Dam Locality No.: W530/03

water & sanitation

Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

JERICHO DAM

FOURTH DAM SAFETY EVALUATION REPORT

January 2016

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EXECUTIVE SUMMARY

Jericho dam is located in the Usutu River about 18 km west of a Town named Amsterdam, in Mpumalanga Province. The dam has a catchment area of 218 km^2. It was designed and built by the Department of Water Affairs in 1966, and was subsequently raised in 1968. The dam is still owned and operated by Department of Water and Sanitation. The dam is used to store water for industrial and domestic purposes.

The dam wall consists of zoned earth fill embankments with a total length of 1006 m which flank a central concrete gravity spillway section. The spillway section is 21.3 m high by 161.8 m wide and is equipped with 4.27 m high by 10.97 m wide radial gates. The gross capacity of the dam is 59.8 million m^3.

With the spillway gates fully open it can discharge at 1 729 m^3/s with the water level at the NOC. With the gates closed, 162 m^3/s can be discharged. The Recommended Design Discharge (RDD) of 205 m^3/s (a flood with a 0.05% exceedence probability) has more than a sufficient freeboard allowance 4.24 m if the gates are fully open.

The dam has been designed and constructed to acceptable standards. There are no serious concerns about the foundations, the stability of the concrete spillway structure, the stability of the earthfill section or the capacity of the spillway. The dam is being maintained to an excellent standard by the Infrastructure Branch of the Department of Water and Sanitation, Central Operations and the local staff at the Usuthu Government Water Scheme.

Important recommendations on the electrical and mechanical equipment included in this report must be assigned a high priority and must be implemented meticulously. Recommendations are also made to upgrade the monitoring system in line with the strategic importance and to improve the operation and maintenance of the dam.

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1. INTRODUCTION AND AVAILABLE INFORMATION

This is the Fourth Dam Safety Evaluation Report completed for Jericho Dam in terms of the Dam Safety Regulations since 1986.

Jericho Dam is located in the Usuthu River about 18 km west of the small town Amsterdam in Mpumalanga. The catchment size is 218 km^2 and the dam's purpose is mainly storage for domestic and industrial use. The Dam was completed in 1966 and raised in 1968 by the addition of the five radial gates on the ogee spillway. The dam was designed, built and is owned by the Department of Water and Sanitation.

The dam has a composite structure with a concrete controlled spillway section in the river, flanked by zoned earth fill sections. There is a stilling basin downstream of the spillway, and galleries in the wall provide pressure relief.

The outlet works right of the spillway consists of four wet well shafts each of 1 676 mm diameter pipes leading to the downstream side. The left most pipe is a river outlet while the other three supply water to the Eskom pump station just downstream of the dam. The river outlet bifurcates downstream into a 1 676 mm pipe and a 200 mm pipe that both end in sleeve valves. All the outlet pipes have upstream controls: the three Eskom pipes are controlled by butterfly valves and the river outlet by a spherical valve.

Jericho Dam has a maximum wall height of 21.3 m above the riverbed and has been classified as a Medium dam with a high hazard potential. It is therefore categorised as a Category III dam. A Professional team for the dam safety evaluation / inspection is therefore required by the dam safety regulations.

The approved professional team is presented in the following table.

Dam component	**Task**	**Name and particulars**
Dam wall: Concrete arch, spillway and foundations	Evaluation and inspection	L van Zyl & CL van den Berg
Flood Hydrology	Flood frequency analysis	D van der Spuy
Outlet works	Evaluation and inspection	V W Kohlmeyer

The following documents were evaluated as part of this evaluation (listed in date of publication sequence):

(i) DAM SAFETY REPORT OF JERICHO DAM, Department of Water Affairs, October **1986**, Report W531-03-EY01, File No B16/91/2, by GP Carmichael and JS Knoesen, C Oosthuizen.

(ii) JERICHO DAM: FIRST ENGINEERING GEOLOGICAL REPORT FOR DAM SAFETY EVALUATION, October **1991**, Report no: 1991-0175, by G Heath and A Schall.

(iii) JERICHO DAM: HANDLEIDING VIR ONDERHOUD EN BEDRYF, Dept of Water Affairs, December **1995**, Highveld Region.

(iv) JERICHO DAM: DAM SAFETY INSPECTION, DEPARTMENT OF WATER AFFAIRS AND FORESTRY, July **1996**, Report no: W530-03-EY02, by H Anderson, C Oosthuizen and HFWK Elges.

(v) JERICHO DAM (W530-03): OPERATIONS AND MAINTENANCE MANUAL, Dept of water Affairs, September **2002**/Revised April 2005, Compiled by Gauteng Region.

(vi) JERICHO DAM: SECOND FIVE-YEARLY DAM SAFETY INSPECTION REPORT, Dept of Water Affairs and Forestry, December **2004**, FJ de Lange (Daling delange & van Tonder (PTY) LTD) and C Oosthuizen.

(vii) JERICHO DAM (W530-03): EMERGENCY PREPAREDNESS PLAN, Dept of Water Affairs, August **2005**.

(viii) JERICHO DAM: THIRD DAM SAFETY INSPECTION REPORT, Dept of Water Affairs, March **2010**, Report no: 20/2/W530/03/D/1/22, LC Hattingh, C Oosthuizen, W van der Westhuizen.

(ix) Flood Frequency Analysis for Jericho Dam, Dept of Water and Sanitation, August **2014**, W500-R001-2014.08, D van der Spuy and MP Roux.

Figure 1: Locality map

2. DESCRIPTION OF THE DAM

The statistics of the dam are summarised below

2.1. General

Owner	Department of Water and Sanitation.
Designed and Constructed by	Department of Water Affairs (1963-66, raised in 1968).
Type	Composite dam with zoned earth fill embankments on the river banks and controlled concrete gravity ogee spillway
Province / Water Resource Management	The dam is situated in the Mpumalanga

Region / Water Management Area	Province but falls under the Gauteng Water Resource Management Region and within the Inkomati Usuthu Water Management Area
Location	Latitude: 30° 39' 18.8'' Longitude: 26° 29' 1.9''
Nearest Town	Amsterdam, Mpumalanga
Completion date	1966
Raised date	1968 by addition of the existing five radial gates
Purpose	Industrial and domestic water supply. The system supplies water to Eskom for power generation
Size	Medium (maximum wall height 21.3 m)
Hazard Rating	High
Classification	Category III
Gross Capacity (2015 silt survey)	59.83 x 10^6 m^3

Concrete Gravity Spillway Section

Type	Controlled ogee with five 4.27m high by 10.97m wide radial gates
Non-overspill crest level (NOC)	RL 1 468.526 m
Full supply level (FSL)	RL 1 466.393 m
Spillway sill level	RL 1 462.735 m
Height above riverbed	21.3 m.
Effective crest length	54.9 m
Width of spillway	5 x 10.97 m
Upstream slope	Vertical
Downstream slope	1V: 0.75H NOC section 1V: 1H spillway section

Earth fill Sections

Non-overspill crest level	RL 1 468.526
Freeboard between NOC and FSL	2.133 m
Crest length	1 006 m
Width of crest	9.14 m
Upstream slope	1H:3V.
Downstream slope	1V: 2H

Outlet works

Outlet pipes	1 x 1 670 mm diameter river outlet pipe

	3 x 1 670 mm diameter Eskom outlet pipes
Upstream control	butterfly valves and spherical valves
Downstream control	3 x sleeve valves for river outlet
Capacity at FSL	91.6 m^3/s

2.2. Spillway

The concrete spillway section in located in the river and is controlled by five radial gates each 10.97 m wide and 4.27 m high. The spillways effective length is 54.9 m and it has a total freeboard of 5.79 m when the gates are open. The freeboard at full supply level is 2.133 m.

