PLANNING OF STORAGE DAM AS WATER SOURCE FOR DOMESTIC USE FOR VERKYKERSKOP TOWNSHIP DEVELOPMENT

DESIGN REPORT

24 October 2007

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A dam is proposed just upstream of the lower border of the settlement, as indicated on the Locality and Catchment Area plan D01 attached. The dam is planned to supply raw water to the township. The dam capacity assumed at basic planning stage in the hydrological study of Schoeman & Vennote was 330 000 m^3. The capacity as determined in the detailed design is 327 200m^3.

The dam is proposed as an earth dam with a wall height of 13.3 meters and a length of 270 meters between the spillway openings and 346 meters including the spillways.

The full supply water surface of the dam is calculated at 6.95 ha as shown on the general layout plan D02.

At the basic planning stage, Schoeman & Vennote assumed a catchment size of 6.8 km^2 and a mean annual precipitation of 740mm and calculated an expected annual delivery at 545 600m^3, using the WR90 model. At detail design stage it was calculated that the dam receives water from a catchment of 6.65km^2 (as determined from the topographical survey of the land). The mean annual precipitation of 712 mm (as supplied by ISCW Agromet Section for the Kestell weather station) was used, calculating the expected annual delivery at 540 000 m^3, which is in the same order as calculated by Schoeman & Vennote.

The spillway of the dam is planned for a capacity to let a 50 year flood through with an additional dry free board of 400 mm, to give a total free board of 1.5 meters.

The total capacity of the spillway, with no free board, will allow for the passage of a flood with return period of 100 years.

For protection of the dam wall a dense grass cover needs to be established on the surface of the wall. To make this possible, the downstream slope of 2:1 is to be covered with a layer of top soil and planted with grass. This eventually will protect the embankment from erosion and even over topping of flood water.

1. FLOOD SIZE

The flood calculations were done according to research done by the Hydrological Research Unit of the Witts University, Midgley, Pullen & Pitman.

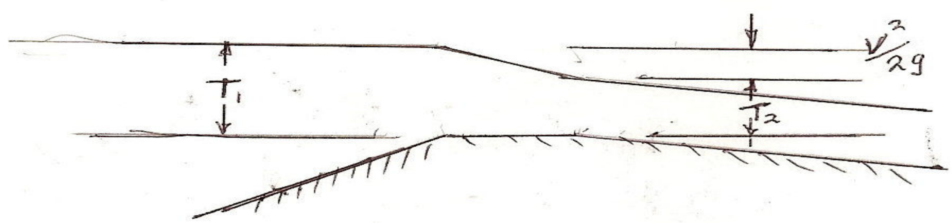
The 50 year flood comes to 85.4 m^3/sec and a 100 year flood comes to 120 m^3/sec.

The HRU calculations were checked against Kovaćs method, which interestingly yields a bigger value for the 1:50 year flood (103m^3/s), but in the same order for the 1:100 year flood (119 m^3/s), the maximum regional flood (Kovaćs) is calculated at 207 m^3/s.

The above calculations were then checked also against the Rational method, giving 100 m^3/s and 125 m^3/s for the 50 and 100 year return periods respectively. The Rational method values were used for the design verification of the spillways as indicated on the Dam Wall Sections and Detail Plan D03.

2. SPILLWAY CAPACITY

The flood capacity of the spillway is calculated by using Manning for determining the eventual flow depth in the spillway and Bernoulli's energy formula for determining the entrance flow depth.



$T_1 = V^2/2g + T_2$ Manning with N=0.035

A slight vertical variation may occur, but as the profile is very flat, the deviation is small enough to ignore.

An open channel spillway is always relatively long and can be considered to be a channel and not a weir, therefore the weir flow formula is not applicable.

3. FLOW DEPTH & FLOW SPEED

To design an open channel spillway on soil, the design can be considered in two ways. The spillway can be designed for a 20 year flood for stability, but for the capacity it must be designed for the design flood.

1. Spillway stability

   Flow speed must be kept low enough not to erode under moderate floods in order to avoid repetitive repairs. The spillway can be designed to take a 20 year flood without erosion damage. If a bigger flood occurs, it is excepted that limited erosion damage may have to be repaired. The spillway is to be protected by a dense cover of grass that will prevent erosion damage in floods of up to 1:20 years.

