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DWAF Water Resource Study in Support of the ASGISA EC Mzimvubu Development Project

Assessment of Pumped Storage and Hydropower Schemes

VOLUME 5 OF 5

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PREPARED BY:

BKS

BKS (PTY) LTD
PO Box 3173
PRETORIA 0001

DWA WATER RESOURCE STUDY IN SUPPORT OF THE ASGISA-EC MZIMVUBU DEVELOPMENT PROJECT

LIST OF STUDY REPORTS

REPORT	**DWA report number**
Summary Report	P WMA 12/000/00/3609
Existing water supply infrastructure assessment	P WMA 12/000/00/3609 Volume 1 of 5
Agricultural assessment and irrigation water use	P WMA 12/000/00/3609 Volume 2 of 5
Groundwater assessment	P WMA 12/000/00/3609 Volume 3 of 5
Water resources assessment	P WMA 12/000/00/3609 Volume 4 of 5
Assessment of potential for pumped storage and hydropower schemes	**P WMA 12/000/00/3609 Volume 5 of 5**
Rainwater Harvesting	P WMA 12/000/00/3609
An assessment of rain-fed crop production potential in South Africa's neighboring countries	P RSA 000/00/12510

Title	***Assessment of potential for pumped storage and hydropower schemes***
Authors	*JH Schroder* *JR Basson*
Project Name	*DWAF Water Resource Study in Support of the AsgiSA-EC Mzimvubu Development Project*
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BKS (PTY) LTD

Approved for BKS (Pty) Ltd

....

Dr MS Basson
Study Leader

DEPARTMENT OF WATER AFFAIRS
Directorate: National Water Resource Planning

Approved for the Department of Water Affairs and Forestry:

....
JA van Rooyen
Director: National Water Resource Planning

....
I Thompson
Chief Engineer: NWRP (South)

DWAF WATER RESOURCE STUDY IN SUPPORT OF THE ASGISA-EC MZIMVUBU DEVELOPMENT PROJECT

ASSESSMENT OF POTENTIAL FOR PUMPED STORAGE AND HYDROPOWER SCHEMES

EXECUTIVE SUMMARY

Introduction

Harnessing the water resources of the Mzimvubu River, the only major river in the country which is still largely unutilised, can potentially be of great socio-economic benefit. Hydropower has been identified as a potential development option of the water resources in the Eastern Cape region, and in particular on the Mzimvubu River. This report provides a desktop assessment of the potential for hydropower development in the Mzimvubu Development Zone. Both pumped storage schemes and conventional hydropower generation at potential dam sites have been assessed.

Pumped storage schemes in the Mzimvubu River Basin and in the surrounding Eastern Cape region were assessed and compared in a first-order analysis to determine the most promising schemes that could be taken forward in more detailed investigations. Pumped storage schemes identified by Eskom and by the DWAF were included in the assessment. The DWAF also assessed the possibility of combining a pumped storage scheme with one of the potential dam sites on the Mzimvubu River, as a multi-purpose development.

The potential for conventional hydropower generation at potential dam sites in the Mzimvubu River was assessed. This included determining the base load and peaking power that could be reliably generated at the dam sites, and estimating the financial viability of the schemes based on some basic economic assumptions. A scheme at Tsitsa Falls, identified in a number of previous studies as a promising hydropower site, was again assessed and compared to the potential hydropower generation at other potential dam sites.

Pumped storage schemes

Site-selection criteria were provided by Eskom and consisted of a reference scheme size of 1000 MW installed capacity, and reservoirs capable of 14 000 MWh energy equivalent storage to provide 14 hours continuous generation. Operating head range, water availability and accessibility were also taken into account. A total of seven pumped storage scheme sites were selected for assessment in the Eastern Cape. Some sites had more than one possible layout and a total of ten scheme options were investigated.

Based on the consideration of technical aspects, cost, risk and uncertainty, environmental aspects and various other factors, comparisons were made of all the options and ratings were given. The options were then ranked to facilitate selection of the five best schemes to be further assessed. Although the task entailed a desktop level of investigation with information gathered being generally of low detail and confidence, this study can be used to compare the ten potential scheme options at the same level of confidence.

Based on the rankings, the most favourable sites that could possibly be further investigated were obtained. Noting that the runoff in the catchment is high, and that the likely sedimentation of dams is significant, off-channel dams primed from an abstraction weir, may be more advantageous. This would unlink the location and layout of a pumped storage scheme from a lower reservoir on a river, and provide greater freedom in selecting possible sites which may be more favourable than those already identified. It may be beneficial to Eskom to conduct another round of site identification, focused on sites with off-channel lower reservoirs, in order to confirm that the sites identified in this study are the most favourable.

Conventional hydropower

Conventional hydropower potential at a number of potential dam sites was assessed for base load and peaking power generation. Three reservoir capacity sizes were considered during the assessment in order to determine the most suitable dam sizes for hydropower and water supply at the various sites. At an assumed assurance of supply of 99.5%, the hydropower that can be continuously generated at the various dam sites on the main tributaries of the Mzimvubu River ranges between 0.4 and 7 MW_C. Approximately 20 MW_C can be continuously generated at a large dam on the main river below the confluence of the tributaries, but the impacts of a large dam close to the estuary are likely to be unacceptable.

As a comparison, a hydropower scheme at the Tsitsa Falls was also considered. The scheme consists of a dam upstream of the falls and a tunnel that bypasses the falls to a point downstream on the Tsitsa River. After making allowance for ecological water requirement releases from the dam, which pass over the falls, water is routed through the tunnel to the turbines for power generation. Although this study differs from previous studies in that ecological water requirements were considered and did reduce the available hydropower, the acceptable flows that should be maintained over the falls were not determined. Approximately 250 MW can be generated at an indicative load factor of 10% for peaking power, or 25MW_C can be generated for base load supply.

A basic economic analysis of off-setting the capital cost of the scheme at the Tsitsa Falls by the sales of generated power, suggested that the generation of peaking power has more potential *as a single-purpose development than base load, although peaking power generation was only just marginal at low discount rates. The generation of peaking power at the potential dam sites generally showed less potential to be economically viable as a single purpose development. Base load power generation showed little potential at the dam sites as only small quantities of hydropower could be generated at a high unit cost. Base load is only likely to be feasible as part of a multipurpose development and will be more suited to local supply.*

Conclusions

Potential pumped storage schemes in the Eastern Cape were analysed and compared, and the five most favourable sites identified for possible further investigation.

Based on the assessment of generating capacity and basic financial feasibility, conventional hydropower developments in the Mzimvubu River appear to show little potential as single purpose developments. Conventional hydropower will most likely be better suited as part of a multi-purpose development. Peaking power generation showed the most potential at the Tsitsa Falls, and a few of the possible dam sites. The acceptable flows that would need to be maintained over the Tsitsa Falls, however, have not been determined.

It should be noted that Eskom recently released information on increased feed-in tariffs for renewable energy, which may improve the feasibility of some of the hydropower development options in the Mzimvubu catchment. Details have been requested from Eskom and their inclusion could result in some changes on the general conclusions reached during this first order assessment.

DWAF WATER RESOURCE STUDY IN SUPPORT OF THE ASGISA-EC MZIMVUBU DEVELOPMENT PROJECT

ASSESSMENT OF POTENTIAL FOR PUMPED STORAGE AND HYDROPOWER SCHEMES

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1 INTRODUCTION

1.1 BACKGROUND

The Mzimvubu River area in the Eastern Cape Province is one of the poorest and least developed parts of South Africa. Development of the area, with the express purpose of accelerating the social and economic upliftment of the people in the region, was therefore identified as one of the priority initiatives of the Eastern Cape Provincial Government. The Mzimvubu Development Project was consequently identified as a Presidential Icon Project and has been accepted as such by the National Government.

Harnessing the water resources of the Mzimvubu River, the only major river in the country which is still largely unutilised, was considered by the Eastern Cape Government as offering one of the best opportunities in the province to achieve such development. In 2007, they therefore established a special-purpose vehicle (SPV) in terms of the Companies Act, the so-called AsgiSA-Eastern Cape (Pty) Ltd (AsgiSA-EC), to initiate planning and to facilitate and drive the development.

The five pillars on which the EC Provincial Government and AsgiSA-EC proposed to build the Mzimvubu Development Project are:

- Afforestation;
- Irrigation;
- Hydropower;
- Water transfer; and
- Tourism.

In 2006 the DWAF Directorate: National Water Resource Planning appointed PSPs to assist in the provision of water-related support to the Eastern Cape Provincial Government (later AsgiSA-EC after its establishment). The main component of the task was supposed to be direct water resource planning inputs to specific development projects, for example an irrigation project, that AsgiSA-EC may identify and want to pursue as a poverty alleviation project. As a secondary component the DWAF undertook to provide some general water resource information that included a hydropower assessment, which could facilitate the identification of other potentially viable projects by AsgiSA-EC. Work in this regard commenced in December 2006.

1.2 STUDY AREA

The conventional hydropower assessment at potential dam sites was conducted for the Mzimvubu River catchment. The identification and assessment of pumped storage scheme sites was conducted for a larger area; the “Mzimvubu Development Zone”, which covers not only the Mzimvubu River catchment, but also neighbouring areas such as the Pondoland area to the north-east and parts of the Mthatha River catchment to the south-west.

1.3 SUMMARY OF FINDINGS OF PREVIOUS STUDIES

A number of previous studies were undertaken to investigate the potential for hydropower generation in the Mzimvubu River catchment. Both pumped storage schemes and conventional hydropower have been assessed in previous studies. The general findings of these reports are that the best potential for conventional hydropower generation exists at the Tsitsa Falls, and that a number of potential pumped storage scheme sites exist in the region.

The relevant information gathered from previous studies that can be used in this study is reported on as required in the relevant chapters.

1.4 PURPOSE OF THE REPORT

The purpose of this report is to present the hydropower component of the work of a general nature by the DWAF to assist the AsgiSA-EC initiatives. Both conventional hydropower and pumped storage schemes were assessed and are included in this report.

Although both pumped storage and conventional hydropower schemes use water-driven turbines for the generation of power, there is a fundamental difference between the schemes with respect to the primary source of energy used. For conventional hydropower, power is generated from harnessing the energy in the streamflow; which is a source of renewable energy. Pumped storage schemes in contrast use the excess energy generated by other sources to pump water to a higher elevation during off-peak periods, from where the water is released for the generation of power during peak demand periods; much like a huge battery.

Potential sites for the development of pumped storage schemes are therefore presented separately in chapter 2, whilst the potential for conventional hydropower generation is covered in chapter 3.

The work has been conducted at a reconnaissance level, and the conclusions reached and the recommendations made are therefore of an indicative nature and could be subject to further investigations and review.

2 PUMPED STORAGE HYDROPOWER ASSESSMENT

2.1 BACKGROUND

The identification of potential pumped storage schemes within the Eastern Cape forms part of the preparatory work conducted for the Mzimvubu Development Project. The aim of this task in the study is to evaluate, at a desktop or reconnaissance level, the different pumped storage sites that were identified by both Eskom and DWAF. This will determine the five most promising sites that could be taken forward in more detailed investigations.

Part of the emphasis of this desktop study has been to try to identify potential pumped storage schemes that can be developed jointly with another potential water resource initiative within the Mzimvubu Basin. This could promote a collaborative development between Eskom and DWAF in the Eastern Cape.

2.2 SITE SELECTION CRITERIA

The following site selection criteria were provided by Eskom.

2.2.1 Capacity

A 1 000 MW installed capacity is assumed as reference size for the schemes. This capacity was designated for two reasons:

- It is in accordance with Eskom's planning strategies where such denominations have been developed to suit the anticipated rate of demand growth.
- To provide a common basis for economic comparison with previous schemes and thus facilitate the selection of a scheme through equitable ranking.

2.2.2 Energy storage

The reservoir capacities should provide for a 14-hour continuous generating capability, i.e. reservoirs capable of a 14 000 MWh energy storage. Once the most promising scheme has been selected for further development, optimisation studies are proposed in order to determine the optimum dam capacity of the selected scheme. This will be determined by comparing the incremental increase in production cost of the entire energy system with the reduction in dam costs when the volume is reduced.

2.2.3 Operation of the scheme

The most economical or optimum operating pattern, which can be achieved with the 14-hour live volume, will eventually be established once a scheme is in operation. This also relates to the topography and scheme configuration at any particular site.

2.2.4 High head conditions

The single stage Francis pump/turbine was modelled and simulated at heads ranging from 350 to 700 m. At this head the ratio of maximum pumping to minimum generating head is limited to 1,2 or 120%.

2.2.5 Water availability

The dams must be close to or within perennial rivers, for the purposes of priming the scheme within a reasonable time period, which was assumed as 2 years for this study.

2.2.6 Accessibility

Sites must preferably be located not very far from the main roads to reduce the cost of access roads.

2.2.7 Costs

Total costs given in the report include only capital costs.

2.2.8 Sediment

Provision for the silt which is often found at the bottom of bodies of water where it accumulates slowly by settling through the water is being incorporated into the studies. This accumulation of silt reduces the storage capacity of the dam, hence requiring larger initial storage capacities.

2.2.9 Geology

The geology of these sites is based on available geological maps of the region and the documented case studies of the problems encountered in the same region. The rock data is then interpolated from geotechnical reports of a study in the same region.

2.3 IDENTIFIED SCHEMES

In total seven sites have been identified for potential pumped storage schemes. At three of these sites there is more than one alternative layout for a pumped storage scheme. The location of the 10 options that have been identified for potential pumped storage schemes are presented in **Figure 2.1**. One of the potential sites identified by Eskom falls within the Mbashe River basin and not the Mzimvubu River basin.

A schematic layout with respect to each individual option is attached in **Appendix A**.

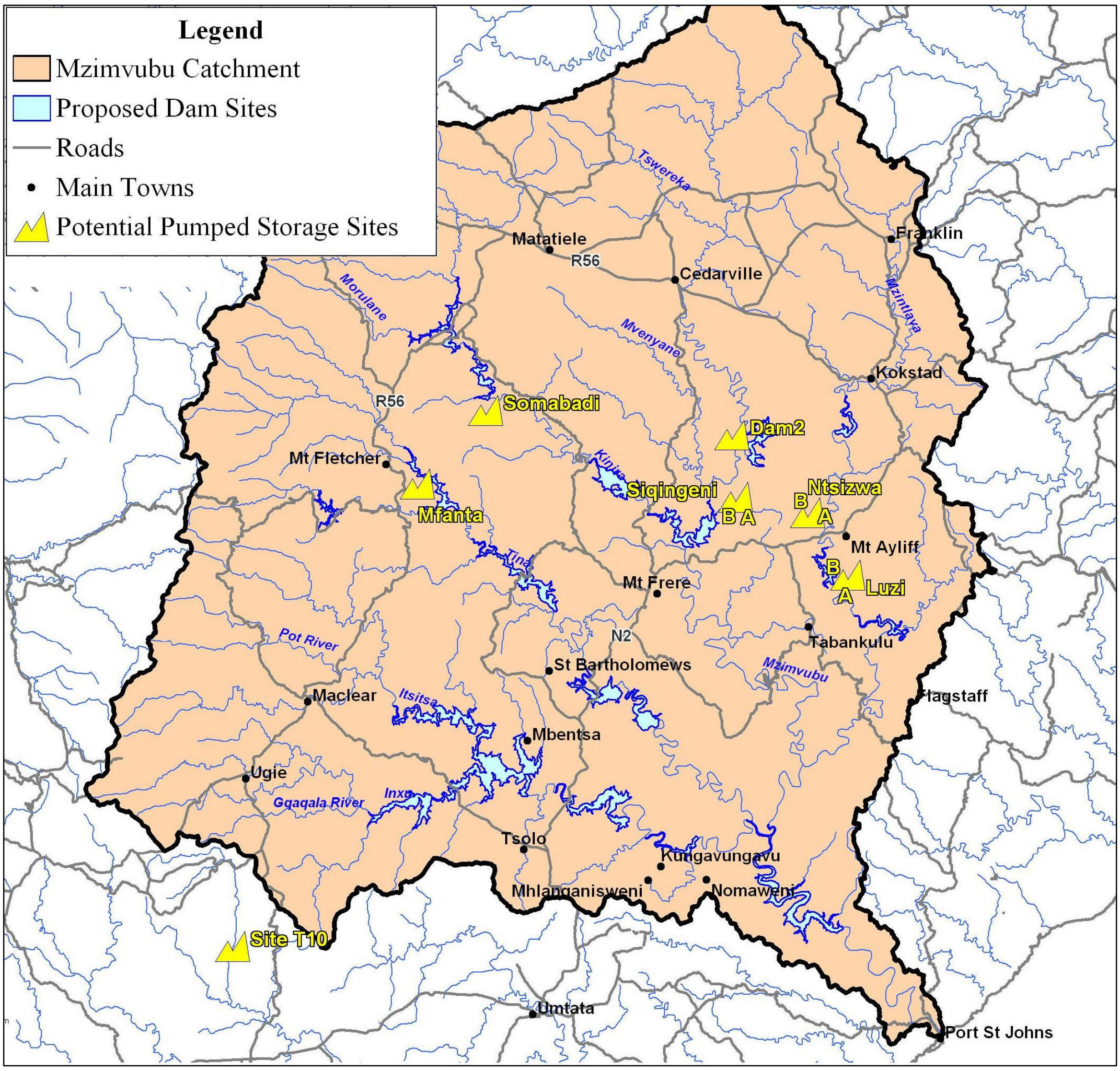

Figure 2.1 Potential pumped storage hydropower sites

2.4 APPROACH FOLLOWED

The main elements of the approach followed are concisely described below in order to provide a broad perspective of the site identification activities.

Candidate sites for a pumped storage scheme were identified at various locations, mainly based on an assessment of potentially favourable topography as well as in the proximity to potential water storage dams.

Specific consideration was also given to the geological conditions, the other main determinant with respect to the siting and layout.

Other items investigated or considered in selecting the five best sites to be taken to a pre-feasibility phase include:

- Existing developments and potential related impacts.

- Environmental sensitivities and potential negative impacts.
- Access roads.

Preliminary layouts and sizing of the main components were done for a 1 000 MW scheme at each of the potentially feasible new sites and layouts, and the costs were estimated. Based on the consideration of technical aspects, cost, risk and uncertainty, environmental aspects and various other factors, comparisons were made of all the options and ratings were given. The options were then ranked to facilitate selection of the five best schemes to be carried forward.

2.5 ASSUMPTIONS

2.5.1 General

It has to be emphasized that this task only entailed a desktop level of investigation. All the information used in the site identification study was gathered by making use of only 1:50 000 maps. Therefore the confidence level with regard to the accuracy of the information is low.

This study could however be used to evaluate all ten of the identified sites at the same level of confidence.

2.5.2 Geology

An overall view of the geology of the area was gained by making use of geological maps of the study area. From these maps very broad information was abstracted.

Upper reservoirs

The upper reservoirs are mostly located on dolerite, while a few are on dolerite and sandstone or dolerite and shale. In this area, weathering of dolerite is expected to be about 10 m.

Rockfill and concrete aggregate will be expensive to obtain from underneath 10 m of overburden. Therefore, zoned earthfill dams with sandstone or weathered sandstone as semi-pervious material and clay from the dolerite as core material, may be the preferred options.

The areas available for the construction of the upper reservoirs are, however, limited and therefore a rockfill-type dam was selected for all the upper reservoirs.

Foundation excavations were assumed to be on the average 2 m for earthfill embankment shells and 5 m for rockfill shells. In order to achieve a watertight (or groutable) foundation, core trenches will have to be excavated to a depth of 10 m.

Lower reservoirs

The centre lines for most of the lower dams appear to be underlain by shale or mudstone in the river sections and lower flanks, while the upper flanks are underlain by dolerite. This configuration does not offer favourable conditions for concrete dams due to problems with sliding and rapid deterioration of the sedimentary rocks and deep weathering in the dolerite. However, most of the rivers within the Mzimvubu catchment have high flow volumes and as a result the lower reservoirs situated in such rivers will require large spillway capacities and will need to be concrete dams.

The sites at and about 20 km west of Bokpoort are different in that they seem to be completely underlain by dolerite. Although foundation excavations are likely to be on average 10 m deep, the bedrock will be suitable for founding of concrete dams.

Concrete aggregate will have to be obtained from dolerite and is likely to be expensive because of the 10 m thick overburden.

2.5.3 Civil works

All civil works were based on 1:50 000 maps and 20 m contours.

Underground civil works

- The diameters of the waterways were determined by using the flow velocities as indicated in **Table 2.1**.

