P WMA 12/T30/00/5212/3

water & sanitation

Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

DIRECTORATE: OPTIONS ANALYSIS

FEASIBILITY STUDY FOR THE MZIMVUBU WATER PROJECT

PRELIMINARY STUDY

AUGUST 2014

FEASIBILITY STUDY FOR THE MZIMVUBU WATER PROJECT

APPROVAL

Report title:	**Preliminary Study**
Authors:	A Pepperell, S Johnson, and various team members
Project name:	**Feasibility Study for the Mzimvubu Water Project**
DWA Report Number:	P WMA 12/T30/00/5212/3
PSP project reference number:	002819
Status of report:	Final
First Issue:	April 2013
Second Issue:	August 2013
Third Issue:	April 2014
Final:	August 2014

CONSULTANTS: JEFFARES & GREEN

Approved for Consultants:

....

S Johnson
Deputy Study Leader

....

A Pepperell
Study Leader

DEPARTMENT OF WATER AND SANITATION (DWS)
Directorate: Options Analysis

Approved for DWS:

....

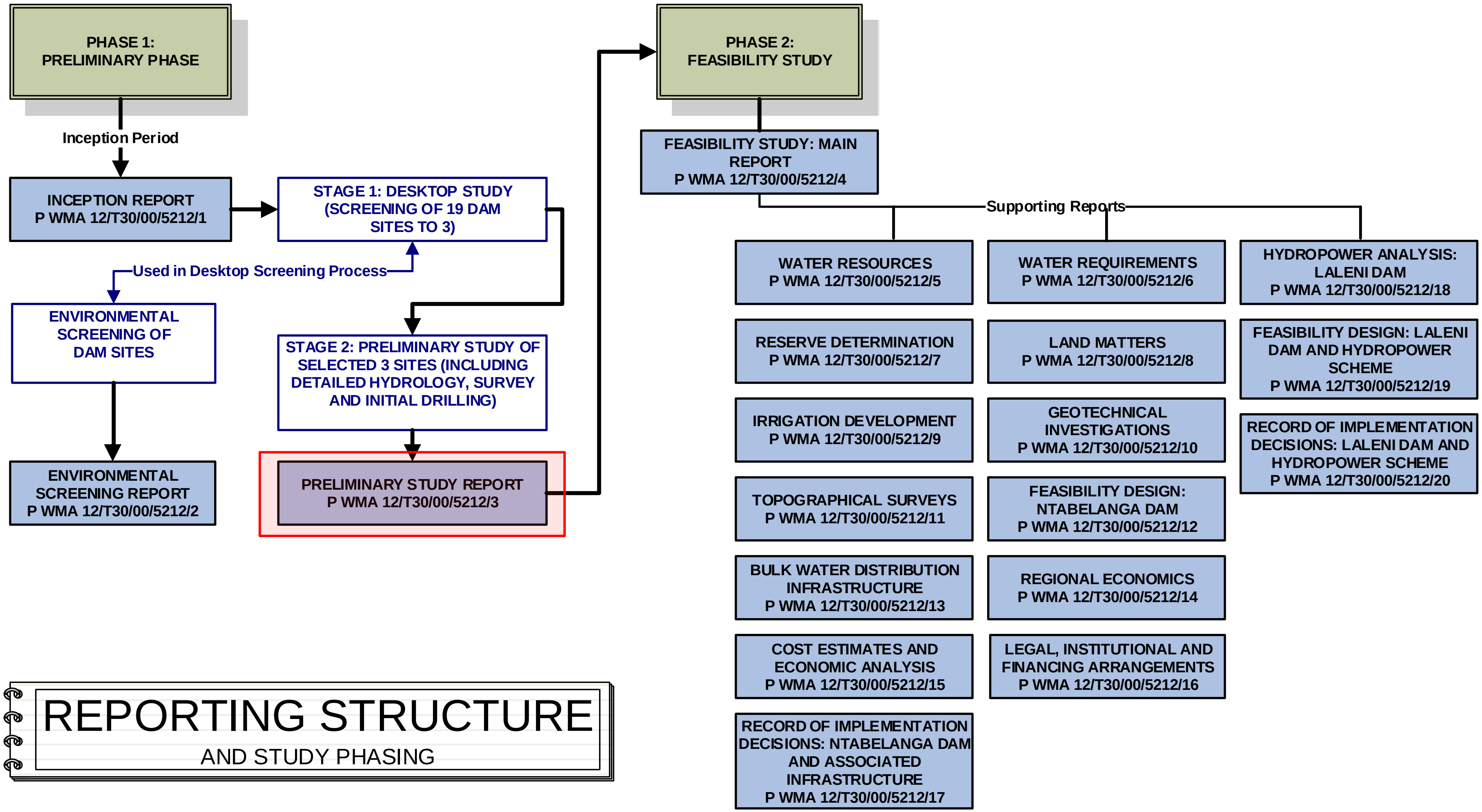
M Mugumo
Chief Engineer: Options Analysis (South)

....

L S Mabuda
Chief Director: Integrated Water Resource Planning

LIST OF REPORTS

REPORT TITLE	**DWS REPORT NUMBER**
Inception Report	P WMA 12/T30/00/5212/1
Environmental Screening	P WMA 12/T30/00/5212/2
Preliminary Study	P WMA 12/T30/00/5212/3
Feasibility Study: Main Report	P WMA 12/T30/00/5212/4
Feasibility Study: Supporting Reports:	
Water Resources	P WMA 12/T30/00/5212/5
Water Requirements	P WMA 12/T30/00/5212/6
Reserve Determination	
Volume 1: River	P WMA 12/T30/00/5212/7
Volume 2: Estuary: Report	
Volume 3 :Estuary: Appendices	
Land Matters	P WMA 12/T30/00/5212/8
Irrigation Development	P WMA 12/T30/00/5212/9
Geotechnical Investigations	
Volume 1: Ntabelanga, Somabadi and Thabeng Dam Sites: Report	
Volume 2: Ntabelanga, Somabadi and Thabeng Dam Sites: Appendices	P WMA 12/T30/00/5212/10
Volume 3: Laleni Dam and Hydropower Scheme: Report	
Volume 4: Laleni Dam and Hydropower Scheme: Appendices	
Topographical Surveys	P WMA 12/T30/00/5212/11
Feasibility Design: Ntabelanga Dam	P WMA 12/T30/00/5212/12
Bulk Water Distribution Infrastructure	P WMA 12/T30/00/5212/13
Regional Economics	P WMA 12/T30/00/5212/14
Cost Estimates and Economic Analysis	P WMA 12/T30/00/5212/15
Legal, Institutional and Financing Arrangements	P WMA 12/T30/00/5212/16
Record of Implementation Decisions: Ntabelanga Dam and Associated Infrastructure	P WMA 12/T30/00/5212/17
Hydropower Analysis: Laleni Dam	P WMA 12/T30/00/5212/18
Feasibility Design: Laleni Dam and Hydropower Scheme	P WMA 12/T30/00/5212/19
Record of Implementation Decisions: Laleni Dam and Hydropower Scheme	P WMA 12/T30/00/5212/20


PHASE 1:
PRELIMINARY PHASE
Inception Period
INCEPTION REPORT
P WMA 12/T30/00/5212/1
STAGE 1: DESKTOP STUDY
(SCREENING OF 19 DAM SITES TO 3)
Used in Desktop Screening Process
ENVIRONMENTAL SCREENING OF DAM SITES
ENVIRONMENTAL SCREENING REPORT
P WMA 12/T30/00/5212/2
STAGE 2: PRELIMINARY STUDY OF SELECTED 3 SITES (INCLUDING DETAILED HYDROLOGY, SURVEY AND INITIAL DRILLING)
PRELIMINARY STUDY REPORT
P WMA 12/T30/00/5212/3
PHASE 2:
FEASIBILITY STUDY
FEASIBILITY STUDY: MAIN REPORT
P WMA 12/T30/00/5212/4
Supporting Reports
WATER RESOURCES
P WMA 12/T30/00/5212/5
WATER REQUIREMENTS
P WMA 12/T30/00/5212/6
HYDROPOWER ANALYSIS: LALENI DAM
P WMA 12/T30/00/5212/18
RESERVE DETERMINATION
P WMA 12/T30/00/5212/7
LAND MATTERS
P WMA 12/T30/00/5212/8
FEASIBILITY DESIGN: LALENI DAM AND HYDROPOWER SCHEME
P WMA 12/T30/00/5212/19
IRRIGATION DEVELOPMENT
P WMA 12/T30/00/5212/9
GEOTECHNICAL INVESTIGATIONS
P WMA 12/T30/00/5212/10
RECORD OF IMPLEMENTATION DECISIONS: LALENI DAM AND HYDROPOWER SCHEME
P WMA 12/T30/00/5212/20
TOPOGRAPHICAL SURVEYS
P WMA 12/T30/00/5212/11
FEASIBILITY DESIGN: NTABELANGA DAM
P WMA 12/T30/00/5212/12
BULK WATER DISTRIBUTION INFRASTRUCTURE
P WMA 12/T30/00/5212/13
REGIONAL ECONOMICS
P WMA 12/T30/00/5212/14
COST ESTIMATES AND ECONOMIC ANALYSIS
P WMA 12/T30/00/5212/15
LEGAL, INSTITUTIONAL AND FINANCING ARRANGEMENTS
P WMA 12/T30/00/5212/16
RECORD OF IMPLEMENTATION DECISIONS: NTABELANGA DAM AND ASSOCIATED INFRASTRUCTURE
P WMA 12/T30/00/5212/17
REPORTING STRUCTURE
AND STUDY PHASING

FEASIBILITY STUDY FOR THE MZIMVUBU WATER PROJECT

REFERENCE

This report is to be referred to in bibliographies as:

Department of Water Affairs, South Africa (2013). ***Feasibility Study for the Mzimvubu Water Project: Preliminary Study***

DWA Report No: P WMA 12/T30/00/5212/3

Prepared for: Directorate – Options Analysis

Prepared by: Jeffares & Green (Pty) Ltd, P O Box 794, Hilton, 3245
Tel: 033 343 6700, Fax: 033 343 6701
Contact: Mr A Pepperell
Email: pepperella@jgi.co.za

Note on Departmental Name Change:

In 2014, the Department of Water Affairs changed its name to the Department of Water and Sanitation, which happened during the course of this study. In some cases this was after some of the study reports had been finalized. The reader should therefore kindly note that references to the Department of Water Affairs and the Department of Water and Sanitation herein should be considered to be one and the same.

Note on Spelling of Laleni:

The settlement named Laleni on maps issued by the Surveyor General is locally known as Lalini and both names therefore refer to the same settlement.

EXECUTIVE SUMMARY

INTRODUCTION

The Mzimvubu River catchment in the Eastern Cape of South Africa is situated in one of the poorest and least developed regions of the country. Development of the area to accelerate the social and economic upliftment of the people was therefore identified as one of the priority initiatives of the Eastern Cape Provincial Government.

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

The five pillars on which the Eastern Cape Provincial Government and AsgiSA-EC proposed to model the Mzimvubu River Water Resources Development are:

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

The Department of Water Affairs (DWA) commissioned the Mzimvubu Water Project with the overarching aim of developing water resources schemes (dams) that can be multi-purpose reservoirs in order to provide benefits to the surrounding communities and to provide a stimulus for the regional economy, in terms of irrigation, forestry, domestic water supply and the potential for hydropower generation amongst others.

The study commenced in January 2012 and is to be completed by April 2014 in three Phases as follows:

- *Inception Phase;*
- *Phase 1 – Preliminary Study; and*
- *Phase 2 – Feasibility Study.*

The purpose of this study is not to repeat or restate the research and analyses undertaken on the several key previous studies described below, but to make use of that information previously collected, to update and add to this information, and to undertake more focussed and detailed investigations and feasibility level analyses on the dam site options that have then been identified as being the most promising and cost beneficial.

PURPOSE OF REPORT

This report summarises the processes and tasks undertaken, findings and recommendations of the Preliminary Study phase which was undertaken before the main Feasibility Study. This followed the Inception Period, for which a separate report number P WMA 12/T30/00/5212/1 has been produced.

This report covers the two stages of this first phase, namely:

- *Stage 1: Desktop Study; and*
- *Stage 2: Preliminary Study.*

DESKTOP STUDY

The objective of the Desktop Study stage was to review available data and information from previous studies undertaken on the Mzimvubu River catchment, and, using this existing information at desktop level, to recommend the three best dam development projects within the study area.

The selection was to be based upon, but not limited to, water requirements, environmental impact, social impact, hydrology, technical evaluation and stakeholder consultation.

The following key previous studies were the main reference documents used in the selection of the three best dam development options:

- *Republic of Transkei Mzimvubu Basin Development: 1987;*
- *DWA Assessment of the Ultimate Potential Future Marginal;*
- *Cost of Water Resources in South Africa, 2010;*
- *DWA Water Resources Study to assist ASGISA-EC: 2010 (BKS); and*
- *ASGISA-EC Business Case for Water Related Opportunities – 2010 (Ingerop).*

The DWA Water Resources Study of 2010 to assist ASGISA-EC was undertaken at a conceptual/desktop level and identified 19 possible dam sites throughout the Mzimvubu River catchment. Each dam assessed in terms of its use for hydropower, irrigation, domestic water supply, inter catchment transfer and overall economic stimulus.

Following this study an additional study was undertaken by Ingerop, called the ASGISA-EC Business Case for Water Related Opportunities – 2010. This report, also undertaken at conceptual level, looked at the same 19 dam sites plus one additional site (Tsitsa Dam Site) and undertook a dam site screening process based on a set of criteria that included the following:

- *Capex / MW produced;*
- *Agriculture potential (irrigation);*
- *Forestry potential;*
- *Population;*
- *Accessibility / proximity to main transport infrastructure; and*
- *Potential use of dams in long term water transfer schemes.*

Based on these criteria the two highest ranked dams were taken forward into a Business Case Study. These two sites were the Ntabelanga and Tsitsa Falls/Laleni Sites.

The desktop work undertaken and the 19 dam sites identified in these studies formed the departure point for this current Mzimvubu Water Project. These 19 sites are listed in the Table ES-1 and are shown in Figure ES-1.

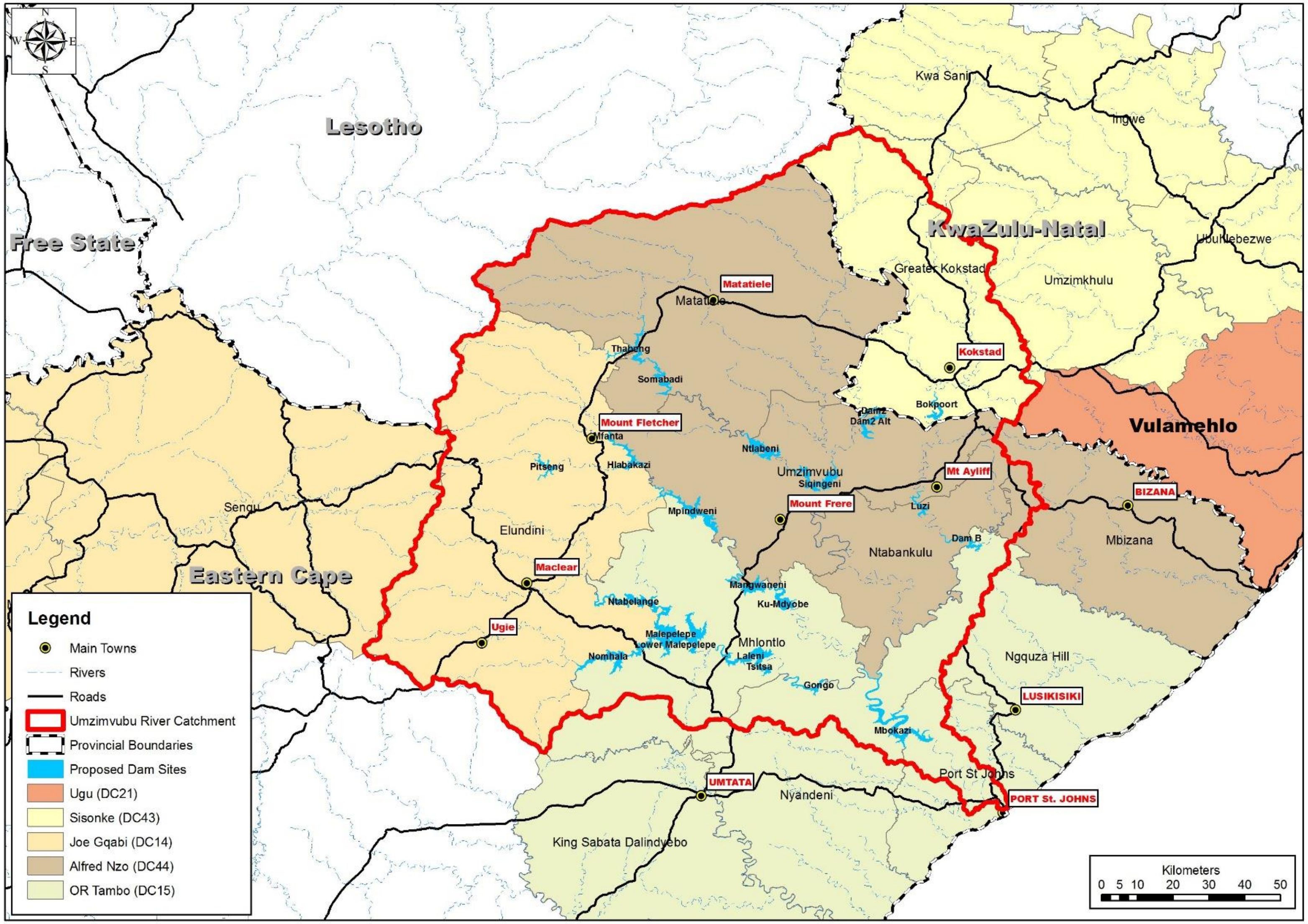


Figure ES-1: Mzimvubu River Catchment Showing Initially Identified 19 Dam Sites

Table ES-1: List of 19 Potential Dam Development Options

Catchment	River	Dam Name
T31	*Upper Mzimvubu*	*Dam 2*
		Siqingeni
T32	*Mzintlava*	*Bokpoort*
		Luzi
		Dam B
T33	*Kinira*	*Thabeng*
		Somabadi
		Ntlabeni
T34	*Tina*	*Pitseng*
		Hlabakazi
		Mpindweni
		Mangwaneni
		Ku-Mdyobe
T35	*Itsitsa*	*Nomhala*
		Ntabelanga
		Malepelepe
		Laleni
		Gongo
T36	*Mzimvubu*	*Mobokazi*

DAM SITE SCREENING AND SELECTION PROCESS

Several selection criteria were proposed to facilitate the selection of the three most suitable dam sites for further investigation. These criteria covered technical, economic, social and environmental considerations.

The criteria used are listed below:

- *Technical and Economic Considerations*
  - *Yield;*
  - *Capital cost;*
  - *Unit Reference Value (URV) of water produced;*
  - *Accessibility;*
  - *Hydropower potential (capex/MW);*
  - *Sedimentation; and*
  - *Forestry potential.*

- *Environmental and Social Considerations*
  - *Potential for irrigated agriculture;*
  - *Potential for domestic water supply;*
  - *Environmental impacts; and*
  - *Job creation.*

The potential for the proposed development options (dams) to provide water for inter-catchment transfers (i.e. augmentation of the Orange and Vaal River Systems) was considered. However the study entitled "Assessment of the Ultimate Potential Future Marginal Cost of Water Resources in South Africa, 2010", undertaken by DWA, clearly indicated that the use of water from the Mzimvubu River for this purpose is very expensive and highly unlikely. On this basis it was deemed pertinent to not include this as a selection criterion for the proposed development of a multi-purpose storage structure on the Mzimvubu River.

The above criteria were work-shopped at Project Steering Committee (PSC) and at regional stakeholder level, and values derived from the above repots and from additional desktop analyses were allocated to each of the 19 potential dam site developments to provide scored rankings of the development options. These additional analyses included an Environmental Screening process for which the findings are provided in separate DWA Report Number P WMA 12/T30/00/5212/2.

The multi-criteria decision making process produced a shortlist of the seven highest ranked dam options taking into consideration what were considered to be the most important criteria.

A summary of the rankings of these seven dam sites against the eight agreed key decision criteria is provided in Table ES-2, with locations indicated in Figure ES-2. (I.E. white squares are best ranked)

Table ES-2: Summary of Seven Selected Dam Sites as an Output from the Screening Workshop

			Medium Impact 2 Medium Cost Medium Potential	High Impact 3 High Cost Low Potential	Very High Impact 4 Very High Cost Very Low Potential	I.E.: 1. Most Favourable 2. Moderately favourable 3. Not favoured 4. Very unfavourable				
Option	**Proposed Dams**	**Rivers**	**Capital Cost (excl. distribution and Access**	**URV of Water Produced (R/m3)**	**Accessibility**	**Hydropower Potential**	**Potential for Irrigated Agriculture**	**Domestic Water Supply Potential**	**Environmental Impacts**	**Job Creation**
6	Thabeng	Kinira	2	2	4	3	1	2	1	1
7	Somabadi	Kinira	3	2	4	2	1	2	2	1
11	Mpindweni	Tina	2	2	2	2	4	2	2	3
14	Nomhala	Tsitsa (Inxu River)	2	3	2	3	2	2	4	2
15	Ntabelanga	Tsitsa	1	1	2	1	1	1	2	1
17	Laleni	Tsitsa	4	2	2	1	4	1	4	3
19	Mbokazi	Lower Mzimvubu	4	1	4	1	4	4	4	3

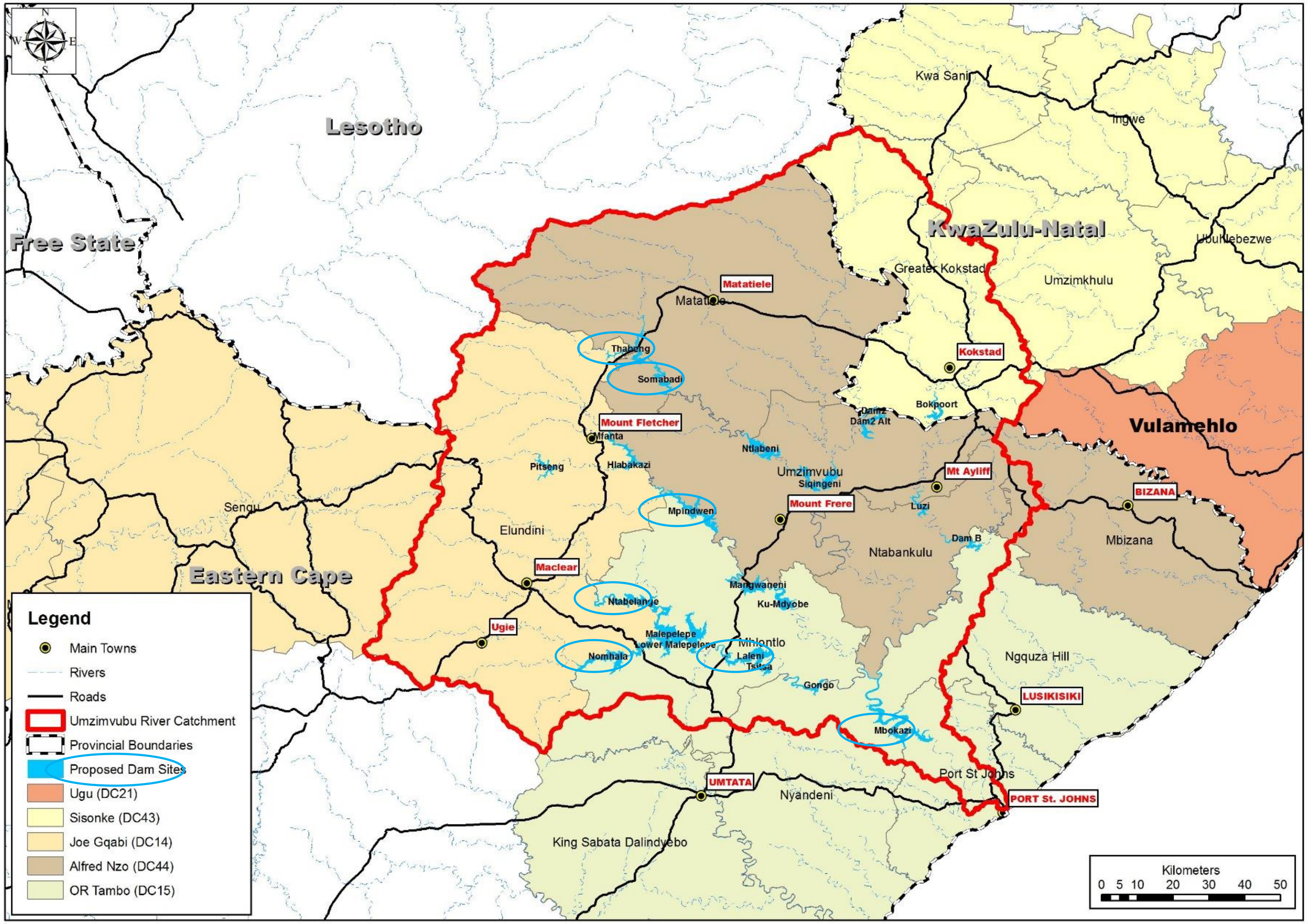


Figure ES-2: Mzimvubu River Catchment Showing Shortlisted 7 Dam Sites

Following a further screening process to take into account, inter alia, strategic development issues along the coastal N2 corridor, and the potential usage of the Tsita River for hydropower development, it was determined and agreed that the highest ranked three dams would be taken forward for further investigation.

These were:

- *Ntabelanga dam on the Tsitsa River (tributary of the main Mzimvubu River);*
- *Thabeng dam on the Kinira River (tributary of the main Mzimvubu River); and*
- *Somabadi dam on the Kinira River (tributary of the main Mzimvubu River).*

The locations of these three dams are shown in Figure ES-3.

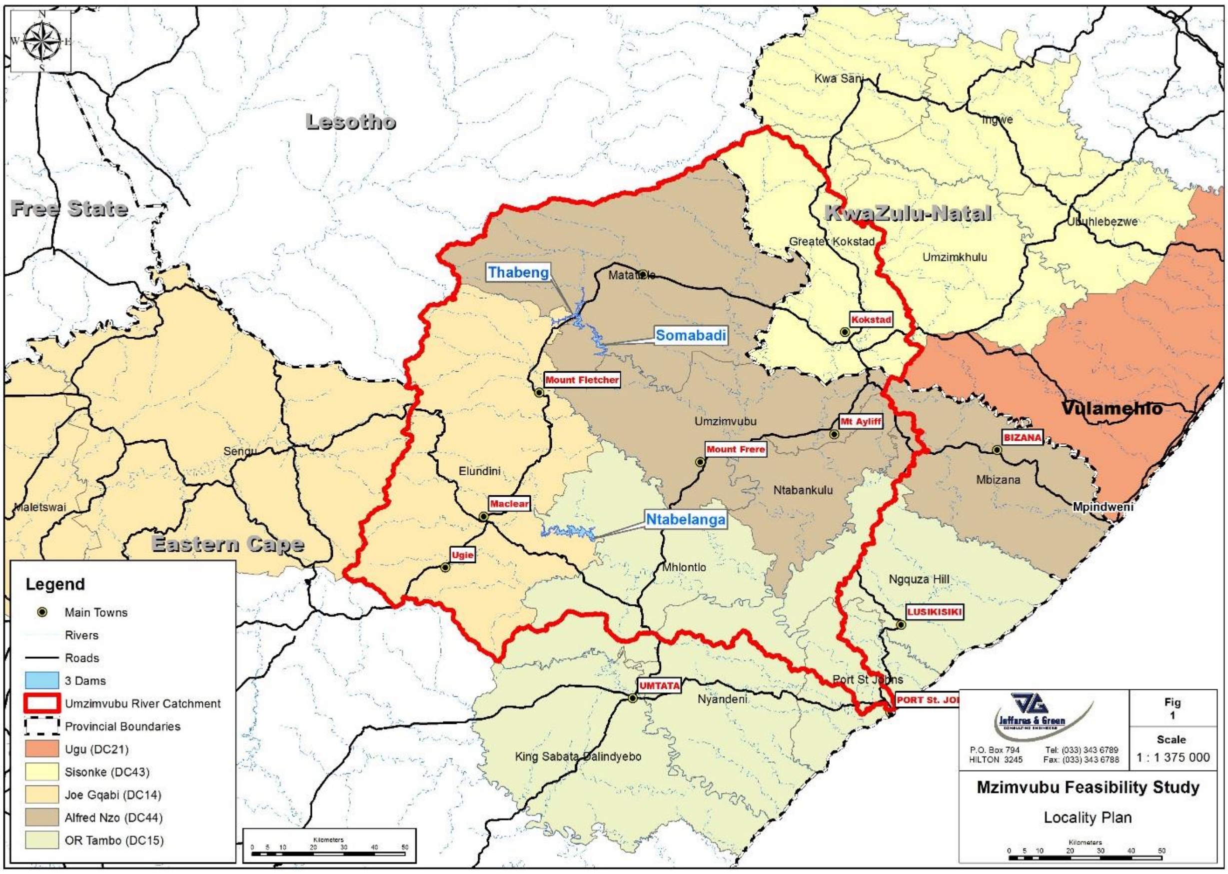


Figure ES-3: Locations of Final Three Dam Sites

PRELIMINARY STUDY

The focus of this second stage of Phase 1 of the study was to gather more information concerning the three selected potential dam development projects, as well as to involve the Eastern Cape Provincial Government and key stakeholders in the process of selecting the single best dam development scheme to be taken forward into the next, feasibility phase, of the study.