2. Spillway capacity

   The spillway must be designed to take the design flood. Minor erosion damage may occur with big floods. The damage can be rectified with a minor input. For protection of the embankment, riprap or gabion mattresses can be used as indicated on drawing D03.

The calculated flow speed and free board (as indicated on D03) in the two spillways are as follows:

- West bank spillway: Flow depth 0.9 m, Flow speed 2.1m/s
- East bank spillway: Flow depth 1.2 m, flow speed 2.5m/s.

4. FLOOD WATER SPILLWAY

The flood water spillways are proposed one at each end of the embankment. Each is to be 30 meters wide. The eastern spillway is to be built at least 200 mm lower than the western spillway so that the minor floods spill only on the one side, leaving the other side relatively dry.

This will allow for dry access onto the dam wall for pedestrians under most conditions.

The total free board for the two spillways are to be 1 200 mm for the western and 1 500 mm for the eastern spillway. Raising the wall an additional 200 of free board can be allowed to compensate for sagging of the dam wall on the long run, reducing the possibility of maintenance in the long run.

The upstream section of each spillway must be completely level across and lengthwise, but in the flow direction of the spillway the downstream canal is to be built at a gradient of 1:100 and level in the width.

5. SERVICE SPILLWAY

The catchment of the dam is very wet, fountains occur up stream of the dam. In the rainy season the spillway could remain wet for months at a time. The grass in the spillways will tend to get waterlogged, killing the grass and loosing the protection against floods.

The constant stream is diverted to a drop inlet structure into which the water flows. From the drop inlet the water flows through a pipeline through the embankment and down the back to the level of the river downstream of the dam. The trickle flow can then flow off harmlessly.

The geohydrologist estimated the wet season fountain flows at 10l/s in a catchment of this size, 250mm pipe will be sufficient.

6. DELIVERY PIPE

The size of the delivery pipe depends on required pump rate needed for pumping water to the settlement. The peak pump demand (peak season and when the boreholes are not engaged) is 5 l/s for which a 100 mm diameter pipe would be adequate. Since the delivery pipe must also function as an outlet for environmental requirements and also emergency drainage of the dam, a larger pipe of 250 mm is proposed.

The pipeline through an earth wall is potentially a weak spot in the dam wall. To stop any leakage along the pipe, three Bentonite collars are proposed to be built around the pipe in the clay core area. The collars are to extend for one meter around the pipe, each being 500 mm thick. A trench is to be dug around the pipe and filled with a Bentonite mix. The mix can consist of 1 part Bentonite and 5 part dry clay.

The Bentonite mix is to be put in the trench dry and well compacted. When Bentonite comes in contact with water, it tends to swell. After placing the trench must be filled as soon as possible. When the Bentonite swells; a tight collar around the pipe is formed.

7. CUTOFF TRENCH

The soil profiles below the dam look very promising. The test holes show dense clay from 400 mm below the surface down to 3.5 meters +. Only in the centre of the valley, on chainage 180 on a depth of 2.5 meters gravel was found which could cause a leak.

In the river bed on chainage 240 on a depth of 2.5 meters, sand deposits were found. A cut-off trench will have to be supplied to a depth of 2.5 meters to seal off the base of the dam, in the centre of the dam wall. Towards the ends of the dam wall the depth of the trench can be systematically reduced to 1 meter.

The function of a cut-off trench is to cut off any water movement along sand, gravel, decomposed roots or tunnels dug by insects or animals below the soil surface.

A second function of a cut-off trench is to secure a foothold for an earth wall on the soil on which it is built.

The soil samples taken below the dam wall show promise. The soils had high clay content and a PI between 14 and 16.

The cut off clay core is shown on drawing D03.

8. EARTH EMBANKMENT

The main feature of the dam is the earth embankment that is responsible for holding back the water in the dam.

The earth wall consists of three separate parts, a central clay core, responsible for sealing the earth wall. Secondly the upstream face responsible for holding back the water and thirdly the downstream portion of the dam giving structural stability to the earth wall.

