when it is required, and to improve fish production that could lead to a better livelihood for the people. They felt that should such an association form there should be a mechanism that ensures it is not only inclusive but also legitimate.

The *Msunduzi* fishermen had no existing fishing controls. They recognized that fishing in protected game areas and on the Pongolapoort Dam was prohibited and fishing was only allowed with a fishing license. However, it was not easy to get such a licence. They felt that hardly anyone on the floodplain has a licence to fish in these areas. They said that although there are no constituted fishing controls on the floodplain, people just knew that one can only fish near his/her area of stay and not anywhere else. In terms of associations, there is an existing committee although it has never been given a name. It has a constitution, which can still be amended if necessary for approval.



Figure 7.24: Fishing vs. Irrigation conflict. A group of concerned local fishermen insisted that the venue for a focus group workshop in May 2004 be held inside a dry riverbed, with nil flows on the Ingwavuma River downstream of the MQotho pan dam. This illustrates the acute shortage of water availability for various uses.

Fishermen in *Mengu* indicated that there was no existing control or association but they are aware that they need to form one and they have raised the matter within the community. They think that it could be a good idea.

Fishermen in *Nsimbi* were asked about existing controls and the formation of associations and they indicated that they were aware that they need to form controls and an association but, due to poverty, their focus is on hunting for food for survival and not on developing associations.

The *Mandlankunzi and Hlanjwana* fishermen responded by saying that they have regulations that they have set up as a community. However, they have never thought of forming an association but they view it as an excellent idea because it can also open doors in terms of funds as they are aware that government mostly funds registered associations for development.

7.3.7.7 Aquaculture and access to fishing

The *Mzinyeni* fishermen did not know what aquaculture development is. Regarding access to other sources, it was their wish to fish in the dam and Ndumu game reserve, but they knew that if they were to utilize resources in these properties, they could be arrested immediately.

The *Msunduzi* fishermen had heard of aquaculture but had never seen it. They wished that they be allowed access to use the dam and the game reserve.

The *Mengu* fishermen had heard of aquaculture. They wished that they be allowed access to use the dam and the game reserve. They believe that no one is utilizing those resources and if allowed to fish in these areas, they could supply the community as a whole and everyone would benefit. They also understood that there would be regulations set and they could not harvest unsustainably.

The *Nsimbi* fishermen knew about aquaculture. It had been set up at Mboza village through the assistance of researchers from the Makhatini Agricultural Research Station, but after sometime, it collapsed. They felt that the problem with aquaculture was the setting of regulations which limit access and use. They felt that aquaculture was labour intensive in the sense that fish need to be looked after, i.e. fed and other tasks that end up costing more than they benefit. Fish in the pans feed naturally, cost nothing and can be obtained freely. They felt that aquaculture was not popular.

The *Mandlankunzi and Hlanjwana* fishermen had heard of aquaculture and wished to have ponds in their area. They were unhappy that access to fish resources from the dam and game reserve was prohibited. They felt that there was plenty of underutilized resources in these areas. They wished to be allowed access because when they catch fish the whole community benefits.

7.3.6.8 Developments that fishermen would like to see taking place

The *Mandlankunzi and Hlanjwana* fishermen responded by saying that they wish that government would assist in deepening the pans because it is one of the causes of fish leaving the pans. Secondly, they wish to see government bringing new methods to enhance fish recruitment and production. Lastly, they also believe that the building of aquaculture ponds could result in the preservation of fish, as they are presently so scarce.

A participant from *Mengu* had had his Pongolapoort Dam fishing licence withdrawn, and his fishing equipment confiscated by EKZN-Wildlife officials, yet this was his livelihood, earning between R2 500-R4 800 per day from fish sales. He said that he had been told that all floodplain communities have access to floodplain pans from which they can fish. Fishing access on the Pongolapoort dam was therefore denied. However, he wished to get back his licence, because the floodplain pans hardly had any fish, as all summer the water was held behind the dam wall to benefit irrigation and other recreational users.

7.3.7.9 Summary of fishing needs

(i) Fishermen felt that they must also have access to irrigation developments since all water seems to be benefiting those irrigating only,

(ii) The summer flood peak is held behind Pongolapoort dam wall causing reduced stream flow on the floodplain which in turn reduced fish yields. On this basis, it was felt that few people from the floodplain should be given permission to fish in the Ndumu game reserve and Pongolapoort Dam under licence. Fish from these sources should then be sold at appropriate points along the floodplain where the whole community can benefit,

(iii) Aquaculture programmes initiated previously did not work. Fishermen felt that a better option would be to build walls around pans to hold back flood waters for longer periods or design some way of doing this. This would improve greatly the pan habitat quality for fish production. The current artificial floods released from Pongolapoort dam flows through very rapidly and is consequently very unproductive,

(iv) Develop formal local fishermen associations and improve their capacity to fish sustainably.

7.3.8 Development perceptions

Due to the high agricultural potential of the land off the floodplain on the Makhatini flats, agricultural development expansion plans are being implemented by the DoA green revolution plan (DAEA, 2002). For example, the Makhathini irrigation scheme expansion was being expanded for cotton growing among other crops. Some developments have been completed and others are underway (in state owned lands on the west side of the river). Hence it was necessary to find out whether the floodplain community members were aware of the planned developments.

Many respondents were more aware of the following planned developments: irrigation, cotton industry, sugar mill and fish farming than they were of tourism development. Irrigation development and the

cotton industry were the best known of the planned developments, having 72 and 64 numbers of respondents respectively.

When communities were asked whether such developments would improve people's livelihood, most respondents perceived that job opportunities would increase, farmers could produce more with irrigation development, the cotton industry would also provide more profits with less intensive farm work, and a sugar mill's availability nearby will reduce the cost of travelling far to sell sugar cane produce. However, communities staying far from the Makhathini irrigation (Mjindi) schemes, felt that only those who are in close proximity were benefiting from the completed developments.

7.3.9 Management perceptions

7.3.9.1 Access and controls

When asked about the access and control of land and resource use on the floodplain, most respondents (36) indicated that there were no controls, apart from land allocation controls, which the *Inkosi* (chief) and *Izinduna* (sub-chief) are responsible for. Also one of the respondents indicated that during a certain period of the year, there is control by the *Izindun*a and *Inkosi* not to hunt certain animals, e.g. fish and birds.

7.3.9.2 Opinion leaders

Communities were asked to state who they felt were opinion leaders in their communities. Most respondents indicated the *Izinduna* (sub-tribal chiefs) and *Inkosi* (tribal chiefs). These leaders, do negotiate for water release, others advise community members on agricultural activities (e.g. Mr Jobe), and help with community projects (e.g. Mr Gumede, elected councilor); Mr Nyathi and Clive Poultney are community development workers; others were mainly community elders.

7.3.9.3 Local institutions and groups

Communities were asked to rate the importance of local institutions with respect to the role that they play in their livelihood. The traditional institution was the most important, followed by spiritual institutions. Communities viewed that NGOs and researchers did not play an important role in their livelihoods (Table 7.19).

Table 7.19: Importance rating of the role played by local institutions	
1	*Inkosi* (Tribal chiefs) (132)
2	Cultural groups (churches and traditional healers (*Isangoma*) (130)
3	*Izinduna* (Sub-tribal chiefs) (128)
4	Elected councillors (108)
5	DoH (106)
6	DWAF (85)
7	Municipality (76)
8	Association, Committees and Co-operatives (e.g. water committees, and farmers association) (75)

9	EKZN-Wildlife (58)
10	DoA (48)
11	DEA (47)
12	Groups (e.g. NGOs, CBOs, Researchers) (9)

Examples of comments expressed about the insignificant role played by NGOs and researchers were in order of the most to the least frequently expressed:

(i) "A lot of development work and research has taken place in our communities for years and years, yet we have never seen benefits in our livelihoods",

(ii) "I am fed up with people coming here to do research after research after research, yet I never see the outcome or the benefits of their research. When they finish asking us so many questions, they leave and we never ever see them again. I am fed up and I do not want to be studied anymore",

(iii) "There are those NGOs that come to do development work, e.g. promote groundnut production. We never saw tangible benefits on the ground. They must have just eaten all the money",

(iv) "Some groups drive tourists through the floodplain and interfere with our private lives, yet they are only benefiting themselves. My community around Tete pan are afraid that soon they will put a fence just like what happened when people were forced out of Ndumu game reserve and a fence was put around it and access was completely denied forever",

(v) "Others come to ask questions about cotton, about tourism, about health issues and many other things and then they vanish. We never hear of the outcome and we never see them again. Soon after, someone else comes to ask nearly the same questions or to ask about something else. It is very annoying".

7.3.9.4 Conflicts

Regarding conflicts in the community, respondents indicated that these are due to the following:

(i) Some *Izinduna* (sub-chiefs) are being excluded from water committees and development initiatives,

(ii) Demand for land on the floodplain, where crop cultivation conflicts with livestock grazing,

(iii) Disagreement on artificial flood release timing between various interest groups: among the floodplain communities, some want winter floods, others spring floods; conservation agencies would like the floodplain to remain purely a conservation area; some upstream users feel that flooding should be reduced to fill up pans only, while floodplain communities want floods to fill up pans and to flood irrigate subsistence lands,

(iv) There was a feeling that the flood release structure was only meeting the needs of the cotton growing sector, and it was felt that decisions arrived at are not really based on consensus or are not inclusive.

Actions taken so far to resolve these conflicts are:

(i) There have been discussions and meetings with the *Izinduna* and *Inkosi* so that land on the floodplain should be shared equally so that all floodplain communities can benefit from its resources and services,
(ii) Those, whose crop fields have been grazed by livestock, receive compensation,
(iii) Setting up of water committees to negotiate flood release needs with DWAF.

Communities were then asked what their opinion was about what needed to be done to resolve such conflicts. Communities felt that:

(i) Rules need to be laid down and everyone should follow them so that the floodplain ecosystem is maintained sustainably,
(ii) Cotton should be grown off the floodplain as cotton grown on the floodplain conflict with everyone else regarding the timing of flood releases from the dam,
(iii) The cultivated areas on the floodplain must be fenced and there should be an area on the floodplain that is put aside for livestock grazing,
(iv) Government should support the floodplain economy by assisting farmers with farming equipments, such as tractors and other farming inputs,
(v) The farmers and the floodplain community should be educated on how to manage and use floodplain resources sustainably,
(vi) Controls should be introduced and upheld for sustainable use of floodplain resources,
(vii) All stakeholders involved in the use of the floodplain should agree to cooperate in order to solve the floodplain issues,
(viii) Due to the fact that not all stakeholders attend the meetings that deal with issues pertaining to floodplain management and floodplain resources use, many respondents felt that meetings are dominated by cotton farmers. The issue of representivity needed to be addressed in order to enhance inclusiveness in decisions taken.

7.3.10 Stakeholder dialogue workshop

The following are floodplain community concerns raised during the dialogue process. Only the key issues are reported here. Details of the actual dialogue process covering all other interests are in Jaganyi et al. (2002).

7.3.10.1 Floodplain Community Problem Statements (2002)

The list of problems is a summary of statements made by the following organizations:

(i) Representative of the Water Committee from the west side of the river (Mr Bathas Nkanini),
(ii) Representative of the water committee from the east side of the river (Mrs Thereza Ndlazi),
(iii) Vice chairman of the Farmers Association – Pongolo Water Association for the Development of Traditional Agriculture (POWADETA). (Mr Mutagati Z Manukuza),

(iv) Representative of the Makanis water committee,
(v) The NGO – Lubombo Waterways Programme (LWWP) – (Charel Bruwer, Clive Poultney and Zeph Nyati).

7.3.10.1.1 Problem Statement: The NGO – Lubombo Waterways Programme (LWWP)

The Water Committee structure was initiated by Charel Bruwer, Clive Poultney and Zeph Nyati in 1988 and served as a forum within which floodplain communities could negotiate flood releases from the dam with the DWAF authority and other key stakeholders such as EKZN-Wildlife and dam property owners. The structure succeeded in informing stakeholders when a flood release would happen. However, it did not succeed in meeting the key needs of individual stakeholders due to the presence of divergent needs among these stakeholders, e.g. the different needs within floodplain communities, farmers in the upper reaches vs. farmers in the lower reaches of the floodplain, floodplain farmers vs. floodplain fishermen, needs of conservation agencies EKZN-Wildlife and sometimes DWAF needs. They believed that there was a need to form a more formal legal structure that can be supported by government, and in which true co-operative governance can function to meet the needs of the people, i.e. forming a water user association (WUA) was a priority.

7.3.10.1.2 Problem Statement – Floodplain Community Water Committee Leaders

(i) It was expressed over and over again that the floodplain is central to people's livelihoods.
(ii) Yet, decision makers were making bad decisions which impacted negatively on the community's livelihood. It was felt that decision makers must come down to grass roots level and experience the way of life of the people so that they can truly understand their problems and needs before making any decisions,
(iii) It was expressed that the floodplain benefits more people than the irrigation schemes, yet government was putting more resources into the irrigation schemes and ignoring completely the importance of floodplain resources, particularly the Makhatini irrigation scheme that benefits fewer people than on the floodplain. It was necessary that all communities affected by the dam participate in the decision making process and the planning of developments that need water from the dam so that the needs of all sectors can be taken into account,
(iv) It was expressed that the area covered by floods had greatly reduced and pan levels reduced rapidly immediately after a flood release. Floods did not stay on the floodplain long enough to enable soils to soak up and retain adequate moisture to sustain crop and pasture growth. As a result droughts were very common, yet the floodplain is the main means of livelihood for many people,
(v) All floodplain communities felt that although the current flood release timing in September was acceptable by negotiated consensus, it was still the wrong time for their needs, particularly crops and fish,
(vi) Artificial floods released from the dam do not support farming. Irrigation is the only way crops can grow well under current conditions,
(vii) There was no flood release in 2001, the reason being that the 2000 flood releases had destroyed structures in Mozambique and because the DWAF national office was still

resolving the problem with Mozambique. This led to a lot of suffering among households because pans had reduced to very low levels and crops could not be grown. Communities felt that it was very important that they be included in the discussions with Mozambique,

(viii) There was conflict of land tenure between tribal communal lands and state owned lands. Many people did not realise that certain areas were state owned lands,

(ix) It was felt that diseases in the community had increased greatly, despite the presence of Shemula Community Water Supply Scheme, which distributes purified potable water, which unfortunately, many people could not afford. Secondly, there was a belief among the community that chemicals used to purify this potable water had some side effects that were making the community ill from many diseases, including TB,

(x) Floodplain communities felt that the needs of wildlife appear to be more important than the needs of people. They felt that the conservation agency EKZN-Wildlife is perceived to be the cause of the problems experienced by communities, since 1948, by erecting fences around game reserves and prohibiting harvesting of resources without providing alternatives. Communities felt that they were unfairly harassed and arrested by EKZN-Wildlife officials for harvesting resources because of their basic need for food and medicine.

7.3.10.1.3 Needs – floodplain community perspective (2002)

Community needs can be categorized on the basis of four common themes:

(i) Decision making needs (management) (formal decision making structure involved in development discussions, transparency, accountability, and empowerment),

(ii) Water resource needs (water availability, water allocation, flood release – timing and magnitude, water quality, fishing, and disease concerns),

(iii) Agricultural needs (water for irrigation, floodplain crops, livestock grazing, and fishing),

(iv) Environmental needs (the reserve issues, water quality, erosion, bad agricultural practices, and monitoring of use).

7.3.10.2 Local government – Jozini Municipality problem statement (2002)

(*by Mr Noel N. Nkosi – Manager***)**

"*The Jozini Local Council is a young municipality, which is in the process of formulating many policies. However, this council is not folding arms and waiting for the unknown. We intended to fulfil our mandate as per the requirements of the constitution of the country. The council fully understand(s) the importance of secured life with sustainable development.*

The municipality recognises that the floodplain is a very important piece or portion of land, which is used by many local communities for, among others, farming, grazing, and natural resource. The Municipality wishes to regulate the following activities:

(i) promote communal water works under tight control of the council; (ii) ensure that water is used in accordance with the water use entitlement as provided in section 22(1) of Act No 36 of the National Water Act, of 1998; (iii) protect water resources by fencing and/or making canals, etc.; (iv) prevent any unlawful water use; (v) regulate the flow of any water course by: clearing its channel, reducing the risk of damage to the land in the event of floods, changing a watercourse back to its previous course where it has been altered through natural courses or otherwise.

The municipality through its councillors runs awareness campaigns to warn people against: (i) cutting down bush and forests so that the beauty of the environment can be sustained for tourism; (ii)absence of bridges in several places along the river means that during summer rains communities can drown while trying to cross the river (iii) discourage communities from drinking raw water because of the prevalence of the water borne diseases (iv) refuse dumping on the plains is prohibited (v) regulate sand mining on the river."

Generally municipalities provide services such as water for domestic, urban and industrial needs, provision of social and economic infrastructure and programmes and the implementation of spatial developments,e.g. Integrated Development Plans (IDPs).

7.3.10.2.1 Needs statement – Jozini Municipality (2002)

(i) Although the Municipal IDP plans view the floodplain as a protected area according to the spatial development plans, the municipal managers (Jozini) definitely recognize that the floodplain is a very important piece or portion of land, which is used by many local communities for, among other things, farming, grazing, and natural resource harvesting.

(ii) Their desired plans are to promote local economic development projects by using the floodplain and therefore they require partnerships to enable this to happen.

7.3.10.3 Local government – Umhlabuyalingana Municipality problem statement (2002)

There was no representative at the workshop and no statements were presented. However, on the basis of personal communication with elected councillors in the area, perceptions and needs are similar to those of the Jozini municipality. Except that their greatest concern was that they had a bigger population of people living adjacent to the floodplain on the east side of the river who need services like clean water and sanitation.

7.4 DISCUSSION

7.4.1 Demographic patterns

Using data from Statistics SA Census 2001, population distribution adjacent to the floodplain was estimated to be 92 369 people making up 16 581 households, with an average household size of seven persons. This made up 28% of the population in the Umkhanyakude District Council (325 052). The district council was divided into two municipalities. Jozini Municpality was located on the west side of

the river and had a population adjacent to the floodplain of about 37 290 people making up 6 717 households, which is 20% of the population in the municipality (184 090). Umhlabuyalingana Municipality was located on the east side of the river and had a population adjacent to the floodplain of about 55 079 people making up 9 864 households, which is 39% of the population in the municipality (140 962).

Population density maps in terms of households/km^2 at the district council scale, shows clearly that the concentration of people adjacent to the floodplain is much higher than elsewhere in the region (Fig 6.3 and Fig 6.4). Due to the fact that the region is largely rural, it was a clear indication of dependence on the floodplain resources. The results of this study strongly support this observation.

The results show that, people own parcels of land 'on the floodplain' ranging from 0.1-3 ha, and 357 ha were cultivated by 85% of respondents (210/247). The traditional authority leadership allocated communal lands on the floodplain. There was an indication of increasing recent immigrants into the areas, especially on the west side of the river – 'off the floodplain', where state lands are located. The state lands have high potential for commercial agricultural irrigation development.

Many people (74%) especially women travelled a distance of about 4 km return and made more than one trip/day, from their houses which are located 'off the floodplain' to utilize the floodplain resources for collecting water, livestock watering, livestock grazing, crop cultivation and watering, fishing and harvesting other wildlife resources. The population was largely made up of subsistence farmers with few commercial farmers. The number of farm labourers was smaller than the number of people who were unemployed. The unemployed depended largely on floodplain resources to supplement their requirements for basic needs. Although the majority of households earned incomes of between R500 and R1000, there were households that earned less than R500 per month and others earned nothing in terms of cash. Majority of the household sizes were above the Statistics SA average value of seven. For example, out of 247 households sampled, 73% had household sizes greater than seven and 13% had household sizes greater than 16 people. This has significant implications for local government service delivery particularly the free clean basic water requirement (i.e. water for drinking, food preparation and personal hygiene), which was based on a lifeline amount of 25 litres/person/day. According to the water services policy on the human right to 'free clean basic water' this amount translates to free clean water of 6000 litres/month/household of 8 individuals. It is important that budget allocations take into account people with households greater than 8.

7.4.2 Floodplain resource use

Rainfall is scarce, highly variable and concentrates in summer (Schulze, 1997). The mean annual precipitation (MAP) in the lower reaches of the Pongolo River catchment where the floodplain is located is much lower (400-600 mm), when compared to that in the mid-catchment upstream of the Pongolapoort Dam (600-800 mm) and the upper Pongola-Bivane catchment (800-1000 mm) (Dent, Lynch and Schulze, 1989; Schulze, 1997). The Pongolo River summer flood peak is held behind the Pongolapoort Dam wall and the Bivane Dam wall located in the upper reaches of the river (Fig 2.1). According to wetland scientists (Heeg and Breen, 1982; Welcomme,. 1976, 1979, 1986; Rosenberg et al., 1995; Keddy, 2002),

the productivity of floodplain wetlands depend on seasonal water level fluctuations caused by floods of adequate volume, magnitude, and seasonal timing (Fig 4.2). The floodplains of many rivers in the world are utilized largely for agriculture, fishing and some sections are preserved for nature conservation. For example, the Mississippi River floodplain in the USA; the Rhine River in western Europe and the Amazon River in South America (Keddy, 2002). In sub-Saharan Africa, some of the well studied floodplain rivers used for agriculture, fishing and nature conservation are in Nigeria, Ghana, Cameroon, Senegal, South Africa, Zambia, Kenya and Tanzania (Welcomme, 1976; Heeg and Breen, 1982; Horowitz and Salem-Murdock, 1990; Barbier et al., 1991; Hollis et al., 1993; Bruwer et al., 1996; Wesselink and Drijver, 1993; IUCN wetlands programme newsletter No. 12, 1996; Barbier and Thompson, 1998; Adams, 1992, 1993, 1995, 2000; WCD, 2000, 2000a).

In northern KZN province, major river systems or catchments located within the DWAF Usutu to Mhlatuze Water Management Area are Mhlatuze River, Mfolozi River, Mkuze River, Pongolo River and Upper Usutu River (Fig 8.2). All have floodplain swamps that are greatly modified due to reduced stream flow. The extensive Mfolozi floodplain swamps were drained since 1952 for the commercial production of sugarcane. Draining the system involved the building and the continuous maintenance of dykes, polders, channels and pumping out water. Floodplain swamps acted as a natural sediment trap (Hutchison and Pitman, 1973; Weiss, Hutchison and Midgley (1975). By draining the swamps for agriculture meant that this natural ecosystem service was lost. As a result, the negative environmental impact is the enhanced sediment accumulation experienced in the St Lucia Lake system and at the joint mouth to the sea (Fig 8.2). To mitigate these environmental impacts, the conservation strategy implemented has involved a lot of money and effort spent through the artificial management of the system, e.g. dredging the lake bed and breaching the mouth when it closes so that its estuarine qualities can be conserved. The point being made here is that before decisions are taken to get rid of other remnant floodplain swamps in the region, like the Pongolo floodplains, cost benefit analyses using environmental economics methods must inform such decisions.

Under natural or unmodified stream flow conditions of the Pongolo River (i.e. pre-dam developments), Heeg and Breen (1982) reported that the Pongolo floodplain received floods in summer. Floods submerged a wide area (13 000 ha) which became a huge fishery (10 414 ha) in summer with an estimated potential yield of between 500 and 750 tons/year. As floods, receded crops were planted. Water levels reduced gradually from summer into the dry months of winter exposing pan margins. Exposed pan margins stimulated the growth of good pasture. The natural or unmodified stream flow reduced the risk of hunger for the majority of the population because rain-fed crops and pasture grew off the floodplain using summer rains, while the flooded floodplain in summer produced fish. During the dry season or periods of low stream flow in winter and spring, the dry land areas off the floodplain were too dry to grow crops and pasture. After the floods had receded, the floodplain soils retained adequate soil moisture to support crops, pasture and wildlife in winter (Heeg and Breen, 1982). The natural system provided a diverse livelihood strategy that sustained the basic needs of many people. Results show that communities perceive that the current modified stream flow (Chapter 4) benefits a few people.

Results of land use show that good soils suitable for agricultural production are mainly situated on the floodplain and in the state lands off the floodplain. Land use for agriculture on the floodplain showed that

almost all areas that could be used for agriculture were under cultivation and the floodplain had value in terms of crop production, although such value had greatly diminished due to the reduced stream flow experienced (Chapter 4). Results also show that not all of the floodplain is productive. For example, areas with high agricultural potential are located around: the Pongolwane-Mthikeni-Nsimbi complex, the Nomanini-Ngodo-Bumbe complex and the Pongolo-Usutu river confluence located in the Ndumu Game Reserve. The rest of the floodplain areas are too narrow (Fig 2.2).

The floodplain communities had used state land areas adjacent to the floodplain for centuries to produce rain-fed crops and livestock (Poultney, 1980). The implication of developing these areas for production of irrigated cash crops would reduce areas for livestock pasture in the region. Therefore, it is important that pasture cultivation or fodder production be integrated into the planning of irrigation production.

Heeg and Breen (1982) estimated that the floodplain, in its natural state (i.e. pre-dam developments), covered an area of 13 000 ha. Based on scientific literature (Keddy, 2002), community perceptions and field observations, it is highly likely that reduced flooding over the years from Pongolapoort dam has reduced the floodplain area drastically, hence reducing the productive areas for crop cultivation, pasture and other forms of wildlife. Due to the reduced stream flow regime, dry soil moisture conditions were experienced most of the year. This had forced people to cultivate in ecologically sensitive areas (pan inlets, pan outlets, pan beds and river banks) that retain adequate soil moisture throughout the year to grow crops (Fig 4.1, Fig 7.1, Fig 7.2).

Cotton is cultivated 'off the floodplain' and 'on the floodplain'. The crop calendar showed that when crops grown on the floodplain are compared, cotton requires more time to ripen and hence stays longer. And because artificial floods from Pongolapoort dam can only be released when all crops are harvested, the needs of non-cotton growing households were affected.

While majority of cotton-growing households on the floodplain preferred to have artificial floods from the dam in September after cotton had been harvested, non-cotton growing households located downstream preferred artificial floods in August, and others requested for floods as early as July.

Indeed, the reason why people requested for floods as early as July and August could be linked to the fact that these months fall within the dry winter periods when the river experiences natural seasonal low stream flows. During this time, drought conditions are experienced and low pan water levels of bad water quality prevails. People who depend on water directly from the river and pans and lack alternative means of finding food and clean drinking water are affected greatly during this period. The fact that the floodplain system receives significantly reduced stream flows from Pongolapoort dam throughout the year – from winter, spring, summer and autumn means that the impact of dry conditions on soil moisture and water levels the following winter are intensified. For example, prolonged dry periods between the first flood and the next flood promote bush encroachment where good quality pasture fields are shaded out by bush and weeds, which in turn affects livestock health. Reduced stream flow enhances community vulnerability to water related diseases and diseases transmitted by vector populations (Coetzee and Bourne, 1996; Chapter 5). Reduced stream flow enhances community vulnerability to impacts of increased salinity and toxic chemicals (Sereda and Meinhardt, 2003; Chapter 5). Poor water quality in

turn affects its use for irrigation, fish production and domestic purposes. In addition, studies by Van Wyk (1963), Archibald et al. (1969) and Orpen (1972), point to the high potential for water to acquire composition similar to seawater during periods of seasonal low flows on the Makhatini flats. Therefore, water of good quality from Pongolapoort dam must be made available annually through artificial flood releases in order to revitalise the systems for downstream needs.

Indeed, all the floodplain water committee leaders felt that diseases in the community had increased greatly, despite the presence of Shemula Community Water Supply Scheme, which distributes purified potable water, which unfortunately, many people could barely afford. Many were still drawing water directly from the river and pans for basic needs and they felt that diseases always increased with decreasing stream flow and increasing rainfall. It was felt that water quality was becoming a problem not only during periods of seasonal reduced stream flow but also most of the year.

So what needs to be done in order to attempt to accommodate the needs of everyone in terms of artificial flood release timing from Pongolapoort Dam?

Cotton is a cash crop with a market available in the region, which makes cotton farmers less vulnerable to food security risks. However, it was pointed out in the stakeholder dialogue workshops that the needs of others must not be undervalued or ignored, and it was proposed that the best option should be that cotton must not be grown on the floodplain, since it was well established in commercial irrigation schemes in the region. Some of the floodplain cotton farmers argued that while this was a good option, they had no access to suitable lands off the floodplain to grow cotton. In addition, cotton grown off the floodplain must be irrigated and they could not afford irrigation infrastructure and equipments. Others stated that they owned irrigation plots on the commercial Makhatini Irrigation Scheme as early as 1985 but by 1996, many had failed to make a success of farming. Very high farmer failure on irrigation schemes 'off the floodplain' was because local, poorly resourced, unskilled farmers were settled on an irrigation scheme designed for mainly big commercial business. In addition the scheme had a centralized management structure run by a managing agent who also owned farming interests. Many farmers found the land tenure systems inappropriate because they had no title and did not live on their farms and this affected farm management (Chapter 6). Furthermore, the high cost of farm inputs and high interest rates made farming much more difficult (Bembridge, 1991, 1993; A'Bear and Louw, 1994). To make matters worse, some people were allocated land holdings that were uneconomically feasible (<10 ha) (Van Rooyen, 1983; DoA, 1994). Uneconomical plot sizes coupled with unskilled application of irrigation water and the poor maintenance of irrigation equipment contributed to irrigation inefficiency and the lack of adoption of the recommended crop technology leading to low yields and a vicious cycle of increasing debt loads (Van Rooyen, 1983; DoA, 1994). Under these conditions, the lack of tangible returns led to decreasing commitment and enthusiasm to continue farming and so many farmers eventually failed to make a success of irrigation farming. Some of the farmers who failed transferred cotton growing from the irrigation schemes to their traditional communal lands on the floodplain where they could grow cotton freely without the high input costs experienced on the irrigation schemes. But because cotton on the floodplain was interfering with the flood release timing needs of very many non-cotton growing households, it was suggested that replacing cotton 'on the floodplain' with other high value crops that do not take too long to ripen was an option that could benefit more people.

Indeed, results show that the flood timing needs of the various user groups did not change for each user activity (gender, crops, livestock, fishing, and domestic activities) because many people were involved in more than one activity in order to diversify food security strategy. In addition, even though people were involved in more than one activity, it was found that crop cultivation determined their flood release timing needs.

All floodplain communities felt that, although the current flood release timing in September was acceptable by negotiated consensus, it was still the wrong time for their needs, particularly for crops and fish. The floodplain water committee leader representing farming interests supported the importance of aligning farming activities and flood releases with seasonal climate rhythms. He argued that crops can only be planted after a flood release. A July flood release does not support crop growing well because there is no winter rain to supplement floods for a good crop. Even September or October floods are not satisfactory because there is no adequate spring rains to supplement crop growth. Good rains come in summer (Dec, Jan, Feb), yet floods were never released in summer. He felt that under current conditions the only way crops can grow well on the floodplain is if they are irrigated. Indeed, analyses of stream flow (Chapter 4) showed that once the Pongolapoort Dam had been built, the stream flow downstream could never be natural again. All the summer rains were held behind the dam walls to provide water for irrigation throughout the year. Yet floodplain agriculture received water in terms of artificial floods, which lasted for just two weeks in a year. The floodplain was no longer operating in a natural way. It was operating like a dry land off the floodplain. So it is true that it requires irrigation to grow a good crop. Indeed field observations throughout the year revealed that many pumps were being put in the river and pans to irrigate lands off the floodplain and 'on the floodplain'.

Reduced stream flow meant that even after a flood release, drought conditions set in easily and soil moisture stress meant that plants do not grow well and bush and weeds shade out good quality pasture quickly, leading to deterioration in animal health. Indeed, the floodplain experiences drought conditions most of the year, which increases during periods of seasonal low stream flow in July, August and September, causing communities to dig in pan beds to collect water for watering crops, watering livestock and water for drinking, hence increasing the risk of disease infection. Communities dug channels in pan beds to direct water to vegetable gardens during low stream flows. A few could afford to buy pumps. Pans are located much closer to their households than the river, but because of the poor water quality in pans most of the year, the majority of residents spend many hours fetching fresh water from the river. Many people were too poor to afford adequate potable water. This implies that the floodplain and the river are likely to remain the primary source of water for the majority of the population for many years to come.

While installing irrigation infrastructure was a good idea, farmers had been told that the DWAF authority manage the dam for flood control and have to release water before summer rains start so as to provide capacity for the summer inflows. The implication was that an annual flood release must take place which risks destroying irrigation infrastructure. On this basis, the conservation agency EKZN-Wildlife had always argued that the best option was to remove all farming from the floodplain so that it remains purely a conservation area so that floods can be released without having to worry that they will destroy humans and their crops and livestock. But the farmers argued that, the floodplain played a central role in their

livelihoods and can cause negative impacts if access is denied without providing alternative land elsewhere that can continue to supplement the basic needs of very many people who are largely poor.

Results of this study strongly support the farmers' arguments. Apart from the Makhatini irrigation scheme area, most land on the east side of the river was mainly sandy soils with a low potential for agricultural development (Fig 6.1). State lands located on the west side of the river had good soils earmarked for commercial irrigation development. But in order to ensure irrigation profitability in terms of land size (Van Rooyen ,1983; Denison and Manona, 2007), water availability and sustainability; and hence improve farmer commitment and enthusiasm to continue farming; it is important that everyone recognizes the fact that, the use of state lands for irrigation can only benefit very few people directly. It is also important that everyone recognize the fact that drought conditions prevail on the floodplain most of the year due to reduced stream flow from Pongolapoort Dam. Therefore, a better option of ensuring that a wider population benefits, was for government to also help floodplain farming communities by providing agricultural implements and technical support, including irrigation equipment like small engine pumps and pipes that can be moved around easily to avoid being destroyed by any floods that may need to be released. The view for the need to diversify agricultural investments and hence ensure ecologically sustainable development as per the requirements of the DWAF reserve concept (DWAF, 1997, 1999, 2004), in a region with limited suitable land and water availability is strongly supported by plot size ideas discussed in detail under the co-management section 8.7.5.3.3. It is argued that diversity in land plot size should be informed by farming goals based on the needs of society, which often range from commercial production that depends on increasing plot size to enhance profitability for certain crops, to high value crop produce that does not depend on land size to enhance profitability, to food security plots for subsistence needs (Denison and Manona, 2007). In striving to address issues of equity, we argue that increasing land size must be limited to a level that ensures sustainable production and 'fair' profitability that attempts to distribute benefits to more people by increasing the number of commercial producers in a population.

Floodplain fishermen also supported the need for a wider population to benefit from the water resources. They argued that summer rains are good for fish production, yet summer rains were held behind the dam wall for the benefit of mainly irrigation, tourism and recreation and commercial fishing. Fishermen felt that, although they got their water allocation share in terms of an annual artificial flood release from Pongolapoort Dam, the flood waters flowed in and out of the pans so rapidly, ending up in Mozambique, to the extent that there was hardly any positive impact on fish production on the floodplain.

Fishermen felt that reduced water levels in pans meant that there was low to hardly any fish catches. Common barbel (catfish) was the most abundant fish because it prefers reduced poor quality stream flow. Fishermen said that there are community beliefs that prohibit eating barbel, however, due to hunger barbel was eaten but it is not the preferred fish type. Production in pans that depend entirely on a supply of water from Pongolapoort Dam were affected the most. Most of the fish sold on the floodplain came from Mozambique. Fishermen felt that the flood regime from Pongolapoort Dam was not good for fish. They felt that, in addition to the fact that floods had reduced, the floods came with so much force that caused pans to scour, and this led to the loss of vegetation that sustained fish, fishing nets were destroyed and fish eggs died. Thereafter pan levels reduce greatly very quickly that the ability for vegetation

regeneration was affected. Fishermen wanted DWAF engineers to help by designing a way of holding back floodwaters in pans in order to maximise ecological functions for natural fish production. They also wanted DWAF engineers to build fish ladders and bypass that allows fish to migrate freely upstream or downstream past the dam wall. Fishermen felt that, under the current artificial system, introducing aquaculture programmes without putting in place systems to hold back flood waters on the floodplain was a waste of time. Indeed, scientific literature supports the views expressed by the fishermen, that under current reduced stream flow, fish production and wildlife production will be sub-optimal (Heeg and Breen, 1982; James (1992); Welcomme, 1976, 1979, 1986; Keddy, 2002; Kleijn et al., 2004). Fishermen felt that if DWAF engineers do not help them to hold back floodwaters in the floodplain pans, then they must be given access to fishing rights in the Pongolapoort Dam and Ndumu Game Reserve. They argued that few people should get licences to fish in these areas and sell the fish to communities at selected points along the floodplain so that the wider community can also benefit. In the short term, they felt that government should also assist them by helping them to acquire fishing implements like boats.

There was a general perception that government was concentrating only on commercial agricultural irrigation development and had ignored other potential developments such as subsistence agriculture and subsistence fishing, tourism and recreation and non-agricultural developments. It is important to recognize that although irrigation farming can contribute to poverty alleviation or reduction, there was a need for the development of a wide-ranging programme, which not only develops agriculture but also improves skills to earn non-agricultural income through the integrated development of the rural-urban link (Backeberg and Odendaal, 1998; Denison and Manona, 2007). In addition, decision makers must realise that there was a lot of land in the region with potential for irrigation (106 000 ha) (DAEA, 2002), but the limiting factor was water availability and diverse needs for land. Therefore, before decisions are taken to invest heavily in expanding irrigation infrastructure it was necessary to make sure that the water allocated for commercial irrigation was not only adequate, but was also fair by taking into account the needs of others, e.g. floodplain water requirements and the reserve (Chapter 4, Chapter 6). The reserve is an amount of water in terms of quantity and quality that can ensure basic human needs and ecologically sustainable development (DWAF, 1997, 1999, 2004). Indeed, a recent comprehensive assessment of water management in agriculture worldwide came up with eight key policy actions for decision makers in order to meet the ever increasing demands on a limited amount of water that the planet has had since creation, which included, among others, the need to change the way we think about water and agriculture, and the need to fight poverty by improving access to agricultural water and its use (CA Framework, 2002; Molden, 2007).

Overall, both floodplain fishermen and crop farmers perceived that irrigation benefits only a few people compared to the floodplain resources, yet the floodplain was not given much attention. Communities perceived that they were blamed for many things, yet they were the victims. For example:

(i) communities perceived that they were blamed for generally over-exploiting resources and destroying the environment,
(ii) communities perceived that they were blamed for hunting wildlife in the area, yet hunting was largely driven by hunger,

(iii) communities perceived that they were blamed for using the floodplain for agriculture, yet this was the most productive land to which they had access to grow a crop,

(iv) communities perceived that they were blamed for over-fishing, yet reduced flooding had reduced fish production,

(v) communities perceived that they were blamed for over-stocking of livestock and causing erosion; yet the productive ancestral lands off the floodplain were utilized largely for irrigation, while on the floodplain, the artificial stream flow regime had led to a reduction in flooding, reduction in crop, fish and livestock production against the backdrop of an increasing population, leading to frequent conflicts over resource exploitation (stock grazing vs. crop fields; increasing demands for land allocation on the floodplain; irrigation vs. fisheries; cotton farming households vs. non-cotton farming households),

(vi) communities perceived that they were blamed for cultivating in ecologically sensitive areas, i.e. pan inlet and outlet channels, levees and inside pans, river banks and fever tree lines around the pans, yet these were the only areas that retained adequate soil moisture to grow a crop most of the year, while the rest of the floodplain experienced drought conditions.

Communities perceived that they were blamed for things that they had no control over. Sociologists (Taylor-Gooby and Dale, 1981) and community development specialists (Ife, 1999) refer to this kind of society problem as '*blaming the victim's scenario*'. The reality is that the source of the problems is mainly located in the dam structure. The dam structure is central to the problems experienced on the floodplain. This fact is supported by the results of the analysis of trends in stream flow (Chapter 4), and it was shown that artificial stream flow downstream of the dam had reduced greatly when compared with virgin stream flow. Specifically, stream flow data in terms of inflows and outflows, hydraulicity index, flood peaks and flood hydrographs showed that:

(i) The period 1984-1998, artificial flood releases from the dam tried to mimic natural patterns in terms of magnitude only. However, trends in seasonal timing were not aligned with natural climate rhythms and were characterised by an annual, single, distinct, sharp peak in October, instead of two gradual peaks in December and February that characterise natural seasonal stream flow patterns (Fig 4.12 and Fig 4.13),

(ii) After the upstream Bivane Dam development in 1995, inflows into Pongolapoort Dam reduced and mean outflows decreased dramatically from 2000 onwards, while maximum outflows in terms of artificial floods reduced in volume, then stabilized (Fig 4.6).

From a biological point of view, if floods released are not aligned with natural seasonal rhythms, they can never meet environmental requirements of a floodplain wetland ecosystem in terms of maximizing ecological functions needed to enhance natural resource regeneration or production (Keddy, 2002; Welcomme, 1979, 1986). Because floods released between 1984 and 2004 were not aligned with natural seasonal timing, big flood volumes did not add any value in terms of natural resource regeneration. The reason why the big flood in 2000 supported production was due to the fact that the dam was so full that it over-spilled in such a way that made it possible for the floodplain to receive adequate amounts of water at the right time of the season.