The main activities undertaken, inter alia, were as follows:

- *Stakeholder involvement;*
- *Environmental screening;*
- *Water requirements (including domestic water supply, irrigation and hydropower);*
- *Hydrological investigations;*
- *Geotechnical investigations;*
- *Topographical survey investigations;*

- *Selection process; and*
- *Reporting.*

As described in the Inception Report (DWA Report Number P WMA 12/T30/00/5212/1), it was decided to change the original approach and to undertake some advance core drilling beneath each embankment wall flank of all three shortlisted dam sites, as well as topographical surveys of the impoundment areas and all three dams, in order to improve the accuracy of information required to estimate costs and to check for any fatal flaws regarding dam wall foundation conditions.

For the same reasons, the water resources yield assessment task (detailed hydrology and WRYM yield modelling) was also advanced to Phase 1 and was also undertaken for all three dams instead of being applied only to one dam in Phase 2 as was originally planned.

The Inception Period and the Desk Top Study period were also used to investigate further sources of data, and to obtain, collate and review such data to be considered during the Desktop Study and to be utilized where appropriate in the Preliminary Study analyses.

Many organisations from different sectors were contacted in order obtain information related to previous investigations as well as to obtain other relevant information that would be useful for the analyses to be undertaken.

The types of information collected from the various organisations were as follows:

- *Spatial data sets relating to water services planning, population, agricultural potential and existing infrastructure;*
- *Previous related studies undertaken in the Mzimvubu River catchment including obtaining reports and hydrological and financial models;*
- *Climatological, streamflow and rainfall data.*

This information was supplemented by fieldwork where it was considered necessary to improve the reliability of the preliminary analyses.

ENVIRONMENTAL SCREENING

A separate report, DWA Report Number P WMA 12/T30/00/5212/2, describes the methodology and findings of the Environmental Screening process undertaken for the 19 site screening process and the second stage preliminary study screening of three sites.

The initially identified 19 potential dam sites underwent a selection process based on ecological and environmental considerations.

A suite of tools was used to determine the potential impacts of each of the proposed dams on the rivers concerned. Sites were assessed in terms of:

- *The Present Ecological State (PES) of the river;*
- *The Ecological Importance and Sensitivity (EIS) of the river;*
- *The National Freshwater Ecosystem Priority Area (NFEPA) status of the river;*
- *The NFEPA status of the wetlands in the system;*
- *The proximities of the dams to estuaries; and*
- *The conservation status of the vegetation types concerned (based on Mucina and Rutherford).*

This information was work-shopped by members of the environmental team working on the project and was processed and analysed using spreadsheets and GIS software, through the multi-step process described in the report. The same team is also undertaking the Reserve Determination *aspects, and the information gathered during the screening informs that task, which is to be described in report number P WMA 12/T30/00/5212/7 (Phase 2).*

The environmental information can be summarised as follows:

- *Six sites had PES scores that were a "B" or higher;*
- *Nine sites had an EIS of "high";*
- *One site had an estuary in its proximity;*
- *Nine sites were likely to inundate, or were upstream of an NFEPA wetland;*
- *Twelve sites inundated or were upstream of an NFEPA river 1 or 2; and*
- *Thirteen sites would impact vegetation types with conservation statuses of "vulnerable" or higher, of which three were classified as "endangered".*

Whilst none of the 19 potential dam sites were considered to have fatal flaws on account of the potential environmental impacts, some had more severe impact ratings than others, and this was taken into consideration into the multi-criteria decision making process used in the Desktop Study Screening stage described above.

The riverine environmental screening perspective of the three preferred dam sites indicated that Thabeng fell into the lowest environmental and ecological impact category and priority protection area whereas Somabadi and Ntabelanga had higher environmental and ecological impacts and fell into the moderate category of priority protection areas.

The environmental screening task team also considered that at this preliminary stage there were no obvious major fatal flaws regarding the potential impacts of the three shortlisted dams on the estuary, given that:

- *The three selected dam sites are located relatively high up in the Mzimvubu catchment, at significant distances from the estuary mouth; and*
- *The volume of river flow to be abstracted, the interference with the natural flow regime, and the volume of sediment trapped, by each dam, would be relatively small compared with the overall mean annual runoff and sediment transported to the estuary by the Mzimvubu River catchment.*

RESERVE DETERMINATION

The environmental team also undertook analyses of the Reserve requirements of the system and classed the Kinira River at Thabeng and the Somabadi as Class C and the Tsitsa River at Ntabelanga as Class D for Ecological Water Requirements (EWR) determination purposes. This has been converted into a EWR quantity of water per annum to be released downstream of each of the three selected dams.

These EWR values were then built into the yield modelling as demands on the system to be drawn before other water requirements are applied.

TOPOGRAPHICAL SURVEY

Existing topographical information was limited to 1:50 000 mapping with contours at 20m intervals. A land survey sub-contractor was procured using DWA's approved supply chain process.

The topographical survey focussed on the land areas that would be inundated by each of the three dam sites. The survey was undertaken using LiDAR aerial methods which produced high resolution imagery and digital terrain models, the latter having an accuracy of a few centimetres and 0.5 m contour intervals. This enable high accuracy area and depth verses capacity curves to be generated for each dam, as well as accurate cross-sections of the valet where each dam wall was to be located.

GEOTECHNICAL INVESTIGATIONS (DRILLING)

The preliminary geotechnical investigations comprised core drilling of boreholes, each 40 m deep, with one on each flank of each of the three selected dam wall centrelines for the second stage of Phase 1.

A full description of the geotechnical investigations undertaken for both Phases 1 and 2 is to be given in DWA Report Number P WMA 12/T30/00/5212/10 – Geotechnical Investigations, which is a Phase 2 deliverable.

Summary of Preliminary Core Drilling Findings

a) Ntabelanga Dam Site Assessment

The geotechnical reconnaissance assessments and subsequent drilling did not identify any fatal flaws in the context of geological or geotechnical constraints. The site is situated in a steep sided, U-shaped valley with a low length to height ratio. There is good founding on dolerite and construction materials appear to be readily available in the basin within relatively short haulage distances.

On the other hand, the steep valley sides made access to the site difficult for investigation purposes. The left flank a few hundred metres upstream of the dam site shows evidence of past sliding, which could be exacerbated during dam filling.

Whilst this may not represent an overly onerous constraint to overall stability, this will be further assessed should this site be selected for further detailed investigation. The dam would inundate roads and cultivated areas in the basin.

b) Thabeng Dam Site Assessment

The investigations undertaken did not detect any fatal flaws that would preclude the construction of a dam at this site. The valley sides are particularly steep which made access for investigation difficult. The site offers good founding and cut-off conditions, mainly on dolerite and also sedimentary rocks on the left flank.

From the initial assessment undertaken, no good sources of core or rock aggregate were identified in the basin, but these appear to occur in abundance a relatively short distance downstream of the site.

As such areas would not be inundated following completion of the dam, their exploitation would incur more stringent environmental and rehabilitation restrictions. A dam at this site would inundate some major infrastructural developments, including roads, pipelines and a water treatment works.

c) Somabadi Dam Site Assessment

No fatal flaws were identified and there is good founding on sandstone. The site occupies a steep U-shaped valley, which is particularly steep on the right flank.

Construction materials appear to occur in abundance in the basin within relatively short haulage distances of the site.

Vehicular and plant access along the dam axis would be difficult on account of the steep valley sides. The reservoir basin would inundate roads and cultivated areas. The pronounced bedding of the sandstone could lead to increased grout takes.

Further detailed geotechnical investigations will be undertaken in Phase 2.

WATER RESOURCES ANALYSES

Detailed hydrological yield analyses were undertaken for the three potential dam sites. This involved updating flow and rainfall records, as well as investigating the topography and land usage in the catchment areas. This provided up to date data to build, calibrate, and run the (WRYM) yield models for each of the three selected dam sites.

It was noted that the resulting figures for Mean Annual Runoff for all three sites were less than had been provided in previous studies. These new figures have been produced using much more detailed analyses and are considered appropriate for further analyses.

Sedimentation rates in each catchment were also reviewed, taking into consideration the land use information gathered, as well as taking cognisance of the recently updated Rooseboom sediment yield mapping of South Africa. Estimated volumes of sediment trapped by each dam over 50 years were produced for use in the yield modelling.

Following the undertaking of the new topographical surveys, updated depth capacity curves were developed to improve the accuracy of the yield models over those of previous studies.

Yield modelling (based on historical flow series as well as on stochastic flow series) was undertaken for the three dams, using a range of potential dam capacities from 10%, to 150% x MAR. Figures were produced for historical firm yield as well as for various assurances of supply plus sedimentation allowance. A comparison of the yield of each of the three dams or 98% reliability is shown in the Figure ES-4 below.

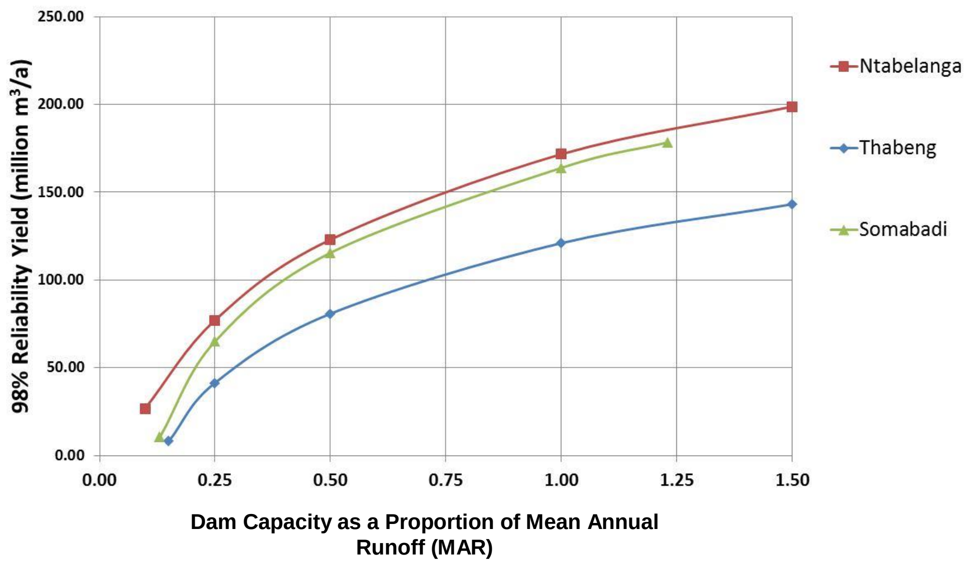


Figure ES-4: Comparison of Yield verses Capacity for the Three Dams

It is evident from Figure ES-5 that for dam capacities greater than 0% of the MAR, the yield curves flatten and topography also becomes a constraint.

Figure ES-5 also shows that the Ntabelanga site would provide the highest Yield verses Capacity characteristic of the three dams. This does not mean that the Ntabelanga would be the best dam per se, as such comparisons should, inter alia, be based on economic aspects including unit cost of water produced.

The raw water requirements were compared with the yields for the range of dam capacities in order to match the dam size to water requirements. The costs of each dam capacity were then used for the determination of the (URV) of raw water produced by each of the various dam options.

The hydropower module of the WRYM model was also used to determine reliable power outputs for each of the dam options investigated.

WATER REQUIREMENTS

This task of the Preliminary Study required the assessment of the water requirements and potential developments for each of the three recommended dam developments at a preliminary level.

This included domestic requirements, irrigation potential, afforestation potential, riverine and estuarine Reserve requirements, as well as hydropower potential.

As with any water source, the cost of developing bulk water supply systems increases with distance from source and with height and topography of terrain. The study area poses all of these difficulties. In order to undertake a comparison of the three potential dam developments on a like-for-like basis, it was decided that the water requirements planning area of each dam should include all communities located within the watershed limits adjacent to and below each dam, and extending downstream to the confluence of each tributary with the main stem of the Mzimvubu River.

DOMESTIC WATER REQUIREMENTS

Two domestic water demand scenarios were investigated:

- *A BASE case supplying only those communities within 180 m above the river; and*
- *A HIGH scenario supplying all communities within the watershed boundary as well as a 15% allowance for supplying addition settlement outside the watershed.*

Information gathered from DWA and the DMs was used to determine the populations to be served and their areal distribution. Per capita consumption and population growth rates were also drawn from the DM's planning criteria to determine overall potable water demands.

Taking all of the above criteria into consideration and applying the same approach to all three dams for comparative analysis purposes, the following raw water demand (on source) projections to the year 2050 were developed.

Table ES-3: Summary of Populations to be Served and Potable Water Demand Projections

	Total Population Served (±2010)		Potable Water Demand (2010)		Potable Water Demand (2050) (1% Growth P.A.)		Add 30% Leakage And Treatment Losses		Add 15% To Serve Adjacent Watershed (High Only)		Total Potable Water Demand	
	Base	High	Base	High	Base	High	Base	High	Base	High	Base	High
			million m^3/a		million m^3/a		million m^3/a		million m^3/a		million m^3/a	
Ntabelanga	**134 633**	**223 686**	**2.95**	**4.90**	**4.39**	**7.30**	**1.32**	**2.19**	**0.00**	**1.42**	**5.71**	**10.91**
Thabeng	**111 564**	**294 784**	**2.44**	**6.46**	**3.64**	**9.62**	**1.09**	**2.89**	**0.00**	**1.88**	**4.73**	**14.38**
Somabadi	**97 303**	**273 743**	**2.13**	**6.00**	**3.17**	**8.93**	**0.95**	**2.68**	**0.00**	**1.74**	**4.13**	**13.35**

Potable: ***Base Case:*** *Population that could be supplied within 180 M altitude above river level*
High Case: *Population within the watershed boundary plus an allowance for over-watershed supply.*

WATER FOR IRRIGATED AGRICULTURE

a) Initial Screening Process
To evaluate the irrigation potential of the three candidate dams it was important to objectively quantify these criteria that would be necessary for the development of a commercially viable irrigation farm.

The three dam sites were evaluated according to these criteria so that they could be objectively ranked at a desktop study level using GIS analysis techniques.

The criteria that were analysed per dam site are as follows:

i. High potential soils.
ii. Slope < 12%.
iii. Elevation < 60m above the river at the dam site, or in the river below the dam site.
iv. Distance < 5km from the dam wall or either side of the river below the dam site.
v. Water deficit – medium to high water on stress (shortage of natural rainfall).

Table ES-4 below shows the resulting areas identified under each category and that 15% of the land area, or 310 400ha, was identified as being in the higher potential soil category..

Table ES-4: Total Areas of Various Soil Potential in Full Mzimvubu Catchment

Soil Potential	***Area identified (ha)***
High	*301 400*
Medium	*884 000*
Low	*795 600*
Total	***1 981 000***

Table ES-5 below shows the areas identified under each category and that 69% of the land area, or 1 370n 876 ha, is identified as having high or medium water stress.

Table ES-5: Areas of Water Stress

Water Stress	***Area identified (ha)***
High	*2 816*
Medium	*1 368 060*
Low	*604 416*
Total	***1 975 272***

The above soil potential and water stress coverages were defined and located using a GIS system, and then further analysed initially to create a BASE water demand scenario. This included filtering of the areas identified using the slope, elevation and distance criteria described in b) and c) above. This was undertaken for all of the original 19 potential dam sites (and some alternative sites) as part of the screening process and the results per dam site are shown in Table ES-6 below.

Table ES-6: Areas of High Potential Agricultural Land Meeting Slope, Proximity and Water Stress Criteria, Per Dam Site

No	Catchment	Total Catchment Agric Land (ha)	Dam	Area (ha)
1	T31	8561	Siqingeni	0
2			Dam2	0
3			Dam2 Alt	0
4	T32	957	Dam B	0
5			Bokpoort	0
6			Luzi	0
7	T33	22647	Ntlabeni	0
8			***Somabadi***	***1261***
9			***Thabeng***	***1553***
10	T34	31976	Mangwaneni	0
11			Ku-Mdyobe	0
12			Mfanta	0
13			Mpindweni	0
14			Hlabakazi	0
15			***Pitseng***	***1476***
16	T35	57953	***Ntabelanga***	***1247***
17			***Nomhala***	***747***
18			Malepelepe	22
19			Lower Malepelepe	22
20			Laleni	0
21			Tsitsa	0
22			Gongo	0
23	T36	0	Mbokazi	0

As shown only five dams would have any appreciable land areas that would meet the identified criteria, these being Somabadi, Thabeng, Pitseng, Ntabelanga and Nomhala.

*When combined with other non-agricultural criteria in a ranking matrix, the three highest ranked dams that emerged for further consideration and study were **Somabadi, Thabeng, and Ntabelanga**. This coincidentally reinforced the decision made to shortlist these three particular dams.*
b) Further Ground-Truthing of Three Dam Sites
With three candidate sites needing to be narrowed down to a single site, further study on the three identified sites was required. It was also important that ground-truthing of the desktop information took place, to ensure that decisions in Phase 1 were being made on reliable and accurate information.

A site visit was organised to physically assess the identified lands from an agricultural perspective, and to correlate physical observations with the desktop mapping. All three dam sites were visited, particularly the potentially irrigable lands identified as meeting the criteria discussed above.

The blocks of land were critically assessed to remove disparate blocks, or small irregular blocks far from the main blocks of identified land. Each theoretical area therefore was modified to some extent prior to the visit. The final areas assessed per dam were shown in Table ES-7.

Table ES-7: Theoretical Areas of High Potential Agricultural Land Relative to Each Dam Site Subject to Site Visit

Dam Site	High Potential Area identified (ha)
Ntabelanga	840
Somabadi	1 327
Thabeng	1 621

c) Some Suitable Crops and Expected Yields

Based on mean annual temperature, frost occurrence, soil types and soil properties, and assuming a medium level of irrigation management input, a variety of possible crops recommended for irrigation are presented in Table ES-8.

Table ES-8: Some Suitable Crops and Estimated Yields for Irrigation Classes III and IV.

Crop	Uses	Suitability	Expected Yield
Cabbage	Food	Moderate	50 tons/ha
Carrot	Food	High	35 tons/ha
Green Bean	Food	High	8 tons/ha
Italian Ryegrass	Nutritious grazing	High	15 tons/ha
Lettuce	Food	Moderate	20 tons/ha
Lucerne	Fodder crop	Moderate	18 tons/ha
Lupin	Forage	High	3 tons/ha
Maize	Grain	Moderate	8 tons/ha
Oats	Winter grazing or green feed	High	7 tons/ha
Onion	Food	High	25 tons/ha
Pecan	Nuts	Moderate	140 Kg/tree
Potato	Food	High	60 tons/ha
Soya bean	Food, oil seed, animal feed	Moderate	3 tons/ha
Spinach	Food	High	25 tons/ha
Tomato	Food	Moderate	35 tons/ha

d) Conclusions from Initial Screening Process

The initial screening process or basic case studies described above identified 504 hectares of land having good irrigation capability at Ntabelanga which is confirmed for irrigation out of the three study areas. However, limitations to irrigation here are restricted extent (hectares) for an irrigation scheme. In addition the area appears to be segmented by wetlands resulting in irrigable areas that are not contiguous.

Somabadi has 1,062 ha of land suitable for irrigation that is fairly contiguous, but has only moderate to good irrigation capability with slightly reduced growth rates for most crops. The area at Thabeng is the same as that at Somabadi plus low lying land, however a greater proportion of the land is suitable for irrigation.

Based on the above, Ntabelanga would be the first choice as an option for irrigation development provided that additional suitable land for the irrigation development can be found adjacent to the current study area. A more detailed soil survey is to be undertaken in Phase 2 together with soil salinity/sodicity/fertility testing, before a final decision is taken.

These conclusions represent a ***BASE*** *water demand scenario, with both distance from the river and elevation above river level significantly affecting the results. Whilst these latter two criteria were used to ensure that the cost of pumping and transferring water from the river were given a high weighting, these criteria significantly limit the areas thus identified.*

Further analyses were therefore undertaken to investigate the case where the development of irrigated agriculture is considered as a means to creating jobs and stimulating the local economy and social upliftment, which approach often considers more than just the pure economics of crop production. For this reason, a ***HIGH*** *water demand scenario was also investigated, focussing on the three shortlisted dam sites.*

e) HIGH Irrigation Water Demand Scenario

The investigations undertaken in Phase 1 identified land areas which could have viable potential for irrigated agriculture. The BASE case criteria used to "home in" on these areas included suitable soil types and depths, terrain slopes being <12%, rainfall being less than sufficient for high yield crop production, pumping head from the river being <60 m, and distance from the river being < 5 km.

Fieldwork was undertaken to ground-truth the soils thus identified. This was in the form of site visits and some auger holes to sample the various soil types and layer thicknesses.

The BASE case studies resulted in potential areas for irrigated agriculture in the three dam supply areas, 504 hectares for Ntabelanga and 1,062 hectares for both Thabeng and Somabadi as described in a) and d) above.

For the HIGH demand scenario, the criteria for identifying potential areas suitable for irrigated agriculture in each dam supply zone were relaxed, in that both the distance from the river, and the limitation on pumping head were not considered.

This resulted in much larger areas of potentially irrigable land being identified, as follows:

- *Ntabelanga: 10 536 ha*
- *Thabeng: 8 800 ha*
- *Somabadi: 7 733 ha*

Given that these larger areas were identified via a GIS modelling exercise and without detailed ground-truthing, it was decided that it would be prudent to reduce these areas by 75% as advised by the agricultural experts from their experience.

This is considered to be a conservative but acceptable approach purely for dam site comparison purposes at this Phase 1 stage but will again be revisited in much more detail in Phase 2 when more extensive ground-truthing and soil sampling will be undertaken to identify the maximum areas that could potentially be irrigated.

In developing irrigation water demand projections for the identified areas were based on those shown in Figure ES-8, the application rates for the different potential crop types.

Table ES-9: Approximate Water Needs of Various Crop Types

Application Rate	Grains	Fodder	Winter Veg	Summer Veg
(mm/annum)*	260-300	250-400	300-350	240-360

***The above application rates are extra-over natural rainfall.*

As the crops that might be grown are unknown for the purposes of comparison of the three dams, a standard application rate of 350 mm/a, was used to calculate the water requirements for irrigation for the three dam site supply areas.

A further 20% was added to the overall irrigation water demand projections to allow for losses and over-application. It is possible application rates and losses might be higher. In Phase 2, the irrigation efficiencies and differences in acceptable levels of assurance of supply between potable and irrigation water will be analysed to a much higher level of detail.

Applying the criteria described above to the three dam supply areas, the total irrigation water demand projections for the BASE and HIGH scenarios would be as shown in Table ES-10.

Table ES-10: Irrigation Water Requirements Used for Comparative Analyses

	Summary: Estimation Of Irrigation Water Requirements					Potential Irrigation Water Requirement	
	Irrigatable Land (ha)			Typical Irrigation Rate (mm/a)		Base	High
	Limit Pumping Head & Distance from River	Area Identified when no Limits Applied	No Limits Applied, but 25% considered viable			million m^3/a	
Ntabelanga	504	10 536	2 634	350	+20% losses>	2.12	11.06
Thabeng	1 062	8 800	2 200	350	+20% losses>	4.46	9.24
Somabadi	1 062	7 733	1 933	350	+20% losses>	4.46	8.12

Combined Water Demand Projections

In order to determine and compare the dam sizes and safe yields required for each option, the following total raw water demand projections to the year 2050 were used:

Table ES-10: Combined Water Requirements Used for Comparative Analyses

	Total Potable Water Demand		Irrigation Water Demand (incl 20% Losses)		Grand Total Water Demand	
	Base	High	Base	High	Base	High
	million m^3/a		million m^3/a		million m^3/a	
Ntabelanga	5.71	10.91	2.12	11.06	7.83	21.97
Thabeng	4.73	14.38	4.46	9.24	9.19	23.62
Somabadi	4.13	13.35	4.46	8.12	8.59	21.47

COMPARISON OF WATER REQUIREMENTS WITH DAM SIZE REQUIRED

In all three cases, the sizing of each dam having sufficient capacity to contain to the 50 year sedimentation accumulation volume, as well as supplying the HIGH scenario water requirements, and the EWR requirements, was relatively small at 10%, 20% and 15% of MAR for Ntabelanga, Thabeng and Somabadi dams respectively. This does not take into account any additional capacity requirement for hydropower generation however.

This is shown in Table ES-12.

Table ES-12: Size Statistics on the Three Dams

	Grand Total Water Demand		98% Reliable Dam Yield	EWR	Dam Size (Gross Volume Including Sediment Allowance)		Dam FSL Water Depth	Estimated Cont. Hydropower That Can Be Generated		Estimated Max Pumping Power Needed	
	Base	High	million m3/a	million m3/a	MAR x	million m3	m	Base	High	Base	High
	million m^3/a							MW	MW	MW	MW
Ntabelanga	7.83	21.97	26.80	52.82	0.10	33.00	31.00	0.27	0.27	0.61	1.71
Thabeng	9.19	23.62	24.80	84.33	0.20	58.00	33.00	0.35	0.35	0.72	1.84
Somabadi	8.59	21.47	21.32	104.98	0.15	54.15	44.53	0.40	0.40	0.67	1.67

Shows that each "minimum" sized dam can reliably supply HIGH scenario demand as well as meeting EWR requirements

HYDROPOWER POTENTIAL

A check was undertaken on each dam to ascertain the amount of reliable (continuous) hydropower that could be generated if a hydropower station were to be built immediately downstream of, or within, each dam wall, with average dam yield released through the turbines at 67% of the maximum head of the dam water depth

The figures in Table ES-12 above show that, for the "minimum"-sized dams, this output would range from 0.27 to 0.40 MW for the three dams.

Estimations were also made as to how much power would be required to transfer and treat the raw water and to pump potable water into the systems served by each dam.

Whilst at this desk-top level this can only be a very approximate estimate, the power requirements for these bulk water supply systems totalled between 0.61 to 0.72 MW for the BASE demand case, to 1.67 to 1.84 MW for the HIGH scenario.

Clearly the requirements for a self-sufficient "hydro-powered" scheme would not be met by these "minimum" dam sizes.

An analysis was therefore also undertaken to determine how much larger/higher the three dams would need to be built to generate the maximum power requirements given above.

The incremental costs of raising the dam walls and installing hydropower plants for this latter set of scenarios was calculated and included in the economic analyses described below.

ECONOMIC COMPARISON OF THE THREE DAM SITE OPTIONS

For each of the options described above, capital cost estimates were prepared so that a discounted cash flow analysis could be undertaken to compare the Unit Reference Values (URV[1]) of water supplied by each of the three dams. The capital cost of the dams were based on current rates for earthfill embankment dams with spillways on a flank.

[1] *URV is the Net Present Value of Capital and O&M costs over the lifespan of the scheme divided by the Net Present Value of raw water supplied over the same lifespan, and is expressed as Rand/m^3*

Calculating the capital costs for the three dams and for the various dam sizes enabled "costing curve" to be produced for the given ranges of dam sizes, which were converted into a dam volume versus cost lookup tables for the economic analysis models.

These dam costing curves are shown in Figure ES-5 below.

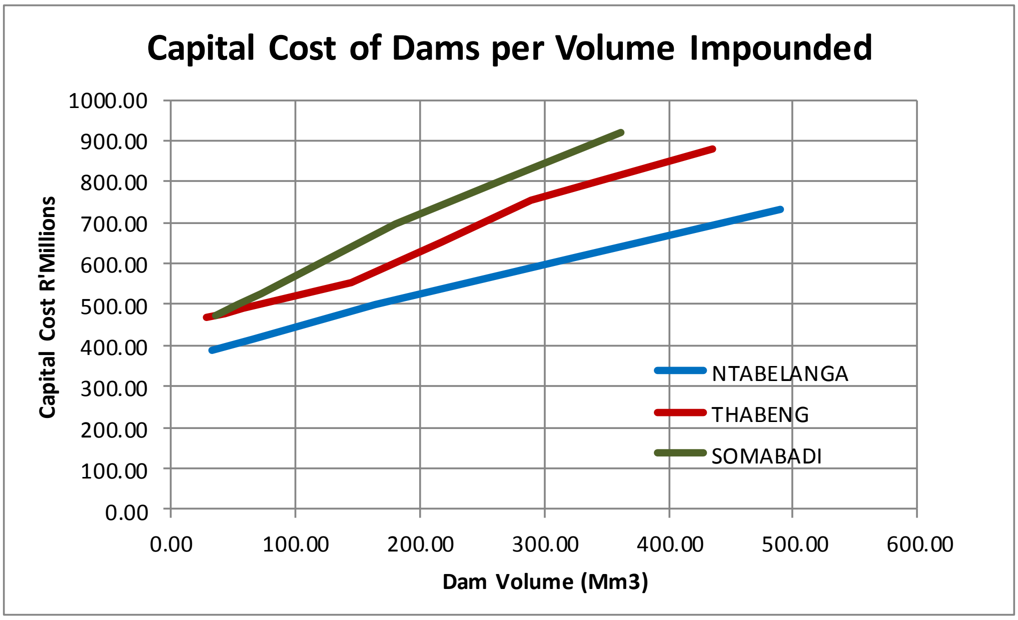


Figure ES-5: Dam Capital Cost Curves

The above chart illustrates that the Ntabelanga dam would have a lower capital cost per million m^3 stored than the other two dam options.

Similar costings were derived for the capital costs of hydropower plant and associated infrastructure using various sources, including the ESKOM Eastern Cape Hydropower Options Report of 2004, costings undertaken by BKS in the 2010 Mzimvubu Report, and with some cross-checking by requesting new budget quotations from suppliers[2]. These were also based on April 2013 price levels. The future price of electricity in terms of 2013 prices were assumed to be R1 000/MWh.

OPTIONS FOR WATER SUPPLY PURPOSES ONLY

Scenarios were investigated firstly for dams to supply raw water only to meet the above range of potable and irrigation demands, with no hydropower component.

For these water supply only options, the resulting URVs are shown in Table ES-13 for the BASE and HIGH demand scenarios.