8.1 CLAY CORE

The clay core extends from the bottom of the cut-off trench to the crest of the dam wall. It consists of soil with clay content of 25% or more and well compacted to form a water tight seal in the embankment. The ideal soils consist of clay with a PI varying from 10 to 20.

8.2 UPSTREAM PORTION

The upstream portion of the dam has a function to supply a stable support in wet conditions for the earth wall. With wet conditions the earth must be coarse enough to withstand water movement and must not become soggy or water logged. When drained, the earth must have structural strength not to slump. As the water level drops, the earth water must flow out of the earth profile fast enough not to cause the earth to become buoyant and slump causing a break in the dam wall. This area must contain earth that is semi pervious, allowing water to flow in and out without earth slumping.

The idea PI for this area would be 5 to 12

8.3 DOWNSTREAM PORTION

The downstream portion of an earth wall is responsible for the structural stability of the earth wall as a whole. It is necessary to maintain structural strength at all times. Water movement through the embankment must be limited to stop any buoyancy that could leed to slumping in the soil.

A filter is supplied to remove excess water from this area. The type of filter will vary according to the type of soil used.

The ideal soil must be porous enough to let water through without loosing structural strength. The placing of a sand filter is responsible for limiting the water in this area. The placing of the filter will allow for intercepting water that may come through the clay core or from under the structure. Placing the filter behind the clay core will stabilise the dam as a whole.

A toe filter may be necessary in some cases where seepage of water may pass through the toe of the wall above ground level. The toe filter will draw seepage down protecting the lower part of the wall. This will be necessary on dam sites on soils that are pervious and excess seepage could occur endangering the dam. In this case the high clay content of the base makes this unnecessary.

The soil found in the valley varies from soil with high clay content in the middle of the valley with a PI around 18, to a sandy silty clay towards the outside of the valley with a PI of 8 – 10. From visual inspection, it should be possible to build the dam wall using soil from within the dam basin.

The clay core can be built from soil coming from the centre and the semi pervious parts of the wall can be built from soils coming from towards the sides of the valley.

9. <u>CONSTRUCTION</u>

9.1 TOPSOIL

The construction procedure starts off by removing 200 mm topsoil from the base of the dam. Topsoil removed is to be stockpiled for later use, when covering the dam wall surface. The topsoil spread over the dam wall will prepare the soil surface for establishing a dense grass cover over the wall.

9.2 CUT-OFF TRENCH

The next step is to dig a cut-off trench, the full length of the dam wall. The soil that will be excavated from the trench is suited for replacing. Because of the high clay content of the soil that is being excavated from the trench can be replaced in another portion that is to be filled up. Any sand or gravel found in the excavation will be removed and could be used in the back portion of the dam wall. It is thus suggested that the excavation can start at one end and as the excavation progresses, the soil can be directly deposited in the excavated area.

9.3 BASE FILTER

A sand filter is to be constructed along the downstream side of the clay core, along the full length of the earth wall. A trench of 2 meters deep and 600mm wide will have to be dug from 1.5 meters below ground level, extending to 500 mm into the earth embankment.

The purpose of the base filter is to intercept any seepage that may come through or from below the clay core, to protect the downstream toe of the embankment.

9.4 EARTH EMBANKMENT

The building procedure must be done in layers with a thickness of 150 to 200 mm. After placing each layer, the soil must be well compacted. If using dam scoops, travelling along the length of the dam wall, the full width of the wall must be compacted by travelling over the full width of the wall. The dam scoops must not track and thus only compact certain areas, but the whole surface.

9.5 COMPACTION

The ideal method of compaction of earth walls of this size is by building the walls, using dam scoops with rubber tyres. The scoops normally used weigh around 40 tons fully laden and this weight is carried by 4 rubber tyres. High density compaction is achieved. **THE USE OF SMOOTH ROLLERS IS NOT PERMITTED**.

The building process must be done in layers of thickness varying from 150mm to 200mm. Each layer should be well compacted.

Compaction of the dam wall must be done to a density of 95 – 98 % Proctor at soil moisture content of between 2 below and 2 above optimum.