Table 2.1 Waterway flow velocities

Waterway section	Flow velocity (m/s)
Headrace Tunnel	5.0
Pressure Shaft	5.5
Concrete-lined Pressure Tunnel	5.5
Steel-lined Pressure Tunnel	8.5
Penstocks	8.5
Draft Tube Extensions	5.0
Tailrace Tunnel	5.0

- Concrete and steel pressure tunnels have maximum slopes of 8%.
- Tailrace tunnels were at slopes no greater than 12.5%.
- Steel-lined pressure tunnels were taken as 300 m in length.
- 80 m of submergence was provided for the machines.
- Penstocks were taken as 65 m in length.
- Draft tubes extensions were taken as 100 m in length.
- Surge chambers have been included for each site. More complete hydraulic calculations during the next phase will determine whether surge chambers are necessary.

- For the main access tunnel, inside dimensions of 8.3 m wide by 8.7 m high were used as well as a 10% maximum grade.
- For the cable tunnel, inside dimensions of 5 m wide by 6 m high were used as well as a 10% maximum grade.

Surface civil works

A) Upper reservoirs

Due to topographical and area constraints, rockfill dams have been used for all upper reservoirs. Allowance has been made to strip and spoil 10 m of overburden in order to gain access to usable rockfill material. This additional cost has been allowed for in the cost estimates.

B) Lower reservoirs

- For on-channel dams on the major rivers, roller-compacted concrete dams have been selected to accommodate the high peak flows.
- For off-channel dams or dams on small tributaries, earthfill-type dams have been selected.
- Allowance has been made within the storage capacity of the on-channel lower reservoirs for sediment build up. The volume of sediment was calculated using a 50-year time period, average sediment yield of 200 t/km^2/a (region 9 standardised average sediment yield) and a trapping efficiency of 95%.

2.5.4 Access roads

A maximum grade of 7% was used.

2.6 EVALUATION OF OPTIONS

Various parameters were considered for comparison of the different options. From these the most indicative/meaningful were selected, quantified or assessed, and organised according to the following main groupings:

- General description and physical parameters
- Operational
- Water supply
- Geological
- Environmental
- Access
- Cost
- Expandability.

The individual items or parameters within the above groupings were **rated** for each of the options, which then formed the basis for the **ranking** of the options. The following guideline was used for rating of the respective items/parameters:

rating 5 = best or preferred
rating 4 = good/above average
rating 3 = average
rating 2 = below average
rating 1 = doubtful or unacceptable.

Given that none of the options has been optimised yet, the quantification of parameters (where applicable/possible) were taken as indicative rather than absolute, and rated in the same way. The headings under each heading/grouping were summarised and the options then ranked accordingly. (Maximum number of ranking positions being equal to the number of options compared.) The respective rankings per heading/grouping were then added to obtain an overall ranking of the respective options. The detailed **ratings** and **rankings** are given in the expanded **Table C-1** in **Appendix C** of the Report. A summary of the sub-**rankings** together with the overall **ranking** is given in **Table 2.2**.

Sensitivity analyses were also performed by assigning weights according to the importance of parameters, resulting in the same outcome, although with increased differentiation amongst options.

2.6.1 Comparative outcome

The outcome of the evaluation is summarised in **Table 2.2**.

Physical parameters

The physical parameters are all based on the topography of each individual site.

Operational

This parameter gives an indication of what the operational characteristics of each scheme will be, based on the topography and layout.

Water supply

The water source and type of abstraction is given as background. Due to the positions of the potential schemes relative to rivers, and the high runoff of water in the catchment, all schemes could be primed in the suitable time frame, and this parameter was therefore not an influence of site preference.

Geological

The type of material, founding depths and the existence of possible unfavourable features for both upper and lower reservoirs are addressed as well as the conditions for excavation of the underground construction.

Environmental

It is very difficult to address environmental aspects based on information indicated on 1:50 000 maps. Therefore the level of confidence with regard to the environmental evaluation is very low.

Access

The lengths of new roads to be constructed as well as the travel distance between the control room (lower level) and the upper reservoir were determined for each option.

Cost

The components which have been estimated based on calculations, and those which have been taken from a previous study with escalation applied, are presented in **Table 2.3**.

Expandability

The criterion for this parameter is based on the area available to enlarge the upper reservoir.

Table 2.2 Summarised ranking of options

Item/Parameter	Options									
	Somabadi	**Mfanta**	**T10**	**Dam 2**	**Siqingeni A**	**Siqingeni B**	**Luzi A**	**Luzi B**	**Ntsizwa A**	**Ntsizwa B**
1. Physical parameters	3	5.5	1	3	7.5	9.5	5.5	3	9.5	7.5
2. Operational	3	10	2	6	4.5	7	1	9	4.5	8
3. Water supply	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4. Geological	1	4	8.5	8.5	4	4	4	4	8.5	8.5
5. Environmental	4.5	2	9.5	9.5	4.5	2	8	6.5	6.5	2
6. Access	4	1	10	7	7	7	7	7	2.5	2.5
7. Cost	1.5	6	1.5	6	6	6	6	10	6	6
8. Expandability	1	6	6	6	6	6	6	6	6	6
Total	**18.0**	**34.5**	**38.5**	**46.0**	**39.5**	**41.5**	**37.5**	**45.5**	**43.5**	**40.5**
Overall Ranking	**1**	**2**	**4**	**10**	**5**	**7**	**3**	**9**	**8**	**6**

Table 2.3 Cost components

Sub head	Description	Source of cost
1	**UNDERGROUND CIVIL WORKS**	
1.1	Headrace intake structure	Taken from previous study
1.2	Headrace tunnel	Calculated
1.3	Pressure shaft	Calculated
1.4	Pressure tunnel (concrete lined)	Calculated
1.5	Pressure tunnel (steel lined)	Calculated
1.6	Penstocks	Calculated
1.7	Machine hall	Taken from previous study
1.8	Transformer hall	Taken from previous study
1.9	Busbar tunnels	Taken from previous study
1.10	Fresh air supply shaft and water drainage tunnel	Calculated
1.11	Smoke shaft	Taken from previous study
1.12	Extended draft tube tunnels	Calculated
1.13	Tailrace surge chambers	Calculated
1.14	Tailrace tunnel (concrete lined)	Calculated
1.15	Tailrace outfall structure	Taken from previous study
1.16	Cable and emergency Exit tunnel	Calculated
1.17	Cable and emergency exit tunnel portal	Taken from previous study
1.18	Main access tunnel	Calculated
1.19	Main access tunnel portal	Taken from previous study
1.20	Construction access to bifurcation tunnel	Taken from previous study
1.21	Construction access to pressure tunnels	Taken from previous study
1.22	Connector tunnel at base of pressure shaft	Taken from previous study
1.23	Access tunnel to powerhouse drainage gallery	Taken from previous study
1.24	Machine hall emergency exit tunnel	Taken from previous study
1.25	Smoke extraction tunnel	Taken from previous study
1.26	Drainage curtain tunnel	Taken from previous study
1.27	Drainage tunnel (from drainage curtain)	Taken from previous study
1.28	Fresh air supply shaft	Taken from previous study

Sub head	Description	Source of cost
2	**SURFACE CIVIL WORKS**	
2.1	Upper reservoir	Calculated
2.2	Lower reservoir	Calculated
2.3	Surface buildings	Taken from previous study
2.4	Permanent site roads	Taken from previous study
2.5	Security fencing	Taken from previous study
3	**MECHANICAL EQUIPMENT**	
3.1	Pump/turbines with governors and spherical valves	Calculated
3.2	Main and auxiliary cranes	Taken from previous study
3.3	Headrace intake mechanical equipment	Taken from previous study
3.4	Tailrace outfall mechanical equipment	Taken from previous study
3.5	Station services and elevators	Taken from previous study
3.6	Dewatering and Drainage	Taken from previous study
4	**ELECTRICAL PLANT – GENERAL CONSTRUCTION**	
4.1	Motor/generator system	Calculated
4.2	Auxiliary system	Taken from previous study
4.3	Lighting, security, fire, communication cable system	Taken from previous study
5	**TRANSMISSION**	Taken from previous study
6	**PERMANENT ACCESS ROADS**	Calculated
7	**CONSTRUCTION CAMP AND VILLAGE**	
7.1	Upper reservoir site	Taken from previous study
7.2	Lower reservoir site	Taken from previous study
8	**PROJECT MANAGEMENT AND OTHER COSTS**	Calculated
9	**OTHER COSTS**	Taken from previous study

2.6.2 Overall rating and sensitivity analyses

Sensitivity analyses were performed by giving greater weight to aspects such as general description of the option, operational considerations and cost, in comparison to lower weightings to items such as geological conditions, environmental considerations and access. This did not significantly change the results, which confirmed the rankings.

2.7 SUMMARY AND RECOMMENDATIONS

2.7.1 Summary

Various sites and optional layouts were investigated with respect to the construction of a pumped storage scheme in the Eastern Cape.

Although this task merely entailed a desktop level of investigation, with all the information gathered from 1:50 000 maps, and the confidence level with regard to the accuracy of the information being low, this study can be used to compare all ten of the identified sites at the same level of confidence.

2.7.2 Recommendations

Based on the ranking of the ten sites, the following five sites appear to be the most favourable:

- Somabadi;
- Mfanta;
- Luzi;
- T10; and
- Siqingeni.

However, with the mean annual runoff within the Mzimvubu Catchment being high, it would also be possible to prime a scheme within a two year period by constructing an abstraction weir within a perennial river. This unlinks the location and layout of a pumped storage scheme from a lower reservoir on the river and provides greater freedom in selecting a possibly more advantageous site and layout in addition to the sites identified up to now.

Therefore it may be to Eskom's benefit to do another round of site identification, focussed at off-channel lower reservoirs, to confirm that the sites identified in this study are the most favourable.

3 CONVENTIONAL HYDROPOWER ASSESMENT

3.1 INTRODUCTION

The preparatory water resources work conducted for the study looked amongst other things, at potential dam sites in the catchment, and what water could be yielded from these dams for local use. This provided an opportunity to also assess the potential for hydropower generation at the potential dam sites.

A first order analysis on hydropower at the potential dam sites was conducted with a monthly water balance model. This model, the Water Resources Yield Model (WRYM), was developed by BKS for the DWAF, and has its origins in Canada, where it was initially developed for hydropower and flood control analysis.

Preliminary costs of the dams and associated hydropower plants were also derived to provide estimates of the total scheme costs, and to provide indicative values of unit cost per generating capacity for comparative purposes. A basic financial feasibility analysis was also conducted to assess the potential of funding a hydropower development with the sales of electricity. Single purpose developments for hydropower generation were only considered at this stage, to provide an initial indication of the potential viability of hydropower development.

3.2 POTENTIAL DAM SITES

A number of previous studies have been conducted on various water resource developments, including hydropower, in the region. Dam sites in the catchment have been identified during these previous studies, and have been assessed for potential water supply, hydropower, as well as for water transfer.

Of the dam sites which were identified in previous studies, and some which were identified during this study, 19 potential dam sites have been selected for hydropower assessment. Potential dam sites were chosen on all of the main tributaries of the Mzimvubu River and on the lower Mzimvubu River below the junction of the tributaries. The location of potential dam sites is displayed in **Figure 3.1**.

These potential dam sites have been analysed for water yield and for hydropower potential. More detail on the potential dam sites analysed for hydropower can be found in the table in **Appendix D**.

The hydropower potential was assessed for gross reservoir storage capacities of 0.5, 1 and 1.5 times the mean annual runoff (MAR) at each of the potential dam sites.

In some cases the topography at the potential dam site limits the dam wall height and thus capacity to less than 1.5 times the MAR. A cap on dam wall height of 100 m was also assumed for this study.

Figure 3.1 Potential Dam sites in the Mzimvubu River catchment

3.3 WATER RESOURCES AND WATER BALANCE

The Mzimvubu River has generally high runoff volumes due to the high rainfall, and mountainous topography in many parts. There are low levels of water utilisation in the catchment, and little regulation of streamflow. This could potentially create a suitable environment for hydropower generation and water abstraction through the implementation of hydraulic structures.

The following components of the water resources were accounted for and included in the yield and hydropower assessments:

- Latest available generalised hydrology
- Urban and rural water requirements

- Irrigation water usage
- Streamflow reduction by commercial forestry and alien vegetation
- Ecological water requirements (EWR)
- Sedimentation and associated dead storage in potential dams

Approximately 134 million m^3/a of water is currently required by consumptive users. This amounts to only 5% of the total annual average streamflow in the catchment. The EWR, also known as the reserve, requires an estimated 880 million m^3/a streamflow to be maintained in the rivers. More detail on the current water users and the environmental water requirements can be found in the *Water Resources Assessment* report, DWAF report number P WMA 12/000/00/3609 Volume 4 of 5.

This study differs from previous studies focused on hydropower due to ecological water requirements being accounted for, and included in the analyses. As such the results of the study may differ from previous studies for similar hydropower development scenarios.

The EWRs were provisionally determined with a desktop model and may be conservative due to the precautionary principle.

3.4 HISTORIC FIRM YIELDS

The firm yields at the potential dam sites were determined using a historic 85 year record period of monthly streamflow data. The inflows, spills, losses and water releases were calculated on a monthly time step to determine the historic firm yields. The firm yields ranged from approximately 13 million m^3/a for a smaller dam high up in the catchment to over 500 million m^3/a for a larger dam on the lower Mzimvubu River.

The historic firm yields provide an indication of the likely quantities of water that could be reliably available for generating hydropower. The yields are also presented in more detail in the *Water Resources Assessment* report, DWAF report number P WMA 12/000/00/3609 Volume 4 of 5. More detail on the WRYM can be found in DWAF (1998).

More detailed simulations for accurate systems planning and feasibility studies make use of stochastic flow sequences.

For comparative purposes and as an initial indication of hydropower potential, the historic flow sequence is assumed to be sufficient.

3.5 HYDROPOWER ASSESMENT

3.5.1 Turbine operation

The assumption was made that releases would not be made from the dams below the minimum turbine operating heads, except for the EWR. The assumed turbine operating range is displayed in **Figure 3.2**.

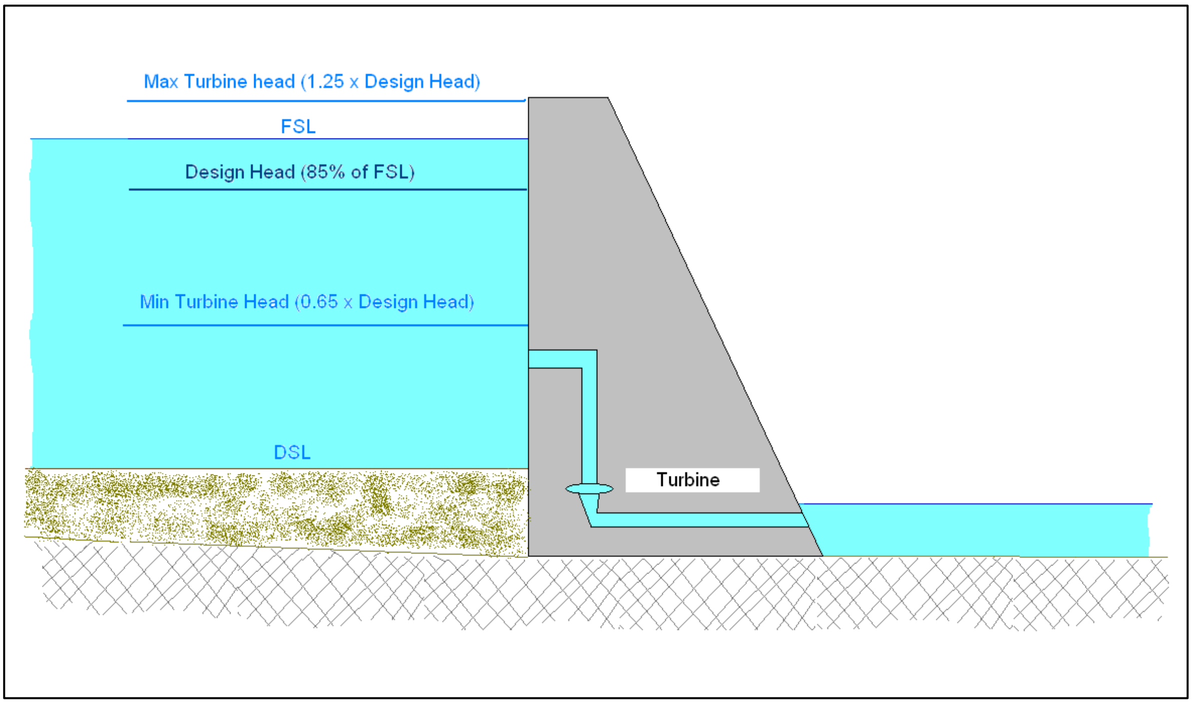

Figure 3.2 Generalised turbine operating range for hydropower simulations

The indicative operating head range is selected to be a realistic, but generalized first order approach to represent the likely capacity of a water turbine in generating power with variable levels of water stored behind the dams.

Turbine design head was assumed to be 85% of the full storage level (FSL), with maximum turbine head being 1.25 times the design head. This is a few meters above the FSL and could accommodate periods when dams are above FSL and spilling. Minimum turbine head is assumed to be 65% of the design head.

Indicative variable turbine efficiencies were coupled to the turbine operating range to take into account the change in the turbine efficiency as water levels in the dams change. The assumed turbine operating range and associated efficiencies are based on the existing power plants at Gariep and Vanderkloof dams on the Orange River, and are presented as a turbine operating curve, listed in **Appendix E**.

3.5.2 Hydropower potential

The power that can be generated at the potential sites is a function of the height of the dam walls, and the magnitude of the flow releases from the dam. The flows that can be reliably released from the dams are dependent both the flow into the reservoir and on the reservoir storage capacity due to the variable streamflow in South African rivers.

Figure 3.4 displays the frequency distribution of inflows into the potential dam site at Laleni. This graph is typical of the variability that occurs in flows at dam sites in the catchment.

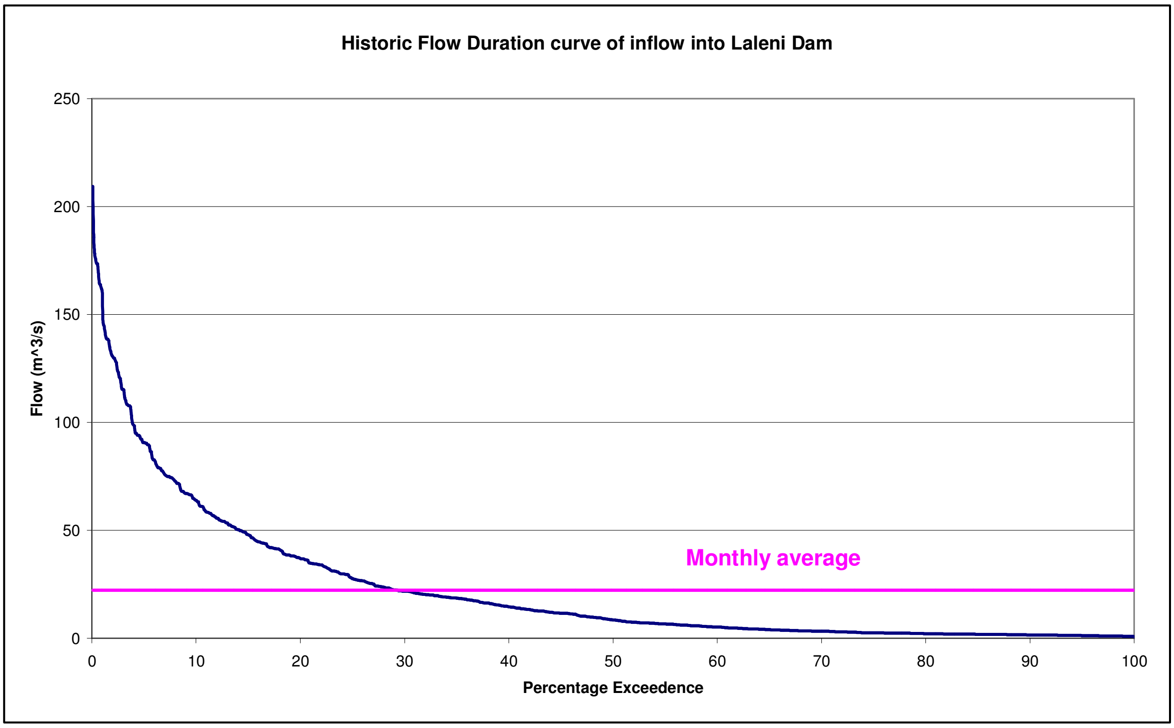

Figure 3.4 Frequency distribution curve typical of inflows into potential dam sites

Flow regimes with extreme high and low flows, likely at dam sites in the Mzimvubu River catchment, are not ideal for hydropower generation. Unless extremely large dams are constructed to store water during high flow periods and augment low flow periods, the hydropower that can be reliably generated is generally low as a result of the variability in river flows.