[2] *(NB: In the case of the Laleni/Tsitsa falls option described below, tunnelling unit costs were derived from previous tunnel estimating studies undertaken by Hatch/Mott MacDonald, as well as the figures used in the 2010 BKS Report, all updated for price escalation to April 2013.)*

Table ES-13: Summary of "Water Supply Only" Options

	Ntabelanga	Thabeng	Somabadi
Minimum Dam Size (MAR x)	0.10	0.20	0.15
Sufficient for HIGH Demand Scenario?	Yes	Yes	Yes
Dam Volume (million m^3)	33.00	58.00	54.15
Dam Wall Height (m)	38.00	40.00	51.53
98% Reliable Yield Available (million m^3/yr)	26.80	24.80	21.32
BASE Raw Water Demand (million m^3/yr)	7.83	9.19	8.59
HIGH Raw Water Demand (million m^3/yr)	21.97	23.62	21.47
	URVs of Raw Water Supplied*		
	R/m^3	**R/m^3**	**R/m^3**
BASE Demand Scenario	6.79	8.58	7.34
HIGH Demand Scenario	2.37	2.99	2.88

** At 8% discount rate*

As can be seen in the above table:

a) Ntabelanga Dam has the lowest URV of water supplied
b) URVs for the BASE demand scenario are high for all dams

OPTIONS FOR SELF-SUFFICIENCY IN HYDROPOWER

In addition to the water-supply only case above, further analyses were undertaken to investigate the incremental cost of upsizing these three dam options so that the dams and the water delivery infrastructure supplied by them could be self-sufficient in energy requirements from hydropower generation at each dam.

In this case, the "minimum size" of each dam, which would have been sufficient for water supply purposes only, needed to be increased in size so that sufficient reliable yield and head would be available to generate the amount of power required.

When undertaking economic analyses of power supply schemes a similar approach was taken to the URV analysis undertaken for water schemes. The difference is that instead of URV, the "Levelized Cost of Energy" was calculated, which is the Net Present Value of Capital and O&M costs over the lifespan of the scheme divided by the Net Present Value of energy supplied over the same lifespan, expressed as Rand/MWh.

Given that water supply is the basic reason for constructing these dams, only the incremental costs over the base costs of the minimum size dam were used to calculate the Levelized Cost of Energy produced by raising each dam and installing the necessary hydropower generation and distribution infrastructure. As with the URV calculation, an 8% discount rate was used.

Table ES-14 below summarizes the results of this analysis.

Table ES-14: Summary of Incremental Costs to Produce Hydropower Self-Sufficiency

	Power Supply to Base Demand Scenario Infrastructure		
	Ntabelanga	**Thabeng**	**Somabadi**
Dam Size With Hydropower (MAR x)	0.45	0.70	0.23
98% Reliable Yield Available (million m^3/yr)	114	97	54
Water Supply Only Dam Cost (R'million)	386	489	500
Incremental Costs for Hydropower (R'million)	219	278	270
	Levelized Cost of Power Produced*		
	R/MWh	**R/MWh**	**R/MWh**
BASE demand case	4 334	4 690	4 917

** At 8% discount rate*

	Power Supply to High Demand Scenario Infrastructure		
	Ntabelanga	**Thabeng**	**Somabadi**
Dam Size With Hydropower (MAR x)	1.50	1.50	1.00
98% Reliable Yield Available (million m^3/yr)	199	143	164
Water Supply Only Dam Cost (R'million)	386	489	500
Incremental Costs for Hydropower (R'million)	474	534	656
	Levelized Cost of Power Produced*		
	R/MWh	**R/MWh**	**R/MWh**
BASE demand case	3 245	3 418	4 777

** At 8% discount rate*

Costs are at 2013 prices, excluding engineering and EIA costs and VAT

As can be seen above, the levelized cost of power thus produced is in the range of R 3 245/MWh to R 4 917/MWh, which is very high considering that current bench marking of what are considered to be viable schemes is normally at the R 1 000/MWh level.

It was therefore not considered to be a viable option to include hydropower generation if only a single "minimum-sized" dam solution is selected for further consideration in Phase 2 of this study.

OTHER CONSIDERATIONS FOR THE SELECTION OF A SINGLE DAM SITE

Other criteria were also used to compare the three dams, some of which were not considered to be pertinent in such decision making, whereas for others the impacts were similar for all three dams.

The more significant criteria included:

i. *Populations Served;*
ii. *Land Requirements;*
iii. *Irrigation Opportunities;*
iv. *Job Creation Opportunities;*
v. *Impacts on Existing Infrastructure;*
vi. *Other Regional Water Supply Schemes Existing or Planned; and*
vii. *Able to Work Conjunctively with Other Major Schemes.*

SUMMARY OF ANALYSES AND DECISION MAKING CRITERIA

The "traffic light" colour coding method used in the tables below shows the simple ranking of the economic criteria between the three dams. No differential weighting was applied to these criteria as this requires qualitative rather than quantitive analysis to be undertaken, which might artificially skew results.

Table ES-15: Comparison of Dams by Numerical & Economics Analyses – Base Demand Case

BASE CASE CRITERIA			
Numbers and Economics	**Ntabelanga**	**Thabeng**	**Somabadi**
Population Served for this Scenario	134 633	111 564	97 303
Total Population within 50 Km of Dam	223 686	94 666	116 337
Irrigatable Areas within Limits Set (Ha)	504	1062	1062
Cost of Dam for Water Supply only (R'million)	386	489	500
Total Demand Supplied (Million M^3/A)	7.83	9.19	8.59
Total Water Available @ 98% (Million M^3/A) (Minimum Dam)	26.80	24.80	21.32
URV of Raw Water Supplied (No Hydropower) (R/M^3)	6.79	8.58	7.34
Is the above Dam Self-Sufficient for Hydropower?	No	No	No
Incremental cost of Raising Dam & Hydro-Plant (R'million)	219	278	270
Levelized cost of Energy Produced by Raising Dam (R/MWh)	4 334	4 690	4 917

Table ES-16: Comparison of Dams by Numerical & Economics Analyses – High Demand Case

HIGH CASE CRITERIA			
Numbers and Economics	**Ntabelanga**	**Thabeng**	**Somabadi**
Population Served For This Scenario	223 686	294 784	273 743
Total Population Within 50 Km Of Dam	223 686	94 666	116 337
Irrigatable Areas within Limits Set (Ha)	2 634	2 200	1 933
Cost of Dam for Water Supply only (R'million)	386	489	500
Total Demand Supplied (Million M^3/A)	21.97	23.62	21.47
Total Water Available @ 98% (Million M^3/A) (Minimum Dam)	26.80	24.80	21.32
URV of Raw Water Supplied (No Hydropower) (R/M^3)	2.37	2.99	2.88
Is the above Dam Self-Sufficient for Hydropower?	No	No	No
Incremental cost of Raising Dam & Hydro-Plant (R'million)	474	534	656
Levelized cost of Energy Produced by Raising Dam (R/MWh)	3 245	3 418	4 777

The other criteria evaluated for each dam and ranked in a similar manner are listed below.

Table ES-17: Comparison of Dams Based on Other Criteria – Both Demand Cases

Other Criteria (Environmental/Resettlement, Jobs, Etc)	***Ntabelanga***	***Thabeng***	***Somabadi***
Area of Land Inundated (Km^2) – No Hydropower	***7.5***	***7.8***	***5.8***
Impacts Existing Nat'l Road and Other Infrastructure?	***Lower***	***High***	***Moderate***
Other Regional Schemes & Sources Existing/Planned?	***Yes***	***Yes***	***Yes***
Able to Work Conjunctively with Other Major Schemes?	***Yes***	***No***	***No***
Sanbi Ecosystem Risk Assessment Results (Catchments)	***Lower***	***Higher***	***Higher***
Job Creation (Estimated Nos. Incl. Catchment Mang't)			
Temporary During Construction	***200 to 300***	***200 to 300***	***200 to 300***
Permanent Ws Operational Staff	***30 to 50***	***30 to 50***	***30 to 50***
Permanent on Irrigated Agriculture Schemes (Base Case)	***50***	***106***	***106***
Permanent on Irrigated Agriculture Schemes (High Case)	***263***	***220***	***193***

Whilst these other criteria show close rankings between the three dams, Ntabelanga in general scored more green and amber than the other two dams, and the significance of Ntabelanga being the only scheme able to work conjunctively with the potential Laleni hydropower scheme made it particularly stand out above the other two dams.

ADDITIONAL ALTERNATIVE OPTION FOR NTABELANGA DAM

Another major option that was identified during the Phase 1 investigations is the potential to operate the Ntabelanga dam conjunctively with a hydropower scheme downstream on the same river, comprising a new dam at Laleni, located close to and above the Tsitsa Falls. This latter scheme (using Laleni dam only) was identified as a best option of many investigated by ESKOM in their Eastern Cape study dated 2004.

This additional conjunctive use option was discussed by DWA and ESKOM at a meeting held on 25 January 2013. The Department of Energy were also informed and are considering information that has been sent to them by DWA.

Preliminary analyses undertaken to date, indicates that there could be economies of scale and other cost-benefits in constructing a "large" Ntabelanga dam to regulate flow to a hydropower scheme at Laleni dam, hydropower tunnel and powerhouse.

The general arrangement of this conjunctive usage scheme is shown in Figures ES-6 and ES-7 overleaf.

Additional hydrological models were therefore included in Phase 1 with the hydropower module of the WRYM model to investigate two options:

a) *A stand-alone Laleni Dam scheme with dam size 0.7 × MAR. This scheme could potentially produce some 27 MW of continuous output (and possibly up to 180 MW peaking power at a load factor of 15%)*
b) *Using a raised Ntabelanga Dam (1.5 × MAR) conjunctively with a small Laleni Dam (0.18 × MAR). This scheme could potentially produce some 25 MW continuous output at Laleni and a further 2 MW continuous at Ntabelanga (again possibly up to 180 MW peaking power at the same load factor)*

.

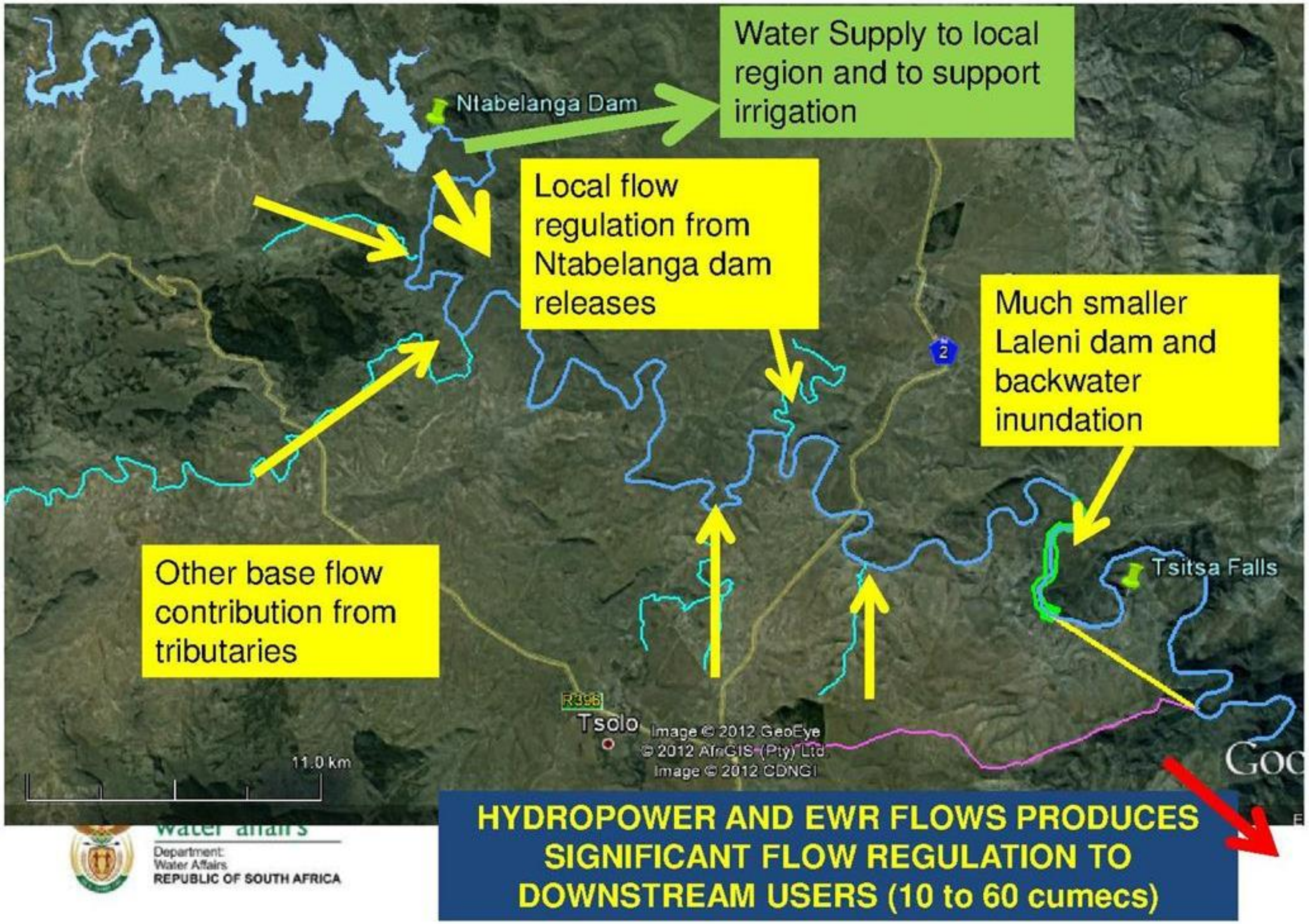


Figure ES-6: General Arrangement of the Potential Conjunctive Use of Ntabelanga and Laleni Dams

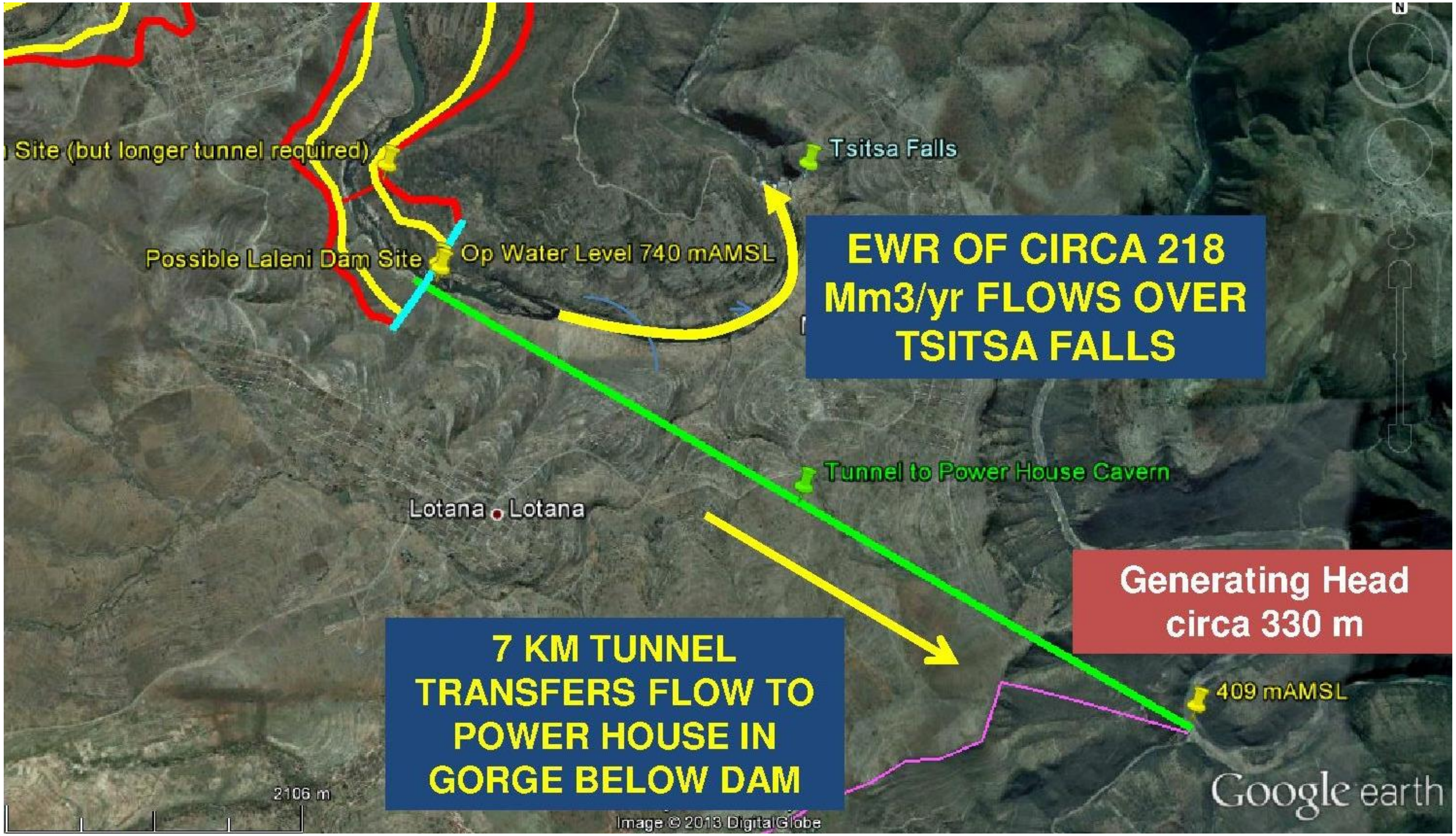


Figure ES-7: General Arrangement of the Potential Hydropower Scheme at Laleni

At this Preliminary Study stage, the above analysis did not take into account the reserve requirements of the river systems downstream of the Ntabelanga and Laleni dams. These requirements will be a significant factor as regards how much water can be diverted through the hydropower plants and returned back to the river in any particular month, and this will be especially pertinent during low flow months, or particularly dry years.

These factors should be taken into account during the more detailed investigations of the conjunctive scheme

High level cost estimations were undertaken, and the incremental cost of implementing the conjunctive scheme b) over and above building the basic Ntabelanga Dam for water supply only were calculated.

Using these incremental costs, the Levelized Cost of Energy produced was calculated at both 15% load factor and 100% (continuous power). The results are shown in Table ES-19:

Table ES-19: Comparison of a Laleni-only Hydropower Scheme with Conjunctive Usage of a Larger Ntabelanga Dam with a Smaller Laleni Dam (Incremental cost of hydropower components only)

Options	Power Output Continuous		Power Output Max		Total Capex at Load Factors:		Levelized Cost of Energy	
	LF:100%	LF:15%	LF:15%	LF:100%	LF:15%	LF:100%	LF:15%	LF:100%
	MW	MW	Rand Millions	Rand Millions	Rand/ MWh	Rand/ MWh	Rand/ MWh	Rand/ MWh
					6% Discount Rate		8% Discount Rate	
a) Laleni only 0.7 MAR Dam	27	180	2 921	2 317	1 143	906	1 490	1 182
b) Laleni 0.18 Dam + Ntabelanga 1.5 MAR Dam	27	180	2 706	2 151	1 043	825	1 361	1 078
			Incremental cost of 27 MW hydropower scheme over water supply only scheme					

Whilst it must be emphasized that this analysis has been undertaken only at a high level at this stage, it indicates that the conjunctive scheme could be built at an incremental cost some 7.5% lower than a stand-alone Laleni hydropower scheme, with the levelized cost of energy produced in the order of ± R 1000/MWh, which is understood to be the benchmark for a viable scheme. (Capital cost estimates for the full conjunctive scheme are given below).

The conjunctive scheme could produce major cost benefits, including potentially significant surplus revenues emanating from energy sales.

The hydropower generation potential of the scheme might also attract private sector interest which could result in a lower requirement for capital financing sourced from the Treasury.

It must be reiterated, however, that this would depend upon the institutional, funding, and operational arrangements developed to implement such a conjunctive scheme, which will be undertaken in Phase 2.

In conclusion, there appears to be merit in further investigating the conjunctive use option as a part of Phase 2 of this study.

CONCLUSIONS & RECOMMENDATIONS

In terms of purely economic comparison of the three dam site options, Ntabelanga is clearly the highest ranked option, having the lowest capital cost and lowest URV for water produced for all configurations considered above.

Having said this, it should be noted that the URV's of raw water produced by all three dams (of "minimum size") are high if only potable and irrigation water requirements are taken into consideration.

Whilst the ranking is less clearly indicated when considering the other impacts described above, the overall conclusion and recommendation based upon the criteria considered above is that the Ntabelanga dam is the best single option to be taken forward into Phase 2 of this study.

The additional benefit that Ntabelanga has over the other two options is that it is well located to operate conjunctively and cost-beneficially with a potential hydropower scheme on the same river.

If such additional use can be realised, then the URV of water produced could reduce accordingly and the economic viability of the dam itself could be realised.

This economic viability and financial sustainability of the selected dam will be investigated in more detail in the Phase 2 study, which will revisit water requirements and existing water infrastructure in much more detail, as well as the cost-benefits of the scheme, including social upliftment, improved services, irrigated agriculture potential, and other job creation opportunities.

Following discussion and consideration of the above findings, the DWA study team concluded that a stand-alone dam at Ntabelanga on the Tsitsa river to supply potable and irrigation water requirements only would be unlikely to be economically viable, but if developed conjunctively with the potential Laleni/Tsitsa falls hydropower scheme, could deliver a viable solution meeting the multi-purpose social and economic upliftment objectives of the scheme.

It was therefore recommended that Phase 2 of this Feasibility Study focus on the development of the larger-sized Ntabelanga Dam to be used conjunctively with the potential Laleni/Tsitsa Falls hydropower scheme.

The full environmental and social impacts of the proposed Ntabelanga Dam solution will also be investigated under the EIA study to be conducted by an independent PSP in parallel during Phase 2. The two study teams are required to work together in terms of planning and transfer of information.

PRELIMINARY COST ESTIMATE FOR THE RECOMMENDED CONJUNCTIVE USE SCHEME

At this preliminary stage, the economic comparison of options has been undertaken by comparing dam infrastructure and associated works required to produce raw water at a satisfactory assurance of supply, and the incremental costs of the dams and associated infrastructure required to produce hydropower.

Water treatment and bulk water distribution costs were not included in such comparisons as the capital and operational unit cost per capita of domestic water supplied, and of raw water supplied to the identified areas of higher irrigation potential were very similar for all options, given the similar nature and topography of the supply areas and settlement distributions therein.

In preparing an overall preliminary cost estimate for the recommended conjunctive use scheme, these other costs have been included below, but it must be emphasized that this is still at a very high level analysis only (ie low level of detail available).

Costs have also been included for the development of the irrigated agriculture schemes and their bulk water supplies.

Catchment management costs have also been included, and such activities should, if possible, commence well before the construction of the Ntabelanga dam to maximize the benefit thereof.

Preliminary estimates of other resettlement and mitigation costs are also included, but these will need to be revisited and needs identified once the EIA study is underway. The EIA study will also address the social impacts and benefits of the proposed scheme.

Finally, the costs of further feasibility studies, site investigations, hydraulic modelling, detailed design, tendering, project management, supervision, and EIA have been added as a typical percentage fee.

Phase 2 will involve more detailed feasibility design of the Ntabelanga dam and water delivery systems which will greatly improve the level of accuracy of estimated costs of this component of the conjunctive use scheme.

Under this ongoing Feasibility Study (Phase 2), the Laleni Dam and associated hydropower infrastructure will not be investigated at such an increased level of detail, as this will be done under a separate Feasibility Study to be undertaken for that component of the conjunctive use scheme.

Caution should therefore be exercised when considering the preliminary cost estimate, which is as given in Table ES-20.

Table ES-20: Preliminary Cost Estimate of Overall Conjunctive Use Scheme

Preliminary Stage Cost Estimates - for Ntabelanga Conjunctive Scheme with Laleni Hydropower			
Component	**Description**	**Capital Cost R'millions**	**Basis of estimate**
Ntabelanga dam and associated works	1.5 MAR dam delivering raw water at dam wall	730	High level estimate - Dam cost estimating model
Ntabelanga dam hydropower works	Generating up to 1.6 MW continuous	40	ESKOM and other derived estimating curves
Ntabelanga water treatment works	50 Ml/day works	450	R9 million per Ml/day*
Ntabelanga bulk treated water distribution system	Distribution of raw water in bulk to supply area	1 124	R7 500 per capita served (cost derived from previous similar rural schemes)*
Ntabelanga irrigated agriculture developments	Raw water supply to edge of fields	450	R18000/m all-in cost x 25 km
Ntabelanga irrigated agriculture developments	Development and equipping of farms supplied with irrigation water	625	R250,000 x 2,500 ha
Ntabelanga land compensation/mitigation costs	Resettlement and other mitigations	80	Estimate only - no detailed info available
Tsitsa catchment management	Restoration and improvement of catchment above dam	300	First three years intensive activity - 600 jobs
Ntabelanga power transmission	New lines and transformers required to power infrastructure	90	Estimate for distribution lines
	Sub-Total	**3 889**	* These works overlap with projects being undertaken by OR Tambo DM
	Engineering and EIA Costs	**389**	10% of total capex
	Sub-Total Ntabelanga	**4 278**	
Laleni dam and associated works	0.18 MAR dam delivering raw water to hydropower plant	464	High level estimate - Dam cost estimating model
Laleni land compensation/mitigation costs	Resettlement and other mitigations	50	Estimate only - no detailed info available
Laleni water delivery tunnel, shafts and penstocks	Sized for 180 MW peak flows, 25 MW continuous	1 085	ESKOM and other derived estimating curves
Laleni hydropower E&M equipment	Sized for 180 MW peak flows, 25 MW continuous	213	ESKOM and other derived estimating curves
Laleni hydropower civil works	Sized for 180 MW peak flows, 25 MW continuous	309	ESKOM and other derived estimating curves
Laleni power transmission lines to grid	Sized for 180 MW peak flows, 25 MW continuous	148	18.5 km x R 8 million/km
	Sub-Total	**2 269**	
	Feasibility Study, Engineering and EIA Costs	**250**	11% of total capex
	Sub-Total Laleni	**2 519**	

NB: These estimates were prepared during Phase 1 Preliminary Stage and are based upon high level analyses using previous reports, as well as updated costing models.
All cost estimates are at May 2013 price levels and EXCLUDE VAT

TABLE OF CONTENTS

FIGURES

TABLES

APPENDICES

LIST OF ACRONYMS

AsgiSA-EC	Accelerated and Shared Growth Initiative for South Africa – Eastern Cape
CAPEX	Capital Expenditure
CFRD	Concrete-faced Rockfill dam
CMA	Catchment Management Agency
CTC	Cost of Company
DAFF	Department of Agriculture, Forestry and Fisheries
DBSA	Development Bank of Southern Africa
DEA	Department of Environment Affairs
DM	District Municipality
DME	Department of Minerals and Energy
DoE	Department of Energy
DRDAR	Department of Rural Development and Agrarian Reform
DRDLR	Department of Rural Development and Land Reform
DWA	Department of Water Affairs
DWS	Department of Water and Sanitation
EA	Environmental Authorisation
EAP	Environmental Assessment Practitioner
EC	Eastern Cape
ECRD	Earth core rockfill dam
EF	Earthfill (dam)
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
EPWP	Expanded Public Works Programme
ESIA	Environmental and Social Impact Assessment
EWR	Environmental Water Requirements
FSL	Full Supply Level
GERCC	Grout enriched RCC
GN	Government Notices
GW	Gigawatt
GWh/a	Gigawatt hour per annum
IB	Irrigation Board
IFC	International Finance Corporation
IPP	Independent Power Producer
IRR	Internal Rate of Return
IVRCC	Internally vibrated RCC
ISO	International Standards Organisation
kW	Kilowatt
LM	Local Municipality
ℓ/s	Litres per second
MAR	Mean Annual Runoff
MEC	Member of the Executive Council
MIG	Municipal Infrastructure Grant
million m^3	Million cubic metres
MW	Megawatt

NEMA	National Environmental Management Act
NERSA	National Energy Regulator of South Africa
NHRA	National Heritage Resources Act
NOCL	Non-overspill crest level
NWA	National Water Act
NWPR	National Water Policy Review
NWRMS	National Water Resources Management Strategy
O&M	Operations and Maintenance
OPEX	Operational Expenditure
PICC	Presidential Infrastructure Co-Ordinating Committee
PPA	Power Purchase Agreement
PPP	Public Private Partnership
PSC	Project Steering Committee
PSP	Professional Services Provider
RBIG	Regional Bulk Infrastructure Grant
RCC	Roller-compacted concrete
REIPPPP	Renewable Energy Independent Power Producer Procurement Programme
RWI	Regional Water Institution
RWU	Regional Water Utilities
SEZ	Special Economic Zone
SIP	Strategic Integrated Project
SMC	Study Management Committee
SPV	Special Purpose Vehicle
TCTA	Trans Caledon Tunnel Authority
ToR	Terms of Reference
UOS	Use of System
URV	Unit Reference Value
WEF	Water Energy Food
WRYM	Water Resources Yield Model
WSA	Water Services Authority
WSP	Water Services Provider
WTE	Water Trade Entity
WUA	Water User Association

LIST OF UNITS

Description	Standard unit
Elevation	m amsl
Height	m
Distance	m, km
Dimension	mm, m
Area	m^2 , ha or km^2
Volume (storage)	m^3 , million m^3
Yield	million m^3/a
Mean annual runoff	million m^3/a
Head of Water	m
Pressure	Pa, kPa, MPa
Diameter	mm dia., m dia.
Power	kW, MW
Energy	kJ, MJ
Temperature	ºC

Description	Standard unit
Velocity, speed	m/s, km/hr
Discharge	m^3/s
Mass	kg, tonne
Force, weight	N, kN, MN
Moment, torque	Nm, kNm, MNm
Ampere	A, kA
Volt	V, kV
Electric power	kVA, kW, MW
Energy used	kWh, MWh, GWh
Acceleration	m/s^2
Density	kg/m^3
Slope (H:V) or (V:H)	1:5 (H:V) or 5:1 (V:H)
Gradient (V:H)	%
Frequency	Hz, kHz, MHz

1. BACKGROUND AND INTRODUCTION

The Mzimvubu River catchment in the Eastern Cape of South Africa is within one of the poorest and least developed regions of the country. Development of the area to accelerate the social and economic upliftment of the people was therefore identified as one of the priority initiatives of the Eastern Cape Provincial Government.