2.3. Earthfill embankments

The earth fill sections of the wall are zoned and consist of a central impervious core with semi-pervious zones on the up- and downstream sides. The wall is shelled by hand packed riprap which is still in excellent condition.

Downstream drainage is achieved through a chimney and blanket drains which connects to a toe drain with 15 manholes on the right flank and 12 manholes on the left flank for monitoring drainage flow. The upstream and downstream slopes are 1V: 3H and 1V: 2V respectively.

3. GEOLOGY

A detailed geological survey was done in 1991 by Heath for the 1st dam safety inspection report. The conditions have not changed since the fist report and therefore it is still found to be applicable. Hattingh (2010) provided a summary in the 3rd dam safety inspection report:

- The spillway is underlain by un-weathered widely jointed granite and the embankments are generally underlain by weathered granite.
- Geological investigations were conducted prior to construction and the drainage holes were drilled and logged.
- Curtain grouting for both the concrete wall and embankments was carried out during construction according to the drawings. There are no records of actual grouting however. Pressure relief holes have also been re-drilled and logged.
- No excessive erosion is expected in the bedrock downstream in the case of spilling.
- The dam slopes are gentle and slope failures are unlikely.

- Kijko et al (2003) published seismic hazard maps that indicated that a Peak Ground Acceleration of 0.13 g, with a 10 % probability of being exceeded in 50 years for this area. It can be considered a moderate seismic hazard level.

4. EVALUATION OF THE HAZARD POTENTIAL AND CHECKING OF REGISTRATION INFORMATION

A Risk and Impact assessment was conducted in the 3rd dam safety inspection report. (2010). The assessment was based on the dam break analysis done in the 1st report (1996) and the procedures described by Oosthuizen (2000).

It was determined that 54 to 74 persons could lose their lives as a result of a dam failure. The probability of failure used was between 5 x 10-4 and 5 x 10-5. Using these parameters the annual risk of fatalities and monetary losses were determined in order to determine the risk level of the dam. The risk level borders between acceptable and unacceptable. This suggests that the dam's current high hazard potential rating is appropriate.

Much of the population downstream reside in the rural areas of Swaziland, which is only about 30 km downstream of the dam. It is considered unlikely that communication with these people will be effective and it is therefore recommended that it must be assumed that the potential loss of life can be about 25% higher than the current estimation. A potential loss of life of about 67 to 93 is recommended to confirm that the High hazard potential assigned by the Dam Safety Office is appropriate.

Failure of the dam will have a negative impact on water supply to Eskom power station which can lead to power stations not being able to function at full capacity. From this perspective the hazard potential should also be accepted as high.

The registration information of the dam is included in Annexure A and no amendments are necessary.

5. FLOOD ESTIMATES

A flood frequency analysis was conducted and a report compiled by the Directorate: Hydrological services in August 2014 by Roux, Rademeyer and Van Der Spuy. This report was reviewed for the purpose of evaluating the spillway capacity.

The statistical analysis suggested that the 10 000 year flood peak estimate should be used as the catchment's maximum flood peak. The 10 000 flood peak was calculated as 300 m^3/s which is much lower than the calculated RMF.

The report recommended that the RMF (Δ) (k = 4.6) of 880 m3/s should be used for the SEF which is lower than the value of RMF(+Δ) recommended as the SED by the SANCOLD Guidelines on Safety in Relation to Floods.

Flood peaks were calculated for a storm duration t_c of 9 hours, as well as corresponding exceedence probabilities. The results are shown in the table below.

Table 1: Estimated flood peaks with corresponding exceedence probabilities

Exceedence probability (%)							
50	20	10	5	2	1	0.5	SEF
Flood peaks (m^3/s)							
70	115	145	170	200	215	235	880

It was recommended that the K value for determining the RMF peak be investigated for the next safety evaluation as the K value currently used is thought to be too high.

The Sancold guidelines recommends the use of RMF(+Δ) for the SED for dams where the probability of failure of the dam should be kept as low as possible due to the impact of failure (hazard potential) and the cost to replace the dam. Jericho Dam clearly falls into this category because of the strategic importance of the dam for power generation.

However, it was decided for the purposes of this 4th dam safety evaluation to also consider both the RMF(+Δ) of 1 480 m^3/s and the RMF (Δ) of 880 m^3/s, obtained from the original report of Kovacs to be on the conservative side, particularly because of the strategic importance of the dam.

The flood with a 0.5% probability of exceedance (1 in 200 year flood) of 235 m^3/s is accepted as the Recommended Design Flood (RDF).

6. EVALUATION OF THE SPILLWAY CAPACITY

The capacity of the spillway was determined in the past three Dam Safety Reports. The results of the previous calibrations (Hattingh, 2010) were found to still be applicable.

The spillway's calibration results from the 3rd dam safety inspection report are given in the table below:

Table 2: Spillway capacity

Scenario	Capacity (m^3/s)
Water at NOC with gates fully open	1 556
Water at NOC under normal operational conditions	1 420
Water at NOC with gates closed	302

The final evaluation of the spillway capacity is the following:

- The flood routing analysis indicates that the spillway can accommodate the un-routed SED based on the more conservative RMF(+Δ) and therefore routed safety evaluation flood with its radial gates fully open or normally operating;

With the gates fully closed the spillway can accommodate the design flood (the 1 in 200 year with an exceedance probability of 0,5%.

The spillway capacity is therefore considered to be adequate and no further analysis is need.

7. EVALUATION OF THE CAPACITY OF THE OUTLET WORKS

The previous report (3rd) indicated that capacity of the outlet works is such that with all the outlets functioning it can discharge at 91.6 m^3/s. This would allow the dam to be drawn down from the FSL to the lowest level in roughly 10.3 days. The capacity of the outlet works with only the river outlet functioning is 22.9 m^3/s which will take 40.1 days from FSL to lowest drawdown level. It was concluded that the outlet capacity is sufficient in the case of an emergency

8. INSPECTION OF THE DAM WALL AND FOUNDATIONS

8.1. General

A site inspection for the purposes of this report was conducted on 12 August 2015. The following persons were present at this inspection:

Mr C L Van Den Berg	Specialist Engineer, Directorate: Dam Safety Regulation, Approved Professional Person (APP)
Mr L Van Zyl	Candidate engineer Directorate: Dam Safety Regulation
H Bekker	Central Operations

This was the 4th dam safety inspection in terms of Dam Safety Regulations of 1986. The water level on the day of inspection was 12.65 m (80 % full). A photo report of the inspection is included in Appendix B. Reference will be made in this section to these photos.

8.2. Concrete gravity wall

The concrete gravity wall is generally in very good condition.

Non-overspill crest

The non-overspill crest (NOC) is generally in a good condition. No signs of movement, settlement or significant cracks were observed. The construction joints also show no adverse movements. Railings are rusted in some areas but they are planning on replacing them.

