A ROOSEBOOM

THE EXTRACTION OF WATER FROM SEDIMENT-LADEN STREAMS IN SOUTHERN AFRICA

Report to the

WATER RESEARCH COMMISSION

By the

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ABSTRACT

This report is a secondary outcome of a research project sponsored by the Water Research Commission titled "The removal of floating and suspended materials from streams".

The main outcome of this project has been the WRC Report No TT95/98, published during July 1998 with the title "The removal of urban litter from stormwater conduits and streams" (by Armitage, Rooseboom, Nel and Townshend).

A third report which has resulted from the research project is titled: "Design guidelines for small purification works" by WM Malan. Whilst the latter report ended up by addressing a wider theme, all three reports were intended to address the various problems that one encounters in separating solids carried by streams from the water.

The report at hand deals specifically with sediment related problems encountered in the extraction of water from rivers and other sediment laden streams. An overview is given of specific problems that have been encountered. This is followed by a brief summary of the relevant sediment transport formulae. A description is given of sediment yield patterns for catchments in Southern Africa, as well as sediment load patterns in local rivers.

In recommending suitable lay-outs for extraction works, rivers that carry mainly loads of fine sediments (clays, silts and sands) are treated separately from those that also carry coarser materials in the form of gravel, cobbles and boulders.

In the case of rivers that carry fine materials mainly as suspended loads, a number of components which have proven to be successful have been integrated into a layout which may serve as a basis for site specific designs.

Where rivers also carry significant loads of coarse materials, it has been found that the Tiroler type weirs that emanate from Europe provide the best solution.

LIST OF SYMBOLS

a distance of reference level above bed level.

C Chézy roughness coefficient.

C Sediment concentration at distance y above bed level.

Ca Reference sediment concentration at distance a above bed level.

d particle diameter

D depth of flow

g acceleration due to gravity

R hydraulic radius

R eddy radius

s energy gradient

v_{ss} particle settling velocity
y distance above bed

κ von Karman coefficient

υ kinematic viscosity

ω angular velocity

LIST OF FIGURES:

ACKNOWLEDGMENTS

As author I am indebted to colleagues who through the years have involved me in problems which involved the extraction of water from sediment laden streams. Had I known how difficult it would be to derive specific recommendations, I would probably not have been so brave as to write this report.

A special word of thanks is due to Mr NJ Myburgh of the Department of Water Affairs and Forestry for providing me with a report covering twelve extraction works investigated by himself.

My sincere thanks are also due to our steering committee. I have not encountered a steering committee which has played such an active role in the research before. I wish to thank our chairman, Mr DS Van der Merwe for his patience and tolerance, allowing us to delve wider than had been the original intention.

Our steering committee has lately consisted of:

Mr DS van der Merwe (Chairman)

Mr J Bhagwan

Mr RW Arnold

Mr B L Kisch

Mr KA Barnett

Mr PD Townshend

Mr M Braune

Prof PW van der Walt

Mr FPJ van der Merwe

Mr C Nel

Prof JM Jordaan

Mr NP Armitage

Mrs CM Smit

1. INTRODUCTION

This report is a secondary outcomeof a research project sponsored by the Water Research Commission titled "The removal of floating and suspended materials from streams".

The main outcome of this project has been the WRC Report No TT95/98, published during July 1998 with the title "The removal of urban litter from stormwater conduits and streams" (by Armitage, Rooseboom, Nel and Townshend).

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The reader's first reaction to this publication may well be:

"Surely with a number of extensive publications available which all deal with the same topic, e.g. BHRA (1989); Bouvard (1992); Raudkivi (1993) and Scheuerlein (1984) there cannot be a need for another publication"?

The author was prompted to write this publication having been called in to try and resolve serious sediment related problems at a number of water extraction works across Southern Africa. As such works are generally substantial, it proves to be very difficult and costly to remedy existing problems. A major reason for these problems lies in the fact that local conditions often differ from those in regions where many of the classical extraction layouts have been developed. Whereas technology that has for instance been developed in the mountainous regions of Europe can readily be applied in our mountain rivers, it is beyond these regions that many of our serious problems are encountered.

In Southern Africa we have to deal with highly variable discharges that often carry heavy loads of suspended sediments. These works have to operate under flood conditions as well as when the flows virtually reduce to trickles. The main emphasis in these guidelines is on dealing with these conditions.

It has fortunately proven possible to provide compact and clear guidelines on designs which from their past experience will operate effectively. This has been done by integrating the most successful components from existing works, locally as well as abroad. A configuration has been developed which can be adapted to suit conditions at each site. In this respect, the author is indebted to Mr NJ Myburgh of the Department of Water Affairs and Forestry, Pretoria. He has made a report available on evaluations of 12 different South African works which have been in operation with varying degrees of success. (Myburgh and Jezewski, 1994). The findings in their report served as a valuable crosscheck for my own experience and information from the literature. The most successful existing local extraction works conform largely to our guidelines. This is gratifying as it proves that successful designs can be typified and replicated with confidence. It must be added however that the three dimensional flow patterns which are generally generated at extraction works are very complex. Physical model studies have proven to be invaluable in optimising layouts in terms of efficiency.

The layout which is presented in chapter 5 is recommended primarily for areas that carry heavy suspended loads, but can also be used for sediments up to gravel sizes. A completely different layout, best known as the Tiroler Wehr (Tyrolean weir), is recommended for streams that carry coarse sediments, including cobbles and boulders (Chapter 6).

As the author has become party to much of this information and insight on a confidential basis, he has refrained from referring to specific works and their problems, as well as solutions. These are therefore dealt with in a generic way.

2. PROBLEM AREAS

As has been indicated in the introduction, differentiation is made between:

(i) Rivers which carry loads of predominantly fine sediments (with a major proportion of the particles typically smaller than 0,3mm in diameter).

(ii) Steep rivers that carry heavy sediment loads which may include gravel, cobbles and boulders.

Whilst most extraction works in Southern Africa are situated on rivers of the first category, most international publications concentrate on solutions that are applicable in dealing with coarser sediments, with the emphasis on sediment exclusion. Exclusion of sediments is achieved by inducing higher concentrations of sediments in certain flow zones and by extracting water from the clearer flow zones. This can only be achieved where particles with relatively high settling velocities are involved.

In those Southern African rivers that carry mainly sands, silts and clays, a large proportion of the annual loads will be carried during flood events. Suspended sediment concentrations then tend to vary only slightly across flow cross-sections. Under these circumstances separation through settling can only be achieved in large settling basins.

The ease with which the relatively small suspended sediment particles become accelerated causes them to be dispersed from flow zones into zones where the sediment transporting capacity is low.

Conditions that are ideal at pump intakes i.e. low velocities and especially low vorticity thus tend to attract suspended particles from passing streams. Even when water is not being pumped, sediments can be fed continuously into a pump's wet well through a connecting opening from areas of high vorticity. Wet wells and other spaces containing slow moving water, which are connected to sediment-laden streams, tend to become filled with sediments.

Pump houses with small outside openings have been found to be more than 80% filled with sediments after having been inundated during a single flood event. Relatively small rapid-flowing streams have the ability to transfer gravel and even cobbles in similar fashion.
Other causes of sediment related problems which have been encountered at water extraction works include:

(i) Changes with time in river channel positions and in cross-sectional shapes.

(ii) Sediment build-up due to flow retardation caused by dams or other structures further downstream.

(iii) Sediment build-up, particularly in deep river pools, due to flood attenuation caused by dams upstream.

(iv) Sediment build-up caused by increased sediment loads.

(v) Bank encroachment, particularly during periods without the major floods which would normally have re-established the full channel width.

(vi) Increased sediment and flood levels caused by vegetation becoming established on sediment deposits in the delta regions of reservoirs, as well as (far) downstream of dams. The growth is often stimulated by nutrient-rich run-off from irrigated areas, especially if such run-off occurs during periods when the rivers would naturally have run dry. Alien vegetation tends to cause increased flooding even in the absence of dams.

(vii) Damage to pumps caused by high sediment concentrations and/or large particle sizes. The damage is often increased as a result of high entrance vorticity levels, which lead to cavitation.

(viii) Differing flow patterns during high and low flows.

(ix) Sediment deposition in unexpected areas, e.g. on the outsides of sharp bends in rivers. This is found in steep, rocky rivers where hydraulic jumps are formed within the upstream legs of bends. Sediments carried by the fast oncoming flows are thus deposited in the backwater behind the hydraulic pumps.

(x) Slumping of deposits of (finer) sediments causing blocking of intakes when water levels are rawn down rapidly.

In order to be able to deal with potential problems, it is necessary to recall the most relevant aspects of sediment transport mechanics.

3. SEDIMENT TRANSPORT MECHANICS

3.1 Introduction

This chapter serves to highlight only those aspects of sediment transport mechanics which are of relevance when water extraction works are being planned and designed.
As the dispersion of suspended sediments often plays an important role in the processes of extraction, the hydraulic mechanisms which are involved need to be understood.