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

The five pillars on which the Eastern Cape Provincial Government and AsgiSA-EC proposed to model the Mzimvubu River Water Resources Development are:

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

As a result of this the Department of Water Affairs (DWA) commissioned the Mzimvubu Water Project with the overarching aim of developing water resources schemes (dams) that can be multi-purpose reservoirs in order to provide benefits to the surrounding communities and to provide a stimulus for the regional economy, in terms of irrigation, forestry, domestic water supply and the potential for hydropower generation amongst others.

1.1 Study Locality

The Mzimvubu River Catchment, which is the study area, is situated in the Eastern Cape (EC) Province of South Africa which consists of six District Municipalities (DM) and two Metropolitan Municipalities (Buffalo City and Nelson Mandela Bay). These include Cacadu DM in the west across to the Alfred Nzo DM in the east with the two Metropolitan Areas being located around the two major centres of the province, East London and Port Elizabeth, both of which border the Indian Ocean.

The Mzimvubu River Catchment traverses three DM’s namely the Joe Gcabi DM in the north west, the OR Tambo DM in the south west and the Alfred Nzo DM in the east and north east. A locality map of the catchment area and its position in relation to the DM’s in the area is provided in Figure 1-1 overleaf.

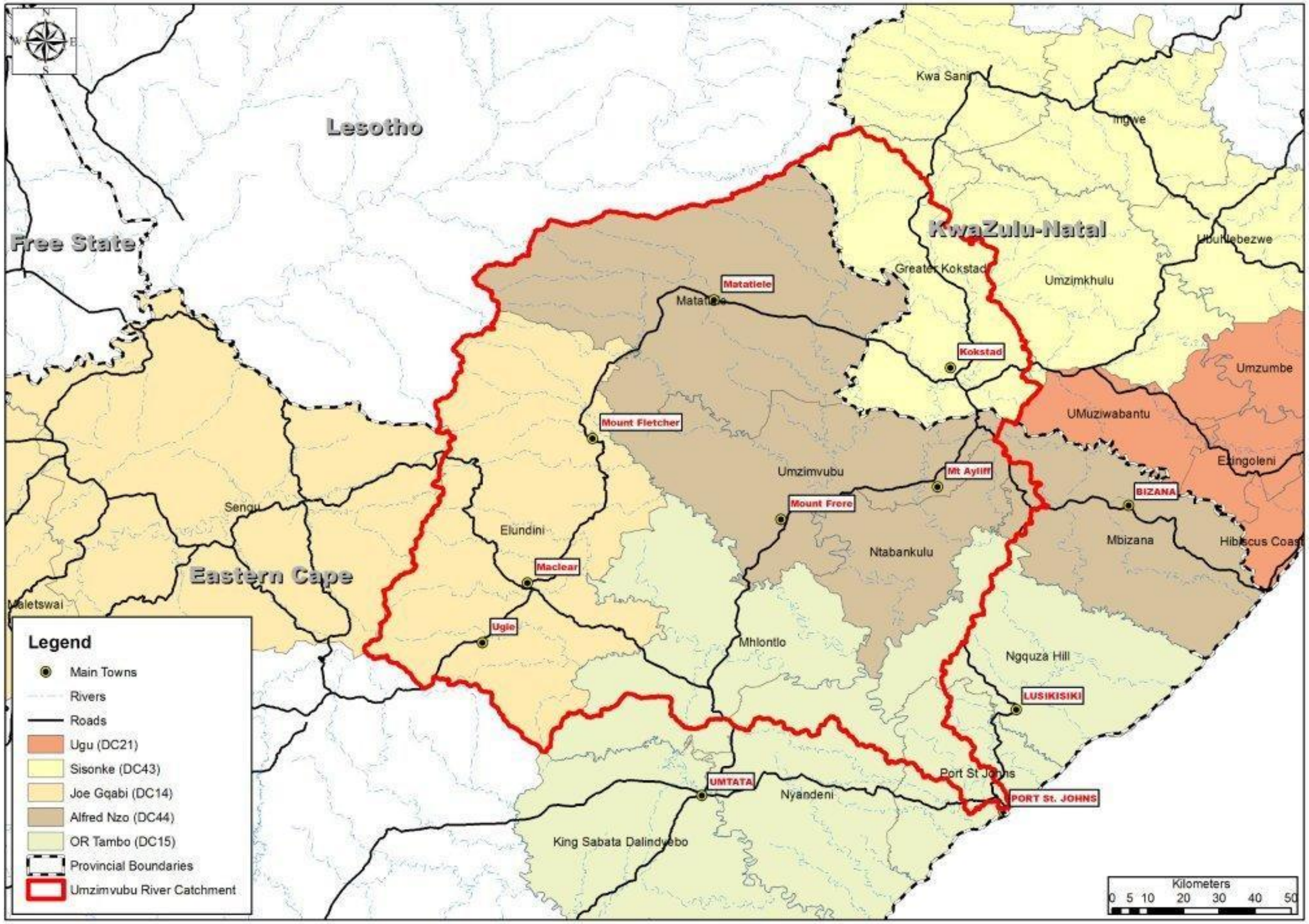


Figure 1-1: Locality Map of the Mzimvubu River Catchment Area

The study commenced in January 2012 and is to be completed by April 2014 in three Phases as follows:

- Inception Phase;
- Phase 1 – Preliminary Study; and
- Phase 2 – Feasibility Study.

The purpose of this study is not to repeat or restate the research and analyses undertaken on the several key previous studies described below, but to make use of that information previously collected, to update and add to this information, and to undertake more focussed and detailed investigations and feasibility level analyses on the dam site options that have then been identified as being the most promising and cost beneficial.

1.2 Inception Phase

The aim of the Inception Phase was to finalise the Terms of Reference (TOR) as well as include, inter alia, the following:

- A detailed review of all the data and information sources that were available for the assignment;
- A revised study methodology and scope of work;
- A detailed review of the proposed project schedule, work plan and work breakdown structure indicating major milestones;
- Provision of an updated organogram and human resources schedule; and
- Provision of an updated project budget and monthly cash flow projections.

The Inception Phase has been completed and culminated in the production of an Inception Report (DWA Report Number P WMA 12/T30/00/5212/1) which also constitutes the final TOR for the study.

1.3 Preliminary Study Phase

This Preliminary Report describes the activities undertaken during the preliminary study phase, summarizes the findings and conclusions thereof, and provides recommendations for the way forward and scope of work to be undertaken during the Feasibility Study phase.

The Preliminary Study Phase was divided into two Stages:

1. Desktop Study
2. Preliminary Study

The aim of the Desktop Study was, through a process of desktop review, analyses of existing reports and data, and screening, to determine the three best development options from the pre-identified 19 development options (from the previous investigation). This process is described in Section 2 of this Report.

The aim of the Preliminary Study was to gather more information with regards to the three selected development options as well as to involve the Eastern Cape Provincial Government and key stakeholders in the process of selecting the single best development option to be taken forward into Phase 2 of the Study.

The main activities undertaken, inter alia, as part of the second stage of Phase 1 were as follows:

- Stakeholder involvement;
- Environmental screening;
- Water requirements (including domestic water supply, irrigation and hydropower);
- Hydrological investigations;
- Geotechnical investigations;
- Topographical survey investigations;
- Selection process; and
- Reporting.

1.4 Phase 2 – Feasibility Study

Upon conclusion of the Preliminary Study a single preferred dam site and scheme development is to be taken forward to Feasibility Study level.

Key activities that will be undertaken during the Feasibility Study are as follows:

- Detailed hydrology (over and above that undertaken during the Preliminary Study);
- Reserve determination;
- Water requirements investigation (including agricultural and domestic water supply investigations);
- Topographical survey (over and above that undertaken during the Preliminary Study);
- Geotechnical investigation (more detailed investigations than during the Preliminary Study);
- Dam design;
- Land matters;
- Environmental Impact Assessment (this will be undertaken in a separate study that will run in parallel to this one);
- Public participation;
- Regional economics; and
- Legal, institutional and financial arrangements.

2. DESKTOP STUDY

The aim of the Desktop Study was, through a process of desktop review and analyses, to determine the three best development options from the pre-identified 19 development options (using data from the previous studies described above).

The first part of the Desktop Study was a thorough review process to enable informed decisions to be made regarding the development options being investigated.

The second part comprised a screening and selection process to determine the best three development options using this existing data.

2.1 Previous Studies

Three particular studies of importance have been undertaken with reference to the development of a dam for multi-purpose use on the Mzimvubu River.

They are as follows:

- Republic of Transkei Mzimvubu Basin Development: 1987.
- DWA Water Resources Study to assist ASGISA-EC: 2010 (BKS).
- ASGISA-EC Business Case for Water Related Opportunities – 2010 (Ingerop).

The first report focussed on a single dam while the other two reports assessed a series of dam sites throughout the catchment. The second two reports (the BKS and Ingerop Reports) were both undertaken at conceptual level only.

The report undertaken in 1987 focussed on the development of a large scale dam at the Mbokazi Dam site in the lower portion of the catchment. This dam would have been of strategic importance and would have been used for the following:

- 1600 MW hydropower plus transmission to East London and KwaZulu-Natal.
- Orange-Fish transfer up to 50m^3/sec over 550km and lifting 1600m.
- Export of water at 90 Mm^3/yr to Arabia by tanker.

The cost of such a dam would be very high and the potential environmental impacts would also be significant both in terms of impounded area as well as flow reduction into the river estuary near Port St Johns.

The DWA Water Resources Study to assist ASGISA-EC in 2010 was undertaken by BKS (now incorporated into the AECOM Group). This report was undertaken at a conceptual/desktop level and identified 19 possible dam sites throughout the Mzimvubu River catchment and assessed each dam in terms of their use for hydropower, irrigation, domestic water supply, inter catchment transfers and overall economic stimulus. A map showing the 19 dam sites is provided in Figure 2-1 overleaf.

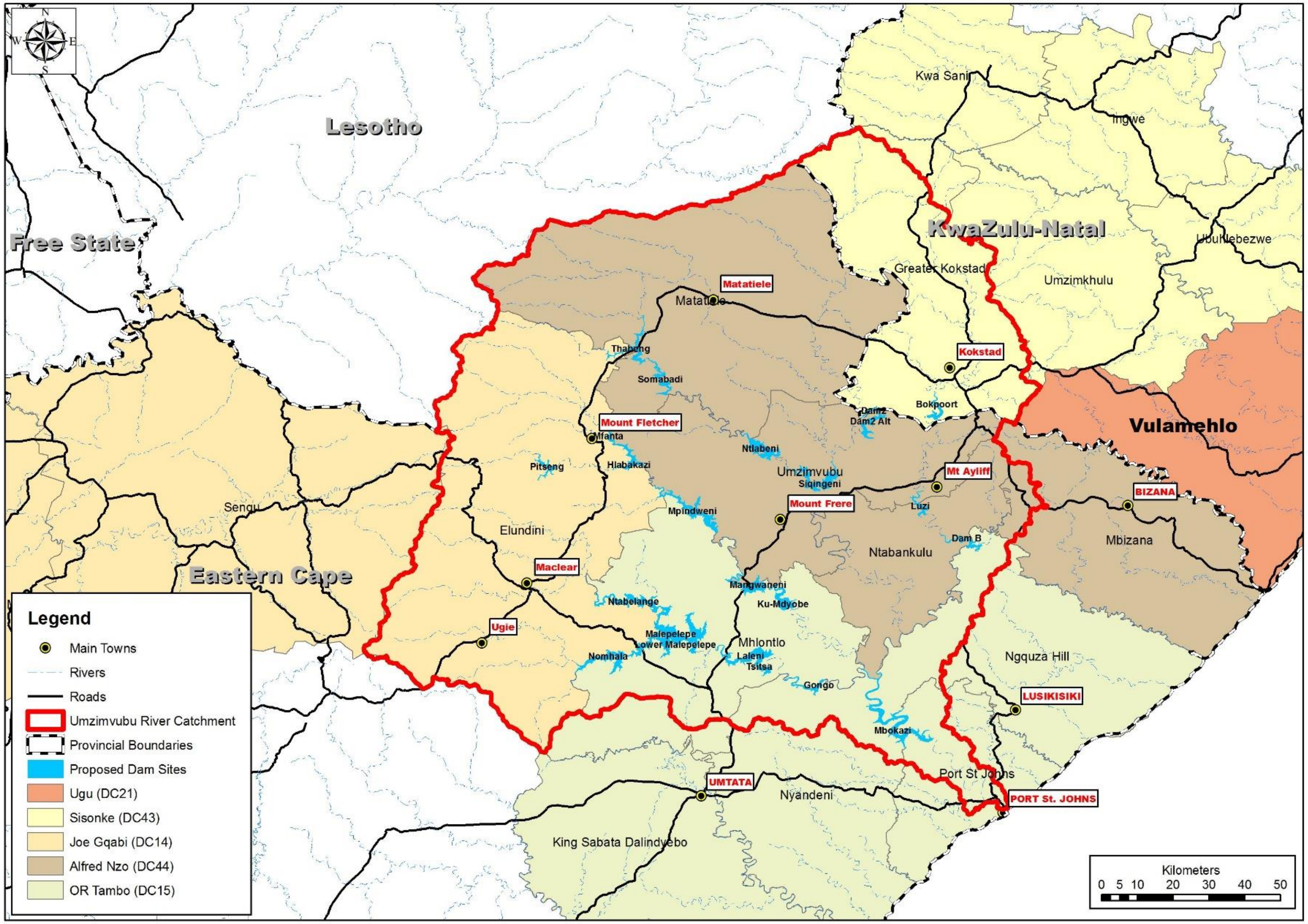


Figure 2-1: Mzimvubu River Catchment Showing Initially Identified 19 Dam Sites

Following the BKS Report an additional report was undertaken by Ingerop, called the ASGISA-EC Business Case for Water Related Opportunities – 2010. This report, also undertaken at conceptual level, looked at the same 19 dam sites plus one additional site (Tsitsa Dam Site) and undertook a dam site screening process based on a set of criteria that included the following:Capex / MW produced;

- Agriculture potential (irrigation);
- Forestry potential;
- Population;
- Accessibility / proximity to main transport infrastructure; and
- Potential use of dams in long term water transfer schemes.

Based on these criteria the two highest ranked dams were taken forward into a Business Case Study. These two sites were the Ntabelanga and Tsitsa Falls/Laleni Sites.

The desktop work undertaken and the 19 dam sites identified in these studies formed the departure point for this current Mzimvubu Water Project.

2.2 National Planning for Water Supply from the Mzimvubu River Catchment

In addition to the studies mentioned above in Section 1.1, an additional document of importance is the Assessment of the Ultimate Potential Future Marginal Cost of Water Resources in South Africa, 2010 (Report no. P RSA 000/00/12610) prepared by the Department of Water Affairs.

This report discusses the future potential use of water from the Mzimvubu River catchment for augmentation of the water supply needs in the Vaal and Orange River Systems.

The report states that the cost of transferring water from the Mzimvubu catchment to the Vaal system is extremely high and other measures such as the reallocation of water (through trading) be considered before this. The projected timing where the need may arise for augmentation is around 2048 (approximately 36 years from now).

Similarly the report indicated that the Orange River System may have a need in 2048 for additional water and discusses the possibility of transferring water from the Mzimvubu River (specifically from the proposed Ntabelanga Dam) into the Kraai River (headwaters of the Orange River). However, the report goes further to conclude that it is doubtful whether the transfer of water from the Mzimvubu catchment for the express purpose of augmenting supplies along the Orange River will ever be necessary and justifiable.

2.3 Dam Site Screening and Selection Process

Several selection criteria were proposed to be used in order to facilitate the selection of the three most suitable dam sites for further investigation. These criteria covered technical, economic, social and environmental considerations.

The criteria used are listed below:

- Technical and Economic Considerations
  - Yield;
  - Capital cost;
  - Unit Reference Value (URV) of water produced;
  - Accessibility;
  - Hydropower potential (capex/MW);
  - Sedimentation; and
  - Forestry potential.

- Environmental and social Considerations
  - Potential for irrigated agriculture;
  - Potential for domestic water supply;
  - Environmental impacts; and
  - Job creation.

The potential for the proposed development options (dams) to provide water for inter-catchment transfers (i.e. augmentation of the Orange and Vaal River Systems) was considered. However, as mentioned above, the study entitled "Assessment of the Ultimate Potential Future Marginal Cost of Water Resources in South Africa, 2010", undertaken by DWA, clearly indicated that the use of water from the Mzimvubu River for this purpose is very expensive and highly unlikely.

On this basis it was deemed pertinent to not include this as a selection criterion for the proposed development of a multi-purpose storage structure on the Mzimvubu River.

The list of the 19 potential dam site names and the rivers and catchments upon which they are situated, is given in Table 2-1.

Table 2-1: List of 19 Potential Dam Development Options

Catchment	River	Dam Name
T31	Upper Mzimvubu	Dam 2
		Siqingeni
T32	Mzintlava	Bokpoort
		Luzi
		Dam B
T33	Kinira	Thabeng
		Somabadi
		Ntlabeni
T34	Tina	Pitseng
		Hlabakazi
		Mpindweni
		Mangwaneni
		Ku-Mdyobe
T35	Itsitsa	Nomhala
		Ntabelanga
		Malepelepe
		Laleni
		Gongo
T36	Mzimvubu	Mobokazi

At this early stage of the study the comparison of options was (as required by Terms of Reference) to be based upon the available desktop information gathered from the previous studies and reports described above, supplemented by some additional information generated using GIS processing and analyses of data obtained from District Municipalities (water and associated infrastructure needs), as well as the identification of the locations and areas of medium to high potential land suitable for irrigated agriculture.

The decision criteria analyses results were presented, discussed and agreed at both PSC and stakeholder level to ensure that at major considerations had been included and that consensus could be reached on the best three dam site options before proceeding with more detailed investigations. The following section discusses those criteria that were considered to be key to this decision-making process.

2.4 Technical and Economic Considerations

2.4.1 *Dam Yield*

The potential yield of a dam is an important consideration when assessing its potential use. The yield is expressed in million m^3/a and reflects the amount of water that available from the dam at a certain assurance of supply year on year after making allowance for sediment trapping (which reduces the dam's gross volume over its lifespan) and Environmental Water Releases (EWR).

At the time of the Screening Workshop (see below) the detailed hydrology had not been undertaken and Mean Annual Runoff (MAR) figures calculated using the WR2005 model were therefore used for comparative purposes.

These figures, taken from the previous Water Resources Study, are included in Table 2-2 below along with Historical Firm Yield (100% assurance of supply) figures from the Water Resources Yield Model (WRYM) for dams of impounded volume equal to 0.5, 1 and 1.5 times the MAR.

Potential dam sites located on the Kinira, Tina and Tsitsa Rivers (tributaries of the main Mzimvubu River) have reasonably high MAR figures largely due to the significant catchment areas above each site.

Potential dam sites lower down these tributaries naturally produce even higher yields than those in the upper portions of the catchment (for example Ntlabeni has the highest yield in the Kinira catchment, Mangwaneni and Ku-Ndyobe have the highest in the Tina and Laleni and Malepelepe have the highest in the Tsitsa Catchment).

Table 2-2: MAR and Yield Figures for all Proposed Dam Sites

Catchment	River	Dam Name	Mean Annual Runoff (million m³)	Wall Height for 1 x MAR Capacity (m)	Historic Firm Yield* (million m³/a)		
					Dam Capacity		
					0.5 x MAR	1x MAR	1.5 X MAR
T31	Upper Mzimvubu	Dam 2	240	19	26	56	73
		Siqingeni	709	80	184	289	
T32	Mzintlava	Bokpoort	130	60	24	37	53
		Luzi	198	63	46	72	93
		Dam B	282	93	82	125	135
T33	Kinira	Thabeng	307	53	102	144	174
		Somabadi	324	59	104	150	183
		Ntlabeni	396	65	138	187	227
T34	Tina	Pitseng	55	34	13	20	24
		Hlabakazi	248	57	62	93	108
		Mpindweni	337	56	84	125	149
		Mangwaneni	414	55	91	140	149
		Ku-Mdyobe	424	80(*)	93	140	
T35	Itsitsa	Nomhala	206	43	43	76	90
		Ntabelanga	403	53	115	155	183
		Malepelepe	696	42	248	277	316
		Laleni	755	62(*)	205	254	
		Gongo	800	100(*)	148		
T36	Mzimvubu	Mobokazi	2520	100(*)	563		

* Wall Heights for 1MAR dam only due to topographical constraints

2.4.2 *Capital Cost*

The capital cost of the proposed dam infrastructure needed to be considered when assessing the development option. This influences the ultimate cost, and affordability of the water supplied by each dam (and significantly influences the unit cost of hydropower energy supplied if this is an option) which affects the financial feasibility of the project.

At the time of this initial screening process, capital cost figures were on hand from the pre-feasibility study and these were used in the screening process. They are provided in Table 2-3 below.

It should be noted that these capital costs only covered each dam wall and associated infrastructure, and did not include costs for other bulk water delivery systems or hydropower plant.

Table 2-3: Estimated Capital Costs of all Proposed Dam Sites for Varying Storage Capacities

Catchment	River	Dam name	Dam cost estimate (R Million)		
			Dam Capacity		
			0.5 x MAR	1 x MAR	1.5 x MAR
T31	Upper Mzimvubu	Dam 2	640	800	980
		Siqingeni	1120	1470	
T32	Mzintlava	Bokpoort	630	910	1110
		Luzi	660	880	1100
		Dam B	1140	1980	2310
T33	Kinira	Thabeng	490	710	790
		Somabadi	520	760	850
		Ntlabeni	590	770	1010
T34	Tina	Pitseng	290	380	450
		Hlabakazi	380	640	870
		Mpindweni	520	640	810
		Mangwaneni	1100	1490	1670
		Ku-Mdyobe	1220	1940	
T35	Itsitsa	Nomhala	490	620	720
		Ntabelanga	350	420	470
		Malepelepe	840	1000	1120
		Laleni	940	1170	
		Gongo	2010		
T36	Mzimvubu	Mbokazi	2070		

2.4.3 *Unit Reference Value (URV) of Water Produced*

Unit reference values (URV) of the bulk raw water supplied by each dam were also previously calculated using the capital costs and yields described above. The URV's provide an indication of the cost of the water being produced and are the preferred tool for comparing options.

URVs were calculated for a 45 year lifespan period, a discount rate of 8%, and with the construction of dams taking approximately three years.

These URVs do not include the cost of treating and distributing the water to the points of use.

The URV's generated in the previous studies were based upon total bulk water available (based on 98% assurance of supply yield) by each dam size, and were not based upon actual water requirements to be supplied by each dam.

This produces much lower URVs than would be determined if only actual water needs are taken into consideration, but was used purely for the desk top comparison basis.

URVs of the actual water supplied by each dam were recalculated to compare the final three shortlisted dams as is described later in this report, and the economic viability of the finally selected dam site will be considered in even more detail as the study moves forward into the Feasibility Stage.

The URV figures from the previous study are provided in Table 2-4.

Table 2-4: Estimated URV of Water Produced for each Proposed Dam Site

Catchment	River	Dam Name	Unit Reference Values (R/m3)		
			Dam Capacity		
			0.5 x MAR	1 x MAR	1.5 x MAR
T31	Upper Mzimvubu	Dam 2	3.70	2.10	2.00
		Siqingeni	0.90	0.80	-
T32	Mzintlava	Bokpoort	3.90	3.70	3.20
		Luzi	2.20	1.80	1.80
		Dam B	2.10	2.40	2.60
T33	Kinira	Thabeng	0.70	0.70	0.70
		Somabadi	0.80	0.80	0.70
		Ntlabeni	0.60	0.60	0.70
T34	Tina	Pitseng	3.40	2.90	2.80
		Hlabakazi	0.90	1.00	1.20
		Mpindweni	0.90	0.80	0.80
		Mangwaneni	1.80	1.60	1.70
		Ku-Mdyobe	2.00	2.10	-
T35	Itsitsa	Nomhala	1.70	1.20	1.20
		Ntabelanga	0.50	0.40	0.40
		Malepelepe	0.50	0.50	0.50
		Laleni	0.70	0.70	-
		Gongo	2.00	-	-
T36	Mzimvubu	Mbokazi	0.60	-	-

2.4.4 *Accessibility*

Accessibility was also considered to be a factor in selecting a dam site because it will impact upon the cost of the construction both in terms of the distance for hauling certain materials as well as the capital cost of road infrastructure that will be required to be developed.

In addition to this, if agricultural potential land is identified, which is one of the focuses of this study, the access to these lands and the transport routes from these lands to major market centres will have a bearing on the financial viability of the scheme.

In order to assess this, an analysis of the dam sites in relation to the main N2 traversing through the catchment was undertaken and the results of this are presented in Table 2-5.

Table 2-5: Distances of Proposed Dam Sites from N2

Dam Name	Distance from N2 Along Accessible Road (km)	Dam Name	Distance from N2 Along Accessible Road (km)
Siqingeni	5.14	Nomhala	26.80
Mangwaneni	13.40	Ntabelanga	30.60
Malepelepe	14.80	Dam2Alt	34.63
Ku-Mdyobe	17.20	Gongo	45.60
Mpindweni	17.80	DamB	58.11
Tsitsa	18.30	Mbokazi	84.20
Laleni	18.40	Hlabakazi	118.00
Bokpoort	19.62	Mfanta	122.00
Ntlabeni	22.00	Pitsang	127.00
Luzi	26.66	Thabeng	166.00
Nomhala	26.80	Somabadi	190.00

Access to the majority of the dam sites was not considered a problem when viewing the results shown in the table above. Dam sites on the list from Mbokazi down to Somabadi are however significantly less favourable than the other dam sites from an access and haulage perspective. It should also be considered that there are other major routes in some cases that link these dam sites to major centres.

2.4.5 *Hydropower Potential*

Hydropower can be an important criterion for the development of a multipurpose dam. The generation of hydropower could provide an additional income stream in order to improve the economic feasibility of the dam.

When considering the hydropower potential it is important to assess the unit cost of the hydropower in addition to the number of Megawatts (MW) that can be produced under different conditions. Figure 2-2 below provides a summary (from the previous studies) as to what the unit cost (Capex/MW) of hydropower was projected to be for each potential dam site. This indicated that these values were all significantly higher than the upper threshold for base-load power.

This benchmark threshold was based upon a potential hydropower scheme at the Laleni dam/Tsitsa Falls site, which had been identified by an ESKOM study as being the best ranked hydropower option in the Eastern Cape region.

Both the Tsitsa Falls (Laleni) site, and the Mbokazi dam site identified in the 1987 Republic of Transkei study, could be used as single purpose developments for significant power generation, however the focus of this study is on the development of a multipurpose development, including water supply and irrigated agriculture, for which these two hydropower options in particular are not particularly beneficial. The recommendations of previous studies proposed that Ntabelanga and Somabadi should be considered for further investigation for hydropower as part of a multipurpose development.

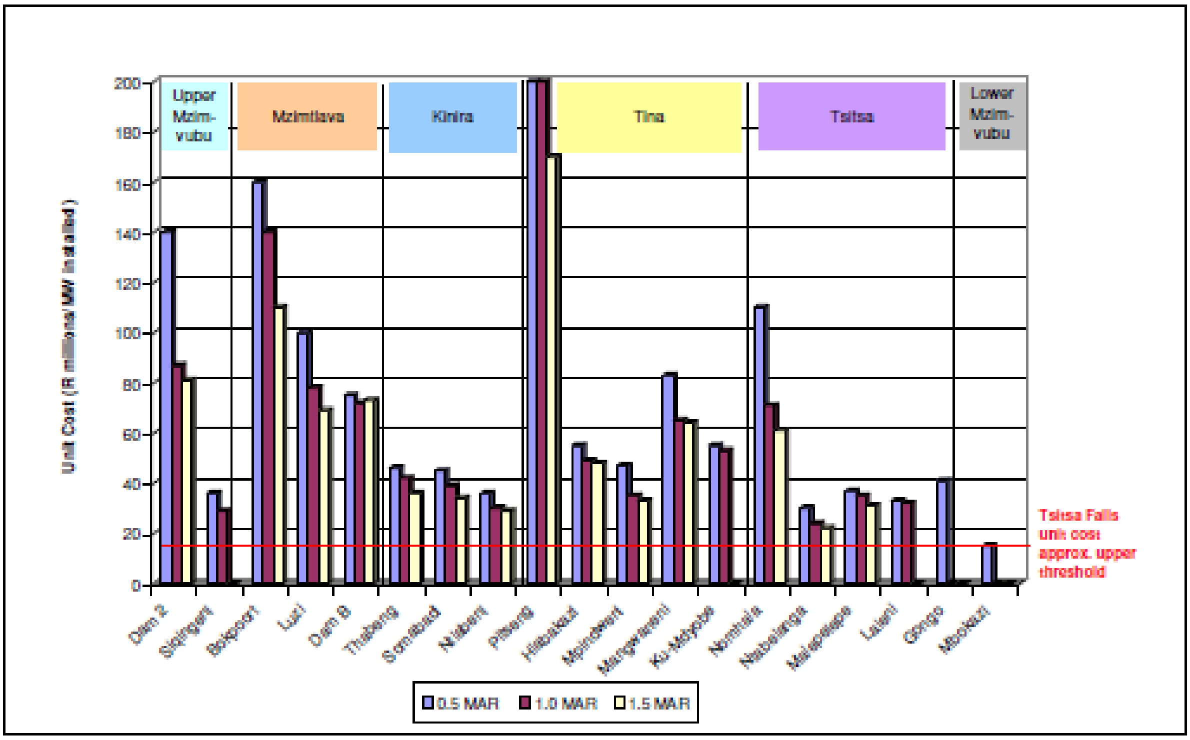


Figure 2-2: Comparisons of Unit Costs of Base Load Hydropower (BKS, 2010)

2.4.6 *Sedimentation*

Sedimentation within the Mzimvubu Catchment is amongst the highest in the country and is therefore a major concern when considering the development of a storage dam on one of the rivers in the catchment. Typically a 50 year sediment allowance is catered for in the design and sizing of a dam and this has a direct impact on the cost of such a structure.

