Small Farm Dams: A TICKING TIME BOMB?

Many of South Africa's small farm dams have become mere sediment traps threatening the country's larger storage reservoirs, as research in the Karoo indicates, writes John Boardman, Ian Foster, Kate Rowntree, Tim Mighall and Tony Parsons.

South Africa is heavily dependent on storage reservoirs to maintain reliable water supplies at times of water stress. Recent estimates suggest that the country already allocates over 98% of its available water resources and that many storage reservoirs are accumulating sediment at a pace that may make water provision at current rates unsustainable.

Across South Africa a plethora of small farm dams and reservoirs have also played an important role in the economic development and sustenance of rural areas – especially those regions with water deficits or prone to drought. Their role has been one of harvesting runoff to provide water for stock or for irrigation. While major dam projects have received much publicity and their historical significance is well documented, small farm dams have been neglected in the literature and their wider role in the landscape largely ignored.

SEDIMENT TRAPS

The longest monitored sediment yield record in South Africa is from the lower Orange River. It is suggested that the decline in sediment yields after 1950 shown by a 40-year-old record was likely to reflect two key factors: a reduction in the amount of sediment available for erosion, and sediment trapping by farm ponds. The latter contention is supported by work done by the authors, as described below.

The data presented point to small farm dams in badly eroded dryland areas playing a significant role in trapping sediment. Although the exact timing of sediment yield increases and the amount of sediment deposited in these small reservoirs varies in relation to local factors, such as the presence or absence of badlands, the extent of rainfed wheat production, the role of fire, both natural and anthropogenic, and the intensity of grazing, the pattering of the authors' findings shows a consistent increase from the early twentieth century, followed by a declining but still high rate of sedimentation after the middle of the century.

Many of these dams are now full and have lost their trapping capacity; others have breached and are beginning to lose their sediment to the downstream system. Do we now have a situation where the myriad of small dams that protected South Africa's larger storage reservoirs are now providing many small stores of sediment threatening those selfsame reservoirs? This article provides evidence to suggest that this is indeed the case and points to the need for more in-depth research into this sediment 'time bomb'.

DIGGING FOR EVIDENCE

About ten years ago, as part of a project on erosion, runoff and overgrazing in the uplands of the Karoo, the authors started to document small dams. Their interest in the history of erosion led them to look at several dams in some detail in order to reconstruct the depositional history of their sediments and identify the drivers of erosion. This work fitted into the ongoing debate on 'desertification' of the Karoo, but shifted the focus from vegetation change to broader landscape change and, in particular, to the erosional history of badlands and gullies (dongas).

While documentary evidence (farm diaries, oral records etc) had provided important information on the history of land management, the sediment contained in these reservoirs provides an historical record of the physical process of catchment erosion and sediment yield. Where documentary evidence has provided the age of dam construction or re-construction, by coring at several points in the reservoirs the project team has been able to estimate the volume of stored sediment. They have then been able to estimate sediment yields for specific periods since dam building by using sediment characteristics to date the different layers.

Dating the sedimentary layers has relied on ^{137}Cs, first seen in 1958 and peaking in 1965, on variations in unsupported ^{210}Pb activities with depth in the sediment column, and on fine gravel layers which can be association with known storms, for example, four extremely wet days from 1 to 4 March 1974 with 209 mm of

South Africa's Van Ryneveldspas Dam on the Sunday's River at Graaff Reinet has a catchment area of 12,382 km^2. By 2009 it is estimated that there will be around 49,1 million m^3 of sediment in the reservoir, with a remaining storage capacity of only 29 million m^3.

Above: *Compassberg Dam breach. Initial breaching occurred in 2000 and this photo, taken in December 2003, shows the establishment of a new gully that is eroding previously stored sediment.*

Right: *By July 2006, a well established gully was cutting back into the stored reservoir sediments. The gully head has extended around 25 m since 2003.*

COMPASSBERG FARM DAM

Catchment area:	6,33 km^2
Relative relief:	662 m
Average annual rainfall:	498 mm
Land use:	Sheep grazing and former cultivated land on valley bottom
Reservoir area:	3,37 ha
Dam age:	ca. 1935
Current status:	Full of sediment; breached in 2000
Average sediment yield:	490 $t/km^2/y^1$*
Total sediment volume:	ca. 50 000 m^3

**Takes into account estimated trap efficiencies*

rain that brought widespread flooding to the Craddock-Graaff-Reinet region.