The larger 1.5 MAR capacity reservoirs assessed at the potential dam sites are expected to have increased firm hydropower available. The benefit of the extra firm power that can be generated at larger dams is, however, dependent on the additional cost of the larger dam, which is highly site specific.

The firm hydropower available at potential dam sites was assumed to be supplied at a 99.5% assurance over the record period. Non-firm or secondary hydropower was estimated in the simulations as the additional power that could be available if spills from dams are also routed through the turbines for power generation.

The emphasis of the analyses is on firm power, and non-firm power will not be elaborated on any further in this report.

The firm power that is estimated to be available at the potential dam sites are first presented in **Figure 3.3** for the 1 MAR reservoir capacities in order to reduce the clutter of too much data. As mentioned, some of the potential dams are limited to less than 1 MAR due to the topography at potential dam sites, or a cap in wall height of 100 m. These are the last three potential dam sites namely, Laleni, Gongo and Mbokazi.

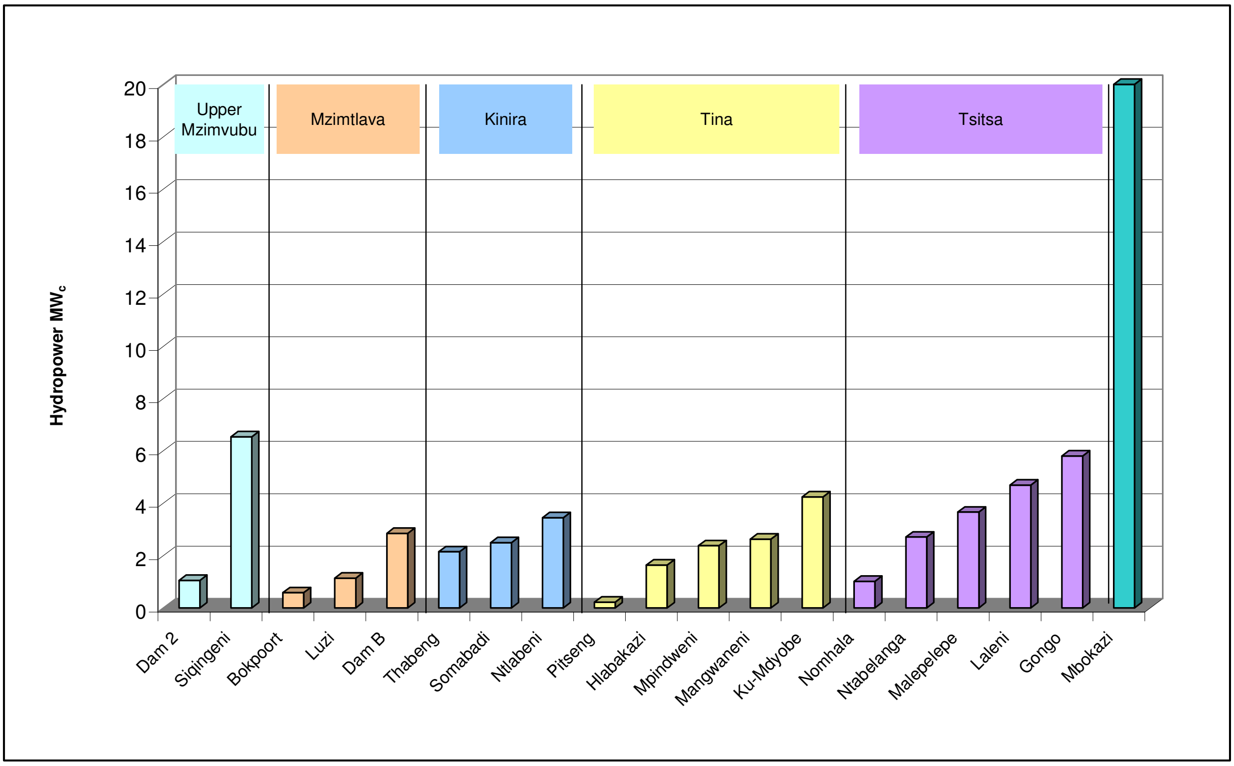

Figure 3.3 Estimated firm hydropower available at potential dam sites

The firm hydropower potentially available at most sites ranged between 1 and 5 MW_C. This is the monthly average power that can be continuously generated at a 99.5% assurance level, and is analogous to base-load power. This can be easily converted for load factor. For peaking power scenarios, a load factor of say 10% will be chosen as indicative.

A higher potential for approximately $20MW_C$ hydropower exists at the large dam below the junction of the tributaries on the Lower Mzimvubu River at the Mbokazi dam site. The negative impacts of the dam on the EWR, and in particularly the estuary situated downstream of the dam, are likely to be significant and possibly unacceptable.

Figure 3.5 presents the hydropower potentially available at the dam sites for larger reservoir capacities of 1.5 MAR, as well as smaller 0.5 MAR capacities, in addition to the 1 MAR capacities previously shown.

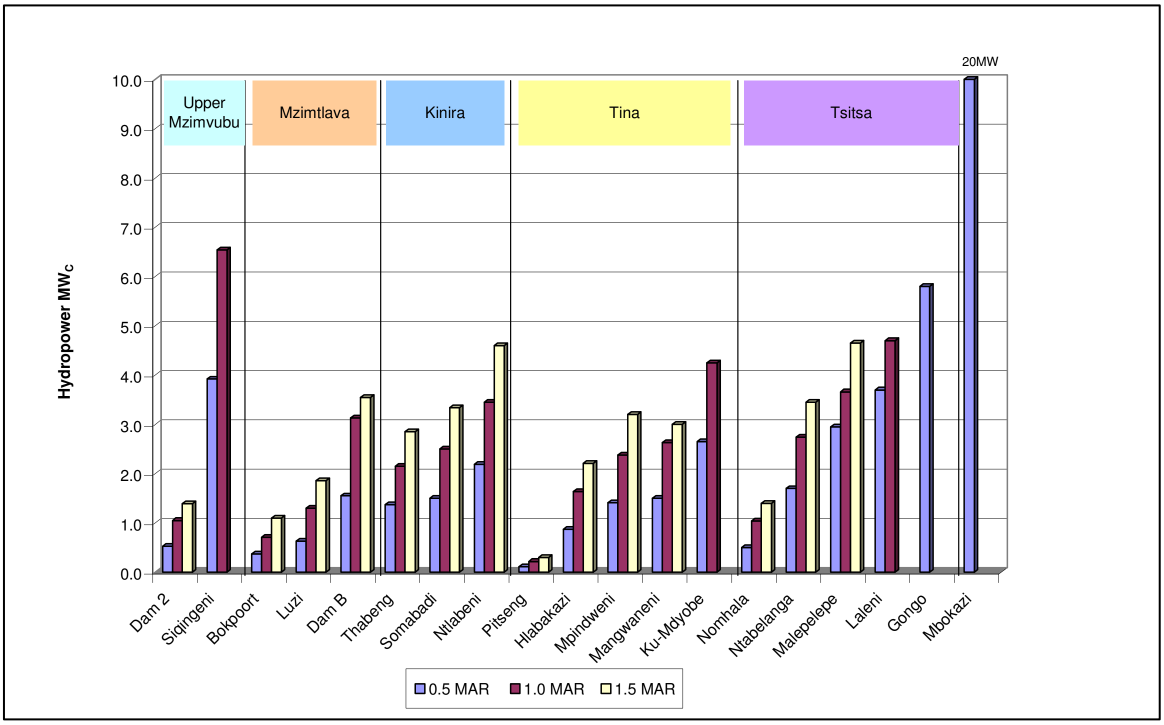

Figure 3.5 Hydropower potential for three reservoir sizes at potential dam sites

3.6 COST ESTIMATES

Costs of the schemes have been estimated to determine indicative total hydropower development costs, and together with the installed generating capacities, unit costs have been determined as a measure of comparison.

Potential dams and the hydropower plants have been costed separately as a first order analysis, to provide an indication of the relative costs of the different components of the hydropower schemes at potential dam sites.

3.6.1 Cost estimates of dams

Costs estimates of potential dams at various levels of detail have been done during previous studies. The available geological information required for estimating dam costs based on foundation conditions also varies in detail between the different dam sites. In general, sufficient geological information is not available to determine the optimal dam types at the various sites. As such generalised catchment geology based on geological maps was used, and suggests that earthfill dams are typically the most suitable for the catchment.

Where topography at dam sites did not accommodate spillways with chutes, roller compacted concrete dams were assumed to be more suitable.

The cost estimates of dams were based on quantities determined from 1:50 000 maps and 20 m contours, and as such are first-order cost estimates. The costs are presented in **Figure 3.6**, and are estimated based on May 2008 prices.

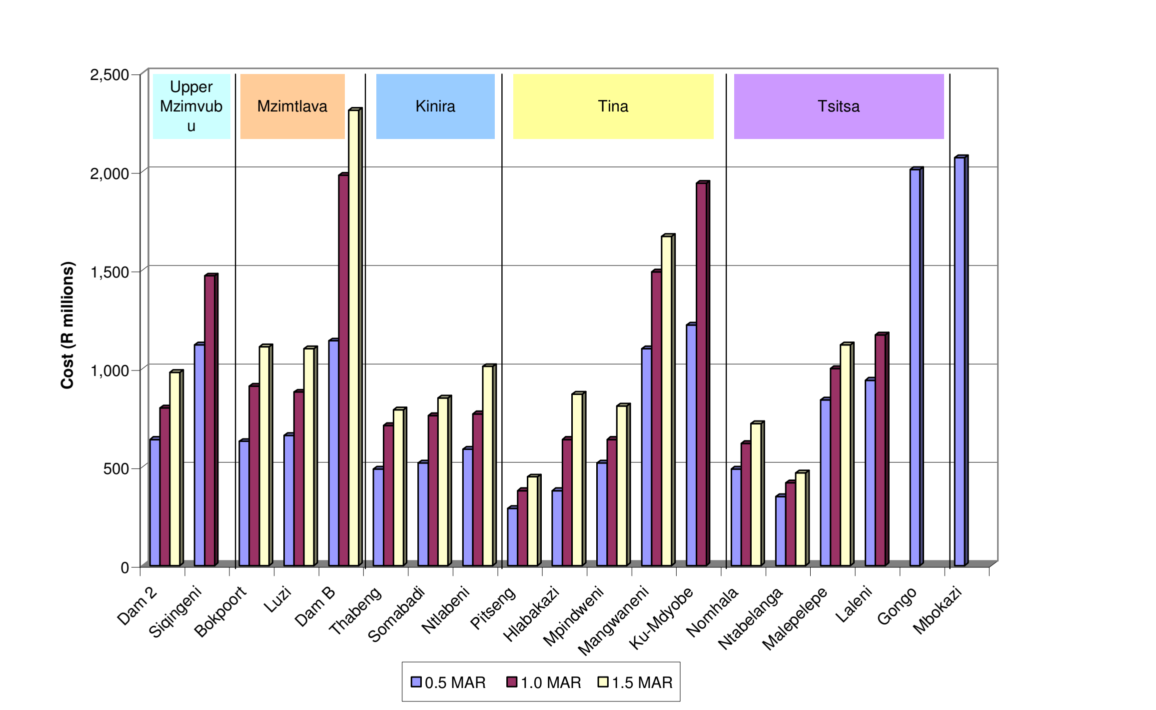

Figure 3.6 Cost estimates of potential dams in the Mzimvubu River catchment

Cost estimates ranged from approximately R350 million for a smaller dam high up in the catchment to over R2 000 million for larger dams lower down in the catchment.

3.6.2 Cost estimates of hydropower plants

The costs of hydropower plants were estimated based on the generating capacity and head of the plants, and did not take any specific conditions at each site into account. These estimates of cost based on generating capacity and head, were derived from a hydropower plant database that was obtained from an international consultancy with global experience in hydropower.

The estimates are for "water to wire" costs. This includes all the electro-mechanical costs which consist of the turbine, generators, exciters, transformers, controls, and the balance of the plant.

Cost estimates of transmission lines are, however, not included.

The costs are presented for base-load hydropower plants at the potential dam sites for the 1 MAR reservoir capacities in **Figure 3.7**, and for peaking hydropower plants for 1 MAR reservoir capacities in **Figure 3.8**.

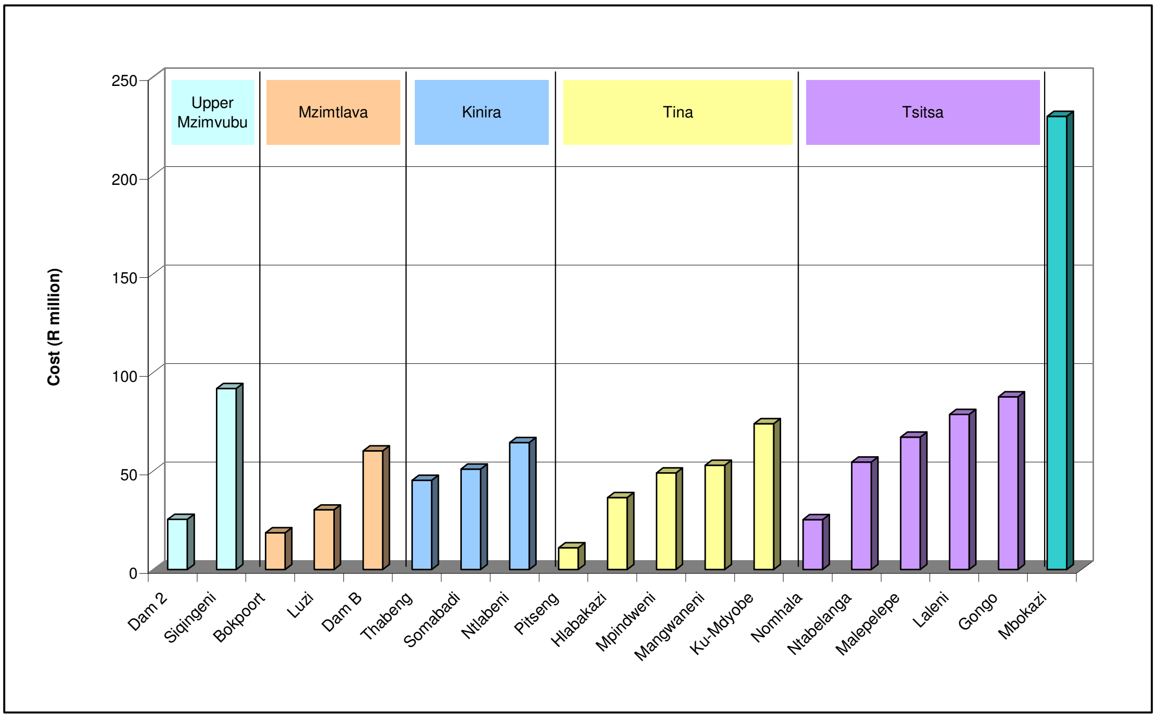

Figure 3.7 Cost estimates of base-load hydropower plants for 1 MAR reservoirs at potential dam sites

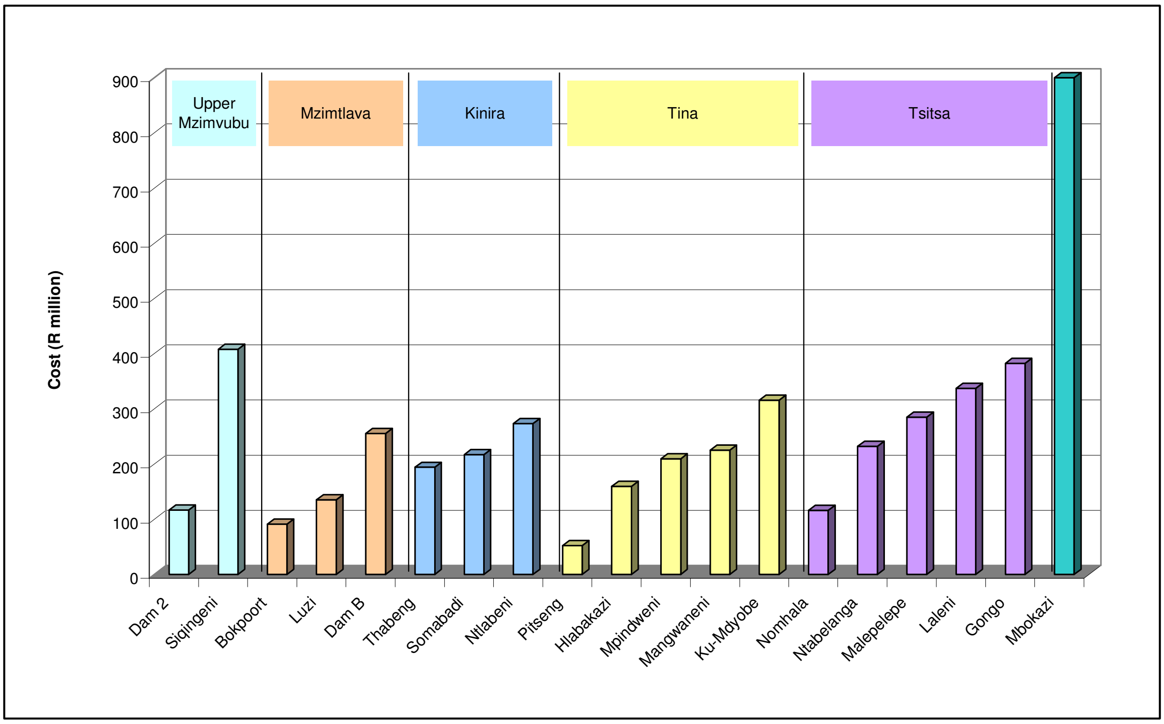

Figure 3.8 Cost estimates of peaking hydropower plants for 1 MAR reservoirs at potential dam sites

The costs of base-load hydropower plants ranged from approximately R20 million for a 0.5 MW_C plant to approximately R200 million for a 20 MW_C plant.

The cost estimates of peaking power plants ranged from R75 million for a 5 MW plant to approximately R900 million for a 200 MW plant.

3.6.3 Total cost estimates of hydropower schemes

The total hydropower scheme costs are the sum of the dam and power plant costs for each particular hydropower scheme. Peaking power schemes have higher total costs by virtue of the higher generating capacity of peaking power.

Total costs of hydropower schemes at the potential dam sites ranged from approximately R400 million to R2 300 million for base-load hydropower generation of between 0.5 and 20 MWc, and approximately R440 million to R3 000 million for peaking power generation of 5 to 200 MW at a 10% load factor. These total scheme cost estimates for base-load and peaking power are presented for 1 MAR capacity reservoirs at the potential dam sites in **Figure 3.9**.

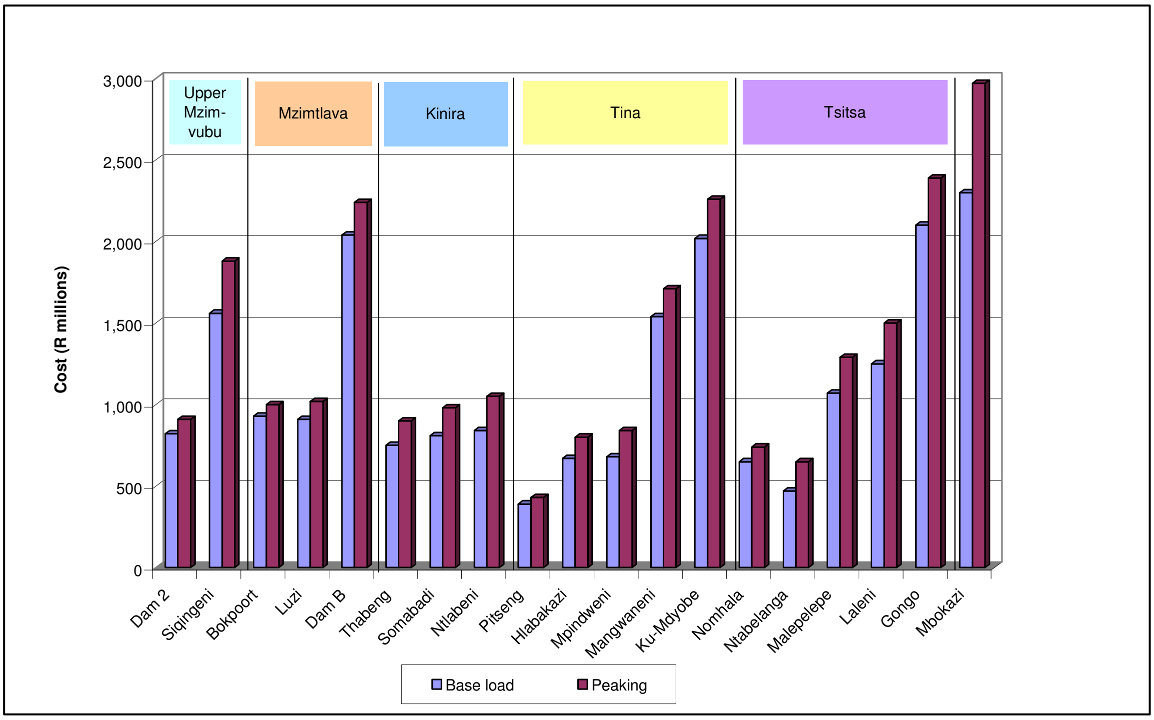

Figure 3.9 Cost estimates of hydropower schemes for base-load and peaking power

The costs of the dams are a considerable portion of the total scheme costs and comprise from 50% to more than 70% of the total scheme cost.