The volumes of artificial floods released between 1984 and 2004 were large enough to imitate the natural flooding of the floodplain and hence meet the goal of floodplain water requirements and the reserve. However, the state of stream flow indicates that they may have met the requirements of the reserve in terms of in stream flow requirements (IFR) but they certainly did not meet the floodplain water requirements due to technical reasons. The presence of the dam wall created an artificial state which requires an artificial system through engineering solutions to hold back floodwaters in order to meet floodplain water requirements (Heeg and Breen, 1982; Rosenberg et al., 1995). As observed by the fishermen, in the absence of such engineering solutions the floods released from Pongolapoort Dam flow in and out of the river and pan system so fast that there was hardly any positive impact on floodplain resource production or regeneration. Therefore the findings of Hughes (2000), which concluded that reserve estimates may not have accounted for the requirements of the Pongolo floodplain, are strongly supported and that although there was sufficient water to meet the demands, as well as the reserve, a revised yield analysis of the Pongolo basin system would need to be confirmed.

Scientific reviews and community perceptions of the impact of reduced stream flows on floodplain resources point to the fact that should the floodplain be destroyed completely by a scenario where artificial floods from Pongolapoort Dam cease without the provision of alternatives, there can be adverse ecological and social justice consequences with negative impacts on irrigation, people and livestock, communities and ecosystem habitats far a field (Chapter 5).

An ecological review found that hydrology (stream flows) on floodplains in terms of water level fluctuations is key to production and natural resource regeneration. The implication is that given the present modified state, some level of natural seasonal stream flows must be restored first, before promoting or investing heavily in projects that require production, e.g. aquaculture, pasture, crop cultivation and wildlife conservation. From an ecological perspective, piecemeal projects, funded on the floodplain without providing an adequate volume and flood duration and seasonal timing, is a total waste of money, time and effort, since the desired outcomes in terms of optimal production are unlikely to be achieved (James, 1992; Keddy, 2002; Kleijn et al., 2004). It is no wonder that, many floodplain communities felt that they were tired of project after project without any significant impact on their livelihood. The ecological perspective (Chapter 5) tells us that, unless some level of environmental stream flows on the floodplain are restored, communities will continue to be frustrated, and in turn government is shown in a bad light for not meeting the needs of the environment and hence the basic needs of the people.

See section 9.4 for conclusions and recommendations.

CHAPTER 8: CO-MANAGEMENT ACTIONS AND INCENTIVES

8.1 INTRODUCTION

This chapter addresses the second key objective of this study, which is to: "Develop a strategic plan founded on democratic processes and institutions which facilitates decision making that directs behaviour and endeavours towards the attainment of the preferred state on the floodplain (to define incentives that can encourage people to change behaviour so that equity, efficiency and sustainable use can be attained)".

It must be noted that, due to the need to address the subject of integration and co-management, the problems of the floodplain have been located not only within a catchment context, but also within a regional context. This approach is in accordance with the principles of holistic thinking (Ife, 1999; Senge, 1990; Senge et al., 1994; Senge et al., 1999) or ecosystem management thinking (Grumbine, 1994ab, 1997; Krebs, 1994; Holling and Meffe, 1996; Yaffee et al., 1996; Meffe et al., 2002; Miller, 1996; Primack, 1998). Both perspectives point to the fact that everything in a system is connected and in order to come up with sound solutions, one should always make those inter-connections and linkages. On this basis, the location of the study area (the floodplain) is shown and discussed within a regional or catchment context.

The purpose of the new National Water Act No. 36 of 1998 (Chapter 1, section 2) is, "*to ensure that the nation's water resources are protected, used, developed, conserved, managed and controlled in ways which take into account, amongst other factors-*

Meeting the basic needs of present and future generations,
Promoting equitable access to water,
Redressing the results of past racial and gender discrimination,
Promoting the efficient, sustainable and beneficial use of water in the public interest,
Facilitating social and economic development,
Providing for growing demand for water use,
Protecting aquatic and associated ecosystems and their biological diversity,
Reducing and preventing pollution and degradation of water resources,
Meeting international obligations,
Promoting dam safety,
Managing floods and droughts,

And for achieving this purpose, to establish suitable institutions and to ensure that they have appropriate community, racial and gender representation."

Clearly, the purpose of the Act is underpinned by the principles of ***equity, efficiency, sustainability and representivity***. But what do these concepts mean in practice? This chapter attempts to define what these concepts mean in practice, particularly with respect to integration and co-management within a catchment management context.

Based on the findings from chapter 4 (trends in stream flow), chapter 5 (ecological interests), chapter 6 (agricultural development interests), it is clear that scientific studies carried out in the early 1980s provided a social, economic and ecological knowledge base. It is highly likely that, had such knowledge been implemented, it may have achieved some level of equitable and efficient water allocation between irrigation and floodplain water requirements.

The findings in chapter 7 (floodplain agriculture and natural resource interests) confirm that despite the scientific knowledge and technical skills required to manage the delivery of flows of water from the dam, which can sustain a diverse socio-economy, the management system has strengthened some sectors at the expense of others. Some sectors now perceive that they are bearing the costs but not gaining any benefits. For example, commercial irrigation agriculture upstream and downstream of the Pongolapoort Dam is growing at the expense of downstream floodplain agriculture, fisheries, eco-tourism potential and biodiversity conservation; and commercial agriculture 'on' the floodplain has grown at the expense of subsistence agriculture, fisheries, eco-tourism potential and biodiversity conservation.

The causes of the current inequitable situation are centred in our failure to implement integrated rural development on a catchment scale through co-operative community-based approaches, failure to apply scientific knowledge, an inability to effect corrective action with commitment in response to evidence of inequities and a move away from the ecological desired state for the system.

In recent years, the new National Water Act No. 36 of 1998 and the methods of determining in-stream flow requirements (IFRs), also known as environmental flows (EF), have been refined (King et al., 2000, 2004), and have raised expectations for protecting and optimising the use of goods and services provided by rivers. However, our knowledge and understanding of the human system required to manage in-stream flows to achieve equitable and sustainable use of resources are still in their infancy. This lies at the heart of the problem on the floodplain.

The diverse conflicting values, in addition to having scientific knowledge and understanding of how the ecosystem functions to deliver goods and services, provide a good foundation for co-operation and trans-disciplinary endeavours. Since evidence indicates that this can be achieved only when we have effective community-based resource management, there is an urgency to develop our capacity to empower people to understand what this means in practice so that they can better manage the way they use and share the water resources.

The fact that we have failed to deliver equity and sustainability, allows us to examine the real reasons for failure by understanding what community-based management really means within the context of catchment co-management and integration.

The following section describes catchment management boundaries, relevant stakeholders and outlines conflicting values. The theory that underpins the practical process of resolving these divergent values through a community-based structure is then outlined under the following subtopics, each defining dynamics, actions and incentives (in some cases) associated with striving to achieve:

(i) Representivity and stability (section 8.3),
(ii) Efficiency, equity and sustainability (section 8.4).

8.2 CATCHMENT MANAGEMENT BOUNDARIES AND STAKEHOLDER GROUPS

8.2.1 Management scales based on nature

According to South Africa's new National Water Act of 1998, water resource planning and management should take place within units defined by nature, i.e. quarternary catchments make up a river catchment (Fig 8.2). To implement the intentions of the Water Act, strategies such as the DWAF National Water Resource Strategy (DWAF, 2004) and the DWAF Water Resources Protection Policy (DWAF, 1999), among others, have been defined. Implementing these strategies and policies on the ground is a key challenge.

For example, according to the DWAF national water resources strategy, there are 19 water management areas (WMA) in South Africa, each made up of several river catchments. Only one catchment management agency (CMA) is envisaged for each WMA (DWAF, 2004). The Pongolo floodplain is located within the Usutu to Mhlatuze WMA (Fig 8.1).

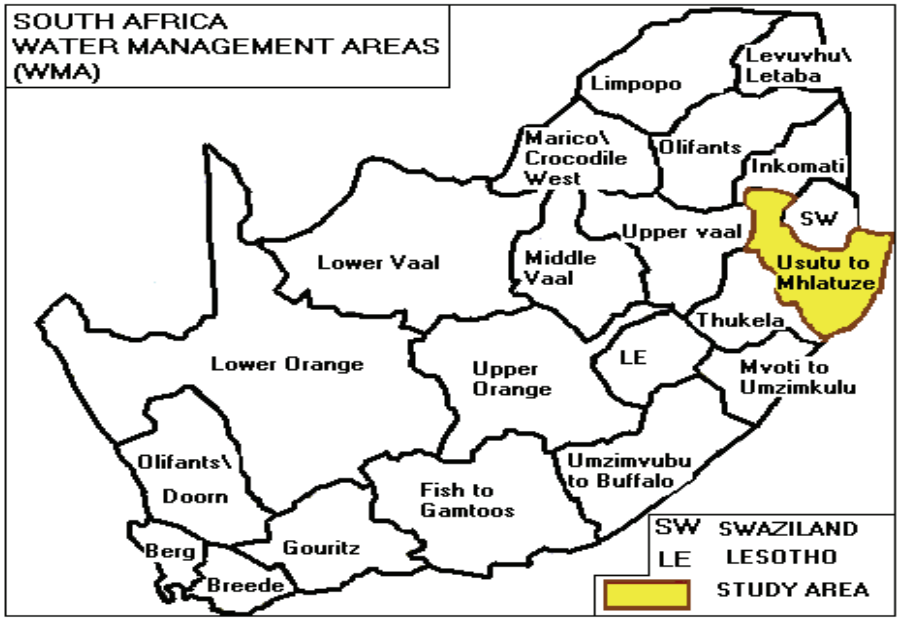


Figure 8.1: South African Water Management Areas (WMA) (Source DWAF).

River systems or catchments within the Usutu to Mhlatuze WMA are: the Mhlatuze River, the Mfolozi River, the Mkuze River, the Pongolo River and the upper Usutu River (Fig 8.2). The focus of the study is located within the Pongolo river catchment, specifically the floodplains downstream of Pongolapoort Dam. Sub-management levels within a catchment are water resource units known as quarternary

catchments or eco-regional types. For example, W45a and W45b are quarternary catchments within which the Pongolo River floodplains are located (Fig 8.2).

According to the DWAF Water Resources Protection Policy (DWAF, 1999), and its implementation strategy, known as Resource Directed Measures (RDM), quarternary catchments or eco-regional types are delineated based on biophysical factors, namely:

(i) Physiographic factors (e.g. altitude, latitude, aspect, slope, climate zone),
(ii) Geological factors that determine geochemical signatures as well as aspects of geomorphology and habitat,
(iii) Regional natural hydrological characteristics (e.g. annual precipitation, seasonality, variability of flow),
(iv) Major natural vegetation types (e.g. bushveld, lowveld, etc.),
(v) Biotic factors including the natural occurrence of certain kinds of organisms (e.g. fish, invertebrates, plants, algae).



Figure 8.2: Quarternary catchments (eco-regional types or resource units) within the Usuthu to Mhlatuze water management area (WMA) comprising five river catchments (Mhlatuze, Mfolozi, Mkuze, Pongola and upper Usutu). The study area is located within the Pongola River catchment (Source DWAF).

The RDM approach enables a catchment to be broken down into water resource units, which are significantly different from each other to warrant their own specification of the 'reserve'. Delineation of water resource units within catchments is done primarily on a biophysical basis (eco-regional types). These water resource units may be broken down further into smaller resource units or may be grouped together on the basis of major land uses and management needs, e.g. agriculture, urban or industry. A reserve determination for an entire catchment would contain delineated water resource units; each unit would have a management class (e.g. A, B, C, or D) and reserve (water quantity and quality objectives) applicable to each resource unit, i.e. quality specifications and monitoring to ensure sustainable use (DWAF Water Resources Protection Policy, 1999).

On this basis, water resource units affected by artificial flood releases from the Pongolapoort dam and may warrant their own specification of the 'reserve'are W44E, W45A and W45B.

8.2.2 Management scales based on political boundaries

Stakeholders affected by artificial flood releases from the dam have to be identified so that they can be mobilised into action through participation in Water User Association structures.

Although the Act stipulates a need to manage water within natural units, implementing such management may be less efficient because political boundaries are mainly different from natural boundaries. Yet, political boundaries form the basis of all organizing from national government through provincial government to local government. However, studies show that planning and management of delineated water resource units based on nature (catchment/watersheds) is likely to be more successful than planning and managing water resource units based on political units or boundaries (Grumbine, 1994, Holling and Meffe, 1996; Yaffee et al*.,* 1996; Meffe et al., 2002).

Superimposing maps based on natural boundaries over maps showing political boundaries identifies relevant stakeholders. For example, when specific land holdings with potential for irrigation expansion development are superimposed over water resource unit boundaries (quarternary catchments or eco-regional types), land holdings affected by artificial flood releases from the dam are: W45B (35, 2, 5, 6, 13,14 and 19); W45A (21-34) (Fig 8.3).

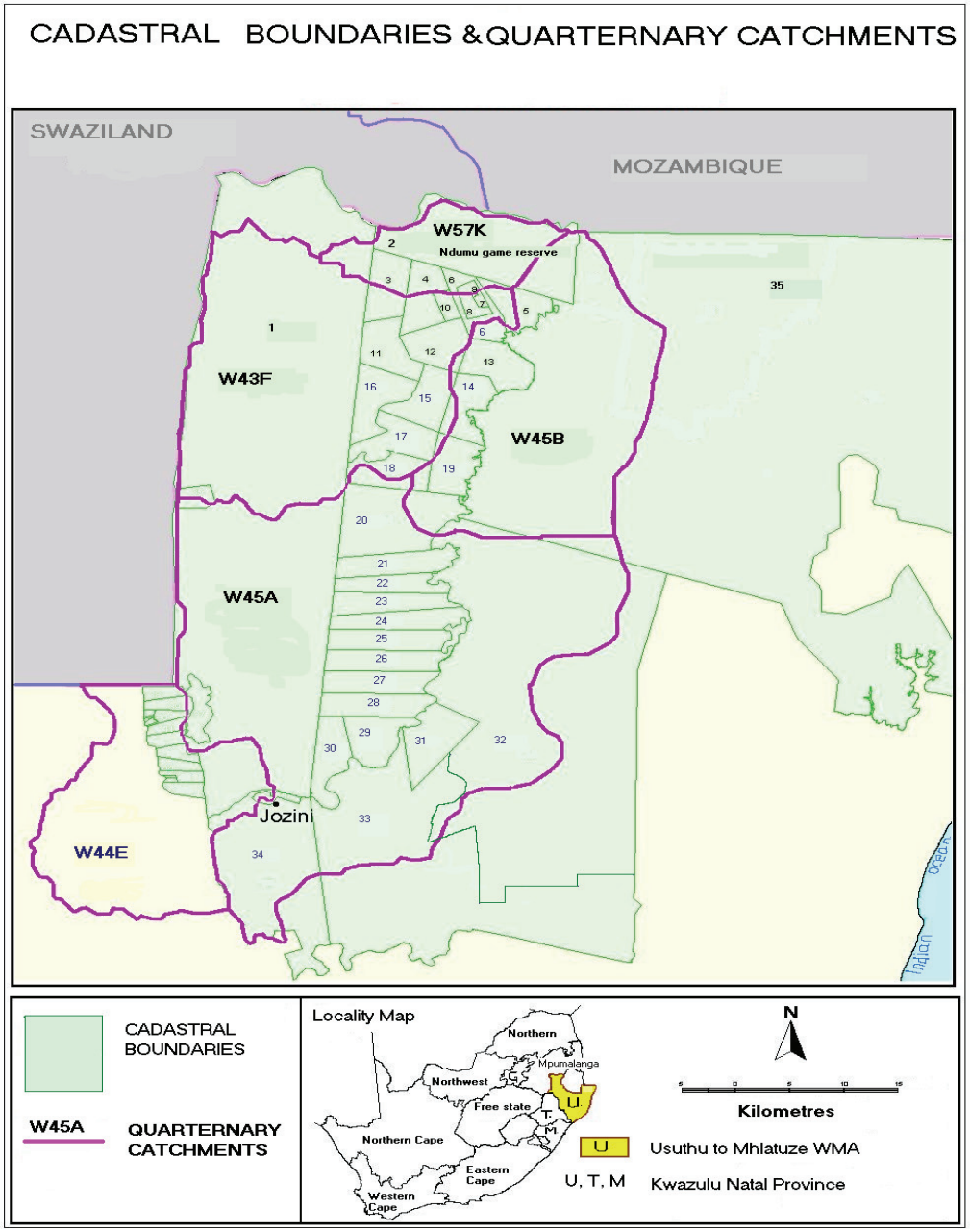


Figure 8.3: Water resource unit boundaries (quarternary catchments or eco-regional types) superimposed over cadastral data (Source DWAF).

In addition, when water resource unit boundaries (quarternary catchments or eco-regional types) are superimposed over tribal authority boundaries (Fig 8.4), parties affected by artificial flood releases from the dam within each unit are identified and listed in Table 8.1.

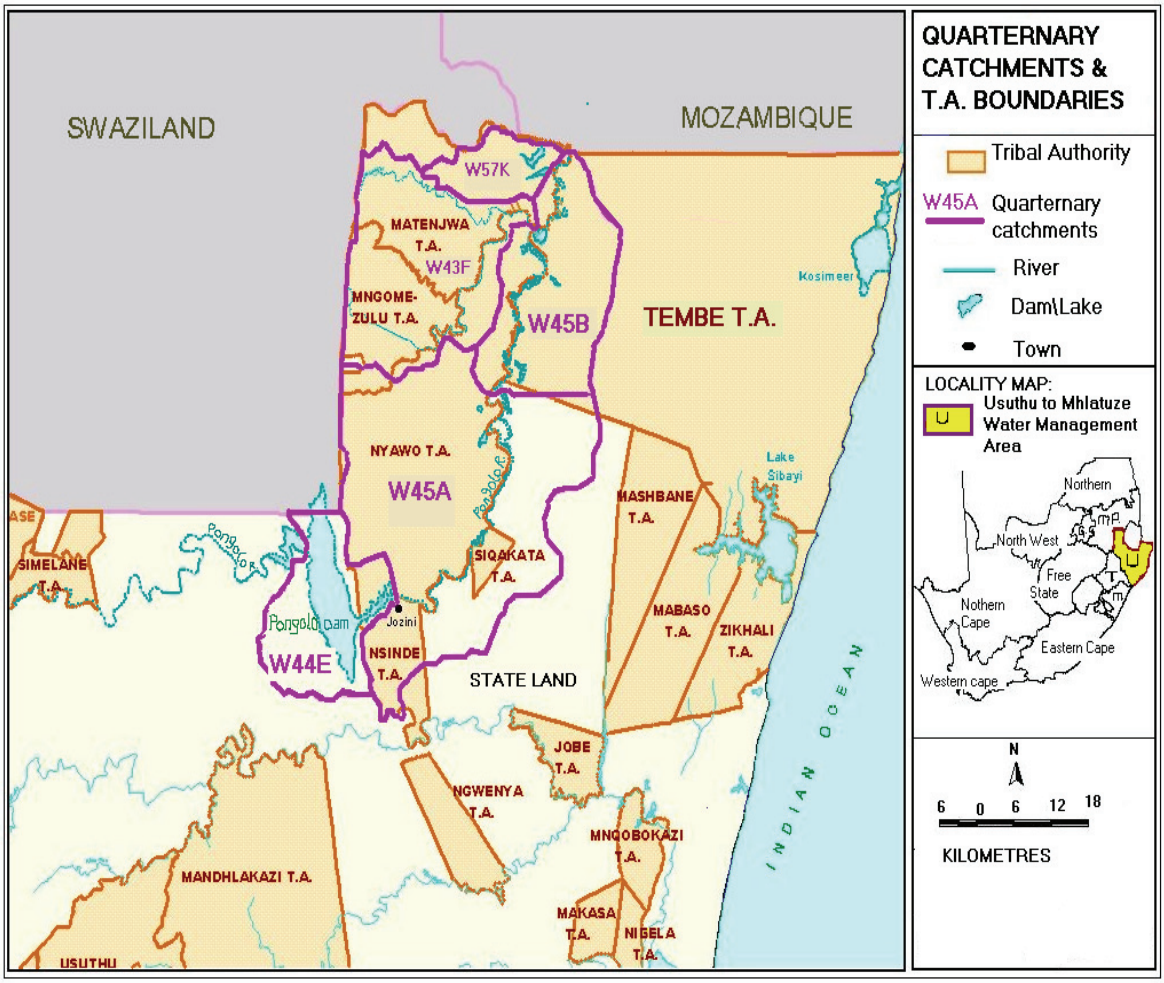


Figure 8.4: Water resource unit boundaries (quarternary catchments or eco-regional types) superimposed over tribal authority boundaries. The two boundaries are different (Source: DWAF).

Table 8.1 also illustrates the complexity of political boundaries when compared with the simplicity of natural boundaries. For example, the complexity is such that the eastern side of the floodplain is within the Jozini municipality (KZ272), while the western side falls under the Umhlabuyalingana municipality (KZ271). This often makes the concept of integrated water resources management less efficient to implement.

Table 8.1: Parties affected by artificial flood releases from the dam at the Quarternary catchment scale (sub-management level based on nature).

Location relative to Pongolapoort Dam	Quarternary catchment scale (natural boundaries)	Authority at the district scale	Authority at the local municipality and traditional authority scale	Affected Wards\Users (See also **section 6.3.2** and **Fig 6.2** for further clarity)
Downstream	W45B	Umkhanyakude District Council DC27	Jozini municipality KZ272	Election wards: 12 13
			Umhlabuyalingana municipality KZ271	Election wards: 6, 8,9
			Matenjwa T.A	Ekukhanyeni, Ndumu, Ndumu Irrigation scheme
			Nyawo T.A	Makhane, Shemula,
			Tembe T.A	Mbangweni, Bhekabantu, Kwandaba, Lulwane, Zama Zama.
			EKZN-Wildlife	Ndumu game reserve and Tembe elephant park
	W45A	Umkhanyakude District Council DC27	Jozini municipality KZ272	Election wards: 1,4,5,6,8,9,10
			Umhlabuyalingana municipality KZ271	Election wards: 7
			State land	Mboza, Hlokohloko, Hlazane, Welcomme, Madonela, Makhonyeni, Makhatini Irrigation scheme, Jozini Municipality
			Siqakata T.A.	Mamfene, Nyawoshane
			Nyawo T.A	Bhekindoda, Kwashukela, Nondabuya, Othobothini
Upstream	W44E	Zululand District Council DC 26	Uphongolo municipality KZ262	Election ward: 1 Dam property owners (EKZN-Wildlife game reserve, Pongola game reserve north and Pongola game reserve south).
		Umkhanyakude District Council DC27	Jozini municipality KZ272	Election ward: 1 (Mkuze Sugar Irrigation and Nature conservation)
			Nsinde T.A	Majozini, Gondile, Jozini Municipality
			Nyawo T.A	Mpondwane
			EKZN-Wildlife	Pongola nature reserve

8.2.3 Stakeholders affected by artificial flood releases

8.2.3.1 Communities

8.2.3.1.1 Downstream stakeholders

(i) Floodplain agriculture and fisheries + dry land agriculture off the floodplain
(ii) Makhatini irrigation scheme,
(iii) Ndumu A and B irrigation scheme,
(iv) Other areas with potential for irrigation,
(v) Local municipality, Jozini,
(vi) Local municipality, Umhlabuyalingana.

8.2.3.1.2 Upstream dam property owners

(i) Irrigation (Mkhuze Sugar Estates),
(ii) Private game reserves and lodges,
(iii) Public game reserves EKZN-Wildlife,
(iv) Local municipality, uPhongolo,
(v) Local municipality, Jozini.

8.2.3.2 Key Regulatory Authorities

(i) DWAF,
(ii) Conservation agency (EKZN-Wildlife),
(iii) DAEA,
(iv) DoH,
(v) Tripartite Permanent Technical Committee (TPTC) (The international water sharing management organisation for the Maputa Basin comprising South Africa, Mozambique and Swaziland).

8.2.4 Summary of conflicting values

There are four key issues limiting agricultural development expansion in order to achieve the full irrigation potential of 106 000 ha on the Makhatini flats (Cedara, 1993; DAEA, 2002). See Chapters 4-7 for more information on the various interest groups.

(i) Conflicting land tenure issues, specifically, relating to issues of property rights and ownership systems, e.g. conflicting land tenure between Tribal Authorities and State lands because some local people are living on state lands under the traditional communal system (no title deed). Others were moved from their lands through apartheid policies,
(ii) Equitable and efficient sharing of available water between economic developments downstream of Pongolapoort Dam, economic developments around Pongolapoort Dam

property owners, economic developments upstream of Pongolapoort dam and the subsistence economy supported through artificial flood releases from the Dam.

(iii) Conflict between irrigation water requirements vs. conservation of the floodplain water requirements (i.e. floodplain water requirements and the reserve),

(iv) The conflicting land use requirements between the long-term conservation of the floodplain to be used purely as a conservation area for eco-tourism vs. subsistence agriculture use. The most productive areas are located on the state lands and the floodplain. The most agriculturally productive areas on the floodplain are located in three areas: the Pongolwane-Mthikeni-Nsimbi complex, the Nomanini-Ngodo-Bumbe complex and the Pongolo-Usutu confluence (Fig 2.2). Incidentally, these areas are also areas of high intrinsic biodiversity value and require conservation protection (EKZN-Wildlife and IDP plans) as ESAs (Fig 8.9 and Fig 8.10). The Pongolo-Usutu confluence area, covering the Ndumu game reserve, is already fenced and protected as a conservation area for eco-tourism and communities do not have access to its resources (Chapter 7). The use of the other two areas (the Pongolwane–Mthikeni-Nsimbi complex and Nomanini-Ngodo-Bumbe complex) for subsistence agriculture causes conflict between subsistence agriculture and the conservation agency (EKZN-Wildlife), whose desire is for communities to leave the floodplain so that it can become purely a conservation area. Reduced flooding over the years has continued to reduce the size of these areas leading to further overexploitation and the degradation of the natural resource base coupled with increasing conflict over areas used for grazing vs. areas used for crop cultivation (Chapter 4, Chapter 7). The implication is that should floodplain communities be denied access to the use of floodplain resources (crops, pasture and fish) without providing tangible, workable alternatives, they will be vulnerable to the effects of droughts, hunger, poverty and disease. Chapter 7 and section 8.4.5.3 and 8.4.5.4 discuss further the co-management of these conflicting values.

Resolving these diverse conflicting values in order to achieve the goal of equitable and efficient water allocations between users can be addressed through appropriate decentralized catchment management structures, where integrated co-management principles are implemented in order to strive to achieve representivity, which in turn enhances the ability to achieve equitable and efficient water allocation among users, thereby promoting social relationships, stability and sustainability in the long term.

8.2.5 Stakeholder dialogue workshop

According to community development principles (Ife, 1999), the best practice is for professionals to assist communities to define their own needs. Professionals, development agencies or government must not define needs independently and then impose them on a community. Best practice is to integrate professionally defined needs (e.g. those identified from the analyses carried out in Chapters 4-7) with stakeholder-defined needs.

Community needs were defined through a stakeholder dialogue workshop where individual stakeholders presented and shared their problems\concerns. The process contributed to the purpose of building a shared understanding of each other's problems, perceptions, values, beliefs and needs, and formed the

initial foundation for developing a common understanding on which subsequent co-management initiatives can be built.

The outcome of this process was problem statements and concerns based on stakeholder perceptions. Before groups can develop common visions and goals, there must be a clear and widely recognised common problem statement (Senge, 1990; Senge et al., 1999). The problem statements help to establish a common understanding of the conditions and to prioritise initiatives needed to solve the problems on a catchment or sub-catchment scale.

Actual problem statements made by the various interest groups are presented and discussed in detail in the relevant Chapters 4-7. Details of the actual dialogue process are in Jaganyi et al. (2003). Table 8.2 summarizes the issues raised by stakeholders affected by artificial flood releases from the dam.

Table 8.2: Summary of issues arising from stakeholder problem statements	
1	Uniqueness of the environment and the dependence of the economy on the environment, e.g. fisheries, agriculture and animal husbandry, tourism.
2	The sensitivity of the system to disturbance, especially environmental disturbance.
3	The construction of the dam has disrupted many environmental and social activities.
4	Inadequate participation/representation of stakeholders in meetings. Timing and duration of flood releases is a problem. The two issues came up repeatedly.
5	The cost of not consulting or communicating issues regarding the releases of water.
6	We should not fail to learn from the good practices of the past as well as avoid some of the bad practices of the past.
7	People involved with management should not presume that they are communicating; they should ensure that they are communicating to people at every level.
8	There are issues of land claims, land registration and titling; it is an important issue that needs to be resolved
9	Flood releases do not only affect the Makhatini flats; it affects people far downstream as well as people upstream, particularly dam property owners.
10	The natural potential productivity of the system is enormous (e.g. agricultural, fisheries, conservation for tourism).
11	The potential for increasing developments and agricultural output is also enormous.
12	The diverse interests and needs of all stakeholders are going to make consensus building a challenging process.
13	It must be clear to everyone that the available water resource is scarce.
14	All are dependent on the river and all are affected by what others do.
15	The last issue is co-operative governance and the need for different departments to co-operate with one another to achieve their objectives.

Stakeholder perceptions of the system expressed in the dialogue workshops (Jaganyi et al., 2003) shows that the economy is complex. Therefore promoting equity, efficiency and sustainability of the economy will require robust and resilient management systems. There are strong self-interests and consequent tensions. Governance will have to have legitimacy.

8.2.6 Summary of stakeholder needs and overlapping priority needs

In order to prioritise problems that need immediate catchment management action, stakeholders listed their needs on colour-coded cards (See Appendix 2 for detailed statements of needs). After sorting these needs, it became clear that the needs could be categorized based on four common themes:

(i) Decision making needs\management (e.g. a formal decision making structure involved in development discussions, transparency, accountability, and empowerment),
(ii) Water resource needs (water availability, water allocation, flood release – timing and magnitude, water quality, the reserve, and fishing),
(iii) Agricultural needs (water for irrigation, floodplain crops, and livestock grazing),
(iv) Environmental needs (the reserve issues, erosion, bad agricultural practices, and monitoring of usage).

The needs listed under 'environment' are similar to 'water resource' needs. The needs that were most common to both regulatory authorities and communities (i.e. overlapping needs), which therefore need immediate catchment effort or action, fell under the category, decision-making (management) needs (Appendix 2). Many cards expressed the fact that they would not only like their voice to be heard within a formal structure in terms of the Water Act, but would also like to be empowered to make decisions and act upon their needs themselves.

8.2.7 Implementation plan based on stakeholder needs

Stakeholder needs listed above point to three actions:

(i) The need to integrate water resource use for economic needs, social needs and ecological needs in order to support a sustainable, diverse economy,
(ii) The integration of economic, social and ecological needs, which requires 'comprehensive reserve determination' to be initiated and effected through a catchment management structure and water user associations at various scales,
(iii) The results of a 'comprehensive reserve determination' are intended to achieve integration, equity and efficiency of use.

8.2.8 Short-term implementation goals

Therefore, the immediate implementation plan, with respect to decision-making, was to:

(i) Ensure that all affected groups are empowered to participate actively in the decision making process through co-management training materials,
(ii) Initiate DWAF processes for setting up formal water user structures (WUAs),
(iii) Initiate building up a 'knowledge base' in accordance with reserve determination needs to support interest based bargaining and decision-making, within the various WUA structures.

8.3 CO-MANAGEMENT ACTIONS FOR ENHANCING REPRESENTIVITY AND STABILITY

8.3.1 Introduction

The overall vision of integrated, sustainable development and the subsequent implementation of stakeholder needs and goals identified in section 8.2.4 and 8.2.5 above requires 'comprehensive reserve determination' to be initiated and effected through a decision making structure: CMA and/or WUAs at various scales within the catchment. It is expected that results of the comprehensive reserve determination would build up a 'knowledge base' to support 'interest based' bargaining and wise decision making that leads to equitable and efficient allocation of water.

However, from the theoretical framework underpinning 'how societies behave and work', it is highly likely that the results of a 'comprehensive reserve determination' intended to achieve integration, equity and efficiency of water use may not be implemented due to political, social and economic dynamics. Because this problem is likely to occur, it is vital that stakeholders understand why, so that they can expect the problems and learn to overcome them. One such empowerment strategy is to 'understand how societies behave and work'.

8.3.2 How societies behave and work

Key lessons to learn from the theory of how societies behave and work, which can improve our understanding of the importance of representivity in achieving co-management and integration and hence fair resource allocation is to try to answer the following questions, among others:

How do we create robust and resilient catchment management structures (e.g. CMAs, WUAs) that have legitimate governance and are able to bind stakeholders with diverse interests through effective decision making, controlling conflict within catchment groups (various water use sectors) and regulating relations with other groups?

How can we empower divergent interests within the catchment to negotiate and reach true consensus on issues of 'fair' access to water for development and water for the reserve (basic needs and the environment)?

How do we empower co-management structures (e.g. CMAs, WUAs) so that they can build a solid foundation for a decision making process that is healthy, with good governance, consensus and with functional equity?

One such initial empowerment strategy is for managers and decision makers to start by understanding the importance of the following basic factors that influence human behaviour and action.

(i) Patterns of human behaviour (culture, norms, values, status, roles, responsibilities) (Hammond, 1978; Haralambos and Holborn, 2000),

(ii) Learning, changing and sharing knowledge (communicating) can lead to human improvement and progress (Hammond, 1978; Levitas, 1983; Senge, 1990; Senge et al., 1999; Breen et al., 2003),

(iii) Policy formulation, implementation and decision making models (Rubin and Weinstein, 1977; Booysen and Erasmus, 2001; Venter, 2001).

Catchment management managers, decision makers and stakeholders must be made aware of the dynamics that come into play during decision-making processes in water resource allocations and that these dynamics limit achievement of 'fair' results. For example, managers rarely have an adequate knowledge base to support decision making when implementing policies; hence the impact of many policies is often underestimated. Managers need to be aware of the various decision-making models and use the most appropriate under any given situation. Also, managers need to be aware of the various political theories underpinning human behaviour in policy implementation and decision making so that they can begin to foresee the impact of these various behaviours and learn to overcome them and to achieve positive outcomes.

8.3.3 Community-based decentralized decision-making perspective and model

The process of mitigating the expected negative outcomes from political theories underpinning human behaviour in decision making is difficult but there is a higher chance of achieving positive outcomes through the use of a participatory, community-based, decentralized decision making model, which has many advantages that result in fair outcomes (Appendix 4). A centralized decision making model has very many disadvantages that result in unfair outcomes (Appendix 3) (Ife, 1999; Smith, 1999; Booysen and Erasmus, 2001; Venter, 2001). Elements of the ecological perspective (holism, sustainability, diversity, equilibrium and balance) and social justice perspectives (structural disadvantage, empowerment, needs, rights, peace, non-violence and co-operation, participatory democracy), together with management perspectives (elements of good leadership, governance and capacity building) strongly support the decentralization view (Ife, 1999; Senge et al., 1999; Breen et al., 2004).

A community-based, decentralized decision-making perspective and model (Ife, 1999) can enhance effective decision making, controlling conflict within groups and regulating relations with other groups? Principles underpinning a community-based, decentralized decision making perspective and model and the dynamics of the socio-political and values framework within which decisions are made are discussed and defined in by Ife (1999). Table 8.3 outlines these principles.

Analysis of the various elements in the current perceived environmental crisis (Table 8.3), points to the fact that one should always take a holistic approach when analysing the cause of a problem. Green writers have reported on studies that clearly show that the problems of the world are linked and inter-connected and to find solutions to the problems, one has to think in terms of linkages and inter-connections among the various elements within the perceived environmental crisis and how they influence the ecological and social justice perspectives (Table 8.3).

Table 8.3: The perceived crisis is explained through ecological thinking and social justice thinking. (Solutions to the perceived crisis are derived by making linkages and interconnections that form a dual foundation in ecology and social justice or the integrated perspective (Adapted from Ife, 1999)			
	PERCEIVED CRISIS		
Environmental perspective	**Eco-socialism** (Gorz, 1980; Ryle, 1988; Mellor, 1992; Pepper, 1993)	**Eco-anarchism** (Bookchin, 1990, 1991; Marshall, 1992).	**Eco-feminism** (Mellor, 1992; Biehl, 1991; Merchant, 1980; Shiva, 1989; Plumwood, 1993)
	Eco-luddism (Illich, 1973; Mander, 1991; Postman, 1993)	**Anti-growth** (Meadows, Meadows, Randers and Behrens, 1972, 1992; Schumacher, 1973; Rifkin, 1985; Trainer, 1985; Gordon and Suzuki, 1990; Lutz, 1992; Postman, 1993; Primack, 1998).	**Green economics** (Pearce, Markandya and Barbier, 1989; Jacobs, 1991; Daly and Cobb, 1989; Henderson, 1988, 1991; Ekins, 1986, 1992; Dauncey, 1988; Trainer, 1989; Manfred Max-Neef, 1991, 1992; George, 1992; Stilwell, 1993).
	Global development (Trainer, 1985, 1989; George, 1979, 1992; Shiva, 1989, 1991; George, 1992; Norgaard, 1994; Latouche, 1991; Trainer, 1985; CCBA, 2003)	**Eco-philosophy** (Eckersley, 1992; Fox, 1990; Marshall, 1992; Naess, 1989)	**New paradigm thinking** (Capra, 1982; Rifkin, 1985; Ornstein and Ehrlich, 1989).
	Work, leisure and the work ethic (Gorz 1983; Trainer 1985; Lipietz 1992).		
	ECOLOGICAL CONCEPTS		
Ecological perspective	**Holism** (Grumbine, 1994; Krebs, 1994; Christensen et al., 1996; Yaffee et al., 1996; Grumbine, 1997; Haeuber & Franklin, 1996; Holling and Meffe, 1996; Primack, 1998; Keddy, 2002; Meffe et al., 2002; Naess, 1989; Fox, 1990; Senge, 1990; Senge et al., 1999; Eckersley, 1992; Marshall, 1992; Ife, 1999)	**Sustainability** (Maslow, 1954; Brundtland report of the world commission on environment & development, 1987; Lubchenco et al., 1991; Ekins, 1992; Kamenetzky, 1992; Max-Neef, 1992; Primack, 1998; Ife, 1999; Edwards-Jones, Davies and Hussain, 2000)	**Diversity** (Darwin, 1859; Soule, 1980; Porrit, 1984; Soule, 1985; Trainer, 1985; Wall, 1990; Kemp and Wall, 1990; Alcock, 1993; Futuyma, 1995; 1998; Primack, 1998; Ife, 1999; Senge et al., 1999)
	Equilibrium or balance (Schneider, 1989; Gates, 1993; Climate Change, 1996; Primack, 1998); (Bawa and Markham, 1995; Climate Change, 1996; Karl et al., 1997; Myneni et al., 1997),	**Equilibrium or balance** (Peters and Lovejoy, 1992); (Schulze, 1997); (Hensley, 1966; Maud, 1968, 1980; King, 1972; Chung, 1982; Shaffer et al., 1992; Boesch et al., 1994; Primack, 1998; Climate Change, 1996; Keddy, 2002).	**Equilibrium or balance** (Young et al., 1985; Odum, 1997;Costanza et al., 1997; Primack, 1998; Du Plessis, 2004; DeWeerdt, 2004); (Trainer, 1985; Plumwood, 1993; Kohn, 1986; Argyle, 1991; Craig, 1993).

	SOCIAL JUSTICE CONCEPTS		
Social justice perspective	**Structural disadvantage** (Foucault, 1972, 1973, 1979; Taylor-Gooby and Dale, 1981; Rojeck, Peacock & Collins, 1988; Clegg, 1989; Ife, 1999)	**Empowerment** (Mills, 1956; Gough, 1979; Dahl, 1961; Alinsky, 1969, 1971; Foulcault, 1973,1979; Liffman, 1978; Chambers, 1981; Chambers, 1983; Feher, Heller and Markus, 1983; Williams, 1989; Senge, 1990; Ife, 1991; Mullaly, 1993; Rouse, 1994; Senge et al., 1994; Chambers, 1997; 1fe, 1999; Senge et al., 1999)	**Needs** (Marcuse, 1964; Illich, 1977; Hammond, 1978; Fay, 1987; Chamber, 1997; Ife, 1999).
	Rights (The universal declaration of human rights – United Nations in 1948; George and Wilding, 1985; Ife, 1999)	**Peace, non-violence and co-operation** (Gandhi, 1964; Gandhi, 1982; Kropotkin, 1972; Rubin and Weinstein, 1977; Kohn, 1986; Gorz, 1989; Argyle, 1991; Craig, 1993; Ife, 1999)	**Participatory democracy** (Participation, decentralisation, education, accountability and obligation) (Senge, 1990; Smith, 1990; Senge et al., 1994; Schein, 1996; Anderson, 1997; Ife, 1999; Senge et al., 1999; Booysen and Erasmus, 2001; Venter, 2001)
	INTEGRATED PRINCIPLES (principles intended to make participatory democracy work in a decentralized decision making structure. Some of the principles relate more to analysis and strategy, and others to practice and they relate to each other in a variety of ways)		
Integrated perspective (Capra, 1982; Rifkin, 1985; Ornstein and Ehrlich, 1989; Ife, 1999; Senge et al., 1999)	Integrated development	Human rights	Empowerment (good leadership, good governance, capacity building)
	Confronting structural disadvantage	Self-reliance	Immediate goals and ultimate visions
	The pace of development	Community building	The integrity of process
	Inclusiveness	Co-operation	Defining need
	Sustainability (anti-growth, green economics)	Community ownership	Self reliance
	Organic development	External expertise	Process and outcome
	Peace and Non-violence	The personal and the political	Consensus

It is argued that linear solutions to the current perceived environmental crisis (Table 8.3) have been unable to provide lasting solutions for meeting human needs.