Riverine sediment transport is typically dealt with under the headings of

- initiation of movement
- bed load transport
- suspended transport

The following discussion relates to a more comprehensive treatise on the mechanisms of sediment transport (Rooseboom, 1992).

3.2 Initiation of movement.

In the case of cohesionless bed particles, movement will commence under the following conditions: In the case of sediment particles smaller than about 2 mm in diameter (Figure 3.1)

$$\frac{gDs \cdot d}{\nu \cdot v_{ss}} = 1.6 \qquad (3.1)$$

Where g = acceleration due to gravity

D = flow depth

s = energy gradient

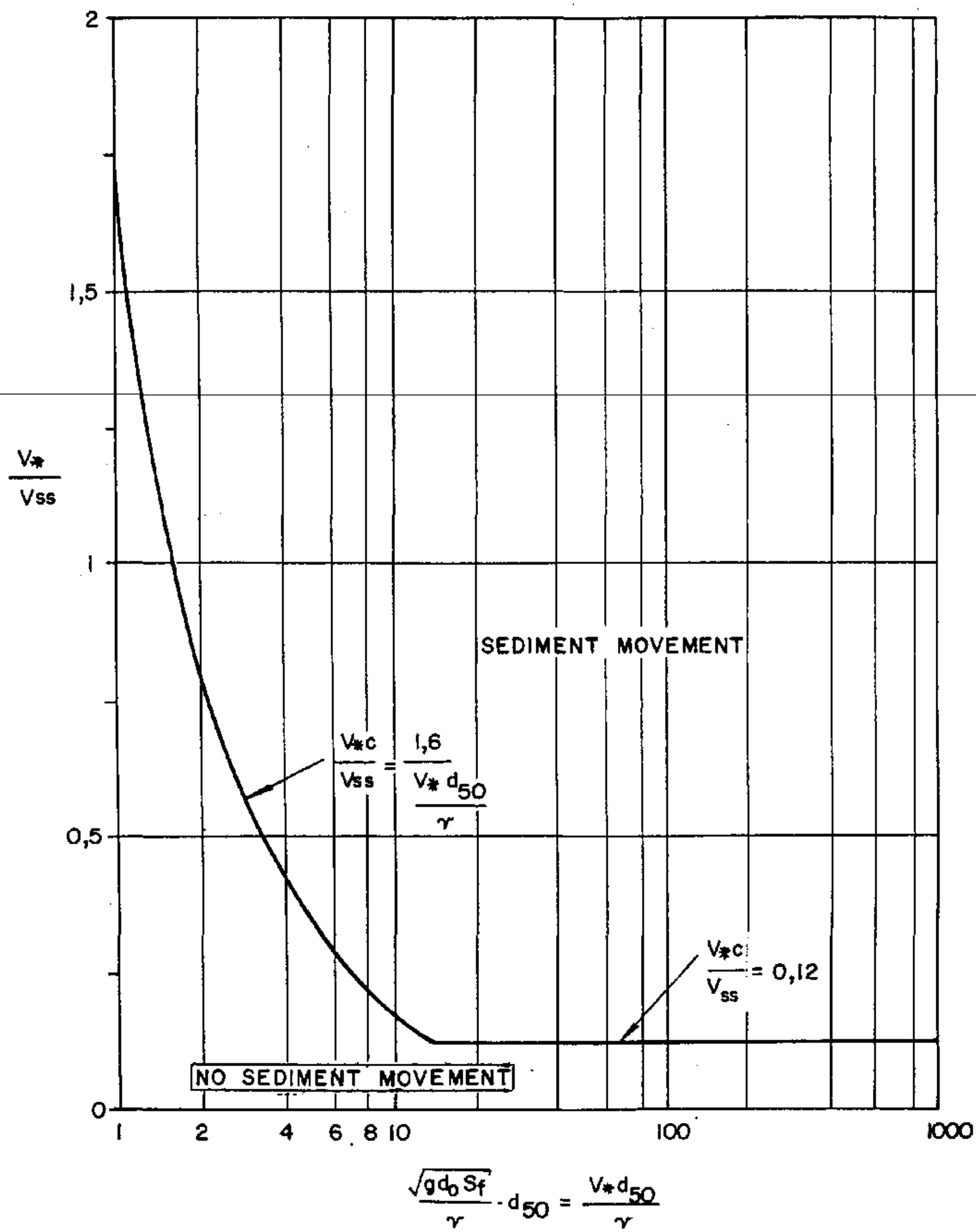

FIGURE 3.1: INITIATION OF SEDIMENT MOVEMENT

d = particle diameter

vss = settling velocity of particles

υ = kinematic viscosity of water $\left(\approx 10^{-6} m^{2}/s\right)$

For particles larger than 2 mm:

$$\frac{\sqrt{gDs}}{v_{ss}} = 0{,}12 \quad \text{.......} \quad (3.2)$$

This latter relationship can be approximated (Henderson 1966) for practical use as

$$d = 11Ds \quad \text{.......} \quad (3.3)$$

Equations 3.1 to 3.3 can thus be used together with the Chézy equation

$$v = C\sqrt{Rs} \quad \text{.......} \quad (3.4)$$

to calculate the average velocity at which cohesionless bed particles will begin to move.

v = average velocity

C = Chézy roughness coefficient

R = hydraulic radius

s = energy gradient (as before)

In the case of deposits that have undergone consolidation and which are cohesive, more sophisticated analyses are required to determine when erosion will start (Basson and Rooseboom, 1998).

What is of importance here is the equilibrium sediment profile, which develops behind a weir. With sediments being fed into a small reservoir without scour gates, equilibrium sediment build-up is soon reached. (Figure 3.2). The remaining storage capacity is thus determined by the sediment profile, which represents the balance between hydraulic sediment transporting capacity and resistance to scour. It has been found (Rooseboom and van Vuuren, 1988) that for a given type of deposited material, the equilibrium profile behind a weir can be predicted. In cases where large capacity gates are provided, relationships which have been calibrated on other comparable reservoirs can be used to model flushing and sluicing operations (Basson and Rooseboom, 1998).

3.3 Bed Load

Once the sediment carrying capacity of a stream just exceeds the critical value, sediment transport takes place mostly close to the bed and this mode of transport is referred to as bed load.
In the context of this document the main application of bed load formulae would be in the calculation of equilibrium profiles - behind weirs and other obstructions. As such calculations need to be performed with relationships that have specifically been calibrated with reservoir data, (Basson and Rooseboom, 1998) the vast array of available bed load formulae will not be dealt with here.