Multiple-purpose developments where the cost of the dams could be split between the different users would therefore be beneficial.

3.6.4 Unit cost of hydropower

The unit costs of hydropower have been determined as the total scheme cost divided by the potential installed generating capacity.

The unit costs ranged from R120 million to R2 500 million per MW_C generating capacity for base-load, which are very high.

Unit costs of peaking power ranged from approximately R16 million to R310 million per generating capacity at the assumed load factor of 10%. Again most of these unit costs for peaking power are also unlikely to be economical.

To provide a better measure of the financial feasibility of hydropower in the catchment, a scheme at Tsitsa Falls was assessed and costed, and a basic financial feasibility analysis was conducted. The hydropower schemes at potential dam sites can then be compared against the financial feasibility of a scheme at the falls. The Tsitsa Falls was selected as it was suggested by previous studies to be the most suitable site in the catchment for hydropower generation.

3.7 TSITSA FALLS HYDROPOWER ASSESSMENT

3.7.1 Introduction

A number of previous studies on hydropower in the Eastern Cape and the former Transkei have identified the Tsitsa Falls as a site with hydropower generating potential (Ninham Shand, 1980 and Watermeyer, Legge, Piesold and Uhlman, 1981). The studies on the hydropower potential at the falls have been conducted at various levels of detail. Some of the previous studies have assessed multiple dam developments, diverting water from other tributaries of the Mzimvubu through tunnels, and using the head at the falls to generate hydropower.

For this study a single dam development near Laleni was considered for a scheme at the falls.

This analysis of hydropower at the Tsitsa Falls will also be used to assess the potential of a homestead garden irrigation scheme, conceptualized by the Eastern Cape Department of Agriculture. The proposed homestead garden irrigation scheme is to be driven by the income generated by the sales of hydropower from a scheme at the Tsitsa Falls. If, however, the hydropower scheme is not feasible as a stand-alone development, then the additional infrastructure and energy requirements to pump water to surrounding areas for homestead garden irrigation, will certainly not be feasible. If the hydropower scheme is feasible, then the larger homestead garden irrigation scheme concept may be considered.

The layout of the potential hydropower scheme at the Tsitsa Falls is presented in **Figure 3.10**.

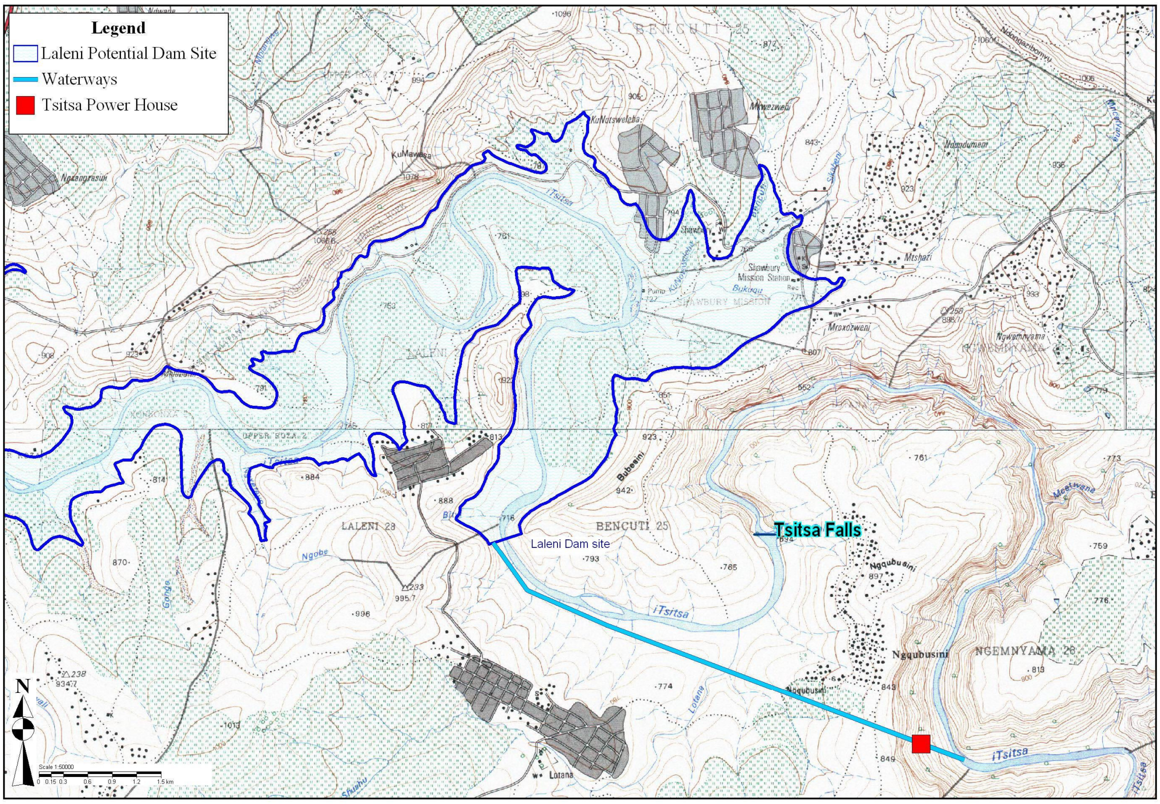

Figure 3.10 Layout of the potential hydropower scheme at the Tsitsa Falls

3.7.2 Hydropower potential at Tsitsa Falls

The hydropower that could be generated at the falls with 0.7 and 1.5 MAR capacity dams upstream of the falls at Laleni was assessed. The same monthly water balance model used to simulate hydropower at the potential dam sites was used for the simulation at the Tsitsa Falls.

The hydropower scheme comprises of a 6 km long tunnel to divert the yield of water from the dam, around the falls to a point below the falls on the Tsitsa River. The simulation included a total net generating head from the upstream dam to a point downstream of the falls on the Tsitsa River of 350 m at full storage level.

The results of this assessment of the hydropower potential at the Tsitsa Falls differ from previous studies, as ecological flows were accounted for in this assessment. Provisional estimates of ecological water requirement (EWR) were assumed to be released from the dam. This EWR release of water would pass over the falls and not be routed through the turbines. The provisional EWR at the Laleni Dam site was based on the present ecological state of the river, and did not specifically take the falls into consideration. The acceptable flows that may be maintained over the falls have not been determined. The provisional EWR required approximately 25% of the average annual streamflow to be maintained in the river and thus over the falls.

The hydropower scheme at the Tsitsa Falls can generate an estimated 25 MW_C as base-load with a 0.7 MAR reservoir capacity dam at Laleni. A larger dam of 1.5 MAR reservoir capacity at Laleni provided enough water to generate 31 MW_C at the Tsitsa Falls. A dam at Laleni with an associated reservoir capacity of greater than 0.7 MAR, will however, flood considerable portions of surrounding villages and houses.

As such the hydropower scheme at Tsitsa Falls with only a 0.7 MAR capacity reservoir at the Laleni dam site will be further considered for this exercise.

The peaking power available from the scheme with a 0.7 MAR capacity reservoir at the Laleni dam site was determined for an indicative load factor of 10%, at 250 MW.

These results compare reasonably with a previous study at the falls that estimated 27 MW_C at the Tsitsa Falls for a smaller upstream dam at Laleni. The differences can be attributed to the inclusion of the EWR in this study and the subsequent reduction in hydropower potential, as well as the updated hydrology with a lower average annual streamflow.

3.7.3 Cost estimates of the Tsitsa Falls hydropower scheme

The cost of the base-load and peaking power schemes at the Tsitsa Falls was estimated based on the same assumptions as used for the hydropower schemes at the potential dam sites. The total cost of the Tsitsa Falls scheme did include cost estimates for all the water ways and the access tunnels to reach the powerhouse, below the falls.

Again, the cost of transmission lines was not included.

The total scheme cost was estimated at R2 600 million for base-load hydropower generation, and R3 700 million for peaking power generation. The corresponding unit costs of hydropower are approximately R100 million per MW_C generating capacity for base-load, and R16 million per MW generating capacity for peaking power. Additional information on the costs of the potential schemes at Tsitsa Falls is presented in **Appendix F.**

3.7.4 Preliminary financial feasibility

Basic analysis assumptions

A basic financial feasibility analysis was conducted to determine whether the sales of hydropower generated at the falls could off-set the capital borrowed to finance the scheme. The scheme was assumed to have a single purpose dam at Laleni for hydropower generation.

A 20 year repayment period was chosen for the analysis. This follows recent suggested international guidelines obtained from a Hydro Finance Handbook. The financial analysis included a range of discount rates representing the difference between the interest rate of capital borrowed, and the inflation in selling price of electricity. Discount rates of 0%, 3% and 6% were used for the analysis. The selling price at the start of the simulation was assumed to be 30 cents/kWh for base-load power, and 100 cents/kWh for peaking power.

A second scenario was conducted based on the hypothetical premise that the cost of power will rise sharply to re-align currently low power costs over the next 5 years. After this, the price will increase according to inflation. The initial sharp increase in the cost and thus selling price of power is assumed to be 10% per annum higher than inflation. This scenario was applied only to peaking power as this is more likely to be feasible. The hypothetical premise on which this scenario is based, although possible, requires some scrutiny.

Results

The basic financial analyses showed that a base-load scheme could not be financed with the sales of hydropower for any of the scenarios. Even at low discount rates, only half the borrowed capital cost could be financed with the sales of power generated.

Peaking power was also not financially feasible at higher discount rates. At lower discount rates, peaking power at the falls is marginal. These results are tabulated in **Table 3.1**.

Table 3.1 Basic financial analysis of Tsitsa Falls hydropower

Load factor	Hydropower	Capital investment possible (R million)			Capital cost
		Discount rate			
	(MW)	0%	3%	6%	(R million)
100%	25	1 300	1 000	800	2 500
10%	250	4 400	3 300	2 500	3 700

The hypothetical scenario of increasing peaking power selling prices over the next 5 years does show more promise, but requires further verification. The results are presented in **Table 3.2**.

Table 3.2 Basic financial analysis of Tsitsa Falls peaking hydropower with assumed power cost increase structure

Hydropower	Years 0 - 5		Year 6 - 20		Investment possible	Capital cost
	Electricity selling price increases	Interest rate on capital	Electricity selling price increases	Interest rate on capital		
(MW)					(R million)	(R million)
250	18%	11%	8%	11%	4 700	3 700

From the results of the basic financial analyses it can be concluded that the base-load scheme does not appear to be feasible. The sales of hydropower could only finance about half the capital cost, and the upper threshold of feasible unit cost for base-load hydropower, is thus assumed to be approximately half that of the Tsitsa Falls scheme.

Peaking power at Tsitsa Falls is marginal at low discount rates. The unit cost of peaking power at Tsitsa Falls is therefore taken as the approximate upper threshold of feasible peaking power cost.

These assumed upper limits of feasible unit cost of power will allow some comparison with the unit costs of base-load and peaking power at the potential dam sites, and could help to determine the potential of a single purpose hydropower development at a potential dam site.

3.8 HYDROPOWER COST COMPARISON

The approximate upper limits of unit costs for base-load and peaking power estimated from the Tsitsa Falls analysis have been superimposed onto the unit costs of base-load and peaking power at the potential dam sites. The results are presented in **Figures 3.11** and **Figure 3.12** for base-load and peaking power respectively.

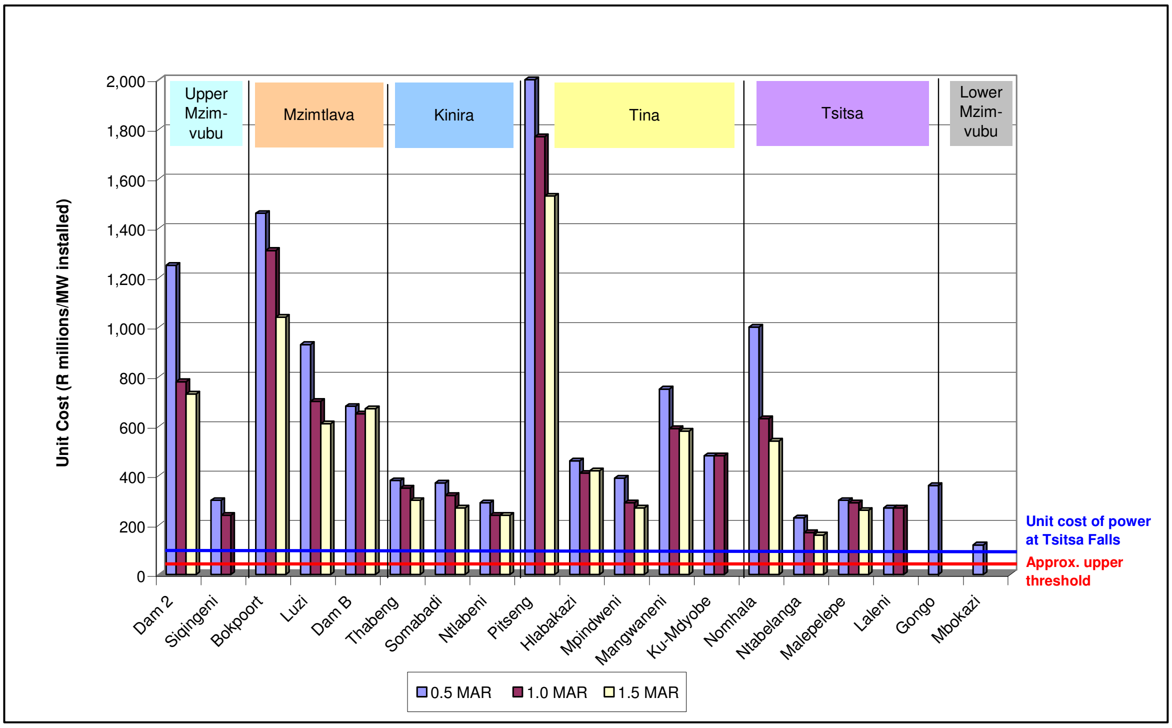

Figure 3.11 Comparisons of unit costs of base-load hydropower at potential dam sites and Tsitsa Falls with the approximate upper threshold of unit cost of power

Figure 3.11 shows that the unit costs of base-load hydropower at the potential hydropower schemes at dam sites, are all significantly higher than the upper threshold for base-load power.

As such, base-load power generation in the catchment utilizing a dam developed for the single purpose of hydropower does not appear to be likely.

In Figure 3.12, only one potential dam site, at Mbokazi, has a unit cost of peaking power similar to that at Tsitsa Falls, the approximate upper threshold of feasible peaking power unit cost. A few more dams on the Kinira and Tsitsa Rivers have slightly higher unit cost estimates of peaking power.

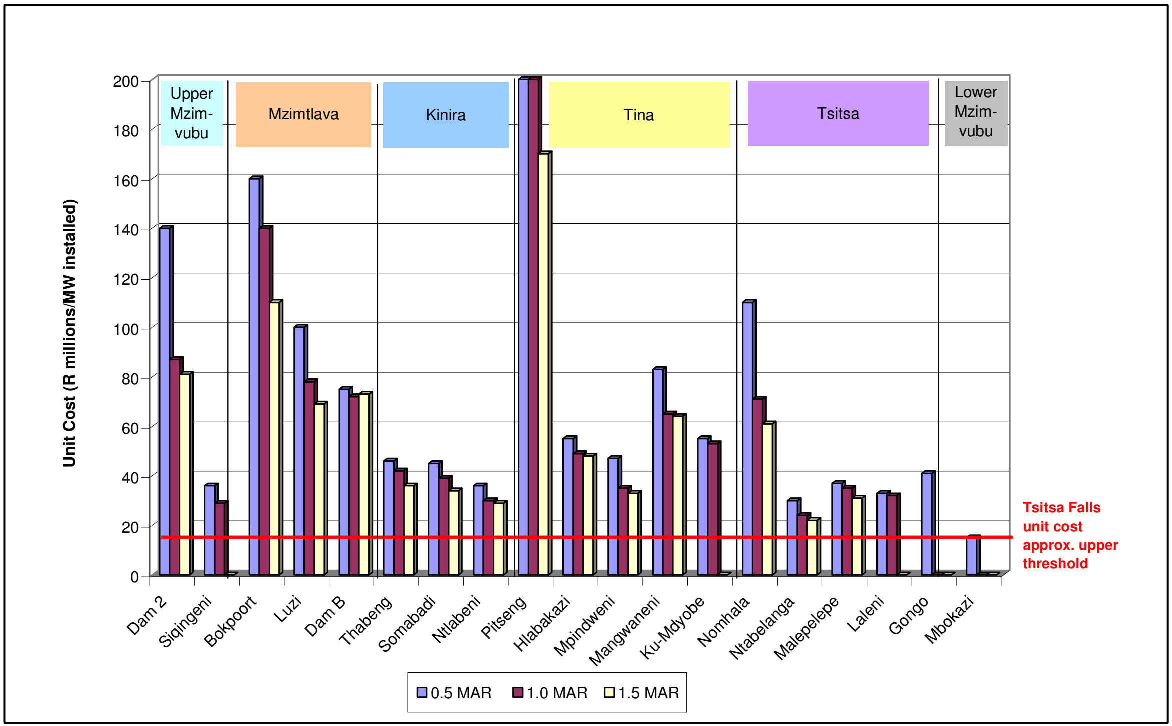

Figure 3.12 Comparisons of unit costs of base-load hydropower at potential dam sites and Tsitsa Falls

The dam site at Mbokazi on the lower Mzimvubu River that does have a similar unit cost of hydropower to Tsitsa Falls, may also be marginally feasible. As previously mentioned, however, this potential dam site is located close to the estuary and is likely to have significant adverse effects on the ecology of the estuary, which is highly valued.

Furthermore a multipurpose development could help off-set the high cost component of the dams, but the dam site near Mbokazi being located low down in the catchment, does not have foreseeable water users located near the dam, and is not a likely candidate for multi-purpose development.

4 DISCUSSION OF RESULTS WITH ESKOM

The results of the preceding hydropower assessment, with basic cost estimates and financial analyses, were presented to Eskom during a workshop by the DWAF and AsgiSA-EC. The findings were accepted by the DWAF and Eskom, and Eskom indicated similar conclusions from previous studies which they conducted.

The presentation and subsequent discussion thereafter did highlight a few differences in current criteria that Eskom use for hydropower identification, and those used for this assessment. These were that Eskom currently use 95% assurance of supply on a monthly basis compared to the 99.5% assurance of supply that was used, and that a load factor of 20% is currently regarded as more suitable for peaking power.

It was requested that one or two of the more feasible sites be re-evaluated with the updated load factor and assurance of supply, to determine whether any noticeable change in the assessment of hydropower potential occurs. It was also requested that if any favourable dam sites for hydropower generation had wall heights capped at 100 m for the assessment, that a higher wall height be considered.

5 ADDITIONAL SIMULATIONS

5.1 SELECTED SITES

Potential hydropower sites were selected for re-analysis with the updated criterion as provided by Eskom. This included; A) the Tsitsa Falls site, B) two dam sites with lower unit costs, and C) two dam sites with walls potentially higher than the capped 100 m.

A) The Tsitsa Falls site was re-assessed with the updated 95% assurance of supply, and peaking power scenario with a load factor of 20%.