For example, conventional linear approaches to the environment see the problems as biophysical problems, to do with air, water, pollutants, chemical reactions, soils, climate and temperature, etc. thus requiring essentially biophysical and technical solutions. Biophysical sciences are largely seen as the major disciplinary base for dealing with these problems. Biophysical scientists are seen as the 'experts' in environmental issues. By contrast, the 'green' response to environmental problems takes a more fundamental or radical approach. It sees environmental problems as being merely the symptoms of a more significant underlying problem. They are the consequence of a social, economic and political order, which is blatantly unsustainable, and thus it is the social, economic and political order which needs to be changed (Ife, 1999). Conventional, linear, technological solutions to environmental problems may be adequate and indeed essential in the short term, but in the long term, they often prove inadequate unless more fundamental social, political and economic change occurs.

The following thought process attempts to find solutions to the current perceived crisis. The ecological thinking that explains how natural systems are organised and how they function in practice, in terms of, equilibrium or balance, sustainability, diversity and holism is linked to the political thought processes and management systems. This understanding is then used to suggest appropriate actions and principles needed to achieve representivity, efficiency and sustainability on issues of 'fair' access to water for development and the reserve (water for basic needs and the environment). The outcome of this process is integrated concepts and principles that form the foundation for community development (Table 8.3). The perceived crisis is explained through ecological thinking and social justice thinking. Solutions to the perceived crisis are derived by making linkages and interconnections between the perceived crisis, ecological perspective and the social justice perspective to form a dual foundation in ecology and social justice or the integrated perspective (Ife, 1999)

Themes such as decentralisation and self-reliance are proposed and an integrated and holistic approach to community development outlined, comprising six components of development: social, economic, political, cultural, environmental and personal/spiritual (Fig 8.5).



Figure 8.5: The six dimensions of community development (Ife, 1999)

The implications for successful integrated catchment management means that achievement of the overall vision of integrated sustainable development and the subsequent implementation of stakeholder needs and goals, identified in section 8.4 and 8.5, must take these six components of development into account. The principle of holism implies that WUA problems must be solved by analysing the possible links and inter-connection of the six components within the group and among other WUA groups in the catchment, in other catchments, and the regional, national and international linkages.

8.3.4 Implications for catchment integration and co-management actions for representivity and stability

If these community-based integrated concepts and principles (Table 8.3) are implemented within a WUA structure, they provide an enabling environment and form the primary values that underpin effective co-operative governance that can guide fair access to water for development and the reserve. Indeed, they form the basis for building a solid foundation for a decision making process that is healthy with good governance, negotiated consensus and with functional equity. They provide an environment that encourages people to change their behaviour so that equity, efficiency and sustainable use can be attained.

Integration of the ecological thinking of diversity into political thought processes, challenges the assumption that there must be one best answer. For example, a diverse set of species of cattle or wheat means that a new disease may strike one or two but is unlikely to affect all. If there is just one species of wheat, a new disease could wipe out the whole crop. Likewise, uniformity of culture may turn out to be uniformity of a mal-adaptive or destructive culture, resulting in the breakdown of human civilization (Ife, 1999). Therefore, diversity encourages a variety of different ways of doing things in order to spread the risk. Diversity encourages a variety of different ways of doing things, so that people can learn from the experiences of others, and change can proceed cautiously on the basis of a variety of accumulated wisdom. Difference rather than uniformity is valued.

According to Ife (1999) and many green writers (Table 8.3), diversity supports the political thought of decentralization, where people should be allowed to find their own solutions and ways of doing things and through horizontal communication, experiences can be shared and lessons can be learned far more effectively than from central, bureaucratic forms of communication. Implications for WUAs and water forums is that people will organise best around needs that are of interest to them, e.g. pump stations in irrigation schemes; extension committees for agriculture; extension committees for livestock; obtaining an adequate water allocation from DWAF for floodplain agriculture; enhancing agricultural development through investor schemes; protecting species and habitats; enhancing the eco-tourism industry and other industries; improving fisheries on the floodplain; expanding irrigation and commercial forestry, etc. There can be as many forums and WUAs as there are needs which promotes representivity; however, central co-ordination is key. Central co-ordination ensures that the various needs and interests are aligned with government policies and to the ecological and social justice thinking.

The only disadvantage of decentralized control is the high level of education needed to make it work. To embark on a programme of participatory democracy without a high level of education or learning programme (or capacity building programme or strategy), which enables the people concerned to effectively participate in decision making, and take action to meet those decisions, is a recipe for failure! As an initial empowerment strategy, it is very important that stakeholders not only understand the elements in ecological, social justice and management perspectives, but are also able to put them into practice.

While recognising that for some purposes more centralised decision making is necessary, or at least co-ordination is required, the principle involved is that no decision or function should occur at a more centralised level than is necessary, so that the perspective of the periphery, rather than the centre, is given priority when disputes arise, rather than the conventional view of central control, which sees the perspective of the centre as the more valid because it is able to take an overview of issues at the periphery (Fig 8.6 and Appendix 3 and 4). When decisions and functions are made at the most appropriate scale, one increases the chances of effective implementation of actions resulting in positive outcomes and sustainability.

The challenge of addressing capacity building needed to make decentralized structures function efficiently can be achieved by an incentive that links capacity building to the funding of all catchment management project initiatives. Project teams must be made to account for the capacity build in target

groups. Project evaluation must show a measurable extent of capacity build in both the project team and the target groups (Breen et al., 2004). Projects initiated must enhance learning and capacity programmes must ensure that people continuously re-enforce their learning abilities needed to sustain change.

On the basis of these findings, an example of a possible decentralized water management organogram showing levels of central control (CC) and decentralized control (DC) is proposed in Figure 8.6 and Table 8.4.

(i) The structure proposes four WUAs on a catchment scale where DWAF is responsible for central functions such as co-ordination, effective networking, information and resource provision, and support for decentralised activities and structures. For example DWAF should be responsible for: co-ordinating the flood release programme; co-ordinating the participatory democracy process of decision making of water resource allocations among the decentralized units (various WUAs) within the catchment; and supporting education programmes, etc. DWAF can seek external expertise, but DWAF should maintain control and leadership to ensure that actions within the various decentralized groups remain within the requirements of government policies and the ecological and social justice perspective, which are in fact supported by the National Water Act, No 36 of 1998. External expertise roles used to assist the various decentralized WUA units should not lead and impose but rather serve and facilitate. DWAF's role as a regulatory authority should be like that of a referee in a football game and the role of the decentralized units should be like the players,

(ii) Followed by many water sectors or forums (such as irrigation, subsistence agriculture, fisheries, tourism and recreation) within the catchment that are linked to specific needs at various geographical locations and where community leadership roles are responsible for central functions,

(iii) Then by a further decentralized level where community groups are responsible for decision making and actions to have decisions met (e.g. crop groups, stock groups, pan level fisheries management, irrigation pump station, recreation and tourism community groups, and municipal service management community groups).

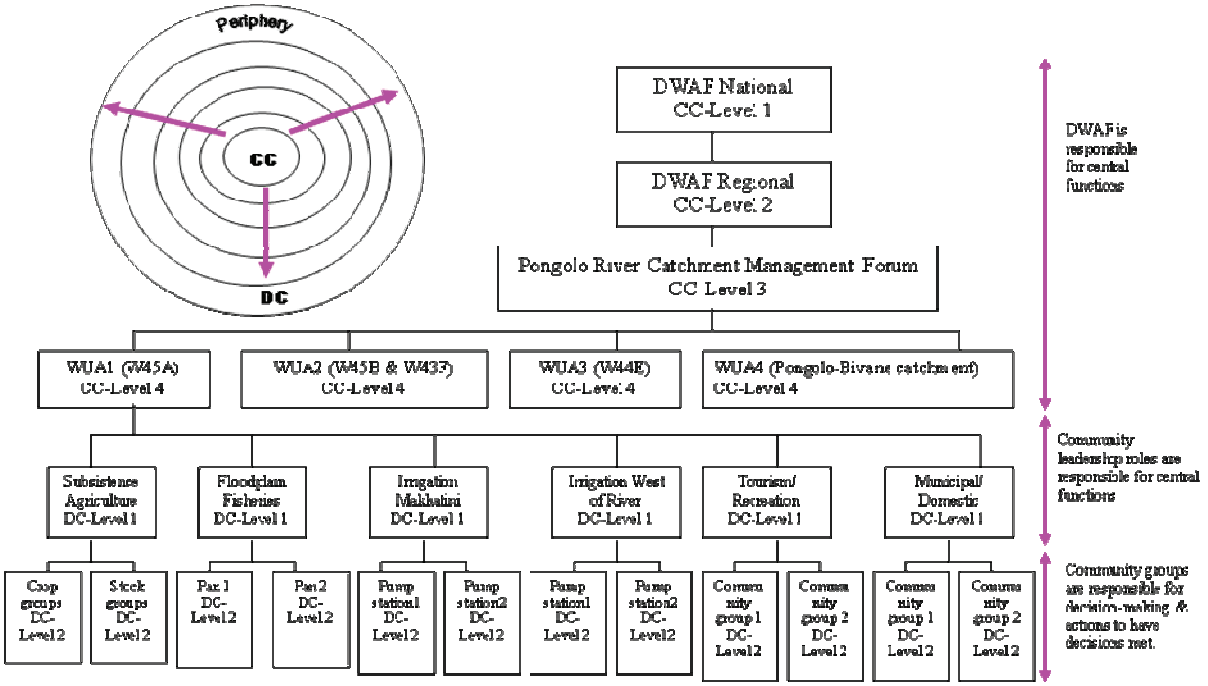


Figure 8.6: Proposed decentralized water management organogram showing levels of central control (CC) and decentralized control (DC). (Due to limited space the last two levels are shown for one WUA 1(W45A). See Table 8.4 for details of other WUAs. The left-hand diagram shows that accountability is downward or outward to the people directly concerned).

Catchment management projects must be initiated at the most appropriate decentralized control level. Among community development specialists concerned with both environmental and social justice crisis (Table 8.3), such an approach to organizing has a higher chance of establishing viable community-based structures which can enhance policy implementation and wise decision making by providing a more viable and sustainable basis for the meeting of human needs and for interaction with the environment. The theory and practice underpinning the strategy of community development represents a vision of how things might be organised differently, so that genuine, ecological sustainability and social justice, which seem unachievable at global, national and regional levels, can be realised in the experience of human community (Ife, 1999).

Table 8.4: An example of a possible decentralized water management structure within the Pongolo River catchment					
DWAF is responsible for central functions.				Community leadership roles are responsible for central functions.	Community groups are responsible for decision making and taking action to meet those decisions.
DWAF NATIONAL (**central control level 1**)	DWAF REGIONAL (**central control level 2**)	PONGOLO RIVER CATCHMENT MANAGEMENT FORUM (**central control level 3**	WATER USER ASSOCIATIONS (**Central control level 4**)	WATER USER SECTORS OR FORUMS (**Decentralized control level 1**)	COMMUNITY GROUPS (**Decentralized control level 2**)
			WUA 1 (W45A)	i) Irrigation Makhatini Scheme.	Pump station 1. Pump station 2, etc.
				ii) Irrigation west side of the river.	Pump station 1. Pump station 2, etc.
				iii) Floodplain and dry land subsistence agriculture (crops and livestock).	Crop groups. Livestock groups.
				iv) Floodplain subsistence fisheries.	Pan 1. Pan 2, etc.
				v) Floodplain recreation and tourism.	Community group 1. Community group 2, etc.
				vi) Municipal domestic and industry services	Community group 1. Community group 2, etc.
			WUA 2 (W45B andW43F)	(i) Irrigation Ndumu B.	Pump station 1. Pump station 2, etc.
				(ii) Irrigation Ndumu A.	Pump station 1. Pump station 2, etc.
				iii) Floodplain and dry land subsistence agriculture (crops and livestock).	Crop groups. Livestock groups.
				(iv) Floodplain subsistence fisheries.	Flooplain Pan 1. Pan 2. Pan 3. Pan 4. Pan 5, etc
				(v) Floodplain recreation and tourism.	Community group 1. Community group 2, etc.
				(vi) Municipal domestic and industry services.	Community group 1. Community group 2, etc.
			WUA (W44E)	(i) Pongolopoort Dam property owners – tourism and recreation and commercial fisheries	Community group 1 tourism and recreation. Community group 2 commercial fisheries, etc.
				ii) Pongolopoort Dam property owners – Irrigation.	Community group 1 irrigation.
				(iii) Municipal domestic and industry services.	Community group 1. Community group 2, etc.
			WUA 4 (Pongola-Bivane catchment	(i) Impala irrigation board	Pump station 1. Pump station 2, etc.
				(ii) Commercial forestry.	Community group 1. Community group 2, etc.
				iii) Other irrigation	Pump station 1. Pump station 2, etc.
				(iv) Municipal domestic and industry services.	Community group 1. Community group 2, etc.

8.4 CO-MANAGEMENT ACTIONS AND INCENTIVES: SUSTAINABILITY, EFFICIENCY AND EQUITY

8.4.1 Introduction

Notions of the ecological meaning of sustainability, equilibrium and balance (Table 8.3) should guide decisions and actions taken to achieve efficiency and equity of water sharing between economic growth, subsistence needs and the reserve.

Ecological thinking in terms of sustainability, equilibrium or balance, can generally be explained as follows. Nature uses certain forces, laws and principles to organise itself. Levels of disturbance are experienced in natural systems when these forces, laws and principles are violated or disturbed. Green writers and ecologists (Table 8.3) have found out that we are more likely to end up with sound solutions when we apply the thinking of nature to problem solving within ecological, social justice and economic spheres of the environment.

The four factors that explain how nature organises itself are sustainability, equilibrium or balance, diversity and holism. While the ecological implications of holism and diversity can help to explain what representivity and stability means in practice (section 8.3), the ecological meaning of sustainability and equilibrium or balance can help to explain what equity and efficiency means in practice.

8.4.1.1 Equilibrium or balance

According to biological conservation studies (Krebs, 1994; Primack, 1998), biological communities within natural systems are adapted to local environmental conditions and can persist in the long-term under naturally induced disturbances or dynamics. Examples of these natural systems are: land resources (forests and grasslands); wetland habitats (swamps, floodplains, mangroves, marshes, tidal marshes, coastal shelf); aquatic habitats (rivers, lakes, open oceans); climate (atmospheric air, temperature, rainfall). However, massive disturbance caused by human developments (e.g. agriculture, mining, industry, deforestation, urbanisation, dams), have either altered these habitats through (e.g. fragmentation), degraded them through (e.g. frequent uncontrolled fires, overgrazing, over harvesting, frequent boating and diving) or degraded them through pollution of water, air and global climate which is of great concern to species and human health (e.g. industrial chemicals and waste; pesticides, sewage, fertilizers, gas emissions from factories and motor vehicles, air pollution, acid rain, acid mine water, toxic metals, increased rates of sediment deposits from eroded hill sides). These disturbances have a combined general impact of reducing populations and driving species and habitats to the point of extinction (Krebs, 1994; Lawton et al., 1995). These human induced threats to species and habitats are happening so rapidly and on a large scale that species and habitats are hardly able to adapt to the changes or disperse to a more hospitable location and so many perish. Therefore, **balancing** human developments with the environment and conservation of ecosystems in order to ensure that ecosystems persist in the long-term is a primary concern of conservation biology (Krebs, 1994; Primack, 1998), for example:

(i) The role of equilibrium in global climate change (Hensley, 1966; Maud, 1968; Maud, 1980; King, 1972; Schneider, 1989; Peters and Lovejoy, 1992; Gates, 1993; Bawa and Markham, 1995; Climate Change, 1996; Karl et al., 1997; Myneni et al., 1997; Schulze, 1997; Primack, 1998),

(ii) Balancing environment & development: beyond global warming (Vitousek, 1994),

(iii) Balancing development with wetland protection: waste treatment and nutrient retention (Young et al.,1985;Costanza et al., 1997; Primack, 1998; Du Plessis, 2004),

(iv) Balancing sediment production, rising sea levels and biodiversity persistence (Chung, 1982; Young et al., 1985; Shaffer et al., 1992; Boesch et al., 1994; Odum, 1997; Costanza et al., 1997; Keddy, 2002; Primack, 1998; Keddy, 2002).

These studies show that natural systems have the ability to monitor changes naturally and make adjustments so that balance can be maintained. This occurs through dynamic equilibrium where by a system is maintained within certain limits. When systems are disturbed within these limits (e.g. through pollution, temperature), they remain resilient and are able to spring back or to resume normal functions. When a system functions out of these limits (e.g. under very high pollution levels; increased rates of global warming), the system loses equilibrium and risks ecological failure. Potentially conflicting natural systems have their interactions controlled in such a way that they are able to co-exist by sharing resources and or may become depended on each other through dynamic tension, e.g. floodplain wetlands and water level fluctuations; fire and vegetation; sedimentation, biodiversity and sea level rise; harvesting natural resources within sustainable yield programmes; the atmosphere and climate dynamics, i.e. warming and cooling.

Maintaining equilibrium is essential if systems are to survive in the long-term. This emphasises the importance of the relationship between systems, and the need to maintain a balance between them. An ecological perspective therefore values balance, harmony and equilibrium.

Implications of the ecological thinking of equilibrium, balance, harmony for a green political thinking is the need to maintain equilibrium, balance, harmony between the ecological, social and economic aspects of life. According to Plumwood (1993), the ecological concern for equilibrium is the capacity to incorporate apparently opposing positions and relationships that are integrated within a perspective of dynamic tension and it is the balance between them that is important and should be maintained, e.g. male and female, competition and co-operation, central and local, mind and body, personal and political, fact and value, subjective and objective, are integrated within a perspective of dynamic tension (Ife, 1999).

An ecological perspective values balance and equilibrium and should seek to maintain them always. For examples, in order to maintain balance, solutions to conflict is peace and non-violence approaches, e.g. mediation, conflict resolution and the building of consensus (Ife, 1999); solutions to building long-term or lasting social relationships is developing co-operative rather than competitive structures is valued (Kohn, 1986; Argyle, 1991; Craig, 1993).

Environmental examples where balance has not been maintained are very unsustainable and very costly to manage and often misery and suffering follows, e.g. pollution and waste management; in terms of gender-

where the domination and exploitation of women by men has led to imbalance; north and the south relationship in terms of global development is seen as that of 'domination and oppression' rather than one of balance and mutual respect (Trainer, 1985).

8.4.1.2 Sustainability

Within an ecological economics context, the meaning of sustainability is that: "*resources should be used only at the rate at which they can be replenished, that output to the environment should be limited to the level at which it can adequately be absorbed (e.g. waste), that systems should be able to be maintained in the long-term, that renewable energy sources should be utilised, and that consumption should be minimised rather than maximised*" (Our common future, the Brundtland report of the world commission on environment & development, 1987; Lubchenco et al., 1991; Ife, 1999; Edwards-Jones, Davies and Hussain, 2000).

The concept of sustainable development can only be useful if it emphasizes 'improving current development' but 'limiting growth'. This has implications for the concept of 'economic development' and 'economic growth'. According to Primack (1998), 'economic development' implies improvements in organization (e.g. infrastructure) but not necessarily increases in resource consumption and should be clearly distinguished from 'economic growth', which is a material increase in the amount of resources used.

When the ecological meaning of sustainability is applied to economic thought in terms of techniques or methods used in organizing the production; allocation and distribution of goods and services people require to meet their material needs, a strong social ethic follows naturally (Maslow, 1954; Kamenetzky, 1992; Max-Neef, 1992); when this happens conventional economics becomes ecological economics (Edwards-Jones, Davies and Hussain, 2000).

According to community development specialists (Ife, 1999), the implications of the meaning of sustainability implies 'limits to growth' approach to economics and social organisation; it implies decentralised small-scale economic activity or localised market economy; it implies putting in place environmental controls; it implies putting in place conservation strategies; it implies a radical reformulation of economic policy and social organisation, e.g. concepts of carrying capacity; controlling natural resource consumption or use; controlling number of individuals who can use or harvest a particular resource; if water is scarce-controlling use by limiting area under commercial irrigation or commercial alien plantation forestry in a river basin or catchment. It requires a system where getting bigger by increasing natural resource consumption is discouraged rather than valued. It requires a radical reformulation of economic policy and social organisation (Ekins, 1992).

In practice, it is essential that any community development activity occurs within a framework of sustainability; otherwise it will simply reinforce the existing unsustainable order, and will not be viable in the long term. If community development is to be part of the establishment of a new social, economic and political order, its structures and processes should be sustainable (Ife, 1999). Therefore it is important to help communities to accept a philosophy of 'small is beautiful' and to enable them to work

out what this means in practice. This in turn brings in notions of 'steady-state', balance, equilibrium and harmony, which are critical aspects of the ecological perspective (Ife, 1999).

Thus, as with human rights, sustainability is not merely a principle, which limits certain forms of community development, but in, a more positive sense can become a critical part of the community development agenda (Ife, 1999).

8.4.1.3 Approach to achieving sustainability, efficiency and equity

Achievement of sustainability, equilibrium and balance requires that environmental economic tools that take into account ecological and social perspectives should be used to determine project economic viability before it can be approved for funding and/or implementation. This effectively means implementing the DWAF reserve concept by acquiring the relevant knowledge base through comprehensive reserve determination and building environmental economic models which integrate ecological and social justice factors or values into hydraulic models of the catchment in order to guide decisions about what is efficient, equitable and sustainable.

It is important that decision makers, managers and stakeholders understand the dynamics of the ecological meaning of sustainability, efficiency and equity in practice. The positive value of being human is that by understanding the implications of how nature functions in management systems, can help managers and decision makers to learn to anticipate environmental problems and their consequences, so that they can learn to put in place corrective measures that avoid any expected negative outcomes or any environmental crisis.

8.4.2 Efficiency

Generally, to an engineer efficiency means getting more for less and this is a sensible thing to aim for. To irrigation engineers, it can mean getting maximum value from every drop of water (CA framework, 2002). Economists view the idea of efficiency differently. According to economists (Parkin, Powell and Matthews, 2000), the pursuit of efficiency can conflict with other more worthy goals, e.g. efficient technology can produce negative environmental outcomes (e.g. dams, irrigation). To an economist, efficient allocation of a resource occurs when we produce the goods and services that people value most highly. Equivalently, resource use is efficient when we cannot produce more goods or services without giving up some other goods or service that we value more highly. For instance, if people value a nuclear-free environment more highly than they value cheap electric power, it is efficient to use higher-cost, non-nuclear technologies to produce electricity. Likewise, dams and irrigation technology yields high quantities of food and fibre but increases ecological and environmental pollution for downstream users. If, for example, people value preservation of the Pongolo floodplain wetland ecosystem, then it is efficient to give up some water for irrigation and produce reduced quantities of irrigated food and fibre and use the saved water to enhance floodplain preservation by developing or installing high-cost water optimisation technology, e.g. inflatable weirs that optimise use of reduced water on the floodplain in order to find more water for irrigation.

To an economist, efficiency is a concept based on value and value is based on people's feelings (Parkin, Powell and Matthews, 2000). Therefore, the efficient quantity of irrigation in the Pongolo River catchment is based on people's feelings and choices. What constitutes an efficient quantity of irrigation? To increase irrigation for a monoculture crop (e.g. cotton or sugar), we must give up some other goods and services. For example, in the case of the Pongolo floodplain, we might give up these values:

(i) give up artificial flood releases needed to sustain subsistence agriculture (crops, pasture, fisheries and other wildlife resources) (Chapter 4),
(ii) give up dry land availability for pasture (Chapter 7),
(iii) give up optimal fish production (Chapter 5 and 7),
(iv) give up good water quality because irrigation causes reduced stream flow which in turn enhances water pollution through excess nutrient and toxic chemicals loading,
(v) give up ecosystem values provided by the wetlands as natural waste treatment and nutrient retention facilities (Chapter 5),
(vi) and give up some commercial forestry to free up more water for irrigation (Chapter 6).

In other words, to increase irrigation, we have to forego the above listed items. If we decrease irrigation, we can have more of these other values. What is the most efficient quantity of irrigation? The answer depends on marginal benefit and marginal cost. If the marginal benefit exceeds the marginal cost, we can use resources more efficiently by increasing the production of irrigation and decreasing the production of other goods and services. The value of the extra irrigation exceeds the value of the other goods foregone. If marginal cost exceeds marginal benefit, we can use our resources more efficiently by decreasing the production of irrigation and increasing the production of other goods and services. The value of the other goods and services exceeds the value of the irrigation foregone. When marginal benefit equals marginal cost, resource use is efficient, and we are producing the efficient quantity of irrigation (Parkin, Powell and Matthews, 2000).

According to (Parkin, Powell and Matthews, 2000), competitive markets make marginal benefit equal marginal cost and use resources efficiently. However, achievement of efficiency is hindered by the following sources which result in markets producing an inefficient quantity, e.g. price ceilings and floors; taxes, subsidies and quotas; monopoly; public goods; external costs and external benefits. The impediments to efficiency are market failures and result in two possible outcomes: underproduction or overproduction. Only if production is at the competitive equilibrium level is deadweight loss zero and resource use efficient.

For instance, from an environmental economics point of view, demand and supply curves of irrigation in a river catchment show why it is important that decisions about water allocations and developments must be informed by a cost benefit analysis that takes into account externalities arising from social and ecological factors (**Fig 8.7**).

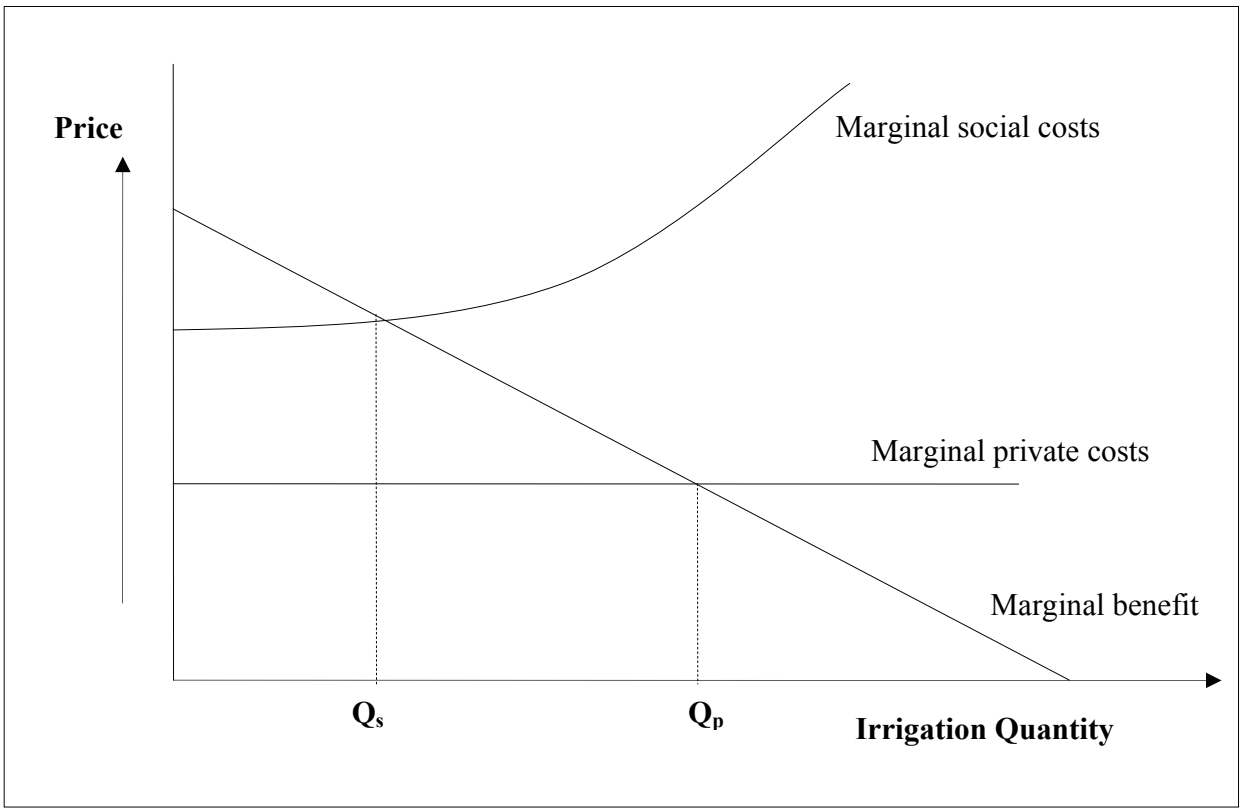


Figure 8.7: Demand and supply of irrigation in a river basin (Parkin, Powell and Matthews, 2000; Edwards-Jones, Davies, and Hussain, 2000; Fargher, 2002).

This figure shows that measures of benefits and costs should include both private values and external values. When appraising the economic benefits and costs of projects or programmes, a reliance on the private benefits and costs, instead of the social implications, can often lead to inefficient outcomes. The optimum private and social allocation of irrigation or any other stream flow reduction activity (e.g. dams, commercial forestry or industries releasing toxic effluents) in a river basin is shown. It can be seen that for every additional unit of irrigation, (or additional unit of toxic effluent) the additional cost to private owners remains constant (marginal private cost curve), whereas for society the costs gradually increase (see marginal social cost curve). In a market, the efficient allocation of goods or services is where its marginal costs equal marginal benefits. When the externalities of irrigation are included (i.e. marginal social cost curve) the efficient allocation is **Qs**. When only private costs are considered (i.e. marginal private cost curve) irrigation would be over-supplied in the market by **Qp** and the community and or wider society would incur real costs (Parkin, Powell and Matthews, 2000; Edwards-Jones, Davies, and Hussain, 2000; Fargher, 2002). Unfortunately, markets consider only the private values of transactions and do not take into account the externalities of goods or services. Hence, in order to obtain the efficient social allocation of irrigation, government intervention may be required.

8.4.3 Equity

According to Parkin, Powell and Matthews (2000), economists generally agree about what is efficient, but there is no agreement about what is equitable or fair. The two main ideas about fairness are that an allocation is unfair if: the results are not fair, or if the rules are not fair. 'Fair-results ideas' generally result in income transfers from the rich to the poor, but income transfer may result in a big trade-off between fairness and efficiency. Secondly, 'fair-rules ideas' require property rights and voluntary exchange, but fair outcome depends upon the initial distribution of attitudes (based on a way of thinking) and resources (Parkin, Powell and Matthews, 2000). The distribution of attitudes and resources depends on government policies and their successful implementation.

According to Edwards-Jones, Davies and Hussain (2000), the following environmental economic tools can support decision making to achieve 'fair-rule ideas' or sustainability or equilibrium or balance. Managers and decision makers should strive to promote their use by building a multi-value knowledge base to support 'fair' decision making. (Note that some of the specific variables or values that may need to be quantified have been identified in Chapters 4-7).

(i) Cost-Benefit Analysis (CBA) (Pearce, 1983; Daly and Cobb, 1989; Pearce, Markandya and Barbier, 1989; Hanley and Spash, 1993; Pearce and Turner, 1990; Jacobs, 1991; Laylard and Glaister, 1994; Edwards-Jones, Davies and Hussain, 2000),

(ii) Environmental Impact Assessment (EIA) & (AEAM) (Holling, 1978; Biswas and Agarwala, 1992; Erickson, 1994; Edward-Jones, Davies and Hussain, 2000),

(iii) Multi-Criteria Appraisal (Bogetoft, Pruzan, 1997; Chambers, 1983; Pretty, 1995; Romero and Rehman, 1988; Edwards-Jones, Davies and Hussain, 2000),

(iv) National Income Accounting (Edwards-Jones, Davies and Hussain, 2000),

(v) Index of sustainable economic welfare (ISEW) (Jackson et al., 1997; Daly and Cobb, 1989; Cobb and Cobb, 1995; Edwards-Jones, Davies and Hussain, 2000).

(vi) Others, e.g. United Nations Human Development Index (UNHDI); Concept of Environmental Space (ES) methodology (FoE, 1995;Wackernagel and Ress, 1997)

8.4.4 Multi-value approach to integrating floodplain agriculture into a diverse rural economy

Due to the Pongolapoort Dam and the upstream Bivane Dam, economic activities upstream of the Pongolapoort Dam, such as irrigation, commercial forestry, tourism and recreation and dam fisheries, are flourishing at the expense of downstream Pongolo floodplain wetlands used for subsistence agriculture (crops, pasture, and artisanal fisheries) and nature conservation (Chapter 7).

The question that needs to be answered is, what is it that needs to be done to bring about a balance between agricultural development, subsistence agriculture and conservation of ecosystems and the reserve?

Agricultural policies in South Africa have multiple objectives, including national food security, maintenance of farmers, enhancing rural employment through land reform policies, e.g. land redistribution for agricultural development (LRAD) intended to alleviate poverty and enhance the economic and socio-economic wellbeing of rural people who are largely poor. Partnerships between communities and organised commercial agriculture are promoted through the expansion of economic agricultural development initiatives, e.g. Makhatini Agricultural Development Plan (DAEA, 2002) (Chapter 6).

The problem is that agricultural policy makers assume that farmland would, and should be managed to maximize food and fibre output. This has led to more and more intensive and extensive agricultural systems, using increased levels of water for irrigation, fertilizers, pesticides and other inputs and increases in farm size and mechanization. Trends in countries in the northern hemisphere show that such agricultural policies cause impacts such as: natural resource over-exploitation, environmental degradation and increasing income differentials (Edwards-Jones, Davies and Hussain, 2000).

The impact of dams and irrigation affecting downstream floodplain wetlands (Chapter 4) and the consequent negative impacts on ecological values (Chapter 5) and socio-economic values (Chapter 7), shows that agricultural policies and impacts caused to the environment in the countries of the north are similar to those in South Africa, but are more intense in South Africa because, among other socio-economic factors linked to the political history of the past (Rubin and Weinstein, 1977), water resources are scarce and highly variable (Schulze, 1997). Potential for agricultural economic development is high on the Makhatini flats; however, water is a limiting factor. Therefore, how can the scarce water resource be shared efficiently and equitably among a variety of diverse interests (commercial irrigation, dam recreation and tourism, protection of floodplain wetlands for nature conservation and subsistence needs, commercial forestry, and other potential opportunities and industries).

The results in Chapters 4-7 show clearly that the LRAD agricultural development policy, intended to enhance equity in land use, appears to be strengthening some sectors at the expense of others (particularly floodplain agriculture). In turn, commercial agriculture on the floodplain has grown at the expense of downstream subsistence agriculture, fisheries, pasture for livestock, tourism potential, biodiversity and nature conservation, amongst others.

From an ecological and social justice perspective (Table 8.3), an approach to agriculture that attempts to achieve some balance between competing interests in terms of equity, efficiency and sustainability, is the multi-value approach that reflects a much broader appreciation of the value of agricultural lands than food and fibre production alone (Traill, 1988; Edwards-Jones, Davies and Hussain, 2000).

A presentation of this wider consideration in terms of the relationship between agricultural intensification and the value of a number of various aspects of the agricultural system, including food yield, environmental quality and rural employment, is shown in Fig 8.8.

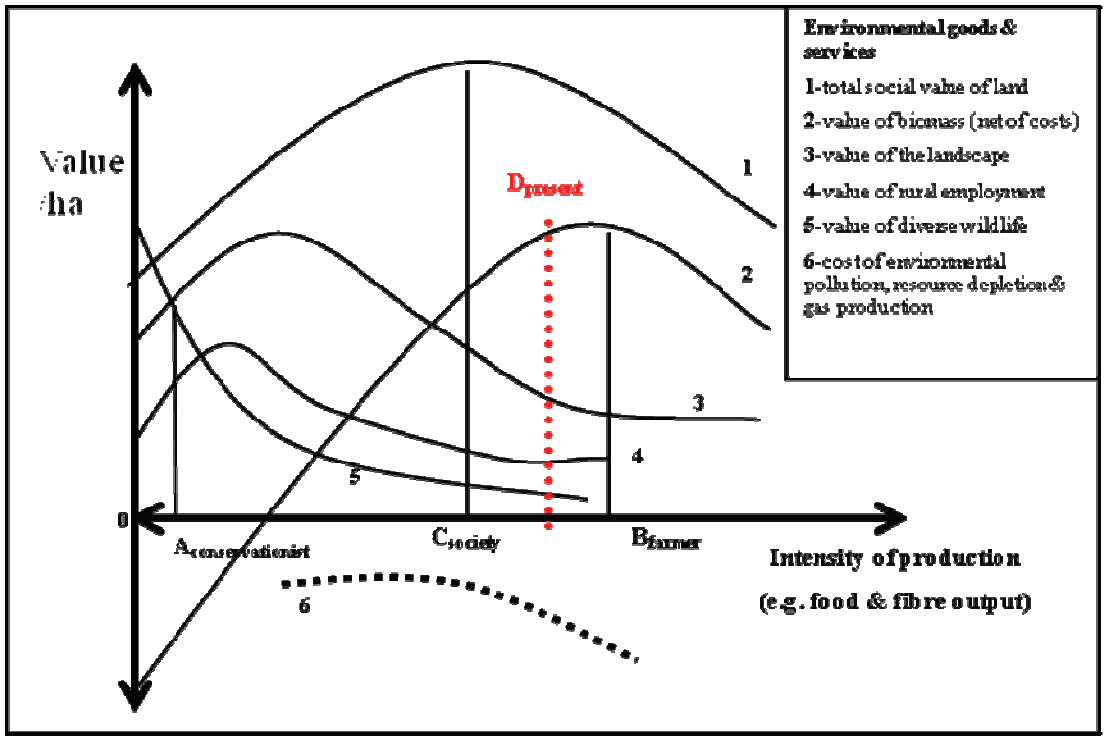


Figure 8.8: Balancing agricultural development and conservation: a multi-value approach. Schematic analysis of multiple values and agricultural production. It is highly likely that we are presently at point Dp (Adapted from Traill, 1988 and Edwards-Jones, Davies and Hussain, 2000).

According to Traill (1988) and Edwards-Jones, Davies and Hussain (2000), the idea behind the multi-value approach is that there is a limit to possible outputs for a combination of goods for any given economic system with a particular state of technology (Traill, 1988; Edwards-Jones, Davies and Hussain, 2000; Molden, 2007).

Preferences of farmers ($B_{farmers}$), society ($C_{society}$) and conservationists ($A_{conservationists}$) will lead them to favour producing different combinations of environmental and food and fibre outputs.

It is technically possible to produce at a certain point, such as $C_{society}$, which will provide society with more of all kinds of goods and services (ecological, economic and social). This point can be referred to as the multi-value social welfare maximizing level of intensity of production ($C_{society}$).

Obviously, the social optimum identified at $C_{society}$ is not the optimal output level for farmers. In fact, farmers would be expected to intensify up to point $B_{farmers}$, because this maximizes their overall returns (Traill, 1988; Edwards-Jones, Davies and Hussain, 2000). Conservationists would be expected to produce at a point where wildlife production is maximized.

The long-term shape of the various curves of agricultural production relative to various values (Fig. 8.8) is determined by a particular economic system with a particular state of technology. Thus the shape of the curve changes over time as that system and its technology changes.

The historical shape of these curves in the developed world, has expanded outwards considerably, but almost entirely horizontally. This is attributed to the market incentives for technical innovation, which have always been for increasing food output. Unless policies adjust incentives accordingly, this path is likely to continue (Edwards-Jones, Davies and Hussain, 2000). Long term, over-intensive agricultural methods that lead to ecological damage (e.g. eutrophication of fishing lakes), can lead to an eventual contraction of the curves leading to a corresponding reduction in social welfare.

Pretty (1995) points out that, in the developing world, factors influencing the shape of these curves are similar to those of the developed world, except for the following key factors that add complexity to the agriculture-environment debate:

(i) food security to assure adequate access to food,
(ii) fair access to land,
(iii) protection of indigenous rights, e.g. a failure to accommodate informal property rights regimes in natural resource management,
(iv) pressures for intensification for growing populations and species loss.