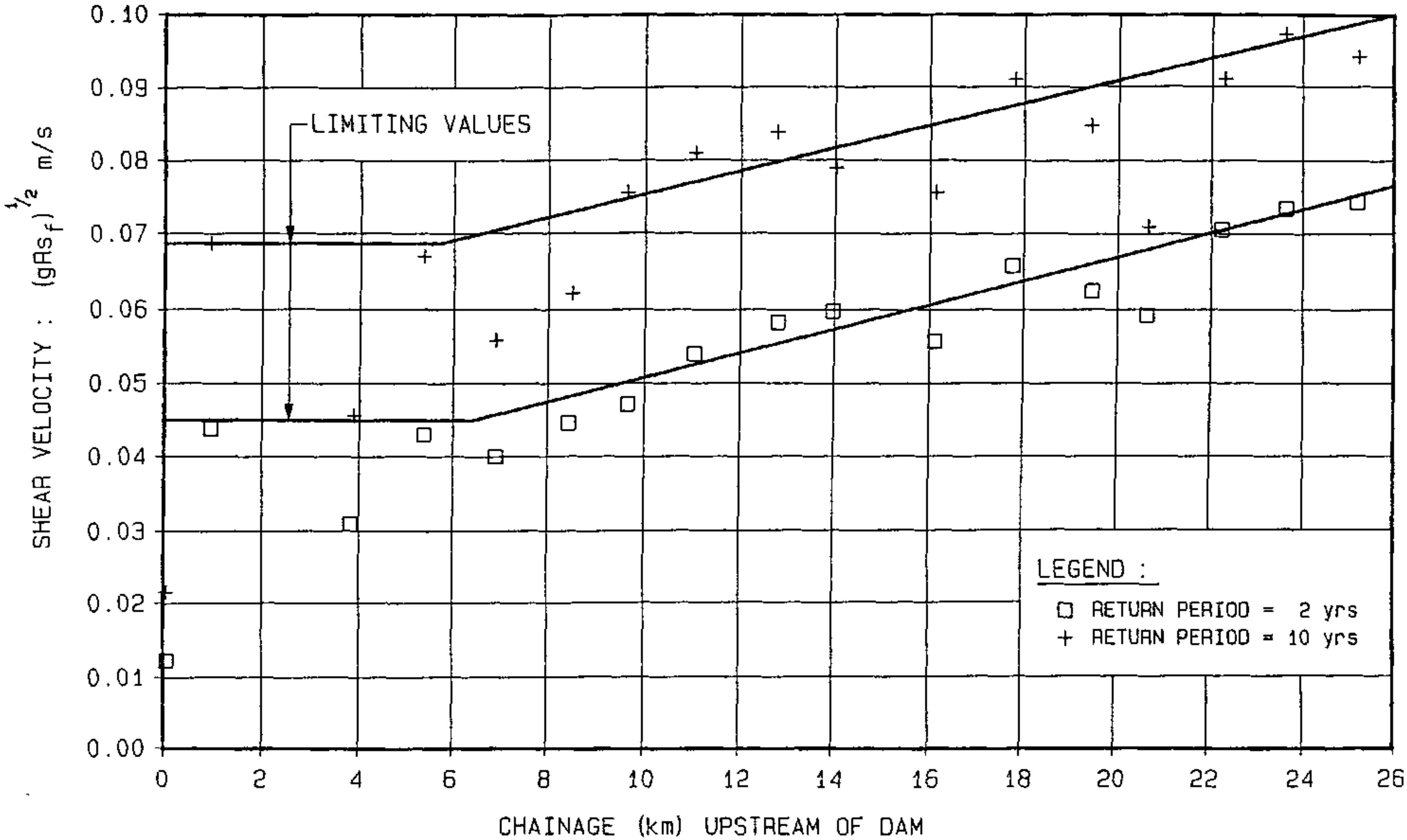

FIGURE 3.2 BUCHUBERG RESERVOIR

SHEAR VELOCITY: DISTANCE FOR FLOODS WITH 2 YEAR AND 10 YEAR RETURN PERIODS

3.4 Suspended load

Sediment particles that are carried by a stream above its bed constitute the suspended load. In the design of water extraction works it is important to understand the mechanisms through which suspended particles are transferred both vertically and horizontally.

Comprehensive mathematical analysis of suspended sediment transport proves that particles are transferred through centrifugal acceleration of the particles within rotating eddies. The centrifugal acceleration that particles undergo is proportional to (Rooseboom 1992).

$$\omega^2 R$$

with ω = angular velocity of the eddy

and R = radius of eddy.

As the angular velocity is equal to the local flow velocity gradient, it means that high velocity gradients and large eddy sizes are indicative of high sediment carrying capacity and also of strong general transfer capacity.

In order to limit suspended sediment transport, velocity gradients as well as eddy sizes should be kept as low as possible. In order to limit the lateral export of suspended sediments from streams, layouts need to be as streamlined as possible in order to limit vorticity.

Vertical variation in sediment concentrations within a stream can be described by the classical formula: (Rouse, 1937).

$$\frac{C}{C_a} = \left(\frac{D-y}{y}\cdot\frac{a}{D-a}\right)^z \qquad (3.5)$$

with $z = \dfrac{v_{ss}}{\kappa\sqrt{gDs}}$

and v_{ss} = settling velocity of particles

υ = von Karman coefficient

g = acceleration due to gravity

D = depth of flow

s = energy gradient

C = sediment concentration at distance y above the bed.

Ca = sediment concentration at reference distance a above the bed.

With very low z-values i.e. with particles small relative to velocities in fast flowing streams, sediment concentrations will vary very little across flow cross-sections and suspensions are nearhomogeneous. As the value of z increases, concentrations near the bed become relatively higher than those above, eventually reaching a stage where suspended transport ceases and only bed load transport occurs. As the value of z decreases further, bed load transport also ceases when the thresholds depicted by equations 3.1 - 3.3 are reached.

In addition to true (turbulent) suspended transport, very small (clay) particles are carried in colloidal suspension whereby the particles are kept in suspension as a result of electro-static charges. Those particles only settle out when the electrostatic charges are neutralised.

4. SEDIMENT TRANSPORT AND DEPOSITION PATTERNS IN SOUTHERN AFRICAN RIVERS

4.1 Introduction

The majority of water extraction works in Southern Africa are found on rivers that transport mainly fine sediments, including clays, silts and sands. The remaining works are found mostly on steep rivers that carry coarse sediments that may include gravel, cobbles and boulders, in addition to fine sediments.

4.2 Sediment concentrations

Where sediment loads consist mainly of fine sediments, the loads are normally found to be availability limited. On the other hand, the loads of coarse sediments are generally determined by the carrying capacities of the streams.

The main characteristic of loads of fine sediments, is their variability. Long term records are therefore required in order to obtain accurate estimates of average annual loads.

In the design of water extraction works, information may not only be required on the average long term sediment load, but also on maximum suspended sediment concentrations that need to be catered for. Unfortunately most of the original South African records of measured sediment concentrations have been lost.

Having processed most of these records, the author can recommend that the following concentrations may be used for design purposes in cases where no records exist and where the size of the project does not warrant a sampling programme:

2% by mass (20 000 mg/1) - this value is likely to be exceeded, particularly during flood events.

4% by mass (40 000 mg/1) - this value is likely to be exceeded from time to time only after exceptionally heavy rainfall storms across the catchment.

6% by mass (60 000 mg/1) - this value is exceeded very rarely and only on rivers that carry heavy sediment loads.

As extreme rainfall events tend to occur over limited areas, the river discharges that carry the highest concentrations may be small. One of the highest concentrations on record of 6.5% by mass (65 000 mg/1) was measured on the Caledon River when the discharge was only some 80 m3/s .

High variability is not only a characteristic of suspended sediment concentrations but also of daily and even annual loads. (Figure 4.1)

As cumbersome and expensive sampling programmes over long periods (5-7 years) are required to determine suspended sediment loads accurately, existing load data is extracted by means of sediment yield maps in areas where loads are availability limited.

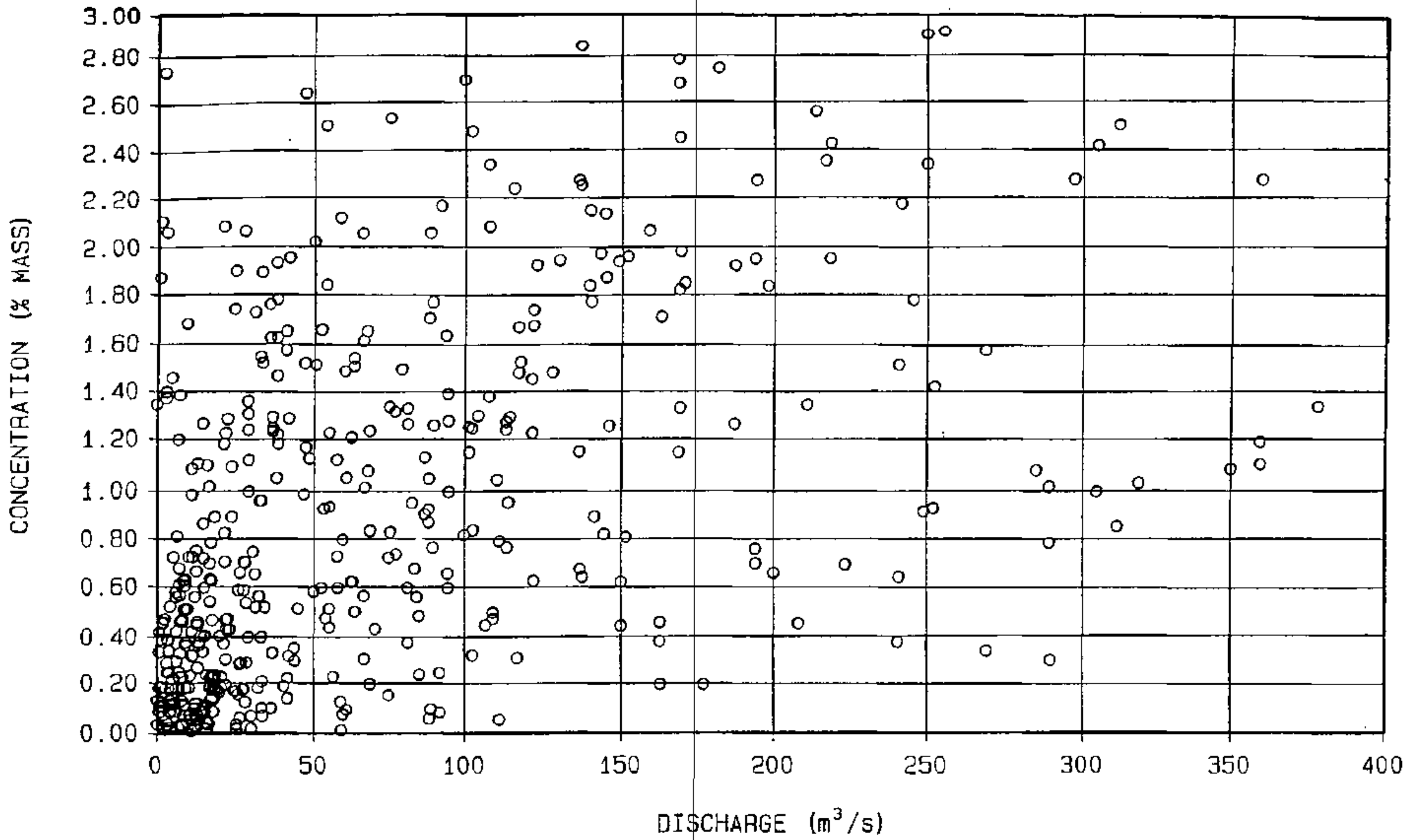

FIGURE 4.1: CALEDON RIVER AT JAMMERSDRIFT : MAY 1969 – MAY 1976
MEASURED SUSPENDED SEDIMENT CONCENTRATIONS : DISCHARGES

4.3 Sediment yields

The data base which has been built up on sediment yields (based mainly on reservoir re-surveys) for different catchments, has been used to develop the most recent sediment yield map of Southern Africa (Rooseboom et al, 1992). This map may be used to estimate average sediment loads where no sediment load data is available (Figure 4.2).