Upstream face

With the dam's water level being fairly high on the day of the inspection (80 % full) not much of the upstream face of the spillway could be evaluated. Some corrosion (exposed aggregate) was however visible on the concrete face just above the water mark. See photo 21 & 22.

Downstream face

The downstream face is in a good condition with no significant deterioration or cracks. Minor plant growth was observed in some areas that should be removed at some stage. Minor leaks were noted on a few horizontal construction joints and a few calcite stains also below horizontal construction joints. See photos 19 & 20.

The block numbers and the vertical contraction joints are not numbered on the downstream face.

Apron and downstream area

The apron / stilling basin is in good condition with no significant erosion visible. There were orange clay deposits from the toe drain into the stilling basin. See photo 10. Black residue from

the sand-blasting that was being used to clean the radial gates was also present in the basin. The concrete in the apron is still in good condition. The downstream area shows no serious erosion. The foundation is exposed just downstream of the basin and consists of mostly solid granite. See photos 10, 11, and 15. Vegetation downstream of the dam is well controlled and no trees or bushes are growing in a wide strip downstream of the dam wall making the inspection of the dam very easy.

Drainage Gallery

The drainage gallery is clean and well maintained. Block numbers are clearly marked on both sides of most of the vertical contraction joints. No significant movement can be seen on vertical contraction joints or horizontal construction joints. A few cracks are visible but they are minor and do not infer any movement or swelling. Some of the vertical contraction joints in the core wall sections are leaking slightly with a build-up of calcite with a dark colour. This is probably due to clay leaking through the joints from the earth fill around the core wall. In the spillway section the calcite marks are white with no dark staining. See photos 23 to 25.

The drainage holes are cleaned with hose pipes once every three months. The total collective flow out of the drainage holes were estimated at about 0.14 l/s from both the left and the right sides of the spillway gallery.

It was reported that the glass fibre partial flumes (photo 28) were delivered many years ago but were never installed correctly. Some of them are in place but not grouted/fixed, while some are out of position completely.

Mechanical and Electrical Equipment - Outlet Works

A detailed mechanical and electrical inspection has again been conducted for the purpose of this 4th dam safety evaluation by Kohlmeyer & Kolarovic on 15 October 2014 and their inspection report is included as Appendix C. According to the report the "outlet works were found to be in a reasonable operating condition and capable of the function for which they were intended. Various items must be urgently attended to as they have not been repaired for an extended period of time."

The outlet structures were in generally good condition. There is some exposed reinforcement due to poor concrete cover. It was noted that the river outlet is "never used" as they are worried they will not be able to close it. Photo 30.

The structural adequacy of all elements of the floodgates.

Gate no 1 was undergoing refurbishment and the rest are planned to be refurbished as well. It was being blocked off with the use of "dryf-bloksluise" – floating barges that stack on top of each other and seal off the spillway through their own weight. (photo 12).

The 4th gate was tested and it functioned without any problems. The main gate controls and remote control boxes on the NOC are well looked after, clean and functioning.

There was some minor spalling further up on the piers in areas (photo 18), but the concrete is generally good condition. No cracking was visible in the reinforced concrete in the areas where the forces of the radial gates are transferred to the piers.

See photos 12 – 18.

Public and Occupational Safety

Safety buoys are in place upstream of dam spillway but many of them have broken off and are floating around against the upstream side of the dam wall. Security gates and fences keep the public away from the outlet works, spillway and the concrete section. Access ladders can be considered into the apron area to facilitate routine inspections and maintenance. Railings on the spillway NOC are rusted in places but they are planned to be replaced.

8.3. Earthfill walls

8.3.1. Toe drain observations for both flanks

Table 3: Manhole flow observations at the toe drain

Manhole number	observations			
	Current (2015)	**2010**	**2004**	**1996**
Right flank				
1 (closest to spillway)	Strong flow and clay/silt deposits	Strong flow	Less than 2	Flows strongly
2	Strong flow and clay/silt deposits	Strong flow with clayey deposit	0.3 l/s	Less than 1
3	moderate flow	Less than 2 with less clayey deposit	Same as 2	Less than 2
4	More than 3	Same as 3 with less clay deposit	Same as 3	Less than 3
5	moderate flow	Same as 4	Less than 4	Less than 4
6	Standing water	Same as 4 with no clayey deposit	Less than 5	Less than 5
7	Standing water	Same as 4 with no clayey deposit	Less than 6	Less than 6
8	Standing water	damp	Little trick	dry
9	Standing water	Standing water	Dry	dry
10	Dry	Standing water	Dry	dry
11	Standing water	Standing water	Dry	
12	Standing water	Standing water	Dry	Standing water
13	Standing water	Standing water	Dry	Standing water

14	Standing water	Standing water	Dry	Standing water
15 (right bank)	Standing water	Standing water	Dry	Standing water
Left flank				
1 (closest to spillway)	Strong flow	Strong flow	< 0.4 Us	Flows strongly
2	moderate flow	Same as 1	Less than 1	Flows strongly
3	moderate flow	Same as 1	Less than 2	More than 2
4	moderate flow	Same as 1	Less than 3	Less than 3
5	moderate flow and no lid	Same as 1	Less than 4	Flows strongly
6	moderate flow and needs repairs	Slightly stronger	Less than 5	More than 5
7	Light flow and needs repairs	Same as 1	Little trick	More than 6
8	Dry	Standing water	Dry	Little trick
9	Dry with rocks	Damp with sand	Dry	Dry with sand
10	Dry with rocks	Damp with sand	Dry	Dry with sand
11	Dry with termite heap	Damp with sand	Dry	Dry with sand
12 (left flank)	Dry	Damp with sand	Dry	Dry with sand

8.3.2. Earthfill Section Right Bank

The right bank earth fill wall is generally in a very good condition - see photos 1 and 5.

Non-overspill Crest of the Earthfill Section Right Bank

The non-overspill crest (NOC) is generally in a good condition. The NOC is covered by a course crusher run. Some disturbance or rutting was observed here and there and most noticeably about halfway along the right bank due to vehicles driving on the wall (photo 3). It is not considered a maintenance problem yet, but it should be monitored and levelled from time to time.

The safety/security fence along the crest was in generally good condition but showed some rusted areas (photo 5).

Visual observation suggests that the crest is still level and that no significant settlement has occurred. This should however be confirmed by a survey as required by the dam safety regulations. No signs of erosion or of holes from burrowing animals.

Upstream Face Earthfill Section Right Bank

The upper part of the upstream face visible above the water level is in a good condition with no signs of cracks or settlement. In the area between full supply level and the current water level the finer gravel between the hand packed riprap has washed out due to wave action. The general condition was the same as in the previous report but the situation should be monitored and maintenance should be done timeously. Many of the safety buoys have broken off and have now "beached" on the upstream slope.

Downstream Face Earthfill Section Right Bank

The downstream slope of the right bank earthfill section is maintained in an excellent condition with minimal vegetation and no signs of movement (cracks, settlement, bulging or sliding), no animal burrows. No signs of leaks or wet pathes. The areas between the packed rip-rap is mostly filled with finer gravel without any significan erosion. See photo 2.

All the manholes in the toe drain were again inspected. Some of the wells had minor obstructions in them in the form of rocks and clayey deposits but they were still in working condition. Some wells needed minor repairs to the covers.