B) Two potential dam sites with lower unit costs, namely Ntabelanga and Somabadi were selected for re-assessment with the updated criterion. These two dam sites, apart from having lower unit costs in the first round of analysis, are also positioned on the tributaries, higher in the catchment, and might have more potential for a multi-purpose development.

C) Two potential dam sites selected to be re-assessed with dam wall heights greater than the capped height of 100m, were Mbokazi on the Lower Mzimvubu, and a second dam site not included in the previous simulations near Mgaqweni on the Lower Tsitsa River. The Mbokazi site was re-analysed with a wall height of 120 m. This corresponds to a reservoir storage capacity of approximately 60% of the MAR. The dam site near Mgaqweni on the Tsitsa River is in a steep valley and possibly more suited to hydropower generation than dams previously assessed which were identified more for storage and water yield. A 140 m high dam was analysed for hydropower at the Mgaqweni site. The associated gross reservoir capacity was just under 1 MAR.

Re-analyses of these sites with the updated load factor and assurance of supply criterion and without a wall height cap, should provide a more complete hydropower assessment, and results that are indicative and more encompassing of the potential in the catchment.

5.2 RESULTS OF ADDITIONAL SIMULATIONS

The simulations of hydropower at the selected sites showed some increase in hydropower availability with the updated criteria proposed by Eskom.

A) The hydropower available at the Tsitsa Falls scheme increased by approximately 20% from 25 to 30 MW_C. At a load factor of 20% for peaking power an estimated 150 MW can be generated.

B) The hydropower available increased by approximately 17% at the two potential dam sites, Ntabelanga and Somabadi. The hydropower potential at the Ntabelanga site increased from an estimated 3.4 MW_C to 4 MW_C, and the potential at the Somabadi Site increased from 3.3 MW_C to 3.9 MW_C. At the load factor of 20%, an estimated 20 MW are available at the two dam sites for peaking power.

The increases in estimated hydropower available at the Tsitsa Falls and two selected potential dam sites, were a result of the lower assurance of supply required in these additional simulations.

C) The increase in hydropower potential available at the Mbokazi and Mgaqweni dam sites, showed increases in hydropower available due to both the reduced assurance of supply, and the increase in generating head as a result of the higher dam walls.

With a dam wall height of 120 m, the hydropower available at the Mbokazi site is estimated at 29 MW_C for base-load, and 145 MW for peaking power at a load factor of 20%. This is an increase of 45% in potential power available at this site with the updated criteria.

The simulation of hydropower at the potential dam site on the Tsitsa River near Mgaqweni, estimated 16 MW_C of hydropower available. This scheme included a 140 m high dam wall, and would cost an estimated R2 730 million rand.

5.3 BASIC FINANCIAL ASSESMENTS

Some basic financial analyses were conducted for peaking power generation at the potential sites that were re-assessed with the updated criteria. Only peaking power was considered as it appears to have more potential in the catchment from the initial assessments. Again, the basic financial assessment assumed a repayment period of 20 years, a starting price of peaking power of 100 cents/kWh, and a discount rate of 3% as a starting point.

A) The Tsitsa Falls scheme could finance the capital cost with the sales of peaking hydropower for discount rates of less than 3.5%. This is a marginal improvement from the initial analyses. Again the analysis does not include transmission lines or operating and maintenance costs, and as such the scheme is still only marginal at lower discount rates.

B) For the two dam sites higher on the tributaries, the sales of 20 MW of peaking hydropower could finance approximately R520 million. This is 80% of the cost of the scheme at Ntabelanga, and 52% of the cost of the scheme at Somabadi. A single purpose development for hydropower at these dam sites is therefore still not likely.

The basic financial analysis at the Mbokazi dam site showed that at a discount rate of 3%, approximately 95% of the total scheme cost estimated at R3 970 million could be financed by the sales of peaking hydropower. The scheme at the site near Mgaqweni on the Tsitsa River could finance approximately 77% of the R2 730 million capital cost with peaking power sales at a 3% discount rate.

Increasing the height of the dam wall at the site near Mbokazi does marginally improve the scheme's potential to pay for the capital cost by the sales of hydropower, but also increases the likely negative effects on the estuary downstream.

The additional assessments show that although the updated criteria and higher dam walls do marginally increase the simulated power available at the potential dam sites, the increase is not significant, and does not change the conclusions of the initial basic financial feasibility analyses.

At the time of writing this report, some updated tariffs that renewable energy sources could achieve were being proposed by the National Energy Regulator of South Africa

(Nersa). These renewable energy feed-in tariffs may have a favourable impact on the feasibility of hydropower in South Africa, and should be considered in further studies.

6 CONCLUSIONS

From the hydropower assessment, which was conducted at a low desktop level of detail, the following preliminary conclusions could be made.

6.1 BASE-LOAD HYDROPOWER

It is doubtful whether any base-load scheme would be feasible as a single purpose development at the current electricity prices. Some base-load options may be potentially viable as part of a multi-purpose development, but due to the small generating capacities, Eskom is not likely to be interested in base-load. One potential scheme at the Mbokazi dam site could generate a large amount of power, but does not show potential to be a multi-purpose development.

As part of multi-purpose developments, base-load schemes may be of use for local supply.

The seasonal effects of releases for power generation on the EWR would need to be considered in more detail should such a scheme become possible.

6.2 PEAKING HYDROPOWER

A few schemes showed marginal potential to be developed for the single purpose of peaking power generation. The scheme at Tsitsa Falls may be potentially feasible and could be considered further. The acceptable flow to be maintained over the falls will need to be determined if this site is to be considered in more detail.

A few potential dam sites may be potentially feasible for peaking power. The implementation of a peaking power scheme as part of a multipurpose development, may improve the feasibility of schemes that are only just marginal as a single purpose development. The site near Mbokazi, although showing marginal feasibility as a single purpose development, has little potential for a multi-purpose development. Sites that do not appear to be feasible as a single purpose development, such as Ntabelanga and Somabadi, may have more potential for a multipurpose development due to their location higher up in the catchment.

If further investigations into hydropower generation at potential dam sites are to be conducted, a few details can be improved on.

The confidence in the value of power at different load factors could be improved. The costs of the hydropower schemes could take specific conditions at the sites into account. The costs of the transmission lines should be included, and the seasonal and diurnal effects of releases for peaking power generation on the EWR could be investigated. Potential new renewable energy feed-in tariffs should be included if they are formalized as they may impact hydropower feasibility.

7 POSSIBLE FURTHER WORK

The confidence in the value of power at different load factors should be improved upon. Possible recent renewable energy feed-in tariffs that have been proposed by the National Energy Regulator of South Africa for mini-hydropower should be investigated to determine if schemes in the Mzimvubu River catchment could benefit from that.

Base-load be considered when part of a multipurpose development, and for local power supply.

Further work concentrating on single purpose developments for peaking power generation should focus on Tsitsa Falls and the site near Mbokazi. If hydropower generation is to be part of a multipurpose development then other potential dam sites such as Ntabelanga and Somabadi may be considered.

Some additional detail should be included in further studies; the specific conditions at each site should be accounted for in the cost of the hydropower plants, and the costs of the transmission lines should be included.

The effects of releases of water for the generation of hydropower on the ecological functioning of the river and the estuary need to be considered in detail. This is particularly important at the Tsitsa Falls.

8 REFERENCES

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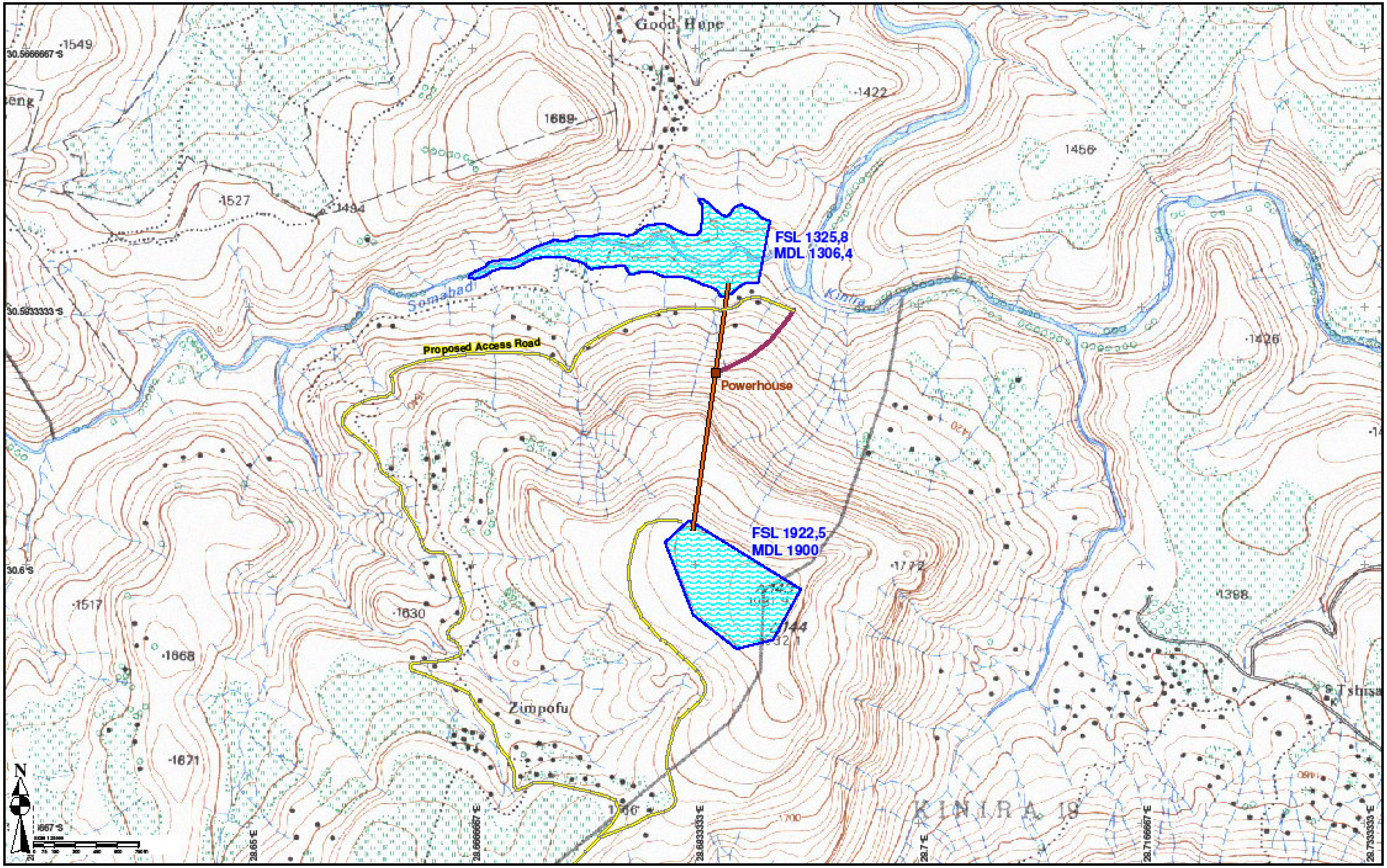
[2] Ninham Shand Inc. 1980. **Supplementary report on the Development of the Laleni Scheme**: Report to Government of Transkei Department of Works and Energy.

[3] Watermeyer Legge, Piesold and Uhlman. 1981. **Transkei Hydro-power Development Proposals to year 2005**: Report to Government of Transkei Department of Agriculture and Forestry.

[4] Watermeyer Legge, Piesold and Uhlman. 1981. **Development of The Tsitsa River for Export Peak Power**: Report to Government of Transkei Department of Agriculture and Forestry.