4.4 Sediment accumulation in reservoirs

In many cases weirs form essential components of river extraction works. Not only do weirs provide the necessary heads required to flush and scour sediments from intake areas, they also serve to direct low flows towards intakes. However, the pools behind weirs tend to become filled with sediments.

Unless large gates (with a total capacity in the order of the 5 year peak flood discharge) are provided, a large proportion of the original storage capacity behind a weir is likely to be lost due to sedimentation. The average water storage depths behind weirs may drop to 300mm or even less.

The shapes of sediment deposits behind weirs need to be analysed not only in terms of the threat that they may pose to the extraction works, but also in terms of build-up upstream of reservoirs. Serious problems have arisen due to under-estimation of the extent of sediment build-up upstream of the actual reservoir basins and large additional areas have had to be expropriated. In unfavourable situations, sediment build-up could occur over a considerable distance upstream of the original full supply line (Figure 4.3).

Simplistic empirical rules on sediment deposit shapes as those quoted in ICOLD (1989) have proven to be very unreliable, particularly in the case of small reservoirs.

Prediction of further equilibrium profiles needs to be based on:

(i) determining the equilibrium sediment level directly behind the weir. This is done by determining the level at which the critical shear velocity of the sediments is exceeded.

(ii) step-wise analysis of the equilibrium sediment profile in an upstream direction. It has been found (Rooseboom and Van Vuuren 1986) that as the sediment profile approaches equilibrium, the shear velocity $\left|\kappa\sqrt{gDs}\right|$ approaches a constant value for a specific flood discharge through the reservoir.

g = acceleration due to gravity

D = flow depths (hydraulic radius)

s = energy gradient

More sophisticated routing calculations have become available (Basson and Rooseboom, 1998). Parameters that define critical or equilibrium conditions should be determined from comparable existing deposits, particularly in the case of cohesive sediments.

Vegetation that becomes established on sediment deposits can increase flow resistance and can complicate matters by inducing an increased build-up of sediments as well as by increasing the resistance to scour of the deposits.

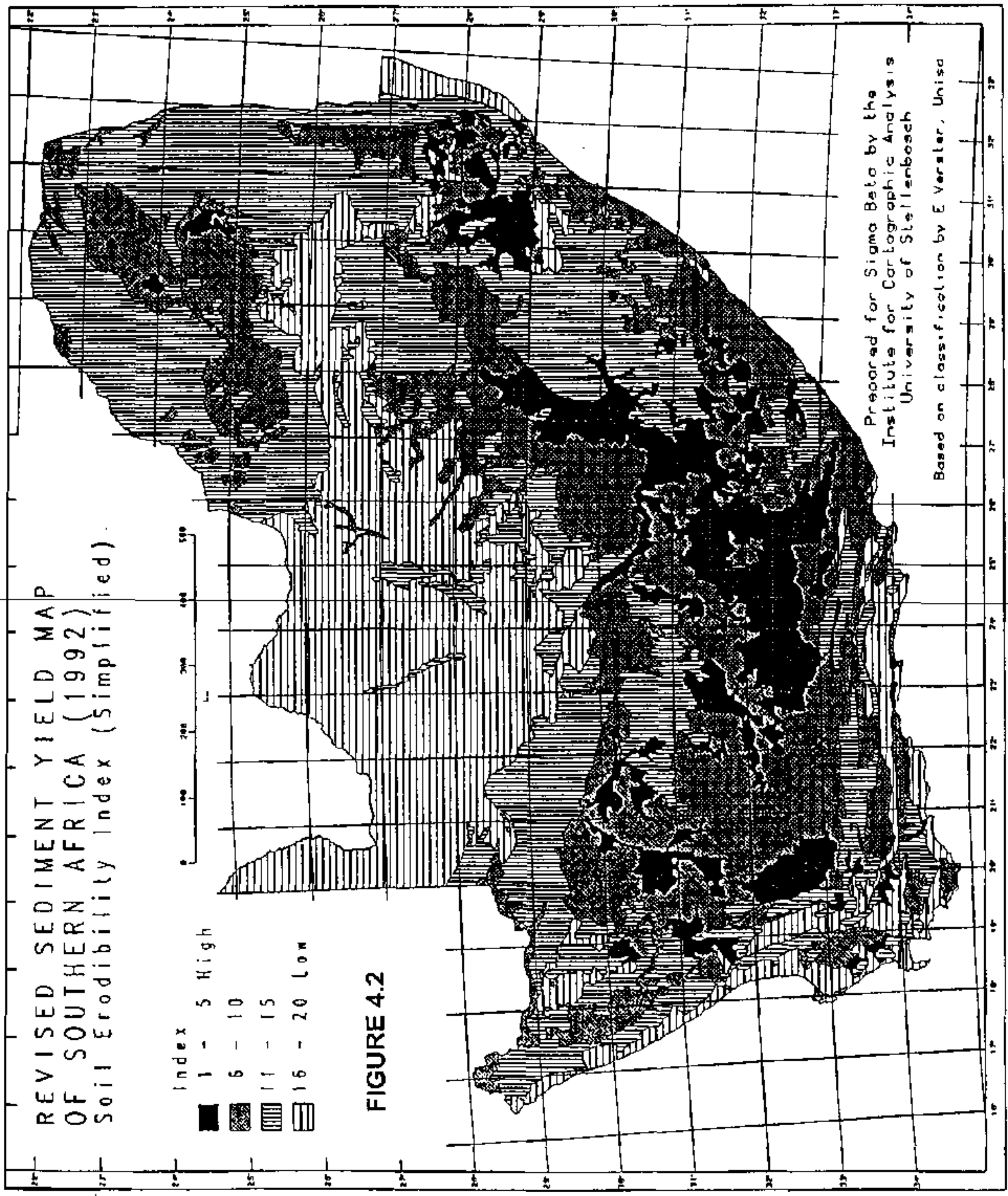
REVISED SEDIMENT YIELD MAP
OF SOUTHERN AFRICA (1992)
Soil Erodibility Index (Simplified)
Index
1 - 5 High
6 - 10
11 - 15
16 - 20 Low
Prepared for Sigma Beta by the
Institute for Cartographic Analysis
University of Stellenbosch
Based on classification by E Verster, Unisa