8.3.3. Earthfill Section Left Bank

The left bank earth fill wall is generally in a very good condition - see photos 34 – 41.

Non-overspill Crest of the Earthfill Section Left Bank

The non-overspill crest (NOC) is generally in a good condition. The NOC is covered by a course crusher run.

Unlike the right bank is seems there is less vehicle access onto the left bank so there is no significant settlement. There is also no security fence on the left bank.

Visual observation suggests that the crest is still level and that no significant settlement has occurred. This should however be confirmed by a survey as required by the dam safety regulations. No signs of erosion or of holes from burrowing animals.

Upstream face Earthfill Section Left Bank

The upper part of the upstream face visible above the water level is in a good condition with no signs of cracks or settlement. In the area between full supply level and the current water level

the finer gravel between the hand packed riprap has washed out due to wave action. As with the right bank there are some "beach" safety buoys against the upstream slope.

There is more vegetation in some places on the left bank than the right, but is minor and the slope is still considered to be in very good condition.

Downstream Face Earthfill Section Left Bank

The downstream slope of the right bank earthfill section is maintained in an excellent condition with minimal vegetation and no signs of movement (cracks, settlement, bulging or sliding), no animal burrows. No signs of leaks or wet pathes. The areas between the packed rip-rap is mostly filled with finer gravel without any significant erosion. See photo 2.

All the manholes in the toe drain were again inspected. Some of the wells had minor obstructions in them in the form of rocks and clayey deposits but they were still in working condition. Some wells needed minor repairs to the covers.

9. EVALUATION OF THE QUALITY OF OPERATION AND MAINTENANCE

An interview was conducted with Mr. Mr H Bekker of Central Operations for Jericho Dam before the site inspection and the following information was obtained.

(i) The latest Operation and Maintenance Manual (OMM) of September 2002 (2005 English version) was not available on site.

(ii) The latest Emergency Preparedness Plan of August 2005 was available. The contact details were not completely up to date and contact details for potentially affected people in Swaziland were not up to date.

(iii) The log book for routine 3 – monthly inspections was available and up to date.

The interview also covered the issues in Regulation (35) (4) (e) of the dam safety regulations which are applicable to dams equipped with floodgates. The following was established:

(i) Adequate security measures are in place to prevent unauthorised persons access to the dam, critical parts of the dam or appurtenant works.

(ii) There are no warning systems to alert the dam operator of incoming floods as the catchment is deemed too small.

(iii) Warning systems to warn persons downstream of the dam of floods or flow releases relies on the telephone system.

(iv) The latest OMM was available.

(v) An alternative power supply is available on site in the form of a standby generator in the event of a power failure.

10. MECHANICAL AND ELECTRICAL INSPECTION

The mechanical and electrical components of the dam were inspected by VW Kohlmeyer and J Kolarovic" in October 2014. Their findings and recommendations are documented in their report on the "Dam Safety Inspection of Mechanical and Electrical Plant, Central Operations dated October 2014 by VW Kohlmeyer and J Kolarovic". Their report is included in **Appendix C** and should be read as part of this report.

According to the report the "outlet works were found to be in a reasonable operating condition and capable of the function for which they were intended. Various items must be urgently attended to as they have not been repaired for an extended period of time."

11. EVALUATION OF THE STABILITY OF THE DAM WALL

11.1. Stability

Comprehensive stability analyses were done during the First Dam Safety Inspection (Anderson: 1996) of which the results were revised during the Third Dam Safety Inspection (Hattingh: 2010) and found to still be applicable.

The spillway's stability was hence not re-calculated as there were no signs of structural instability upon the inspection, and the load conditions on the dam have not changed since the last Dam Safety Inspections. The previous analysis is summarized below:

- Conservative material properties were used for the foundation and concrete
- The load conditions included normal operational and extreme combinations (RMF-peak water levels, full uplift and seismic loads)
- The results showed no unacceptable stresses even with larger seismic loads being applied. The dam was found to be stable

Hattingh (2010) analysed the stability of the concrete tongue wall. The analysis was found to be still applicable. The analysis is summarised below:

- The same material properties used by Anderson's analysis (1996) were used.
- The load conditions included normal conditions and extreme conditions (water level at NOC, and water level at FSL with seismic loads).
- Stability was calculated using active and passive soil pressures to obtain factors of safety for sliding and overturning. The calculations were also used for a stress analysis.

- The results concluded that the tongue walls are stable and that there are no unacceptable stresses in any of its sections.

The tongue wall transition between a concrete gravity dam wall and an earthfill dam wall is a South African design feature that has been used successfully in a number of dams. . We are not aware of any design guidelines documenting the design approach. It is based on the assumption of "passive" soil pressure on the downstream side and "active" soil pressure and water pressure on the upstream side using a traditional two dimensional stability analysis. It can be modelled more realistically as a three dimensional problem where the movement and settlement of the embankment in the area of the transition will influence the forces on the tongue wall. Although no incidents of unsafe conditions have been reported in any of these dams, caution is recommended. In new designs, a filter behind the tongue wall should be considered as a precaution against cracking of the tongue wall. This was used during the raising of Flag Boshielo Dam.

It is therefore recommended that the behaviour of the tongue walls should be monitored continuously during the routine inspections. This should be done by observing any cracks, movement and seepage inside the galleries and also outside on both the concrete and the earth fill sections. Particular attention should be given to material seeping through the contraction joints in the tongue wall.

11.2. Earth fill Slope stabiltiy

Anderson (1996) conducted a stability analysis for the earth fill embankment which was reviewed and accepted by Hattingh (2010) who also conducted a sensitivity analysis for assumed cohesion values versus friction angles under extreme load conditions.

Both analyses were reviewed and found to still be applicable and the wall is considered to be stable.

12. MONITORING

Only the water level is recorded at the dam. A geodetic survey network to monitor absolute displacements or crack width meters to monitor relative displacements have not been installed. Flow gauges in the galleries have been placed in the galleries but the installation was never completed.

The monitoring system of this strategic important Category III dam should be upgraded as follows:

I. The flow monitoring gauges in the lower drainage gallery should be installed correctly so that the flow in the galleries can be monitored.

II. Ladder access should be provided to the exit point of the flow from the lower gallery below the river outlets so that the total flow from the gallery can be measured with a bucket and a stopwatch.

III. A method should also be designed to measure the total flow of water and sand from the left and right bank toe drains. A bucket and stopwatch and a sand trap can be considered.

13. RECOMMENDATIONS OF THE 2010 DAM SAFETY EVALUATION

Seven recommendations were made in the previous safety evaluation report (Hattingh: 2010). The following of those recommendations were carried out successfully:

- No. 1. The implementation of especially the priority recommendations contained in the mechanical and electrical inspection report were attended to.
- No. 3. Monitor the toe drain at least once a month and record the observations. This is being done every 3 months without a measuring structure. Sand is never removed.
- No. 4. The embankments and the area 20 m downstream of the embankments is kept clean of trees and shrubs as part of ongoing maintenance.

The following recommendations have not been implemented and/or need further attention.