Finding old dams has been a challenge and, to date, with the focus on the Karoo, the oldest investigated is at Cranemere (1843), located some 10 km west of Pearston in the Eastern Cape and made famous by Eve Palmer in her book ***The Plains of Camdeboo***. The project team has concentrated on small catchments where the history of land use is known and where, because of their small size, most eroded sediments are not stored on footslopes or hillslopes but reach the dam.

SITE SELECTION

This allows them to reconstruct the history of catchment sediment yields from the sediment stored in the dam. Sites for detailed investigation were chosen partly based on contrasting land uses within the catchments. All have been subject to sheep farming in historical times; some are overgrazed, others less so; some include formerly cultivated areas, some not. Some include badland erosion (an intricate network of small gullies), but in all cases the channel network has been deepened by gully erosion to form the characteristic linear dongas of the Karoo.

Results indicate that, ***in extremis***, badlands probably developed as a result of overgrazing between 1850 and 1950. Once established they persist and even reduced stocking rates seem to have little direct effect in terms of re-colonisation of grasses and shrubs. In parts of the area, dryland wheat production on valley floors, especially in the first half of the twentieth century, led to severe erosion and badland formation. However, badlands have also appeared in the catchments where there is no documentary evidence of cultivation.

GANORA FARM DAM

Catchment area:	2,78 km^2
Relative relief:	281 m
Average annual rainfall:	338 mm
Land use:	Grazing; includes about 15% badland areas
Reservoir area:	5,23 ha
Dam age:	1910
Current status:	74% full and unbreached
Average sediment yield (1939-97):	662 t/km^2/y^1*
Total sediment volume:	109 303 m^3

*Takes into account estimated trap efficiencies

One of the more surprising conclusions of the work is that the extensive gully systems appear to have been fully developed before the first aerial photographs were taken in 1945 and have changed little since, contributing little sediment to the dams. At present, they act as efficient conduits of water and sediment between the main source areas – hillslopes and badlands – and rivers and dams. Erosion of gullies in the nineteenth century under intense grazing pressure seems most likely, and there is some documentary evidence to support this.

Documentary evidence has, in some cases, provided the age of dam construction or re-construction. Estimates of dam trap efficiency have continued to be a challenge, especially at Cranemere where the dam wall has been raised on at least three occasions since it was first built in the 1840s.

Badland at Compassberg in the Sneeuberg.

SEDIMENT STORAGE IN SMALL DAMS

While investigating a small number of dams in detail the authors have become aware of the number and variety of these small dams. Mapping an area of just over 80 km^2 revealed 95 small dams. Their age and size vary. Some are still functional in terms of holding water, but many are now full of sediment, may be breached, and are no longer capable of water retention.

Estimating amounts of sediment stored in the small reservoirs is difficult, but details of two typical ones at Compassberg and Ganora are provided in the boxes on pages 32 and 33. Sizes vary, but 50 000 m^3 of sediment per dam would seem a reasonable estimate. A very conservative estimate of sediment storage in small reservoirs would be 2 million m^3 in an area of 100 km^2. Assuming a sediment density of around 1,35 t/m^3 this would be equivalent to a store of 27 000 t/km^2.

DAM BREACHING AND SEDIMENT LOSS

Most dams in the area investigated are earth-built, with only 18 stone-built ones often constructed with assistance of government grants in the mid-1950s and one as recently as 1980. With the exception of the latter, all stone-built dams are full of sediment and currently store no surface water. Breaching of stone-built dams is rare, but has happened on occasion, resulting in stored sediment being released directly into the channel.

Those dams constructed of earth may have a stone-built spillway or a spillway on bedrock which resists erosion. However, during exceptional rainfall events the dams fill, the spillway cannot cope and overtopping occurs at the lowest point of the earth wall. This may result in erosion of the wall and the development of an incised channel through the dam sediment.