FIGURE 4.2

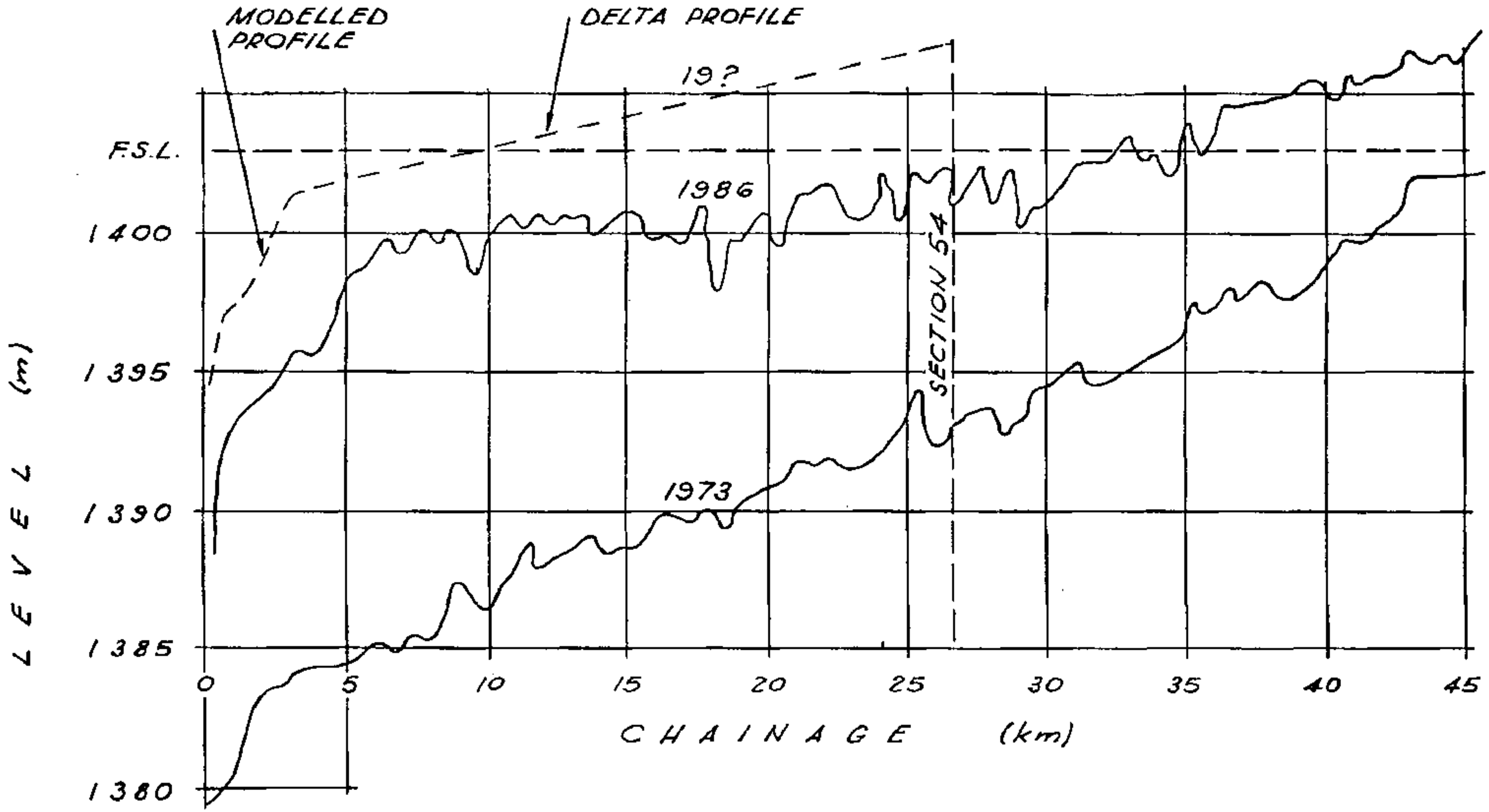

FIGURE 4.3: WELBEDACHT RESERVOIR:
RECORDED AND PREDICTED BED PROFILES

5. WATER EXTRACTION FROM RIVERS THAT CARRY HEAVY LOADS OF FINE SUSPENDED SEDIMENTS

5.1 Introduction

The two main options that are available for the extraction of water consist of:

(i) Installing pumps where there is sufficient natural water depth available and it is not necessary to erect a control structure across the river.

(ii) Creating controlled water and sediment discharge conditions by means of weirs and auxiliary works, which limit the ingress of sediments into pumps or canals.

As low flow conditions are common to most Southern African rivers and natural stable pools are often not available, weirs form essential components of many extraction works.

5.2 Weir-less installations

This category includes pumps that are installed in or alongside natural pools in rivers, often on the outsides of bends in the rivers. Such installations are very common in smaller scale irrigation schemes and have also been used for relatively large temporary pumping projects. They are best suited to stable river channel configurations and limited variations in water levels and are generally too vulnerable to be used in large scale permanent installations. A notable exception is found in the form of pumps that are mounted on trolleys which can be moved on rails up and down sloped banks as river levels rise and fall. Such installations have been used successfully in cases where river levels change slowly and where ample warning time is available with regard to imminent changes in water levels, e.g. along the lower Orange River. These sloping installations have an advantage above wet-well tower installations because they will not extract higher concentrations of sediments than are present in the flowing water.

Pumps mounted on floats to accommodate changes in water levels have not found wide application in Southern Africa, mainly due to the high variability in flow levels as well as problems caused by floating debris.

Pumps have been mounted on the upstream ends as well as the downstream ends of bridge piers. Where debris is a problem, it is better to have a pump at the downstream end of a pier.

The success rate of water extraction towers that were not constructed in conjunction with weirs or dams has been low on Southern African rivers. The high vorticity levels which are typically generated at the inlets of isolated towers not only pose a cavitation threat to pumps but also lead to abnormally high rates of sediment ingress as was explained before. Having been confronted by a number of massive towers with serious problems, the author must sound a warning against their use unless adequate water depths and low enough vorticity levels can be guaranteed. Such towers work best where they are built in conjunction with weirs in which case they form integrated components of the weir lay-outs (See Figures 5.1 and 5.2).

5.3 Weir installations : a basic lay-out

With many of the most suitable sites for storage dams on rivers having been utilised, an increasing number of smaller weirs are being constructed for extracting water from sediment laden rivers, often to provide water to off-channel storage facilities. From a sedimentation point of view it is highly advantageous to have off-channel storage instead of storage on the supplying river. As even relatively small storage reservoirs trap most incoming sediments, storage losses due to sedimentation tend to be

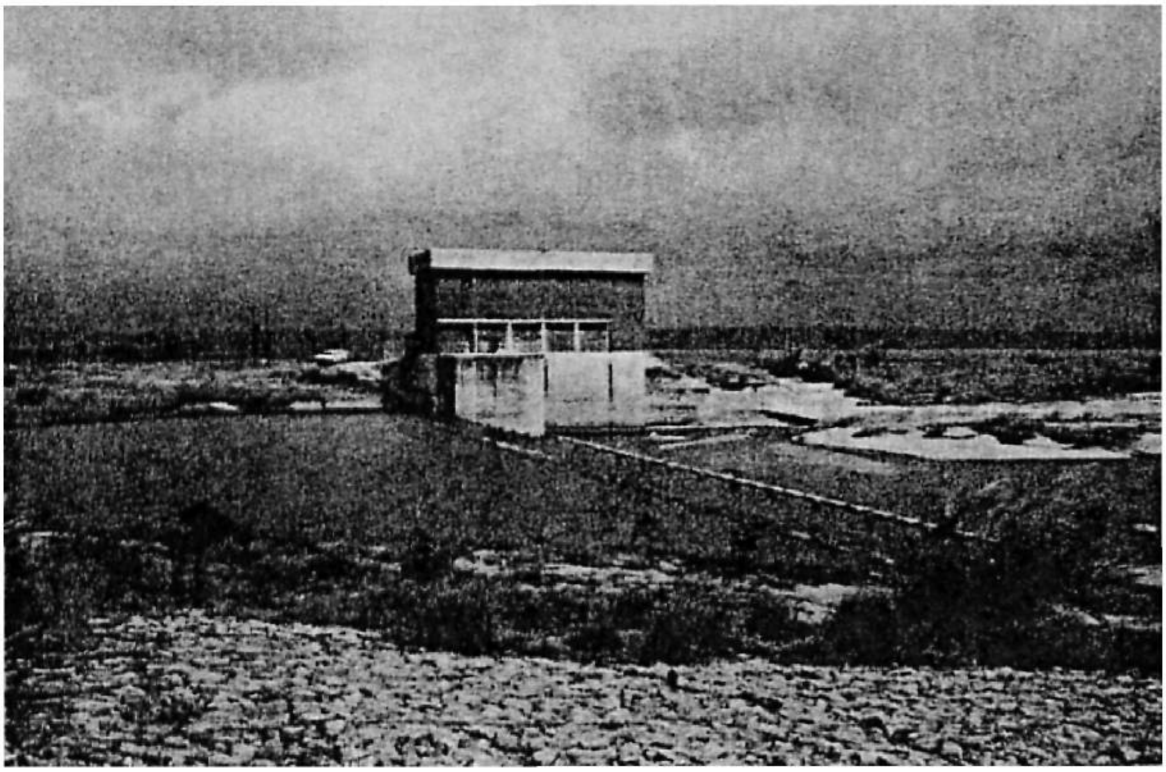

FIGURE 5.1(a) Mhlatuze River – Mhlatuze Water Board
Example of an extraction tower properly integrated with a weir
Photograph: NJ Myburgh DWAF