- No. 5. Replace the missing buoys. Was done but about half the buoys have broken off again.
- No. 6. Regularly update the EPP. The contact details of the Inkomati Usuthu CMA in Nelspruit / MBombela, the Department of Water Affairs in Swaziland and the National Directorate of Water (DNA) of Mozambique and Administração Regional de Águas - South (ARA-Sul) in Mozambique should be obtained and included in the contact details page of the EPP.
- No. 7. Implement the mechanical and electrical logbook.

14. RECOMMENDATIONS OF THIS REPORT

The following additional recommendations are made:

14.1 The recommendations in the report on the "Dam Safety Inspection of Mechanical and Electrical Plant, Central Operations dated October 2014 by VW Kohlmeyer and J Kolarovic" should be read as part of this recommendation and should be implemented meticulously.

14.2 The monitoring system of this strategic important Category III dam should be upgraded.

a. The flow monitoring gauges in the lower drainage gallery should be installed correctly so that the flow in the galleries can be monitored.

b. Ladder access should be provided to the exit point of the flow from the lower gallery below the river outlets so that the total flow from the gallery can be measured with a bucket and a stopwatch.

c. The total flow the earth fill sections' toe drains should also be monitored. A method should also be designed to capture the sand from the toe drain so that the total amount of sand coming out of the drain can be monitored every 3 months.

14.3 The behavior of the tongue wall should be monitored continuously during routine inspections. This should be done by observing any cracks, movement and seepage inside the galleries and also outside on both the concrete and earth fill sections. Particular attention should be given to material seeping through the contraction joints in the tongue wall.

14.4 Implement the mechanical and electrical logbook.

14.5 The safety buoys should be given further attention as the last design was not sufficient.

14.6 A survey of the NOC and the spillway to verify the total freeboard of the dam as required by regulation 35 (5) has not yet been done. This is not considered urgent in view of the more than adequate spillway capacity of the dam and can therefore be delayed until the next dam safety evaluation over 5 years.

14.7 The contact details of the Inkomati Usuthu CMA in Nelspruit / MBombela, the Department of Water Affairs in Swaziland and the National Directorate of Water (DNA) of Mozambique and Administração Regional de Águas - South (ARA-Sul) in Mozambique should be obtained and included in the contact details page of the OMM. The contact details can be obtained through the DWS Branch for International Water Cooperation and the DWS delegates on the Joint Water Commissions between South Africa and Mozambique and the TPTC (Tripartite Permanent Technical Committee between South Africa, Swaziland and Mozambique. For the EPP, the Disaster Management Centre in Pretoria should be used to communicate with the neighbouring states.

Appendix A: Registration information

Department of Water and Sanitation - Dam Safety Office

Registration Details of a Dam Registered in terms of Dam Safety Legislation of Chapter 12 of the National Water Act (Act No. 36 of 1998)

(Please note that registration for dam safety legislation is not an entitlement for water use in terms of Chapter 4 of the National Water Act)

Departmental File No. : 12/2/	W530/03	*WARMS Dam ID:*	5749
Water management area	3	*Dam Status:* DAM	*Drainage Nr:* W53D
Name of dam	JERICHO DAM		
Latitude	26 39 19	*Longitude* 30 29 4	*Lat sec:* 19.00
			Long sec: 4.00
Town nearest:	AMSTERDAM		
Distance from town (km)	18		
Name of farm	JERICHO 304 IT		
District	ERMELO		
Province:	MPUMALANGA	*Region:*	GAUTENG
Date of completion	1966		
Completion date for raising	1968		
River	USUTU		
Wall type	EARTHFILL & GRAVITY		
Wall height (m)	21.3		
Crest length (m)	1167.8		
Spillway	CONTROLLED OGEE		
Capacity (1000 cub. m)	59500		
Surface area of water (ha)	982.5	*Catchment area (sq km)*	218
Purpose	MUNICIPAL USE & INDUSTRIAL USE		

Owner	*Person in Control (if not the same as the owner)*
DIRECTOR-GENERAL	REGIONAL DIRECTOR: GAUTENG
DEPT. OF WATER & SANITATION	DEPT. OF WATER & SANITATION
PRIVATE BAG X313	PRIVATE BAG X 995
PRETORIA	PRETORIA
0001	0001
Tel no. (012) 336 7500	*Tel no.* (012) 392 1300
Cell no.	*Cell no.*
Email / Fax	*Email / Fax*

Designer	*Contractor*
OWNER	OWNER

Registration date: 1/5/1987

Size	Medium	*Hazard Rating:*	High	*Category*	3
Classification date:	12/7/1988	*Date Last DSI:*	2/1/2010		
Date Completion certificate:		*Number Last DSI:*	3		

Appendix B: Photo report of inspection

1) View of the right bank earth fill wall

2) Downstream slope of the right bank earth fill wall showing some grass growth but mostly in excellent condition

3) Disturbance because of trucks on the crest. Has been filled with larger rocks

4) Cracking on the concrete sill on the earth fill crest

5) Corrosion of the base plate strip of the fence

6) View of the Power Station from the right wall. The earth fill 90 degrees to the dam wall is to isolate the transformer station

7) The pump station situated just right of the spillway.

8) Steps on the downstream slope right of spillway

9) Slow flowing water in one of the tow drain wells close to the spillway

10) Apron of the spillway. The orange clay in the water washes out from the galleries discharge holes

11) Downstream view of the spillway with the five radial gates visible. Downstream area with exposed foundation in the foreground.

12) The 1st gate undergoing refurbishing. The water stops / "dryf blok sluise" to close the opening under the gate are visible under the gate