The figures given in the previous studies indicated that sedimentation amounts may be higher in the Mzintlava and upper Mzimvubu catchment areas, which made the proposed dam sites in these catchments less favourable. In the Tsitsa catchment the Ntabelanga dam site was considered to be the most suitable from a sedimentation perspective and had the lowest percentage sediment accumulation in relation to storage volume out of all 19 dam sites. There was little difference between the three sites in the Kinira catchment, with high sedimentation rates, while the sites in the Tina catchment had similar figures with percentages of storage volume 30% higher than those of the Ntabelanga site.

2.4.7 *Forestry Potential*

Forestry potential was included as a selection criterion due to the fact that if storage was created in the catchment it may allow for an increase in afforestation due to additional reliable yield having been created in the catchment.

The area downstream of the dam includes areas that are potentially viable for forestry. The extent of these areas vary depending on the position of the dam in the catchment. In cases where a dam was higher up in the catchment such dams were generally considered to have a higher potential than others in terms of the selection criteria. The information used for this classification of forestry potential per site was obtained from the Ingerop Business Case Study (2010).

2.4.8 *Potential for Irrigated Agriculture*

The potential for a proposed dam to be used for irrigated agricultural land was seen as an important selection criterion due to the impact this would have on the economic benefits of the communities in this area. This was seen as being a key to addressing the issue of livelihood creation which is one of the fundamental aims of this study.

A desk top screening process was undertaken assessing the amount of land below each of the dams that may be viable for irrigated agricultural land development. Key criteria in this assessment were as follows:

- Assessment of low, medium and high potential soils. Only high potential soils (soil structure, type of soil and soil depth) were considered;
- Only areas with 12% or less slope were considered;
- Only areas that have a medium to high water deficit were considered;
- Areas within 5km distance from river downstream of the dam;
- Only areas that were within 60m vertical elevation of the invert of the river were considered; and
- The river was viewed as a conveyance structure for irrigation water.

The basis of comparison was the identified area of "viable" land suitable for irrigated agriculture that could be supplied by each dam.

2.4.9 *Domestic Water Supply Requirements*

There are many areas within the Mzimvubu Catchment area that do not have access to a sustainable water supply for domestic use. As part of the approach to develop a multipurpose storage structure it would be beneficial if the preferred development option was positioned such that it was able to service as many these unserviced people as possible with potable water, thus assisting in the process of addressing these services backlogs.

Utilising information provided from the DWA Water Services Department an analysis of the areas of need in relation to the proposed dam sites was undertaken and the dams ranked as low, medium or high potential.

2.4.10 *Environmental and Social Considerations*

Phase 1 of the study included an Environmental Screening task, and this was undertaken early in the study period so that initial findings could be used as another decision making criteria.

A separate report on this Environmental Screening process has been produced as DWA Report Number P WMA 12/T30/00/5212/2.

2.4.11 *Environmental Screening*

As described in the above-mentioned Environmental Screening report, a suite of tools were used to assess the 19 proposed dam sites and their potential impacts on the biota within the systems where they occurred.

A "dam site suitability score", derived from assessing the data from the various tools considered, was assigned to each dam site. Potential dam sites with "dam site suitability scores" that were "moderate" to "very low" were considered to be ecologically important areas.

Six of these sites (Dam 2 Alt, Siqengeni, Nomhala, Malepelepe, Laleni and Mbokazi) were seen as unsuitable for the construction of a dam as they occurred in ecologically and environmentally sensitive and/or important areas.

Seven dams (dams Bokpoort, Somabadi, Ntlabeni, Hlabakazi, Pitseng, Mpindweni and Ntabelanga) were considered to be potentially suitable dam sites.

These sites, however, were only considered as dams sites if:

i) Dam sites with higher "dam site suitability scores" (4's and 5's) cannot be considered for reasons outside of this report; and/or

ii) Ground-level assessments are carried out to determine the suitability of these sites for the construction of the dam.

Dams Luzi, Dam B, Thabeng, Mangwaneni, Ku-Mdyobe and Gongo had "high" and "very high" dam site suitability scores, and from an ecological and environmental perspective were seen as the most suitable sites for the potential dam construction. However other considerations (e.g. social, geotechnical, financial, etc.) may have required that less suitable dam sites be considered.

From an ecological and aquatic ecosystem resource perspective, dam sites Luzi, Dam B, Thabeng, Mangwaneni, Ku-Mdyobe and Gongo, with high dam site suitability scores, were considered as immediate potential sites for the proposed dam.

2.4.12 *Social Considerations*

The main aim of the Mzimvubu Water Project is the socio-economic upliftment of the largely undeveloped and impoverished communities within the Mzimvubu River catchment area. Part of this is hoped to be achieved through the creation of temporary and permanent jobs through the development of a multipurpose scheme.

The agricultural developments that may be developed as a result of the dam are proposed to assist in job creation along with the provision of water to urban centres where development may have been curbed in the past due to water shortages.

Full details of the environmental screening process are contained in DWA Report Number P WMA 12/T30/00/5212/2.

2.5 The Final Screening Process

Key information on each of the 19 dam site development options, as generated by the above screening process, is given in **Appendix A**.

Each development option was rated against the same set of decision criteria to develop a colour-coded comparison matrix in order to inform and guide the decision as to which three dam site options should be investigated further during Stage 2 of Phase 1 – i.e. the Preliminary Study.

The final set of decision criteria and the ratings given to each potential dam site development for these criteria were presented, discussed and agreed at a screening workshop attended by members of the study team, members of the PSC and a wider set of regional stakeholders through a public invitation process.

2.5.1 *The Screening Workshop*

The Screening Workshop was held in the form of a Stakeholder Forum on the 27th June 2012 just outside of Mthatha. A wider stakeholder group (wider than the Project Steering Committee) was invited to be part of the Screening Workshop due to the strategic importance of the project as well as the aim of developing a multi-purpose water resource that will be used by as many spheres of society and business as possible.

The involvement of stakeholders in this decision-making was seen as a key tool in maximising the economic benefit of the project, and gaining consensus.
The objectives of the workshop were to:

- Present and discuss the selection criteria;
- Present information on each option to allow for a comparison;

- Prioritise which three development options should be further investigated in this phase of the Study; and
- Augment the existing information with specialist inputs from the DWA and other key stakeholders.

2.5.2 *Outcomes of the Screening Workshop*

The following is a summary of the decisions taken at the workshop for each dam development option regarding whether or not to include them for further investigation.

- **Upper Mzimvubu**
  - Dam 2 – Removed from further investigation – limited to no potential against key criteria especially agricultural and job creation. In addition high cost anticipated.
  - Siqengeni - Removed from further investigation – limited to no potential against key criteria especially agricultural and job creation. In addition high cost anticipated.

- **Mzintlava**
  - Bokpoort - Removed from further investigation– limited to no potential against key criteria especially agricultural and job creation. In addition high cost anticipated.
  - Luzi - Removed from further investigation– limited to no potential against key criteria especially agricultural and job creation. In addition high cost anticipated.
  - Dam B - Removed from further investigation– limited to no potential against key criteria especially agricultural and job creation. In addition high cost anticipated.

- **Kinira**
  - Thabeng – Included for further investigation – good potential for a multi-purpose dam due to potential for development of irrigated agriculture, domestic water supply and hydropower while having a comparatively low anticipated cost. Accessibility is the only negative considered.
  - Somabadi – Included for further investigation – good potential for a multi-purpose dam due to potential for development of irrigated agriculture, domestic water supply and hydropower while having a comparatively low anticipated cost. Accessibility is the only negative considered.
  - Ntlabeni - Removed from further investigation – due to no potential for irrigated agriculture development and therefore limited job creation potential.

- **Tina**
  - Pitseng - Removed from further investigation – due to high cost, low yield, limited domestic water supply potential and accessibility reasons.
  - Hlabakazi - Removed from further investigation – due to no potential for irrigated agriculture development and therefore limited job creation potential as well as limited hydropower potential and accessibility problems.
  - Mpindweni – Included for further investigation – largely due to hydropower potential and moderate potential across most criteria except agricultural potential and job creation.
  - Mangwaneni - Removed from further investigation – due to no potential for irrigated agriculture development and therefore limited job creation potential as well as high capital and unit cost of water.
  - Ku-Mdyobe - Removed from further investigation – due to no potential for irrigated agriculture development and therefore limited job creation potential as well as high capital and unit cost of water and limited hydropower and domestic water supply potential.

- **Tsitsa**
  - Nomhala – Included for further investigation – Moderate potential across all selection criteria although a negative environmental impact is considered likely.
  - Ntabelanga – Included for further investigation – high potential for development across majority of selection criteria.
  - Malepelepe - Removed from further investigation – due to high cost, no agricultural potential and therefore limited job creation potential and high environmental impacts.
  - Laleni – Included for further investigation – only hydropower potential (checks to be undertaken to determine the importance of linkage to Provincial Industrial Development initiatives)
  - Gongo - Removed from further investigation due to high cost, no agricultural potential and therefore limited job creation potential and moderate to high environmental impacts.

- **Lower Mzimvubu**
  - Mbokazi – Included for further investigation – only hydropower potential (checks to be undertaken to determine the importance of linkage to Provincial Industrial Development initiatives)

In summary, seven development options remained for a small amount of additional analysis to finally arrive at the three sites required. These seven dam sites were as follows:

- Thabeng;
- Somabadi;
- Mpindweni;
- Nomhala;
- Ntabelanga;
- Laleni; and
- Mbokazi.

A summary of these seven dam sites against the eight agreed key decision criteria is provided in Figure 2-3, with the locations of these dams shown in Figure 2-4.

			Medium Impact 2 Medium Cost Medium Potential	**High Impact 3 High Cost Low Potential**	**Very High Impact 4 Very High Cost Very Low Potential**	**I.E.:** 5. Most Favourable 6. Moderately favourable 7. Not favoured 8. Very unfavourable				
Option	**Proposed Dams**	**Rivers**	**Capital Cost (excl. distribution and Access**	**URV of Water Produced (R/m³)**	**Accessibility**	**Hydropower Potential**	**Potential for Irrigated Agriculture**	**Domestic Water Supply Potential**	**Environmental Impacts**	**Job Creation**
6	Thabeng	Kinira	2	2	4	3	1	2	1	1
7	Somabadi	Kinira	3	2	4	2	1	2	2	1
11	Mpindweni	Tina	2	2	2	2	4	2	2	3
14	Nomhala	Tsitsa (Inxu River)	2	3	2	3	2	2	4	2
15	Ntabelanga	Tsitsa	1	1	2	1	1	1	2	1
17	Laleni	Tsitsa	4	2	2	1	4	1	4	3
19	Mbokazi	Lower Mzimvubu	4	1	4	1	4	4	4	3

Figure 2-3: Summary of Seven Selected Dam Sites as an Output from the Screening Workshop

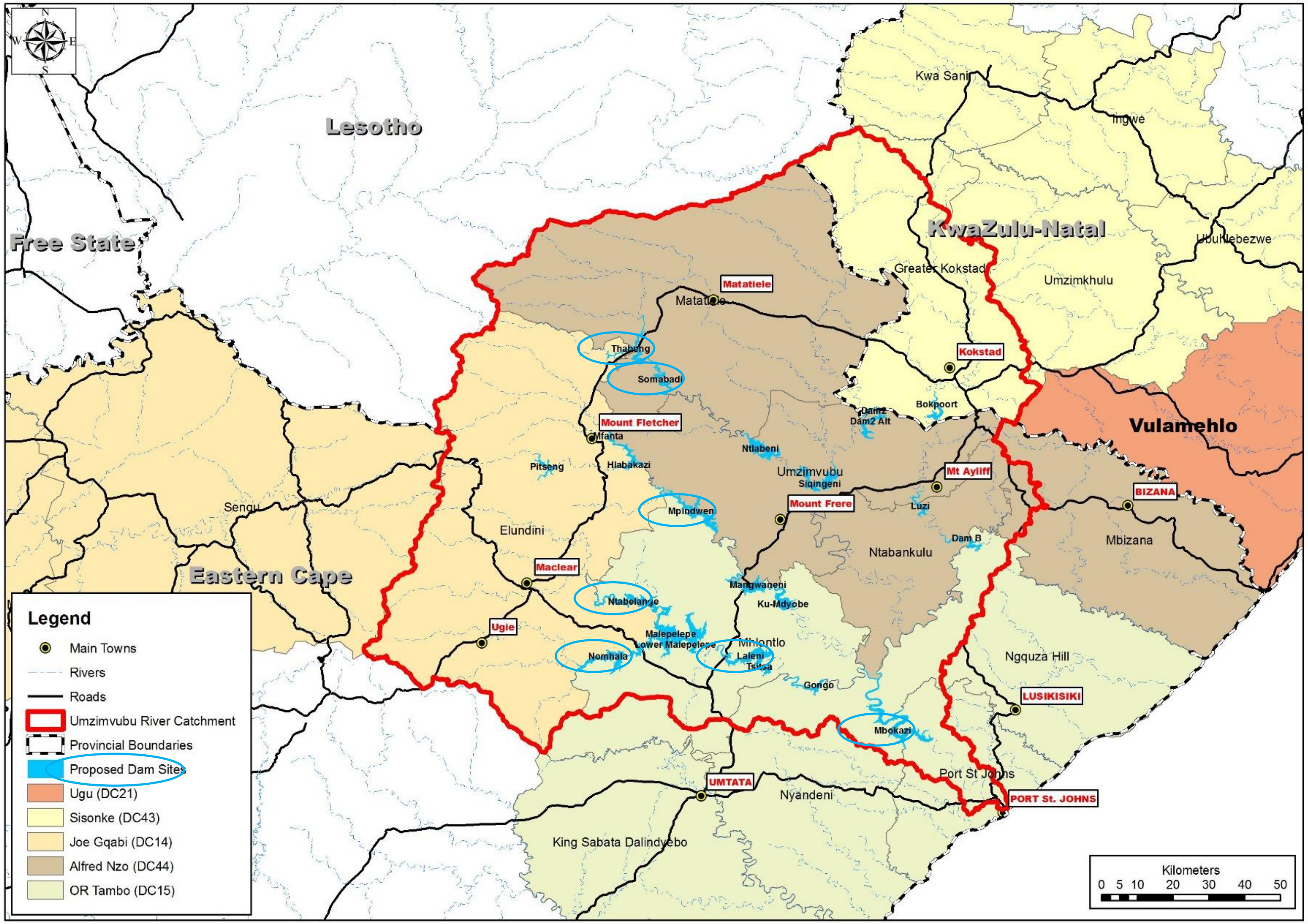


Figure 2-4: Mzimvubu River Catchment Showing Shortlisted 7 Dam Sites

2.6 Additional Analysis of Seven Selected Options

At the conclusion of the Screening Workshop the study team was tasked with further investigating the following issues before a final decision could be taken on the three preferred dam development options:

- The plans that ESKOM have for the Mzimvubu Catchment area in terms of power supply and the interest they may have in generating hydropower to feed into the national grid;
- Confirmation of the severity of the environmental impacts at each of the seven preferred sites; and
- Obtain information on regional development initiatives planned within the Mzimvubu Catchment and assess their importance in relation to the positioning of a proposed dam development option.

2.6.1 ESKOM Initiatives and Planning

Contact was made with ESKOM's Chief Engineer for Grid Operations in the Region based in East London.

ESKOM had been inundated with numerous enquiries from potential Independent Power Producers (IPPs) wishing to utilize the water resources of the Mzimvubu Catchment to produce hydropower. Many of these are not serious contenders and are seeking funding from ESKOM itself, which is not the policy being followed at present. There are also several ongoing bidding rounds for renewable energy projects in the region including many wind farms, and all of these have to be considered by the Department of Energy before deciding which projects meet the feed-in tariff bid rates and other criteria requirements and are ultimately shortlisted. Selling power into the grid is therefore currently a highly competitive business.

Key aspects of any potential hydropower or other power generation project will be the unit cost of power produced, the nature of production (i.e. continuous base load or peaking power), and the additional cost of transferring the power produced into the existing grid lines, where distance from the existing infrastructure is a major cost factor.

For this reason the smaller micro-hydro plants e.g. 1 MW are often not feasible as the cost of transmission lines for a new plant to the main grid adds too much cost per unit supplied to the bid rate. These additional costs are called evacuation infrastructure costs.

Plants of 5 MW and above offer much more economy of scale as, for example, the evacuation infrastructure costs for a 20 MW plant would not normally be any higher than for a 5 MW plant.

Each proposed hydropower scheme must therefore be taken on its own merits. It was agreed that once the Mzimvubu project has reduced the choices down to three potential development options, ESKOM would work closely with the team to assist in properly investigating both potential quantum and economic viability of utilising the hydropower produced. This would include development of either a continuous base load station, or one which is used in peak periods (i.e. a larger output for shorter time per day).

As regards quantum, ESKOM stated that they can "evacuate" almost any amount of power produced by an IPP, but would need to check their main infrastructure carrying capacity to ensure that it could take the additional power produced. An example of this is where the potential total outputs of proposed wind farms in the Port Elizabeth area exceeds the current grid carrying capacity and it would be necessary for ESKOM to upgrade their main transmission lines at significant additional cost.

They estimated that the existing lines passing through the Mzimvubu area could take up to the ±150 MW which could be produced by the separate potential multi-dam project being proposed by others and being considered by the PIIC but this would need to be carefully reviewed if such projects moved forward.

Therefore in general at this stage it was apparent that there seemed to be no impediment to considering the production of hydropower at any of the likely final three sites and selling this power into the local grid. However each case would have its own evacuation infrastructure costings attached to it which will affect the unit cost of power delivered to the grid, and the actual income generated by the dam itself.

2.6.2 *Environmental Impacts*

As discussed in the Environmental Screening Report, the impacts of each of the seven identified development options on the environment were reassessed in order to compare each of them in relation to each other. The following is a summary of the identified environmental impacts at each site:

i) Thabeng – The only dam to receive a dam site suitability score of 5 indicating it is suitable for development. Some vulnerable vegetation types are known to occur in the area and would need to be considered.
ii) Somabadi – Received a dam site suitability score of 3 indicating it is potentially suitable for development. It was considered to have a high Ecological Importance and Sensitivity (EIS) and has “vulnerable” vegetation types in the area. In addition National Freshwater Ecosystem Priority Areas (NFEPA) wetlands were identified upstream of the dam site which are important for blue cranes.
iii) Mpindweni – Received a dam site suitability score of 3 indicating it is potentially suitable for development. It was considered to have a high EIS and has “vulnerable” vegetation types in the area.
iv) Nomhala - Received a dam site suitability score of 2 indicating it is unsuitable for development. It was considered to have a high EIS and has “endangered” vegetation types in the area. In addition the river at this point is classified as a code 2 NFEPA river and wetlands which are important for blue cranes were identified.
v) Ntabelanga - Received a dam site suitability score of 3 indicating it is potentially suitable for development. It was considered to have a high EIS and has “vulnerable” vegetation types in the area. In addition wetlands will be inundated although they are not considered to be NFEPA wetlands.
vi) Laleni - Received a dam site suitability score of 2 indicating it is unsuitable for development. It was considered to have “endangered” vegetation types in the area, and will have NFEPA wetlands inundated. In addition the river at this point is classified as a code 2 NFEPA river.
vii) Mbokazi - Received a dam site suitability score of 1 indicating it is unsuitable for development. The major impact that this dam was identified to have would be on the estuary which is considered to be very sensitive and highly important.

It is important to note that none of the environmental issues identified constitute fatal flaws but should be used to indicate which dam sites are more favourable than the others.

2.6.3 *Development Initiatives in the Mzimvubu Catchment*

It was considered important to review the current planned development initiatives within the Eastern Cape, and specifically the Mzimvubu Catchment, and to assess the possible impacts that the development of a dam may have on these initiatives.

Additional documentation was collected subsequent to the Screening Workshop in order to obtain further information on possible development initiatives within the Eastern Cape, and specifically the Mzimvubu Catchment.

Documents of importance that were obtained are as follows:

a) Prioritised Strategic Projects for the Eastern Cape Province developed by the Eastern Cape Department of Economic Affairs, Environment and Tourism (DEAET) in August 2010.
b) The Wild Coast Strategic Environmental Assessment for the Port St Johns Local Municipality developed by SRK
c) The Integrated Wild Coast Development Programme developed by the Department of Economic Development, Environmental Affairs and Tourism (DEDEAT) and the Eastern Cape Socio Economic Consultative Council (ECSECC) in March 2012.
d) Proposed Hydro-Electrical Power Schemes in the Eastern Cape and KwaZulu-Natal. A private sector initiative presented by EB Steam and Laman and Partners dated 22 January 2012.

A summary of each of these documents obtained is provided in the sub sections below.

a) Prioritised Strategic Projects for the Eastern Cape

The Eastern Cape Department of Economic Affairs, Environment and Tourism (DEAET) drafted the Prioritised Strategic Projects for the Province in August 2010. According to this report, several strategic projects have been identified which aim to harness Government spending for the economic recovery of the Eastern Cape Province.

A large emphasis is placed on reinstating the domestic economy on a new growth path. High potential sectors identified are located near the two Industrial Development Zones (IDZs), namely East London and Port Elizabeth, as well as the Wild Coast Development Zone and the Central Hinterland.

The report states that the urgent renewal of the primary sector requires investment in agricultural infrastructure, which will bring activity to the rural parts of the Province. Hence the realization of prioritizing the following clustered investments:

i) Logistics
ii) Water and Energy
iii) Telecommunications
iv) Renewable Energy
v) Forestry
vi) Agriculture and Environmental Management

The integrated Wild Coast Transport Hub is bolstered by the approved N2 Toll Road which reduces the travel distance between Mthatha and Durban by 75km. The route proposed by the South African National Roads Agency SOC Limited (SANRAL) will improve access to the Mzimvubu catchment and will link to the recently refurbished Mthatha Rail Line. The route of the N2 toll Road is shown in figure extracted from the report and is presented as Figure 2-5.

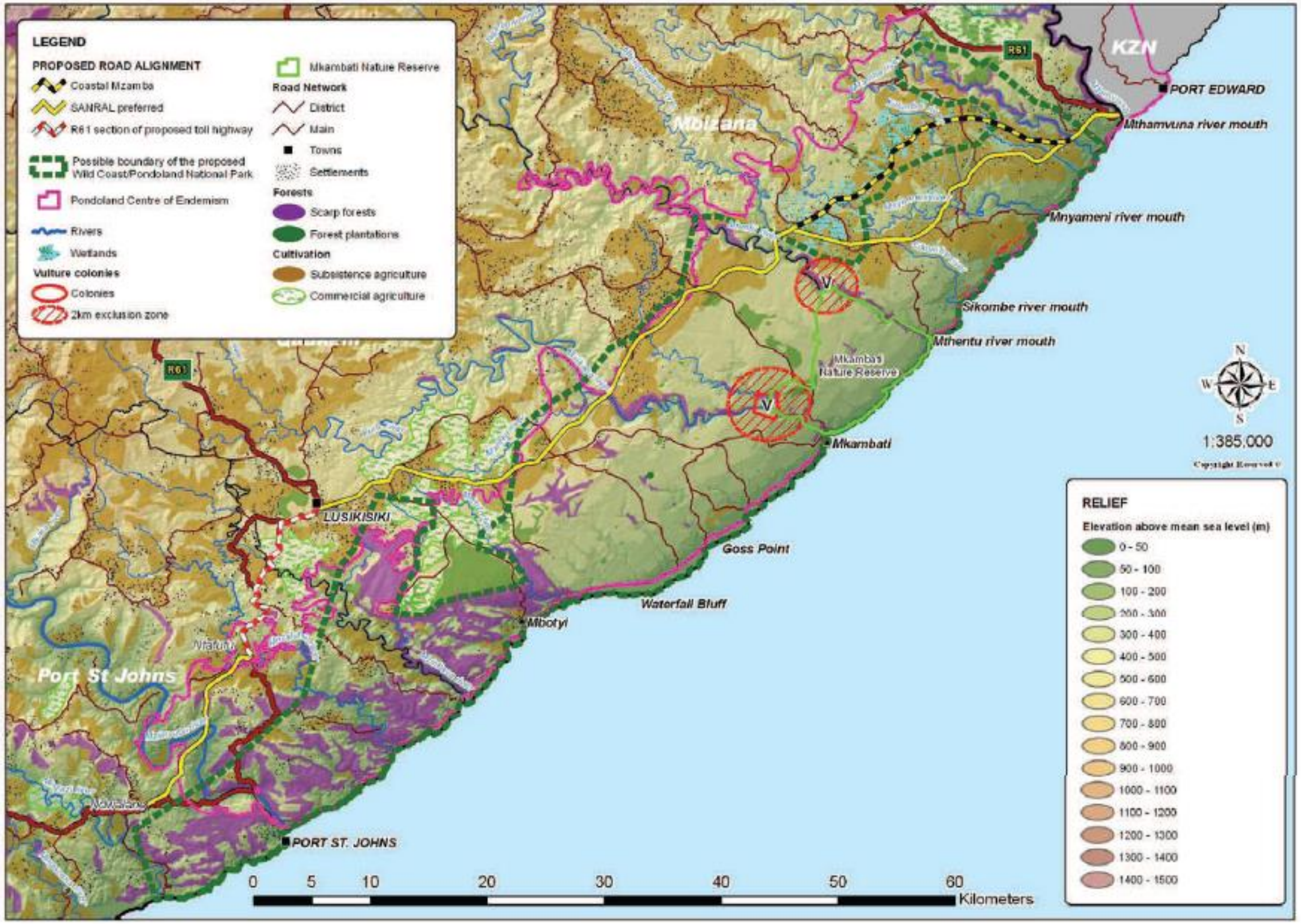


Figure 2-5: Proposed N2 Toll Road (Extraction from Prioritised Strategic Project Report DEAET 2010)

The East London Port Upgrade project is earmarked as a critical catalyst for High Impact Priority Projects (HIPP) including:

- The N2 Corridor Upgrade.
- The **Mzimvubu basin water development**.
- Forestry Cluster.
- **Agricultural development**, including bio-fuels.
- Kei rail initiative.
- Road infrastructure upgrade.

In the report reference is made to one of the prioritised projects identified under the Water and Energy cluster as the "**Ntabelanga Multi-purpose Water Resource Development**." The report states this development will provide several benefits including inter alia: the generation of hydropower; irrigation potential; regional water treatment plant and bulk water distribution network; job creation; and water supply. One of the key considerations noted in the DEAET report is the developed linkages with road and energy networks. The report further states that the Wild Coast Transport Hub, is therefore a critical link in the success of this resource development.

A summary of all the Prioritised Strategic Projects is indicated in Table 2-6.