APPENDIX A

Pumped storage scheme site layouts

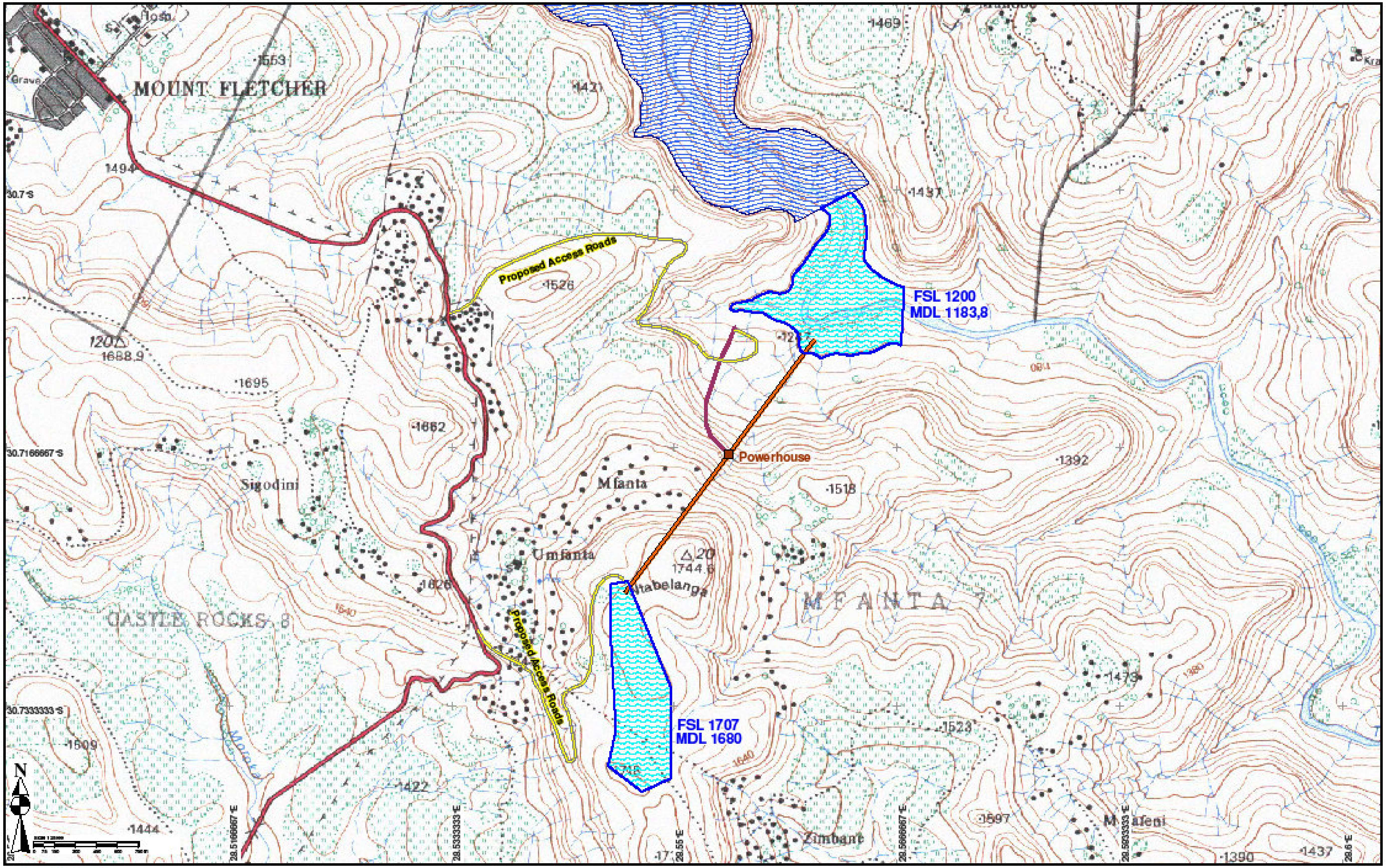


BKS (Pty Ltd) Engineering and Management

MZIMVUBU CATCHMENT DEVELOPMENT

Somabadi Pumped Storage Scheme - Layout

FIGURE A-1

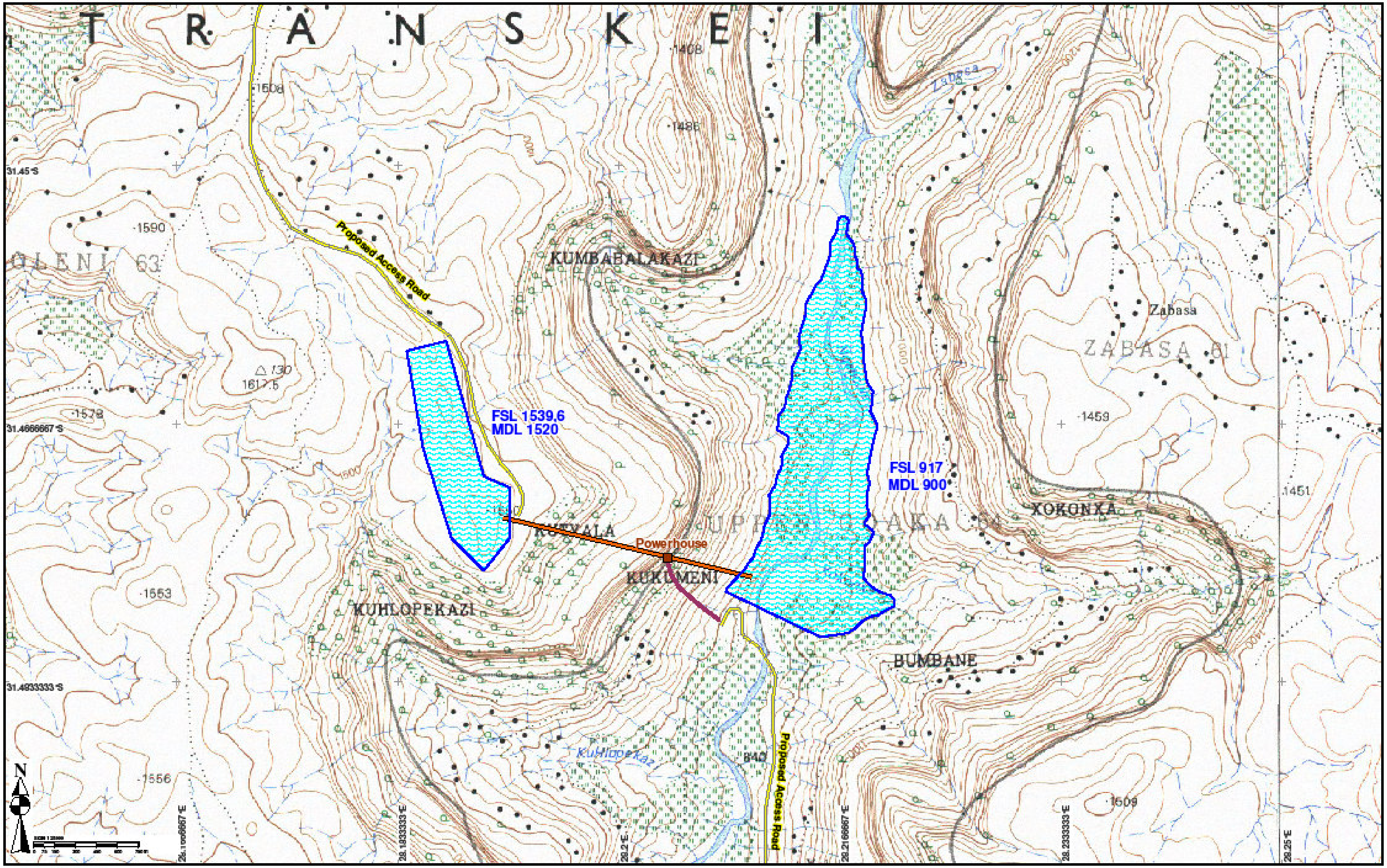


BKS (Pty Ltd) Engineering and Management

MZIMVUBU CATCHMENT DEVELOPMENT

Mfanta Pumped Storage Scheme - Layout

FIGURE A-2

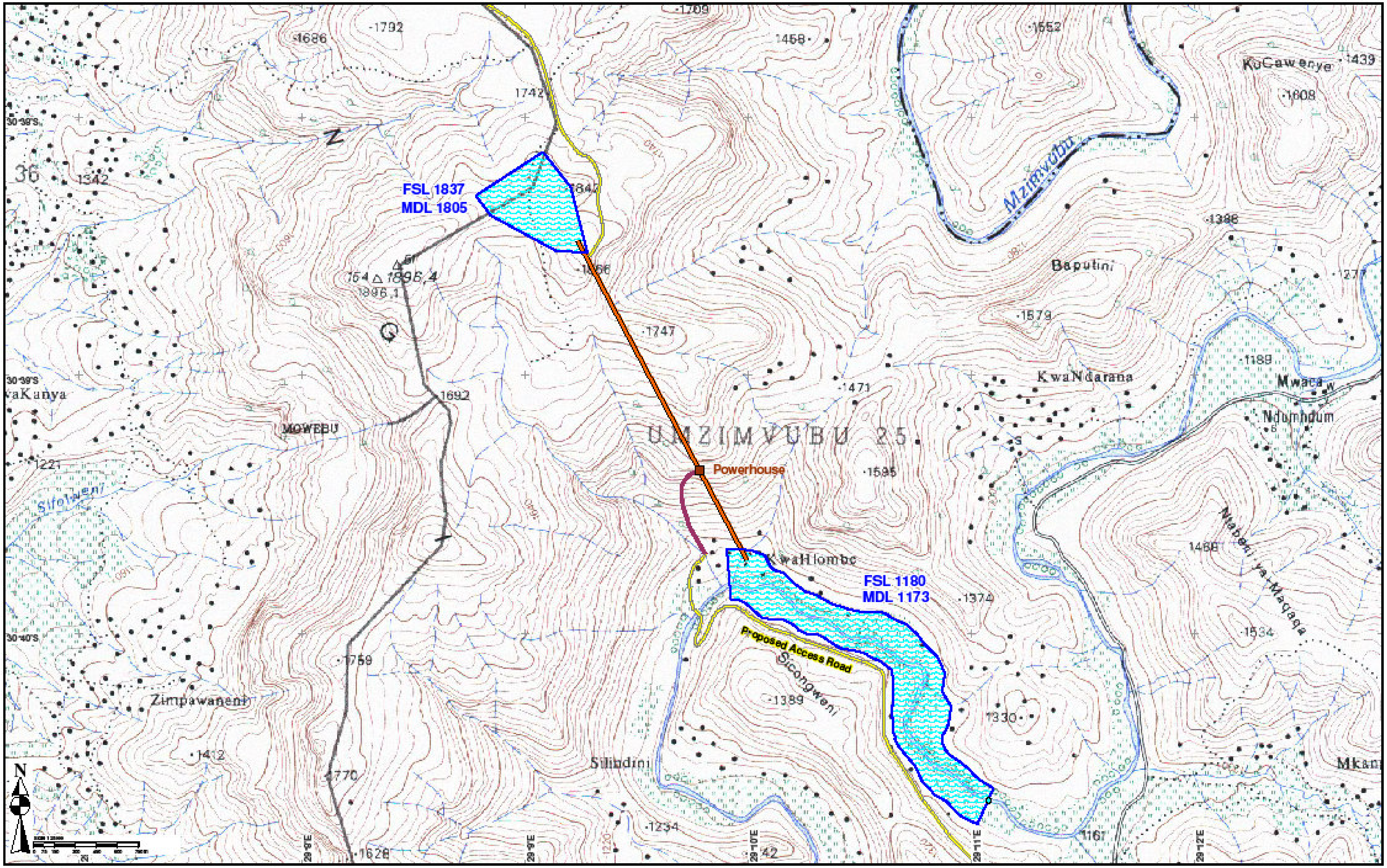


(Pty Ltd) Engineering and Management

MZIMVUBU CATCHMENT DEVELOPMENT

Site10 Pumped Storage Scheme - Layout

FIGURE A-3



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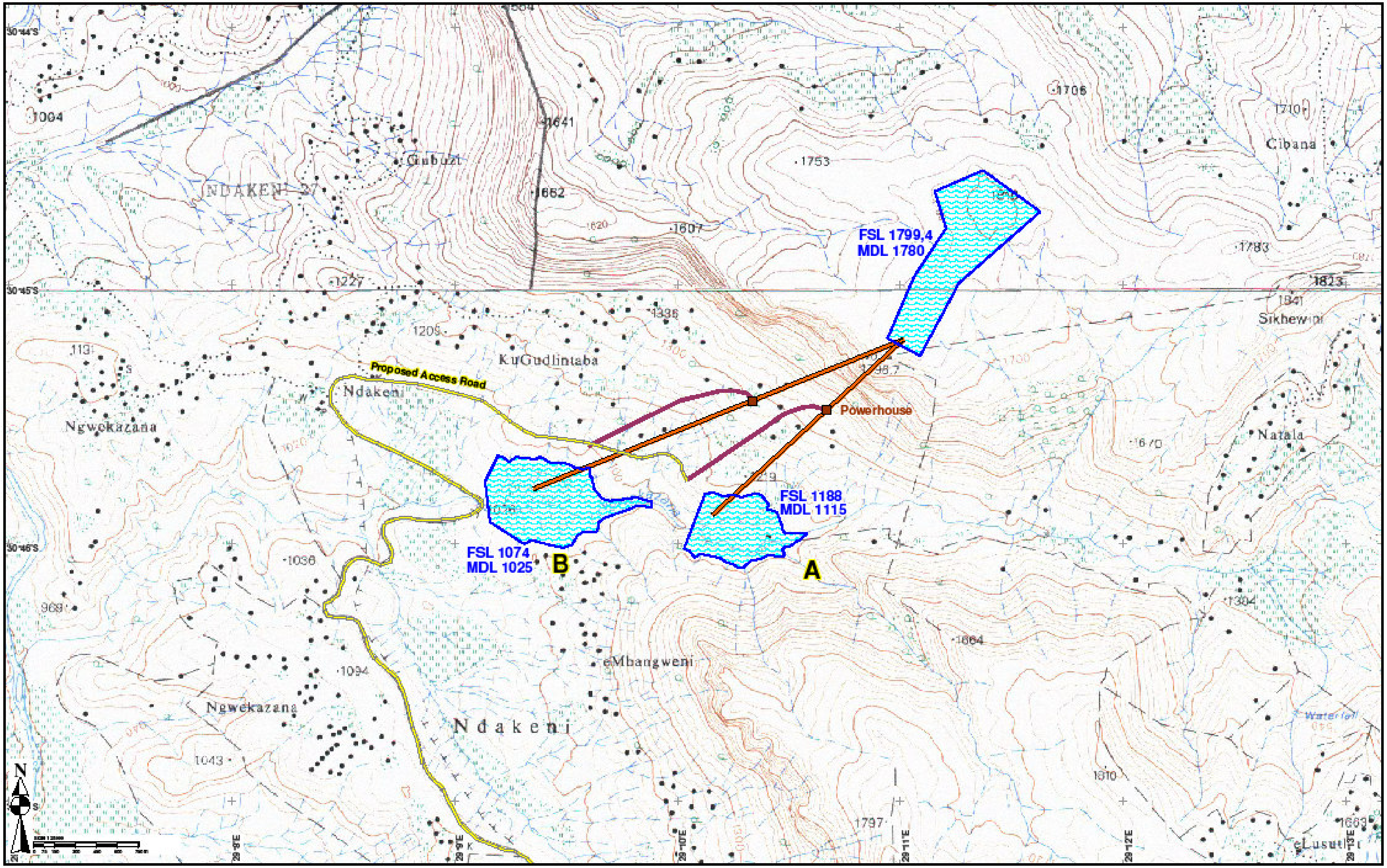
MZIMVUBU CATCHMENT DEVELOPMENT

Dam2 Pumped Storage Scheme - Layout

FIGURE A-4



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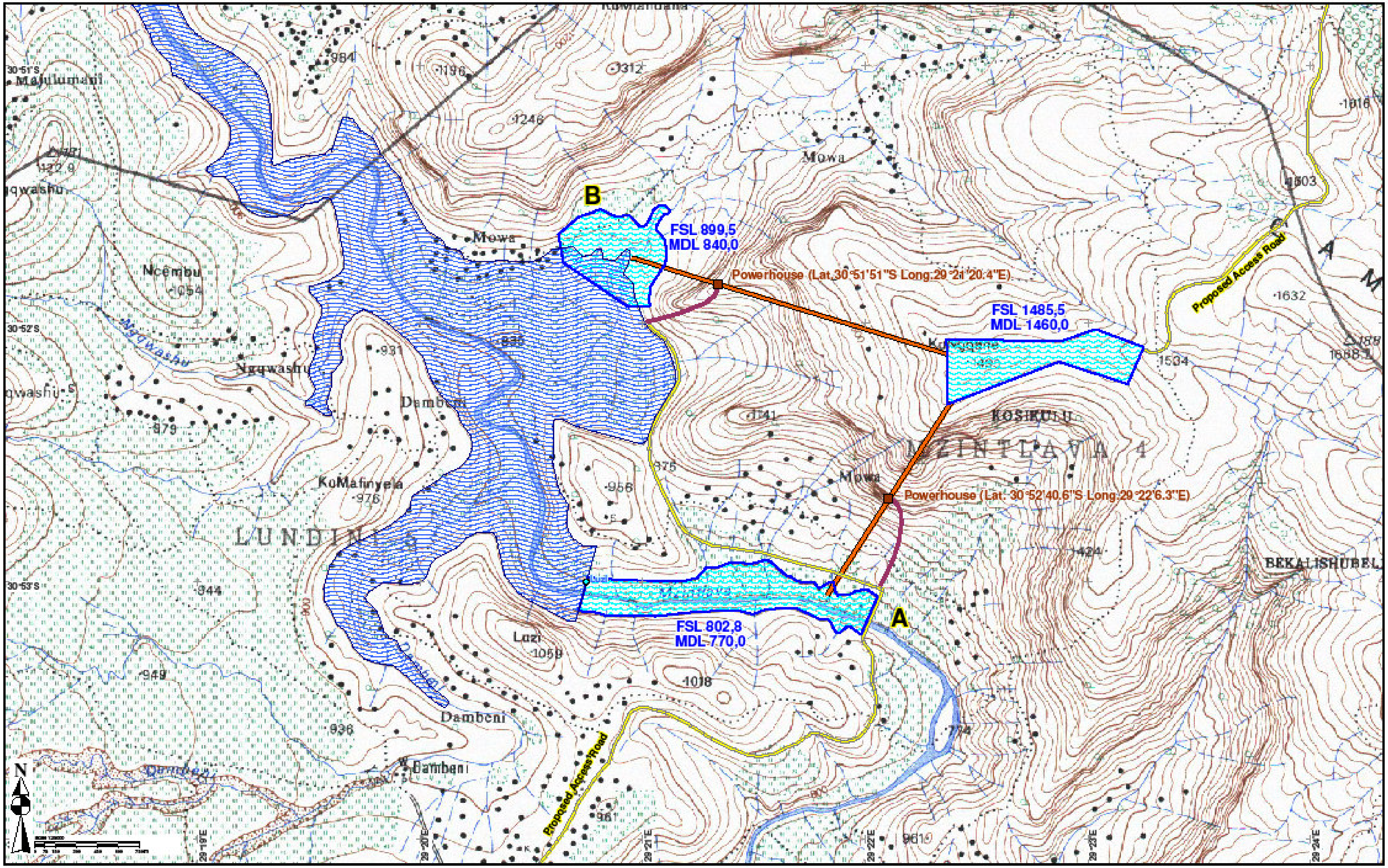
MZIMVUBU CATCHMENT DEVELOPMENT

Siqingeni Pumped Storage Scheme - Layout

FIGURE A-5



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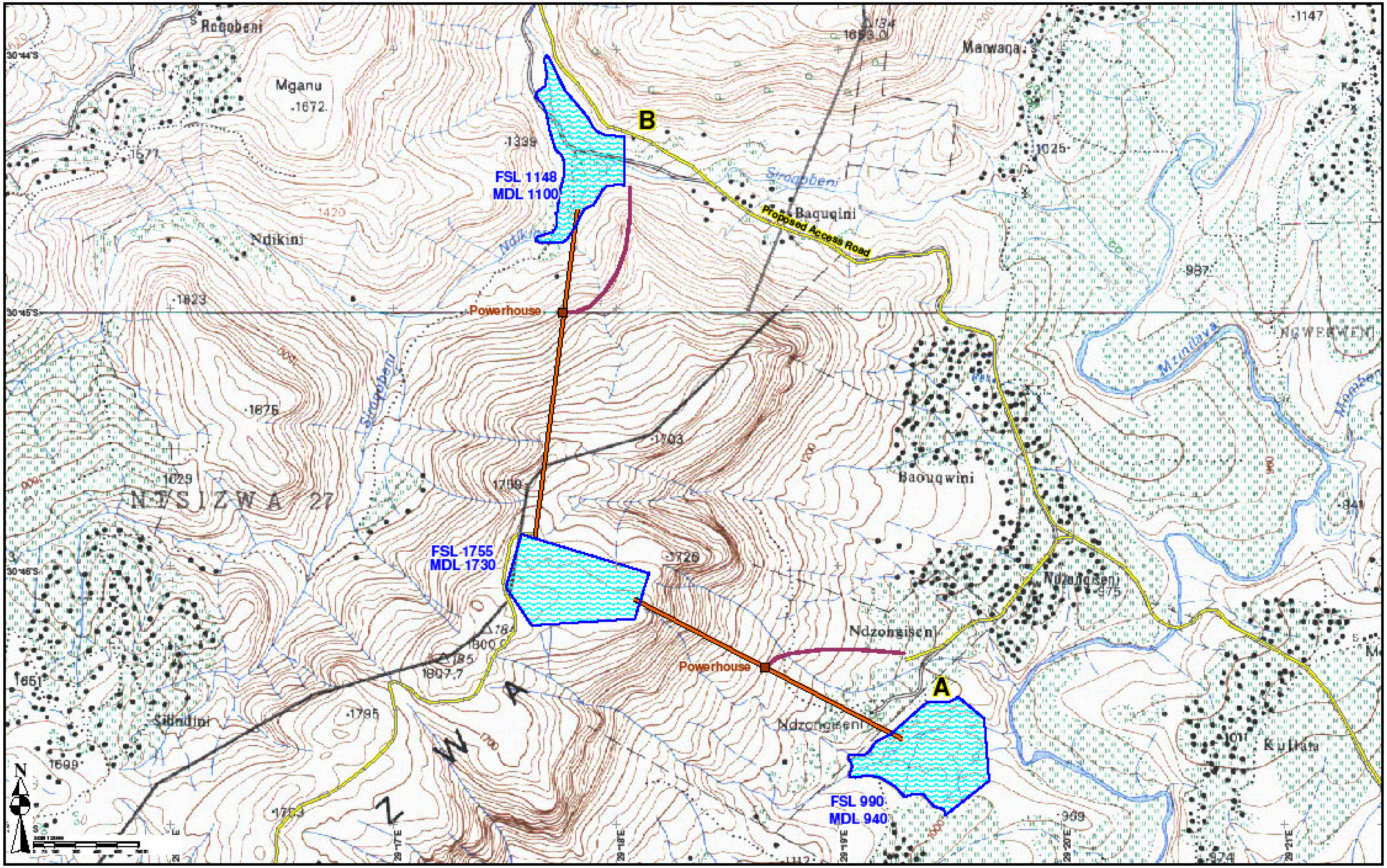
MZIMVUBU CATCHMENT DEVELOPMENT

Luzi Pumped Storage Scheme - Layout

FIGURE A-6



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MZIMVUBU CATCHMENT DEVELOPMENT | **Ntsizwa Pumped Storage Scheme - Layout** | **FIGURE A-7**

APPENDIX B

Pumped storage scheme cost

Dam 2 Pumped storage scheme

Sub Head	Description	COST (R million)
1	**UNDERGROUND CIVIL WORKS**	**2 953.7**
1.1	Headrace intake structure	105.7
1.2	Headrace tunnel	0.0
1.3	Pressure shaft	126.1
1.4	Pressure tunnel (concrete lined)	247.2
1.5	Pressure tunnel (steel lined)	332.3
1.6	Penstocks	100.0
1.7	Machine hall	405.8
1.8	Transformer hall	91.9
1.9	Busbar tunnels	8.4
1.10	Fresh air supply and water discharge tunnel	33.7
1.11	Smoke shaft	8.4
1.12	Extended draft tube tunnels	24.6
1.13	Tailrace surge chambers	180.0
1.14	Tailrace tunnel (concrete lined)	92.1
1.15	Tailrace outfall structure	122.4
1.16	Cable and emergency exit tunnel	31.7
1.17	Cable and emergency exit tunnel portal	192.1
1.18	Main access tunnel	125.7
1.19	Main access tunnel portal	129.5
1.20	Construction access to bifurcation tunnel	30.1
1.21	Construction access to pressure tunnels	9.6
1.22	Connector tunnel at base of pressure shaft	1.7
1.23	Access tunnel to powerhouse drainage gallery	27.5
1.24	Machine hall emergency exit tunnel	6.4
1.25	Smoke extraction tunnel	3.5
1.26	Drainage curtain tunnel	10.2
1.27	Drainage tunnel (from drainage curtain)	10.3
1.28	Fresh air supply shaft	4.7
2	**SURFACE CIVIL WORKS**	**1 273.9**
2.1	Upper reservoir	599.0
2.2	Lower reservoir	564.7
2.3	Surface buildings	70.1
2.4	Permanent site roads	32.4
2.5	Security fencing	7.6
3	**MECHANICAL EQUIPMENT**	**1 195.3**
3.1	Pump/turbines with governors and spherical valves	976.4
3.2	Main and auxiliary cranes	34.4
3.3	Headrace intake mechanical equipment	38.5
3.4	Tailrace outfall mechanical equipment	66.6
3.5	Station services and elevators	74.7
3.6	Dewatering and drainage	4.8
4	**ELECTRICAL PLANT - GENERAL CONSTRUCTION**	**1 475.2**
4.1	Motor / generator system	735.0
4.2	Auxiliary system	645.2
4.3	Lighting, security, fire, communication cable systems	95.1
5	**TRANSMISSION**	**315.0**
6	**PERMANENT ACCESS ROADS**	**428.0**
7	**CONSTRUCTION CAMP AND VILLAGE**	**896.3**
7.1	Upper reservoir site	58.6
7.2	Lower reservoir site	837.8
8	**PROJECT MANAGEMENT AND OTHER COSTS**	**900.8**
9	**MISCELLANEOUS**	**470.0**
SUB-HEAD	**TOTAL**	**9 908.3**
	10% Contingencies	990.8
	TOTAL COST	**10 899.1**

LUZI OPTION A PUMPED STORAGE SCHEME

Sub Head	Description	COST (R million)
1	**UNDERGROUND CIVIL WORKS**	**2 871.6**
1.1	Headrace intake structure	105.7
1.2	Headrace tunnel	24.3
1.3	Pressure shaft	141.6
1.4	Pressure tunnel (concrete lined)	74.6
1.5	Pressure tunnel (steel lined)	323.6
1.6	Penstocks	96.5
1.7	Machine hall	405.8
1.8	Transformer hall	91.9
1.9	Busbar tunnels	8.4
1.10	Fresh air supply and water discharge tunnel	40
1.11	Smoke shaft	8.4
1.12	Extended draft tube tunnels	23.8
1.13	Tailrace surge chambers	180
1.14	Tailrace tunnel (concrete lined)	113.1
1.15	Tailrace outfall structure	122.4
1.16	Cable and emergency exit tunnel	47.6
1.17	Cable and emergency exit tunnel portal	192.1
1.18	Main access tunnel	160
1.19	Main access tunnel portal	129.5
1.20	Construction access to bifurcation tunnel	30.1
1.21	Construction access to pressure tunnels	9.6
1.22	Connector tunnel at base of pressure shaft	1.7
1.23	Access tunnel to powerhouse drainage gallery	27.5
1.24	Machine hall emergency exit tunnel	6.4
1.25	Smoke extraction tunnel	3.5
1.26	Drainage curtain tunnel	10.2
1.27	Drainage tunnel (from drainage curtain)	10.3
1.28	Fresh air supply shaft	4.7
2	**SURFACE CIVIL WORKS**	**1 616.9**
2.1	Upper reservoir	979.3
2.2	Lower reservoir	527.4
2.3	Surface buildings	70.1
2.4	Permanent site roads	32.4
2.5	Security fencing	7.6
3	**MECHANICAL EQUIPMENT**	**1 195.3**
3.1	Pump/turbines with governors and spherical valves	976.4
3.2	Main and auxiliary cranes	34.4
3.3	Headrace intake mechanical equipment	38.5
3.4	Tailrace outfall mechanical equipment	66.6
3.5	Station services and elevators	74.7
3.6	Dewatering and drainage	4.8
4	**ELECTRICAL PLANT - GENERAL CONSTRUCTION**	**1 475.2**
4.1	Motor / generator system	735
4.2	Auxiliary system	645.2
4.3	Lighting, security, fire, communication cable systems	95.1
5	**TRANSMISSION**	**315**
6	**PERMANENT ACCESS ROADS**	**285**
7	**CONSTRUCTION CAMP AND VILLAGE**	**896.3**
7.1	Upper reservoir site	58.6
7.2	Lower reservoir site	837.8
8	**PROJECT MANAGEMENT AND OTHER COSTS**	**912.5**
9	**MISCELLANEOUS**	**470**
SUB-HEAD	**TOTAL**	**10 038.0**
	10% Contingencies	1 003.8
	TOTAL COST	**11 041.8**