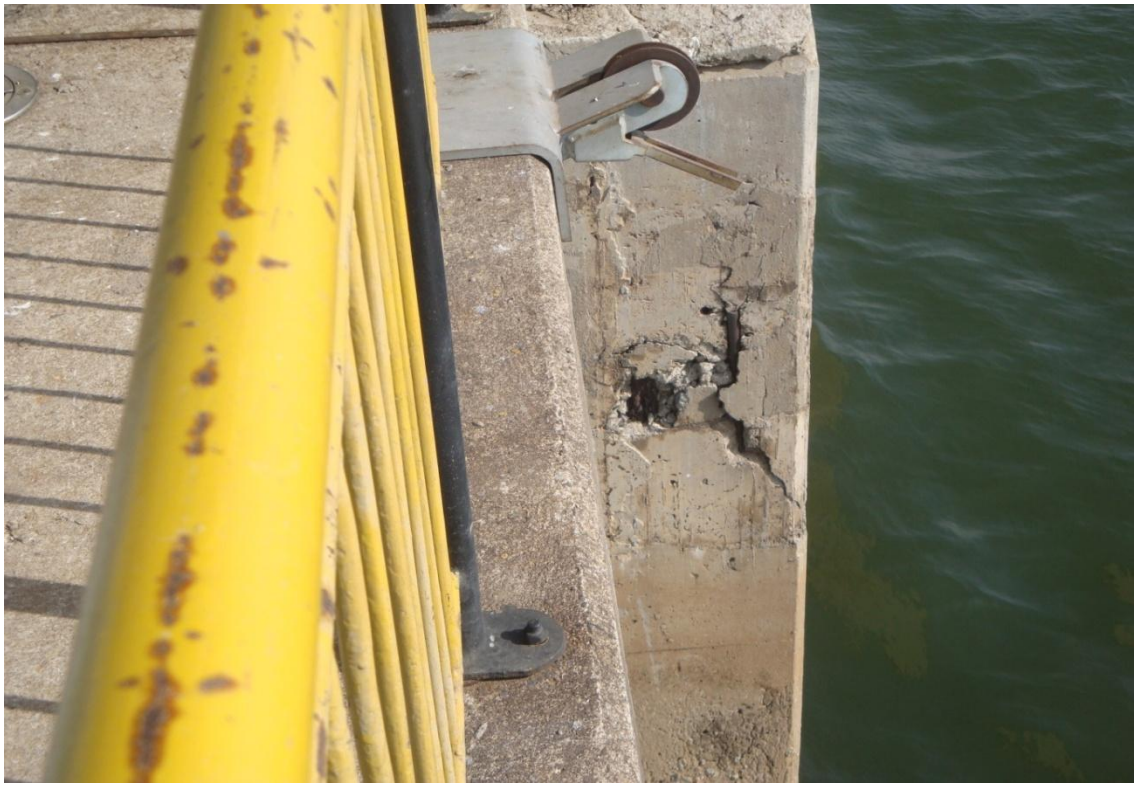
13) Control panels for the radial gates

14) Testing the 4th radial gate

15) Downstream river bed of spillway. Note the exposed solid granite bedrock exposed closer to the stilling basin.

16) the spillway NOC with the radial gate control stations

17) Refurbished 3rd gate fixture compared to the 4th gate



18) Spalling on one of the piers' upstream surfaces.

19) Minor leaks and vegetation seen on the spillways ogee

20) Downstream slope of the concrete wall. Some vegetation growth and leakage visible.

21) Minor corrosion (exposed aggregate) on the upstream face of the wall.

22) Minor corrosion (exposed aggregate) on the upstream face of the wall.

23) Left: Mineral/clay leakage at the vertical contraction joint between blocks 1 and 2.
24) Right close up of the mineral clay deposits.

25) Left: Mineral deposits at one of the vertical contraction joints.
26) Right: Water discharge out of one of the pressure relief holes

27) Clay deposition on the gallery floor

28) Flow measuring station for pressure relief holes. Most of the stations have not been installed properly.

29) The clayey water from the pressure relief holes being carried away through the outlet

30) Outlet Tower: The three outlet pipes that supply water to the pump station

31) Delivery pipe from Westoe dam on the left flank seen from the spillway.

32) Westoe delivery pipe showing some rust at the top connection.

33) The delivery pipe's outlet on the left banks upstream end closest to the spillway. The emancipated buoys can be seen.

34) Close up of the Westoe delivery pipe's outlet.

35) Minor cracking in the concrete sill on the crest.

36) The left bank's crest

37) Downstream slope protection of the left bank

38) Some of the few minor vegetation on the upstream slope of the left bank

Appendix C: Mechanical and electrical inspection report

JERICHO DAM
DAM SAFETY INSPECTION OF MECHANICAL/ELECTRICAL PLANT AND EQUIPMENT
CENTRAL OPERATION

The operation, maintenance and general condition of the mechanical/electrical plant and equipment was evaluated on 15 October 2014.

INSPECTION

The outlet works were found to be in a reasonable operating condition and capable of performing the function for which they were intended. Various items must be urgently attended to as they have not been repaired for an extended period of time.

RECOMMENDATIONS

The following recommendations are made with regard to the maintenance of the equipment.

Levels of Priority:	Priority
Rectify as soon as possible	1
Rectify within two years	2
Rectify within five years	3
Rectify as soon as opportune	4

1.	RADIAL AND SERVICE GATE CONTROL ROOM	
1.1	The service gate is still fitted with the old rubber coated spring steel seals. The seals must be replaced with rubber seals of the latest departmental design.	2
1.2	Rails must be installed in the storage position for easy and safe storage of the service gate.	2
1.3	A grappling arrangement must be installed for improved and safer operation. This is probably the reason why service gate has never been used.	1
1.4	A "plug" was found stored against the wall. Further details of the use, design, operating instructions and position must be established and provided to Strategic Asset Management for approval for use.	2
1.5	New control panels for the remote operation of the radial gates were installed. The units must be tested on a regular basis for operational reliability.	1
1.6	The lights are installed in a very high position with no access for maintenance or repair. The lights must be repositioned and the control switch for the lights be installed adjacent to the electrical distribution panels.	2
1.7	The inner cover of the distribution panel must be refitted to the panel to avoid operations personal being exposed to open electrical wiring.	1
2.	SERVICE GATE CRANE	
2.1	The sheave wheels were found to be corroded and must be refurbished.	1
2.2	The power connection to the crane must be repaired.	1

2.3	The gear box is leaking oil. The reason must be found and repaired.	2
2.4	The corroding rails and crab wheels must be cleaned and refurbished.	1
2.5	All the drive gears are dry and have not been lubricated for an extended period. The gears must be cleaned and lubricated with a good quality open gear lubricant.	1
2.6	Safety covers must be fitted over all rotating elements to improve the safety of service personnel and to comply with the Occupational Health and Safety Act.	1
2.7	Handrails must be installed on the crane to improve safety of personnel.	1
2.8	The crane has been found very dirty with pigeon manure all around. The crane must be cleaned on a regular basis.	1
2.9	The operating personnel must be training in the operation of the system in order that the artisans are not required to operate the units for them.	1
3.	SCREEN GRAPPLE	
3.1	The missing keep plate of shaft securing the sheave to the grapple must be replaced, the missing bolt replaced and the other bolts tightened.	1
3.2	Operating instructions must be provided for the grapple and affixed in close proximity of the unit.	1
4.	OUTLET PIPES	
4.1	Access could not be gained to the inside the pipes as there was no service gate available and the isolating valves are not operational. The pipes and valves must be inspected internally at first opportunity.	2
4.2	A blank flange must be removed for inspection from one of the three spare upper level outlets, to establish the condition of the flanges and outlet pipes.	3
4.3	Access manholes with hinged blank flanges must be installed downstream of the butterfly valves for inspection, testing and refurbishing of the valves and pipes.	3
5.	CRANE IN ISOLATING VALVE CHAMBER	
5.1	The chain hoist of the crane has been refurbished and load tested in accordance with the OHS Act. The unit must be operated and tested on a regular basis.	1
5.2	The anchor plates of the rails are corroded. They must be refurbished or replaced.	2
6.	BUTTERFLY VALVES	
6.1	The butterfly valves are not sealing. The sealing of the valves must be reinstated and the seals checked and adjusted where required on a regular basis as per departmental operating instructions.	1
6.2	The hydraulic operating systems were refurbished and seemed to be operational. The limit switches of the previous system must be removed and the installation cleared up. The hydraulic power packs must be checked on a regular basis in accordance with the guidelines as note in the log book.	1
6.3	The valves must be operated on a regular basis to ensure their continued operation and availability when required.	1
6.4	The height of the handrails around counter weights must be increased to improve the protection of the person against injury.	1