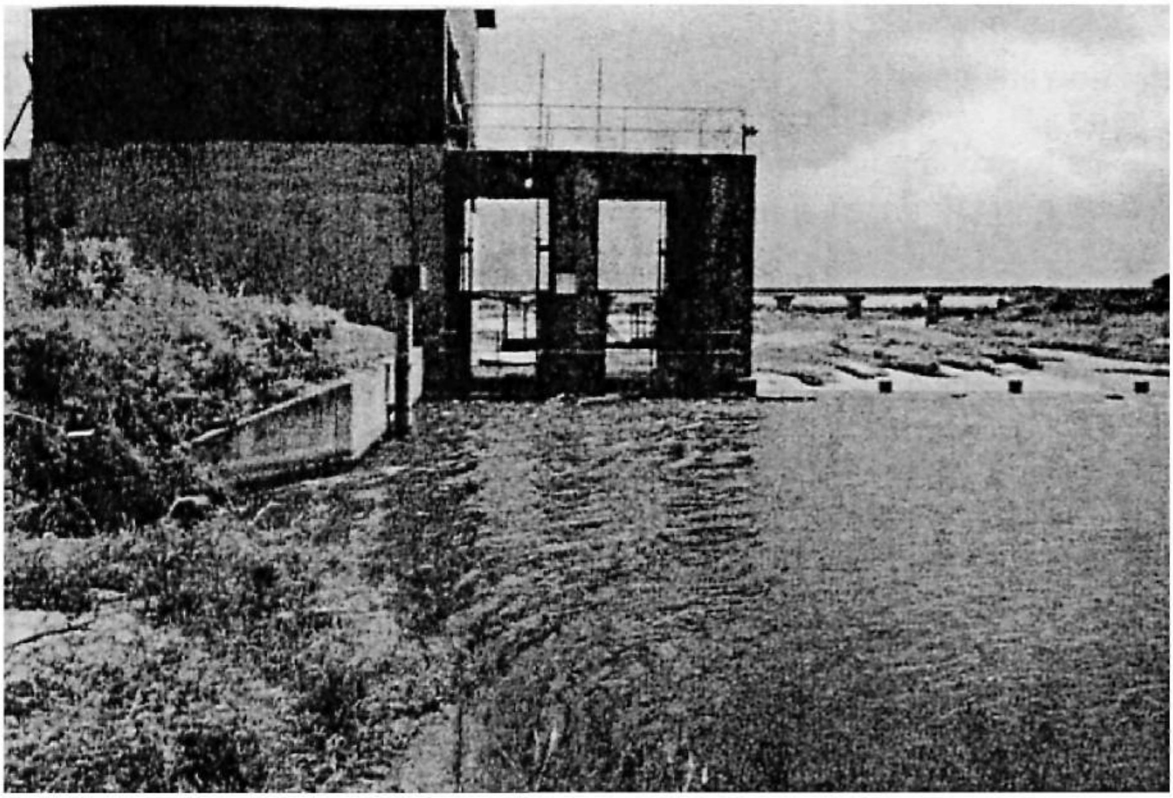

FIGURE 5.1(b): Mhlatuze Water Board Weir
Downstream view of intake area photograph
Photograph: NJ Myburgh DWAF

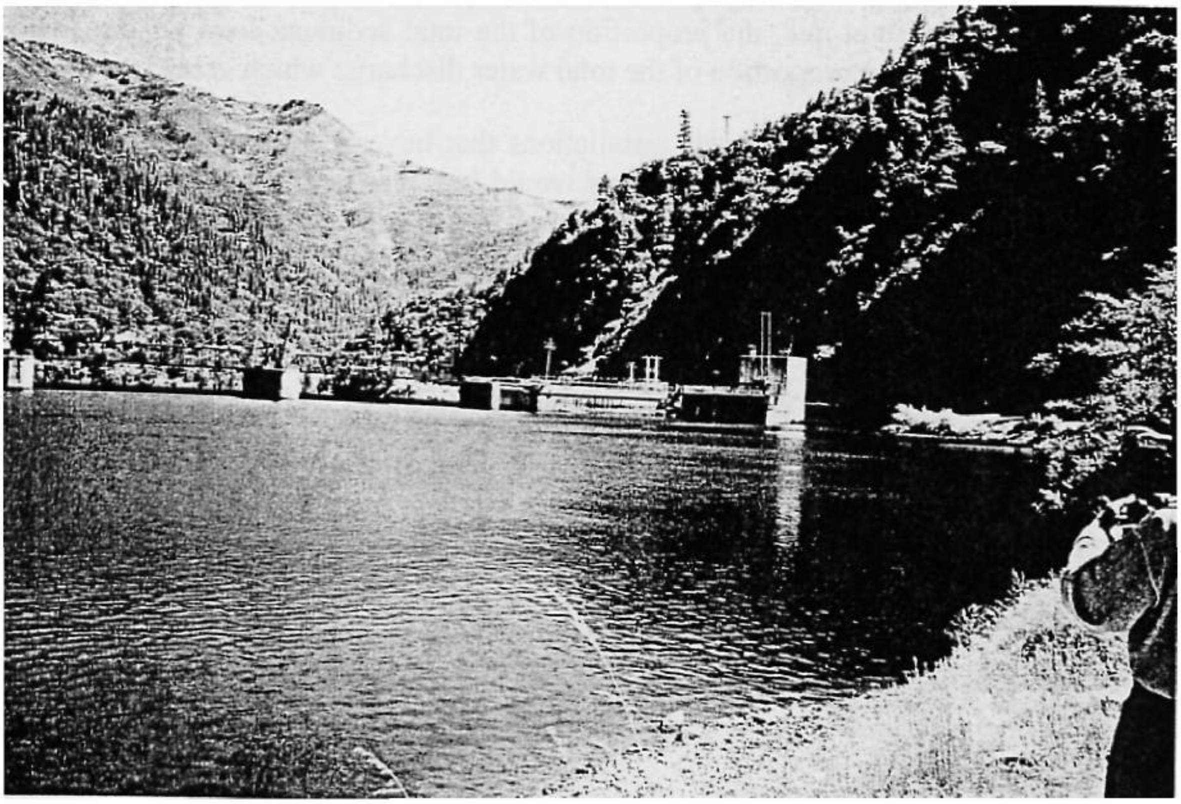

Figure 52(a): Extraction works California, USA
Intake at right bank in line with scour gate. Large sluicing gates to left

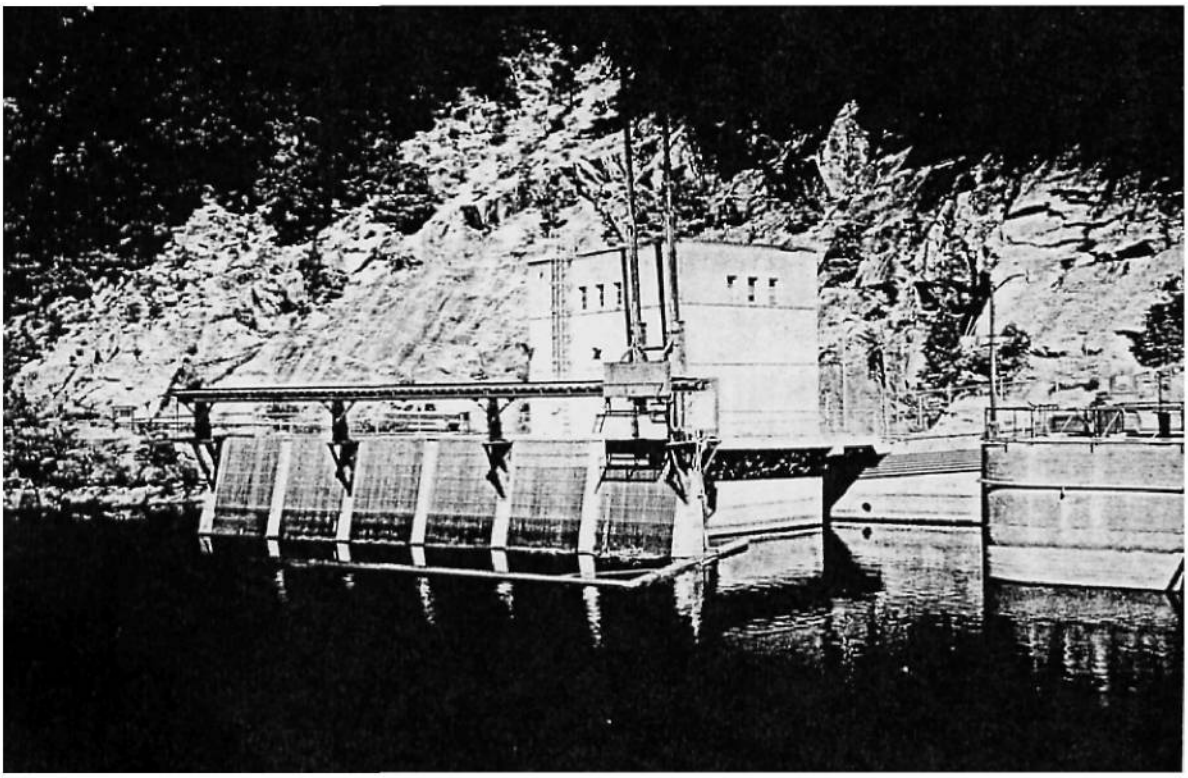

Figure 52(a): Close up view of grid-inlet with outer wall of scour gate
Note flooding boom to keep flotsam out.

much less in the case of off-channel storage. This is due to the fact that sediment concentrations tend to reach high peaks over short periods. If water is thus extracted from a river stream at a near constant rate, the proportion of the total sediment load which is extracted tends to be much lower than the proportion of the total water discharge which is being extracted.

When the collection of information on weir installations that have been successful was started, it was anticipated that a number of different lay-outs would be identified. An "ideal" basic lay-out can however be identified, which can be adapted or simplified to suit specific conditions.

The lay-out as shown is for extraction in a downstream direction. For sideways extraction, the components need to be rotated.

Without a pump station some of the components will fall away where water is being fed into a long distance tunnel or canal.

The basic lay-out (Figure 5.1) may contain:

Weir	A
Spillway	B
Open intake	C
Screen intake	D
Scour gates	E
Scour chamber	F
Collection channel	G
Control gate(s)	H
Transition channel(s) or tunnel(s)	I
Vortex suppressor	J
Settling basin	K
Pumps	L
Low notch weir	M
Groyne	N

In designing the different components, the following should be borne in mind:

A Weir

It is generally accepted that the best position for the weir is somewhat downstream of the halfway mark in a bend of a river. This action however, tends to be dampened by the presence of the weir, as the spiral flow components that work downwards along the outside bank are weakened when flow velocities are caused to decrease.