8.4.5 Application of the multi-value approach in decision-making

Floodplain agriculture can be integrated into a diverse rural economy by implementing a multi-value approach to agriculture. This means that development frameworks should not promote irrigation agriculture only or eco-tourism development only or nature conservation only. Development frameworks should seek to promote diverse strategies planned on a catchment and regional scale, so that society can get all kinds of goods and services which can provide diverse livelihood opportunities for a rural population that is largely poor and unemployed.

The multi-value frontier provides a way of thinking about how best to make the necessary dynamic shifts, ranging from nature conservation on one hand to intensive production on the other, as we strive to achieve desired levels of ecological sustainability, equilibrium or balance (Fig 8.8).

Therefore, managers, decision makers and leaders should strive to develop and gain the knowledge that informs a wise shift, along the multi-value frontier, through the knowledge innovation chain (Davenport, De Long and Beers, 1998; Tiwana, 2000; Breen et al., 2004) and then link that knowledge to the hydraulic model of the catchment (Hughes, 2000; Basson and Beck, 2002) which then makes predictions about the possible impacts of various scenarios on ecological, economic and social values, so informing wise decision making that can lead to wise shifts along the multi-value frontier – as we strive to achieve desired levels of ecological sustainability, equilibrium or balance, and hence, efficiency and equity.

8.4.5.1 Where are we now on the multi-value frontier?

Where we are now on the multi-value frontier is not known due to a lack of data which could enable a holistic view of the Pongolo River catchment in terms of representivity, sustainability, efficiency, and equity. It is very important that a comprehensive reserve determination study of the catchment is initiated according to the requirements of the Adaptive Environmental Assessment and Management (AEAM) framework, which should be set up in the form of a hydraulic model for the whole catchment (see Chapter 4). Data from the AEAM process should then continuously provide input into relevant decision making analyses tools (e.g. MCA, EIA and CBA). The output from these decision making processes should have the ultimate goal of ensuring that developments in the catchment do not cause ecological failure and consequently social injustice.

8.4.5.2 Which direction do we wish to move on the multi-value frontier?

The various interest groups that exist (irrigation; commercial forestry; nature conservation, tourism and recreation; floodplain fisheries; floodplain subsistence agriculture-crops and livestock and others) would obviously favour moving more in one direction than another. Each interest group has its own fundamental beliefs or preferences about the 'best' state of agriculture and the environment, hence creating a political debate around these issues (e.g. the Agriculture-Environment Debate). Chapters 4-7 have clearly illustrated the dynamics among these interest groups.

Based on theories of how societies behave and work, it would be highly desirable to move towards a social welfare maximizing level of intensity of agricultural production ($C_{society}$), which would provide society with more of all kinds of goods and services (ecological, economic and social) because this point enhances equity, sustainability and social stability in the long term (Hammond, 1978; Haralambos and Holborn, 2000).

8.4.5.3 How do we achieve a shift towards economic growth along the multi-value frontier?

8.4.5.3.1 Introduction

Deciding on which direction to shift systems is mostly political; however, determining how best to achieve that shift depends on political and economic policies (Edwards-Jones, Davies and Hussain, 2000) and the level of technologies (Molden, 2007).

Key factors that determine shifts on the multi-value frontier, among others, are linked to property rights and ownership systems, because each type of property right and ownership system provides people, both owners and non-owners, with different incentives for action (Bromley, 1989, 1991). Within each property right and ownership system, various policies are put in place to adjust incentives accordingly. According to Edwards-Jones, Davies and Hussain (2000), a system of strong private property in combination with free markets for food and other goods will tend, (other things being equal), to move towards greater production intensification.

A co-management perspective requires that managers, decision makers, community leaders and stakeholders understand the dynamics of property rights and ownership systems of natural resources, so that they can begin to think about how the various policies put in place are going to adjust incentives and the impact of those incentives on the ecological and social wellbeing of others.

Property rights are a critical element in the management of natural resources, because much of economic analysis concerns the system of production and sale of goods, the legal and institutional conditions that determine the conditions of ownership, transfer and use of those goods is clearly important. While Neoclassical economists operate with very simplified models of ownership and exchange, institutional economists like Commons (1968/1926) and more recently Bromley (1989) have tended to focus on institutional complexities of the ownership system. There are four conventional basic categories of property rights recognized in economic analyses and a more recent unusual fifth category (Edwards-Jones, Davies and Hussain, 2000).

Table 8.5 Categories of property rights recognized in economic analyses (Bromley, 1989 in Edward-Jones, Davies and Hussain, 2000)

	Property rights	**System of ownership**
1	Private property	Which is owned by individuals
2	State property	Owned on behalf of the citizens of a nation by the state
3	Common property	Which is managed collectively by a particular group
4	Ownerless or open access assets	Which are not owned by any group or individual
5	An unusual 5th category has been recently suggested – 'property of all humanity' concept is an interesting attempt to justify the case in favour of preservation of certain unique world heritage sites in perpetuity, because no group or even nation could hold the right to destroy such assets.	

Each of these categories of property (Table 8.5) provides people – both owners and non-owners with different incentives for action. Understanding basic positions such as, what justifies ownership, and what are some of the factors that make up a right of ownership or property right can provide a platform on which to assess the moral and political implications of different management strategies and the way in which they approach property issues (Edwards-Jones, Davies and Hussain, 2000).

Becker (1977) reported five main established arguments that have been advanced for recognizing some system of property rights in society, i.e. rights to hold property, namely: prior appropriation or first occupancy, social welfare or utility, natural rights and political liberty, moral character and virtue (Edwards-Jones, Davies and Hussain, 2000). It is important that managers and decision makers understand the arguments used to claim or to recognize specific rights to hold property and the limitations associated with each argument and its implications on resource allocation (Becker, 1977; Bromley, 1989 in Edwards-Jones, Davies and Hussain, 2000).

According to Edwards-Jones, Davies and Hussain (2000), the property concept implies a relationship between the owner, owned property and non-owners (Bromley, 1989). Ownership can be thought of as a 'bundle of rights', which gives the owner a certain freedom in how to use goods and property in relation to that property and to other people. The central aspect of the functioning of property rights regimes includes concepts of: access/exclusivity, transferability, duration, formality, prohibition or use

restrictions, management system (Bromley, 1989; Bromley, 1991; in Edwards-Jones, Davies and Hussain, 2000).

While the notion of private property is so familiar in western society that its origins and justifications are rarely questioned (Edwards-Jones, Davies and Hussain, 2000), the same does not apply to many of the developing countries in the South. The issue of justification for property ownership is particularly relevant in environmental management because of the lack of a clear concept of ownership for a number of environmental goods. Some argue that the lack of private property rights to these kinds of goods is leading to their economic mismanagement. Others argue that it is misguided to think of these goods in terms of 'property' at all; they suggest it is the very economic commoditization of these goods – treating them as property that can theoretically be bought and sold – that in itself creates the problems of mismanagement (Edwards-Jones, Davies and Hussain, 2000). They argue that we need to conceive of environmental management using a fundamentally different kind of language and concepts from ones of economic value, e.g. issues of entitlement, duties of care, community stewardship and intergenerational equity (Sagoff, 1988).

The implications of this analysis is that in striving to promote diverse livelihoods that improve the quality of life of the people through economic growth, while ensuring ecological and social justice sustainability within a catchment, requires managers, decision makers, community leaders and stakeholders to understand the dynamics of property rights and ownership systems of natural resources, so that they can begin to think about how the various policies put in place are going to adjust incentives and the impact of those incentives on the ecological and social wellbeing of others. It is necessary that mangers and decision makers understand the impacts of the use of the various property rights and ownerships systems when allocating resources.

According to the Makhatini Integrated Development Master Plan, the main goal is to promote the optimal and sustainable use of agricultural and tourism potential (DAEA, 2002, DAEA, 2008). (More details can be seen in Chapter 6).

Key factors that are likely to limit achievement of the goals are linked to sharing water and land resources on a basis that enables economic production and profitability, while ensuring that the large rural population who have depended on the same natural resources of the region for centuries for subsistence needs, are not marginalized.

The list below highlights development issues on the Makhatini flats, so that they can be viewed and integrated within a rural development and social welfare context. Figure 8.11 shows protected game reserve areas and forest reserves relative to human settlements before 1995. When the pre-1995 map is compared with the regional Spatial Development Plans (IDPs) of local government in 2002 (Fig 8.9 and Fig 8.11), the following can be observed in terms of plans for developments (Pre-1994 and Post 1994):

(i) The new boundaries largely conflict with areas of previous human settlement (pre-1995), and this has implications for land restitution, reform and land tenure issues, which are in turn slowing down development progress.

(ii) The dense human settlements adjacent to areas designated as 'environmentally sensitive areas (ESAs)', e.g. along the Pongolo River floodplain, or areas designated as 'areas of high intrinsic biodiversity value' or areas designated as 'game reserves' and 'forest reserves' (Fig 8.11, Fig 6.3 and 6.4). The dense rural human population surrounding these areas is a clear indication of dependency on these resources for basic needs. This dependence means that there will be serious negative social justice impacts if the methods used to designate areas for development and nature conservation areas exclude communities without providing viable alternative options.

(iii) The Pongolo river floodplain area is designated as a conservation area (ESA) in the 2002 IDPs. Historically the communities have utilized the floodplain for subsistence agriculture, livestock and fishing needs. Implications of designating it as an ESA are to have it used purely as a conservation area so that it can be developed for the eco-tourism industry; yet, it is the only immediate fertile soil resource that is available to the majority of floodplain communities for fishing, growing crops and livestock production for subsistence needs (see Fig 6.1 and Chapter 7). The Pongolapoort Dam development reduced stream flow and the annual artificial flood releases from the dam have not sustained the floodplains' food producing potential. However, even under reduced stream flow, some level of food production has been retained (Chapter 7).

There are other conservation areas within the Pongolo River catchment managed by the public entity or conservation agency, EKZN-Wildlife, and are reserved purely for conservation and eco-tourism (e.g. Ndumu game reserve, Tembe game reserve, Pongolopoort Dam, Ithala game reserve) and local communities have no access to these areas and have developed a negative perception of these areas because they perceive that they do not benefit from them directly in terms of meeting their basic needs for food (fish, game meat, grazing, and crops), yet, the apartheid policies of the previous government pushed them out of these areas (Chapter 7).

It must be remembered that previous development plans had been put in place from about 1985 with the goal of integrating black floodplain farmers into modern commercial agricultural systems on the Makhatini irrigation scheme, the area adjacent to the floodplain, so that the floodplain could, hopefully, remain purely a conservation area (Heeg and Breen, 1982). By the late 1990s, many had failed to be successful commercial farmers (Van Rooyen, 1983; Bembridge, 1991, 1990, 1993; DoA, 1994; Bruwer, Poultney and Nyathi, 1996; Perkins and Arendse, 2002; Jaganyi et al., 2003). They reverted to utilizing the floodplain, but brought back with them commercial farming practices learned from the irrigation schemes. Unfortunately, these practices have not been compatible with other more traditional floodplain farming practices and floodplain ecological dynamics, hence disadvantaging many other subsistence farmers on the floodplain (Chapter 7). In addition, only a small proportion of the population can effectively benefit directly from irrigation schemes in terms of plot owners and farm labourers (Van Rooyen, 1983; Bembridge, 2004; Denison and Manona, 2007).

The question that managers and decision makers need to ask is, if new agricultural development policy and conservation eco-tourism policy or any other development policy is implemented in the region, what impact would it have on subsistence agriculture and the wellbeing of the local communities? It is important that a rational appraisal is carried out and the outcomes tested in a stakeholder workshop, before implementation, to avoid 'unfair' outcomes.

(iv) There is high potential for agricultural development (about 106 000 ha of irrigable soils), but water availability limits development to its full potential. For example, pre-1994, there was water available from Pongolapoort Dam for irrigating some 33 000 ha of sugar. Post-1994, additional dam developments upstream for sugar expansion had reduced water availability on the Makhatini flats in 2002 to 10 000 ha of sugar or about 20 000 ha if it is cotton. There are also plans for developing secondary agri-processing plants for local and international markets (DAEA, 2002; Chapter 6). A key point made is that, only a small proportion of the population can benefit directly from commercial agriculture. Therefore development frameworks should include other alternatives.

(v) The reduction in water availability for irrigation on the Makhatini flats, appears to have stimulated expansion of conservation areas as private game reserves\farms for eco-tourism, game meat and trophy hunting in the region. Conservation area expansion in the upper and mid-catchment of the Pongolo River and in other parts of the region have more recently, largely happened through South Africa's land reform programme, in which game reserves are created and managed through negotiated partnerships with local communities, private conservation concession agreements and the public nature conservation agency, EKZN-Wildlife. Are these partnerships successful? Who are the beneficiaries and who is paying the costs?

The following are some of the dynamics that come into play in decision-making on issues of co-management and integration.

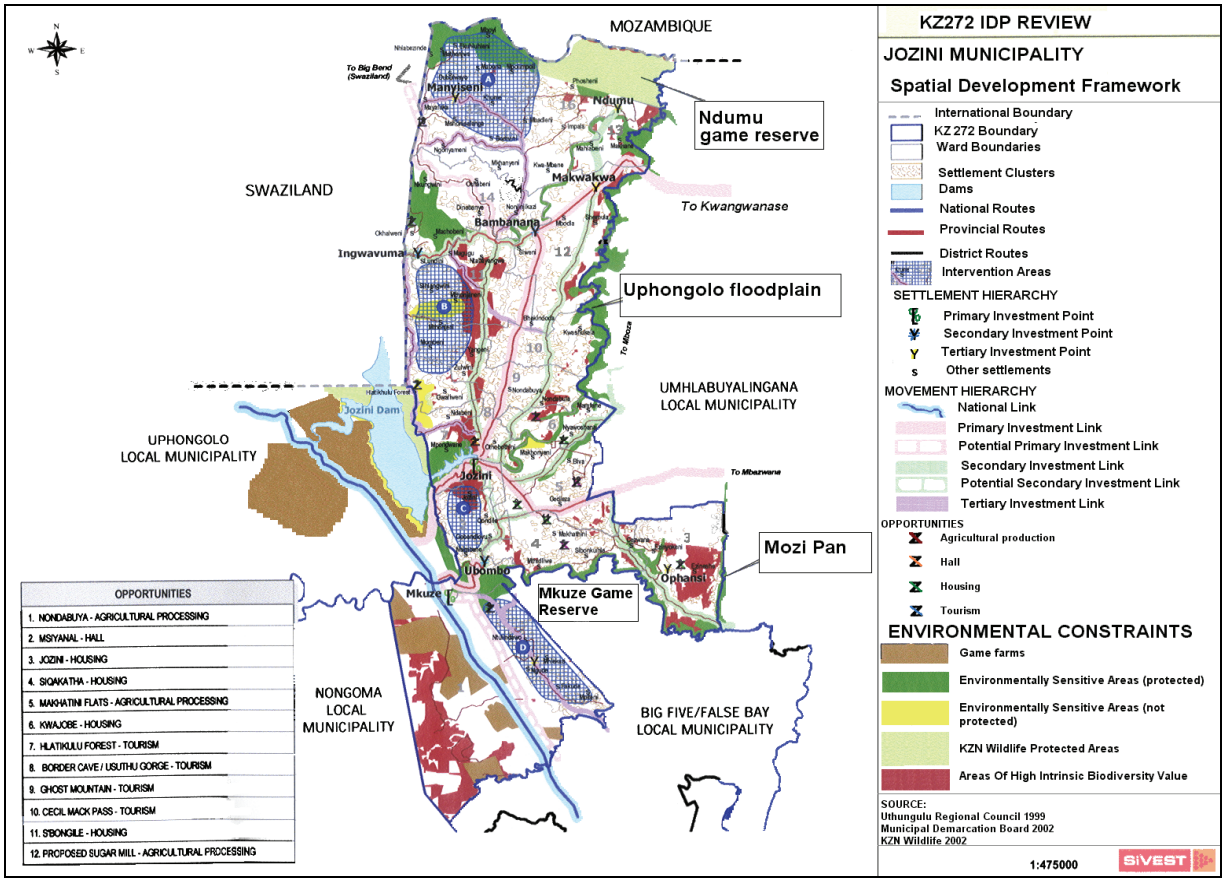


Figure 8.9: Spatial development framework – Jozini municipality KZ272 IDP review (2002).

Human population in the Jozini municipality (Statistics SA – Census 2001 database)		
	Population – 2001	No. of Households
Jozini municipality	140962	25968
Population Adjacent to the Pongolo River Floodplain	37290	6717

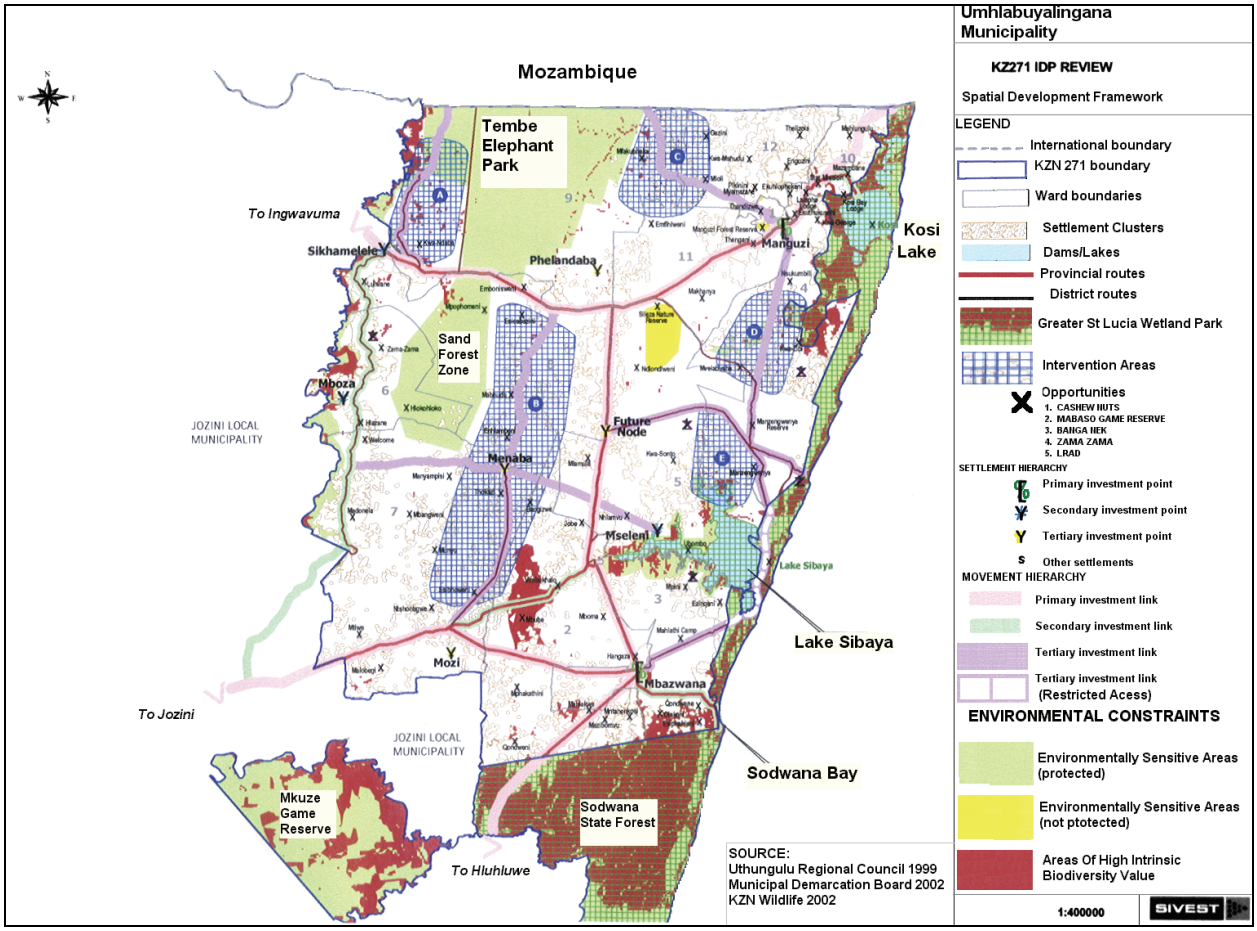


Figure 8.10: Spatial development framework – Umhlabuyalingana municipality, KZ271 IDP review (2002).

Human population in the Umhlabuyalingana municipality (Statistics SA – Census 2001 database)		
	Population – 2001	No. of Households
Umhlabuyalingana municipality	184000	33545
Population adjacent to the Pongolo River Floodplain	55079	9864

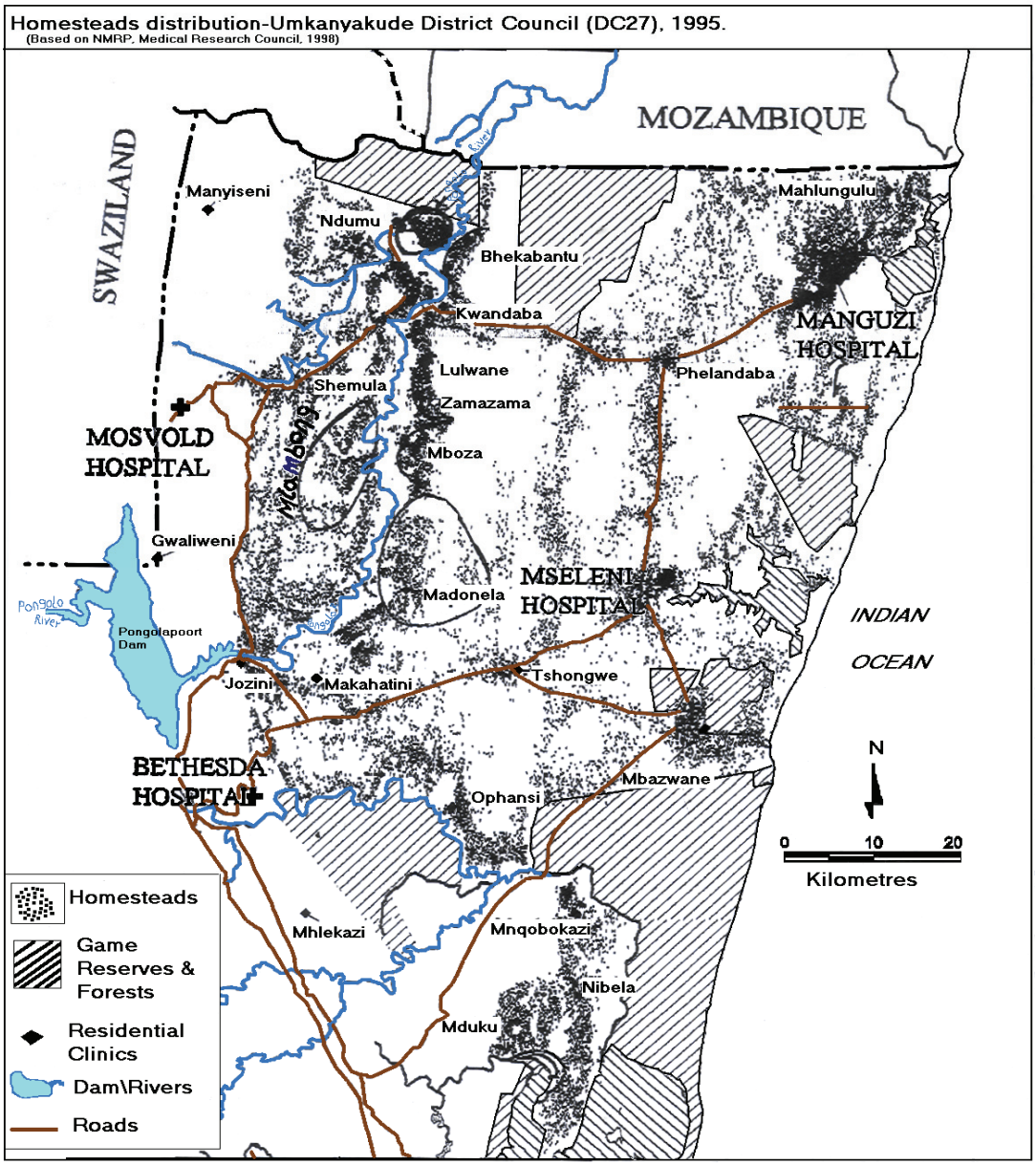


Figure 8.11: Protected area game reserves and plantation forestry in Maputaland are shown relative to human settlements before 1995. (Homesteads in the Umkanyakude district councils (DC27), formerly known as Ubombo and Ingwavuma districts of KwaZulu-Natal Province. The resident human population currently utilizing the floodplain live beyond the normal reach of floodwaters and their homesteads are located adjacent to the floodplain).

8.4.5.3.2 The challenges of fair access to water for economic production

There are challenges to sharing scarce water resources equitably and efficiently between upstream commercial forestry, commercial irrigation agriculture, and recreation-eco-tourism industry and other potential industries vs. protection of downstream floodplain wetlands that provide ecological goods and services, which support a subsistence rural economy (see Chapter 4 for details). According to the principles of integrated community development (Table 8.3), the practical implications of promoting a diverse regional economic livelihood strategy that takes into account ecological and social factors and hence sustainability, efficiency and equity means that:

(i) Since water is a limiting factor, the quantity of commercial irrigation in a catchment should be kept at a level where the negative impacts on ecological and consequently social justice factors are minimized. Balancing economic development of irrigation with ecological and social factors, effectively translates into limiting the number of people who can directly benefit from irrigation farming within a catchment as well as limiting the effective area under irrigation in a catchment (see Chapter 4 for details of the meaning of the concept of the DWAF reserve in practice),

(ii) Likewise, the quantity of commercial forestry (a stream flow reducing activity) in a catchment should be kept at a level which is sustainable in terms of ecological and social justice factors as in (i) above,

(iii) Polluting industries within the catchment must be kept at a level that is ecologically sustainable, i.e. pollution waste from economic growth which ends up in a river should be at a level that makes it possible for others to use the water resource,

(iv) Floodplain wetlands must be maintained with adequate water requirements because they provide free excess nutrient retention services and some areas are preserved for nature conservation while other areas support a huge subsistence economy,

(v) Other primary industries such as natural forestry and fisheries should develop economic strategies that benefit the local population directly.

8.4.5.3.3 The challenges of fair access to land for economic development

(1) Introduction

Water and land resources are key limiting factors to developments on the Makhatini flats. The greatest challenge facing managers and decision makers is how to achieve equitable and efficient allocation of land and water resources for sustainable development and conservation that can satisfy the needs of investors as well as the needs of the local huge rural population that is largely poor.

One of the major challenges facing the national government is to eradicate extreme poverty, hunger and malnutrition through the agrarian revolution and other related programmes and generally work towards achieving millennium development goals (MDGs) (DAEA, 2002, 2008).

According to the KZN MEC of DAEA, Mr ME Mthimkhulu (Annual reports 2008/2009), the agriculture programmes face dauntingly huge transformation backlogs regarding the inclusion of those previously excluded from commercial activities. The extent of the social and economic transformation challenge faces some 15 million people nationally, who are vulnerable to food security, out of which 3.5 million live in KZN province.

The Makhatini integrated development plans intend to contribute to the national goals by alleviating poverty in the region by increasing agricultural production (crop production and agri-business opportunities) and expanding the tourism potential.

An analysis of previous agricultural development initiatives in the region between 1984 and 2006 showed clearly that the flow of benefits to the majority of floodplain communities had little impact (Chapter 6). The conservation areas created had little impact on the social wellbeing of floodplain communities (Chapter 7). It is highly likely that the new goals of poverty alleviation will not be achieved if things are not done differently.

(2) Land access for agricultural development

The views in section 8.4.5.3.3 (i) are strongly supported by a study that evaluated the performance of 317 smallholder irrigation schemes covering 50,000 ha in the former black homelands of South Africa (Denison and Manona, 2007). They found that funding from government, allocated for smallholder irrigation schemes, only impacts directly some 31 300 families in the whole country who have access to plots and can benefit directly, and that there was little impact on the rest of the rural poor even when the multiplier effects to the downstream economy are considered, because about 17 million rural people were in a state of poverty.

Denison and Manona (2007) argue that there is a widespread perception that these irrigation schemes have potential for substantial economic growth, employment, poverty alleviation and therefore they continue to attract hundreds of millions of Rands in government investments annually, but they have never been able to achieve economic growth, increase employment and benefit from the significant multiplier effect linked to agriculture. Studies by (Van Rooyen, 1983; Bembridge, 1990, 1991, 1993, 2004) strongly support these views. Denison and Manona (2007) suggest that doing things differently requires decision makers to:

(i) Invest in rural poverty and food security through agrarian reform needs to extend well beyond irrigation initiatives in order to have a meaningful impact on the plight of the rural poor; investing and creating synergies between on-scheme and off-scheme interventions is needed,
(ii) Not only invest in major funding on low risk engineering and agricultural hardware components but to also invest heavily in capacity building,
(iii) Be aware of the fact that, key success factors in irrigations schemes were found to be, whole enterprise planning, institutional clarity, i.e. clear and enforced rules of engagement and land size and tenure,

(iv) Be aware of the fact that, insecure tenure limits incentive to make investments and provides no room for a land leasing market.

Key factors found to influence sustainability of agricultural production were found to be:

(i) Plot size, which should be able to yield sufficient cash income to cover costs. Without profitability and hence commercial viability, all other efforts are unlikely to succeed,

(ii) Farmers who work small plots are forced to pursue a number of other livelihood practices of which irrigation may be just a small part and therefore with a negative impact on commitment and interest. Full time farming is an incentive to engage in management and operation of the scheme,

(iii) Profitability is enhanced by medium to high value crops,

(iv) If risk of losses could not be absorbed, farmers refused to continue engaging in farming, because they was no incentive for farmers to invest their energy,

(v) Ensuring larger farm sizes was likely to result in greater cash returns for the individual farmer taking the risk (income from total hectares) and may have a positive benefit from economies of scale, which improves feasibility from a farmers' perspective. Therefore, addressing land allocation and consolidation challenge can ensure that intervention initiatives will have great success in moving beyond marginal benefit to individual farmers,

(vi) Land allocation and consolidation must enhance individual farmer profitability and must not be based on the scheme as a whole (i.e. total scheme acreage), which may be profitable to the overall commercial partner but not necessarily profitable to the individual farmer on his parcel of land. (This has indeed, been a key-limiting factor for many smallholder farmers on the Makhatini irrigation scheme (see Chapter 6 and Chapter 7),

(vii) Land consolidation enhances the chances of accessing and competing successfully in large stable markets that offer fixed contracts with strict quality controls. For example, packers and agri-processing companies generally require commitment of substantial hectares to ensure a secure supply of produce to meet their delivery contracts,

(viii) Farmers must connect with the value chain to ensure success, i.e. farmers must be good at crop production as well as at contracting with the agri-business that controls the marketing of the high value food chains. According to Backeberg (2005), success of commercial smallholder farmers is further limited by the political history of South Africa, which created mistrust and prejudice among the various races and cultures. Co-operation, (instead of competition and tension) is not only, required among races, but also, co-operation is required among ethnicity, gender, age and economic class. Mistrust and prejudice in turn create negative emotions such as apprehension, anxiety, anger and accusations expressed bluntly or reservedly, making the act of co-operation very difficult to achieve. This in turn influences or reduces greatly the options available to small-holder farmers, necessary to achieve access to higher value markets through access to contracts with the agri-business sector; hence small farmers or small land holdings are generally locked out of the value chain and are unable to generate the cash surplus needed to cover high overheads and management costs,

(ix) If the desire is to engage with a more commercial orientation, e.g. commodity crops, large contract partnerships, individual enterprise on a large scale, the constraints of climate, soil

conservation and fertility, crop suitability, skills levels, market access and partnership options are likely to call for strategies for a land leasing market to increase holding size,

(x) An exception to land consolidation is producing high value produce with no need for collective contracting or land intervention.

According to the evaluation above, four key factors that determine agricultural production success emerge as:

(i) Increasing land size (land consolidation) that enhances profitability,
(ii) Secure land tenure,
(iii) Producing high value crops, and,
(iv) Ability to access markets.

On the basis of the analysis of the land dynamics above, i.e. issues of plot size, economies of scale, profitability, value chains and markets, exclusion from the value chain and markets, enthusiasm and commitment to continue farming; it is important that the approach to land allocation and consolidation should be informed by the goals of farming. Due to the fact that land availability for agricultural production is a limiting factor, just like water availability for agricultural production is a limiting factor, equitable and efficient allocation and use of land resources should be based on strategies that diversify use in order to meet the diverse needs of the people.

For example, due to the fact that land availability is not limitless, coupled with the fact that water availability for irrigation development and expansion is a limiting factor; sustainable, equitable and efficient allocation of land resources according to the principles of integrated community development (Table 8.3), means that only a small proportion of the population can utilise the land resources effectively for commercial production which depends on increasing land size for profitability. However, increasing land size must be limited to a level that ensures sustainable production and 'fair' profitability that attempts to distribute benefits to more people by increasing the number of commercial producers in a population. Overall diversity in land plot size should be informed by farming goals based on the needs of society which often range from commercial production which depends on increasing plot size to enhance profitability for certain crops, to high value crop produce that does not depend on land size to enhance profitability, to food security plots for subsistence needs.

According to Denison and Manona (2007), land allocation and consolidation strategies in terms of plot size should be informed by the following specific diverse needs:

(i) Commercially oriented production on consolidated farm enterprises,
(ii) Lower risk diversified farming styles,
(iii) Land consolidation initiatives, providing opportunities for those who wish to expand operations through leasing, share-cropping or consolidation of larger farms,
(iv) Food production initiatives off scheme and the land leasing link.

(3) Land access for conservation and eco-tourism development

In a region like the Makhatini flats, where there are many rural poor people, who are competing for scarce land and water resources, certain dynamics come into play and can influence decision making relating to accessing available land. These dynamics are discussed in section (8.4.5.3.4 to 8.4.5.3.6) and section (8.4.5.4). They relate to:

(i) Land for commercial agriculture, or,
(ii) Land for livestock development, or,
(iii) Land for game and eco-tourism or,
(iv) Land for nature conservation and eco-tourism (8.4.5.4.3), or
(v) Land for subsistence agriculture (8.4.5.4.3).

A key finding emerging from these studies is to promote a diverse strategy where many competing needs exit.

8.4.5.3.4 The challenges of making decisions about game farming vs. livestock farming

In addition to the challenge of disease transmission from game animals to livestock, studies comparing the value of game farming vs. livestock farming by relating them: to environmental variables such as rainfall and large herbivore biomass in wildlife and pastoral areas in the African savanna (Coe et al., 1976; Krebs, 1994), to the net above ground primary (plant) productivity and herbivore biomass in agricultural systems and natural systems (Oesterheld et al., 1992; Krebs, 1994), and to meat production found that:

(i) rainfall was a key determinant of meat production because meat production increased with rainfall (Coe et al., 1976),
(ii) wild herbivores in general were less efficient than cattle at converting plants into meat (Skinner, 1972; King and Heath, 1975; Walker, 1976; Coe et al., 1976; Oesterheld et al., 1992).

These findings have significant implications in areas where the DAEA is trying to promote food security through the LRAD programme by ensuring that communities have adequate access to land for food production (crops and livestock development). If the land is not located in an arid zone, and if the immediate goals of society are food security, then it is more efficient to use that piece of land for agricultural production (food, fibre and livestock) than game farming. Such decisions should be supported by further research and a rational appraisal comparing other alternative values.

8.4.5.3.5 The challenges of game farming and eco-tourism

Other studies argue that game farming and eco-tourism are more profitable than livestock production and therefore, in striving to achieve overall equity, efficiency and sustainability on a catchment scale through

balancing economic growth, social needs and ecological needs, the question that managers and decision makers need to ask is:

(i) To what extent does game farming and eco-tourism support the social wellbeing of the local population? If the game reserve excludes the local population from utilizing the natural resources they have enjoyed for centuries for basic survival, then tangible alternative options should be put in place to ensure food security and socio-economic wellbeing,

(ii) The practice of game farming for trophy hunters, which involves, 'largely selling hunting privileges for high fees on the international market' and 'adequately stocking the land with animals first' (Baskin, 1994), brings in concepts of 'source' and 'sink'. The sink is 'killing them', but there has to be a sustained source and where are these sources and are they sustainable? If the focus is on making huge profits, it is highly likely that such incentives may encourage people to work outside the limits of 'sustained – yield programmes', as in the East African case in the 1970s-1980s (Primack, 1998). Although the East African wildlife declines were largely driven by social instability and increasing trade in wildlife (Paine, 1969; Burill et al., 1986; Burill et al., 1986; Fitzgerald, 1989; Jones, 1990; Pimm, 1991; Poten, 1991; Dobson and Poole, 1992; Hemley, 1994; Lawton and May, 1995; Caughley and Gunn, 1996; Webster, 1997; Primack, 1998), it is necessary that decision makers have answers to who are the beneficiaries and who is paying the ecological and social costs, so that they can start thinking about what needs to be done in order to bring about balance.

(iii) Can the present methods of human interaction with these wild animals help the animals survive in the long term? (Laws, 1970; Geist, 1988; Fitzgerald, 1989; Poten, 1991; MacNab, 1991; Jones, 1990; Lewis et al., 1990; Poole, 1996; Hemley, 1994; Webster, 1997; Michler, 2002). It is highly likely that many years down the line, humans will drive these animals to extinction on the African continent because under the current property rights and ownership systems relating to wild animals (e.g. hunting and trading), the animals may find themselves evolutionary unfit to adapt to environmental changes, and may be unable to persist in the long term (Primack, 1998),

(iv) Are game farms truly serving the interests of ecological conservation by extending the effective area of a public wildlife protected preservation or conservation area?

(v) Public conservation agencies responsible for protecting wildlife and habitats inside and out of game reserves (e.g. EKZN-Wildlife) should form partnerships with private game reserves that make it possible to monitor wildlife inside these private game reserves so that corrective measures can be put in place to protect species that may be dangerously declining towards local, regional or national extinction (Lawton and May, 1995).

8.4.5.3.6 Selecting agricultural production areas vs. conservation areas

The following ideas can guide decisions for selecting areas within the catchment that maximise conservation in terms of species diversity or maximise agricultural production (crops and livestock). A study carried out by Coe et al. (1976) in Krebs, 1994, on the relationship between rainfall and the standing crop of large herbivore biomass (Kg/km^2) in wildlife and pastoral areas in the African savanna showed that biomass or meat production (Kg/km^2) steadily increases with rainfall. Another study by

Western (1989) on the relationship between rainfall and the standing crop of large herbivore biomass (Kg/km^2) in wildlife and pastoral areas in the African savanna, showed that diversity or number of species increases with rainfall up to regions of intermediate rainfall (i.e. 200-800 mm) and then diversity starts decreasing in regions with rainfall >800 mm.

The practical implications of these studies suggest that, if the goal of society is food and fibre production, the greater the rainfall in an area, the higher the agricultural production. On the other hand, if the goal of society is to conserve species diversity (conservationist ideas), then we should not concentrate our wildlife areas in regions with high rainfall (>800 mm), because it is more efficient to use such areas for agricultural production (e.g. the upper reaches of the Pongolo River catchment are dominated with plantation forestry because tree production is most efficient in these areas).

Wildlife areas should be largely, located in regions with lower rainfall (<800 mm) in order to maximise the number of large herbivore species conserved. In the case of the Pongolo River catchment, wildlife areas that benefit conservation in terms of maximizing species diversity should be located in the lower reaches, were the floodplain is located and in the mid-reaches; indeed wildlife areas are presently located in these areas. Of course, it must be realised that the agricultural potential of the mid and lower reaches could be greatly increased with irrigation water. But if water is a limiting factor, then decisions made about the most appropriate alternatives that benefit society the most must be supported by rational appraisals of the costs and benefits of the following alternatives:

(i) private game farming and eco-tourism,
(ii) private game farming, livestock production and eco-tourism,
(iii) public game reserves and eco-tourism,
(iv) dry land crops and livestock production,
(v) and others.

8.4.5.3.7 The challenges of ownership of natural resources within forestry

They include co-management and integration issues:

(i) sharing scarce water resources for production between upstream commercial forestry vs. commercial irrigation agriculture, recreation-eco-tourism industry and downstream floodplain wetlands,
(ii) production within the commercial forestry plantation industry, e.g. biological growth and optimal harvesting strategies and financial appraisals of forestry economics which determine under what conditions it may be optimal to eliminate that resource altogether (Edwards-Jones, Davies and Hussain, 2000),
(iii) balancing commercial exploitation of natural forestry with the social wellbeing of local rural populations living adjacent to that forest who have livelihood strategies that depend on forest resources with no other livelihood alternatives (Bromley and Chapagain, 1984; Pretty, 1995; Bromly, 1989, 1991; Edwards-Jones, Davies and Hussain, 2000).