7.	SPHERICAL VALVE	
7.1	The valve is not operational; it has been in the closed position for years and could not be tested as nobody on site knows how to operate it. The support equipment seems to be un-operable; the hydraulic cylinder is badly corroded etc. The isolation capability of the outlet must be reinstated, and kept in a fully operational condition.	1
7.2	A decision must be taken whether the valve will be made operational in accordance with the original specification or its operation simplified by discarding the service seal or replacing it with a different type of valve.	1
7.3	The operating procedures must be located and displayed in a prominent position adjacent to the unit.	1
7.4	The valve must be operated on a regular basis by the operational staff to ensure its availability when required. Any faults must be reported to the competent artisans as soon as they are noted.	1
8.	SLEEVE VALVES	
8.1	Both the large scour and small river discharge sleeve valves could not be operated. A water supply for lubrication must be provided for testing and operating the valves.	1
8.2	The gearboxes of the screw jack drive system are losing oil. The gearboxes must be refurbished and the lubrication system kept in operational condition.	1
8.3	The sliding surface of the rear seal of the valve is very rough. Surface must be buffed and polished to ensure suitable life and operation of the seal.	1
8.4	The stainless steel barrel is corroding. The barrel must be cleaned, refurbished and kept in a clean and operational state.	1
8.5	The corrosion that is visible on valve body must be repaired in accordance with the departmental corrosion protection specification.	1
8.6	The screw jack sleeves are corroding. They must be cleaned and corrosion protected.	1
8.7	Suitable access must be provided to the valve in order that the valves that are dirty and will be kept in a clean operational condition.	1
8.8	Access to the small sleeve valve is difficult. Suitable access and an access platform must be provided to ease and promote the required inspection and maintenance.	1
8.9	Flow charts of the valve discharges must be provided inside the control room.	1
9.	RADIAL GATES	
9.1	The radial gates are sealing reasonably well with only two small leaks that were found. The sealing may deteriorate if the gates are being exercised as required. The gates must be exercised on a regular basis.	1
9.2	Two gates will be refurbished this financial year when rubber seals of the new stoplogs have been successfully repaired. The refurbishment programme must be initiated as soon as possible.	1
9.3	The trunnion bearing grease nipples were painted over thus indicating a very long period since they were last greased. The bearings must be greased.	1
9.4	The hoists have not been exercised on a regular basis. The units must be operated on a regular basis to ensure their availability when required.	1
9.5	The old limit switch system has been replaced. The new control panel has been installed. The system must be checked on a regular basis to ensure its operability.	1
9.6	The open gear drives on all the gates have inadequate lubricant. The gears must be cleaned and lubricated with a good quality open-gear type lubricant.	1
10.	GALLERY	
10.1	The light switches have been replaced. The water resistance of the system must be checked and upgraded if found to be substandard.	1

10.2	There is a fault in the switch board resulting in a non-availability of the lights in the gallery. The problem must be identified and repaired.	1
10.3	The pipe leading to spherical valve that is exposed in the gallery must be corrosion protected.	2

11. GENERAL

11.1	The Departmental Operation and Maintenance Log Books must be implemented and utilised to ensure that the plant and equipment is regularly exercised and maintained.	1
11.2	The new stoplogs are leaked badly as the seals have come loose. They have been removed and the rubber seals will be re-fitted.	1
11.3	Only one trained operator is available on site to operate the equipment. More operators must be trained to be available to operate the dam.	1
11.4	Handrails on the dam wall are badly corroded and must be replaced.	2
11.5	The beam of the monorail has no indication of load carrying capacity. The rating of the beam must be checked, the beam load tested and the rating prominently displayed on the beam.	1
11.6	The loose earth cables must be attached properly.	1
11.7	The pipe delivering water from Westoe Dam to Jericho Dam, that crosses the earth embankment portion of the wall, is corroded and is leakage at the Viking-Johnson coupling. The bolts must checked, washers fitted, bolts tightened properly and corrosion protection of pipe refurbished.	1
11.8	The Corroding chain of the monorail must be cleaned and protected with molybdenum disulphide.	1
11.9	The condition of the generally poorly maintained Electrical installation must be improved. i.e. open panel doors, dirty panels and equipment that is not operational and not repaired.	1

12. OPERATING AND MAINTENANCE PROCEDURES

12.1 It is considered to be the responsibility of the Operational Personnel to implement the use of and ensure adherence to the procedures specified in the Logbooks and to inform the Maintenance Personnel of faults and maintenance procedures specified in the Logbooks.

12.2 The plant must be operated and operational maintenance must be conducted by the operators and not the artisans in order that the artisans can be productively employed to do the more intricate repair work.

12.3 Inspections by Competent Artisans must be done at regular intervals as also called for in the Logbooks to ensure reliability of the plant and equipment and to comply with the Occupational Health and Safety Act.

12.4 Provision is made in the Logbooks for Senior (Supervisory) Personnel to certify that the condition of the plant recorded in the Logbooks is a true reflection of the condition of the plant and equipment. This is essential to ensure that the plant and equipment is correctly operated and adequately maintained and complies with the Occupational Health and Safety Act at all times.

V.W. Kohlmeyer
Chief Engineer: Mechanical Engineering Services
Strategic Asset Management
Date:

J. Kolarovic
Chief Engineer: Mechanical Engineering Services
Strategic Asset Management
Date:

Appendix D: Capacity Table from the 2015 Silt Survey

DEPARTMENT OF WATER AFFAIRS

CAPACITY DETERMINATION - Jericho 2003 W530-03

(1) GAUGE PLATE READING (M)	(2) CONTOUR (M)	(3) NEW AREA (HA)	(4) ORIGNAL VOLUME (CUB M)	(5) NEW VOLUME (CUB M)	(6) VOL SED BETWEEN CONTOURS (CUB M)	(7) ACCUM VOLUME SEDIMENT (CUB M)	(8) %SED BETWEEN CONTOURS	(9) ACCUM % SED
18.53	1471.00	1640.36	121837134.	120190192.	-137.	1646932.	.00	1.35
17.53	1470.00	1505.80	106121528.	104474448.	1944.	1647069.	.01	1.55
16.53	1469.00	1373.27	91743808.	90098672.	7402.	1645125.	.06	1.79
15.53	1468.00	1229.32	78742904.	77105176.	25528.	1637724.	.22	2.08
14.53	1467.00	1075.02	67233599.	65621396.	13912.	1612196.	.23	2.40
F.S.L.	-- V.V.H.							
13.94	1466.41	982.47	61146536.	59548248.	56297.	1598284.	1.43	2.61
13.53	1466.00	916.83	57221031.	55679044.	19367.	1541987.	.23	2.69
12.53	1465.00	809.82	48651793.	47129168.	-60640.	1522620.	-.80	3.13
11.53	1464.00	722.08	41068090.	39484832.	35783.	1583260.	.53	3.86
10.53	1463.00	624.56	34356035.	32808558.	28128.	1547477.	.47	4.50
9.53	1462.00	566.71	28406162.	26886818.	-10443.	1519348.	-.20	5.35
8.53	1461.00	493.74	23138668.	21608878.	46111.	1529791.	1.00	6.61
7.53	1460.00	422.29	18515089.	17031410.	105717.	1483680.	2.62	8.01
6.53	1459.00	364.49	14486752.	13108788.	66620.	1377963.	1.91	9.51
5.53	1458.00	321.75	10990419.	9679076.	42370.	1311343.	1.41	11.93
4.53	1457.00	275.72	7987122.	6718149.	78427.	1268973.	3.20	15.89
3.53	1456.00	205.62	5537514.	4346968.	165386.	1190546.	8.89	21.50
2.53	1455.00	152.16	3677625.	2652465.	144235.	1025161.	10.73	27.88
1.53	1454.00	87.77	2333274.	1452348.	225152.	880926.	24.62	37.75
.53	1453.00	52.61	1418716.	762942.	178501.	655774.	32.30	46.22
-.47	1452.00	29.35	866063.	388789.	107302.	477274.	35.30	55.11
-1.47	1451.00	14.98	562056.	192084.	69289.	369972.	40.61	65.82
-2.47	1450.00	7.28	391419.	90736.	57221.	300683.	48.64	76.82
-3.47	1449.00	4.95	273769.	30307.	63338.	243462.	67.66	88.93
-4.47	1448.00	.20	180160.	36.	72561.	180124.	99.95	99.98
-5.47	1447.00	.00	107563.	0.	51171.	107563.	100.00	100.00
-6.47	1446.00	.00	56392.	0.	33864.	56392.	100.00	100.00
-7.47	1445.00	.00	22528.	0.	18251.	22528.	100.00	100.00
-8.47	1444.00	.00	4277.	0.	4109.	4277.	100.00	100.00
-9.47	1443.00	.00	168.	0.	168.	168.	100.00	100.00