LUZI OPTION B PUMPED STORAGE SCHEME

Sub Head	Description	COST (R million)
1	**UNDERGROUND CIVIL WORKS**	**3 004.4**
1.1	Headrace intake structure	105.7
1.2	Headrace tunnel	0
1.3	Pressure shaft	151.8
1.4	Pressure tunnel (concrete lined)	237.8
1.5	Pressure tunnel (steel lined)	332.3
1.6	Penstocks	100
1.7	Machine hall	405.8
1.8	Transformer hall	91.9
1.9	Busbar tunnels	8.4
1.10	Fresh air supply and water discharge tunnel	37.5
1.11	Smoke shaft	8.4
1.12	Extended draft tube tunnels	24.6
1.13	Tailrace surge chambers	180
1.14	Tailrace tunnel (concrete lined)	97.6
1.15	Tailrace outfall structure	122.4
1.16	Cable and emergency exit tunnel	37
1.17	Cable and emergency exit tunnel portal	192.1
1.18	Main access tunnel	137.1
1.19	Main access tunnel portal	129.5
1.20	Construction access to bifurcation tunnel	30.1
1.21	Construction access to pressure tunnels	9.6
1.22	Connector tunnel at base of pressure shaft	1.7
1.23	Access tunnel to powerhouse drainage gallery	27.5
1.24	Machine hall emergency exit tunnel	6.4
1.25	Smoke extraction tunnel	3.5
1.26	Drainage curtain tunnel	10.2
1.27	Drainage tunnel (from drainage curtain)	10.3
1.28	Fresh air supply shaft	4.7
2	**SURFACE CIVIL WORKS**	**1 891.7**
2.1	Upper reservoir	1 100.0
2.2	Lower reservoir	681.5
2.3	Surface buildings	70.1
2.4	Permanent site roads	32.4
2.5	Security fencing	7.6
3	**MECHANICAL EQUIPMENT**	**1 195.3**
3.1	Pump/turbines with governors and spherical valves	976.4
3.2	Main and auxiliary cranes	34.4
3.3	Headrace intake mechanical equipment	38.5
3.4	Tailrace outfall mechanical equipment	66.6
3.5	Station services and elevators	74.7
3.6	Dewatering and drainage	4.8
4	**ELECTRICAL PLANT - GENERAL CONSTRUCTION**	**1 475.2**
4.1	Motor / generator system	735
4.2	Auxiliary system	645.2
4.3	Lighting, security, fire, communication cable systems	95.1
5	**TRANSMISSION**	**315**
6	**PERMANENT ACCESS ROADS**	**307**
7	**CONSTRUCTION CAMP AND VILLAGE**	**896.3**
7.1	Upper reservoir site	58.6
7.2	Lower reservoir site	837.8
8	**PROJECT MANAGEMENT AND OTHER COSTS**	**955.5**
9	**MISCELLANEOUS**	**470**
SUB-HEAD	**TOTAL**	**10 510.6**
	10% Contingencies	1 051.1
	TOTAL COST	**11 561.7**

MFANTA PUMPED STORAGE SCHEME

Sub Head	Description	COST (R million)
1	**UNDERGROUND CIVIL WORKS**	**3 126.9**
1.1	Headrace intake structure	105.7
1.2	Headrace tunnel	62.9
1.3	Pressure shaft	121
1.4	Pressure tunnel (concrete lined)	94.9
1.5	Pressure tunnel (steel lined)	375.5
1.6	Penstocks	114.1
1.7	Machine hall	405.8
1.8	Transformer hall	91.9
1.9	Busbar tunnels	8.4
1.10	Fresh air supply and water discharge tunnel	56.2
1.11	Smoke shaft	8.4
1.12	Extended draft tube tunnels	28.4
1.13	Tailrace surge chambers	180
1.14	Tailrace tunnel (concrete lined)	197.1
1.15	Tailrace outfall structure	122.4
1.16	Cable and emergency exit tunnel	47.6
1.17	Cable and emergency exit tunnel portal	192.1
1.18	Main access tunnel	159.9
1.19	Main access tunnel portal	129.5
1.20	Construction access to bifurcation tunnel	30.1
1.21	Construction access to pressure tunnels	9.6
1.22	Connector tunnel at base of pressure shaft	1.7
1.23	Access tunnel to powerhouse drainage gallery	27.5
1.24	Machine hall emergency exit tunnel	6.4
1.25	Smoke extraction tunnel	3.5
1.26	Drainage curtain tunnel	10.2
1.27	Drainage tunnel (from drainage curtain)	10.3
1.28	Fresh air supply shaft	4.7
2	**SURFACE CIVIL WORKS**	**1 745.8**
2.1	Upper reservoir	729.8
2.2	Lower reservoir	905.7
2.3	Surface buildings	70.1
2.4	Permanent site roads	32.4
2.5	Security fencing	7.6
3	**MECHANICAL EQUIPMENT**	**1 195.3**
3.1	Pump/turbines with governors and spherical valves	976.4
3.2	Main and auxiliary cranes	34.4
3.3	Headrace intake mechanical equipment	38.5
3.4	Tailrace outfall mechanical equipment	66.6
3.5	Station services and elevators	74.7
3.6	Dewatering and drainage	4.8
4	**ELECTRICAL PLANT - GENERAL CONSTRUCTION**	**1 475.2**
4.1	Motor / generator system	735
4.2	Auxiliary system	645.2
4.3	Lighting, security, fire, communication cable systems	95.1
5	**TRANSMISSION**	**315**
6	**PERMANENT ACCESS ROADS**	**51**
7	**CONSTRUCTION CAMP AND VILLAGE**	**896.3**
7.1	Upper reservoir site	58.6
7.2	Lower reservoir site	837.8
8	**PROJECT MANAGEMENT AND OTHER COSTS**	**927.6**
9	**MISCELLANEOUS**	**470**
SUB-HEAD	**TOTAL**	**10 203.2**
	10% Contingencies	1 020.3
	TOTAL COST	**11 223.5**

NTSIZWA A PUMPED STORAGE SCHEME

Sub Head	Description	COST (R million)
1	**UNDERGROUND CIVIL WORKS**	**2,990.00**
1.1	Headrace intake structure	105.7
1.2	Headrace tunnel	20.1
1.3	Pressure shaft	147.7
1.4	Pressure tunnel (concrete lined)	101.4
1.5	Pressure tunnel (steel lined)	306.4
1.6	Penstocks	92.9
1.7	Machine hall	405.8
1.8	Transformer hall	91.9
1.9	Busbar tunnels	8.4
1.10	Fresh air supply and water discharge tunnel	62.5
1.11	Smoke shaft	8.4
1.12	Extended draft tube tunnels	22.4
1.13	Tailrace surge chambers	180
1.14	Tailrace tunnel (concrete lined)	165.7
1.15	Tailrace outfall structure	122.4
1.16	Cable and emergency exit tunnel	52.9
1.17	Cable and emergency exit tunnel portal	192.1
1.18	Main access tunnel	171.4
1.19	Main access tunnel portal	129.5
1.20	Construction access to bifurcation tunnel	30.1
1.21	Construction access to pressure tunnels	9.6
1.22	Connector tunnel at base of pressure shaft	1.7
1.23	Access tunnel to powerhouse drainage gallery	27.5
1.24	Machine hall emergency exit tunnel	6.4
1.25	Smoke extraction tunnel	3.5
1.26	Drainage curtain tunnel	10.2
1.27	Drainage tunnel (from drainage curtain)	10.3
1.28	Fresh air supply shaft	4.7
2	**SURFACE CIVIL WORKS**	**1 036.2**
2.1	Upper reservoir	517.8
2.2	Lower reservoir	408.2
2.3	Surface buildings	70.1
2.4	Permanent site roads	32.4
2.5	Security fencing	7.6
3	**MECHANICAL EQUIPMENT**	**1 195.3**
3.1	Pump/turbines with governors and spherical valves	976.4
3.2	Main and auxiliary cranes	34.4
3.3	Headrace intake mechanical equipment	38.5
3.4	Tailrace outfall mechanical equipment	66.6
3.5	Station services and elevators	74.7
3.6	Dewatering and drainage	4.8
4	**ELECTRICAL PLANT - GENERAL CONSTRUCTION**	**1 475.2**
4.1	Motor / generator system	735
4.2	Auxiliary system	645.2
4.3	Lighting, security, fire, communication cable systems	95.1
5	**TRANSMISSION**	**315**
6	**PERMANENT ACCESS ROADS**	**243**
7	**CONSTRUCTION CAMP AND VILLAGE**	**896.3**
7.1	Upper reservoir site	58.6
7.2	Lower reservoir site	837.8
8	**PROJECT MANAGEMENT AND OTHER COSTS**	**862.1**
9	**MISCELLANEOUS**	**470**
SUB-HEAD	**TOTAL**	**9 482.9**
	10% Contingencies	948.3
	TOTAL COST	**10 431.2**

NTSIZWA B PUMPED STORAGE SCHEME

Sub Head	Description	COST (R million)
1	**UNDERGROUND CIVIL WORKS**	**3,059.40**
1.1	Headrace intake structure	105.7
1.2	Headrace tunnel	14.9
1.3	Pressure shaft	123
1.4	Pressure tunnel (concrete lined)	209.7
1.5	Pressure tunnel (steel lined)	340.9
1.6	Penstocks	103.5
1.7	Machine hall	405.8
1.8	Transformer hall	91.9
1.9	Busbar tunnels	8.4
1.10	Fresh air supply and water discharge tunnel	31.2
1.11	Smoke shaft	8.4
1.12	Extended draft tube tunnels	25.3
1.13	Tailrace surge chambers	180
1.14	Tailrace tunnel (concrete lined)	112
1.15	Tailrace outfall structure	122.4
1.16	Cable and emergency exit tunnel	58.1
1.17	Cable and emergency exit tunnel portal	192.1
1.18	Main access tunnel	182.8
1.19	Main access tunnel portal	129.5
1.20	Construction access to bifurcation tunnel	30.1
1.21	Construction access to pressure tunnels	9.6
1.22	Connector tunnel at base of pressure shaft	1.7
1.23	Access tunnel to powerhouse drainage gallery	27.5
1.24	Machine hall emergency exit tunnel	6.4
1.25	Smoke extraction tunnel	3.5
1.26	Drainage curtain tunnel	10.2
1.27	Drainage tunnel (from drainage curtain)	10.2
1.28	Fresh air supply shaft	4.7
2	**SURFACE CIVIL WORKS**	**938.5**
2.1	Upper reservoir	610.2
2.2	Lower reservoir	218.1
2.3	Surface buildings	70.1
2.4	Permanent site roads	32.4
2.5	Security fencing	7.6
3	**MECHANICAL EQUIPMENT**	**1,195.30**
3.1	Pump/turbines with governors and spherical valves	976.4
3.2	Main and auxiliary cranes	34.4
3.3	Headrace intake mechanical equipment	38.5
3.4	Tailrace outfall mechanical equipment	66.6
3.5	Station services and elevators	74.7
3.6	Dewatering and drainage	4.8
4	**ELECTRICAL PLANT - GENERAL CONSTRUCTION**	**1 475.2**
4.1	Motor / generator system	735
4.2	Auxiliary system	645.2
4.3	Lighting, security, fire, communication cable systems	95.1
5	**TRANSMISSION**	**315**
6	**PERMANENT ACCESS ROADS**	**277**
7	**CONSTRUCTION CAMP AND VILLAGE**	**896.3**
7.1	Upper reservoir site	58.6
7.2	Lower reservoir site	837.8
8	**PROJECT MANAGEMENT AND OTHER COSTS**	**862.7**
9	**MISCELLANEOUS**	**470**
SUB-HEAD	**TOTAL**	**9 489.6**
	10% Contingencies	949
	TOTAL COST	**10 438.6**

SIQINGENI A PUMPED STORAGE SCHEME

Sub Head	Description	COST (R million)
1	**UNDERGROUND CIVIL WORKS**	**3 010.8**
1.1	Headrace intake structure	105.7
1.2	Headrace tunnel	45.4
1.3	Pressure shaft	148.4
1.4	Pressure tunnel (concrete lined)	34.8
1.5	Pressure tunnel (steel lined)	340.9
1.6	Penstocks	100
1.7	Machine hall	405.8
1.8	Transformer hall	91.9
1.9	Busbar tunnels	8.4
1.10	Fresh air supply and water discharge tunnel	43.7
1.11	Smoke shaft	8.4
1.12	Extended draft tube tunnels	25.3
1.13	Tailrace surge chambers	180
1.14	Tailrace tunnel (concrete lined)	181.5
1.15	Tailrace outfall structure	122.4
1.16	Cable and emergency exit tunnel	58.1
1.17	Cable and emergency exit tunnel portal	192.1
1.18	Main access tunnel	182.8
1.19	Main access tunnel portal	129.5
1.20	Construction access to bifurcation tunnel	30.1
1.21	Construction access to pressure tunnels	9.6
1.22	Connector tunnel at base of pressure shaft	1.7
1.23	Access tunnel to powerhouse drainage gallery	27.5
1.24	Machine hall emergency exit tunnel	6.4
1.25	Smoke extraction tunnel	3.5
1.26	Drainage curtain tunnel	10.2
1.27	Drainage tunnel (from drainage curtain)	10.3
1.28	Fresh air supply shaft	4.7
2	**SURFACE CIVIL WORKS**	**1 252.2**
2.1	Upper reservoir	757.8
2.2	Lower reservoir	384.3
2.3	Surface buildings	70.1
2.4	Permanent site roads	32.4
2.5	Security fencing	7.6
3	**MECHANICAL EQUIPMENT**	**1 195.3**
3.1	Pump/turbines with governors and spherical valves	976.4
3.2	Main and auxiliary cranes	34.4
3.3	Headrace intake mechanical equipment	38.5
3.4	Tailrace outfall mechanical equipment	66.6
3.5	Station services and elevators	74.7
3.6	Dewatering and drainage	4.8
4	**ELECTRICAL PLANT - GENERAL CONSTRUCTION**	**1 475.2**
4.1	Motor / generator system	735
4.2	Auxiliary system	645.2
4.3	Lighting, security, fire, communication cable systems	95.1
5	**TRANSMISSION**	**315**
6	**PERMANENT ACCESS ROADS**	**270**
7	**CONSTRUCTION CAMP AND VILLAGE**	**896.3**
7.1	Upper reservoir site	58.6
7.2	Lower reservoir site	837.8
8	**PROJECT MANAGEMENT AND OTHER COSTS**	**888.5**
9	**MISCELLANEOUS**	**470**
SUB-HEAD	**TOTAL**	**9 773.5**
	10% Contingencies	977.4
	TOTAL COST	**10 750.9**

SIQINGENI B PUMPED STORAGE SCHEME

Sub Head	Description	COST (R million)
1	**UNDERGROUND CIVIL WORKS**	**3,186.70**
1.1	Headrace intake structure	105.7
1.2	Headrace tunnel	41.3
1.3	Pressure shaft	138.2
1.4	Pressure tunnel (concrete lined)	96.9
1.5	Pressure tunnel (steel lined)	315
1.6	Penstocks	92.9
1.7	Machine hall	405.8
1.8	Transformer hall	91.9
1.9	Busbar tunnels	8.4
1.10	Fresh air supply and water discharge tunnel	68.7
1.11	Smoke shaft	8.4
1.12	Extended draft tube tunnels	23.1
1.13	Tailrace surge chambers	180
1.14	Tailrace tunnel (concrete lined)	273.7
1.15	Tailrace outfall structure	122.4
1.16	Cable and emergency exit tunnel	63.4
1.17	Cable and emergency exit tunnel portal	192.1
1.18	Main access tunnel	194.2
1.19	Main access tunnel portal	129.5
1.20	Construction access to bifurcation tunnel	30.1
1.21	Construction access to pressure tunnels	9.6
1.22	Connector tunnel at base of pressure shaft	1.7
1.23	Access tunnel to powerhouse drainage gallery	27.5
1.24	Machine hall emergency exit tunnel	6.4
1.25	Smoke extraction tunnel	3.5
1.26	Drainage curtain tunnel	10.2
1.27	Drainage tunnel (from drainage curtain)	10.3
1.28	Fresh air supply shaft	4.7
2	**SURFACE CIVIL WORKS**	**1 082.7**
2.1	Upper reservoir	681.2
2.2	Lower reservoir	291.3
2.3	Surface buildings	70.1
2.4	Permanent site roads	32.4
2.5	Security fencing	7.6
3	**MECHANICAL EQUIPMENT**	**1 195.3**
3.1	Pump/turbines with governors and spherical valves	976.4
3.2	Main and auxiliary cranes	34.4
3.3	Headrace intake mechanical equipment	38.5
3.4	Tailrace outfall mechanical equipment	66.6
3.5	Station services and elevators	74.7
3.6	Dewatering and drainage	4.8
4	**ELECTRICAL PLANT - GENERAL CONSTRUCTION**	**1 475.2**
4.1	Motor / generator system	735
4.2	Auxiliary system	645.2
4.3	Lighting, security, fire, communication cable systems	95.1
5	**TRANSMISSION**	**315**
6	**PERMANENT ACCESS ROADS**	**270**
7	**CONSTRUCTION CAMP AND VILLAGE**	**896.3**
7.1	Upper reservoir site	58.6
7.2	Lower reservoir site	837.8
8	**PROJECT MANAGEMENT AND OTHER COSTS**	**889.1**
9	**MISCELLANEOUS**	**470**
SUB-HEAD	**TOTAL**	**9 780.6**
	10% Contingencies	978.1
	TOTAL COST	**10 758.7**

SOMBADI PUMPED STORAGE SCHEME

Sub Head	Description	COST (R million)
1	**UNDERGROUND CIVIL WORKS**	**2,925.00**
1.1	Headrace intake structure	105.7
1.2	Headrace tunnel	22.5
1.3	Pressure shaft	138
1.4	Pressure tunnel (concrete lined)	103.4
1.5	Pressure tunnel (steel lined)	349.5
1.6	Penstocks	103.5
1.7	Machine hall	405.8
1.8	Transformer hall	91.9
1.9	Busbar tunnels	8.4
1.10	Fresh air supply and water discharge tunnel	34.4
1.11	Smoke shaft	8.4
1.12	Extended draft tube tunnels	26.1
1.13	Tailrace surge chambers	180
1.14	Tailrace tunnel (concrete lined)	121.4
1.15	Tailrace outfall structure	122.4
1.16	Cable and emergency exit tunnel	42.3
1.17	Cable and emergency exit tunnel portal	192.1
1.18	Main access tunnel	148.5
1.19	Main access tunnel portal	129.5
1.20	Construction access to bifurcation tunnel	30.1
1.21	Construction access to pressure tunnels	9.6
1.22	Connector tunnel at base of pressure shaft	1.7
1.23	Access tunnel to powerhouse drainage gallery	27.5
1.24	Machine hall emergency exit tunnel	6.4
1.25	Smoke extraction tunnel	3.5
1.26	Drainage curtain tunnel	10.2
1.27	Drainage tunnel (from drainage curtain)	10.3
1.28	Fresh air supply shaft	4.7
2	**SURFACE CIVIL WORKS**	**967.3**
2.1	Upper reservoir	646.1
2.2	Lower reservoir	211
2.3	Surface buildings	70.1
2.4	Permanent site roads	32.4
2.5	Security fencing	7.6
3	**MECHANICAL EQUIPMENT**	**1 195.3**
3.1	Pump/turbines with governors and spherical valves	976.4
3.2	Main and auxiliary cranes	34.4
3.3	Headrace intake mechanical equipment	38.5
3.4	Tailrace outfall mechanical equipment	66.6
3.5	Station services and elevators	74.7
3.6	Dewatering and drainage	4.8
4	**ELECTRICAL PLANT - GENERAL CONSTRUCTION**	**1 475.2**
4.1	Motor / generator system	735
4.2	Auxiliary system	645.2
4.3	Lighting, security, fire, communication cable systems	95.1
5	**TRANSMISSION**	**315**
6	**PERMANENT ACCESS ROADS**	**273**
7	**CONSTRUCTION CAMP AND VILLAGE**	**896.3**
7.1	Upper reservoir site	58.6
7.2	Lower reservoir site	837.8
8	**PROJECT MANAGEMENT AND OTHER COSTS**	**851.7**
9	**MISCELLANEOUS**	**470**
SUB-HEAD	**TOTAL**	**9 369.0**
	10% Contingencies	936.9
	TOTAL COST	**10 305.9**

