APPROPRIATE METHODS TO PROVIDE SUSTAINABLE WATER SUPPLY IN EXISTING DAMS

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ABSTRACT

South Africa is fast approaching a crisis in the demand for water due to numerous reasons. This is a semi-arid region with an average rainfall of less than 500mm pa. Although there are about 1500 water supply dams in SA, the potential for new dams is severely limited. With the increase in dam losses due mainly to sedimentation and the phenomenon of reducing and variable rainfall, we need to find methods to augment the water supply in our existing dams to meet the increasing demand. This paper discusses the problems of water supply and some methods to address the problem.

1. INTRODUCTION

Water, unlike electricity, is a finite resource in South Africa. With the increase in population; improved standard of living; developing industry; increased need for irrigation for food security; the demand for water is increasing rapidly.

Further, our ageing dam infrastructure of about 1500 medium to large water supply dams have lost considerable storage from sedimentation. The effect of global warming is now having an effect on high evaporation rates as well as more extreme events in floods and droughts.

This puts a significant constraint on our countries' water supplies. We have a limited potential to build more dams, as well as the cost, social and environmental issues attached to new dams.

One way to address these problems is to utilize existing dams and provide effective methods to raise the full supply levels (FSLs) to gain additional water storage.

2. THE PROBLEMS

2.1 The increasing demand for water

2.1.1 Population

The population is increasing rapidly. This is due partly to improved health facilities to reduce mortality; as well as influx of people from neighbouring SADC countries. The trend indicates that the increase in population migrates to the urban areas whereas rural population increase is low.

The government has undertaken to provide water to nearly all citizens, thereby increasing the demand to millions of people who previously did not have piped water.

Further, with the increase in job opportunities, most people's lifestyles have improved considerably and with improved lifestyle comes increased water usage.

2.1.2 Industry

The increasing supply of industry, mining and power-generation to meet a growing South Africa, requires increased demand for water.

2.1.3 Agriculture

Even though agriculture accounts for more than 60% of water in SA, there is increasing demand for agriculture to produce more food and hence the requirement for more water.

2.2 Losses

Whilst there are considerable losses due to:

- aging and leaking pipelines and fittings
- unrecorded and illegal connections resulting in unaccountable usage and loss of revenue
- inefficient irrigation practices
- illegal abstractions from rivers and dams
- sedimentation due primarily to disturbed and poor land use management

these are not discussed in detail here, except for sedimentation.

Of about 50 dams surveyed for sediment accumulation in the 1980/90's, the total volume lost to sediment was in the order of 1555 million m^3 over an average 10 - 15 year period. This amounts to almost 150 million m^3 per annum which is equivalent to one large dam capacity lost per year!

Even though dam design makes provision for loss of storage to sediment, it nevertheless is a considerable loss. Unfortunately this is a reality we must live with as measures to reduce sediment loss have not been very successful.

2.3 Variable rainfall

South Africa has always suffered from periods of extreme rainfall, from floods to droughts and dam engineers take this into account in determining the assured yield of the dam.

However, there is now growing evidence that the extremes in climate are increasing. This is attributed to the effects of global warming.

With increased temperatures, evaporation rates are higher. With increased frequency of flood producing rainfall of high intensity, dams are filled to overflowing and valuable water lost to the sea. Further sediment loads increase from erosion from extreme floods. The durations of low rainfall are increasing leading to prolonged droughts. These all adversely affect the dam and the assured yield reduces as a consequence.

2.4 Ecological Reserve

The provision of additional water in dams for the ecological requirements of the downstream river, has largely been overlooked in our dams in the past. This has led to poor water quality in the river systems downstream of dams, with adverse effects on both human and riverine ecology downstream of dams.

Consequently the ecological reserve has become a fundamental provision in the National Water Act of 1998 and dams are required now to provide storage for ecological releases from dams. Whilst the ecological reserve varies between dams, it still can account for about 10 - 20% of the total capacity.

Further, in order to stimulate early reproductive cycles in riverine species, it is necessary to release a large amount of water from the dam to simulate an early seasonal flood. The flow rate to produce this is not readily produced by bottom outlet valves, and a gated system is then required for large discharge. The Berg River Dam is the first such dam in South Africa to release up to 200 m^3/sec for environmental purposes.

3. HOW TO EXTEND WATER RESOURCES

This requires a multi faceted approach which includes:

- reducing losses
- reducing usage
- reusing effluent water
- constructing more dams
- inter-basin and cross country transfers
- desalination and
- increasing the storage in existing dams

4. RAISING DAMS

Increasing storage in existing dams is probably the quickest and most cost effective means to gain more capacity.