****
GROSS CAPACITY = 59548248. (CUB. M.)
TOTAL VOL. SEDIMENT = 1598284. (CUB. M.)
*TOTAL PERC. SEDIMENT = 2.61 % *
****

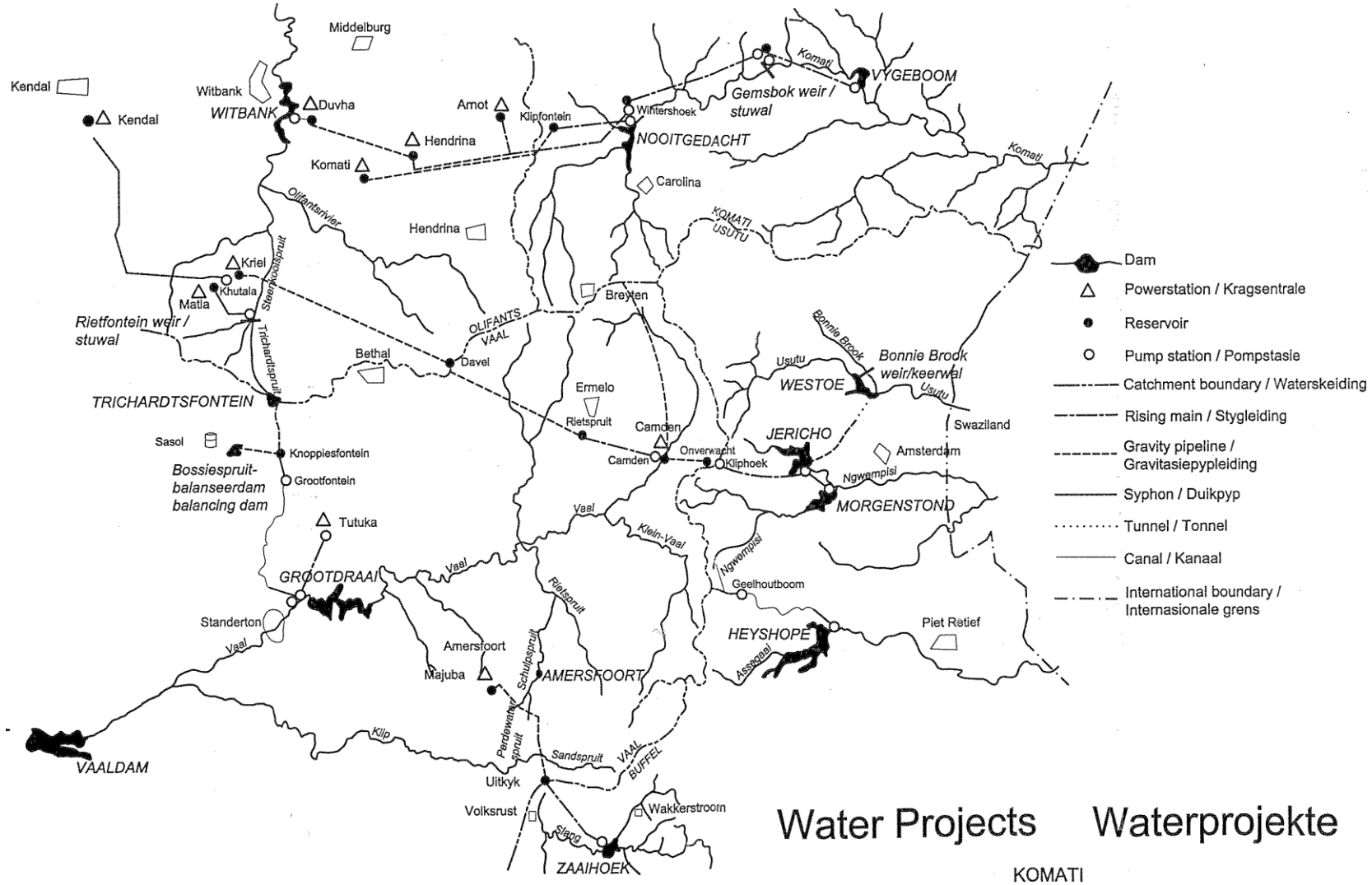
DEPARTMENT OF WATER AFFAIRS

Jericho 2003 W530-03

COMPARISON BETWEEN THE EVAPORATION AREAS
BEFORE AND AFTER SEDIMENTATION.

GUAGE PLATE READING	CONTOUR (M)	ORIGINAL AREA (HA)	AREA AFTER SEDIMENTATION
18.53	1471.00	1640.31	1640.36
17.53	1470.00	1505.73	1505.80
16.53	1469.00	1373.57	1373.27
15.53	1468.00	1231.55	1229.32
14.53	1467.00	1078.68	1075.02
F.S.L.	-- V.V.H.		
13.94	1466.41	989.43	982.47
13.53	1466.00	929.28	916.83
12.53	1465.00	805.63	809.82
11.53	1464.00	715.76	722.08
10.53	1463.00	631.86	624.56
9.53	1462.00	561.33	566.71
8.53	1461.00	495.56	493.74
7.53	1460.00	431.86	422.29
6.53	1459.00	377.05	364.49
5.53	1458.00	325.94	321.75
4.53	1457.00	277.37	275.72
3.53	1456.00	216.32	205.62
2.53	1455.00	160.76	152.16
1.53	1454.00	112.51	87.77
.53	1453.00	73.10	52.61
-.47	1452.00	41.13	29.35
-1.47	1451.00	21.59	14.98
-2.47	1450.00	13.77	7.28
-3.47	1449.00	10.37	4.95
-4.47	1448.00	8.41	.20
-5.47	1447.00	6.20	.00
-6.47	1446.00	4.14	.00
-7.47	1445.00	2.71	.00
-8.47	1444.00	1.13	.00
-9.47	1443.00	.07	.00
-10.47	1442.00	.00	.00

Appendix E: Locality Map



Water Projects Waterprojekte

KOMATI
USUTU
USUTU-VAAL
SLANG

Appendix F: Drawings

The following drawings are attached:

	Drawing No.
General plan	**45372/66**
Foundation elevation	**43282/64**
Concrete sections	**43283/64**