8.4.5.3.8 The challenges of ownership of natural resources within fisheries

They include co-management and integration issues:

(i) sharing scarce water resources for production between upstream commercial forestry vs. commercial irrigation agriculture, recreation-eco-tourism industry and downstream floodplain wetlands.

(iv) balancing commercial exploitation of fisheries with the social wellbeing of local rural populations utilizing the fisheries for basic livelihoods with no other livelihood alternatives (Bromley and Chapagain, 1984; Pretty, 1995; Bromly, 1989, 1991; Edwards-Jones, Davies and Hussain, 2000).

8.4.5.3.9 The challenges of regulating pollution waste

The challenge relates to determining an optimum level of pollution or socially optimal pollution level arising from economic growth and the practical regulation of pollution waste from economic growth (Holdgate, 1979; Young, 1985; Edwards-Jones, Davies and Hussain, 2000).

8.4.5.3.10 The challenges of energy production from non-renewable natural resources

The challenge lies in developing alternative energy sources that are environmentally friendly.

For example, coal mining causes acid mine water to pollute fresh water resources. The burning of fossil fuels and the consequent impacts of green house gases on climate change by an increase in the earth's temperatures, which in turn is causing rapid shifts (increasing frequency) in weather patterns (droughts, storms and hurricanes) and a rise in sea levels (Maud, 1968, 1980; King, 1972; Chung, 1982; Schneider, 1989; Shaffer et al*.,* 1992; Gates, 1993; Boesch et al*.,* 1994; Bawa and Markham, 1995; Climate Change, 1996; Karl et al., 1997; Myneni et al., 1997; Primack, 1998 Keddy, 2002).

A rise in sea levels in turn causes destruction of coastal human developments, and causes coastal wetland habitats to disappear (e.g. coastal shelf, estuaries, tidal marshes, mangroves, floodplains and deltas). During the dry season, when a river has low stream flow, sea rise can cause backwater flows up-river hence influencing the fresh water quality and limiting its use for irrigation, livestock, game, basic needs and other wildlife. Increasing the earth's temperatures means that agricultural production areas in terms of areas where crops grow efficiently (heat units) have to shift (Peters and Lovejoy, 1992; Schulze, 1997). Therefore, environmental impact assessments should strive to ensure that new developments take into account such impacts (e.g. initiatives such as the Climate, Community and Biodiversity Alliance CCBA, 2003). Relevant long term climate change research should be initiated to monitor the impact of temperature change on crop growing efficiency, wildlife and livestock changes. Data from such studies should be linked to the hydraulic model of the catchment.

8.4.5.3.11 The challenges of energy production from renewable natural resources

(i) Ensuring that the bio-fuel industry does not impact negatively on national food security,
(ii) Ensuring that only crops that produce bio-fuel most efficiently are promoted.

8.4.5.3.12 Approach to overall actions for guiding economic growth (increasing production) on the multi-value frontier

(1) Introduction to the general approach

Overall, best practice strategy is to promote a diverse regional rural economy (e.g. ecology, eco-tourism, mining, agriculture, and manufacturing).

Integration of the ecological thinking of sustainability, equilibrium and balance implies that environmental economic tools that take into account ecological and social justice perspectives should be used to determine project economic viability before it can be approved for funding and/or implementation or in monitoring or evaluation programmes.

Due to the presence of a large rural population, the majority of Pongolo River floodplain communities depend on the floodplains' natural resources for subsistence farming and fishing with few job alternatives in the commercial irrigation sector, nature conservation and eco-tourism. Therefore, before approving projects that can be implemented in the region in order to promote a diverse rural economy, which can provide job opportunities and improve the livelihoods of the rural poor, regulating authorities should ensure that environmental impact assessment reports show clearly how ecological and sociological sustainability is going to be taken care of.

Projects should be subjected to evaluation procedures to establish their sustainability in terms of ecological and social justice factors. According to these studies (Fearnside, 1987; Whitten, 1987; Rich, 1990; Anderson, 1990; Goodland, 1990; Fearnside, 1990; Goodland, 1992; Chau, 1995; Steer, 1996; Kapur et al.,1997; Primack, 1998); in order to encourage MDBs and local and international investors to operate more responsibly, the relevant regulating authorities (e.g. Development Banks, DTI, DoA, DEAT, DAEA, EKZN-Wildlife, Local government and relevant investment and economic development authorities) should include the following criteria when evaluating projects for funding and in evaluating their environmental impacts:

(i) Be able to distinguish between projects intended for, 'economic development' which is improvements in organization (e.g. infrastructure) and projects that increase resource consumption 'economic growth', which is a material increase in the amount of resources used. This implies that before approving economic growth projects involving resource consumption, decision makers must think about how the project is going to impact on sustainability and on the concept of 'limits to growth' by ensuring that the DWAF reserve concept has been taken into account (Chapter 4).
(ii) Ensure that economists include ecological and social criteria in project evaluation (environmental costs of projects are often ignored or minimized because they are considered

as externalities), in order to avoid situations where unrealistic optimistic predictions about production schedules and prizes of commodities are made while minimizing potential problems. For example, accurate models of a project should include costs and benefits, including effects on soil erosion, loss of biological diversity, and impact of water pollution on the health and diet of local people, and loss of income associated with the destruction of renewable resources.

(iii) Have a clear understanding of potential problems associated with the project by ensuring that the issues in Table 8.6 below are addressed.

Table 8.6: Criteria for approving projects for development so that environmental and ecological impacts can be minimized (from Primack, 1998)

1	Surveys and pilot studies are undertaken and that no results are disregarded or ignored.
2	Evaluate comparable projects elsewhere to determine the successes and failures. Understand why previous unsuccessful projects were funded in the first place and why host governments or new local investors wanted them anyway? Who were the winners and who were the losers? Understand why the previous mistake should not be repeated, and how things might be done differently. For example, Primack (1998) reported that, very often host countries want large projects to proceed regardless of unfavourable reviews because: The projects provide temporary jobs, economic prosperity (for local business leaders who make large profits on project contracts) and often some release from social tensions for the duration of the projects. The G8-countries that support the banks encourage these loans in order to stabilize governments in host countries that are friendly to interests of the G8, but which may lack popular local support. Bank officials are in the business of making big loans, and so they will continue to make big loans for projects that experience should tell them are not economically profitable or environmentally sound.
3	If cost benefit models for development projects that include environmental and ecological effects find that a project is environmentally destructive, it should not be approved for funding or implementation in order to make the MDBs and local and international investors operate more responsibly by designing more environmentally friendly alternatives.
4	Even after cost benefits models for development projects that include environmental and ecological effects find that a project is environmentally non-destructive, or acceptable, results from the models should be shared and discussed openly with relevant stakeholders, affected and interested parties before implementation (Goodland, 1992). This should take the form of public examination; independent evaluations; and discussions of environmental impact reports by relevant independent professional bodies and local organizations affected by projects being considered for funding.

5	According to Primack (1998), since the governments of the G8-countries primarily fund the MDBs, the elected representatives of the MDB member countries, the national media and conservation organizations should carefully scrutinize MDB policies. Careful scrutiny of its future actions, particularly the lending done by the affiliated International Finance Corporation and Import-Export banks, which lend to the Private Sector, should take place. Watching the funding decisions of the MDBs rather than their speeches and reports is crucial, as they have proven to be extremely effective at public relations. It is also true that the MDBs have no enforcement authority; once the money is handed over, countries can therefore choose to ignore the environmental provisions in an agreement, despite local and international protests. One option, in such a case, would be to cancel further funding for these projects and delay new projects until governments and their organisations show a willingness to address serious problems. The MDBs should use their power well and foster responsible use of the earth's resources. Likewise the same approach should apply to evaluating policies implemented by relevant local institutions involved in funding economic growth and development (both government and private policy).
6	It is very important that MDBs and host countries and their regulating authorities should require that new projects must be environmentally responsible, hire highly qualified ecological and environmental staff to review new and on-going projects; conduct more thorough environmental analyses, including impact assessments, and adapt a management policy that recognizes links between economic development, growth and environmental sustainability (Steer, 1996), which recognizes that there is a high environmental cost for inappropriate economic policies; and that reducing poverty is often crucial to protecting the environment and that economic growth must incorporate environmental values.
7	To implement such policies requires increased lending and funding in the area of environmental management. As a priority, government funding should be made available for independent evaluations/audits of projects. For example, the number of environmental projects funded by the world bank has been steadily increasing, and is heavily oriented toward pollution abatement and control, but also includes funding for biodiversity conservation, forest management and the conservation of natural resources.

(2) Implications of funding agricultural investment developments on the Makhatini flats.

(i) In terms of agricultural investments, it is necessary that the relevant regulating authorities, e.g. DoA, DAEA, DWAF and local government ensure that the investing organisations involved and the relevant development agencies operate in an environmentally responsible manner that conforms to the set of criteria listed in section 8.4.5.3.12 (i) above. The goal of such criteria must be to ensure that economic growth is at a level that does not impact negatively on the ecological and social justice components of the environment.

(ii) DoA, DAEA should ensure that only crops that grow efficiently in the region are promoted (Schulze, 1997).

(iii) Funding and approval of development initiatives on the Makhatini Flats should take into account the fact that, within the Pongolo River catchment water availability for economic growth is a limiting factor (Chapters 4 and 6). Therefore, ecologically sustainable limits to developments should be set within which irrigation or any other stream flow reduction activity should not exceed. The limits to such developments should be informed by results from the DWAF reserve determination (Chapter 4). In terms of the DWAF reserve concept, pollution waste from economic growth should not destroy (or use up) the resource base to the

extent that others cannot use it. Ecological and social justice thinking should be taken into account when setting agricultural economic limits in terms of water availability.

(iv) A large human population on the Makhatini flats, coupled with the fact that water availability is a limiting factor for irrigation expansion, means that not everyone can be allowed to irrigate. Demand management strategies should be put in place to ensure that only a certain number of people can be allowed to irrigate to promote sustainability and profitability of irrigation farms (Chapter 6).

(v) Actions that can find more water for irrigation should be promoted, e.g.

  (a) optimizing water use on the floodplain wetlands through engineering solutions (Chapter 4),
  (b) optimizing water use on irrigation schemes through, among other suggestions, efficient irrigation technologies and equipment and ensuring crop water requirements are achieved efficiently (Van der Stoep, Benade, Smal and Reinder, 2005; Molden, 2007).

(vi) The rest of the population (those who are not irrigation farmers) should use dry land rain-fed agricultural systems. They should be trained to adopt water conservation techniques (in-field rain water harvesting and soil moisture conservation technologies) in order to promote sustainable livelihood strategies that enable them to grow crops and farm livestock on dry land (Smith, 2003; Van Rensburg, Botha, Anderson, Van Staden, Macheli, 2003; Beukes, De Villiers, Mkhize, Sally and Van Rensburg, 2003; Molden, 2007),

(vii) Promote other alternatives in the non-agricultural sector of the economy (Chapters 4 and 6),

(viii) DWAF should ensure that Pongolo River catchment hydraulic model informs sustainable land use planning.

(3) Implications of funding eco-tourism investment developments on the Makhatini flats

(i) The overall, best practice strategy is to promote a diverse regional rural economy (ecology, eco-tourism, mining, agriculture, and manufacturing),

(ii) Lessons learned from the Yellowstone National Park study in the USA (Power, 1991; Primack, 1998), is that, regional economic strategies should not focus on eco-tourism alone, but should seek to promote a diverse set of regional economic strategies that can provide diverse livelihood opportunities for the majority of the rural population who are largely poor and unemployed. The approach worked well in the USA in a diverse regional economy that provided a variety of opportunities (ecology, tourism, service industries, real estate, mining, agriculture, and manufacturing) (Power ,1991; Primack, 1998). Eco-tourism has the potential to provide justification for protecting biological diversity, particularly when eco-tourism activities are integrated into overall development and management plans of a region (Whelan, 1991; Wells and Brandon, 1992, 1993; Southgate and Clark, 1993). In Africa, where eco-tourism projects are largely promoted on their own, one often still finds very many impoverished local people who depend on the primary industries of subsistence agriculture, fishing, and forestry,

(iii) Private production of wildlife for economic gain (as opposed to production for nature conservation being the primary goal) has been increasing since 1994 (reported in several articles in the Farmers Weekly Magazine between July 2007-April 2008). Game reserves and game farms are producing for game meat markets, live game trade markets, and for the lucrative trophy hunting markets for the USA and EU hunters. The economic value of South Africa's game ranching industry was estimated at nearly R5 billion (Farmers Weekly, page 26, November 30, 2007). Such dynamics can lead to competing land-use needs within the catchment (e.g. commercial game farming, commercial crop production, nature conservation and land for subsistence needs). Partitioning of land and water resources among these competing needs should be informed by rational efficient and equitable decisions,

(iv) South Africa's land reform funding models in the wildlife or game and eco-tourism industry are also increasing. Consideration of projects for implementation on the Makhatini flats, should ensure that, partnerships formed must define and implement 'fair' property rights and ownership systems that enhance project viability and sustainability by ensuring that the large local poor populations are not disadvantaged through:

(a) denying them access to use natural resources enjoyed for centuries without providing them with tangible or viable alternatives, i.e. there must be fair trade-offs,
(b) ensuring a 'fair' distribution of benefits for the local rural economy,
(c) rejecting the 'unfair practice' of trans-regional or trans-national capital scenarios where money moves from the poor areas to the rich areas (Trainer, 1985). In such a scenario, the local people do not see any direct benefits and therefore cannot be expected to give up unsustainable illegal practices, e.g. subsistence farming inside reserves, poaching, hunting, fishing or grazing practices.

(v) Before approving eco-tourism projects, regulating authorities (DEAT, DAEA) should ensure that environmental impact assessment reports show clearly how the surrounding impoverished farming and fishing communities are going to benefit. Projects must be subjected to the evaluation procedures in section 8.4.5.3.12 (i) above, to establish their sustainability in terms of ecological and social justice factors. According to Primack (1998), in addition to eco-tourist facilities providing a sanitized fantasy experience, they must also help visitors understand the serious social and environmental problems that endanger biological diversity (Klein et al., 1995; Giese, 1996). This has significant relevance to any planned eco-tourism ventures, not only on the floodplain, but also in the region as a whole.

8.4.5.4 How do we achieve a shift towards nature conservation benefits on the multi-value frontier?

8.4.5.4.1 Introduction

This section outlines the challenges experienced when striving to achieve a shift towards reducing production or economic growth in order to shift towards conservation benefits or sustainability on the multi-value frontier.

Based on literature reviews from ecological (Primack ,1998) and environmental spheres (Ife, 1999), it has become very clear that balancing economic development and conservation of the environment is in the best interest of man.

The interest of conservation is to preserve or protect the natural environment, comprising species and their habitats (wetlands, grasslands, forests and soils), water resources (wetlands, rivers, lakes and sea), from threats arising from human activity mainly from economic development and growth. The output from economic development and growth often threatens the long term survival of species and habitats through processes such as: habitat fragmentation, destruction and degradation (e.g. pollution waste, erosion, overexploitation, impacts of alien species, etc.) (Primack, 1998).

Key regulating authorities responsible for conservation are:

(i) DEAT and DAEA (e.g. through environmental impact assessments for developments),
(ii) DWAF (through water resources reserve determination and monitoring; pollution waste determination and monitoring),
(iii) The conservation agency, EKZN-Wildlife, (through long term monitoring of species and habitats).

According to (Primack ,1998; Edwards-Jones, Davies and Hussain, 2000), examples of policy instruments that can be used to inform decisions that enable a shift towards nature conservation benefits on the multi-value frontier are:

(i) Pollution and waste management policies,
(ii) Rational appraisal of the costs of conservation/preservation against the benefits of development,
(iii) Conservation policy instrument – SSSI (sites of special scientific interest),
(iv) Conservation policy instrument – ESAs (systems of conservation of environmentally sensitive areas),
(v) Conservation policy instrument – conservation concessions or negotiated management systems,
(vi) UNESCO, Man and the biosphere reserves.

8.4.5.4.2 Rational appraisal of the costs of conservation against the benefits of development

(1) Introduction

According to Beckerman (1992), the rational appraisal of the costs of conservation is easy because they have a market value. For example, costs of conservation could be:

(i) Opportunity costs (e.g. foregone irrigation has a market value),
(ii) Conservation expenses (e.g. monitoring pollution waste, policing reserves or water resources and prosecuting those endangering water resources, species and habitats has a market value).

However, estimating the benefits (values) of environmental goods and services from conservation or protection that impact on human welfare is not so straightforward.

Therefore, when making co-management decisions about conservation or development, managers and decision makers should insist that rational thinking, arising from the use of the following methods, informs production of knowledge intended to evaluate the cost of conservation\protection\preservation against the benefits of development of natural resources (water, wetlands, forests and grasslands).

Tools that can be used to develop the necessary knowledge base that can support such decisions are:

(i) The concept of total economic value (TEV),
(ii) The concept of a safe minimum standard,
(iii) The challenges of costs relative to benefits of species preservation,
(iv) The challenges of development and conservation/preservation/protection decisions.

Managers and decision makers need to also take into account the challenges facing the use of these methods in practice. For example:

(2) Concept of total economic value (TEV) methods

In cases where TEV techniques have been used, results must be supplemented by debates about environmental conservation through public or open forums, rather than determined by privately assessed valuations. The final output or result should reflect a wider range of criteria than economic efficiency alone (Sagoff, 1988).

(3) Concept of safe minimum standard (SMS) methods

Is often used in the absence of data\knowledge that can support conservation vs. development decisions. The concept states, 'adopt the safe minimum standard unless the social costs are unacceptably large', which means that one adopts a level of environmental protection and preservation that safeguards against the degradation or loss of natural resources (e.g. water, wetlands, natural forests and grasslands and species), unless such protection results in 'unacceptable' losses of social welfare through preventing potentially beneficial developments (Bishop, 1978). In the absence of data\knowledge, the concept of a

best choice cannot be made objectively, but is dependent on the attitudes of the decision makers to the various risks involved in the choices available. Selecting the correct criterion to use is a function of the decision makers personality (is he risk-averse or a risk-taker?) and the state of the environment (can it stand a loss?). The correct decision will therefore vary according to changes in these factors. It is a politically/socially-determined issue (conservation or development), which will reflect society's judgement about the relative merits of the two alternatives. According to Edwards-Jones, Davies and Hussain (2000), 'unacceptable social losses' can be construed as a strength of the SMS position, requiring the decision making process to acknowledge arguments beyond direct utilitarian considerations, even if, in the end, utilitarian arguments carry the day.

(4) The challenges of evaluating costs relative to benefits of conservation

(i) That the distribution of costs and benefits of any conservation plan is highly significant, as it is the local people who will bear the brunt of the economic costs in terms of lost jobs and the secondary effects of depopulation in rural areas,

(ii) That the benefits of preserving the species accrue to society as a whole, both now and in the future.

According to Edwards-Jones, Davies and Hussain (2000), these two issues are equity and political. If local government, in response to local voter preferences, determines resource use, economic arguments will often dominate. Although from a conservationist point of view, large global existence values may exist for the species or habitat (wetlands or natural forests), from an economic and social view, they do not themselves provide jobs and local incomes.

8.4.5.4.3 The challenges of development versus conservation/preservation/protection decisions

(1) Introduction

A key challenge here is to define policies or methods that can enhance a shift towards nature conservation benefits on the multi-value frontier (Fig 8.8).

Whitby and Saunders (1996) evaluated the effectiveness of ESAs and SSSIs, which have been used by the Ministry of Agriculture, Fisheries and Food in the UK since 1987. Table 8.7 shows trends in ESA use in the UK since 1987.

Table 8.7: Number and area of ESA agreements in England (Source: Ministry of Agriculture, Fisheries and Food, 1990, 1991 in Edwards-Jones, Davies and Hussain, 2000).

	1987	**1988**	**1989**	**1990**	**1991**	**Total**
Number of new agreements	1330	1090	350	186	105	3660
New area under agreement (ha)	31230	68700	8970	2 650	1 560	113110
Cumulative area (ha)	31230	99930	108900	111 550	113 110	113110
Average area of new agreements (ha)	22.7	55.4	25.6	14.2	14.9	
Total ESA cost (million pounds)	4.9	9.3	9.5	10.5	11.1	
Mean cost (pounds/ha)	156.9	93.1	87.2	94.1	98.1	

Table 8.8 compares the two policy instruments (ESAs and SSSIs) and makes three key conclusions:

(i) They work well under a system of strong private property rights,
(ii) SSSIs were cheaper than ESAs in the level of environmental protection they afforded,
(iii) Blanket ESA schemes appeared to overcompensate certain farmers.

Table 8.8: Comparison between ESA and SSSI as policy instruments to enhance conservation (Edwards-Jones, Davies and Hussain, 2000)

Sites of Special Scientific Interest (SSSI) (Spash and Simpson, 1994).	**Environmentally Sensitive Areas (ESA)** (Ministry of Agriculture, Fisheries and Food, 1990, 1991 England, in Edwards-Jones, Davies and Hussain, 2000).
A much more tightly targeted system aimed at providing minimum ecological heritage. Sites are designated according to a set of ecological criteria established to protect the 'rarest' and 'most important' natural habitat sites. If the landowner wishes to develop the land and put it to productive use and if the development has potential to cause damage (potentially damaging operation-PDO), e.g. drain a wetland habitat, which is ecologically unacceptable damage, the authority must establish a management agreement with the owner. The management agreement covers: (i) the practices that are unacceptable, and, (ii) a sum for financial compensation for the owner in light of his lost opportunity cost, which varies from agreement to agreement and depends on the opportunity cost estimated by the farmer, and the budgetary constraints of the authority, (iii) in the case of total disagreement, the authority can push for compulsory purchase of land on which they cannot reach agreement.	A much broader designation. Farmers are offered a fixed payment for adopting certain environmental practices which they are free to accept or reject.
Most SSSI sites had certain areas that were inaccessible anyway, hence offering them a natural level of protection from development that does not have to be compensated because it has no opportunity cost. In other words, payments only have to be made on SSSIs that are threatened.	All farmers inside the ESA boundaries are eligible to receive payments, which are set on three levels or tiers, the value of each tier depending on the extent of the new practices that have to be adopted. These range from simple agreements to avoid the use of certain fertilizers, up to, more proactive conservation management.
SSSIs were cheaper than ESAs in the level of environmental protection they afforded	Blanket ESA schemes appeared to overcompensate certain farmers
The assumptions regarding property rights that underlie the SSSI conservation regime: (i) They work well under a system of strong private property rights, (ii) The SSSI recognizes only the right to draw benefits from property ownership and the right to compensation by the state if this is denied in the interests of wider national conservation goals, (iii) The property right systems are essentially politically determined.	The assumptions regarding property rights that underlie the ESA conservation regime: (i) They work well under a system of strong private property rights, (ii) The ESAs confer an additional right of ownership on farmers, namely the right to claim an additional payment from government in exchange for certain behaviour. (iii) The property right systems are essentially politically determined.
Constrains/limitations: (i)-The fact that the land owner can get financial compensation for lost opportunity costs gives him an incentive to develop the land, (ii) In a worst case scenario, where the land owner does not have strong property rights (e.g. the Pongolo floodplains); and where a whole farm becomes designated, and a farmer is stripped of a major part of his livelihood, and furthermore with land assets worth nothing because no-one can develop them once they are designated, coupled with a situation where an authority has budget constraints, it means that the land owner will bear the full costs of lost opportunities. In such a case, compensation can only become 'fair' from the point of view of the landowner, in a case where society as a whole gains from designation.	**Constrains/limitations**: (i) Payments are often limited by state budget constraints

(2) Conservation policy limitations

Edwards-Jones, Davies and Hussain (2000), strongly warn us of the short-comings of the study by Whitby and Saunders (1996). Whitby and Saunders (1996) evaluated the use of ESAs and SSSIs as

policy instruments to achieve nature conservation benefits in the UK where there is a system of strong private property rights.

Edwards-Jones, Davies and Hussain (2000), argue that the study by Whitby considers extremely narrow criteria, namely, hectares protected and ignores social dynamics, ecological dynamics and economic dynamics under common property and open access regimes. Indeed, these factors are central to the problems facing the Pongolo River floodplain wetlands, designated as an ESA in the regional Spatial Development Plans (IDPs) of local government in 2002 (See Fig 8.9 and Fig 8.10).

In attempting to integrate social, ecological and economic dynamics affecting developments and conservation (or the environment) on the Pongolo River floodplain and the adjacent Makhatini flats, key issues have been described in detail in Chapters 4-7 and highlighted in section 8.4.5.3. These key issues boil down to:

(i) Water sharing between economic developments, subsistence needs, nature conservation and the reserve,
(ii) Land sharing for economic developments, subsistence needs and nature conservation,
(iii) Equitable and efficient allocation of land and water resources for sustainable development and conservation that can satisfy the needs of a huge rural population that is largely poor.

A large rural population found living in Maputaland and largely dependent on natural resources for basic needs, is the greatest challenge facing the use of any policy instruments that enable a shift towards enhancing nature conservation benefits on the multi-value frontier.

Therefore, one would need to assess the possible impact of the use of any policy. According to Edwards-Jones, Davies and Hussain (2000), impact assessments must take into account the following limitations in the use of any policy or methods before and after project implementation:

(i) Social welfare and rural development must be included in the assessment:

From an ecological economics perspective, conservation policies should increasingly be seen as part of a wider rural development policy which may have other objectives, such as income support for farming communities or employment opportunities for other rural services, etc. A rational appraisal should support the decisions taken.

(ii) De-linking income support measures from production output levels to environmental targets instead:

Very significant market distortions exist in the opportunity costs facing farmers, and the effectiveness and cost of both ESAs and management agreements are thereby significantly affected. For instance, European Union countries spent about US$ 29 billion on conservation agreements with farmers between 1992-2003. Increasingly, the European agricultural policy is attempting to come to terms with these distortions by decoupling income support measures

from production output levels and linking them directly to environmental targets. Studies investigating agri-environment schemes in the Netherlands support this view (Kleijn et al., 2004).

Implications for the Pongolo River floodplain is that even if the floodplain becomes purely a protected area, environmental targets can never be achieved under the current reduced flow regime (Chapter 4). Ecological\environmental targets can only be achieved when stream flow regimes that satisfy ecological interests are implemented (Chapter 5).

(iii) There is no guarantee that SSSIs, ESAs or other methods will produce either an ecological minimum or sustainable resource allocation in the long term:

Market established levels of environmental protection may approximate optimal budget allocations between those engaged in bargaining, but these represent constrained maximization subject to the property rights, transaction costs and budget constraints of those involved; yet, there is no guarantee that the conservation methods used will produce either an ecological minimum or even, in the longer term, a sustainable allocation of resource use.

(iv) Issues of strong private property rights vs. common property rights:

The assumptions regarding property rights that underlie conservation regimes are critical. For example, ESAs confer an additional right of ownership on farmers, namely the right to claim an additional payment from government in exchange for certain behaviour. The SSSI recognizes only the right to draw benefits from property ownership and the right to compensation by the state if this is denied in the interests of wider national conservation goals. For instance, environmentalists have often argued that ownership of an SSSI should confer responsibilities without compensation, in the same way that, for example, owners of listed buildings in the United Kingdom may be barred from making any adaptations to them on the grounds that they are a part of the national heritage that must be preserved. Grants may be provided only for repair or renovation, but not to compensate for the physical discomfort of leaky roofs and/or draughty windows.

(3) Possible impacts of implementing conservation policies on the floodplain

(i) Issues of property rights and ownership systems

Key factors that determine shifts on the multi-value frontier are linked to property rights and ownership systems because each type of property right and ownership system provides both owners and non-owners with different incentives for action (Bromley, 1989, 1991). Within each property right and ownership system, various policies are put in place to adjust incentives accordingly.

ESAs and SSSIs work well under a system of strong private property rights as in the United Kingdom. The floodplain does not have a system of strong private property rights, and therefore it is highly unlikely that they will work well on the floodplain.

A key challenge to implementing conservation policy on the Pongolo floodplain is that there are conflicting views on the property rights and ownership systems.

From a traditional point of view, the floodplain communities perceive certain rights on the floodplain as ownerless or open access assets, which are not owned by any group or individual, e.g. floodplain pans for fishing and pan marginal areas for livestock grazing and forest patches for firewood, etc. Land on the floodplain has been allocated through traditional systems of land allocation through the tribal authorities. Individuals own specific pieces of land used for cultivating crops. The traditionally allocated piece of land can be inherited and sub-divided among sons. And indeed, communities have traditionally utilized the system in this way for centuries. Results of the social survey showed that all productive land had been allocated, although most of it has become marginal due to reduced flooding (Chapter 4 – fig 4.3 and Chapter 7). These traditional rights and ownership systems are not recognised in modern systems because of a lack of formal title from the state; hence the land cannot be used as security to secure development loans (Pretty, 1995). Such land is often referred to as communal land or communal areas.

On the other hand, state authorities perceive the floodplain as state property owned on behalf of the citizens of the nation by the state. The government authorities, who are largely responsible, are DWAF (manage artificial flood releases), DoA and DAEA (manage agriculture and environmental issues) and EKZN-Wildlife (manage wildlife conservation), and the Department of Land Affairs.

It is important to remember that, when all is said, at the end of the day, politics influences what will be done, because property rights and ownership systems are essentially politically determined and depend on the goals of government.

Due to the absence of strong property rights on the floodplain, the following section discusses the impact of implementing conservation policy on the floodplain, by taking into account issues of property rights, social welfare and rural development, and the importance of linking conservation efforts to environmental targets that can at least achieve an ecological minimum and sustainable resource allocation.

Due to the presence of a dense human population, who have largely no alternative livelihoods, and on the basis of the ecological thinking of sustainability, equilibrium and balance, best practice, that minimizes the negative impacts in terms of an immediate option, would be to try to reach a balance between economic development, subsistence needs and conservation.

Decisions should be supported by Environmental Impact Assessments (EIA) clearly showing the pros and cons of policy impact in terms of social dynamics, ecological dynamics and economic dynamics under private, common property or open access regimes before they are implemented. Implementing any policy framework without evaluating its impacts and testing the outcomes of this evaluation in a stakeholder workshop is highly likely to produce unfair outcomes.

This is because the floodplain communities are already bearing the social costs of the current impacts of the Pongolapoort Dam-induced reduction in stream flows on the floodplain wetlands and the consequent reduction in goods and services it produces, namely, reduction in its food and natural resource producing qualities (Chapter 7). Also, the floodplain land is the only highly productive piece of land to which many floodplain communities have access in order to grow crops. All other productive land adjacent to the floodplain is state land earmarked for commercial irrigation development. Most of the other lands in the vicinity of the floodplain are largely marginal coastal, sandy soils with most areas having low to no potential for agricultural production (Chapter 6).

The implications of the ESA policy instrument on the population living adjacent to the floodplain (excluding the wider Maputa land plains) would have to take into account:

(i) Several farm parcels owned by floodplain communities (Fig 4.3),
(ii) The population adjacent to the floodplain, comprising 92 369 people made up of 16 581 households with an average of about >8 people per household, according to the SA 2001 Census data (Chapter 6 and 7),
(iii) Other farm ownership details, such as the number of farms owned by a household (Chapter 7),
(iv) People who own farms on the floodplain but have not been accounted for in the population figure above of 92 369 because their households are not immediately adjacent to the floodplain.

It is highly likely that payments would be limited by state budget constraints and that the payments offered may be too low, i.e. lower than the opportunity cost of developing the land (in the case of SSSIs) or continuing with the old bad environmental practices (in the case of ESAs) from the farmers' perspective, remembering that each individual agreement must identify the farmer's individual opportunity cost for the land.

The implications of these economic dynamics of the marginal costs associated with ESAs, coupled with ecological and social impacts currently being experienced as a result of reduced stream flow, means that floodplain farmers would have to be paid (in terms of a true lost opportunity costs) an amount of money that makes it possible for them to purchase an alternative fertile piece of land elsewhere. The lost opportunity costs for fishermen would need to be taken into account as well (Chapter 7).

Clearly, conservation policies on the floodplain should be seen as part of a wider rural development policy which may have other objectives, such as income support for farming communities, or employment opportunities for other rural services, etc.

It must be pointed out that previously, development plans (conservation and irrigation schemes) that claimed to take into account social welfare and rural development on the Makhatini flats, never achieved the goals with respect to meeting the needs of floodplain communities. Only a few people benefited, while the majority of the population are still dependent on floodplain and dry land agriculture (Chapter 6 and Chapter 7).

(ii) Conservation needs versus floodplain community needs

EKZN-Wildlife is the conservation agency responsible for protecting species and habitats. EKZN-Wildlife's priority option expressed in stakeholder workshops is for floodplain farmers to leave the floodplain so that it can become purely a conservation or preservation area used for eco-tourism and recreation and operated as conservation concessions.

During stakeholder workshops, floodplain communities strongly objected to this view (Jaganyi et al., 2003). In addition, results of the social survey (Chapter 7) support the fact that the welfare of floodplain communities is still largely dependent on floodplain natural resource maintenance through annual artificial flood releases. Due to the ever-increasing cost of living, social grants and pensions from government supplement whatever food resources are obtained from the floodplain. The floodplain's natural resources support a large subsistence economy which mainly has no access to capital but whose welfare is largely dependent on floodplain natural resource goods and services. The needs of these floodplain-dependent people may not enter government financial accounting appraisals of potential revenues from agriculture/forestry/fishing and protected or private area nature conservation yields, yet their welfare is wholly dependent on floodplain maintenance.

The second option for the conservation agency, EKZN-Wildlife, has been that floodplain farmers should adapt certain conservation practices on the basis of moral grounds and that they should obey existing environmental legislation. For example, the needs of EKZN-Wildlife are that cotton farming should not be practiced on the floodplain, farming activities should keep out of ecologically sensitive areas (pan beds, river inlets and outlets, river banks), communities should not over-harvest resources (fish, pasture, wildlife), and that artificial flood release timings from the dam should be as near natural as possible.

On the basis of the social survey, many floodplain farmers indicated that they see the value in upholding these requirements; however, on a practical basis, they have no alternative means of livelihood. It is no wonder that none of these requirements are being implemented by floodplain farmers because the relevant government regulating authorities (EKZN-Wildlife, DoA, DAEA and DWAF) are not offering farmers an alternative in terms of financial compensation in light of lost opportunity costs or other livelihood alternatives (e.g. adequate floodplain water requirements, or alternatives in the non-agricultural sector of the economy) (Chapter 7).

It may be that the assumptions used to make the decision not to compensate farmers for lost opportunity are similar to those made by Whitby and Saunders (1996) in their theoretical analysis of marginal costs per protected area associated with ESAs and SSSIs, which suggest that there is some natural level of protection that does not have to be compensated because it has no opportunity cost. However, results of the social survey on the floodplain (Chapter 7) showed that, even under the current reduction in stream flow, the floodplain still had some level of opportunity costs.

Edwards-Jones, Davies and Hussain (2000), give a worst case scenario, where a whole farm becomes designated, and a farmer is stripped of a major part of his livelihood, and furthermore, with land assets worth nothing because no one can develop them once they are designated, coupled with a situation where

an authority has budget constraints; this means that the land owner will bear the full costs of lost opportunities. They suggest that, in such a case, compensation can only become 'fair' from the point of view of the landowner, in a case where society as a whole gains from designation. It has been suggested that, the free market offers ways to resolve these issues through conservation concessions and integrated conservation development projects (ICDPs).

However, according to reported reviews, it appears that conservation concessions (Ellison, 2003) and ICDPs (Christensen, 2004) have not worked very well in areas where there were many competing needs for the same resources, e.g. a high human population depending on these resources for basic needs, coupled with demands to have the resources developed for economic needs. This has direct implications for the Pongolo River floodplain wetlands.

Indeed, green writers (Table 8.3), who are against global inequality, have criticized environmentalists in the more affluent nations for supporting such projects in the developing world, which deny local people access to local subsistence resources that they have enjoyed for centuries in the name of conservation, or by limiting economic exploitation, and jobs needed to support diverse livelihoods. Yet the governments of the north followed a similar route to economic prosperity through the process of industrialization. Indeed, northern environmentalists have often been charged with using the environment to perpetuate colonialist domination (Trainer, 1985, 1989; George, 1979, 1992; Shiva, 1989, 1991).

A third option for the conservation agency EKZN-Wildlife has been to use conservation legislation and prosecute offenders in a court of law (e.g. illegal fishing, wildlife poaching, growing crops in ecologically sensitive areas, i.e. pan inlets and outlets channels, levees and inside pans, river banks and fever tree lines around the pans). In the case of current floodplain use for agriculture, where crops are grown in ESAs due to reduced stream flow caused by upstream dams for irrigation (Chapter 7), implementing conservation legislation would mean putting some 100 000 people living in the immediate vicinity of the floodplain behind bars.

Yet, complex relationships of the biophysical dynamics, e.g. soils (Chapter 6), reduced modified stream flow (Chapter 4), socio-economic dynamics of water and society on a catchment scale (Chapters 6 and 8) have shown clearly that the biophysical state and reduced stream flow on the floodplain caused by dams and upstream irrigation and commercial forestry has reduced the goods and services produced by the floodplain (crops, fish, pasture and wildlife). The reduction in production of natural goods and services has in turn influenced the behaviour of communities with respect to farming practice and resource exploitation. Results of the social survey show clearly that floodplain communities perceive that DWAF flood releases were not meeting their needs nor the needs of the environment (Chapter 7). Therefore the behaviour of floodplain farmers can only change under changed stream flow regime or by providing alternative means of survival.

Therefore, effective integration and co-management implies that before using conservation legislation to prosecute offenders in a court of law, for example those cultivating in ecologically sensitive areas (ESAs), the responsible authorities, e.g. DWAF, DAEA and EKZN-Wildlife should be willing to initially use holistic thinking to develop a knowledge base on a catchment scale (e.g. DWAF reserve determination

studies) that critically analyses the situation using hydrology, biophysical, ecological and economic determinants on a catchment scale in order to ensure that the situation does not arise where we are just blaming the victims (Chapter 7). The knowledge should then be presented for discussion in a relevant co-management stakeholder structure (WUA), in the presence of decision makers within DWAF, DAEA, DEAT, municipalities, communities and relevant stakeholders, so that decisions can be taken about what needs to be done in terms of solutions and alternatives. After such decisions have been taken and implemented, if offenders are still found, then only should they be prosecuted. The nature of environmental problems is such that the impacts are often felt many kilometres away from the source. Regulating authorities should not be hasty in applying conservation legislation to impoverished communities, yet when it comes to, 'who is really destroying the environment?', it could be big developments, located both inside and outside ESAs, elsewhere in the region, yet regulating authorities often do nothing. Therefore, a holistic knowledge base is the key because it enables the truth, allows for effective decision making, helps control conflict within groups and regulates relations with other groups, thereby creating better ecological outcomes and improved social dynamics among stakeholders in the long term.

Given the diverse stakeholder interests found on the floodplain and the catchment as a whole, it must be realised that there is different legislation protecting all stakeholders. For example, the constitution of the country will have to be obeyed (co-operative governance, equity of access to information and inclusivity); the integrated fashion of the National Water Act and other environmental laws; the international conventions that South Africa is signatory to; the Promotion of Administrative Justice Act which demands that the reasons for decisions are transparent and that the officials concerned have adequately applied their minds to all issues; and even DWAF, whose hand is on the sluice gates of the dam, will have to work within the laws. If the processes needed to reach a negotiated consensus violate any of these issues, the affected communities will be able to mount a legal challenge. It is very important to get stakeholders to understand that the processes leading to the decisions are the key. If the process in reaching a decision is wrong on any one of the above, as Mark Dent puts it, then there can be 'logjams' of court cases (Dent, 2003).

For example, the holistic approach taken in analysing the problem in this study has revealed that, neither the communities nor EKZN-Wildlife, nor DWAF managers have control over the negative environmental outcomes on the floodplain, because hydrology is a key-limiting factor in ecological processes (Keddy, 2002) and current patterns of natural hydrology have been greatly altered by the dam and the dam design (Chapters 4, 5 and 7). The primary control over these factors is in the hands of the DWAF authority who have the ability and mandate to do something about dam design and water resource allocations and the DoA, DAEA has the ability and mandate to regulate intensity of food and fibre production by balancing developments and conservation and by ensuring that development impacts on the environment are mitigated.

Due to the fact that irrigation development expansions are largely intended to produce high value cash crops (sugar, spices, etc.), in addition to the fact that jobs created in the commercial irrigation agricultural sector cannot amount to many because of economic dynamics, only a very small percentage of the total population can be gainfully employed in the irrigation sector. The rest of the population will need to have

access to alternative means of survival. The floodplain's natural resources have the potential to provide these alternative means of survival (crops, fish, pasture and wildlife), which have greatly reduced due to upstream dams. Therefore, relevant regulating authorities should provide communities with alternative livelihoods before using relevant environmental legislation to prosecute people particularly those cultivating in ESAs.