Table 2-6: Prioritised Strategic Projects for the Eastern Cape

Priority	Zone			
	Wild Coast	Port Elizabeth	East London	Hinterland
Logistics	• Integrated Transport Hub • Provincial Parks Infrastructure	• Twinned Gateways • Relocation of Tank Farm and Manganese Terminal to Coega	• Upgrade of EL Harbour • R72-N2-N6 Link	• Provincial Parks Infrastructure
Water & Energy	• Ntabelanga Multi-Purpose Water Resource Development	• Project Mthombo • CCGT Power Station		• Bulk Water Transfer from Ntabelanga
Telecomms		• SeaCom Cable	• SeaCom Cable	
Renewable Energy			• Electric Vehicle Project • Bio-fuels Industry Development • Enabling Support for Alternative Energy Source Industries	
Forestry & Agriculture	• Forestry Development • Agricultural Development		• Bio-fuels Industry Development	
Environmental Management	• Environmental Management Framework (Emf) For Wild Coast • Wild Coast Illegal Cottages Investigations		• EMF for Buffalo City Municipality	• Operationalisation of landfill sites • Peddie Revitalisation Programme • Environment Sector EPWP Projects

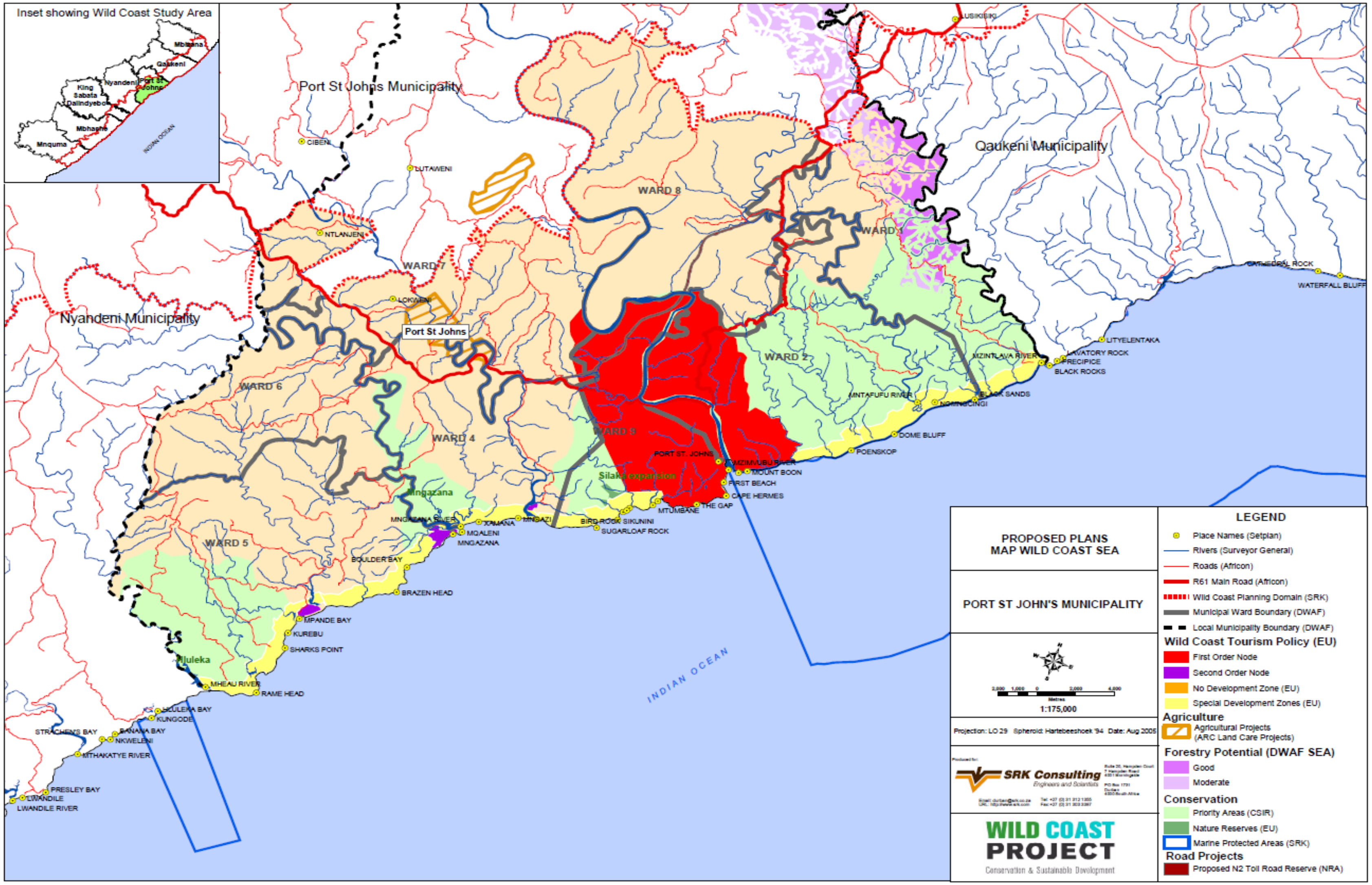


Figure 2-6: Proposed Plans from the Wild Coast Strategic Environmental Assessment

b) Integrated Wild Coast Development Programme

The Department of Economic Development, Environmental Affairs and Tourism (DEDEAT) have developed the Integrated Wild Coast Development Programme. The programme is aimed at accelerating project development through the deployment of financial and technical support. It is also a means of acquiring resources for project development and execution.

The programme identifies the lack of economic activity across the Eastern Cape. After assessing both Gross Value Added (GVA) and Gross Domestic Product (GDP) across the province, the development index reduces (i.e. gets worse) the further east in the Province one moves, while the services backlogs increase.

The Mzimvubu Catchment falls directly within this eastern area being referred to and reinforces the overarching aim of this study which is to improve the socio-economic conditions of the communities through the development of a multi-purpose storage structure.

Key focus areas of the Wild Coast Development Programme are:

- Infrastructure;
- Sector Support;
- Small Town development;
- Skills Development; and
- Waste and Environmental.

The execution of these focus areas is aligned in the following Key Projects, namely:

- N2 Wild Coast Road and Wild Coast Meander;
- Small Town Development (Port St Johns, Nyandeni Precinct, King Sabatha Dalindyebo and Mbizana); and
- Agro Processing.

2.6.4 Proposed Hydro-Electrical Power Schemes in the Eastern Cape and KwaZulu-Natal

At the time of this stage of the study, a private sector initiative was being put forward for the development of series of dams and tunnels within the Mzimvubu Catchment for the generation of approximately 170 MW of power. The five dams proposed to be constructed as part of this scheme are:

1. Ntlabeni (Kinira River);
2. Siqengeni (Kinira River);
3. Mangwaneni (Tina River);
4. Malepelepe (Tsitsa River); and
5. Laleni (Tsitsa River just above Tsitsa Falls).

These dams include some of the 19 identified dam sites under consideration.

The approach of the current Mzimvubu Water Project is the development of a multi-purpose storage structure which will maximise the stimulus to the regional economy, whereas the focus of this private initiative was purely for hydropower.

It is currently unknown whether this private initiative will proceed to implementation and therefore the Mzimvubu Water Project could not base decisions on it. However, cognisance was taken of the fact that some, if not all, of these five dams may be developed in the future as single purpose structures.

It was therefore noted that it may be possible for the final recommended option of the Mzimvubu Water Project to be incorporated into this private initiative at a later stage and may provide an additional income stream to the development. This was therefore carried forward for consideration during the Preliminary Study stage.

2.6.5 Summary of Impacts of Planned Development Initiatives on Dam Development Options

After reviewing the information at hand on the planned development initiatives within and around the Mzimvubu Catchment it was felt that the current selection criteria and the analysis of each dam site in relation to those criteria sufficiently covered any planned development initiatives.

For example it is clear that there are plans throughout the Eastern Cape to develop agricultural projects wherever possible and this has already been included in the analysis. Mention is made of the need for bulk water supply and this is covered through the assessment of the development options for their potential to provide domestic water supply.

Mention is also made of the development of the N2 Toll Road in the documents obtained. While it is understood that the road may bring development along the road corridor it is not considered to significantly impact on the decision making process on which three dams should be taken forward for further investigation. The reason for this is that the majority of the road corridor lie well outside of the Mzimvubu Catchment and it may be pertinent to link other water resource development initiatives outside of the catchment to the N2 Toll Road.

For any development initiatives around Port St Johns it will be possible to make downstream releases in order to provide water to these initiatives.

2.7 Recommendations for Final Selection

After taking into consideration the above analyses, the outcomes of the Screening Workshop, and the additional desktop analysis undertaken subsequent to the workshop, a final discussion was held at a PSC Meeting held on 26 July 2012.

Four dams were removed from further investigation based on the following reasons:

- Nomhala was considered to have relatively low yield potential and greater environmental impacts than Ntabelanga along with a higher URV value than some options and was therefore recommended to be removed from further investigation.
- Laleni and Mbokazi were considered to be largely single purpose dam sites for hydropower. Both of these development options are considered to have no agricultural potential and therefore their potential for job creation is considered to be low. Both dam sites were considered to have high environmental impacts, with Mbokazi in particular, considered to have a high impact on the important and sensitive estuary of the Mzimvubu River. Due to the fact that the main aim of this project is the stimulus of the regional economy through the development of a multi-purpose storage it was agreed to remove them from further investigation.
- Mpindweni was considered to have medium potential for most of the selection criteria but has no agricultural potential and therefore low job creation potential. It was therefore agreed to take this out from further investigation.

It was therefore proposed and agreed at the subsequent PSC meeting that the final three dam sites for further investigation during the Preliminary Study stage would be the following:

- **Thabeng on the Kinira River.**
- **Somabadi on the Kinira River**
- **Ntabelanga on the Tsitsa River.**

The locations of these three dams are shown in Figure 2-7.

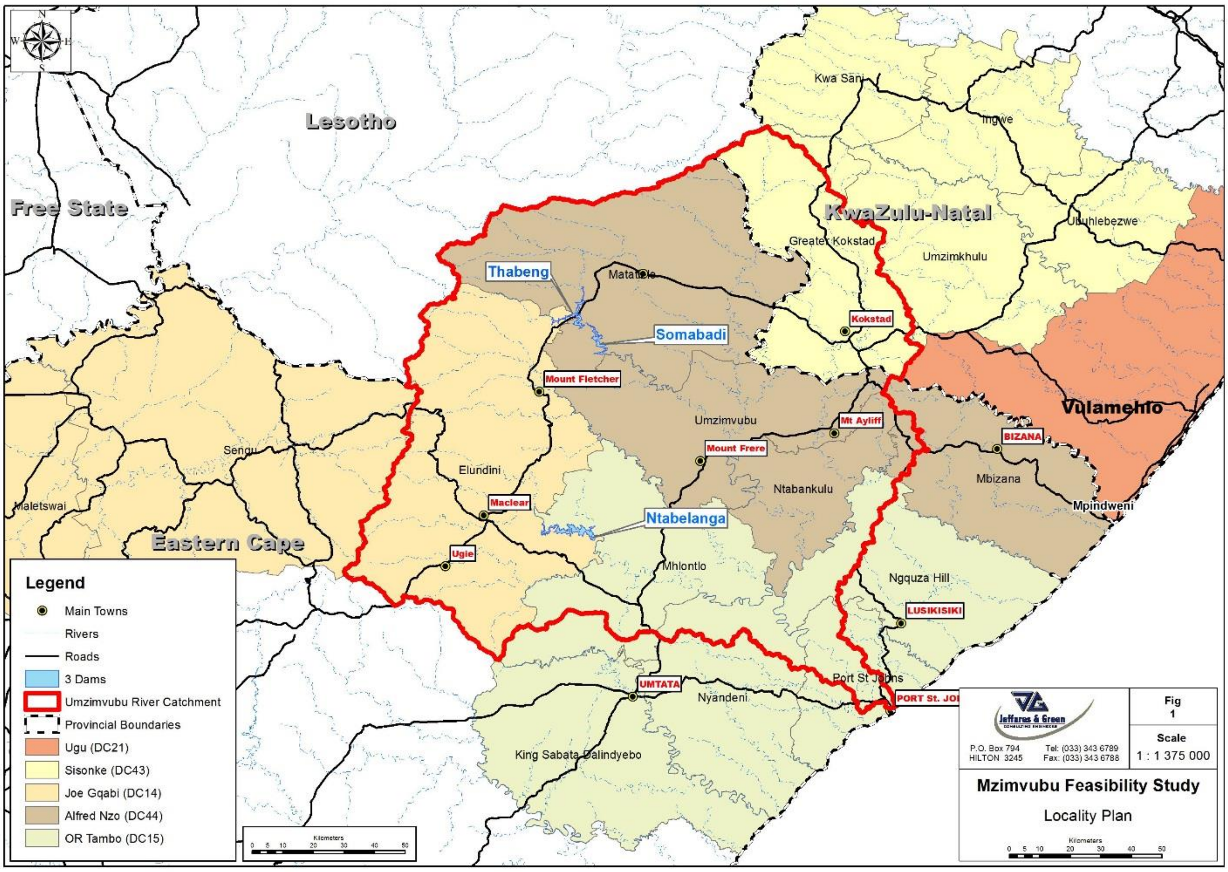


Figure 2-7: Locations of Final Three Dam Sites

3. PRELIMINARY STUDY – ACTIVITIES UNDERTAKEN

3.1 Purpose of Study

Following on from the Desktop Study stage, the aim of the Preliminary Study was to gather more information with regards to the three selected development options as well as to involve the Eastern Cape Provincial Government and key stakeholders in the process of selecting the single best development option to be taken forward into the Phase 2 Feasibility Stage of the Study.

The main activities undertaken, inter alia, as part of the second stage of Phase 1 were as follows:

- Stakeholder involvement;
- Environmental screening;
- Water requirements (including domestic water supply, irrigation and hydropower);
- Hydrological investigations;
- Geotechnical investigations;
- Topographical survey investigations;
- Selection process; and
- Reporting.

As described in the Inception Report (DWA Report Number P WMA 12/T30/00/5212/1) it was decided to undertake some advance core drilling beneath each embankment wall flank of all three shortlisted dam sites, as well as topographical surveys of the impoundment areas of all three dams to improve the accuracy of information required to estimate costs and to check for any fatal flaws that might be present as regards dam wall foundation conditions.

For the same reasons, the water resources yield assessment task (detailed hydrology and WRYM yield modelling) was also advanced to Phase 1 for all three dams instead of being applied only to one dam in Phase 2 as was originally planned.

The Inception Period and the Desk Top Study period were also used to investigate further sources of data, and to obtain, collate and review such data to be considered during the Desktop Study and to be utilized where appropriate in the Preliminary Study analyses.

3.2 Information Sources

Several different organisations from different sectors were contacted in order obtain information related to previous investigations as well as to obtain other relevant information that would be useful in the analysis that was required to be undertaken. The organisations that were contacted are as follows:

- AsgiSA-EC;
- Department of Water Affairs – Regional and National;
- Office of the Premier – Eastern Cape;
- Alfred Nzo District Municipality;
- OR Tambo District Municipality;
- Joe Gcabi District Municipality;
- Sisonke District Municipality;
- Eastern Cape Department of Economic Affairs, Environment and Tourism;
- ESKOM;
- University of Pretoria;
- University of Stellenbosch;
- Department of Environmental Affairs;

- Water Research Commission (WRC);
- AURECON Consulting Engineers;
- BKS (now AECOM) Consulting Engineers;
- Makhoatse Narasimulu and Associates; and
- Umpisi Engineers.

3.3 Overview of Data and Information Received

The types of information collected from the various organisations are as follows:

- Spatial data sets relating to water services, population, agricultural potential and existing infrastructure;
- Previous related studies undertaken in the Mzimvubu river catchment including obtaining of reports and hydrological and financial models; and
- Climatological, streamflow and rainfall data.

A summary Table 3-1 is provided overleaf of the different types of data and information received and from where they were obtained.

Table 3-1: Summary of Data Received/Obtained (1 of 2)

DATA	SOURCE
Environmental - General	
Eastern Cape Critical Biodiversity Areas	SANBI
Wetlands	SANBI
Land cover	SANBI
Land Use	SANBI
SANBI Data - Full suite	SANBI
• Land cover (NLC 2000)	SANBI
• Biomes	SANBI
• Protected Areas	SANBI
• Threatened Ecosystems	SANBI
• Vegetation Types	SANBI
• Wetlands	SANBI
• Water Management Areas	SANBI
ENPAT - National Dataset	
• BioAtlas	ENPAT
• Biological Productivity	ENPAT
• Biomes	ENPAT
• Drainage Regions	ENPAT
• Erodibility Index	ENPAT
• Geology	ENPAT
• GGP (1994)	ENPAT
• Land Use	ENPAT
• Morphology	ENPAT
• Population	ENPAT
• Rainfall	ENPAT
• Runoff	ENPAT
ENPAT - Provincial Dataset	
• Biospheres	ENPAT
• Catchments	ENPAT
• Conservation	ENPAT
• Soils	ENPAT

DATA	SOURCE
• Veld Types	ENPAT
Groundwater	GRIP
Rivers	DWA
Dams - Existing	DWA
Contours (20m)	SG Data
Afforestation areas	
DWAF plantations	ASGISA
Private Plantations	ASGISA
Private Managed Plantations	ASGISA
Hydrometric Data	
Rainfall Stations (Daily, monthly and Annual Depth)	DWA Regional: Craddock
Streamflow Gauges (Daily, Monthly and Annual Discharge)	DWA Regional: Craddock
Streamflow Gauges (Monthly **Discharge/Stage))**	HYDSTRA
Population / Community Data	
• Community footprints	DWA 2008
• Household count	ESKOM - 2006 Spot Imagery
• Rural/ Urban split data	Municipalities
Infrastructure	
DWA Water Schemes - Planned and Current (incl. pumpstations/ wtw/ reservoirs/ pipelines etc.)	DWA
Infrastructure - Roads/ railway/ powerlines etc.	SG Data
HV and MV Powerlines	ESKOM
Other	
Heritage sites	SAHRA/ AMAFA
ALL DATA FROM PRE-FEASIBILTY PHASE	
Woodland Areas	BKS
State Managed Plantations	BKS
Natural Forests	BKS
Forestry Activity	BKS
Forestry Potential	BKS
New Natural Forests	BKS
Catchment area rivers	BKS
Critical Biodiversity Areas	BKS
Commercial Irrigated Land	BKS
NECF Commercial Areas	BKS
Potential PSS	BKS (Golder)
Proposed Dam Sites	BKS (Golder)
Community Footprints by DM	BKS
Backlog Data and Community Services	BKS
EC Evaporation	BKS
Rainfall - Average MAP	BKS
KZN DWAF Schemes	BKS (Bigen)
KZN Land Use	BKS (Bigen)
KZN Livestock	BKS (Bigen)
KZN Need Clusters	BKS (Bigen)
KZN Pollution	BKS (Bigen)
KZN Rainfall	BKS (Bigen)
KZN Sanitation Schemes	BKS (Bigen)
KZN Rehabilitation Water	BKS (Bigen)
KZN Rehabilitation Sanitation	BKS (Bigen)

DATA	SOURCE
KZN Schemes 2007	BKS (Bigen)
KZN 100m contours	BKS (Bigen)
KZN WMAs	BKS (Bigen)
Boreholes	BKS
Bulk Pipelines	BKS
Digitized Projects	BKS (Mike Wells)
Mvula Trust Projects	BKS
Reservoirs	BKS
Service Supply Timeframes	BKS
WWTW	BKS
Tribal Authority Areas	BKS
WR4322 - Region	BKS
Industrial Areas	BKS
Mines and Quarries	BKS
District Municipalities Water and Sanitation Projects - Infrastructure	
Infrastructure Inputs	Sisonke DM
Infrastructure Inputs	OR Tambo DM
Infrastructure Inputs	Alfred Nzo DM

Table 3-2 shows the rainfall stations for which varying lengths of record length were obtained for use in the hydrological analysis as part of the study. .

Table 3-2: Rainfall Stations

SAWS Gauge Number	Gauge Name	SAWS Gauge Number	Gauge Name
0178881	Mount Fletcher Ink	0152475	Nqadu Heights Plantation
0179344	Colwana Bos	0152640	Qumbu
0179501	Cancele	0152792	Bencutti Plantation
0179713	Amanzamnyama Bos	0178378	Elands Heights
0179790	Ishatsheni Bos	0178807	Kromhoek
0179864	Mount Frere Ink	0178615	Delvillebos
0206588	Sinclair	0178585	Bloegomhof
0206738	Avondale Sap	0179353	Etwa Bos
0207108	Ade	0152482	Cengcane Bos
0207337	Qachasnek	0152792	Bencutti Plantation
0207402	Mont Plaisir	0152259	Bele Plantation
0207531	Matatiele	0152054	Mhlahlane Plantation
0207560	Matatiele Ink	0150635	Lisburn
0151604	Maclear	0150581	Barkly Pass Pol
0151623	Hopefield	0178807	Kromhoek
0152190	Ntywenka Plantation	0151402	Ugie Mun
0152259	Bele Plantation	0152172	Ceka Plantation
0152468	Isolo	0178689	Sheeprun

Table 3-3 shows the streamflow gauges for which varying lengths of record length were obtained for use in the hydrological analysis as part of the study.

Table 3-3: Streamflow Gauges

Streamflow Gauge Number	Gauge Name
T3H001	Mabele River @ Gladstone
T3H002	Kinira River @ Kinira Drift
T3H003	Tsitsa River @ Halcyon Drift
T3H005	Tina River @ Mahlungulu
T3H006	Tsitsa River @ Xonkonxa
T3H007	Mzimvubu River @ Ku-Makhola
T3H009	Mooi River @ Maclear
T3H014	Inxu River @ St Augustine Mission
T3H019	Kinira River @ Mgungundlovu

3.4 Topographical Surveys

Previous studies relating to the Mzimvubu River Basin have relied upon existing mapping which typically had contour intervals of 20 metres. Newer Google Earth imagery also only offers elevation accuracies of between ±15 and ± 30 metres.

Such accuracy was considered insufficient for Phase 1 of this study, as it was considered important to use more accurate elevation data to generate elevation verses area verses volume information for the three shortlisted dam sites, as well as cross-sections of each of these three dams being investigated in Phase 1.

Undertaking a more detailed survey in Phase 1, with contour intervals at 0.5 m, would provide early information to be able to produce more reliable area/volume verses depth information, which in turn improved the yield modelling results. The new topographical information also provided accurate cross-sections at the dam wall, which also improved the cost estimation accuracy. Finally, the aerial imagery produced by the new topographical survey provides up to date information regarding land use, roads and settlements, which will greatly assist the Environmental and Social Impact Assessments, as well as information required for land aspects, compensation, resettlement, etc.

It was therefore decided to utilize a part of the Provisional Sum allowed for in the Contract to undertake a detailed topographical survey of the dam wall centreline and the inundation footprints of each of the three identified dam sites at Ntabelanga on the Tsitsa River, and at Thabeng and Somabadi, on the Kinira River.

A Terms of Reference, Survey Specification and Request for Proposals were prepared, and quotations were invited from established specialist surveying companies for these services, through the DWA's normal procurement process.

The contract to undertake the topographical survey was awarded to Southern Mapping Geospatial (Pty) Ltd (SMG)

The topographical survey was carried out using an aircraft mounted LIDAR[3] system that scanned the ground below with a 70 kHz laser beam rate resulting in a dense DTM of the ground surface and objects above the ground.

Digital colour images were also taken from the aircraft and rectified to produce colour orthophotos of the project area.
The survey was flown at a height of some 1200m and an image pixel size of 15cm was obtained.

3.4.1 Deliverables

A full suite of survey data files, imagery, and other information was supplied to the Study Team on DVDs. This includes:

CAD design files in Microstation DGN, DWG and DXF format showing:

- Orthophoto tiles layout;
- LiDAR point block layout;
- Contours at 0.5m, 2m and 10m intervals*;
- The project area surveyed with boundaries;
- Ortho-rectified aerial images with a 15cm pixel resolution in GeoTiFF and ECW format;
- Composite images of the different dam areas in 0.5m pixel resolution;
- Thinned Ground and Non-ground LiDAR laser points in ASCII format; and
- Full Ground and Non-Ground LiDAR laser points in ASCII format.

*These contours have been smoothed and are merely an aesthetic representation of the ground shape.

All of the above data are in the Hart94 WG29 coordinate system with orthometric heights as calculated in TerraScan using the SAG2010 geoidal model.

Also provided on CD were the following supporting documentation:

- Google Earth Image Overlay;
- Ground survey report; and
- A Factual Report.

3.4.2 Detailed Report on Surveys

Full details of these surveys are given in DWA Report Number P WMA 12/T30/00/5212/11 - Topographical Surveys which is a Phase 2 deliverable.

3.5 Hydrology

The Rainfall-Runoff and Yield Hydrology was undertaken and completed in detail for the three preferred dam sites.

The detailed report on methodology and outputs of these hydrological aspects is presented in DWA Report Number P WMA 12/T30/00/5212/5 – Water Resources, which is a Phase 2 deliverable.

3.5.1 Yield Hydrology

The purpose of the yield hydrology analysis of the three selected dam sites in the Mzimvubu Catchment was to assess the water resource capability (or "yield") of each dam, for a range

[3] ***LiDAR** (**Li**ght **D**etection and **R**anging or **L**aser **I**maging **D**etection and **R**anging) is an optical remote sensing technology that can measure the distance to, or other properties of, targets by illuminating the target with laser light and analyzing the backscattered light.*

of storage options, while including releases to support downstream environmental water requirements and the possible long-term loss of available storage in the dam as a result of sedimentation.

The analysis posed significant challenges, mainly because of the limited amount of quality measured hydro-meteorological data available in the Mzimvubu catchment. As a result, significant additional effort was required for the collection of available data sets. However, the final results obtained from the analysis are considered to reasonably represent the water resources characteristics of the three dams and their catchments and fall within the confidence levels generally accepted for such assessments.

Rainfall-runoff modelling was the primary activity of the hydrological assessment and involved a process whereby the runoff response of the Kinira and Tsitsa River catchments were simulated based on the monthly time-series of representative catchment rainfall data.

For this purpose, the enhanced Water Resources Simulation Model 2000 (WRSM2000) was used, a model which has been under continuous development by the South African Water Research Commission (WRC) for over 20 years.

In setting up and calibrating the rainfall-runoff models, cognisance was taken of the upstream land use in the catchment areas, which included assessment of soil types, terrain characteristics, erosion, forestry, agriculture, and existing small dams.

This process produced data files that were used in the yield model simulations as well as an updated assessment of the Mean Annual Runoff (MAR) of the rivers at the proposed location of the dam sites under investigation.

The rainfall-runoff results presented by the BKS report were based entirely on the WR2005 Study configurations and inputs. During Phase 1 of this study several of the input parameters were changed as a more detailed investigation was undertaken in obtaining the required input information. The change in input values for various parameters, mainly rainfall and landuse, required the rainfall-runoff model to be re-calibrated against the observed streamflow data (this will be reported upon fully in the DWA Report Number P WMA 12/T30/00/5212/5 – Water Resources, which is a deliverable of Phase 2 of this Study).

The change in inputs and the re-calibration against observed data resulted in some differences in the resultant naturalised streamflows produced in this study when compared to the BKS study.

The rainfall results in this study differed from the BKS study in several instances, with some of the quaternary catchments having similar values and others having values up to 20 % different. These differences were considered to be as a result of the use of additional rainfall data (through the inclusion of additional rainfall gauges) in the patching process and, to a lesser extent, due to the extension of the rainfall record from 1920 – 2009, as opposed to 1920 – 2004 (WR2005). For more information on the development of quaternary catchment rainfall in each system, refer to the above-referenced Water Resources Report.

The landuse used in the rainfall-runoff modelling was based on the latest information available at the time of this study. These values, especially the area of forestry in each quaternary catchment, differed significantly, often as much as 50 %. In order to confirm the validity of the new landuse information used in the modelling, Alan Bailey of Royal Haskoning DHV was contacted as he played an integral role in the configuration and development of the WR2005 database, which was used in the BKS Study.

Mr Bailey agreed that the approach used in this study was more detailed than in the WR2005 study, which was used by BKS, and confirmed that the new landuse areas may be more representative for use. In addition, the WR2005 rainfall-runoff configuration in WRSM2000 did not include allocations for farm dams, which were included in this study. While the impact on the limited number of farm dams in the system is not considered to be significant, this would have had an impact on the results when comparing the two output datasets (i.e. J&G 2013 vs. BKS/WR2005).

These changes to the inputs of the rainfall-runoff modelling enabled a reasonable calibration to the recorded streamflow data at the gauge below the proposed dam site in each system (i.e. the Tsitsa and Kinira River Systems). Thus, the results were adopted for use in Phase 1 of this study. These results will be reviewed and refined, where necessary, in Phase 2 of this study.

These MARs as developed by the above process, were as summarized in the following Table 3-4.

Table 3-4: Summary of Mean Annual Runoff Values for the Three Selected Dam Sites

Dam Site	MAR (million ^{m3}/a)
Somabadi	361
Thabeng	290
Ntabelanga	327

3.5.2 Environmental Water Requirements

Environmental Water Requirements (EWR) are very important to downstream ecosystems and are related to the characteristics and timing of natural streamflows.

A Rapid Reserve Determination was undertaken for comparison of the three dam sites, with a summary of the results as presented in Table 3-5.

The yield modelling simulations included these allowances for EWR using these rapid reserve determinations.

The finally selected dam site will include an Intermediate Reserve Determination, which may change the EWR value selected.

Table 3-5: Summary of Rapid Reserve Determination Results for the Three Selected Dam Sites

Dam Site	Rapid EWR Class	Annual EWR Allowance (million m^3/a)	% MAR – Total Flows (%)	% MAR – Maintenance and Drought Low Flows (%)
Somabadi	C	104.98	29.08	22.91
Thabeng	C	84.33	29.08	22.91
Ntabelanga	D	52.82	15.90	12.26

2.5.3

3.5.3 Sedimentation

The dam yield analysis process required an assessment of the volume of sediment that would be trapped by each dam over its lifespan.

The empirical Rooseboom Method of calculating sediment deposition in each dam was undertaken.

The detailed calculations are presented in detail in the above mentioned Water Resources report, however, Table 3-6 presents the V_{50} sedimentation allowance volume (storage allocation to accommodation 50 years of sedimentation into the dam without impacting upon the yield of the impoundment).

Table 3-6: Summary of Sedimentation V_{50} values for the Three Selected Dam Sites

Dam Site	Sedimentation V_{50} (million m^3)
Somabadi	42.80
Thabeng	38.44
Ntabelanga	29.30

3.5.4 Yield Analysis

The time-series generated from the rainfall-runoff modelling were used as an input into the enhanced Water Resources Yield Model (WRYM) in order to undertake the yield scenarios. The purpose of the yield analysis of the three dams was to assess the yield of each dam for a variety of situations, based on the hydrological characteristics of its catchment, the dam's physical basin characteristics, the impacts of sedimentation, the usable dam capacity, and allowing for releases for downstream environmental water requirements. For this purpose, a number of scenarios were defined for each dam as summarised in Tables 3-7 to 3-9.