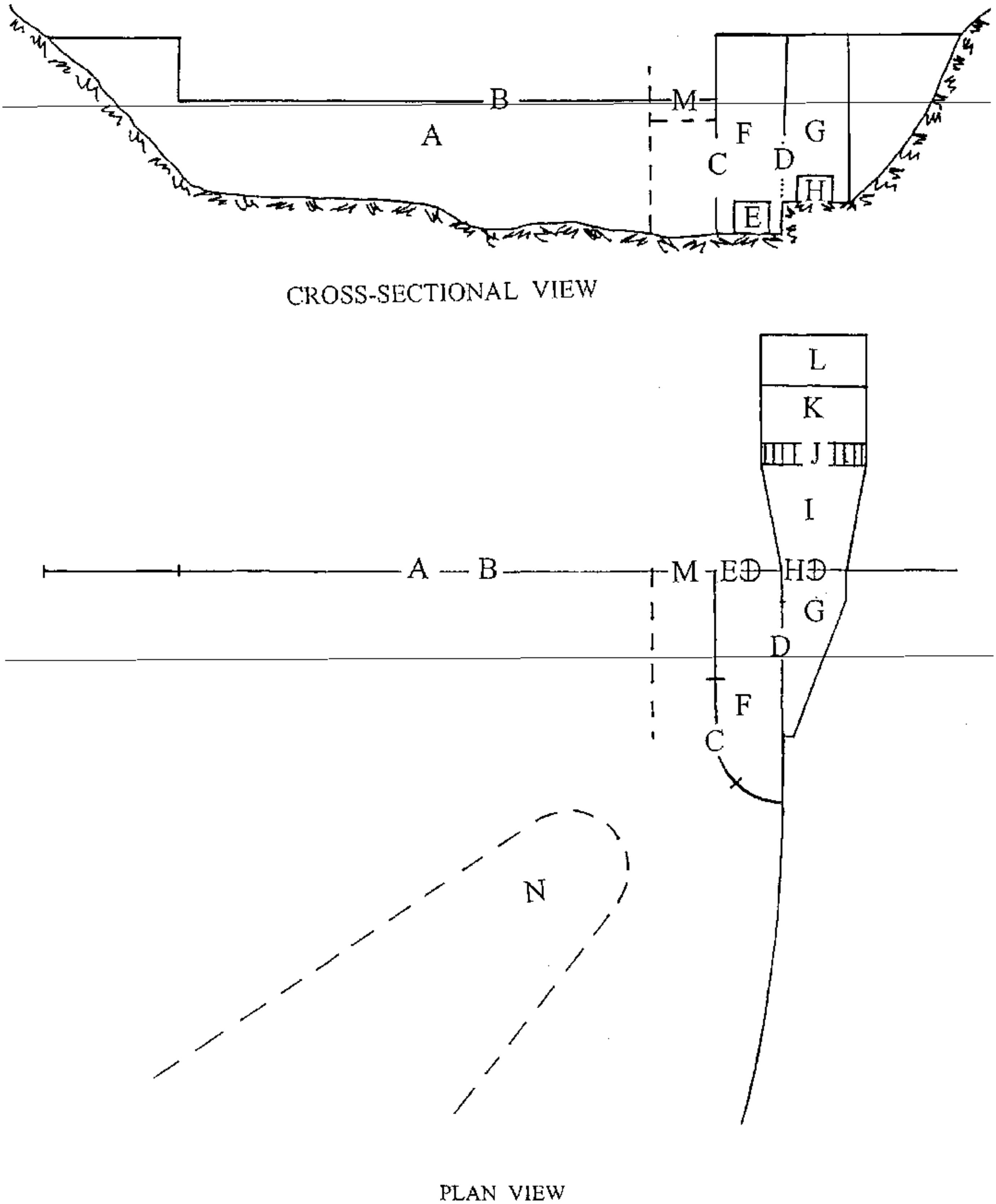

Figure 5.3: Basic lay-out

It is possible on the other hand to induce local scour by increasing velocities and by decreasing flow radii (in plan) by means of groynes or other structures. It has been found possible to create scouring conditions even along the insides of bends by means of such structures.

Not all bends are suitable for the construction of weirs for extraction purposes. The outsides of bends on steep rocky rivers for instance can be subject to heavy sediment deposition during floods. On solid foundations weirs tend to be concrete or rollcrete gravity structures. On poor, erodable foundations Ambursen-type abutment and slab weirs have been successfully employed for extraction works.

B Spillway

The spillway must obviously have sufficient discharge capacity to limit flood damage. An important aspect in this type of spillway design is that water levels downstream of the scour gates need to be low enough to make scouring possible. It is sometimes necessary to enforce a hydraulic jump some distance downstream of the weir for this purpose.

C Open intake

An important function of the wall, which contains the open intake, is to keep floating debris out. For this reason the upper level of the intake opening should be low enough to prevent floating objects from being sucked through. Flow velocities through the opening must therefore also be low enough through the intake. The bottom of the opening on the other hand needs to be high enough to create sufficient gradient for flushing sediments from the scour basin as well as to create sufficient space for temporary accumulation of sediments.

D Screen intake

The screen serves to stop suspended debris. Screen opening sizes therefore depend on the sizes of objects which can be allowed to be passed downstream. As screens tend to become blocked by relatively small masses of debris their openings need to be as large as possible. It is generally more practical to settle suspended debris (as opposed to floating debris) out in a settling basin rather than to trap it with screens. The upper edge of a screen should also be below the water surface in order to limit the entanglement of floating debris (See Figure 5.4).

E Scour gate(s)

Scour gates need to be positioned low enough to keep sediment levels down. At the same time they cannot be so low as to not be able to discharge freely when required.

F Scour chamber

The dimensions and shape of the scour chamber are of major importance. Apart from its function to collect sediments that settle out temporarily, the outer wall serves an important function by inducing scour along its outside perimeter. If properly shaped, the chamber may be considered to be equivalent to half a bridge pier with the capacity to induce deep scour around it, particularly at the upstream end. (Colleague Leon Fürstenburg of Knight Piesold first convinced me of the beneficial use that could be made of pier scour mechanisms at extraction works.)

Given that the scour depth for a pier (and also half a pier) is directly proportional to the pier width, it is beneficial to have the scour chamber as wide as possible from the point of view of limiting sediment build-up around the intake area during floods. However, the high vorticity levels which are typically generated in scour chambers are unfavourable from the point of view of pumps, and it is thus not advisable to pump directly from a scour chamber . The outer wall of the scour chamber should be

**Fig 5.4 (a) Serious clogging of screens by water hyacinths.
Niger River, Mali**

Fig 5.4 (b) Niger River, Mali: Accumulation of water hyacinths.

streamlined and its downstream section should run parallel to the flow direction (in plan) in order to be able to pass floating debris downstream over the spillway crest, particularly where a low notch is provided.

G Collection channel

In order to limit sediment accumulation in the collection channel, velocities here should be relatively high and constant. For this reason the channel floor is raised and it widens in a downstream direction.

H Control gate(s)

Due to their high costs, the sizes of gates are kept as small as possible. This leads to high downstream velocities and excess energy has to be dissipated. Transitions may also be required to develop smooth uniform flow prior to the water reaching a settling basin or pump intakes

J Vortex suppressor

Where vorticity needs to be dampened prior to water reaching pump intakes or settling basins a vortex supressor needs to be installed in order to create smooth uniform flow conditions (See Figure 5.5).

Stacked pipe walls consisting of asbestos cement pipes have proven to be very effective for this purpose. (A pipe length to inside diameter ratio of 10 may be recommended for this purpose).

K Settling basin

Where it is necessary to settle out particles of given sizes settling basins are required. Bouvard (1992), Raudkivi (1993) and Mehrotra (1997) provide valuable information concerning the design of settling basins.

L Pumps

The basic layout can be used in conjunction with either a wet well or dry well installation. The components associated with the pumps can be integrated into a pump tower adjoining the weir.

M Low notch weir

A low notch weir can serve two purposes. Firstly it helps to maintain a low flow channel towards the intake in sediment-filled reservoirs. Secondly it can pass floating debris which accumulates around the intake over the weir. This can be very valuable in cases where large volumes of floating debris such as trash or water hyacinths prove to be a problem.
The efficiency of a low notch weir in passing floating materials can be increased substantially by providing a guide wall, which concentrates flow past the intake wall.

N GROYNES

Groynes and other flow directing structures have proven to be very effective in keeping sediment deposit levels low in front of intakes. As most sediment accumulation takes place during floods, such accumulation can be limited if high scouring capacities can be generated around the intake area. This is achieved through groynes which concentrate flows, pushing up velocities and also by increasing the curvature of flow lines (in plan).