The advantages of raising dams are:

- a modest raising of 2m to 4m can result in a 10-50% increase in storage volume depending on the dam characteristics
- therefore by raising about 5 dams it is equivalent to approximately one new dam
- there is a minimal environmental impact in the supply of construction materials, displacement of communities and adverse impact on flora and fauna
- considerably less cost than building a new dam and
- shorter time to construct and impound to gain the valuable water supply

5. METHODS TO INCREASE DAM CAPACITY

These are essentially done by using:

- conventional construction

- electro-mechanical gates
- automatic spillway gates
- removing sediment

5.1 Conventional construction

This is done using conventional methods of quarrying for additional fill and or rock, placing and compaction to the existing embankment to provide additional strength required for the raising. The spillway and abutments are raised in mass or reinforced concrete and often are also anchored to the rock to provide additional stability.

There is a reasonable adverse environmental impact in providing the construction materials as well as the construction activity of traffic, noise and air pollution and it has a high carbon footprint. Further by providing a fixed raised spillway, the high flood level and backwater effect increases, leading to the purchase of more land above the previous high flood level which will be inundated by the raised high flood level.

A fixed raising also does not provide a sufficiently large release of water for downstream environmental flows.

Raising dams by conventional means is also more costly than the alternatives as well as taking a longer time to construct and impound water.

However, in South Africa, conventional raising of dams is preferred, for good reasons, over some of the alternatives in raising dams.

Nevertheless, with the increasing demand for water and the constraints on the fiscus, conventional raisings should be carefully considered against the advantages of the alternatives.

5.2 Electro-mechanical gates

These gates require an external source of power, mainly electrical, to operate them.

The most common of these gates in South Africa are radial and vertical lift gates.

They are not favoured in Southern Africa because they require ongoing maintenance and are prone to failure. The assurance of operation is uncertain especially on dams in remote locations. However, they are acceptable on large category III dams where there is a permanent operator presence at the dam.

5.3 Automatic gates

These essentially fall into 3 categories:

- rubber dams
- fuse gates
- self opening and restoring gates

5.3.1 Rubber Dams

The rubber type dams, such as the Bridgestone and Obermeyer gates are used overseas, mostly in northern hemisphere countries and have not found application in South Africa.

There is an element of mechanism required to inflate and pressurize the bags, some of which have been recorded to fail in some cases, thereby losing the additional stored water.

5.3.2 Fuse gates and embankments

These gates or earth embankments are fixed structures on the spillway which are designed to fail at a certain high recurrence flood event. Once the fuse gate or embankment fails, it passes the flood to ensure dam safety but the additional storage obtained by the raising is then lost. It can then also take some time to restore the fuse such that impounding of the dam cannot commence immediately. These fixed type structures also cannot release water for environmental purposes.

5.3.3 Self opening and closing gates

These are gates which attach to an existing spillway to increase the water level in the dam. When a flood occurs and the water levels rise over the gates, the gates will open automatically and sequentially to release the flood waters in proportion to the inflowing flood hydrograph. When the water level recedes after the flood has passed, the gates will close automatically to retain the increased full supply level.

These types of gates are the:

- TOPS spillway gates suitable for ogee and side channel spillways which can increase water levels from 0,5 to 8m.

Photograph 1 TOPS Gate open to pass flood water at Mnjoli Dam, Swaziland

- FDS crest gates which are suitable for ogee type spillways and which can raise water levels from 0,5 to 4m.

Photograph 2   2m high Crest Gates, Australia

- FDS Scour gate which is used in low dams up to 15m and river weirs. Its primary function is to remove sediment whilst it is still mobile during floods.

Photograph 3   Large Scour Gate under 10m head at Matsoku weir, Lesotho highlands Water Scheme

These types of gates do not require any external source of power, either electrical or mechanical, to activate them. The activation to open and close is automatic and is determined by water levels only.

These gates do not require regular maintenance or control systems and consequently are suitable for dams in remote locations.

They have the added advantages of:

- minimizing high flood levels and therefore land compensation costs and relocations
- opening manually to release large flows for environmental purposes when required
- cost effective and quick to install for early impounding of the dam
- closing automatically to retain the increased full supply level

A number of these types of gates have been installed and working well on dams and weirs in Southern Africa.

REMOVING SEDIMENT

South Africa has lost and will continue to lose a considerable volume of storage in river weirs and dams due to the accumulation of sediment. Some river weirs have silted up completely .

Photograph 4 Typical river weir which is totally silted up. Note the degradation of sediment on the downstream side, which is also an ecological concern.

Professors Rooseboom and Basson in WRC report № TT91/97 on dealing with Reservoir Sedimentation, have indicated that to have any chance of effectively maintaining a weir free of sediment, the gate should be able to pass in the order of a 1:2 year flood peak. This usually requires a large outlet area, often considerably more than what is provided by present outlets.