T10 PUMPED STORAGE SCHEME

Sub Head	Description	COST (R million)
1	**UNDERGROUND CIVIL WORKS**	**2 864.0**
1.1	Headrace intake structure	105.7
1.2	Headrace tunnel	57.4
1.3	Pressure shaft	127.2
1.4	Pressure tunnel (concrete lined)	84.4
1.5	Pressure tunnel (steel lined)	340.9
1.6	Penstocks	103.5
1.7	Machine hall	405.8
1.8	Transformer hall	91.9
1.9	Busbar tunnels	8.4
1.10	Fresh air supply and water discharge tunnel	31.2
1.11	Smoke shaft	8.4
1.12	Extended draft tube tunnels	25.3
1.13	Tailrace surge chambers	180
1.14	Tailrace tunnel (concrete lined)	111.3
1.15	Tailrace outfall structure	122.4
1.16	Cable and emergency exit tunnel	31.7
1.17	Cable and emergency exit tunnel portal	192.1
1.18	Main access tunnel	125.7
1.19	Main access tunnel portal	129.5
1.20	Construction access to bifurcation tunnel	30.1
1.21	Construction access to pressure tunnels	9.6
1.22	Connector tunnel at base of pressure shaft	1.7
1.23	Access tunnel to powerhouse drainage gallery	27.5
1.24	Machine hall emergency exit tunnel	6.4
1.25	Smoke extraction tunnel	3.5
1.26	Drainage curtain tunnel	10.2
1.27	Drainage tunnel (from drainage curtain)	10.3
1.28	Fresh air supply shaft	4.7
2	**SURFACE CIVIL WORKS**	**1 471.9**
2.1	Upper reservoir	980.9
2.2	Lower reservoir	380.8
2.3	Surface buildings	70.1
2.4	Permanent site roads	32.4
2.5	Security fencing	7.6
3	**MECHANICAL EQUIPMENT**	**1 195.3**
3.1	Pump/turbines with governors and spherical valves	976.4
3.2	Main and auxiliary cranes	34.4
3.3	Headrace intake mechanical equipment	38.5
3.4	Tailrace outfall mechanical equipment	66.6
3.5	Station services and elevators	74.7
3.6	Dewatering and drainage	4.8
4	**ELECTRICAL PLANT - GENERAL CONSTRUCTION**	**1 475.2**
4.1	Motor / generator system	735
4.2	Auxiliary system	645.2
4.3	Lighting, security, fire, communication cable systems	95.1
5	**TRANSMISSION**	**315**
6	**PERMANENT ACCESS ROADS**	**278**
7	**CONSTRUCTION CAMP AND VILLAGE**	**896.3**
7.1	Upper reservoir site	58.6
7.2	Lower reservoir site	837.8
8	**PROJECT MANAGEMENT AND OTHER COSTS**	**896.6**
9	**MISCELLANEOUS**	**470**
SUB-HEAD	**TOTAL**	**9 862.5**
	10% Contingencies	986.2
	TOTAL COST	**10 848.7**

APPENDIX C

Pumped storage scheme comparative characteristics of options

Table C-1: Comparative Characteristics of Options

Item/Parameter	Metric or measurement	Somabadi	Rating	Mfanta	Rating	T10	Rating	Dam 2	Rating	Siqingeni A	Rating	Siqingeni B	Rating	Luzi A	Rating	Luzi B	Rating	Ntsizwa A	Rating	Ntsizwa B	Rating
1. General Description of the Option																					
Upper Reservoir - 14-hour storage																					
Full supply level	m	1,922.5		1,707.0		1,539.6		1,837.0		1,799.4		1,796.7		1,486.0		1,489.3		1,750.0		1,755.0	
Minimum drawdown level	m	1,900.0		1,680.0		1,520.0		1,805.0		1,780.0		1,780.0		1,460.0		1,460.0		1,730.0		1,730.0	
Lower Reservoir - 14-hour storage																					
Full supply level	m	1,325.8		1,200.0		917.0		1,180.2		1,188.0		1,074.0		802.0		899.5		990.5		1,148.0	
Minimum drawdown level	m	1,306.4		1,183.8		900.0		1,173.2		1,115.0		1,025.0		800.5		840.0		940.0		1,100.0	
Head																					
Maximum gross head	m	616.0		523.0		640.0		664.0		684.0		772.0		686.0		649.0		810.0		655.0	
Minimum gross head	m	574.0		480.0		603.0		625.0		592.0		706.0		658.0		561.0		740.0		582.0	
Waterway Lengths (approximate)																					
Headrace tunnel	m	120.0	4	300.0	3	316.0	3	-	5	250.0	4	250.0	4	140.0	4	-	5	125.0	4	80.0	4
Pressure shaft	m	635.0	3	495.0	4	600.0	3	610.0	3	700.0	2	720.0	2	700.0	2	650.0	3	790.0	2	580.0	3
Pressure tunnel - concrete-lined	m	580.0	5	475.0	5	485.0	5	1,455.0	2	200.0	5	615.0	4	450.0	5	1,400.0	2	660.0	4	1,205.0	2
Pressure tunnel - steel-lined section	m	300.0	3	300.0	3	300.0	3	300.0	3	300.0	3	300.0	3	300.0	3	300.0	3	300.0	3	300.0	3
Penstocks	m	65.0	3	65.0	3	65.0	3	65.0	3	65.0	3	65.0	3	65.0	3	65.0	3	65.0	3	65.0	3
Draft tube extension	m	100.0	3	100.0	3	100.0	3	100.0	3	100.0	3	100.0	3	100.0	3	100.0	3	100.0	3	100.0	3
Tailrace tunnel	m	650.0	4	945.0	3	610.0	4	505.0	5	1,000.0	2	1,500.0	2	650.0	4	535.0	5	1,025.0	2	600.0	4
Overall waterway length	m - shorter is better	2,450.0	4	2,680.0	4	2,476.0	4	3,035.0	3	2,615.0	4	3,550.0	3	2,405.0	4	3,050.0	3	3,065.0	3	2,930.0	4
Access Tunnel Lengths																					
Main access tunnel	m	1,300.0	3	1,400.0	3	1,100.0	4	1,100.0	4	1,600.0	3	1,700.0	3	1,400.0	3	1,200.0	4	1,500.0	3	1,600.0	3
Cable tunnel	m	800.0	3	900.0	3	600.0	4	600.0	4	1,100.0	3	1,200.0	3	900.0	3	700.0	4	1,000.0	3	1,100.0	3
RANKING		**3**	35	**5.5**	34	**1**	36	**3**	35	**7.5**	32	**9.5**	30	**5.5**	34	**3**	35	**9.5**	30	**7.5**	32
2. Operational																					
Active reservoir storage	million m^3	10.4	3	12.2	2	9.8	4	9.6	4	9.7	4	8.3	5	9.1	4	10.3	3	8.0	5	10.0	3
Waterway length to min gross head ratio	ratio - lower is better	4.3	4	5.6	2	4.1	4	4.9	3	4.4	4	5.0	3	3.7	5	5.4	2	4.1	4	5.0	3
Max gross head / minimum gross head	% (lower is better)	1.07	4	1.09	3	1.06	4	1.06	4	1.16	2	1.09	3	1.04	4	1.16	2	1.09	3	1.13	2
Est. generating discharge at rated head	m^3/s - lower is better	205	3	245	2	196	3	190	3	194	3	167	4	180	3	206	3	159	4	200	3
Rated condition head loss	m - lower is better	17.0	4	16.3	4	17.6	4	20.1	3	18.1	4	24.1	2	18.0	4	19.2	3	22.7	3	19.1	3
Hydraulic & equipment efficiency	1.0 best, relative indices	0.998	4	0.993	2	0.998	4	0.995	3	0.998	4	0.993	2	1.000	5	0.994	3	0.996	4	0.995	3
Proven technology (pump/turbine head)	Yes/No	Yes	5	Yes	5	Yes	5	Yes	5	Yes	5	Yes	5	Yes	5	Yes	5	No	3	Yes	5
RANKING		**3**	27	**10**	20	**2**	28	**6**	25	**4.5**	26	**7**	24	**1**	30	**9**	21	**4.5**	26	**8**	22
3. Water Supply																					
Description	NA	Somabadi River		Tina River		Nqancule River		Mzimvubu		Mzimvubu		Mzimvubu		Mzintlava		Mzintlava		Mzintlava		Mzintlava	
Type of abstraction	NA	On-channel		On-channel		On-channel		On-channel		Off-channel		Off-channel		On-channel		Off-channel		Off-channel		Off-channel	
4. Geological																					
Upper reservoir																					
Type of material	NA	Dolerite		Sandstone/dolerite		Sandstone		Dolerite/ Shale		Dolerite		Dolerite		Dolerite		Dolerite		Dolerite		Dolerite	
Founding depth	shallow, medium, deep	Medium/deep	2	Medium/deep	2	Medium/deep	2	Medium/deep	2	Medium/deep	2	Medium/deep	2	Medium/deep	2	Medium/deep	2	Medium/deep	2	Medium/deep	2
Unfavourable features	high, medium, low risk	low	4	medium	3	medium	3	medium	3	medium	3	medium	3	Low	4	Low	4	medium	3	medium	3
Lower reservoir																					
Type of material	NA	Sand/mudstone		Sand/mudstone		Sandstone/shale		Dolerite		Dolerite/shale		Dolerite/Shale		Dolerite/Shale		Dolerite		Dolerite		Dolerite	
Founding depth	shallow, medium, deep	Medium/deep	2	Medium/ deep	2	Medium/deep	2	Medium/deep	2	Medium/deep	2	Medium/deep	2	Medium/deep	2	Medium/deep	2	Medium/deep	2	Medium/deep	2
Unfavourable features	high, medium, low risk	low	4	low	4	medium	3	medium	3	low	4	low	4	medium	3	medium	3	medium	3	medium	3
Underground construction																					
Conditions for excavation	poor, medium, good	Medium/poor	2	Medium/poor	2	Medium/poor	2	Medium/poor	2	Medium/poor	2	Medium/poor	2	Medium/poor	2	Medium/poor	2	Medium/poor	2	Medium/poor	2
RANKING		**1**	14	**4**	13	**8.5**	12	**8.5**	12	**4**	13	**4**	13	**4**	13	**4**	13	**8.5**	12	**8.5**	12

Table C-1: Comparative Characteristics of Options

Item/Parameter	Metric or measurement	Somabadi	Rating	Mfanta	Rating	T10	Rating	Dam 2	Rating	Siqingeni A	Rating	Siqingeni B	Rating	Luzi A	Rating	Luzi B	Rating	Ntsizwa A	Rating	Ntsizwa B	Rating
5. Environmental																					
Social																					
Agricultural potential	Favourable	Favourable	4	Favourable	4	Less Favourable	2	Uncertain	3	Favourable	4	Favourable	4	Less Favourable	2	Uncertain	3	Uncertain	3	Favourable	4
Displacement of people	Uncertain	Favourable	4	Favourable	4	Favourable	4	Uncertain	3	Uncertain	3	Favourable	4	Favourable	4	Uncertain	3	Uncertain	3	Favourable	4
Access route (accessibility to site)	Less Favourable	Favourable	4	Favourable	4	Uncertain	3	Uncertain	3	Favourable	4	Favourable	4	Favourable	4	Favourable	4	Favourable	4	Favourable	4
Infrastructure development (electricity, etc.)	Potential fatal flaw	Positive Impact	5	Positive Impact	5	Positive Impact	5	Positive Impact	5	Positive Impact	5	Positive Impact	5	Positive Impact	5	Positive Impact	5	Positive Impact	5	Positive Impact	5
Economic																					
Loss of local income due to project		Favourable	4	Favourable	4	Uncertain	3	Uncertain	3	Favourable	4	Favourable	4	Less Favourable	2	Uncertain	3	Uncertain	3	Favourable	4
Generation of local income employment		Uncertain	3	Favourable	4	Less Favourable	2	Less Favourable	2	Favourable	4	Favourable	4	Favourable	4	Favourable	4	Favourable	4	Favourable	4
RANKING		**4.5**	24	**2**	25	**9.5**	19	**9.5**	19	**4.5**	24	**2**	25	**8**	21	**6.5**	22	**6.5**	22	**2**	25
6. Access																					
Length of permanent access road	km - lower is better	36	3	7	5	37	3	57	2	36	3	37	3	38	3	41	3	33	3	31	3
Travel distance, control room - upper reservoir	km - lower is better	36	3	9	5	92	1	43	3	55	2	55	2	63	2	63	2	15	4	15	4
RANKING		**4**	6	**1**	10	**10**	4	**7**	5	**7**	5	**7**	5	**7**	5	**7**	5	**2.5**	7	**2.5**	7
7. Cost																					
Cost for 14 hour storage project	ZAR million	10,306	4	11,224	3	10,849	3	10,899	3	10,751	3	10,759	3	11,042	3	11,562	2	10,431	4	10,439	4
RANKING		**2**	4	**6.5**	3	**6.5**	3	**6.5**	3	**6.5**	3	**6.5**	3	**6.5**	3	**10**	2	**2**	4	**2**	4
8. Expandability																					
Area available to expand upper reservoir	Yes/no - yes is better	Yes	4	No	2	No	2	No	2	No	2	No	2	No	2	No	2	No	2	No	2
RANKING		**1**	4	**6**	2	**6**	2	**6**	2	**6**	2	**6**	2	**6**	2	**6**	2	**6**	2	**6**	2
Sum total of category rankings		18.5		35		43.5		46.5		40		42		38		45.5		39.5		36.5	
OVERALL RANKING		**1**		**2**		**8**		**10**		**6**		**7**		**4**		**9**		**5**		**3**	

APPENDIX D

Conventional hydropower:

Dam sites analysed

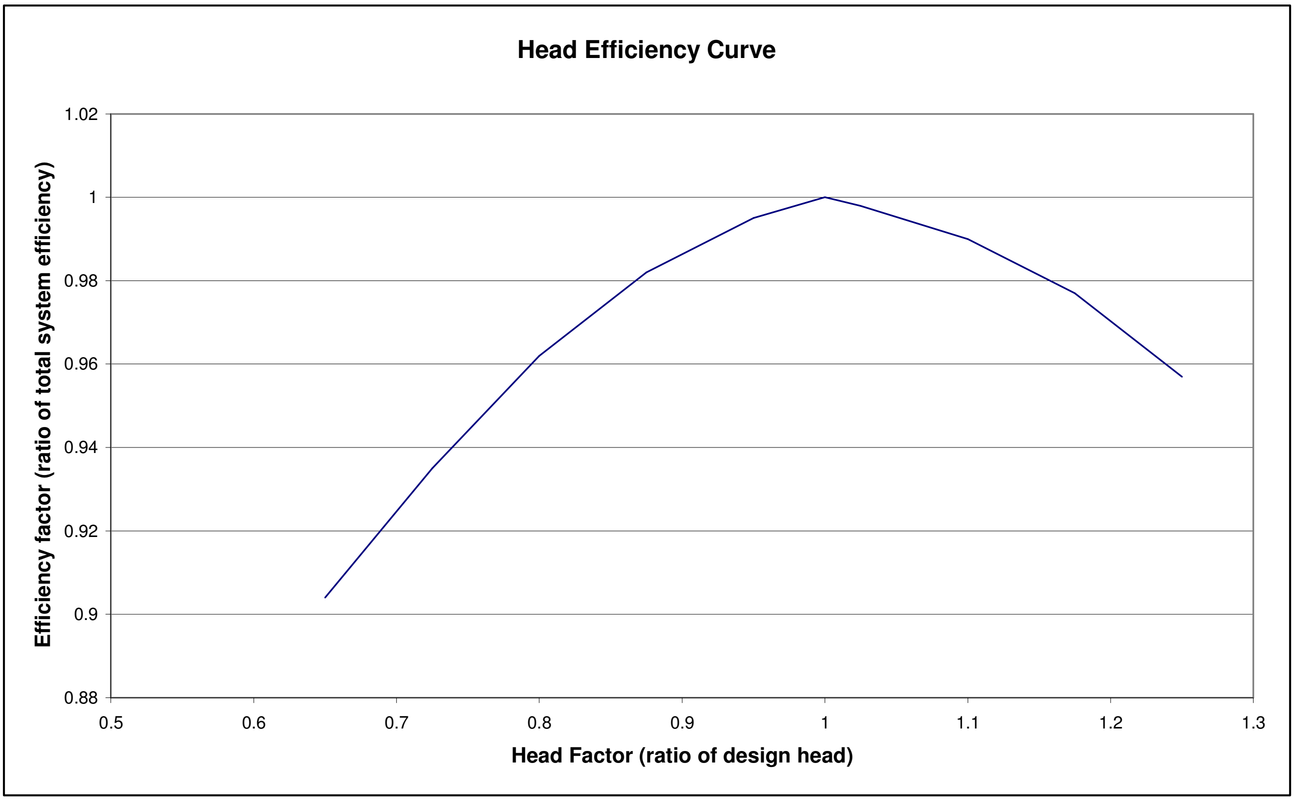
Sub-catchment	River	Dam name	Mean annual runoff (MAR) (million m^3/a)	Wall height (1 MAR storage capacity) (m)
T31	Upper Mzimvubu	Dam 2	240	49
		Siqingeni	709	80
T32	Mzintlava	Bokpoort	130	60
		Luzi	198	63
		Dam B	282	93
T33	Kinira	Thabeng	307	53
		Somabadi	324	59
		Ntlabeni	396	65
T34	Tina	Pitseng	55	34
		Hlabakazi	248	57
		Mpindweni	337	56
		Mangwaneni	414	55
		Ku-Mdyobe	424	80 (*)
T35	Itsitsa	Nomhala	206	43
		Ntabelanga	403	43
		Malepelepe	696	42
		Laleni	755	62 (*)
		Gongo	800	100 (*)
T36	Lower Mzimvubu	Mbokazi	2 520	100 (*)

(*) Wall height for dam below 1 MAR due to limitation

APPENDIX E

Conventional hydropower:

Turbine operating curve



Head Efficiency Curve
1.02
1
0.98
0.96
0.94
0.92
0.9
0.88
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
Efficiency factor (ratio of total system efficiency)
Head Factor (ratio of design head)

APPENDIX F

Conventional hydropower:

Cost estimates of Tsitsa Falls

COSTS ESTIMATED FOR TSITSA FALLS HYDROPOWER (MAY 2008 PRICES)

Cost estimates (R million)			
		0.71 MAR dam size	
	Description	**Base-load**	**10 % load factor**
1	**UNDERGROUND CIVIL WORKS**	**903**	**1 169**
1.1	Headrace intake structure	16	20
1.3	Pressure shaft	31	31
1.4	Pressure tunnel (concrete lined)	304	367
1.5	Pressure tunnel (steel lined)	88	105
1.6	Penstocks	12	29
1.7	Machine hall	44	133
1.8	Transformer hall	11	32
1.10	Fresh air supply and water discharge tunnel	8	8
1.11	Smoke shaft	4	4
1.12	Extended draft tube tunnels	25	36
1.15	Tailrace outfall structure	10	10
1.16	Cable and emergency exit tunnel	21	21
1.17	Cable and emergency exit tunnel portal	60	60
1.18	Main access tunnel	57	57
1.19	Main access tunnel portal	40	40
1.20	Construction tunnels	20	20
2	**SURFACE CIVIL WORKS**	**1 071**	**1 071**
2.1	Upper reservoir	1 061	1 061
2.3	Surface buildings	8	8
2.5	Security fencing	2	2
3	**MECHANICAL EQUIPMENT**	**92**	**451**
3.1	Pump/turbines with governors and spherical valves	83	414
3.2	Main and auxiliary cranes	2	9
3.3	Headrace intake mechanical equipment	2	10
3.4	Tailrace outfall mechanical equipment	3	17
3.6	Dewatering and drainage	2	2
4	**ELECTRICAL PLANT - GENERAL**	**76**	**497**
4.1	Motor / generator system	47	312
4.2	Auxiliary system	24	161
4.3	Lighting, security, fire, communication cable systems	5	24
5	**TRANSMISSION**	**-**	**-**
6	**PERMANENT ACCESS ROADS**	**60**	**60**
7	**PROJECT MANAGEMENT AND OTHER COSTS**	**190**	**290**
	TOTAL	**2 256**	**3 358**
	10% Contingencies	**226**	**336**
	TOTAL COST	**2 482**	**3 694**