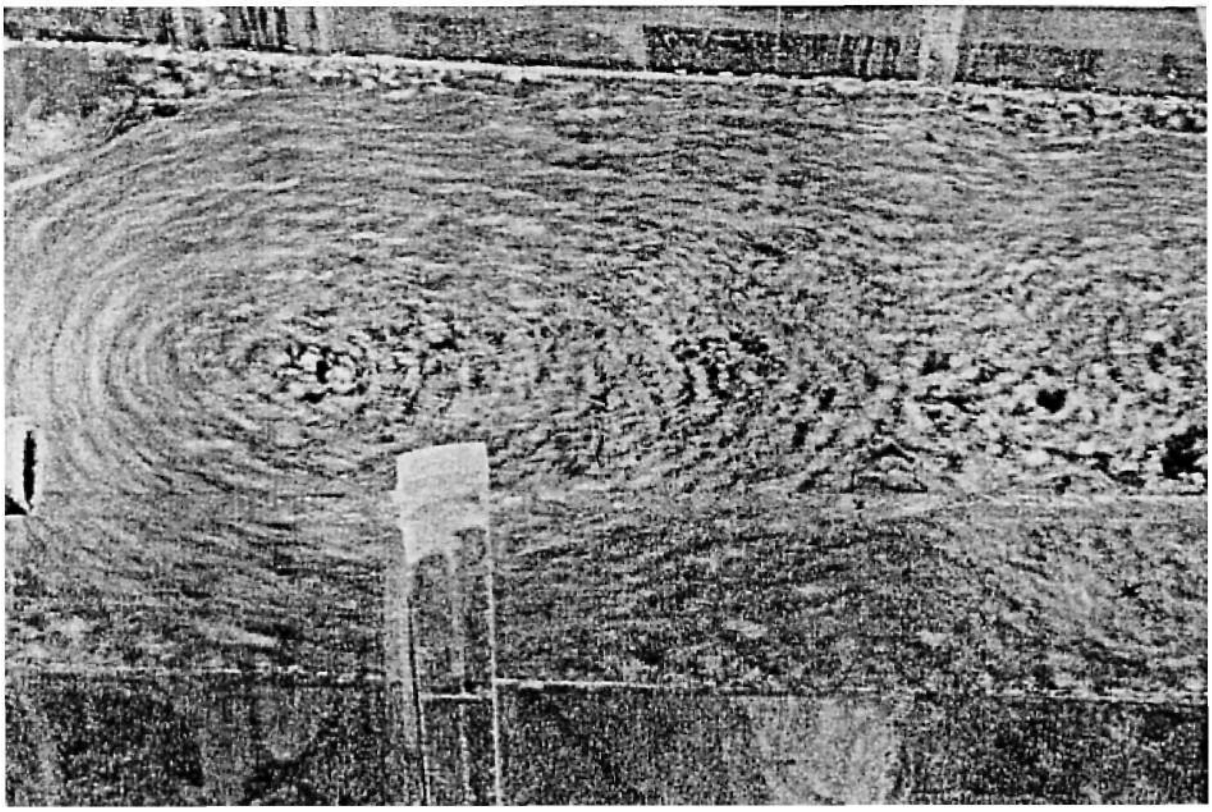

FIGURE 5.5(a): Strongly developed vorticity at pump intake

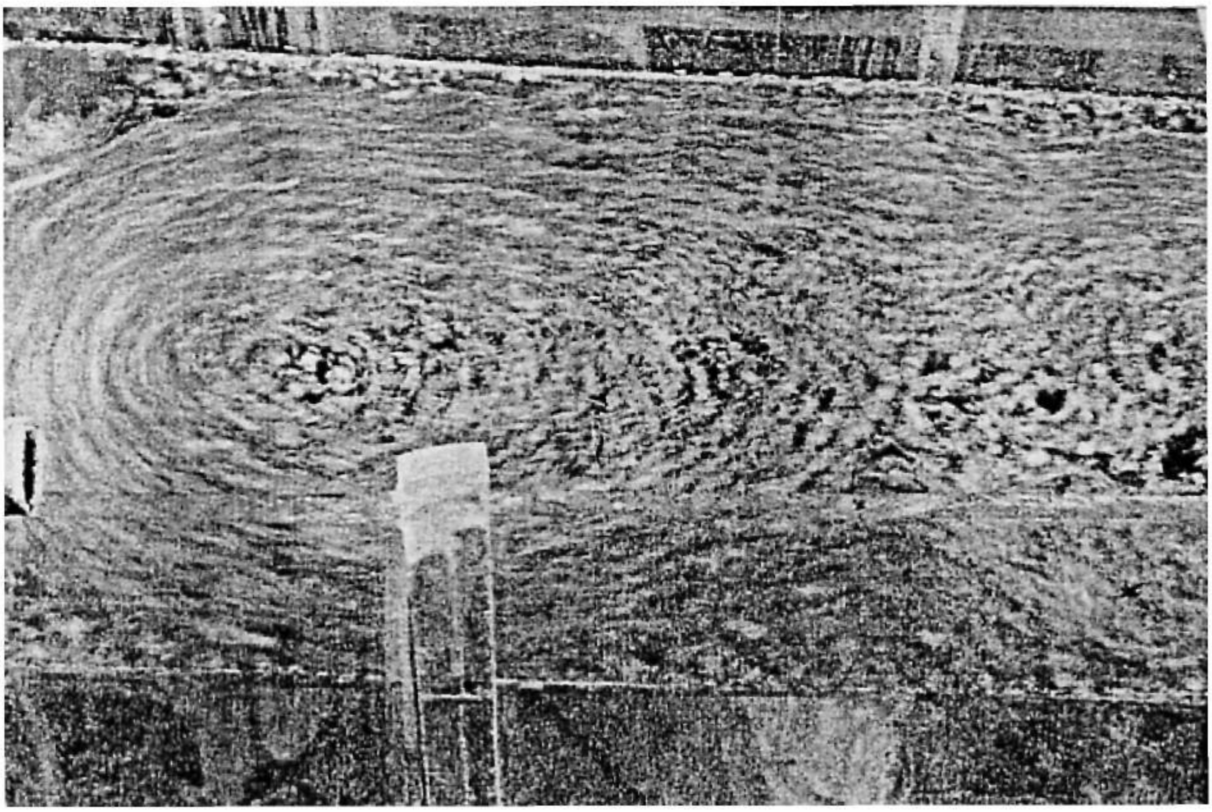

FIGURE 5.5 (b) Vortex suppresor

It is often not possible to design such structures theoretically as small variations in lay-out can impact significantly on efficiency. Physical model studies are thus required to optimise lay-outs.

6. WATER EXTRACTION FROM RIVERS CARRYING COARSE SEDIMENTS – TIROLER WEIRS

Where streams transport large quantities of coarse sediments (gravel, cobbles and boulders) the Tiroler weir provides the only real solution.

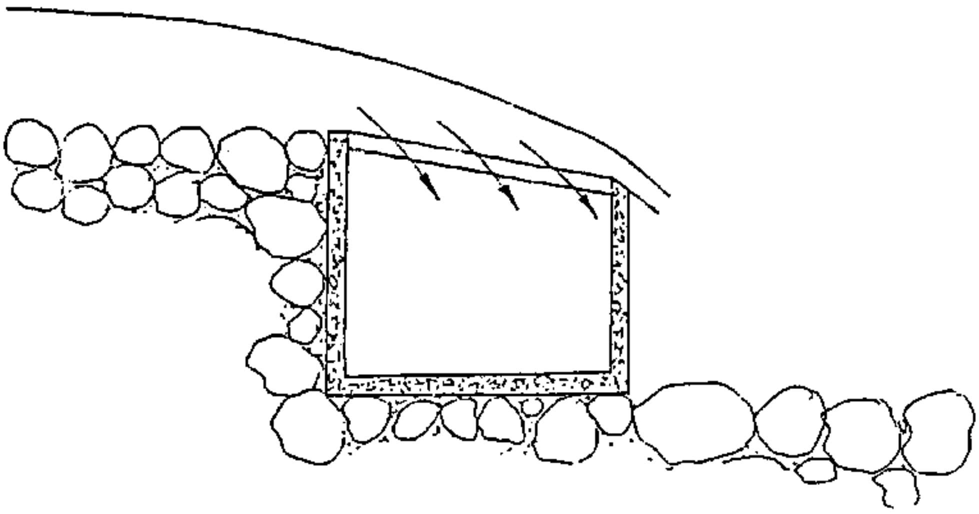

Figure 5:6
Tiroler Weir Cross Section

In essence the Tiroler Wehr (weir) consists of a channel across the bed of the stream covered by a grid, which lets only water and finer sediment through. Sediment particles that are too big to pass through, roll over the grid to be carried further downstream. Water passing through the grid together with the finer sediments is thus passed through a settling basin where the coarser particles are settled out to be flushed back into the main stream, downstream of the weir.

A large head difference is required to be able to transport the particles to the stilling basin and to flush the settling particles back to the river. Tiroler weirs can therefore only be used on very steep river sections unless the sediments which pass through the grid are to be removed mechanically on a regular basis.
For comprehensive design information, the reader is referred to Scheuerlein (1984).

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