Given the current poor ecological state of the floodplain caused by reduced stream flow due to expanding irrigation and the consequent reduction in floodplain goods and services that enhance the social welfare of many people who generally have no alternative access to capital and whose welfare is largely dependent on floodplain natural resource goods and services, and in the absence of alternative means of survival, many floodplain communities are highly likely to move away into the big cities to find work, leading to overcrowding mainly in the cities' informal areas (slums) and a reduction in their quality of life. Social anthropologists (Hammond, 1978) and green writers (Max-Neef, 1992) tell us that generally all humans strive for a good quality of life and therefore a poor quality of life, due to overcrowding in urban slum environments, cannot be a desired alternative for any human being.

Also, in the absence of alternative means of survival, many rural folk are highly likely to find themselves engaging in illegal activities for basic survival (e.g. crime, illegal fishing and wildlife poaching). It is highly likely that the costs incurred by the state to control crime and by the conservation agencies responsible for protected areas and outside protected areas in terms of administration, monitoring, fences and maintaining surveillance agents, would be very high under these social pressures. Indeed, the use of legislation by the conservation agency EKZN-Wildlife to prosecute offenders has, over the years, led to very bad social relationships between communities and EKZN-Wildlife (Chapter 7, Jaganyi et al., 2003).

Some of the issues raised relate to the fact that game reserve eco-tourism facilities (game viewing, hunting lodges and other facilities) become too expensive for ordinary local citizens to afford and eventually local citizens get excluded from enjoying these resources due to the huge expenses involved. For example, Lewis et al. (1990) reported a case in Zambia, where the local people were excluded because of the very expensive hunting licences which the local people could not afford. The local people started to perceive the government wildlife service personnel as acting only in the interest of the safari (tour) companies and having little regard for local concerns. As a consequence, the attitudes of the local people changed, increasing illegal poaching of animals leading to a dramatic wildlife population decline during the 1970s and 1980s. Lewis et al. (1990) summarized the feelings of these people through a speech made by the chief:

"*Tourists come here to enjoy the lodges and view the wildlife. Safari (Tour) companies come here to kill animals and to make money. We are forgotten---Employment here is too low. Luangwa Lodge employs only about 4 people, and safari hunting employs no one. How can you ask us to cooperate with conservation when this is so*?"

The Pongolo floodplain communities expressed similar feelings towards protected conservation areas in the results of the social survey and in stakeholder dialogue workshops (Chapter 7). They felt that they had been totally excluded from these areas and had no access to the use of the resources in these areas

after apartheid policies pushed them out of these areas since 1948 (Jaganyi et al., 2003). In terms of outside protected areas, for example the floodplain, communities perceive that they are blamed for destroying the environment, yet they have no alternative. They perceive that government, through EKZN-Wildlife, appears to value animal life more than it values people. It is highly necessary that government finds alternatives for these people because they are bearing the costs of irrigation and conservation/preservation or protection in the region.

Co-management and integration through CMA and WUA structures (Section 8.3) should seek to resolve such conflicting values by defining appropriate property rights and ownerships systems within the wildlife industry and fair trade-offs that can diversify the regional economy by ensuring that it does not focus on eco-tourism alone, but also provides opportunities for alternative livelihoods in a region where the majority are poor and unemployment is high. New developmental frameworks should strive not to push local communities deeper into poverty.

Indeed, the findings of this study support the 'win-win illusion' views of Christensen (2004) about 'poor people and protected areas'. Christensen (2004) reported that over the past two decades efforts to heal the rift between poor people and protected areas have failed. It is indeed very true that the theme of the World Parks Congress (2003), held in Durban, South Africa, reflected the demands of the time – 'Benefits beyond boundaries'. According to Christensen (2004), there was open conflict between indigenous people advocating for 'poverty alleviation' and conservationists calling for 'protected areas', leading to discussions about poverty and development at the World Parks Congress. It was argued that protected areas are integral to poverty reduction and national development strategies.

But some conservationists maintained that the goals of biodiversity conservation have never been compatible with economic development (Redford, 1991, 1992; Redford and Sanderson, 1992; Brandon, Redford and Sanderson, 1998; Redford and Sanjayan, 2003). They argued that the goals for biodiversity conservation must not be to 'exploit it' but to 'conserve it' only. This is supported by the simple fact that nature conservation and economic production exist on opposite extremes of a production continuum (Traill, 1988; Edwards-Jones, Davies and Hussain, 2000). While some conservationists support game farms and trade in game animals (Western, 1989; Baskin, 1994), others feel that game farming and trophy hunting and trade may have adverse impacts on wildlife biodiversity (Ehrenfeld, 1978; Geist, 1988; Ehrenfeld, 1989; Fitzgerald, 1989; Jones, 1990; Lewis et al., 1990; Poten, 1991; MacNab, 1991; Poole, 1996; Hemley, 1994; Webster, 1997; Michler, 2002). Others see ecosystem–service science as the only way forward for conservation in an environment where there are many competing interests (MEA, 2005; Armsworth et al., 2007; Falkenmark et al., 2007; Molden, 2007).

Indeed, at the World Parks Congress (2003), anthropologists argued that parks and protected areas are fundamentally incompatible with the rights and aspirations of impoverished local communities. Anthropologists criticised 'protected area' conservation, calling it an "old fortress model that excluded people" and in addition there was a growing backlash against 'protected areas' from anthropologists and poor people advocates, asserting that conservation and development are two sides of the coin of colonialism (Christensen, 2004).

Prominent economists have supported the anthropology arguments above by using utilitarian ethical arguments to criticize conservation movements and their preservationist orientation. Utilitarian economic arguments put forward are that the reason why species and habitat destruction occurs is because alternative human wants and needs have outweighed the protection\preservation values of species and habitats (Beckerman, 1992; Spash and Simpson, 1994; Edwards-Jones, Davies and Hussain, 2000). For instance, although Beckerman (1992) acknowledges the vast complexity of forces threatening habitat destruction and species loss resulting from economic activity, he argues that simple decision rules such as 'all organisms have equal value and must be preserved' are worthless when there are a multitude of competing reasons for pursuing environmentally damaging development projects. Beckerman (1992) attacks strongly what he perceives as 'overly zealous efforts at species or habitat preservation, particularly in the face of pressing human needs in developing countries. He suggests that preservation or nature conservation is often a 'middle-class' western obsession, carried out at the expense of the poor, both between the classes within nations, and between rich and poor nation states. Instead Beckerman (1992) calls for a rational appraisal of the costs of preservation against the benefits of development.

The bottom line is that, 'people', 'indigenous and non-indigenous' and 'conservationists and non-conservationists' will do whatever it is that they have to do to meet their basic needs for food and shelter. Max Neef (1992) and Hammond (1978) support these views. It is over-crowding and the methods used that make a difference in the rates at which the environment is destroyed or degraded. If this is the case then the concept of excluding people from protected areas needs to be revisited. Perhaps, we should focus more on redefining methods of human interactions with the environment, by allowing local communities to harvest resources within sustained yield limits through licences. This also implies that if the various human needs and nature conservation needs have to be met, a mix of projects should be allowed. The projects should make their goals explicit so that there is a mix of purely conservation projects (e.g. protected areas reserved for wildlife only), conservation and development projects (e.g. areas where eco-tourism projects like ICDPs can be allowed) and purely development projects and then proceed to negotiate from there and be willing to make the necessary trade-offs (Christensen, 2004).

The thinking reported by (Christensen, 2004) is similar to the concept of the UNESCO Man and the biosphere reserves (Young, 1992; Batisse, 1997) and the multi-value approach to agriculture (Traill, 1988; Edwards-Jones, Davies and Hussain, 2000) and the ecological thinking of sustainability/balance and equilibrium (Table 8.3). Others support these views and propose that the way forward for conservation, under pressing social needs, is through eco-system service science (Armsworth et al., 2007). Expected outcomes of all of these approaches would be a diverse livelihood strategy.

The UNESCO Man and the biosphere programme recognizes the role of people in shaping the natural landscape, as well as the need to find ways in which people can sustainably use natural resources without degrading the natural environment.

One of the key goals for the programme is the maintenance of samples of varied and harmonious landscapes resulting from long-established land use patterns. The research framework integrates natural and social science research and includes investigations of how biological communities respond to different human activities, how humans respond to changes in their natural environment, and how

degraded ecosystems can be restored to their former conditions. The general pattern of man and the biosphere reserve includes undisturbed core-protected areas (undisturbed, with monitoring activities only, but no tourism and recreation), surrounded by a buffer zone (in which traditional human activities are monitored and managed and non-destructive research and monitoring is carried out, and where tourism and recreation is allowed) and a transition zone (in which sustainable development, experimental research, human settlements, recreation and eco-tourism is allowed). The programme has been reported to be very successful (e.g. in 1998 there were 327 reserves in 85 countries covering 200 million ha). Clearly UNESCO Man and the biosphere reserve agrees with the concept of the multi-value approach to agriculture. These two instruments are more likely to achieve success in nature conservation benefits in a densely populated environment than the use of ESAs, SSSIs, conservation concessions or negotiated management agreements whose conservation development outcomes may end up pushing local communities deeper into poverty. In cases where such policies have been implemented, they must actively strive to ensure the social and economic wellbeing of local communities is improved, because both communities and projects are competing for the same scarce resources (land and water), so rendering poor communities very vulnerable.

CHAPTER 9: CONCLUSIONS AND RECOMMENDATIONS

9.1 TRENDS IN STREAM FLOW

9.1.1 Conclusions

1) When compared with virgin stream flow, the current artificial stream flow regime downstream of the Pongolapoort Dam was found to have greatly reduced in magnitude and the timing of seasonal events had also shifted.

2) It was also found that reduced stream flow downstream of the Pongolapoort Dam cannot only be attributed to upstream economic developments that reduce stream flow (dams, irrigation and commercial alien plantation forestry) but also to dam design and the lack of appropriate engineering solutions. For example, stream flow trends showed that under the current set up (i.e. as long as the dam is in place), no matter how great or small the volume of water made available for floodplain water requirements (artificial flood releases), the fact that the system is artificial means that the present forces generated by flood waters do not allow for flood waters to remain on the floodplain long enough to optimise ecological functions needed to produce a diverse set of goods and services. An artificial system (engineering solutions) would need to be developed to enable the water to remain on the floodplain for the desired period. Secondly, the timing of the floodwaters must be aligned with natural seasonal rhythms. If the timing of these releases is not aligned with natural seasonal rhythms, environmental goals or targets required to make the floodplain function as an aquatic wetland ecosystem (in terms of goods and services produced) can never be attained.

3) Heeg and Breen (1982) showed that the following goods and services were produced under a virgin stream flow regime before dam developments. The floodplain had an area of 13 000 ha with diverse habitats, rich not only in biodiversity but also producing diverse ecosystem goods and services whose production was sustained by seasonal rhythms combining climate factors and water level fluctuations through summer, autumn, winter and spring. Nature or climate controlled the equitable partitioning of the resource between agricultural use and fishing. Rainfall concentrated in summer with the highest run-off in February, which produced a flood peak that enabled the river to break out of the main river channel and inundate the adjacent areas, creating a huge fishery (10 414 ha). Water level fluctuation, from high flood level to maximum pan retention level, was for a period of not less than two months. During summer, community livelihoods were sustained by fish and rain-fed crops grown off the floodplain. During periods of low stream flow, over the dry winter months, crops were grown on the floodplain because floodplain soils retained adequate moisture to sustain plant growth (crops, pasture and wildlife) after floods had receded. The livelihood strategy was diverse because the effects of drought, such as crop failure and hunger, were reduced. The implication is that altering natural patterns of stream flow can

affect floodplain biodiversity and the range of ecosystem goods and services produced by reducing harvestable yields. Therefore, to achieve sustainability, modified or artificial stream flow would need to ensure that a diverse livelihood strategy is sustained.

Reviews of other international studies of floodplain wetlands strongly support these ideas. A view emerging from these studies is that the most sustainable option in the long term is to protect the floodplain by allocating an amount of water that makes it possible for it to produce a diverse set of goods and services (ecological services, social goods and economic goods).

4) A key goal of national government is to grow the economy so that more jobs can be created. This view is reflected in the DWAF national water resource strategy (2004) which uses the concept of integrated water resources management to achieve this goal, which states that, "*integrated water resources management is intended to enable us to meet the needs of our people for water, jobs and economic growth in a manner that also allows us to protect and, where necessary, rehabilitate our aquatic ecosystems. Above all, integrated water resources management will make it possible for us to use our precious water to assist in addressing the overwhelming need to eradicate poverty and remove inequity in South Africa*".

The views of the National Water Resource Strategy (2004) imply that Scenario 1 (with no flood releases) should only be supported if scientific data, in terms of cost benefit scenarios, is produced, which shows that should we destroy the floodplain completely so that it becomes a dry land (i.e. pans outside game reserves dry out killing subsistence fishing, marginal pasture, marginal crops, and wildlife; pans inside game reserves dry out killing all wildlife, fish, and eliminating sources of drinking water and natural wetland vegetation grazed by game animals), alternative uses of water saved from Scenario 1 (352 million m^3) will still be able to meet the basic needs of all floodplain people by eradicating poverty and inequity through jobs and economic growth, while ensuring that effluents ending up in the water resources from economic growth do not pollute the water resources to the extent that the quantity and quality of water left in rivers cannot meet the economic, social and basic needs of others.

DWAF proposed two scenarios – Scenario 1 (with no flood releases) and Scenario 2 (with flood releases). Literature reviews point to the fact that wetlands are the cradle of human civilisation and giving them an economic value in monetary terms in order to justify their conservation is underestimating infinity. Wetland conservation should be based on ecological, ethical and moral values instead and developments should always strive to enhance ecosystem services. On this basis, values in terms of goods and services from the two development scenarios proposed by DWAF were identified and compared qualitatively and are summarised in the table below.

	Scenario 2 – with flood releases (Water balance – 102 million m^3)	**Scenario 1 – with no flood releases** (Water balance – 352 million m^3)
(i)	Floods enable some level of economic growth off the floodplain	Absence of floods greatly enhances the level of economic growth off the floodplain
(ii)	Floods enable some level of nature conservation (protected areas) to be sustained on the floodplain	Absence of floods destroys the potential for sustaining nature conservation (protected area)

	(e.g. pans inside game reserves are maintained by flooding to produce wildlife, fish, sources of drinking water & natural wetland vegetation grazed by game animals).	on the floodplain (e.g. pans inside game reserves dry out killing all wildlife, fish, and eliminating sources of drinking water & natural wetland vegetation grazed by game animals).
(iii)	Floods enhance the value of the landscape in terms of aesthetic beauty and potential for tourism and recreation (hotels, lodges, holiday homes)	Absence of floods reduces or destroys the value of the landscape in terms of aesthetic beauty hence lowering potential for tourism & recreation (hotels, lodges, holiday homes)
(iv)	Floods enable some level of a subsistence economy to be sustained on the floodplain by enhancing production of natural land & aquatic resources (e.g. crops, pasture, fishing, poles and grasses for building houses and for making arts and crafts, wild vegetables, medicines, fruit and bush meat).	Absence of floods completely destroys the subsistence economy (e.g. pans outside game reserves dry out killing subsistence fishing, marginal pasture for livestock, marginal crop fields and wildlife).
(v)	Floods limit commercial irrigation farming on the floodplain because they maintain the floodplain wetlands environment which limits development of irrigation infrastructure for commercial farming	The absence of floods destroys the floodplain wetlands transforming the environment into dry land and enhancing potential for commercial irrigation. However, the risk of the irrigation infrastructure being destroyed on the floodplain is too high with the current dam design. The dam wall would have to be higher than it is now so that it can effectively act as a flood control/protection against natural cyclone events, frequent in the region, e.g. Domoina in February 1984 and more recently, Favia in February 2006.
(vi)	By reducing floodplain water requirements & increasing their effectiveness using engineering solutions, commercial irrigation farming off the floodplain can be enhanced greatly	Absence of floods can increase commercial irrigation farming off the floodplain greatly.
(vii)	Potential for other water based economic growth is relatively limited with floods	Potential for other water based economic growth is relatively enhanced in the absence of floods
(viii)	Floods enhance the capacity of the reserve to absorb excess nutrients & waste from economic growth	The absence of floods reduces the capacity of the reserve to absorb excess nutrients & waste from economic growth, hence decreasing long term ecologically sustainability developments (e.g. too much water is taken out of a river with an excess input of nutrients and waste, altering the natural shape, structure & function and hence further disabling use of the resource. Or the water resource is modified greatly by enhanced erosion, sedimentation and habitat degradation resulting from intensive and extensive economic growth in the catchment).

(ix)	Scenario 2 (with flood releases) is more likely to achieve equity, efficiency and sustainability in the short and long term	Scenario 1 (with no flood releases) is less likely to achieve equity, efficiency and sustainability in the short and long term. Therefore Scenario 1 (with no flood releases) should only be supported if scientific data is produced using environmental or ecological economics methods and used to build cost benefit scenarios which shows that, should we destroy the floodplain completely so that it becomes a dry land, alternative uses of water saved from Scenario 1 (352 million m^3) will be able to meet the basic needs of all floodplain people by eradicating poverty and inequity through jobs and economic growth, while ensuring that effluents ending up in the water resources from economic growth do not pollute the water resources to the extent that the quantity and quality of water left in rivers cannot meet the economic, social and basic needs of others.

Therefore the best option (in the short-term) is to implement DWAF Scenario 2 (with flood releases) but put in place a system that makes it possible to use less floodplain water to achieve the desired ecological effect, so that more water can be saved for economic growth. Therefore, suggestions by Heeg and Breen (1982), requiring an artificial system to be put in place (e.g. inflatable weirs) as a means of optimizing water use to achieve the desired effect, is highly supported.

5) Then (in the long term) fine tune the desired level of floodplain protection in terms of water allocations that balance economic growth, social development and ecological sustainability (the reserve) by building a knowledge base that links stream flow to ecological, social and economic factors in order to compare various scenarios of levels of goods and services that the water resource can produce sustainably.

Reserve determination must be guided by the fact that climate limits the amount of water available for use in a catchment per annum. Water is therefore a limiting factor, as there is not enough water available to maximise economic production to its full potential without risking ecological failure and consequently social injustice caused by the inability of the water resources to absorb pollution waste from economic growth. Water is therefore a renewable, natural resource with a limited amount of resilience to the pressures and demands of use. In terms of sustainability, the implication is that water can only be used at the rate at which it can be replenished, input of waste should be limited to the level at which it can be adequately absorbed or purified, etc. Some of the direct implications are:

(i) Developments in a catchment must be maintained at the level where their impacts do not cause aquatic systems to lose resilience (ecological failure) with social injustice consequences,

(ii) The level of developments in the catchment that reduce stream flow, e.g. irrigation, and alien (exotic) plantation forestry, should be controlled,

(iii) Only a certain number of people in a catchment should be allowed to irrigate so that sustainability can be maintained. Indeed, this thinking is strongly supported by the National Environmental Management (NEMA) Act No. 107 of 1998, which requires that, through environmental impact assessment (EIA), developers must show that their developments have not only taken into account economic gain, but also ecological and social sustainability before approval is granted.

6) Between the 1970s to 1994, development interventions in the area, in terms of dam design, nature conservation schemes, agricultural irrigation development and floodplain water requirements that were implemented, did not take into account knowledge obtained through a holistic perspective and made the livelihoods of many local communities more difficult. Even after 1994, agricultural developments that have been implemented have not taken into account holistic thinking, and it is highly likely that long term sustainability cannot be assured.

Best practice must be guided by a good conceptual development framework, which takes into account interests of local communities. Development frameworks should be conceptualised using community-based principles and implemented within a decentralized community-based co-management structure, operating on community-based principles and values (Ife, 1999).

For example, by 2004 the long-term plan envisioned by Heeg and Breen (1982) had not been achieved. Heeg and Breen (1982) had hoped that the level of irrigation developments would be such that the use of the floodplain for subsistence needs would be outlived and the floodplain would became purely a nature conservation area, protected by EKZN-Wildlife. The lack of implementation of a community-based approach to development is the reason why the long-term vision put forward by Heeg and Breen (1982) was not achieved. It indicates that (in the short-term) development goals should take into account the importance of the floodplain for local livelihoods and must therefore try to arrive at scenarios that balance economic growth with floodplain protection needed to enhance the efficiency of the reserve and consequent support for subsistence needs.

Due to the presence of a very large local rural population, it is very important that before decisions are made which assume that the use of the floodplain for subsistence needs has been outlived and that the floodplain should became purely a nature conservation area or allowed to become a dry land as per Scenario 1 (with no flood releases), it is important that such a decision is informed by cost benefit scenarios produced using ecological economics methods that determine the most likely alternatives, including industries in the non-agricultural business sector (i.e. opportunities outside the primary industries of agriculture, forestry and fishing) that can contribute significantly to providing job opportunities to supplement or do away with subsistence agriculture on the floodplain. Therefore ideas suggested by Backeberg and Odendaal (1998), which require that farming be supplemented by the development of a wide-ranging programme which not only develops agriculture but also improves skills to earn non-agricultural income through integrated development of the rural-urban link, are strongly supported.

Another example of a bad conceptual development framework was the dam design. The design of the dam and irrigation development plans, carried out in the late 1960s to the early 1970s, took into account the interests of sugar investors (30 000 ha) on the Makhatini flats and ignored completely the interests of downstream floodplain communities. The dam altered the natural stream flow regime which impacted negatively by (1) reducing the quantities of ecosystem services produced by the floodplain to support a subsistence economy (crops, pasture, fisheries) thus reducing food security for the people, and (2) reducing the diversity of wildlife in the natural environment, hence lowering the value of the landscape in terms of potential for tourism and recreation. When the world prices of sugar fell, investors simply pulled out leaving behind this huge dam that had altered the natural flow of the river downstream, destroying a strong subsistence economy and the natural environment. Had the dam design and irrigation development taken into account local subsistence needs and ecological needs, maybe the limits to irrigation would have been set from the beginning in the whole catchment and the dam wall would have been higher than it is now so that it could effectively act as a flood control, while ensuring that natural patterns of stream flow (at least in terms of timing) were maintained down stream; that fish ladders would have been installed to allow natural migration of fish along the river; that the dam should have been designed to release sediment with flood water; and that inflatable weirs were installed to optimise water used for flood releases by ensuring that smaller quantities achieved the desired ecological effect (by enabling appropriate seasonal water level fluctuations), so that more water could be saved for irrigation and other livelihood strategies.

7) The immediate need identified from a DWAF perspective was: "To put in place a stakeholder decision making structure involved in water based development discussions and implementations that is transparent, accountable and empowered to make wise decisions". Therefore, it is necessary to strengthen co-management structures like Water User Associations and Catchment Management Agencies and enhance their capacity to invest in co-management initiatives.

9.1.2 Recommendations

1) To support the implementation of a diverse livelihood strategy, the best option (in the short-term) is to implement DWAF Scenario 2 (with flood releases) but put in place a system that makes it possible to use less floodplain water to achieve the desired ecological reserve effect so that more water can be saved for economic growth. Therefore, suggestions by Heeg and Breen (1982), requiring an artificial system to be put in place (e.g. inflatable weirs) as a means of optimising water use to achieve the desired production of ecological goods and services on the floodplain, is highly supported.

2) Determine the quality component of the reserve by building a knowledge base on a catchment scale that links stream flow or water levels to the following factors: ecological, biophysical, social and economic. Data from these monitoring programmes must then be linked to a hydraulic model of the catchment system (Dent, 2000; Hughes, 2000; Basson and Beck, 2002) so that model calibration and validation can be enhanced and water use optimised by comparing various scenarios of levels of goods and services (economic, social and ecological) that the available water resource can produce sustainably.

(i) The ecological knowledge base needed is described in detail in Chapter 5,

(ii) Biophysical aspects would have to be quantified in the whole catchment (soils, vegetation, etc.),

(iii) The social and economic knowledge base should answer the following questions:

(a) Considering the very large local rural population, has the use of the floodplain for subsistence needs been truly outlived (in terms of quantitative evidence) or is it that reduced stream flow has merely enhanced drought conditions leading to a situation whereby a lot of effort is put into farming and fishing for little gain?
(b) Is this condition influencing human migrations from the area?
(c) Should a decision be taken which assumes that the use of the floodplain for subsistence needs has been outlived, what would the social and economic impact be if the floodplain were to become purely a nature conservation area under EKZN-Wildlife?
(d) What would the impact be in the social and economic spheres if Scenario 1 (with no flood releases) was implemented? Specifically, what are the cost benefit scenarios that determine the most likely alternatives for using the saved water, including industries in the non-agricultural business sector (i.e. opportunities outside primary industries, agriculture, forestry, fishing, tourism and recreation) that can contribute significantly to providing job opportunities to supplement or do away with subsistence agriculture on the floodplain? Can pollution waste from these economic scenarios meet the requirements of the reserve under Scenario 1 (with no flood releases)?

(iv) Output from the hydraulic model should provide information that helps stakeholders and decision makers make wise decisions with respect to the reserve regime, management class and ecologically sustainable development. For example:

a) The desired level of floodplain protection,
b) Desired type and level of economic growth,
c) Knowledge of the proportion of the population supported by a cash economy from economic growth. Type and quantity of pollution produced from commercial ventures and source (point source and non-point source) in order to implement the 'polluter pays' principle fairly,
d) Knowledge of the proportion of the population supported by a subsistence economy. Type and quantity of pollution produced from a subsistence economy and source (point source and non-point source) and can the 'polluter pays' principle be implemented fairly,
e) Identify interventions or gaps that require research and development to find solutions to the problems limiting achievement of the ecological component of the reserve.

(v) Output from the hydraulic model should also provide information that aids the determination of an appropriate basic human needs reserve by ensuring that the following information is

factored into short and long term plans to inform decisions on a reserve regime and management class and basic human needs. For example:

(a) Accurate demographic data must be used,
(b) Determine the degree to which a population stops using water directly from the river for basic needs (i.e. the ability to pay for clean, treated water for drinking, food preparation and personal hygiene),
(c) Determine the prevalence of water related diseases and how the reserve may influence risks to health (e.g. malaria, bilharziasis, cholera, typhoid fever, dysentery, diarrhoea, polio, yellow fever, hepatitis, river blindness, parasitic worms, scabies, trachoma, etc.) and the nature of a public health strategy to be put in place,
(d) Determine the ability of local municipalities to provide treated, clean water to all households,
(e) Identify interventions or gaps that require research and development to find solutions to the problems limiting achievement of the basic human needs reserve.

3) Set up decentralized co-management water user association structures according to community-based principles (transparent and accountable) and empower them to participate actively in making wise decisions and acting upon those decisions to have them met. For example, an empowerment strategy would ensure that:

(i) Professionals transfer to stakeholders all knowledge obtained from (ii) above-ecological, biophysical, social and economic, so that they are empowered to actively get involved in water based development discussions and implementations in the region,
(ii) Teach communities so that they understand what community-based principles and values are and then ensure that they have been empowered to actively participate in conceptualising development frameworks to suit their local needs,
(iii) Empower communities so that they can actively get involved in scientific monitoring programmes, data analyses and interpretation as a means of reducing monitoring costs, promoting capacity building and self regulation.

4) An environmental impact assessment (EIA) is a statutory requirement for consideration of environmental and social impacts of developments alongside financial and economic criteria. Such studies, that look into the costs and benefits of re-designing Pongolapoort Dam, should be initiated so that it can meet the following needs: the dam wall becomes higher than it is now so that it can effectively act as a flood control, while ensuring that natural patterns of stream flow (at least in terms of timing) are maintained downstream; fish ladders are installed to allow natural migration of fish along the river; the dam is designed to release sediment with flood water; and that inflatable weirs are installed to optimise water used for flood releases by ensuring that smaller quantities achieve the desired ecological effect (by enabling appropriate seasonal water level fluctuations), so that more water can be saved for irrigation and other livelihood strategies.

9.2 ECOLOGICAL INTERESTS

9.2.1 Conclusion

9.2.1.1 Quantify ecological dynamics that influence water quality and water related disease and disease vector populations on a catchment scale

There are volumes of research carried out by aquatic (wetlands) scientists that lack purpose, goals, strategies and plans aimed at achieving successful conservation goals.

A better approach to aquatic (wetland) research requires researchers to take into account the fact that hydrology, which translates into climate, soil moisture and stream flow, **determines** the ability of aquatic systems to sustain production of goods and services through ecological processes, which are **influenced** by the following variables in order of importance: fertility/nutrient gradients; salinity; disturbance (seasonal water level fluctuations, erosion, grazing, fire, ice, waves); competition; herbivory; and sedimentation.

Aquatic (wetlands) ecosystem resilience and persistence through time reduces greatly by suppressing natural dynamic processes through effects of dams, dyking, and draining put in place for flood control, irrigation and hydropower production. Impacts of these structures upon natural stream flow regimes downstream of alluvial floodplain wetlands can be stabilized water levels, decreased flooding, increased flooding, shifted flood timing where floods happen at times that are different from natural seasonal times, or where wetlands are drained completely for agriculture in the case of many inland and coastal deltas.

The change in stream flow does not only influence water quality and vegetation integrity, but also influences the prevalence of disease and disease vector populations.

Therefore, in systems downstream of dams where natural stream flow has been greatly modified, such as the alluvial Pongolo River floodplain (i.e. by reducing flooding and shifting seasonal timing), with subsequent impacts further downstream on the coastal delta at the bay of Maputo in Mozambique, it is very important that the dynamic interaction of these variables and how they influence ecological processes in these systems should be understood. The knowledge acquired from these studies (i) must be incorporated into hydraulic models to build various scenarios that inform stakeholders, planners, managers, and decision makers on how to recreate artificial stream flow in terms of quantity, quality and the desired level of protection (ii) should inform the design, optimisation of plans, systems and structures that can imitate nature more closely, thus causing less negative impacts on natural processes that sustain production of ecosystem goods and services which are needed to sustain socio-economic benefits in the long-term).

Specific studies designed to collect ecological knowledge base for wetland protection should be linked to an overall goal that defines the desired level of protection. That is, protection that strives to balance development with environmental sustainability. The information collected for each of the following variables should take into account the following points:

Water level fluctuations

Studies carried out on the floodplain must aim to provide knowledge that informs a desired level of protection by setting an upper and lower water level fluctuation limit that can maximize production of ecological goods and services. Determining a desired level of protection requires development of quantitative models that link hydrology, ecology and human behaviour to predict, not only the direction of change, but also the amount that is probable. Models developed should strive to integrate human behaviour by aligning people's perceptions, beliefs, norms and values with the policies in place.

Fertility/nutrients

Agriculture contributes a huge amount of excess nutrients that wash into the rivers, dams and wetlands through non-point sources, which are difficult to control or to regulate. Excess nutrients contribute to poor quality water for downstream users by increasing salinities, eutrophication and creating a 'dead zone' of oxygen-poor water, killing fish and other forms of wildlife. Under conditions of reduced stream flow, the impact of pollution on aquatic systems increases, which in turn increases the risk to loosing resilience and persistence through time. In such a case, a key concern of regulating authorities must be how to improve water quality and restore stream flow. An approach to mitigating negative impacts of excess nutrients is to create innovative systems that can exploit the ecosystem services produced by wetlands such as the ability to filter out excess nutrients from agricultural and urban runoff, preventing eutrophication of downstream waters. Restoration of the natural stream flow on the Pongolo floodplain can contribute to improving water quality greatly. Under the current modified state of the River, engineering solutions will be needed to enable the restoration of some level of natural stream flow. In addition, the creation of new wetlands which are integrated within the intensively cultivated agricultural landscape in the Pongolo River catchment can improve water quality arising from non-point sources.

The best practice requires one to start at the catchment scale and prioritise what to restore/create. Areas where the hotspots for biodiversity habitat, water quality, and flood control overlap get highest priority for restoration/creation. The approach has proved to be a powerful local planning tool in the USA. It has been found that a key factor to restoring effective wetlands is to create wetlands like those that characterize the native landscape, while ensuring that alien invasive species are controlled. The Pongolo River floodplain meets such criteria and requires that regulating authorities should give it highest priority for restoration. For example, the knowledge that various combinations of water level fluctuations with various levels of increasing nutrient fertility can produce various types of wetland communities needs to be explored further through research. Specifically, it is known that, wetland types (bogs, fens, marshes and swamps) can be produced along a gradient of varying water level fluctuations with fertility (gradients of nutrient poor to nutrient rich environments). Bogs prefer nutrient poor environments (oligotrophic) with permanent water levels, while wooded swamps prefer nutrient rich environments (eutrophic) with water level fluctuations ranging from long periods to short or rare. Local planning tools with goals targeting improvement of water quality for downstream users can apply such knowledge to guide the designing of innovative systems where water, rich in nutrients from agriculture, passes through, e.g. wooded swamps. A recommendation is to initiate a research programme whose aim is to find ways of integrating wetlands into agricultural drainage systems and design such drainage systems in a way that

helps wetlands to work better at improving water quality, like giant sponges that absorb huge amounts of nutrients. The Department of Agriculture & Environmental Affairs and the Land Care programme in partnership with DWAF, EKZN-Wildlife and Specialist wetland researchers (hydrologists and biologists) should lead such a project.

When making decisions about wetland research aimed at improving water quality, funders, researchers, managers and decision makers must take into account the following key points influencing wetlands:

(i) A review of studies where wetlands have been restored or where new ones have been created to improve water quality or where the restoration of a particular native species was required showed that success in terms of achieving these conservation targets or goals happens only when natural hydrology is restored first. Managers and decision makers need to be aware of the fact that piecemeal projects, funded to enhance conservation targets (water quality or vegetation integrity or re-introduction of native species) without providing some level of natural stream flow, are a total waste of tax payers money, a waste of researchers' time and effort, since the environmental outcomes can never be achieved. Water quality and vegetation integrity research projects must be linked to a programme that attempts to restore some level of natural hydrology (adequate volume, flood duration and seasonal timing) so that the knowledge base produced can inform decisions about the desired level of protection that is ecologically sustainable.

(ii) Programmes to improve water quality must target the whole catchment. For example, effectiveness of the use of riparian buffer strips intended to protect water quality (excess nutrients & erosion) in water bodies (river and pans), is greatly enhanced by ensuring an appropriate balance between the proportion of natural forests and agriculture in the catchment. Such an approach would have to be implemented as a means of supporting the functioning of the floodplain as an efficient nutrient regulator.

Sediments

Soil erosion processes in River catchments causes soil particles to get washed down by rain into aquatic systems where they pile up forming sediments. Sedimentation is a useful natural feature of wetlands. In the short-term, one is inclined to view sedimentation as a negative factor, more so when sedimentation rates are increased by human activities (e.g. erosion enhanced by agriculture), and particularly when small wetlands or floodplain pans are filled-in. Yet when one considers the processes of sedimentation on a geological time scale, natural rates of erosion and sedimentation are in fact useful natural processes.

For example, in the long term, many coastal and inland alluvial floodplain wetlands like the Pongolo River floodplain are dependent on sedimentation to create new habitats for biodiversity. While naturally induced rates of sedimentation are important for biodiversity, enhanced rates of sedimentation, induced by intensive human activity (e.g. agriculture and road construction), can kill plant and animal life. In fact, under conditions of enhanced rates of erosion, sedimentation is considered to pose the greatest threat to aquatic life, followed by, exotic or alien species and impoundments-dams and other hydraulic structures.

In managing aquatic systems, managers must not only take into account the immediate threats posed by sedimentation to plant and animal life but also the positive long term impacts of the rates of sedimentation (e.g. creating new habitats for biodiversity and protecting coastal habitats from sea rise). Rising sea levels mean that coastal wetlands and habitats such as the coastal shelf, estuaries, tidal marshes, mangroves, floodplains and deltas have to shift backwards. Also, coastal human developments become highly vulnerable to impacts of sea rise and the associated risk of structures being destroyed increases.

Therefore, where sea levels are rising, the rates of sedimentation must exceed the rates of sea level rise, or else salt marshes and other habitats will disappear. For example, in Jiangsu province, China, coastal recession of the southern Yellow River delta has occurred at 20 to 30 m annually and tidal land has sunk at rates of 5 to 10 cm/year over the past 50 years. The Mississippi River empties its waters into the Gulf of Mexico in Louisiana, USA. Dams and constructed levees restrict rivers from accumulating new sediment and reduced sediment loads appear insufficient to counteract the effects of coastal subsidence and rising sea levels. As a result, 65 km^2 of wetlands are lost each year. It is important to note that, over larger time scales of centuries and millennia, the balance between erosion, sedimentation, subsidence and emergence produces much of the physiographic diversity of coastal wetlands. This physiographic diversity provides the habitat template that generates biological diversity.

Wise management of sediments in a catchment requires that managers understand sediment dynamics from source to sea by developing sediment or soil erosion yield models of the catchment which provide information to support decision making by enabling simulation of different management scenarios, and the prediction of the effectiveness of proposed changes in land use within a catchment on a long and short term basis. Such models have been used to predict amounts of land use in a catchment, which is required to sustain the biotic integrity of streams and wetlands (e.g. quantities of urban, agriculture, riparian forest and natural forest); the creation of new habitats to support biodiversity, protecting coastal habitats from sea rise.

There is hardly any data on the effects of sediments on wetland plants and animals on the Pongolo River system post dam development. On the basis of studies from literature and the fact that dams and levees reduce sediment loads of rivers, it would be desirable if sediments deposited in dams could be enabled to reach floodplains and deltas through engineering solutions that make this possible during annual, artificial flood releases. It is therefore necessary to set up a database with parameters for developing a sediment yield model for the Pongolo River catchment up to the bay of Maputo which can serve as an information base for catchment planners who may need to make decisions on an allowable intensity of land use (e.g. urban, agriculture, riparian forest and natural forest) as well as serving as an information base for any engineering solutions that may need to be undertaken.

Salinity

Salinity is measured in terms of electrical conductivity (EC) or (TDS), total dissolved solids in Mg/L which makes up the non-toxic constituent of water quality, e.g. sodium, calcium, potassium, magnesium, chloride, bicarbonate, sulphate, silica, and total alkalinity.

The Pongolo River and floodplain is a freshwater ecosystem. However, naturally, the rivers of northern KZN province namely, the Pongolo, Mkuze and Mfolozi have high concentrations of dissolved solids during periods of low river flows (July, August and September). Expanding irrigation agriculture both upstream and downstream of the Pongolapoort dam is likely to reduce flows and hence decrease the diluting power of the river. Reviews of studies showed that salinization had been found to be a potentially serious problem on the floodplain pans. Saline water seeps from the underlying marine cretaceous sediments, which then becomes concentrated due to evaporation. Nyamiti, Mhlolo and Tete pans were found to be affected in this way. Therefore, annual floodwaters are required to dilute the saline pan water which is used for subsistence socio-economic needs (e.g. drinking, watering food gardens and livestock) and ecological processes needed to sustain fresh water biological communities. Increasing irrigation upstream requires that dam salinities must be monitored, because downstream irrigation depends on good water quality from the dam.

Toxic constituents in water quality

It is important that the planning of developments that release toxic effluents into the river (irrigation and mills) must make sure that there is an adequate quantity of water available in terms of environmental stream flow needed to dilute, break down and flush out such waste. Therefore, in addition to monitoring salinities, the toxic constituent in dams and floodplain rivers and pans must be monitored.

Water related diseases

Malaria: Although a literature review identified factors influencing malaria cases in the area which are known to peak in autumn as being pools of water created by rainfall over autumn, irrigation spillages and the use of DDT, it is highly likely that the current stream flow regime (a flood peak in September followed by extremely stabilized reduced flows for the rest of the year) plays a significant role in reducing malaria cases. However, studies that are more conclusive need to be carried out to provide more clarity on the relationship between malaria cases and stream flow so that the knowledge can be used to influence decisions that strive to achieve goals that balance malaria disease management, appropriate environmental stream flow regime and irrigation development designs that minimize the creation of preferred habitats for mosquitoes and other disease vector populations.

Schistosomiasis: From literature, it appears that a natural flow regime with appropriate seasonal fluctuations is likely to keep the snail populations in balance, whereas stabilizing flows would interfere with the ecology of the system, causing snail population explosion and enhancing disease transmission. There is need for data linking disease incidence, snail ecology and flows on the Pongolo River and floodplain system.

Other water related diseases: A review identified the following diseases to be potentially water related diseases in South Africa: cholera, typhoid fever, dysentery, diarrhoea, polio, yellow fever, hepatitis, river blindness, parasitic worms, scabies, trachoma, etc. A summary of the diseases, mode of transmission, prevention and trends with an emphasis on Northern KZN showed that all water related diseases are endemic or prevalent in northern KZN where the Pongolo River and floodplain is located.

Poverty, coupled with a lack of access to adequate quantities of clean water and unhygienic living conditions enhance infection rates of these diseases, causing epidemics. For instance, transmissions of bacterial and amoebic diseases that cause epidemics (e.g. cholera, typhoid fever, amoebic dysentery and diarrhoea) are prevalent in areas with poor or no sanitation facilities – so that during periods of rainfall peaks in summer, run-off contaminates water bodies with infected faecal waste. Epidemics of these diseases are also linked to periods of low flows (July, August, September), when communities have to dig into dry riverbeds to obtain water for basic needs. On a municipal scale, epidemics occur when sanitation and water purification mechanisms fail and contaminate water bodies.