On the Runde River in Zimbabwe, a TOPS gate 12 m long by 4 m high was installed to pass a 1:2 year peak and has worked regularly to open to pass floods over the last 10 years**.**

Photograph 5 TOPS Scour Gates on the Runde River, Zimbabwe

Photograph 6 River reach upstream of Runde weir with negligible sediment build up over 10 years

Even large dams such as the 30m high Gilbert Eyles Dam in KwaZulu Natal is totally silted up and its function as a water supply dam is lost.

Photograph 7 30 m high Dam in KwaZulu Natal totally silted up!

6.1 Retrofitting Scour Gates

It is possible to recover a substantial volume of storage lost to sedimentation behind weirs and medium sized dams. This can be done by a series of successive flushes but only during periods of higher than normal flow in order to recharge to the weir after each flush.

An automatic scour gate can be retrofitted to an existing concrete weir or dam spillway. It requires careful design of the existing structure to accommodate the scour tunnel and float chamber. This work may be constructed against a full head of water and therefore requires careful construction.

However, once the gate is installed, the weir can be flushed a number of times and once most of the sediment is removed, the scour gate will minimize the sediment build up in the weir or dam.

The method of doing so is shown in fig. 1.

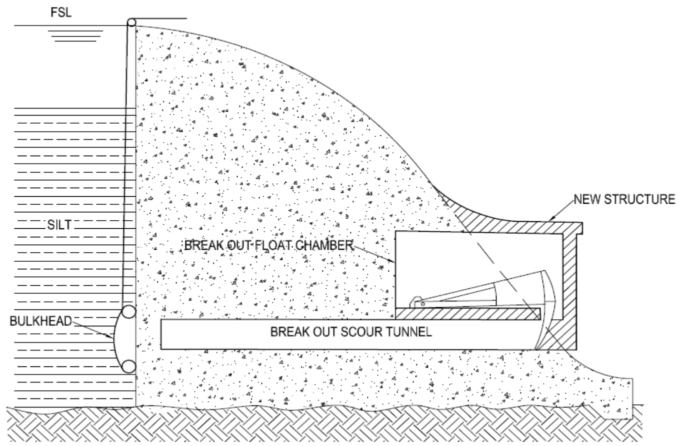

Figure 1.1 Break out and build new structure and fit scourgate

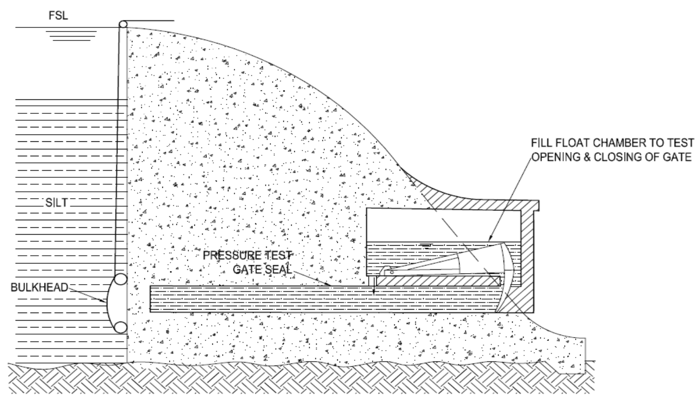

Figure 1.2 Water test scour tunnel and gate

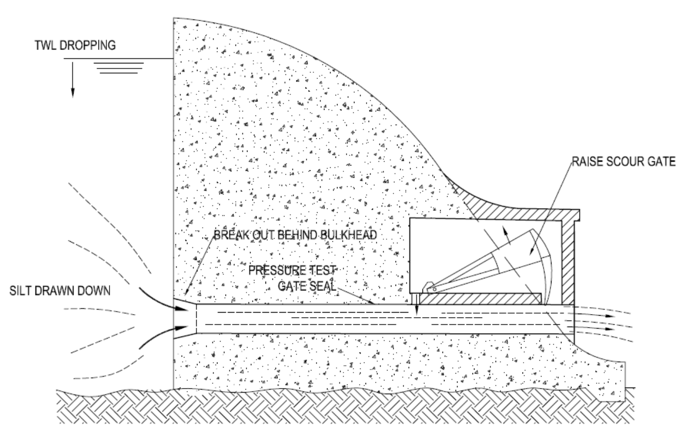

Figure 1.3 Scour tunnel open to discharge silt

7. CONCLUSION

The importance of increasing water supply in South Africa is generally accepted.

Of the different options available to meet our forthcoming water crisis, raising existing dams offers the easiest, quickest and most cost effective means to provide sustainable water in our existing dams.

Of the methods available to increase storage in existing dams, conventional methods provide the safest methods but they are generally more expensive and take longer to construct than raising with gates.

Of the gated options to raise dams, the suite of automatic self-actuating gates to open and close that are developed in South Africa offer an affordable and technically acceptable solution to increasing water supply.

The urgency in South Africa to provide additional water supply and the pressure on funding, makes raising dams with automatic self-actuating gates more essential.

8. REFERENCES

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