Of 95 small farm dams mapped in the Sneeuberg, 46 (48%) are full of sediment and incapable of water storage. Of the 95, 28 of the dams are breached and therefore potential sites of sediment loss. Having acted for up to 170 years as sites of water and sediment storage the reservoirs are now beginning to act as sources of sediment in that gullies are eating back into the sediment fill.

For example, the Compassberg Dam wall was breached as a result of 118 mm of rain on 24 March 2000; the dam was already full of sediment. Since 2000, a gully has begun to eat back into the sediments in the reservoir above the breach. Breaching is also occurring as a result of animal burrowing activity in dam walls. Many dams are therefore providing a ready source of sediment to downstream sections of rivers and reservoirs. If the authors' conservative estimates of 27 000 t/km^2 are correct, there is a large volume of sediment waiting to be mobilised in a relatively short time.

BIG DAMS

Amounts of sediment stored in big dams are given in Roosemboom et al. (1992). Generally their figures apply to a period before the mid-1980s. To estimate current storage some extrapolation has to be done.

The nearest big dam to the study area in the Sneeuberg is the Van Ryneveldspas at Graaff Reinet. This dam on the Sundays River, has a catchment area of 13 382 km^2 and surveys show that about 47 million m^3 of storage capacity remained in 1978 with about

Badland in the Sneeuberg; willows in the distance occupy the site of the infilled small dam.

31 million m³ sediment partly filling the reservoir. This suggests an average deposition rate of 584,906 m³/y and that by this year there will be around 49,1 million m³ of sediment in the reservoir with a remaining storage capacity of about 29 million m³. At present rates of sediment transport this suggests a dam life of about 50 years.

POTENTIAL IMPACT OF SMALL DAMS

It is not known how many small farm reservoirs there are in South Africa, however, the project team was surprised by their density, and their sediment storage capacity, in a small area of the Sneeuberg.

A simple and conservative extrapolation from mapping in the Sneeuberg suggests that in a catchment of 13,382 km² (the area of the catchment of the Van Ryneveldspas Dam) there could be as many as 10 000 of these reservoirs. If each is the size of the Compassberg reservoir, containing about 50 000 m³ of sediment, then there is a potential for around 500 million m³ of sediment storage in the catchment.

The sediment stored in Sneeuberg dams is largely fine-grained – it is not coarse bedload. The potential for movement as suspended load means that the material could reach large dams quite quickly.

The increasing availability of small farm reservoirs which are full of sediment, and perhaps the continuing failure to repair breaches, suggests that the sediment yields in rivers will increase and large reservoirs will fill quicker than in the past. However, available potential sediment for downstream transportation exceeds the remaining capacity of a reservoir such as the Van Ryneveldspas by an order of magnitude.

Such crude calculations also ignore changing climate – in the Sneeuberg at least there is good evidence for increased intensity of rainfall events over the last 50 years, a continuation of this trend would lead to an increase in breaching and more rapid sediment evacuation from dams. There is also evidence of changing land use. The effect of changing land use is difficult to predict since decreasing stocking rates should be influencing runoff and erosion, but changes in farm practice from dominantly sheep to wildlife/conservation are introducing an unknown factor.

FUTURE WORK

The above analysis, based on evidence from a small number of farm reservoirs in the Sneeuberg area of the Karoo, has pointed to a potential problem of significant magnitude; these reservoirs, small in size but large in number, provide a ready source of sediment for the larger storage reservoirs downstream.

The project team aims to assess the actual number of small reservoirs in a major catchment that has a storage reservoir at its downstream limit. In addition, there is a need to know the approximate volumes of stored sediment within these farm reservoirs and the rate at which the sediment is being released from dams that are breached. The research will involve construction of a GIS database in which information for individual reservoirs will be stored and field surveys to calculate sediment storage and rates of sediment release.

Dates of breaching will be established through interviews with local land owners and by an analysis of farm diaries, historical photographs, aerial photographs and satellite imagery. Of particular concern in this project is the number of breached dams and the rate at which sediment is being recycled from these sites to impact on downstream river systems and, more importantly, the rate at which sediment is likely to be reaching large reservoirs.

Give the present estimates of the amount of sediment stored in farm reservoirs, they may indeed be a ticking bomb that may leave South Africa facing a water crisis much sooner than anticipated.

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