The most important solution to these diseases is the provision of sufficient and safe water for basic needs, the provision of sanitation facilities for safe disposal of faecal waste, improvement of income and social wellbeing, controlling disease vectors, e.g. mosquitoes and rats, enhancing the health of domestic livestock, and monitoring industrial effluents and irrigation practices.

A high rural human population, coupled with reduced stream flows and increased toxic input caused by irrigation and effluents from existing and proposed industries, means that, in addition to the need to implement an environmental flow regime that enables good water quality to be sustained, the DoH must put in place a public health strategy. The public health strategy should be a co-management activity among relevant government departments and communities to ensure that adequate water allocations for public health purposes are effected on the Pongolo floodplain and adjacent areas.

The public health strategy would need to recognise the fact that government alone cannot effectively reach everyone, given the high numbers of poor people in the study area. To adequately improve disease control and enhance primary health care among the rural population, a multi-sectoral, co-management approach involving local communities and the relevant regulatory authorities (local government, DoH, DWAF, DAEA), co-ordinated through a water user association (WUA), is key to achieving sound sustainable solutions. The community-based approach can be used within this structure to mobilize relevant parties and get them to actively participate in adopting existing cost effective technologies, e.g. rain water harvesting tanks, pit latrines, and solar pasteurisation technology, among others. Such an approach would go a long way to supplement government subsidies and improve the social wellbeing of people.

9.2.1.2 Integrate ecological data with social and economic factors

It must be recognised that the ecological knowledge produced in this review and through further research can not provide solutions to the problems and needs raised by the regulating authorities in section 5.4. Wise solutions and decisions can only be derived from ecological data that is linked to social and economic factors on a catchment scale. This is the only way that resource allocation policies can attempt to define what is equitable and efficient, and solve issues of representivity and sustainability. Integration, co-ordination and implementation of studies and their outcomes can only be successful if they are

initiated through co-management structures like Water User Associations and Catchment Management Agencies.

9.2.2 Recommendations

9.2.2.1 Determine the desired level of protection of the floodplain

Determining a desired level of protection of the river and floodplain requires development of quantitative models on a catchment scale that link hydrology, ecology and human behaviour to predict not only the direction of change, but also the amount that is probable. The implication is a need to initiate a co-ordinated integrated research programme involving multi-disciplinary research teams to start building an ecological knowledge base that provides understanding of the dynamic interaction of the variables influencing ecological processes (hydrology\soil moisture\stream flow; fertility/nutrient gradients; salinity; disturbance (seasonal water level fluctuations, erosion, grazing, fire, ice, waves); competition; herbivory; sedimentation; toxic constituents and diseases.

Models developed should strive to integrate human behaviour by aligning people's perceptions, beliefs, norms and values with the policies in place.

The monitoring programme must be designed in a way that local communities take ownership and responsibility for monitoring within a community-based structure of management (e.g. WUAs, CMAs). This would cut monitoring costs and increase community awareness and self-regulation.

Specific studies initiated must have a focused goal aimed at providing the following knowledge:

Water level fluctuations

Knowledge that informs a desired level of protection by setting an upper and lower water level fluctuation limit that can support ecologically sustainable development.

Fertility/nutrient gradients/excess nutrient control

Pongolo river floodplain can contribute greatly to improving water quality only if some level of a natural stream flow regime is restored. In addition, creating new wetlands which are integrated in the agricultural landscape in the catchment can also contribute greatly to improving water quality problems arising from non-point sources in the catchment. It is therefore, recommended that a research programme is initiated whose goal should be to find ways of restoring wetlands and integrating newly created wetlands into agricultural drainage systems and design such drainage systems in a way that helps wetlands in a river catchment to work better at improving water quality, like giant sponges that absorb huge amounts of excess nutrients. The DoA, DAEA and the Land Care Programme in partnership with DWAF, EKZN-Wildlife and Municipalities and specialist wetland scientists (hydrologists and biologists) should lead such a project.

The goal of integrated studies must not only aim at setting water resource quality objectives (in terms of upper and lower specification limits) but must strive to find innovative ways to improve water quality and optimise water use by exploiting ecosystem goods and services produced by wetlands (e.g. design systems where water, rich in excess nutrients from agriculture, passes through wooded swamps). Such systems must be informed by knowledge from nutrient cycling studies explained below.

It is recommended that research studies that provide an understanding of nutrient cycling processes, soil fertility and soil acidity in intensive agricultural systems in the Pongolo River catchment be promoted to ensure that non-point source pollution problems of water bodies arising from excess nutrients in the system are minimized. The goal of such studies must be to gain an understanding of the dynamic relationship between environmental factors determining crop production (e.g. nutrient availability, temperature and soil moisture) and the nature of nutrient supply (e.g. fertilizer and soil mineralization) relative to factors that determine soil fertility (e.g. soil chemical factors, chemical composition of decomposing litter and the nature of soil disturbance, e.g. tillage). The studies in agricultural fields (above) must be supplemented with similar studies that seek to understand the same dynamic relationship of nutrient processes on the Pongolo River floodplain system so that the functioning of the wetland, as an effective excess nutrient regulator, can be optimised. The outcomes of such studies should be:

Provide advice to managers of agricultural systems

Advice needed to apply the most appropriate source of nutrient supply to crops (i.e. the type that will reduce excess nutrient loads into water bodies),

Advice on appropriate timing and rate of application of nutrients that minimizes the risk of excess nutrients leaching into water bodies,

Advice on sources causing soil acidity in fields, e.g. natural acidification processes that lead to impoverished soil bases lost through processes of erosion and leaching; enhanced soil acidification caused by alien plantation forestry; acid rain; cultivation which enhances aeration and a more rapid bacterial oxidation of N containing organic compounds and a net production of acid; nitrification of ammoniacal fertilizers and the subsequent leaching of nitrates with Ca and Mg; and the export of basic nutrients (K, Ca and Mg) in the harvest and symbiotic N fixation of leguminous plants.

Provide advice on appropriate use of lime to alleviate negative impacts of soil acidity.

Provide advice to managers of wetland systems

Provide advice on an appropriate environmental flow regime that makes it possible for the Pongolo River floodplain system to function as an effective excess nutrient regulator.

Link data from above studies to hydraulic models of the catchment

Ensure that hydraulic engineers obtain data from such studies so that they can incorporate it into catchment models aimed at fine tuning the desired level of protection that can support ecologically sustainable developments in terms of the reserve requirements.

When making decisions about wetland research aimed at improving water quality, funders, researchers, managers and decision makers should take into account the fact that:

(i) Piecemeal projects funded to enhance conservation targets (water quality or vegetation integrity) on the floodplain, without providing some level of natural stream flow, is a total waste of tax payers' money, and a waste of researchers' time and effort, since the environmental outcomes can never be achieved. Water quality and vegetation integrity projects must be linked to a programme that attempts to restore some level of natural hydrology (adequate volume and flood duration and timing) so that a knowledge base can be built through research to inform decisions about the desired level of protection.

(ii) Programmes to improve water quality (excess nutrients & erosion) in water bodies (rivers and pans), using riparian buffer strips can only be effective when supplemented with a programme aimed at balancing the proportion of natural forests and agriculture in the whole catchment, and that such an approach would have to be implemented as a means of supporting the functioning of the floodplain as an efficient nutrient regulator.

(iii) Programmes aimed at providing knowledge to estimate the reserve and improve water quality should target a catchment scale, a sub-catchment scale or a quaternary catchment scale.

Sediments

When managing aquatic systems, managers should not only take into account the immediate threats posed by sedimentation to plant and animal life but also the positive long-term impacts of sedimentation which are needed to create new habitats for biodiversity while protecting coastal habitats from sea rise. A key goal for managing sediments in a catchment must acknowledge the fact that, over longer time scales of centuries and millennia, the BALANCE between erosion, sedimentation, subsidence and emergence produces much of the physiographic diversity of coastal wetlands. This physiographic diversity provides the habitat template that generates biological diversity. Therefore, the wise management of sediments in a catchment requires that managers understand sediment dynamics from source to sea.

There is hardly any data on the effects of sediments on wetland plants and animals on the Pongolo River system post dam development. On the basis of studies from literature and the fact that dams and levees reduce sediment loads of rivers, it would be desirable if sediments deposited in dams could be enabled to reach floodplains and deltas through engineering solutions that make this possible during annual, artificial flood releases. It is therefore necessary to set up a database with parameters for developing a sediment yield model for the Pongolo River catchment up to the bay of Maputo which can serve as an information base for catchment planners who may need to make decisions on an allowable intensity of land use (e.g.

urban, agriculture, riparian forest and natural forest) as well as serving as an information base for any engineering solutions that may need to be undertaken.

Salinities & toxic constituents in water

Managers need to note that the river experiences natural salinity during periods of low flows (July to September). An increase in upstream irrigation enhances the risk of poor water quality (high salinities and a high toxic load) for downstream users. Downstream irrigation and mills will increase pollution in the river and floodplain pans. It is very important that the planning of developments that release such pollution (irrigation and mills) should ensure that there is an adequate quantity of water available in terms of environmental stream flow needed to dilute, break down and flush out such waste. Therefore, studies that monitor salinities and the toxic constituent in dams, river, and floodplain pans must be initiated and the data obtained must then be linked to a hydraulic model of the system.

Water related diseases

In addition to malaria and schistosomiasis, potentially water related diseases in the study area are: cholera, typhoid fever, dysentery, diarrhoea, polio, yellow fever, hepatitis, river blindness, parasitic worms, scabies, trachoma, etc. It is important to initiate studies that aim at providing clarity on the relationship between water related diseases and stream flow so that the knowledge can inform the development of appropriate environmental flows that mitigate the impacts of these diseases to humans. The knowledge from these studies should inform the development of a public health strategy. The public health strategy would need to recognise the fact that government alone may not effectively be able to reach everyone, given the high numbers of poor people in the study area. To adequately improve disease control and enhance primary health care among the rural population, a multi-sectoral co-management approach, involving local communities and the relevant regulatory authorities (Municipalities, DoH, DWAF, DAEA), co-ordinated through a water user association (WUA), is key to achieving sound sustainable solutions. The community-based approach can be used within this structure to mobilize relevant parties and get them to actively participate in adopting existing cost effective technologies, e.g. rain water harvesting tanks, pit latrines, solar pasteurisation technology, among others. Such an approach would go a long way to supplementing government subsidies and improving the social wellbeing of people.

9.2.2.2 Strengthen co-management structures

It must be recognised that ecological knowledge base on its own can not provide solutions to the problems and needs raised by the regulating authorities in section 5.4. Wise solutions and decisions can only be derived from integrated studies whose outcomes help to define what is equitable and efficient, and solve issues of representivity and sustainability. Therefore, put in place co-management structures like Water User Associations and Catchment Management Agencies and strengthen their capacity to invest in co-management initiatives.

9.2.2.3 Identify possible opportunities that exist under the current reduced flooding state

The current approach to research on ecological interests in this study has concentrated on the negative impacts of reduced flows on the floodplain wetland ecosystem. It is important that a study be carried out to also identify possible opportunities that exist under the current reduced flooding state, instead of just concentrating on the weaknesses. These opportunities can then be weighed against weaknesses or constraints and used to build possible scenarios.

9.3 AGRICULTURAL DEVELOPMENT INTERESTS

9.3.1 Biophysical and demographic factors

9.3.1.1 Biophysical factors

Before decisions are made to destroy the floodplain completely, using the DWAF Scenario 1 (no flood releases) (Chapter 4), a good strategy for agricultural development (or any other development policy) should weigh out the costs and benefits of alternatives carefully to determine the best option that can promote a diverse economy while balancing ecological and social sustainability in the long term. For example a strategy to diversify the economy should ensure that the floodplain receives adequate water requirements for fisheries production and tourism and recreation development (Chapter 7). It should be recognized that, in its natural state under virgin stream flow, the floodplain had very high primary production over an area covering 13 000 ha. The flooded area in summer became a huge fishery (10,414 ha) with an estimated production of >750 000 tons of fish, while crops were grown off the floodplain on the Makhatini flats using summer rains. The flooded water receded slowly and the local people planted crops following the receding floods right into winter. Even though winters were dry, floodplain soils retained adequate soil moisture to support crop growth. In addition, virgin stream flow enhanced the value of the landscape greatly in terms of aesthetic beauty. It is often said that, on seeing the view of the floodplain lands for the first time, an early European Portuguese explorer is said to have described it as, 'nature so beautiful, so wild and so free with enormous potential for tourism and a recreation industry'.

Presently, dams have modified stream flow to a great extent by reducing it, leading to a reduction in production of goods and services. A key question that needs to be asked and answered in cost benefit scenarios is: how much of these goods is society willing to give up in order to find more water for commercial irrigation? These goods and services have greatly reduced under current modified reduced stream flow trends (Chapter 4). The impact on ecological factors (Chapter 5) and the subsistence economy (Chapter 7) has been shown. Given the huge rural human population, economic growth in commercial agriculture and the non-agricultural sectors alone are unlikely to mitigate these impacts and find a balance between agricultural development and the environment. Reviews of studies and a social survey carried out in Chapter 7 shows that the most sustainable strategy in the long term is to implement artificial flood releases to maintain the floodplain so that it can contribute to supporting diverse livelihood strategies (Chapter 4, 5, 7, 8).

Soil textures off the floodplain, on the Makhatini flats, are good for commercial agricultural irrigation development. Soil textures on the floodplain are also good for agriculture and nature conservation. Soil textures off the floodplain, on the east side of the river where floodplain communities live, are mainly marginal sandy soils suitable for agriculture. The implication of climate, soils and biophysical features suggest that should floodplain communities be denied access to the use of floodplain resources (crops pasture and fish) without providing tangible workable alternatives, they can very easily become vulnerable to the impacts of droughts, hunger, poverty and disease.

A climatic factor such as temperature, which is an indicator of the energy status of the environment, limits the distribution of plants and animals in nature. The study area lies in the mid-latitudes where plant physiology is adapted to the strong seasonal rhythms of mean temperatures (meso-thermal plants). For example, the seasonal rooted aquatic macrophyte, *Potamogeton crispus,* found in floodplain pans (which plays a role in regulating the nutrient phosphorus), starts germinating in April, when temperatures start dropping. This implies that many plants (crops and wild plants) will grow most efficiently when their growing time is aligned with seasonal factors like rain/moisture availability, temperature, and RH. If soil moisture becomes available at the wrong time of the season, other factors needed to enable optimum or efficient growth, like temperature in terms of 'heat units' and RH, will limit growth or harvestable yields.

For example, moisture-growing season in terms of soil water availability is lowest in the lower catchment (October to March, 150-175 days) when compared to the mid-catchment (September to March, 175-200 days) and the upper catchment (September to April, 200-225 days). The implication is that crops that are grown on the Makhatini flats whose growing season is more than 150-175 days might not grow efficiently, even under irrigation, due to other seasonal changes that come into play such as temperature, which determines optimum heat units required for efficient growing and ripening and may therefore limit harvestable yields. It is therefore important that only crops that grow efficiently should be promoted.

The lower catchment experiences higher temperatures and RH than the mid and upper catchments. The implication is that agricultural and public health pest populations in the lower catchment grow faster and have more life cycles/annum under the high temperatures and the RH experienced and hence pests cause more damage to crops and human health on the Makhatini flats. This has implications for high input costs for crop protection and high pollution loading (pesticides).

To limit the damage caused by pest populations in agriculture and public health in the lower catchment, nature or climate put in place a strategy to reduce the negative impact caused by pest populations through patterns of natural or virgin seasonal flows. Virgin flows ensured that crops were grown on the floodplain when pest populations were low, during autumn, winter, and up to early spring after summer floods had receded. Crops grown during this period had the right number of days required to provide adequate heat units needed for growing and ripening, such as maize and beans. In summer high temperatures and adequate moisture ensured rapid growth of plants and insects with a high turn-over rate of life cycles per season, resulting in a huge abundance of plant and insect life which was utilized as food by fish in the inundated floodplain. Fish production meant that fish protein was easily available in the diets of the communities. The implication is that crops that grow most efficiently in autumn, winter and spring should be promoted on and off the floodplain because natural patterns of stream flow and climate help to

reduce the costs of farm inputs in terms of pesticide used to control pests and diseases and the external costs that pesticides inflict on the environment, through excess pesticides in soils, water bodies and their effect on non-target organisms, e.g. beneficial insect pollinators and natural enemies of pests. The second implication is that fish production should be promoted during summer by ensuring that floodplain pans are inundated up to high flood level in order to submerge pan marginal vegetation. Submerged vegetation provides both shelter and food (plants and insects) for young fish, thereby enhancing production and harvestable yields (Chapter 7).

Water for irrigation development is stored in Pongolapoort dam but has to be shared with upstream irrigation and floodplain releases. The Dam management challenge is to ensure that the water is adequate and is of good quality. Evaporation values from the dam have been shown to be higher than precipitation values. High evaporation rates can influence good quality water availability because salts tend to concentrate with the lowering of water levels and may limit irrigation use, particularly during periods of drought and under current reduced inflows from upstream which are likely to be loaded with excess nutrient pollution from upstream agriculture. Floodplain pans also depend on getting good quality water from the dam annually to flush-out accumulated salts coming from underground seepage. The high rates of evaporation in the area means that floodplain pans have to be recharged yearly to maintain their fresh water qualities and the goods and services they provide to support basic livelihoods (crop and livestock watering, fishing, drinking, bathing, wild foods). Healthy people in turn provide more productive labour to the commercial farming industry.

The MAR (Mean Annual Run-Off) and MAP (Mean Annual Precipitation) on the Makhatini flats is much lower than in the mid and upper catchment; this implies that the Makhatini flats is more vulnerable to the effects of soil water stress on plants (crops and wildlife). Indeed, soil water stress (number of days plants are under stress/month) is much higher in the lower catchment in summer, while during winter, soil water stress is high in the whole catchment. Gross annual irrigation requirements in the lower catchment are much higher than in the mid and upper catchment areas. This should inform decisions for equitable and efficient allocations. The implication for soil water stress patterns in the catchment, is that more water would be required downstream than upstream to enhance harvestable yields in summer.

In the lower catchment, ground water takes on the characteristics of sea water and may not be suitable for irrigation or domestic use, particularly during periods of low flows. During periods of low flows, underground saline seepage water enters the river and pans. Pans are affected more than the river by saline seepage water because high evaporation rates reduce water levels and therefore the water becomes more concentrated. To sustain plant and animal life in these pans an annual dilution by artificial floods of good water quality from Pongolapoort Dam is required.

In the planning of development of irrigation schemes, the geological formations that limit use of the ground water for irrigation need to be taken into account. The long gentle slopes on the Maputaland plains mean that considerable attention would need to be given to the drainage aspect, because of the ability of salt to accumulate in the deeper layers of certain soils, salinity in the underlying cretaceous rocks has the potential for enhancing water and soil salinization. In addition, the rapid permeability of the sandy soils can enhance the salinity of seepage water to the river and floodplain.

A temperature aspect, which influences use of the study area as a tourism destination, is the very high daily maximum temperature in summer (e.g. highest maximum value recorded in February is 40.3^{o}C). Humans experience serious to acute discomfort between December and March and only between mid-June and late July can the climate be described as comfortable.

9.3.1.2 Demographic patterns

National trends in population growth show that people are migrating from rural to urban areas. However, growth rates, on a national scale, were reported to be declining in 2005.

In 2001, the human population adjacent to the floodplain was 28% (92 369) of the total population in Umkhanyakude district council, DC27 (325 052). The majority of this population live on the east side of the floodplain, 60% (55 079 people in 9 864 households), and 37 290 people in 6 717 households live on the west side of the floodplain where potential for agricultural development exists. The population growth rate in municipalities where the floodplain lies in the lower catchment has been increasing steadily since the 1960s, with far higher household sizes (mainly >7) than in the upper catchments. This has great implications for (i) the provision of basic services to communities by government; (ii) the use of the LRAD policy on land redistribution for agricultural development (Chapter 6); and (iii) the use of the ESA policy instrument intended to enhance nature conservation benefits on the floodplain (Chapter 8). For example, the basic human needs reserve, i.e. water for drinking, food preparation and personal hygiene was based on a life-line amount of 25 litres/person/day. According to the water services policy on the human right to 'free clean basic water' this amount translates to free clean water of 6000 litres/month/household of 8 individuals. One has to pay for use of water over this limit. It is highly likely that this amount of water is inadequate for the majority of households in the lower catchment due to high household size (>8). Since the majority of people have neither an individual monthly income, nor annual household income, it is also highly unlikely that they can afford to pay for this water. The implication is that many will continue to depend directly on the resources of the river and floodplain for subsistence for a long time to come (Chapter 7). Therefore, water allocations in the catchment for commercial forestry and irrigation would need to take into consideration the need to allocate adequate water to sustain production of river resources needed for the subsistence needs of the majority of the population (drinking, watering crops and livestock, maintaining production of pasture and fish).

An analysis of population distribution adjacent to the river in the whole catchment showed that a 'very high density' of human population lives adjacent to the river from where the floodplain begins in the lower catchment. However, in the mid and upper catchments, there is a range of 'hardly any to no people' living adjacent to the river. Clearly, this indicates that there is a greater and direct dependency on the river resources among communities in the lower catchment when compared with those in the mid and upper catchments.

The municipalities found in the mid and upper catchments have far smaller populations when compared to those municipalities in the lower catchment. Vast areas in the mid and upper catchments are under commercial agriculture, commercial forestry and game reserves. Commercial irrigation development in the lower catchment is therefore desirable given that the labour force availability is high, and it will

provide some degree of employment for the local population; however, the water allocation requirements for irrigation would need to take into consideration requirements for subsistence needs (drinking, watering crops and livestock, maintaining production of pasture and fish).

On the basis of income statistics many floodplain communities are poor. In many instances, this leads to high levels of dependency on and even unsustainable use of the natural resources of the floodplain to sustain basic livelihoods. Backeberg and Odendaal (1998) suggested that, although subsistence irrigation farming can make a contribution to poverty alleviation in rural areas, it would have to be supplemented by the development of a wide-ranging programme which not only develops agriculture but also improves skills to earn non-agricultural income through integrated development of the rural-urban link.

Lessons from national accounting data fully support the views of Backeberg and Odendaal (1998), that only diversifying the economy and enhancing skills can achieve profound poverty alleviation.

From national and regional job opportunity trends, it appears that the three most important industry sectors found to offer more job opportunities in the non-agricultural business sector and which should be considered for promotion in the study area, are, in order of the most important: wholesale and retail trade; community/social/personal services; and manufacturing. Plans to promote such industries must be promoted, together with skills development strategies.

It must be noted that, although the agriculture/forestry/fishing sector is a primary industry and does not contribute as much to GDP when compared to finance, real estate, business services and manufacturing, it provides jobs to many unskilled people (farm labourers), while producing essential goods and services needed to sustain human life. An interesting observation from the national accounting data is that GDP trends (2001-2005) were declining in the agriculture/forestry/fishing sector, yet irrigation and commercial forestry were increasing (e.g. when observed through the reduction in the Pongolapoort Dam yield, section 4.3.4.3.1; increasing water abstraction trends, section 4.3.4.3.2; and expanding forestry, DWAF report on commercial timber resources 2001/2002; 2002/2003; 2003/2004). If we equate increasing water abstractions to increasing agricultural production, then why is the contribution to GDP declining? What is influencing this decline? Is the cause within irrigation, forestry or fishing? Is the decline due to economic dynamics, technical dynamics, social dynamics or ecological dynamics? It is important that reasons for the distinct declining trend in contributions to GDP be investigated to determine the cause so that measures can be put in place to ensure that sustainable production quantities are maintained. Note that the dynamics in the relationship between GDP and resource consumption has been explained by Molden (2007).

Lessons from the history of agricultural development, in addition to the national accounting data and description of the biophysical state above, fully support the views of Backeberg and Odendaal (1998), that profound poverty alleviation can only be achieved by diversifying the economy and enhancing skills through integrated development of the rural-urban link.

9.3.1.3 Recommendations: biophysical and demographic considerations

Municipalities found in the mid and upper catchments have far smaller populations when compared to those municipalities in the lower catchment. Vast areas in the mid and upper catchments are under commercial agriculture, commercial forestry, game reserves and game farms. Commercial irrigation development in the lower catchment is therefore desirable, given that the labour force availability is high, and it will provide some degree of employment for the local population; however, in striving to achieve sustainability, efficiency and equity (Chapter 8), the water allocation requirements for irrigation would need to take into consideration requirements for subsistence needs (drinking, watering crops and livestock, maintaining production of pasture and fish) (Chapter 7).

Due to the very high human population downstream of the Pongolapoort Dam, it is very important that the planning of developments in the area be aligned very closely to the requirements of the National Water Act and the National Environmental Management Act. Both acts prescribe for development that balances ecological, social and economic considerations.

A strategy for development must be to diversify the economy, by promoting not only irrigation agriculture off the floodplain, but also strategies to improve skills that make it possible to promote industries in the non-agricultural business sector of the South African economy, which have high potential to provide job opportunities to the high human population present and have been identified as, in order of importance: (1) the wholesale and retail trade, repair of motor vehicle, motor cycles & personal household goods; hotels & restaurants; (2) community/social/personal services; (3) manufacturing; and (4) agriculture/forestry/fishing.

A strategy for development in the region must take into account the fact that floodplain communities live in areas with sandy soils that are marginal. A strategy for development should ensure that communities are not denied access to the use of the floodplain resources without providing tangible workable alternatives (e.g. opportunities both in the commercial agricultural sector and non-agricultural sector) because the high human population means that only a limited number can be gainfully employed. Many have no income and will therefore continue to depend on the floodplain resources for subsistence needs. The implication is that should floodplain communities be denied access to the use of floodplain resources (crops, pasture and fish) without providing tangible workable alternatives, they can very easily become vulnerable to the impacts of droughts, hunger, poverty and disease.

A strategy for commercial agricultural development should ensure that only crops that grow efficiently in the area, in terms of climatic factors, are promoted. In the spirit of promoting development strategies that diversify the economy to achieve sustainability, equity and efficiency; it is highly recommended that fish production is promoted during summer to promote efficient production by ensuring that floodplain pans are inundated up to high flood level in order to submerge pan marginal vegetation (Chapter 7). Submerged vegetation provides both shelter and food (plants & insects) for young fish thereby enhancing production and harvestable yields. Ensure that the floodplain ecosystem receives annual artificial flood releases that mimic natural seasonal rhythms to sustain the fisheries and improve the natural value of the agricultural landscape for both tourism and subsistence agriculture.

A strategy for development should take into account the fact that gross annual irrigation requirements in the lower catchment are much higher than in the mid and upper catchment areas. This should inform decisions for equitable and efficient allocations. The implication for soil water stress patterns in the catchment, is that more water would be required downstream than upstream to enhance harvestable yields in summer.

Due to the saline nature of ground water in the area, a strategy for development should investigate the potential use of ground water in terms of quantity and quality for irrigation, livestock watering and domestic purposes particularly during periods of low flows. To what extent can ground water in the area supplement these needs?

A temperature aspect, which influences use of the study area as a tourism destination, is the very high daily maximum temperature in summer (e.g. highest maximum value recorded in February is 40.3^{o}C). Humans experience serious to acute discomfort between December and March and only between mid-June and late July can the climate be described as comfortable.

Before decisions are made to destroy the floodplain completely, using the DWAF Scenario 1 (no flood releases) so that more water can be found for economic growth, a good integrated development strategy (agricultural development and tourism and recreation development) must weigh out the costs and benefits carefully to determine ecological, social and economic sustainability in the long term. Co-management thinking outlined in Chapter 8 should guide decisions taken to achieve sustainability, equity and efficiency (Chapter 8).

9.3.2 Downstream agricultural development plans

Apartheid policies are the cause of the current problems experienced. The implication is that planned developments requiring the use of vast areas of the land resources should have a solid plan that shows clearly how the basic needs of this huge rural population, who suffered greatly under apartheid, will be taken care of. Any approved development should not push people deeper into poverty.

Key constraints facing agricultural expansion in the region are: water availability, land tenure rights and institutional arrangements.

The implication of the huge population data, on the Makhatini flats as a whole; economic dynamics of farming reported by Van Rooyen, 1983 and DoA, 1994; water availability (Chapter 4 section 4.4) that takes in to account efficiency, equity and sustainability (section 8.4); is that a very small proportion of any community can achieve benefits in terms of profits. Only a few people can gainfully own these agricultural irrigation scheme ventures. It also means that only a small proportion of the total population can work as labourers in these ventures. It must also be realized that, even if more farmers can benefit on smaller plot sizes (<20 ha), under different cropping programmes and management systems, water availability would still limit the number that can benefit directly from irrigation agriculture (Chapter 4 section 4.6.2). These ideas are strongly supported by the multi-value approach to agriculture (Edward-

Jones, Davies and Hussain, 2000; Chapter 8); plot size ideas (Denison and Manona, 2007) and arguments that suggest the need to transform the way we think about water and agriculture in Africa (Molden, 2007).

The fact that only a few people can benefit from irrigation farming means that the rest of the population have to find alternatives for survival. All stakeholders must be willing to participate in negotiations aimed at achieving fair trade-offs (Chapter 8). Indeed these dynamic are reflected in the current tensions over the need for water rights among floodplain fishermen who do both activities of fishing and growing crops on the floodplain (Chapter 7); nature conservation agencies who want people to get out of the floodplain so that it can become purely a conservation area (Chapter 5); downstream irrigation farmers who want to expand irrigation activities to full potential (106 000 ha) (section 6.2-6.6); Pongolapoort dam property owners who use the dam for irrigation, tourism and recreation (section 6.7 and 6.8); expanding upstream irrigation and commercial forestry (section 6.9). On the other hand, the DWAF, in addition to regulating all water use, they would like people to get out of the floodplain so that the dam can be safely managed for flood control due to the fact that cyclones are frequent in the area (Chapter 4).

Small-scale aquaculture technology implemented failed and it did not provide the intended incentive of finding an alternative means of fish production other than floodplain pans (so that more water could be found for irrigation). Floodplain fishermen prefer to have water rights to support both floodplain fisheries and subsistence agriculture (Chapter 7).

The diversity of water needs means that water use in the catchment should be subject to appropriate investigations, negotiations and fair trade-offs within community-based decentralized structures (WUAs) (section 8.3 and 8.4).

9.3.2.1 Recommendations: downstream agricultural development plans

Apartheid policies are the cause of the current problems experienced on the Makhatini flats. The implication is that planned developments requiring the use of vast areas of the land resources should have a solid plan that shows clearly how the basic needs of this huge rural population, who suffered greatly under apartheid, will be taken care of. Any approved development should not push people deeper into poverty.

Policy statements that were suggested by Bembridge (1991, 1993) and those by A'Bear and Louw (1994), and more recently by Denison and Manona (2007) and Molden (2007) are strongly supported and should be implemented in order to achieve the overall goal of fostering an appropriate economically viable and environmentally responsible irrigated and dry land agriculture, food production and rural development system for the Makhatini area aimed at improving the quality of life (Bembridge, 1993).

To achieve long-term sustainability, environmental principles and issues would have to be addressed first. Environmental principles require that we recognise the many interfacing and interacting systems operating in varieties of complex ways to produce the problems. It is important to recognise that Makhatini Irrigation Scheme was simply an operating system, nested within other larger and smaller operating systems. For instance: larger systems (national and regional economic system, government

departments and policies relevant to agricultural development). Smaller systems such as -local agricultural production system, irrigation system, socio-economic & cultural system in which farmers find themselves, institutional/organisational system, financial system, environmental system. That the goals and objectives within each sub-system have to be compatible with other sub-systems and the overall mission statement and if not harmonized no amount of investment for the perfection of one of the sub-systems can make the scheme achieve its potential.

On this basis, a key recommendation would be to carry out diagnostic institutional/organisational studies that improve the alignment of national government policies relevant to agricultural development to the goals and objectives within each local sub-system:

(i) Regional economic system,
(ii) Financial system,
(iii) Irrigation system,
(iv) Socio-economic & cultural system in which farmers find themselves (e.g. see details in section (v) below,
(v) Local agricultural production system (crops, livestock, irrigated pasture, aquaculture). According to Bembridge (1993), the approach should initiate farming systems research and adaptive on-farm research so that farming systems for both dry land and irrigation farming can be improved, including the integration of livestock into the farming system. Such studies should be able to also provide knowledge to questions such as: Is the figure of 20 ha –30 ha a standard which can be applied across the board-in other commercial farming systems with decentralized management? What are the appropriate plot sizes for subsistence irrigation farmers? What are the appropriate plot sizes for food security? Plot size ideas are discussed further under co-management section 8.4.5.3.3. It is suggested that plot size should generally be determined by the specific goals of farming and access to markets and integrated with the needs of society. On the Makhatini flats commercial farm size is limited by other competing needs for land (game reserves and game farms for eco-tourism, nature conservation and subsistence agriculture supporting a huge rural population). Farms size is also limited by competing needs for available water. How can we best achieve sustainability, efficiency and equity (Chapter 8).
(vi) Environmental system. For example, within the environment sub-system, it is necessary to monitor soil conditions, salinization, water quality, pollution, implement integrated pest management approaches, how to dispose excess pesticides, what to do with excess nutrients, how to contain soil erosion. Generally monitor and audit reserve requirements. Ensure that only crops that grow efficiently are promoted. Generally Chapter 5 (ecological interests) should guide the building of a knowledge base in the environmental system.

Information from these six categories above should not only be aligned to national policies but should also be linked and integrated in hydraulic models in order to inform decisions taken to improve resource allocation, improve systems, structures, strategies, and processes as well as fine tuning the reserve determination outcomes (Chapter 4 and 8).

The goal of these diagnostic institutional/organisational studies should also be to evaluate the success of the 'restructured plans' and to provide knowledge that informs new plans – in terms of the degree to which they are meeting the needs of all stakeholders involved (irrigation farmers, farming agents, investors and dry land farmers).

According to management studies, the principle that underpins this thinking is that, the only way profound change can be achieved is to ensure that people's inner values, aspirations and behaviour change with outer shifts in processes, strategies, practices and systems. It is not enough to change laws, strategies, structures and systems, unless the thinking that produced those laws, strategies, structures and systems also changes (Senge et al., 1999). Implied here is a need to not only align people's perceptions, beliefs, norms and values with the irrigation scheme system, structure, strategies and practices, but also to the intentions of the relevant government policies.

9.3.3 Initiate studies to define water based needs in areas outside the scope of this study

Initiate socio-economic and cultural surveys in other areas within the catchment that were not in the scope of this study in order to identify and document water problems and needs and to build a holistic knowledge base that enables us to locate and link individual problems within a catchment context and enhance problem solving (section 8.3 and 8.4).

(i) **Downstream of Pongolapoort dam**: Initiate surveys to identify and document water problems and needs of relevant irrigation schemes, areas proposed for irrigation expansion, areas for game farms tourism and recreation. Identify water problems and needs of irrigation in relation to other stakeholders. Use the information from the survey to set up or enhance development of functional decentralized water user associations.

(ii) **Upstream Pongolapoort dam property owners**: Initiate surveys to identify and document water problems and needs of irrigation, tourism and recreation and other relevant stakeholders. Use the information from the survey to set up or enhance development of functional decentralized water user associations.

(iii) **Upstream Pongola – Bivane catchment**: Initiate surveys to identify water problems and needs for commercial forestry, irrigation and other relevant stakeholders. Use the information from the survey to set up or enhance development of functional decentralized water user associations.

9.4 FLOODPLAIN AGRICULTURE AND GENERAL NATURAL RESOURCE USE INTERESTS

9.4.1 Conclusions

The Pongolo River floodplain was the first system in South Africa for which water requirements (environmental flows) were determined with a view to sustaining the productivity of the natural environment so that it would continue to service the needs of people living nearby. The allocation of water from the Pongolapoort Dam was justified based on economic, social and environmental

considerations, and was adopted for implementation by DWAF. Based on community perceptions in this study, it is clear that the allocation of water and its delivery since 1984 has not afforded the floodplain system the socio-economic and environmental protection envisaged. This does not mean that a decision should be taken to do away with flood releases because, even under the current reduced flooding regime, the floodplain has retained a small level of production that contributes to sustaining the basic needs of many rural people who are largely poor.

Out of 247 households interviewed, 74% felt that the river and floodplain were important resources for drinking, bathing, crops, fishing, grazing, livestock watering and provision of other wildlife resources. It is therefore important to be aware that most areas on the west side of the river have fertile soils and are targeted for commercial agricultural irrigation development. All areas on the east side of the river have sandy soils, except for the areas which form the floodplain, Makhatini irrigation scheme and Ophansi irrigation scheme further south. Soils found off the floodplain on the east side of the river where floodplain communities live are mainly sandy soil textures with hardly to any potential for growing many crops. The implication is that should floodplain communities be denied access to the use of floodplain resources, without providing workable alternatives, they could easily become highly vulnerable to the effects of droughts, hunger, poverty, and disease.

It must also be recognised that water allocation in the region supports two economies. (i) An economy largely based on irrigation developments off the floodplain that benefits fewer people directly. (ii) A subsistence economy that largely depends on floodplain resources that helps to supplement the basic needs of a huge rural population found living adjacent to the floodplain. The concern of managers and decision makers should not only be focused on agricultural irrigation developments but must also consider improving access to good quality water from Pongolapoort dam to promote the livelihoods of the huge subsistence economy. This implies that plans must be put in place to restore some level of natural stream flow on the floodplain and to improve water quality.

9.4.2 Recommendations

A decision must not be taken to do away with flood release from Pongolapoort Dam because, even under the current reduced flooding regime, the floodplain has retained a small level of production that contributes to sustaining the basic needs of many rural people who are largely poor. Decisions taken to get rid of the Pongolo floodplains through the DWAF no-flood release scenario must be informed by cost benefit analyses using environmental economics methods.

A decision must not be taken to deny people access to the use of the floodplain resources without providing workable alternatives, because biophysical aspects such as soils and climate support the fact that communities could easily become highly vulnerable to the impact of drought, hunger, poverty, and disease.

Cotton requires more time to ripen and hence stays longer on the floodplain. But because cotton on the floodplain was interfering with the flood release timing needs of very many non-cotton growing

households, it is proposed that replacing cotton 'on the floodplain' with other high value crops that do not take too long to ripen is an option that could benefit more people.

State lands had good soils earmarked for commercial irrigation development, but in order to ensure irrigation profitability in terms of land size, water availability and sustainability; and hence improve farmer commitment and enthusiasm to continue farming; it is important that all stakeholders recognize the fact that, the use of state lands for irrigation can efficiently benefit very few people directly. It is also important that all stakeholders recognize the fact that drought conditions prevail on the floodplain most of the year due to reduced stream flow from Pongolapoort Dam. Therefore, a better option of ensuring that a wider population benefits, was for government to also help communities in communal areas, i.e. the floodplain farming and fishing communities. Government should not only focus on supporting investments in commercial irrigation development 'off the floodplain', but must also provide support that improves the livelihoods of the huge subsistence economy through the following proposals, which should be co-ordinated through the DWAF formal water user association structure formed (*Imfunda yo Phongolo* water user association):

(i) Promote the formation of local farmer and fishermen associations per pan,

(ii) Strive to ensure equitable allocation of water between irrigation and floodplain farming, fishing and nature conservation by restoring some level of natural stream flow on the floodplain enabled through the design of some way to retain floods on the floodplain longer, improve access to good quality water from Pongolapoort Dam, build fish ladders and bypass that allows fish to migrate freely upstream or downstream past the dam wall and then promote aquaculture production,

(iii) In the absence of mechanisms installed to hold floodwaters on the floodplain, all floodplain communities felt that, although the current flood release timing in September was acceptable by negotiated consensus, it was still the wrong time for their needs, particularly for crops and fish production. Therefore, their immediate needs could be met through the following support from government:

   (a) Allow fish resource harvesting in game reserves and on the Pongolapoort Dam by licence and create selling points along the floodplain so that the whole community benefits. Help fishermen to acquire fishing implements like boats,
   (b) Due to the current reduced grazing areas and reduced flooding, pasture cultivation or fodder production should be integrated into the crop programmes of irrigation production to supplement livestock feed requirements,
   (c) Under the current reduced stream flow conditions the only way crops can grow well on the floodplain is if they are irrigated. An option that can ensure that a wider population benefit was for government to also help floodplain-farming communities by providing agricultural implements and technical support, including irrigation equipment like small engine pumps and pipes that can be moved around easily to avoid being destroyed by any floods that may need to be released. In addition, communities must also be taught to adapt soil moisture conservation technologies.