Table 3-7: Yield Analysis Scenarios Investigated– Somabadi Dam Site

Scenario		Reservoir					EWR		
Code	Name	FSL (mAMSL)	MOL (mAMSL)	Tot Cap (million m^3)	Live Cap (million m^3)	Area (km^2)	Class	Req. (million m^3/a)	Req. (%MAR)
01	Current + 0.10 MAR + C Class EWR	1302.1	1301.0	47.080	4.280	4.081	C	104.979	29.1%
02	Current + 0.25 MAR + C Class EWR	1310.4	1301.0	90.250	47.450	6.379	C	104.979	29.1%
03	Current + 0.50 MAR + C Class EWR	1320.9	1301.0	180.500	137.700	9.901	C	104.979	29.1%
04	Current + 1.00 MAR + C Class EWR	1333.9	1301.0	361.000	318.200	15.764	C	104.979	29.1%
05	Current + 1.50 MAR + C Class EWR	1339.6	1301.0	444.030	401.230	18.344	C	104.979	29.1%

Table 3-8: Yield Analysis Scenarios Investigated – Thabeng Dam Site

Scenario		Reservoir					EWR		
Code	Name	FSL (mAMSL)	MOL (mAMSL)	Tot Cap (million m^3)	Live Cap (million m^3)	Area (km^2)	Class	Req. (million m^3/a)	Req. (%MAR)
01	Current + 0.15 MAR + C Class EWR	1364.9	1363.9	43.500	5.060	5.023	C	84.332	29.1%
02	Current + 0.25 MAR + C Class EWR	1369.8	1363.9	72.500	34.060	6.912	C	84.332	29.1%
03	Current + 0.50 MAR + C Class EWR	1378.3	1363.9	145.000	106.560	10.125	C	84.332	29.1%
04	Current + 1.00 MAR + C Class EWR	1387.6	1363.9	290.000	251.560	15.456	C	84.332	29.1%
05	Current + 1.50 MAR + C Class EWR	1396.2	1363.9	435.000	396.560	20.703	C	84.332	29.1%

Table 3-9: Yield Analysis Scenarios Investigated – Ntabelanga Dam Site

Scenario		Reservoir					EWR		
Code	Name	FSL (mAMSL)	MOL (mAMSL)	Tot Cap (million m^3)	Live Cap (million m^3)	Area (km^2)	Class	Req. (million m^3/a)	Req. (%MAR)
01	Current + 0.10 MAR + D Class EWR	917.3	916.7	32.230	2.930	4.031	D	52.823	15.9%
02	Current + 0.25 MAR + D Class EWR	925.7	916.7	81.750	52.450	8.512	D	52.823	15.9%
03	Current + 0.50 MAR + D Class EWR	932.7	916.7	163.500	134.200	15.050	D	52.823	15.9%
04	Current + 1.00 MAR + D Class EWR	940.6	916.7	327.000	297.700	24.213	D	52.823	15.9%
05	Current + 1.50 MAR + D Class EWR	947.3	916.7	490.500	461.200	32.844	D	52.823	15.9%

The results for each of the scenarios undertaken per dam site are presented in Tables 3-10 to 3-12.

Table 3-10: Yield Analysis Results – Somabadi Dam Site

Scenario		HFY	Yield (Million m3/a) at RI, annual assurance		
Code	Name		1:4	1:20	1:50
		(million m^3/a)	75.0%	95.0%	98.0%
01	Current + 0.10 MAR + C Class EWR	8.38	11.60	11.45	10.40
02	Current + 0.25 MAR + C Class EWR	48.40	73.40	72.40	65.00
03	Current + 0.50 MAR + C Class EWR	107.40	128.20	127.30	115.50
04	Current + 1.00 MAR + C Class EWR	147.60	184.50	183.20	163.90
05	Current + 1.50 MAR + C Class EWR	161.60	201.50	200.90	178.40

***Notes**: (1) HFY = Historical firm yield, based on an analysis over a 90-years period, from 1920 to 2009 (hydrological years).*
(2) RI = Recurrence interval of failure, in years, based on a long-term stochastic yield analysis of 201 50-year generated streamflow sequences.

Table 3-11: Yield Analysis Results – Thabeng Dam Site

Scenario		HFY	Yield (Million m3/a) at RI, annual assurance		
Code	Name		1:4	1:20	1:50
		(million m^3/a)	75.0%	95.0%	98.0%
01	Current + 0.15 MAR + C Class EWR	7.15	9.30	9.00	8.20
02	Current + 0.25 MAR + C Class EWR	30.35	48.00	47.40	41.40
03	Current + 0.50 MAR + C Class EWR	76.50	92.30	90.90	80.80
04	Current + 1.00 MAR + C Class EWR	108.60	141.10	139.20	121.00
05	Current + 1.50 MAR + C Class EWR	133.90	168.00	166.50	143.20

Table 3-12: Yield Analysis Results – Ntabelanga Dam Site

Scenario		HFY	Yield (MillionCM/a) at RI, annual assurance		
Code	Name		1:4	1:20	1:50
		(million m^3/a)	75.0%	95.0%	98.0%
01	Current + 0.10 MAR + D Class EWR	23.30	29.18	29.00	26.80
02	Current + 0.25 MAR + D Class EWR	65.90	93.00	91.50	77.10
03	Current + 0.50 MAR + D Class EWR	114.00	140.50	138.50	123.00
04	Current + 1.00 MAR + D Class EWR	157.60	201.00	192.90	171.70
05	Current + 1.50 MAR + D Class EWR	186.45	221.10	218.20	198.80

3.6 Geotechnical Investigations

As described above, the decision was made to undertake some core drilling of the three shortlisted dam sites in Phase 1, to supplement the geotechnical reconnaissance that was originally planned. This was to provide early information to inform dam type selection, and to ensure that there were no fatal flaws that would affect the dam type selection, cost, or overall viability of any one of the three dam sites.

These investigations comprised core drilling of boreholes, each 40 m deep, with one on each flank of each proposed dam wall centreline.

A full description of the geotechnical investigations undertaken in both Phases 1 and 2 is given in DWA Report Number P WMA 12/T30/00/5212/10 – Geotechnical Investigations, which is a Phase 2 deliverable.

3.6.1 Summary of Findings

a) Ntabelanga Dam Site Assessment

The geotechnical reconnaissance assessments and subsequent drilling did not identify fatal flaws in the context of geological or geotechnical constraints. The site occupies a steep sided, U-shaped valley profile with a low length to height ratio. There is good founding on dolerite and construction materials appear to be readily available in the basin within relatively short haulage distances.

Conversely, the steep valley sides have proved difficult to access the site for investigation purposes. The left hand side river bank a few hundred metres upstream of the dam shows evidence of past sliding, which could be exacerbated during dam filling.

Whilst not appearing to represent an overly onerous constraint to overall stability, this will be further assessed should this site be selected for further detailed investigation. The dam would bring about inundation of roads and agriculture in the basin.

b) Thabeng Dam Site Assessment

The investigations undertaken did not detect any fatal flaws that would preclude the construction of a dam at this site. The valley sides are particularly steep and whilst this is conducive to a good area to storage ratio it renders mechanical access difficult. The site offers good founding and cut-off conditions, mainly on dolerite and also sedimentary rocks on the left flank.

From the initial assessment undertaken, no good sources of core or rock aggregate were identified in the basin, but these appear to occur in abundance a relatively short distance downstream of the site.

As such areas would not be inundated following completion of the dam their exploitation would incur more stringent environmental and rehabilitation restrictions. A dam at this site would inundate some major infrastructural developments, including roads, pipelines and a water treatment works.

c) Somabadi Dam Site Assessment

No fatal flaws were identified and there is good founding on sandstone. The site occupies a steep U-shaped valley, which is particularly steep on the right flank.

Construction materials appear to occur in abundance within relatively short haulage distances of the site.

Vehicular and plant access along the dam axis is made difficult by to the steep valley sides. Inundation of roads and cultivation would occur in the basin. The pronounced bedding of the sandstone could lead to increased grout takes.

3.7 Water Requirements

3.7.1 Introduction

In Phase 1, a high level assessment of future water demands was undertaken to be able to estimate the required size and cost of each of the three shortlisted dams being investigated.

Primary water demands to be considered in this regard were as follows:

- Potable water supply;
- Water for agriculture;
- Forestry; and
- Environmental water requirements (EWR).

A further potential use for water in these catchments would be to generate hydropower, although, (unless diverted to another catchment), such water demand is not normally a net consumer of water within a catchment, but is typically used and released back into the system. The water used for hydropower can also constitute the same water that is released downstream for eventual use for potable supply, irrigation, and/or EWR, but obviously not the spillage portion.

Forestry itself is not a demand on the river system per se other than its interception of rainfall into the catchments, which reduces runoff. This demand, as well as water intercepted by dams and other abstractions located above each studied dam site, is taken into consideration when developing the yield hydrological models.

Environmental water requirements at each dam are determined by the ecological needs of the river system below the dams, and were determined using the methodologies described in the reserve determination section of this report. The EWR for each dam has thus been provisionally determined by the reserve determination team and has been incorporated as a “demand channel” in the Water Resources Yield Modelling (WRYM) described in the relevant section of this report.

The main water requirements described below therefore focus on the potable water supply and irrigated agriculture water demands within the zones that could be viably served by each of the three dams.

Only once these primary water requirements had been determined to size the dams, were further options then investigated regarding the hydropower potential of these dams.

3.7.2 Potable Water Supply

a) Initial Screening Process

The existing coverage and future needs of potable water supply in the catchment were one of the criteria used in screening the initial 19 dam sites, and this has been described elsewhere in this report.

Information on these criteria was gathered and analysed using a GIS system. The levels of coverage and needs criteria were ranked as a part of the overall selection process which was used to shortlist to three dam sites, upon which more detailed investigations were undertaken regarding population and water demands.

b) Potable Water Demands for the Shortlisted Three Dam Sites

The methods used to determine water demand projections at this preliminary study level were presented to and agreed with the key stakeholders at a PSC meeting. GIS was information obtained from both DWA and the District Municipalities, which included the locations, extents and populations of communities, digital terrain models, sizes and extents of the water supply systems that had been developed, or were planned to be implemented.

In general, the principle applied was to not exclude any existing schemes or sources from the water demand projections at this stage, as there was always the possibility that both existing and future schemes might in future be supplied by the new dams being considered under this project.

In Phase 2, this situation will be revisited and schemes that already have viable, reliable, and cost-effective sources would be removed from the overall demand projections.

In terms of developing the required system coverage and projected potable water demands, two scenarios were considered, namely a BASE case whereby “expected” demands have been estimated, and a HIGH case, whereby growth scenarios have been used that represent the “upper end of possible demand”.

The “BASE case” demand scenario is derived from the total population that can be supplied from the river within 180 m altitude above river level (actually an “expected” scenario). This relates to limiting the pumping head and pressure classes of pipe to 18 bar, which, in the case of the three dams being investigated, happens to include a high proportion of the communities within the watershed boundaries running parallel to the river.

The “HIGH” demand scenario is the total population within the watershed boundary (including those at significantly higher elevation than 180 m above river level) plus allowance of 15% for over-watershed supply (an upper end of possible demand). This latter allowance assumes that some of these over-watershed communities could be supplied by treated water storage tanks located along crests of the watershed boundary.

This provides a range of potable water demands upon which the economic comparison of the three dams can be based on a similar basis. These allowances are deemed to include some headroom for potential commercial and small industrial demand.

The **Figures 3-1, 3-2 & 3-3** below show this situation graphically with BASE case demand communities indicated in **green** and the additional HIGH case communities in **orange**.

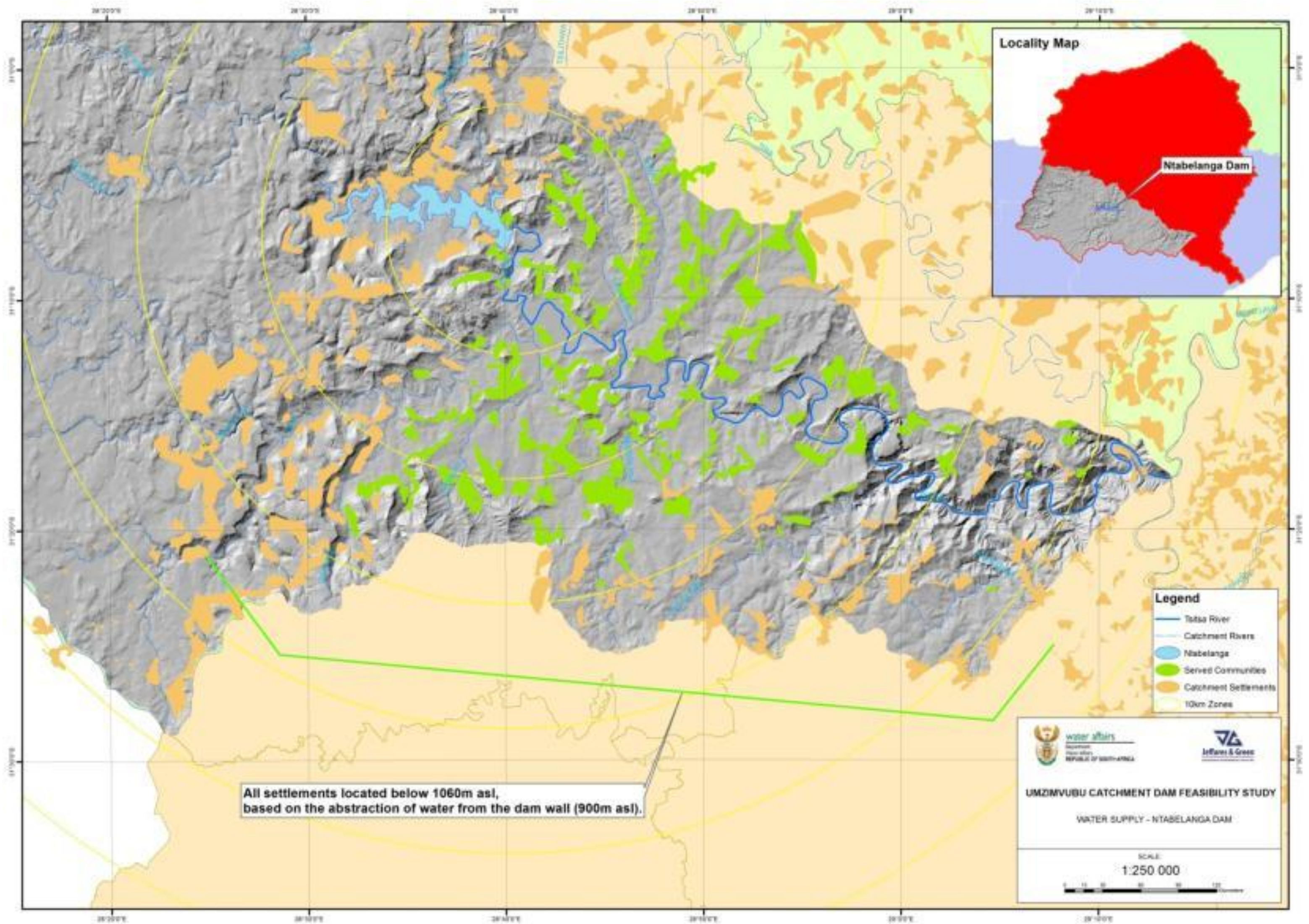


Figure 3-1: Potential Communities that could be supplied by Ntabelanga Dam

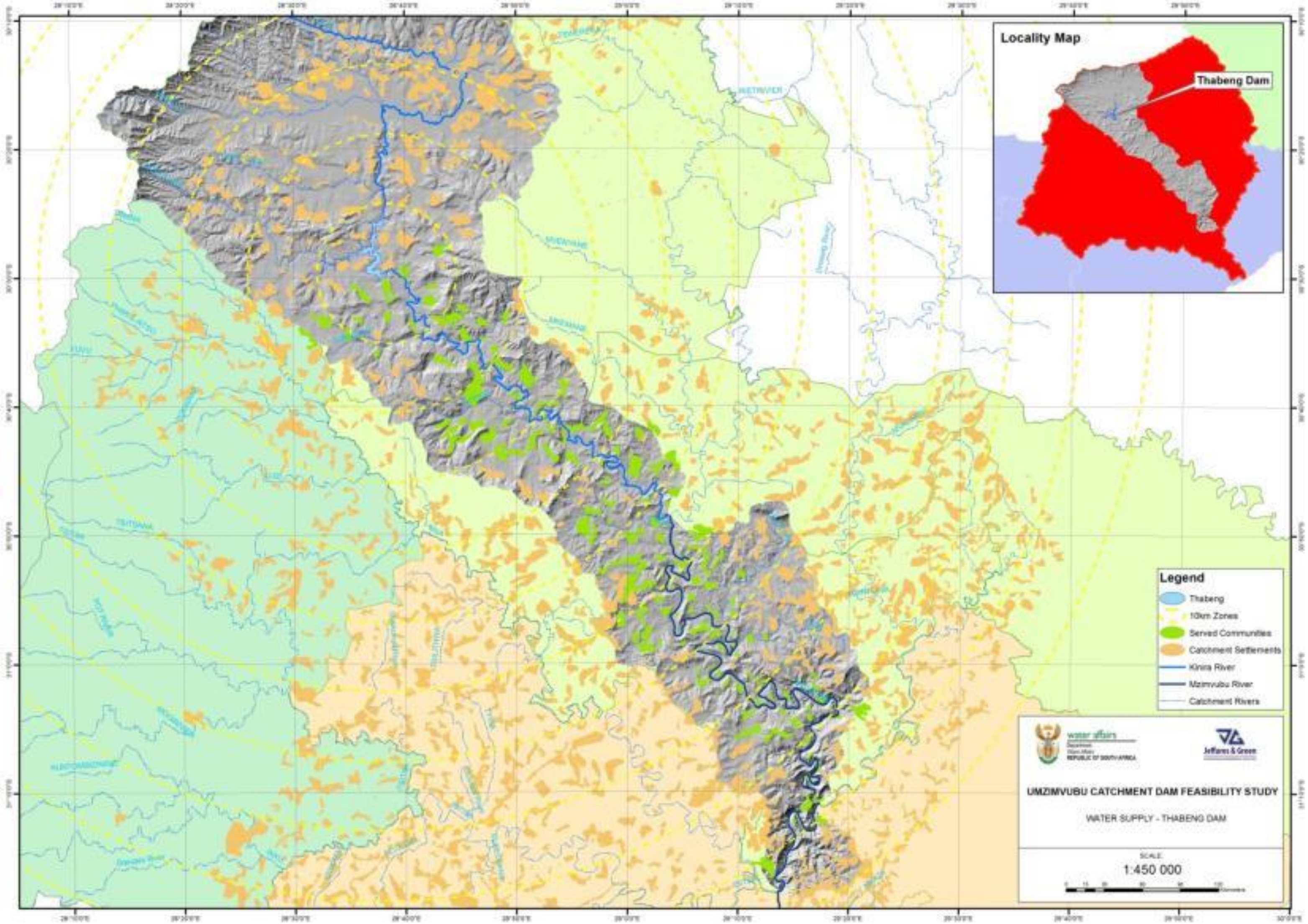


Figure 3-2: Potential Communities that could be supplied by Thabeng Dam

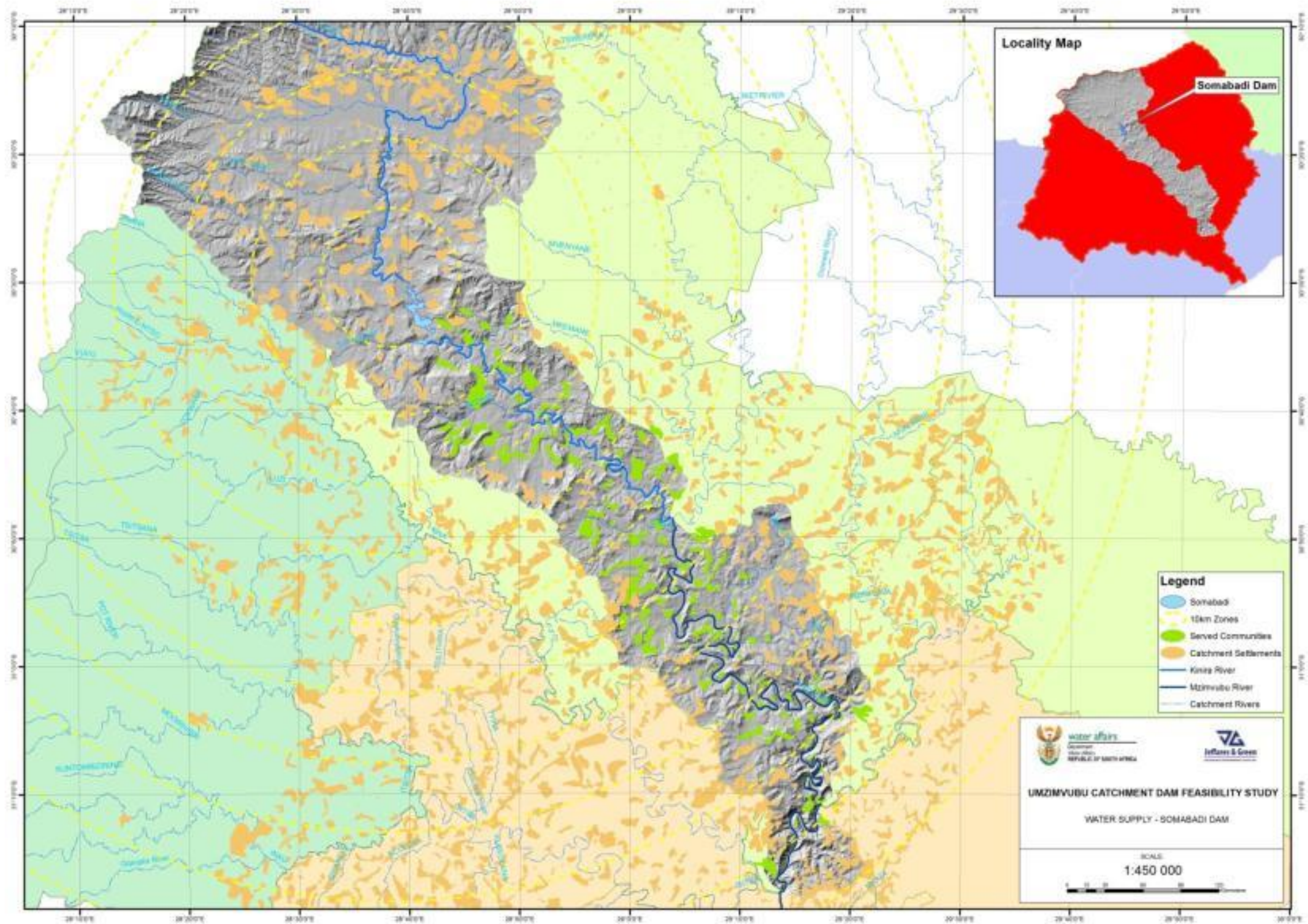


Figure 3-3: Potential Communities that could be supplied by Somabadi Dam

For the purposes of this comparative analysis, per capita demand was based upon the recommendations given in the "Guidelines for Human Settlement Planning and Design" produced by CSIR under the patronage of the Department Housing. These guidelines give typical per capita demands for standpipes as 25 ℓ/h/d, for yard connections with dry sanitation as 55 ℓ/h/d, and for house connections in developed areas 80 to 120 ℓ/h/d. Given the mostly rural perspective of these supply areas, a nominal 60 ℓ/h/d was used for comparison purposes, with both population and demand growth taken as 1% p.a., through to 2050 from the base year 2010 population figures. This is a 30 year planning horizon beyond the date of 2020, during which time all of the delivery infrastructure should have been implemented.

Abstraction losses, water treatment and distribution losses were set at 30%, which assumed that water conservation measures would need to be implemented from the outset of any distribution system developments.

Whilst it could perhaps be construed that the HIGH scenario could produce a significant over-estimation of raw water demand, there could be significant abstraction efficiency losses to contend with, given that parts of the overall scheme would probably be supplied from river abstraction points downstream of each dam, recapturing raw water released from the dam.

Whilst the above basis of population, annual growth rates, per capita consumption, and losses factors can also be debated, for this high level Phase 1 analysis, the same figures have been applied equally to all three dams so that comparison can be made on a like-for-like basis.

This will be revisited in much more detail during the feasibility study of the selected single dam, during Phase 2.

The downstream extents of the supply areas shown in the above figures are of different sizes for each dam. The criteria used for this comparative analysis was to set the lateral boundary widths of each supply zone to be at the watershed between parallel catchments, and to also include supplies to all communities below each dam that cannot otherwise be supplied with raw water from the main stem of the Mzimvubu river itself, downstream of the particular tributary in question. Whilst the flow regulation impact of each dam does carry on past this distance downstream of each dam, the actual influence of the dams on the regulation of flows in the main stem of the Mzimvubu is very low compared with the much larger flow regime of the main river.

This produced supply areas downstream of each dam with lengths as follows:

Ntabelanga:	50 kms
Thabeng:	110 kms
Somabadi:	100 kms

Considering the areal distribution of the communities to be served in each of the three supply areas, it was interesting to note that Ntabelanga has a far high concentration of communities requiring water supply closer to the dam, than the other two dams

This is illustrated in Figure 3-4.

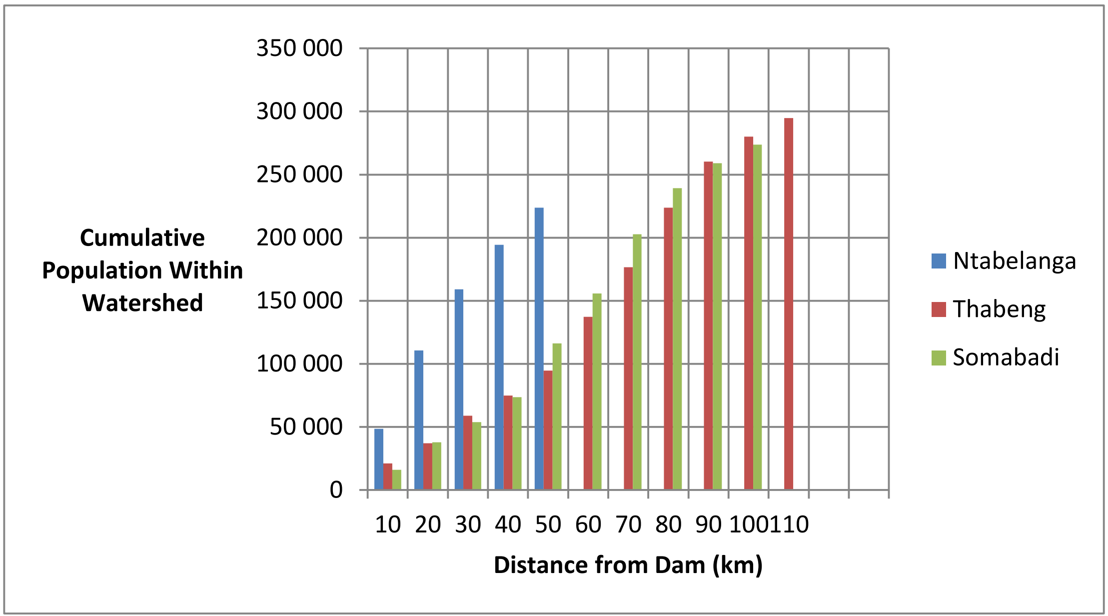


Figure 3-4: Cumulative Population Served Downstream of Each Dam Site Option

Taking all of the above criteria into consideration and applying the same approach to all three dams for comparative analysis purposes, the following raw water demand (on source) projections to the year 2050 were developed.

Table 3-13: Raw Water Demands to Year 2050 for BASE and HIGH Scenarios

	Total Population Served (±2010)		Potable Water Demand (2010)		Potable Water Demand (2050) (1% Growth P.A.)		Add 30% Leakage And Treatment Losses		Add 15% To Serve Adjacent Watershed (High Only)		Total Potable Water Demand	
	Base	High	Base	High	Base	High	Base	High	Base	High	Base	High
			million m³/a		million m³/a		million m³/a		million m³/a		million m³/a	
Ntabelanga	134 633	223 686	2.95	4.90	4.39	7.30	1.32	2.19	0.00	1.42	5.71	10.91
Thabeng	111 564	294 784	2.44	6.46	3.64	9.62	1.09	2.89	0.00	1.88	4.73	14.38
Somabadi	97 303	273 743	2.13	6.00	3.17	8.93	0.95	2.68	0.00	1.74	4.13	13.35

Potable: **Base Case:** Population that could be supplied within 180 M altitude above river level
High Case: Population within the watershed boundary plus an allowance for over-watershed supply.

3.7.3 Water for Irrigated Agriculture

a) Initial Screening Process

Phase 1 of the study is to select the dam site that makes best possible use of the water resources of the Mzimvubu River catchment. Many criteria influence the selection of sites, all of which have their particular focus.

One of the criteria that could influence selection of a site is the potential for developing irrigated agriculture around or below the site in question. This would allow the development of a multi-purpose dam, but the added benefits of job creation, food production, income generation, and enhancement of food security in what is traditionally a poor region, makes this criteria of enormous interest.

To evaluate the irrigation potential of the three candidate dams it was important to objectively quantify those factors that would contribute to development of a commercially viable irrigation farm, notably:

i. **Soils -** Are there good quality irrigable soils in the proximity of the dam? (as determined by soil series, soil depth and soil texture)
ii. **Slope –** For a large farm to be commercially viable, it will require mechanisation, and therefore land slopes need to be within the limit that can be mechanically farmed.
iii. **Proximity to water source –** For commercial viability as dictated by the cost of irrigation bulk infrastructure, the water source should be located within certain horizontal and vertical distance of the irrigable lands.
iv. **Natural rainfall –** Areas with high natural rainfall would typically not respond as well to irrigation when compared to areas with a medium to low occurrence of natural rainfall.
v. **Water -** Is there enough supplied by the proposed dam?

The three dam sites were evaluated on these same criteria so that they could be objectively ranked undertaken as a desktop study using GIS analysis techniques.

The criteria were analysed per dam site as described below:

i. Soils – Soils across the catchment were classified on a 1km x 1km raster grid basis as either “high”, “medium” or “low” potential, based on an algorithm which took into account the soil series, depth and texture.
ii. Slope – Slope across the catchment was calculated from existing elevation data, and slopes less than 12% were considered suitable for mechanised farming operations.
iii. Proximity to water source – For economic viability reasons, the areas considered were limited to those within 60m vertical elevation of the river at or below each proposed dam, and 5km horizontal distance from the dam or the river below the proposed dam. This allowed the river below a potential dam to be used as a natural channel for conveying water to high potential areas downstream of a dam.
iv. Water deficit – Mean annual precipitation (MAP) was expressed as a ratio to mean annual evapotransiration. Areas were then classified as “low”, “medium” and “high”. A “low” classification means the area has a low MAP to evapotranspiration ratio, and therefore a significant water stress, which will likely severely limit the yield potential and choice of crops that can be grown. It will therefore respond well to irrigation.