(d) Pans are located much closer to households than the river, but because of the poor water quality in pans most of the year, the majority of residents spend many hours fetching fresh water from the river. Hence they were highly vulnerable to impacts of poor water quality (salinity and toxic chemicals) and an enhanced ability to be infected by water related diseases. Many people were too poor to afford adequate quantities of clean potable water. This implies that the floodplain and the river are likely to remain the primary source of water for the majority of the population for many years to come. Eliminating the direct dependence on the river and pans for water for basic needs should be a priority for government. This can be achieved by improving service delivery through the provision of clean basic water and sanitation. Due to the fact that majority of the household sizes were above the Statistics SA average value of seven, it was important that municipality budget allocations must also take into account people with households greater than eight. Eliminating direct dependence on the river and pans can also be enhanced if subsidies for clean basic water are supplemented by helping communities acquire rainwater harvesting equipment and relevant simple technologies in order to secure good water quality for drinking and for livestock watering.

(e) It is important to recognize that although irrigation farming can contribute to poverty alleviation or reduction, there was a need for the development of a wide-ranging programme, which not only develops agriculture but also improves skills to earn non-agricultural income through the integrated development of the rural-urban link.

9.5 CO-MANAGEMENT ACTIONS AND INCENTIVES

The new water law and the policies developed to implement the law are firmly grounded within the theory and principles that underpin the integrated perspective of community development. The law takes into account economic, social and ecological needs and requires that existing diverse human needs must be taken into account in decision making about water allocations. It is presently ten years since the law was enacted, and although some water sectors perceive that they have not experienced the positive outcomes of the water law, it is premature to make conclusions that suggest a need to shift the law and the policies, because they have largely not been implemented to the full extent.

The challenge lies in establishing suitable decentralized co-management institutions within the catchment and ensuring that they have appropriate community, racial and gender representation and that the theoretical integrated principles are practiced. Community development studies point to the fact that the pace of development in human societies is slow, but it can be enhanced through appropriate decentralized structures, good leadership, good governance, capacity building and resources to invest in new initiatives that promote new ways of doing things so that change can be experienced.

Furthermore, other key principles that must be practiced to enhance the pace of development are: maintain the link between immediate goals and ultimate visions; the integrity of the processes determines outcomes; encourage organic development by enabling a community structure to develop in its own

unique way; nurture organic development; take into account the natural pace of community development by allowing the community group to maintain control and leadership.

9.5.1 Actions needed to enhance representivity and stability

Stakeholders affected by artificial flood releases from the dam have to be identified so that they can be mobilised into action through participation in Water User Association structures. On this basis, water resource units affected by artificial flood releases from the Pongolapoort dam and may warrant their own specification of the 'reserve' are W44E, W45A and W45B.

It is important for decision makers to be aware of the fact that although the Act stipulates a need to manage water within natural units, implementing such management is less efficient because political boundaries are mainly different from natural boundaries. Yet, political boundaries form the basis of all organizing from national government through provincial government to local government. However, studies show that planning and management of delineated water resource units based on nature (catchment/watersheds) is likely to be more successful than planning and managing water resource units based on political units or boundaries.

Through stakeholder dialogue processes the overlapping priority need between community and regulatory authority needs identified and hence requires immediate catchment management action was, '*Decision making needs\management (e.g. a formal decision making structure involved in development discussions, transparency, accountability, and empowerment)*'.

Short-term implementation goals needed to put the identified priority need into action are:

1) Initiate DWAF processes for setting up formal water user structures (WUAs). Note that this goal has been achieved and a formal WUA structure has been formed (*Imfunda yo Phongolo* WUA – see details in Chapter 7. The WUA represents the interests of users in quarternary catchments W45A and W45B). Note that the WUA representing the interests of users in quarternary catchments W44E, i.e. dam property owners has also been formed – see details in Chapter 6 section 6.7 and 6.8).

Co-management must be organised on a catchment scale in order to enhance achievement of not only representivity and stability but also equity and efficiency with respect to water allocations. Therefore, it is necessary to form appropriate decentralized formal WUA structures in the catchment and one overall central catchment forum for the Pongolo River. The centralized co-management structure is where all WUAs are represented so that they can participate in decision making and in negotiating for any necessary trade-offs about water allocations on a catchment scale. All structures local and central must strive to put into practice integrated co-management principles that enable representivity (*community, racial and gender representation*), which in turn enhances the ability to achieve fair water allocation among users, thereby promoting social relationships, stability and sustainability in the long term.

There can be as many decentralized WUAs and forums as there are needs because people are more likely to remain committed and to actively participate in discussing and acting on matters that affect them

directly. The only disadvantage of decentralized control is the high level of education needed to make it work. To embark on a programme of participatory democracy without a high level of education or learning programme (or capacity building programme or strategy), which makes it possible for the people concerned to effectively participate in decision-making and actions to have those decisions met, is a recipe for failure! As an initial empowerment strategy, it is very important that stakeholders not only understand the elements in ecological, social justice and management perspectives, but are also able to put them into practice.

2) Initiate building up a 'scientific knowledge base' to support interest based bargaining and decision-making, within the various WUA structures through dialogue processes.

Use the knowledge innovation chain (Breen et al., 2004) to provide decision support to the WUA structures by initiating and building the relevant holistic knowledge base through the DWAF comprehensive reserve determination procedures which must include the building of ecological\environmental economic models which can integrate ecological and social justice factors or values into the hydraulic model of the catchment in order to guide decisions about what is efficient, equitable and sustainable, with respect to water requirements needed to support diverse livelihood strategies in the catchment.

Managers, decision-makers must generate new knowledge from time to time using the knowledge innovation chain, in terms of evaluations, audits, assessments, defining needs and empowerment strategies, in order to keep up with the pace of change by contributing greatly to effective policy implementation, improvement, effective decision-making and controlling conflict within and among WUAs, through learning, changing and sharing knowledge – ultimately leading to human improvement and progress.

Projects initiated to build scientific knowledgebase must have a capacity building requirement.

3) Ensure that all affected groups are empowered to participate actively in the decision making process through co-management training materials and learning by doing through project initiatives. Note that this process was initiated during the course of the project, but ended with the project. In practice it should be a continuous on-going process and should be linked to new project initiatives.

A strategic approach to ensuring that capacity is build is to link it to the funding of projects initiated in the catchment. Projects must show how they are going to meet the representivity requirement by ensuring that they have appropriate community, racial and gender representation. Project teams must be made to account for the capacity build in target groups. Project evaluation must show a measurable extent of capacity build in both the project team and the target groups (Breen et al., 2004).

Capacity building strategies should also be linked to addressing the various change initiatives identified for each of the various interest groups (Chapter 4-8).

Capacity building initiatives must have outcomes that will enhance the ability of the various interests groups to have creative dialogue that leads to negotiating to an agreed consensus using community based development principles and approaches for managing change. So that the ultimate goal of equitable and efficient (or fair) water allocations can be achieved through wise and effective decision-making, controlling conflict within groups and regulating relations with other groups.

Stakeholders should be taught co-management thinking outlined in Chapter 8 so that they can learn to appreciate the difficult dynamics and challenges involved in resource allocation that attempts to balance environment and development issues.

Managers and decision makers must be taught what good leadership, good governance and capacity building means in practice.

Representivity and stability is enhanced when local and central community structures created have legitimate governance and are able to bind stakeholders with diverse interests through effective decision making, controlling conflict within catchment groups (various water use sectors) and regulating relations with other groups?

Representivity and stability is enhanced when local and central community structures with divergent interests are empowered to negotiate and reach true consensus on issues of 'fair' access to water for development and water for the reserve (basic needs and the environment).

Representivity and stability is enhanced when local and central community structures are empowered to adopt integrated principles that enable the building of a solid foundation for a decision making process that is healthy, with good governance, consensus and with functional equity?

Catchment management managers, decision makers and stakeholders must be made aware of the dynamics that come into play during decision making processes in water resource allocations and that these dynamics limit achievement of 'fair' results. For example, managers rarely have an adequate knowledge base to support decision making when implementing policies; hence the impact of many policies is often underestimated. Managers need to be aware of the various decision-making models and use the most appropriate under any given situation. Also, managers need to be aware of the various political theories underpinning human behaviour in policy implementation and decision making so that they can begin to foresee the impact of these various behaviours and learn to overcome them and to achieve positive outcomes.

The implications for successful integrated catchment management means that achievement of the overall vision of integrated sustainable development and the subsequent implementation of stakeholder needs and goals, must take these six components of development into account (social, economic, political, cultural, environmental and personal/spiritual). The principle of holism implies that WUA problems must be solved by analysing the possible links and inter-connections of the six components within the group and among other WUA groups in the catchment, in other catchments, and the regional, national and international linkages.

9.5.1.1 Recommendations for actions needed to enhance representivity and stability

Implement actions stated in section 9.5.1 above.

9.5.2 Actions needed to enhance sustainability, efficiency and equity

The four factors that explain how nature organises it self are sustainability, equilibrium or balance, diversity and holism. While the ecological implications of holism and diversity can help to explain what representivity and stability means in practice (section 8.3), the ecological meaning of sustainability and equilibrium or balance can help to explain what equity and efficiency means in practice.

9.5.2.1 General actions

Floodplain depended subsistence livelihoods can be integrated into a diverse rural economy by implementing a multi-value approach to agriculture or development. This means that development frameworks should not promote irrigation agriculture only or eco-tourism development only or nature conservation only. Development frameworks should seek to promote diverse strategies planned on a catchment and regional scale, which can provide livelihood opportunities for a rural population that is largely poor and unemployed.

The multi-value frontier provides a way of thinking about how best to make the necessary dynamic shifts, ranging from conservation on one hand to intensive production on the other – as we strive to achieve desired levels of ecological sustainability, equilibrium or balance, needed to enhance social well-being (Fig 8.8).

Generally the dynamics on the multi-value frontier are such that, as production increases, impacts such as, natural resource over-exploitation, environmental degradation, and increasing income differentials increase with increasing production in agriculture and industry (Fig 8.8).

A system of strong private property in combination with free markets for food and other goods will tend, (other things being equal), to move towards greater production intensification. Market incentives increases production unless policies adjust incentives, production continues, and can lead to ecological damage, and hence negative social impacts.

In striving to promote diverse livelihoods that improve the quality of life of the people through economic growth, while ensuring ecological and social justice sustainability within a catchment, requires managers, decision makers, community leaders and stakeholders to understand the dynamics of property rights and ownership systems of natural resources, so that they can begin to think about how the various policies put in place are going to adjust incentives and the impact of those incentives on the ecological and social wellbeing of others. It is necessary that mangers and decision makers understand the impacts of the use of the various property rights and ownerships systems when allocating resources.

It is also important that decision makers, managers and stakeholders understand the dynamics of the ecological meaning of sustainability, efficiency and equity in practice so that they can design appropriate policies to achieve balance between developments and the environment. In practice, notions of the ecological meaning of sustainability, equilibrium and balance should guide decisions and actions taken to achieve efficiency and equity of water sharing between economic growth and subsistence needs. The positive value of being human is that by understanding the implications of how nature functions and by applying it to management systems can help managers and decision makers to anticipate environmental problems, their causes and consequences, so that they can put in place corrective measures to avoid any expected negative outcomes or any environmental crisis.

Achievement of sustainability, equilibrium and balance requires that environmental economic tools that take in to account ecological perspectives should be used to determine project economic viability before it can be approved for funding and/or implementation and or monitoring and evaluation programmes. This effectively means implementing the DWAF reserve concept by building the relevant knowledge base through comprehensive reserve determination and building environmental economic models which integrate ecological and social justice factors or values in to hydraulic models of the catchment in order to guide decisions about what is efficient, equitable and sustainable.

It must be noted that, ecological goods and services and social impacts are often left out of the rational appraisals of the costs and benefits of project plans and evaluations due to the fact that putting market values of such goods and services is not as straight forward as putting market values on economic goods. Unfortunately, markets consider only the private values of transactions and do not take into account the externalities of goods or services, e.g. social costs associated with increasing production, hence, in order to obtain the efficient social allocation of developments in a catchment, government intervention may be required.

Stakeholders should be taught co-management thinking outlined in Chapter 8 so that they can start appreciating the dynamics and challenges involved in resource allocation that attempts to balance development and environment. For example, they must understand the thinking that can inform decisions that enable a shift towards economic growth along the multi-value frontier (section 8.4.5.3), and the thinking that helps to reduce production by shifting systems towards nature conservation (section 8.4.5.4). All decisions must be supported by rational appraisals of the costs and benefits of possible alternatives.

According to the Makhatini Integrated Development Master Plan of the KZN DAEA, the main goal is to promote the optimal and sustainable use of agricultural and tourism potential (DAEA, 2002, 2008).

Key factors that are likely to limit achievement of the goals are linked to sharing water and land resources on a basis that enables economic production and profitability while ensuring that the large rural population, who have depended on the same natural resources of the region for centuries for subsistence needs, are not marginalized.

Therefore, to mitigate the negative impacts of expanding development, notions of the ecological meaning of sustainability, equilibrium and balance should guide decisions and actions taken to achieve efficiency

and equity of water sharing between economic growth and subsistence needs and the reserve. On this basis, a fair allocation of water and land resources for development should be informed by the following principles:

9.5.2.2 Actions to achieve fair access to water for economic production

There are challenges to sharing scarce water resources equitably and efficiently between upstream commercial forestry, commercial irrigation agriculture, and recreation-eco-tourism industry and other potential industries vs. protection of downstream floodplain wetlands that provide ecological goods and services, which support a subsistence rural economy (Chapter 4-7). According to the principles of integrated community development (Table 8.3), the practical implications of promoting a diverse regional economic livelihood strategy that takes into account ecological and social factors and hence sustainability, efficiency and equity means that managers and decision makers must put a limit to the expansion of projects that require resource consumption to achieve economic growth (see section 8.4.1 and 8.4.5.3.2 for clarity). The limits and any necessary trade-offs must be informed by results from the DWAF reserve determination studies.

9.5.2.3 Actions to achieve fair access to land

Based on analysis of the land dynamics (section 8.4.5.3.3), i.e. issues of plot size, economies of scale, profitability, value chains and markets, exclusion from the value chain and markets, enthusiasm and commitment to continue farming; it is important that the approach to land allocation and consolidation should be informed by the goals of farming and the needs of the people. Due to the fact that land availability for agricultural production is a limiting factor, just like water availability for agricultural production is a limiting factor, equitable and efficient allocation and use of land resources should be based on strategies that diversify use in order to meet the diverse needs of the people.

Diversity in land plot size should be informed by farming goals based on the needs of society, which often range from commercial production that depends on increasing plots size to enhance profitability for certain crops, to high value crop produce that does not depend on land size to enhance profitability, to food security plots for subsistence needs.

9.5.2.4 Decisions about floodplain agriculture vs. conservation benefits

Clearly, UNESCO Man and the biosphere reserve agree with the concept of the multi-value approach to agriculture. These two instruments are more likely to be more successful at achieving nature conservation benefits in a densely populated environment than the use of ESAs, SSSI or conservation concessions or negotiated management agreements whose conservation development outcomes may end up, pushing local communities deeper into poverty. In cases where such policies have been implemented, they must actively strive to ensure the social-economic wellbeing of local communities is improved, due to the fact

that, both communities and projects are competing for the same scarce resources (land and water), hence making poor communities very vulnerable.

In the short term, the floodplain wetlands should be managed along the lines of conservation and development until such a time that the communities have alternative livelihoods and do not need it any more for subsistence livelihoods, then, it can become purely a conservation area (Chapter 7).

The process of negotiating wise development vs. conservation trade-offs within a WUA structure should be supported by a knowledge base largely developed through DWAF catchment wide comprehensive reserve determination processes whose outcomes must be linked to a hydraulic model of the catchment to inform predictions about the possible ecological and social impacts of various development/conservation scenarios (Chapter 4).

Effective integration and co-management implies that before using conservation legislation to prosecute offenders in a court of law, e.g. those cultivating in ecologically sensitive areas (ESAs); or through pollution waste regulation, the responsible authorities EKZN-Wildlife, DAEA, DWAF, should be willing to initially use holistic thinking developed through DWAF comprehensive reserve determination to develop a knowledge base on a catchment scale that critically analyses the situation using biophysical, ecological and economic determinants on a catchment scale in order to ensure that a situation does not arise where we are just blaming the victims.

9.5.2.5 Water management boundaries vs. political boundaries

The concept of integrated water resources management (IWRM) is made more difficult to implement on the ground because water management boundaries (water management areas and catchments) are different from management scales based on political boundaries (traditional wards, election wards, municipalities, district councils, provinces). Because water forms the basis for life and human development; the planning, management and implementation of developments vs. the environment and conservation or sustainability can be greatly enhanced (in terms of efficiency, equity, sustainability & hence effectiveness of service delivery among other things) in a scenario whereby the two boundaries become one and the same (Fig 8.1, Fig 8.2). For example, **what if** Pongolo River catchment becomes a municipality and the quaternary catchments form wards. Scientifically it makes working with the forces of nature (with respect to ecology) much more easy to comprehend, and hence improve overall efficiency in planning and ensuring sustainability by aligning ecological boundaries with political boundaries – hence government systems used in organizing the production, allocation and distribution of goods and services people require to meet their economic (material) needs and social needs within a catchment context.

9.5.2.6 Recommendations for actions to enhance sustainability, efficiency and equity

Managers, decision makers and stakeholder must learn the co-management thinking outlined in Chapter 8 so that they can start appreciating the dynamics and challenges involved in resource allocation that attempts to balance development and environment. For example, they must understand the thinking that

can inform decisions that enable a shift towards economic growth along the multi-value frontier (section 8.4.5.3), and the thinking that helps to reduce production by shifting systems towards nature conservation (section 8.4.5.4). All decisions must be supported by rational appraisals of the costs and benefits of possible alternatives.

Initiate the DWAF comprehensive reserve determination studies.

Due to the fact that markets consider only the private values of transactions and do not take into account the externalities of goods or services, e.g. social costs associated with increasing production, in order to obtain the efficient ecological and hence social allocation of developments in a catchment, government intervention may be required.

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APPENDICES

APPENDIX 1: ASSESSMENT OF STUDIES ON ARTIFICIAL FLOODS FOR FLOODPLAIN RESTORATION AND MANAGEMENT.

Evaluation of the potential, limitations and implementation difficulties of creating artificial floods (Modified from-IUCN wetlands programme newsletter No.12 January 1996).

	Economic Benefits or Returns		Management decisions
Location	Natural Floodplain	Irrigation Development	
Nigeria, Komoduga-Yobe basin, Hadejia-Nguru wetlands. Dam constructed for irrigating cereals (Adams 1992) Before dam (2000 km^2 in 1971). After dam (300 km^2 1984) (Hollis et al. 1993)	US$ 32 per 1000 m^3 of water	US$ 0.15 per 1000 m^3 of water -excluding operational costs (Barbier et al. 1991).	Relevant authorities (government, water boards, researchers) discussed and agreed that although yields from intensive irrigation schemes are higher per ha than from floodplain agriculture, the high operational costs of the schemes reduce the benefits substantially. It was agreed that artificial flooding should play a role in the maintenance of rice, dry season agric., fuel wood, timber, fish, wildlife and ground water recharge.
Cameroon, Logone River. Barrage constructed across the floodplain to create lake Maga to supply water to an irrigation project. Area covered-6000 km^2 in 1960s	Fishing-earnings of US$500\month, Dry season pastures - 300,000 cattle, 10,000 sheep and goats, Game reserve-Waza with various wildlife and attracts 6000 tourists\year	Due to supply of water to irrigation schemes, flooding was insufficient to grow floating rice and fish yields decreased by 90%	Potential to release water to rehabilitate the floodplain was identified. A hydrological model of the floodplain was developed to assess the effect on floodplain re-inundation of various options for releasing water. A socio-economic model was used to determine the benefits of each option in terms of improved fisheries, agriculture and herding (Wesselink and Drijver 1993). Substantial investment was required to re-engineer the embankments. The expected benefits exceeded the estimated costs over 30 years by US$4.5 million. A pilot release was made in 1994. Hydrological and socio-economic data was collected and analysed to help verify the predictions.
Mali, Mauritania and Senegal share Senegal River Basin. In 1986, one dam called Manantali was built in the headwaters for hyro-electric power and to regulate flows in the River. Another dam was built near the River mouth to	250,000 ha of flood recession agriculture, forests and wildlife habitat	Due to a delay between dam construction and irrigation scheme development and installation of turbines, it was	The Institute of Development Anthropology-IDA carried out a comprehensive cost-benefit analysis. They suggested the best economic option is to use the Manantali dam in the headwaters both to release artificial floods to conserve the floodplain ecosystem, to generate hydroelectric power and to provide for commercial irrigation (Horowitz and Salem-Murdock 1990). The shared basin organisation rejected the IDA position-due to politics. While floods benefit rural

inhibit sea water intrusion into the River and allows its use for irrigation as well as regulating water levels to facilitate transport. Area covered before dam (250 000 ha). After dam (50,000 ha)		agreed that artificial floods should be released for a transitional period of 10 years. However, releases made were ill timed, inundated only about 50,000 ha, flooded out newly planted crops, resulted in 20% less electricity being generated which was not cost effective.	poor, electricity benefits the urban elite, commerce, and industry (as there is little rural electrification) and provides income for loan repayments.
Zambia, Kafue River. The River has been developed to harness its potential for hydro-power generation. The Kafue gorge dam was constructed immediately below the flats (wetlands) in 1972, followed by a regulatory dam at Itezhitezhi 250 km upRiver-constructed to release an artificial flood for the maintenance of wetlands and the support of people dependent on them.	Kafue flats wetland has fisheries, livestock grazing and recession agriculture to support the livelihoods of some 100,000 people.		Research results undertaken before construction of the Itezhitezhi dam led to an agreement to release an artificial flood of 300 m^3 per sec during periods low flow years for a four-week period in March. The flood did not produce the benefits intended. The artificial flood comes later and recedes earlier and water levels are maintained at significantly higher levels throughout the whole year. Operators of the dam observe their own priorities which are incompatible with flow regimes that will benefit Riverine habitats and populations. Ecologists have not maintained pressure on authorities to apply or improve these provisions
Kenya, The Tana River has a mean flow of 180 m^3 per sec. The dam is constructed upstream of the floodplain. Dam construction is upstream of the floodplain.	It has an extensive floodplain and delta which supports a huge human population and wildlife within a wide area that is extremely arid for most of the year.		Designers and developers intend to cater for floodplain needs and those of hydro-power generation. Because silt is important just as water for the maintenance of the productivity of the floodplain, the dam is designed to release sediment with the flood water. Data is being collected to model how much water is required to simulate a flood and the timing of this in relation to upstream and local rainfall

Tanzania-The Rufiji River, a dam was designed to specifically make flood releases			The Rufiji has an extensive floodplain and a very large delta where the River meats the Indian ocean. These ecosystems supports about 100 000 people through fisheries, flood dependent paddy rice, recession agriculture and delta products-mangroves, molluscs, crustaceans and fin-fish for local and off shore fisheries.
South Africa, Pongolo River. A dam built in the 1960s with a view to irrigate 40,000 Ha. No assessments were made of impacts of the impoundment on the local population of the some 70,000 people dependent of recession agriculture, fishing and other wetland products, nor on the biodiversity of a game reserve downstream of the dam (Bruwer et al., 1996).			The dam changed the whole flooding regime, which led to reduction of wetland habitat and reduced the productivity of agriculture and fisheries. Initial releases of water were made at the wrong time of the year and crops were either washed away or rotted. In 1987 communities were involved in decision making regarding when flood waters should be released. Water committees were established representing five user groups (fishermen, livestock keepers, women, health workers). These committees were successful at implementing people's views leading to improved management of the floodplain to the benefit of users. However, people's views are not correct. The perceptions are wrong and the floodplain continues to degrade.

APPENDIX 2: STAKEHOLDER NEEDS DEFINED THROUGH DIALOGUE WORKSHOPS

Decision making (management) needs	
1. All affected groups must be empowered to participate actively and equitably in the decision making process	13. Prevent releasing water without consultation of the members
2. Whoever makes the decisions, the process must be transparent and decision makers accountable.	14. Form an institution in this area. That fits into the law eg. WUA or CM Forum,
3. Can we form one single committee out of this workshop?	15. Viva/forward with water committees
4. Water release must be made by water committees	16. Decision making should be consultative (e.g.) other stakeholders interest is not served
5. Lack of representation during decision making	17. Conflict resolution method to meet differing requirements
6. The need for active participation by "downstream" communities in the decision process.	18. Lack of communication
7. Water committees lack transport to attend meetings	19. Lack of information around issues
8. People affected by decisions need to have power over those decisions.	20. No communication when water is released
9. Implement the 1998 National water Act –now	21. Lack of training
10. No formal meetings related to water release	22. There must be mechanisms for implementation review.
11. Lack of consultation as it is hard to take decisions without having to consult each other	
12. There is a lot of confusion especially with local authorities and local government structures which makes it difficult to take decisions because we don't know whom to consult between the two	

The water resource needs	
1. Prevent water pollution	11. Lack of transformation services, e.g. white community in rural areas have access to water as compared to black communities living in the same area. (Isigodi)
2. Impact of DIP tank 'muthi' on dams and River life (e.g. fish).	12. Upstream usage is limiting inflow
3. Make sure enough water is released to reach all the floodplain	13. Lack of access to clean water
4. Adequate water for drinking and animal consumption	14. Shortage\Access to water
5. Water makes fishing possible	15. Dam is virtually fully allocated
6. Provision of adequate drinking water systems	16. The available water resource (After the reserve has been determined) must be distributed equitably with comprehensive stakeholder participation
7. Water for drinking by livestock	17. The detailed reserve (As per the water ACT for both River and wetland) must be determined before any other allocations are made
8. Water for various domestic uses	18. Water is too expensive especially for those who have piped water, e.g. no free 6000 litres of water as compared to other areas.
9. Water release brings along fish	19. Proper management of water resource to benefit tourism industry (birds viewing on the reeds),

10. Equitable use of water resource downstream and upstream	20.The dam represents a large body of water in a very dry area and as such represents a tremendous opportunity.

Agricultural needs	
1. Increased agricultural development upstream of dam needs control.	13. Correct volume\release of water to adequately benefit agriculture
2. Commercial agriculture in its current context is not equitable or environmentally sustainable.	14. Proper flood release timing to benefit agriculture, e.g. Maize cultivation in September=Good yields.
3. Unstructured agricultural practices both commercial and subsistence.	15. Water must be released in August.
4. Preservation of the floodplain to benefit agriculture (best agric practices).	16. Water must be released in July.
5. Commercial farming in flood zone is detrimental to biodiversity.	17. Need enough water for floodplain cultivation
6. Need for investigations of reasons for pest invasion of some floodplain crops.	18. Need enough water for OFF-floodplain irrigation
7. It must be recognised that agriculture is a vital part of the floodplain economy.	19. Need water for watering vegetables
8. All agricultural development must conform to the Environmental Conservation Act.	20. We need canals from the Rivers to the vegetable gardens.
9. Agriculture must integrate with all the other sectors.	21. Promote the appropriate crops and fish farming.
10. Prevent wash away of crops during floods.	22. Market availability where we can sell our produce/products
11. Get access to water for irrigation	23. Self-improvement of farmers through farmer-support services
12. Get access to water for livestock.	24. Advanced training on modern commercial farming skills

Environment needs	
1. Misuse of the environment	12. Maintenance of the environments
2. Prevention of the natural resource depletion, e.g. wild animals	13. Water must always be present in the pans and River
3. Soil erosion by Rivers caused by sand winning and tree cutting	14. Proper timing and magnitude of releases to stimulate the natural system
4. Prevention of soil erosion	15. FLOOD EFFECT selection for a wide variety of elevations/types of pan
5. Prevention of deforestation	16. This unique floodplain if allowed to operate as naturally as possible given acknowledged constraints, can support a diverse rural economy
6. Fishing and hunting to be monitored	17. Access to the environmental resources
7. Cutting down of vegetation on the River bank and cultivating on the Riverbank	18. Sustainable use of vegetation and aquatic animals (fish),
8. Regulate sand mining in the River	19. Flood managed to benefit reed harvesting (thatching, grazing and building),
9. Stop bad agricultural practises on the floodplain and flats	20. Flooding to benefit medicinal plants and indigenous edible plants
10 Maintaining the environmental integrity of this very important floodplain system is a national and international obligation	21. Releases optimised to help malaria control
11. In order not to foreclose on the future options (e.g. Tourism) the system should be managed to operate as far as possible in the natural flood regime	22. Water release bring disease, i.e. malaria.

APPENDIX 3: CENTRALIZED DECISION MAKING STRUCTURE: ADVANTAGES AND DISADVANTAGES.

(*e.g. One CMA or one WUA within the catchment made up of water user 'representatives*)

Advantages	Disadvantages
Decentralized control recognises that for some purposes more centralised decision making is necessary, or at least co-ordination is required. Where centralised functions exist, they should preferably be of communication and co-ordination, effective networking, information and resource provision, and support for decentralised activities and structures.	Sometimes implementation of central functions within a decentralized set-up is not possible or not effective due to lack of resources, skills, knowledge, leadership, which in turn weakens decentralised activities and structures. Thus supporting the view that participatory democracy or decentralized decision making is unworkable, and providing justification for the implementation of central control that has a tendency to promote negative outcomes such as inequity, unfairness, exploitation and oppression.
	Central control reinforces pluralist and elitist forms of politics in decision making, hence effectively advantaging central control. Pluralist politics is often criticised for the extent to which it portrays the state as merely a neutral referee in the competition between interest groups. Critics point out that the state's capacity for independent action on its own behalf is undervalued. It is also possible that despite competition a limited series of interests could dominate for prolonged periods (Smith 1990; Booysen and Erasmus 2001). Elite politics states that society is divided into elites – drawn from the higher socio-economic classes that have power – and the masses that are excluded from power; the elites have relative consensus on the values that should guide society; and public policy reflects this consensus and not the demands of the masses, which are viewed as relatively apathetic and/or powerless. Because of the elite's vested interest in the maintenance of the system, one can expect policy changes to be characterised by conservatism and incrementalism resulting in a limited series of interests dominating for prolonged periods (Anderson 1997). For instance, often claims of centralised governance to ensure equity are often illusory (Ife, 1999). Therefore, pluralist and elitist forms of politics are far from the empowerment deal.
	Central control promotes 'representative democracy', which involves an effective transfer of power to an elite (those elected). Consequent disempowerment of the people in whose interests democracy is supposed to work, e.g. decisions are made by leaders rather than as a result of democratic processes. The effective power of the individual citizen is limited and often reduced to the symbolic gesture of voting every few years, which often becomes a meaningless ritual.
	In a central control model, the perspective of the centre (e.g. one CMA in the catchment), is given priority when disputes arise, because the perspective of the centre is viewed as being more valid because it is able to take an overview, hence effectively advantaging central control.

	The perspective of the periphery (decentralized units, e.g. many WUAs), becomes disadvantaged or powerless in the process because the perspective of the centre (e.g. one CMA in the catchment) is viewed as being more valid because it is only able to take an overview of the needs of the decentralized WUAs, hence effectively disadvantaging the control or the power of decentralized units. Also positive outcomes such as community building and accountability are not enhanced within such a central model.
	Accountability is decreased in a central control model. The representative democracy perspective of accountability views accountability upward or to the centre, i.e. to the leaders or representatives directly concerned as being much more important because the leaders or representatives make the decisions for 'the people' concerned and expect that the 'people concerned' be responsible for ensuring that the decisions made by elites are carried out. It reinforces pluralist and elitist forms of politics in decision making, hence effectively advantaging central control. Accountability upward or to the centre leads to a situation where the people concerned at the periphery are more likely to loose positive outcomes such as accountability, community ownership of processes and structures, community ownership of material things, sustainability while enhancing community powerlessness, disadvantage, and instability.

APPENDIX 4: DECENTRALIZED DECISION MAKING STRUCTURE: ADVANTAGES AND DISADVANTAGES

(*e.g. many water sectors or forums such as irrigation, subsistence agriculture, fisheries, tourism and recreation, within the catchment, that are linked to specific needs at various geographical locations***).**

Advantages	**Disadvantages**
Decentralized control is more likely to ensure equity and fairness than central control, because at this level, it is easier to learn to implement concepts and principles such as: accountability, ownership, community building, the integrity of processes, non-violence approaches, inclusiveness, consensus building, empowerment, sustainability, individual enthusiasm and willingness to commit to participation.	The people concerned have to learn to acquire and implement these concepts. The learning process is long and slow and requires committed leadership roles to find adequate resources that can sustain change in the initiating phase
Decentralized control ensures that no decision or function should occur at a more centralised level than is necessary and this enhances positive outcomes such as: equity and fairness, stability, accountability, ownership, community building, the integrity of processes, non-violence approaches, inclusiveness, consensus building, empowerment, sustainability, individual enthusiasm and willingness to commit to participation.	Decentralized control requires that people are educated well enough to make sound decisions and this requires time, leadership, skills, knowledge and resources to achieve the desired outcomes. Sometimes lack of leadership and resources needed to reinforce learning new practices leads to promoting the view that decentralized control is unworkable, and hence the system reverts to central control, which, in most cases, tends to promote negative outcomes, e.g. exploitation and oppression.
Decentralized control recognises that for some purposes or functions, more centralised decision making is necessary, or at least co-ordination is required. Where centralised functions exist, they should preferably be of communication and co-ordination, effective networking, information and resource provision, and support for decentralised activities and structures.	Sometimes implementation of central functions is not possible or not effective due to lack of resources, skills, knowledge, leadership, which in turn, weakens decentralised activities and structures because standards are not maintained. For example, some units are more resourced and have more skills and knowledge than others have, thus supporting the view that participatory democracy or decentralized decision making is unworkable, and providing justification for the implementation of central control that has a tendency to promote negative outcomes such as inequity, unfairness, exploitation and oppression.
In a decentralized model, accountability is downward or outward to the people directly concerned because it requires involvement of 'the people' concerned in making decisions and that the 'people concerned' be responsible for ensuring those decisions are carried out. Accountability is enhanced through (i) community ownership of material things giving people more reason to become actively involved at community level, and it can be a more efficient use of resources. (ii) Community ownership of structures and process, which requires that communities be in control of things such as the delivery of services such as: water, health, education, decisions	Accountability and community ownership can only be achieved by initiating, stimulating and supporting such community control and ownership, by providing people with the necessary resources, skills and confidence to undertake such responsibilities. The process of providing people with necessary resources, skills and confidence to undertake community ownership of responsibilities such as processes and structures and materials is a slow learning process with a high risk of not being effective in the absence of good leadership and resources.

about local activities, housing, local development.	
In a decentralized model, the learning process is enhanced. A prerequisite to effective participation in decision making is being well informed about the issues at stake and the consequences of particular decisions. Educating the people concerned in decision making is a principle requirement needed to make participatory democracy or decentralized decision making to work. It requires that the people concerned learn new knowledge and are able to act upon it to produce credible results. This takes a level of awareness and education higher than is generally understood as being necessary for participation in currently existing forms of representative democracy. Although the learning process is slow, the outcomes are credible, sustainable and profound change takes place, which in turn enhances confidence, enthusiasm and willingness to commit to participation. The people concerned should learn and practice ecological and social justice principles relating to analysis and strategy. For instance those relating to analysis: integrated development; confronting structural disadvantage; human rights; sustainability; empowerment and defining need. Those relating to practice are: maintain the link between immediate goals and ultimate visions; maintain the link between the personal and the political; the nature of the process determines outcomes; encourage organic development by enabling a community structure to develop in its own unique way; nurture organic development; take into account the natural pace of community development by allowing the community group to maintain control and leadership, also principles that enhance obligation, decentralization and accountability. Ife (1999), illustrates in detail the knowledge and conditions required to enable good practice.	Central control supporters view participatory democracy as unworkable, due to the high levels of education needed to make it work. To embark on a programme of participatory democracy without an education programme that makes it possible for the people concerned to effectively participate in decision making is a recipe for failure! Factors that serve to support the views of those who see participatory democracy as unworkable are: fear and anxiety of change. The feeling that there is not enough time, there is no help in terms of skills needed to coach, train or teach people, no resources. The feeling that it is not relevant; the feeling that leaders are not 'walking the talk', lack of a mechanism for measurement and assessment and corrective action of desired goals, conflict between the believers of participatory democracy or decentralized control and the believers of central control or representative democracy (Senge et al. 1999). The lack of good leaders, the delays experienced in learning new ways of doing things, lack of resources to implement actions means that the success process in terms of new ways of doing things, new results, enhanced credibility for decentralized decision making, enhanced confidence and enthusiasm and willingness to commit to participatory democracy will be slow and if investments are not put in place to reinforce these learning abilities, the process can die.
A decentralized model enhances the willingness/obligation of the people concerned to participate. Participatory democracy can be seen as people's right to self determination which requires that people are well informed about the relevant issues well enough to not only effectively participate in decision making, but also to act upon the decisions made, this enhances a feeling of enthusiasm and a willingness to commit to participation. One cannot force people to participate, but a climate can be created in which people feel a strong moral obligation or duty to participate. Participatory democracy enables a practice where people's participation becomes genuine rather than the 'tokenism practice' of granting minimum concessions,	A strategy of participatory democracy is far from straight forward. Often community members have better things to do with their time, when they detect tokenism; they would rather leave than spend valuable time on useless consultations and on making decisions with little significant import. A strategy of participatory democracy involves more than simply setting up different structures and expecting them to work. It cannot be achieved quickly, as it involves reversing some strong trends in contemporary society namely: the structural constraints and vested interests opposing participatory democracy are strong and entrenched, e.g. protection of power and control, privilege, profit, global inequality, patriarchy etc.

especially to appease radical demands. Although participatory democracy is seen as a result of a longer-term development process, and thus, should become one of the goals and mechanisms of community development, the ultimate vision and outcomes are worth striving for, e.g., stable society or community or organisations, a balance between social, economic and environmental aspects in society wellbeing required to achieve long term stability. In practice, key principles, which will enhance positive outcomes, which ensure that people feel compelled, or enthusiastic and willing to commit to participatory democracy or decentralized decision making, are: community building; the integrity of process; non-violence approaches; inclusiveness; and consensus building? Ife (1999), illustrates in detail the knowledge and conditions required to enable good practice.	Participatory democracy is a result of a longer-term development process, and requires resources, skills, knowledge and good leadership to continuously reinforce learning abilities and strategies needed to achieve long term community development (Senge et al. 1999). Inadequate provision of these needs leads to promoting the view that participatory democracy is unworkable, and hence the system reverts back to central control which, in most cases, tends to promote negative outcomes, e.g. exploitation and oppression, power and control, enhanced instability in society.

APPENDIX 5: CAPACITY BUILDING REPORT

The following capacity building products and targets were achieved:

(i) A situation analysis report and a shared vision for a preferred, achievable and sustainable state of the floodplain system.

(ii) A strategic plan for action and guiding principles, processes, structures for intervention that can lead to participatory co-management and integration of livelihoods into a diverse rural economy.

(iii) An implemented strategic plan. All affected and interested parties (communities, service providers, resource managers, decision makers and regulators, etc.) have been mobilised and are willing, committed and enthusiastic to initiate and sustain processes defined in (ii) above- which are required to transform patterns of behaviour so that they direct patterns of resource use towards sustainability. Although the affected parties are aware of factors needed to change behaviour, resources are needed to put these factors into action by promoting co-operative governance over resource use; improving leadership and management skills necessary to advance economic and social welfare; providing access to training necessary to enable people to accept and sustain new land-use practices; protect and rehabilitate natural resources through minimising destructive practices and introduction of new systems; instil a culture of continuous learning to underpin co-operative governance and strategic adaptive management.

Specific target groups engaged and the capacity achieved were:

1) Enhanced leadership, research and management capacity of previously disadvantaged individuals (students and professionals). Specifically the project enhanced capacity by supporting two Masters Students namely: Salagae MA and Nkosinathi Matiwane. Salagae graduated with a Masters in Environment and Development. In addition capacity was built through vocational employment of 23 undergraduate students from the Faculty of Science and Agriculture and one PhD student from the School of Social Sciences-who participated in collecting social survey data.
2) Engaged people from rural communities (farming and non-farming households) living in the pilot area to gain confidence in co-operative governance;
3) Engaged decision makers/managers of (service providers, government departments-National and Provincial, i.e. DWAF, DAEA, EKZN-Wildlife, DoH), particularly those individuals working and servicing pilot study areas to have improved understanding and ability to link local people to water resource management and co-operative governance;
4) Engaged NGOs, CBOs, research institutions, that have a function and responsibility in the pilot study area to have improved understanding and ability to link local people to water resource management and co-operative governance;
5) Engaged policy advisors in provincial and national government to have improved input into policy debate from rural people on the floodplain;
6) Enhanced capacity in the development and implementation of trans-disciplinary, multi-institutional projects to be evident amongst research managers.

Indeed, the scale of impact of this project is such that the authors have received positive recognition for work done both internationally through IWMI-CA who sponsored Chapter 5 and nationally. For instance, on the national scale, senior managers in DWAF have recognised the contribution of this project with respect to enhancing understanding relating to integrating socio-economic factors in water resource modelling. Towards this recognition, Dr Joan Jaganyi has been appointed to serve on the DWAF Advisory Council Committee for water resources modelling for three years.