In summary, GIS analysis methods were thus used to select areas, per potential dam site, that met the following criteria:

- High potential soils.
- Slope < 12%.
- Elevation < 60m above the river at the dam site, or in the river below the dam site.
- Distance < 5km from the dam wall or either side of the river below the dam site.
- Water deficit – medium to high water stress (shortage of natural rainfall).

i) Soil Potential

Across the catchment, the soil potential is as shown in Figure 3-5 below.

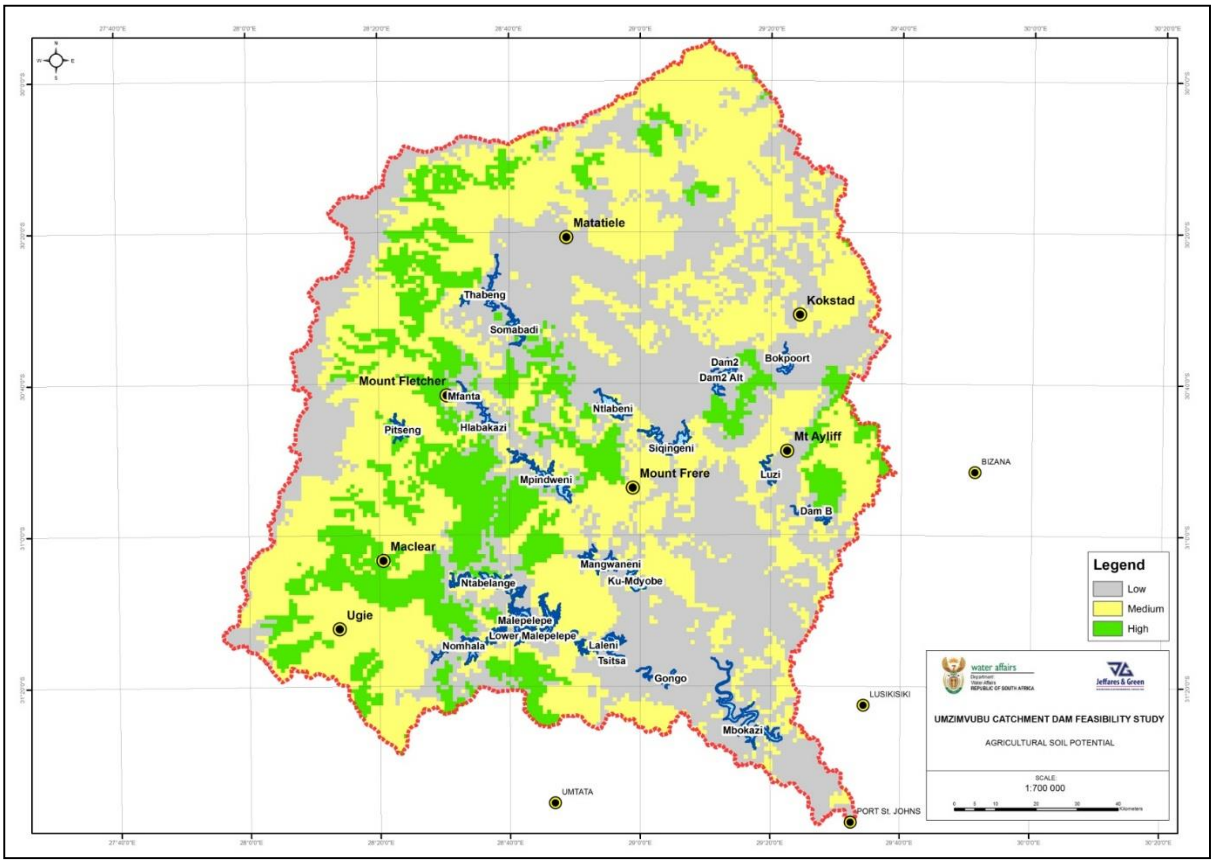


Figure 3-5: Identification of High, Medium and Low Potential Soils (Mzimvubu Catchment)

Table 3-14 below shows the resulting areas identified under each category.

Table 3-14: Total Areas of Various Soil Potential in Full Mzimvubu Catchment

Soil Potential	Area identified (ha)
High	301 400
Medium	884 000
Low	795 600
Total	**1 981 000**

Thus, 15% of the land area, or 310 400 ha, was identified as being in the higher potential soil category.

ii) Water Stress

Across the catchment, water stress is shown in Figure 3-6.

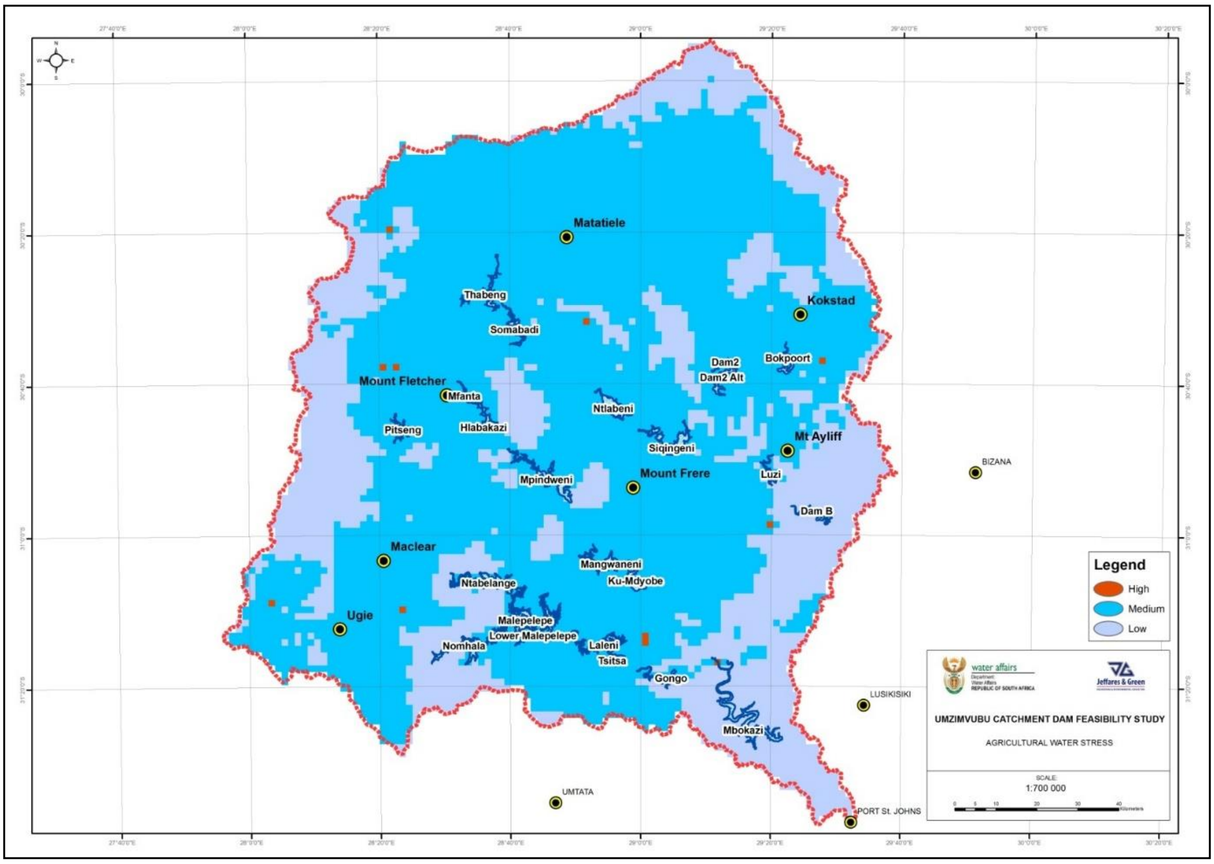


Figure 3-6: Identification of High/Medium/Low Water Stress areas Over Mzimvubu Catchment

Table 3-15 below shows the areas identified under each category.

Table 3-15: Areas of Water Stress

Water Stress	Area identified (ha)
High	2 816
Medium	1 368 060
Low	604 416
Total	**1 975 272**

Thus, 69% of the land area, or 1 370 876 ha, is identified as having high or medium water stress.

iii) GIS Analyses

The above soil potential and water stress coverages were defined and located using a GIS system, and then further analysed initially to create a BASE water demand scenario.

This included filtering of the areas identified using the slope, elevation and distance criteria described in b) and c) above.

This was undertaken for all of the original 19 potential dam sites (and some alternative sites) as a part of the screening process and the results per dam site are as shown in Table 3-16 below:

Table 3-16: Areas of High Potential Agricultural Land Per Dam Site

No	Catchment	Total Catchment Agric Land (ha)	Dam	Area (ha)
1	T31	8561	Siqingeni	0
2			Dam2	0
3			Dam2 Alt	0
4	T32	957	Dam B	0
5			Bokpoort	0
6			Luzi	0
7	T33	22647	Ntlabeni	0
8			**Somabadi**	**1261**
9			**Thabeng**	**1553**
10	T34	31976	Mangwaneni	0
11			Ku-Mdyobe	0
12			Mfanta	0
13			Mpindweni	0
14			Hlabakazi	0
15			**Pitseng**	**1476**
16	T35	57953	**Ntabelanga**	**1247**
17			**Nomhala**	**747**
18			Malepelepe	22
19			Lower Malepelepe	22
20			Laleni	0
21			Tsitsa	0
22			Gongo	0
23	T36	0	Mbokazi	0

Only five dams had any appreciable land area that met the identified criteria, these being Somabadi, Thabeng, Pitseng, Ntabelanga and Nomhala.

When combined with other non-agricultural criteria in a ranking matrix, the three highest ranked dams that emerged for further consideration and study were Somabadi, Thabeng, and Ntabelanga. This coincidentally reinforced the decision made to shortlist these three particular dams.

b) Further Ground-Truthing of Three Dam Sites

With three candidate sites needing to be narrowed down to a single site, further study was required on the three identified sites. It was also important that ground-truthing of the desktop information took place, to ensure that decisions in Phase 1 were being made on reliable and accurate information.

A site visit was organised to physically assess the identified lands from an agricultural perspective, and to correlate physical observations with the desktop mapping. All three dam sites were visited, particularly the lands identified as meeting the criteria discussed above.

The blocks of land were critically assessed to remove disparate blocks, or small irregular blocks far from the main blocks of identified land. Each theoretical area therefore was modified to some extent prior to the visit. The final areas assessed per dam were as follows in Table 3-17.

Table 3-17: Agricultural Land Relative to Each Dam Site Subject to Site Visit

Dam Site	High Potential Area identified (ha)
Ntabelanga	840
Somabadi	1 327
Thabeng	1 621

Soils were sampled using a hand operated soil auger. Diagnostic depth was 1.2 m. Soils were classified according to the system widely used in South Africa (Soil Classification. A Taxonomic System, for SA. Soil Class. Working Group. Dept. Agric. 1991). 23 soil observations were conducted.

The following properties were recorded per soil horizon:

- lower depth;
- clay content;
- sand grade;
- colour;
- structure;
- wetness;
- hazard;
- gravel;
- stones;
- effective root depth;
- ameliorated root depth;
- topsoil organic carbon;
- outcrops; and
- total available moisture.

Additionally, three soil samples were taken for laboratory analyses to test for salinity and sodicity hazards.

It should be noted that the area to be evaluated was large (in excess of 3,500ha) and rapid (and limited) sampling was therefore required to cover the entire area at this preliminary study stage.

More detailed sampling and testing of soils are planned for Phase 2 of this study.

Figure 3-7: Augering of identified soils below Ntabelanga Dam

GOOD – HUTTON SOIL **BAD – KATSPRUIT SOIL**

Figure 3-8: Soil Brought to the Surface from the Auger Hole

c) Results of Ground-Truthing

i) Ntabelanga

It is estimated that 60% of the area (504 ha) has Hutton 2200 salm and Hutton 2100 salm soil types. Orthic topsoils overlie red apedal subsoils. Effective root depth is more than 1.2 m. Depth limiting material to rooting was seldom encountered. Topsoil texture is sandy loam becoming sandy clay loam in the subsoil. Soils thus have luvic character as clay has moved from top to subsoil over time.

Textural transition from top-to subsoil is gradual providing free root penetration. Water holding and storage capacity is moderate with calculated total available moisture (TAM) being 116 mm/m, which is favourable. Infiltration is rapid. Base status is mesotrophic in that leaching is moderate. Exchangeable cations (Ca, Na, Mg, K) should thus be in the range of 5 to 15 cmol+/Kg with moderate CEC's expected. Soil pH is likely to be about 6. Phosphorous levels will also be moderate.

Nitrogen and sulphur in the topsoil will also be moderate as organic carbon levels are average (1%). Soil structure is apedal tending to weak crumb which will provide a good rooting medium with little restriction. These soils are suited to irrigation.

It is estimated that 40% of the area (336 ha) is occupied by wetlands, where wetness is present year round. Surface water is common. Soil forms identified here are Katspruit 1000 cl and Tukulu 1120 sacllm. Soil texture is sandy clay loam to clay. Infiltration is slow. Anaerobic conditions occur in the soil profile (shown by grey hues with red and yellow mottles) which is very unfavourable for cropping. These soils are totally unsuited to irrigation.

ii) Somabadi

It is estimated that 80% of the area (1062 ha) has Hutton 2200 salm and Hutton 2100 salm soil types. Orthic topsoils overlie red apedal subsoils. Effective root depth ranges from 40cm to more than 1.2 m. Depth limiting material in the shallower soils is either saprolite (weathered rock) or hard rock.

Topsoil texture is sandy loam becoming sandy clay loam in the subsoil. Soils thus have luvic character as clay has moved from top to subsoil. Textural transition from top-to subsoil is gradual. Water holding and storage capacity is moderate with calculated total available moisture (TAM) being 40 mm/m (shallower soils) to 116 mm/m (deeper soils). Infiltration is rapid. Base status is mesotrophic in that leaching is moderate. Exchangeable cations (Ca, Na, Mg, K) should thus be in the range of 5 to 15 cmol+/Kg with moderate CEC's expected. Soil pH is likely to be about 6. Phosphorous levels will also be moderate.

Nitrogen and sulphur in the topsoil will also be moderate as organic carbon levels are average. Soil structure is apedal tending to weak crumb which will provide a good rooting medium with no restrictions. These soils are suited to irrigation.

The remaining 20% of the area (265 ha) has shallow duplex soils (Sepane 1110 cl and Swartland 1111 cl soil forms) and lithosols (Glenrosa 1111 sacllm).

Effective rooting depth is commonly shallow with either saprolite or hard rock limiting root development. Profile texture is clay loam to clay. Profile structure is massive to moderate blocky. Rooting will be impaired. Increase salinity and sodicity levels may occur at these sites. A wetness hazard frequently occurs in the subsoil due to poor drainage. These soils present limiting conditions for irrigation.

iii) Thabeng

A large portion of the Thabeng study area overlaps the Somabadi area. The difference is that Thabeng includes some low-lying areas where marginal soils (Tukulu with wetness hazard and donga erosion occurs).

It is estimated that 1062 ha has Hutton 2200 salm and Hutton 2100 salm soil types. Orthic topsoils overlie red apedal subsoils. Effective root depth ranges from 40 to more than 1.2 m. Depth limiting material in the shallower soils is either saprolite (weathered rock) or hard rock. Topsoil texture is sandy loam becoming sandy clay loam in the subsoil. Soils thus have luvic character as clay has moved from top to subsoil.

Textural transition from top-to subsoil is gradual. Water holding and storage capacity is moderate with calculated total available moisture (TAM) being 40 mm/m (shallower soils) to 116 mm/m (deeper soils). Infiltration is rapid. Base status is mesotrophic in that leaching is moderate. Exchangeable cations (Ca, Na, Mg, K) should thus be in the range of 5 to 15 cmol+/Kg with moderate CEC's expected. Soil pH is likely to be about 6. Phosphorous levels will also be moderate.

Nitrogen and sulphur in the topsoil will also be moderate as organic carbon levels are average. Soil structure is apedal tending to weak crumb which will provide a good rooting medium with no restrictions. These soils are suited to irrigation.

The remaining 559 ha has shallow duplex soils (Sepane 1110 cl and Swartland 1111 cl) and lithosols (Glenrosa 1111 sacllm) as well as donga erosion. Effective rooting depth is commonly shallow with either saprolite or hard rock limiting root development. Profile texture is clay loam to clay. Profile structure is massive to moderate blocky. Rooting will be impaired. Increase salinity and sodicity levels may occur at these sites. These soils present limiting conditions for irrigation.

c) Overall Irrigation Potential

Although soil types are a key element of irrigation potential, other important factors also require consideration, in particular climate and topography. Overall, the land areas sampled and observed for each dam were classified according to an eight class scale as shown below:

- Class I – very high potential;
- Class II – high potential;
- Class III – Good potential;
- Class IV – Moderate potential;
- Class V – wetland;
- Class VI – very restricted potential;
- Class VII- Low potential; and
- Class VIII – Very low potential.

Classes I to IV are generally considered suitable for irrigation, while Classes V to VIII are generally considered unsuitable.

The breakdown of soil classes per dam site are as shown in Table 3-18.

Table 3-18: Breakdown of Soil Classes per Dam Site

	Extent (ha)	Irrigation Class III (ha)	Irrigation Class III to IV (ha)	Irrigation Class V (wetland) (ha)	Irrigation Class VII (ha)	Irrigation Capability and Recommendation	Limitations to irrigation within Classes III and IV
Ntabelanga	840	504	-	336	-	504 hectares are recommended for irrigation, having good potential. Remainder is wetland and is unsuited to irrigation.	Some shallow soils
Somabadi	1327	-	1062	-	265	1062 hectares are recommended for irrigation, having good to moderate potential. Rest is unsuited duplex soil, outcrops and dongas.	Low Mean Annual Temperature. Some shallow soils
Thabeng	1621	-	1062	-	559	1062 hectares are recommended for irrigation, having good to moderate potential. Rest is unsuited duplex soil, outcrops and dongas.	Low Mean Annual Temperature Some shallow soils

d) Some Suitable Crops and Expected Yields

Based on mean annual temperature, frost occurrence, soil types and soil properties, and assuming a medium level of irrigation management input, a variety of possible crops recommended for irrigation are presented in Table 3-19.

Table 3-19: Some Suitable Crops and Estimated Yields for Irrigation Classes III and IV.

Crop	Uses	Suitability	Expected Yield
Cabbage	Food	Moderate	50 tons/ha
Carrot	Food	High	35 tons/ha
Green Bean	Food	High	8 tons/ha
Italian Ryegrass	Nutritious grazing	High	15 tons/ha
Lettuce	Food	Moderate	20 tons/ha
Lucerne	Fodder crop	Moderate	18 tons/ha
Lupin	Forage	High	3 tons/ha
Maize	Grain	Moderate	8 tons/ha
Oats	Winter grazing or green feed	High	7 tons/ha
Onion	Food	High	25 tons/ha
Pecan	Nuts	Moderate	140 Kg/tree
Potato	Food	High	60 tons/ha
Soya bean	Food, oil seed, animal feed	Moderate	3 tons/ha
Spinach	Food	High	25 tons/ha
Tomato	Food	Moderate	35 tons/ha

e) Recommendations from Initial Screening Process

i) Ntabelanga
A significant portion of the 840 ha is occupied by wetlands which are unsuited to irrigation. It is estimated that the remainder of the area (504 ha) is suited to irrigation, carries good potential and will produce somewhat favourable crop yields under irrigation. The 504 hectares of land suitable for irrigation however appears segmented by wetlands, and is thus not contiguous. This poses a problem to irrigation infrastructure.

It is anticipated that other suitable land for irrigation, not identified in the desk-top study, may exist at the periphery of the current study area. More detailed soil studies are required to verify if this land exists, and the irrigation suitability and extent thereof.

ii) Somabadi
Of the 1327 ha study area, 1,062 ha has good to moderate irrigation capability. Some of these sites are fairly large and contiguous. Cooler temperatures will possibly result in reduced growth rates with resultant crop yields slightly lower than at Ntabelanga.

iii) Thabeng

The site includes the Somabadi study area, as well as some low lying land which has soils largely unsuited to irrigation. 1,062 ha is suitable. Somabadi is thus the preferred site compared to Thabeng.

f) Conclusions from Initial Screening Process
504 hectares of land having good irrigation capability at Ntabelanga presents preferred potential for irrigation out of the three study areas. However, limitations to irrigation here are restricted extent (hectares) for an irrigation scheme. In addition the area appears segmented by wetlands resulting in an irrigable extent that is not contiguous.

Somabadi presents 1,062 ha of land suitable for irrigation that is fairly contiguous, but has moderate to good irrigation capability presenting slightly reduced growth rates for most crops. Thabeng (same study area as Somabadi plus low lying land) has a greater proportion on land unsuited to irrigation.

Based on the above, Ntabelanga would be the first choice as an option for the irrigation development provided additional suitable land for the irrigation development can be found adjacent to the current study area. A more detailed soil survey is to be undertaken in Phase 2 together with soil salinity/sodicity/fertility testing, before a final decision is taken.

If additional land at Ntabelanga cannot be found, then Somabadi would be the second choice in selection for an irrigation project.

Deep Hutton soils occur at the three study areas. This is a preferred soil type for cropping under irrigation, provided effective rooting depth is more than 80 cm. A wide variety of pastures, crops and vegetables are suited to the prevailing climate and soils. Average yields will be achieved, provided crop and irrigation management is maintained to required standards.

This initial screening process applied very stringent filtering criteria in order to adopt a conservative approach when identifying which dam site has the highest potential for irrigated agriculture. These conclusions therefore represent a **BASE** water demand scenario, with both distance from the river and elevation above river level significantly affecting the results. Whilst these latter two filters were used to ensure that the cost of pumping and transferring water from the river were given a high weighting, these filters do significantly limit the areas thus identified.

Further analysis was therefore undertaken to investigate the case where the development of irrigated agriculture is considered on the basis of a means to create jobs and stimulate the local economy and social upliftment, which approach often considers more than just the pure economics of crop production. For this reason, a **HIGH** water demand scenario was also investigated, focussing on the three shortlisted dam sites.

g) HIGH Irrigation Water Demand Scenario

The investigations undertaken in Phase 1 have identified land areas which could have viable potential for irrigated agriculture. The BASE case criteria used to “home in” on these areas included suitable soil types and depths, terrain slope being <12%, rainfall being less than sufficient for high yield crop production, pumping head from the river being <60 m, and distance from the river being < 5 km.

Despite this phase of the study being at desk top level of detail, some fieldwork was undertaken to ground truth the soils thus identified. This was in the form of site visits and some auger holes to sample the various soil types and layer thicknesses.

The BASE case studies resulted in potential areas for irrigated agriculture in each of the three dam supply areas ranging from 504 hectares (Ntabelanga) to 1,062 hectares (for each of Thabeng and Somabadi). This particular case employed a fairly conservative approach, and it was therefore also deemed necessary to develop a HIGH demand scenario in order to test all three dam sites for a full range of water demand projections.

For the HIGH demand scenario, the criteria for identifying potential areas suitable for irrigated agriculture in each dam supply zone were relaxed, in that both the distance from the river, and the limitations on pumping head were removed as filters.

This resulted in much larger areas of potential irrigated land being identified, as follows:

- Ntabelanga: 10 536 ha
- Thabeng: 8 800 ha
- Somabadi: 7 733 ha

These areas are located as indicated in Figures 3-9, 3-10 & 3-11 below.

Given that these larger areas were identified via a GIS modelling exercise and without detailed ground-truthing, it was decided to apply a significant reduction factor (25%) to these figures as the agricultural experts considered that, from their experience, only a much smaller proportion of the total areas initially identified at such high desk-top level would likely be suitable and viable for irrigated agriculture in this region.

This is considered to be a conservative but acceptable approach purely for dam site comparison purposes at this Phase 1 stage but will again be revisited in much more detail in Phase 2 when extensive ground-truthing and soil sampling will be undertaken to maximize the potential land areas that could be viable for irrigated agriculture.

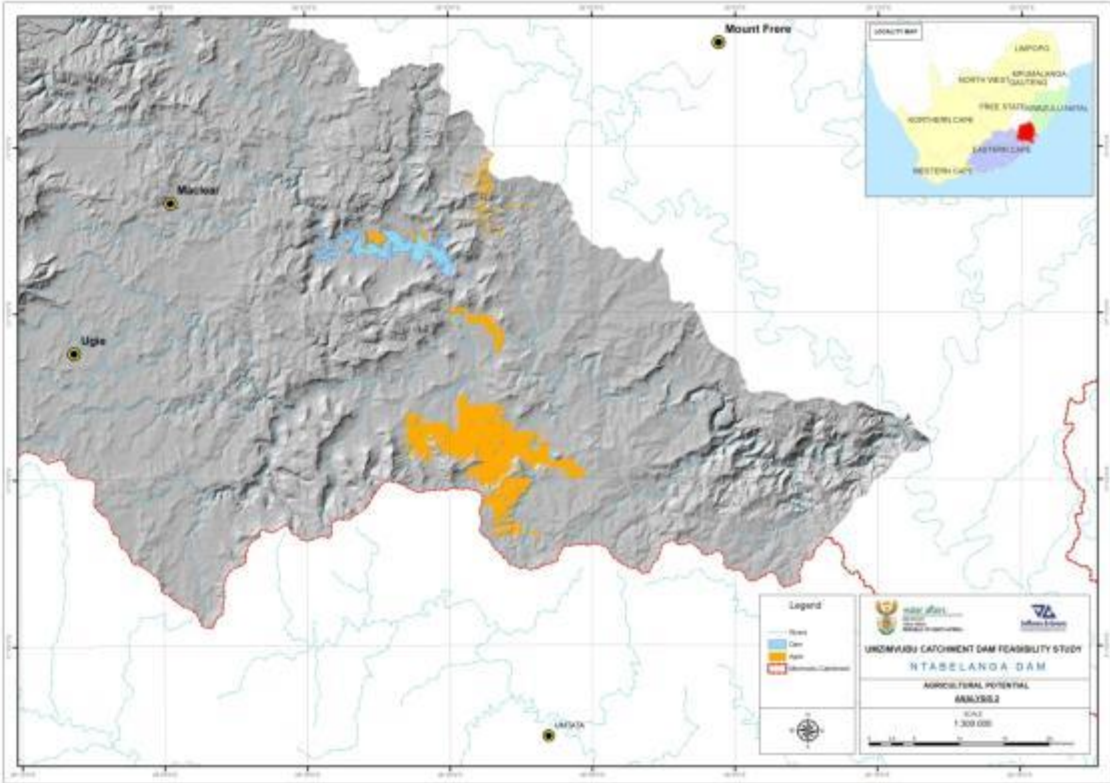


Figure 3-9: Maximum Potential Land that could be Irrigated by Ntabelanga Dam

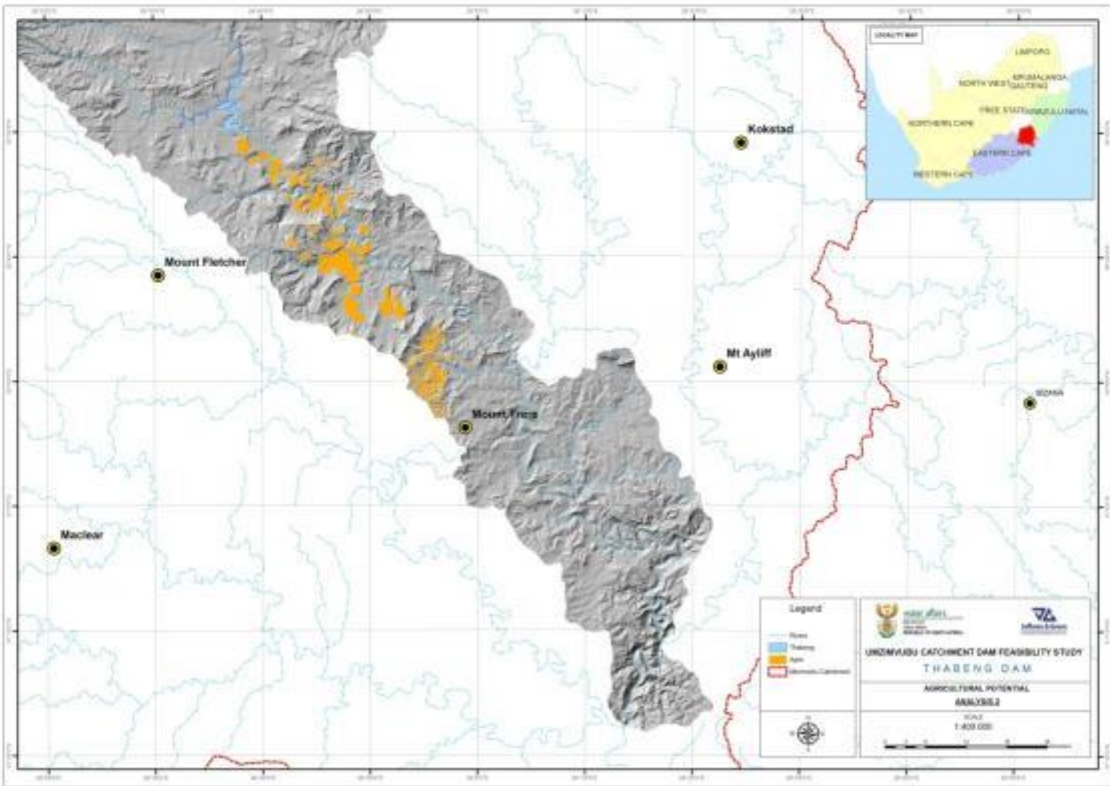


Figure 3-10: Maximum Potential Land that could be Irrigated by Thabeng Dam

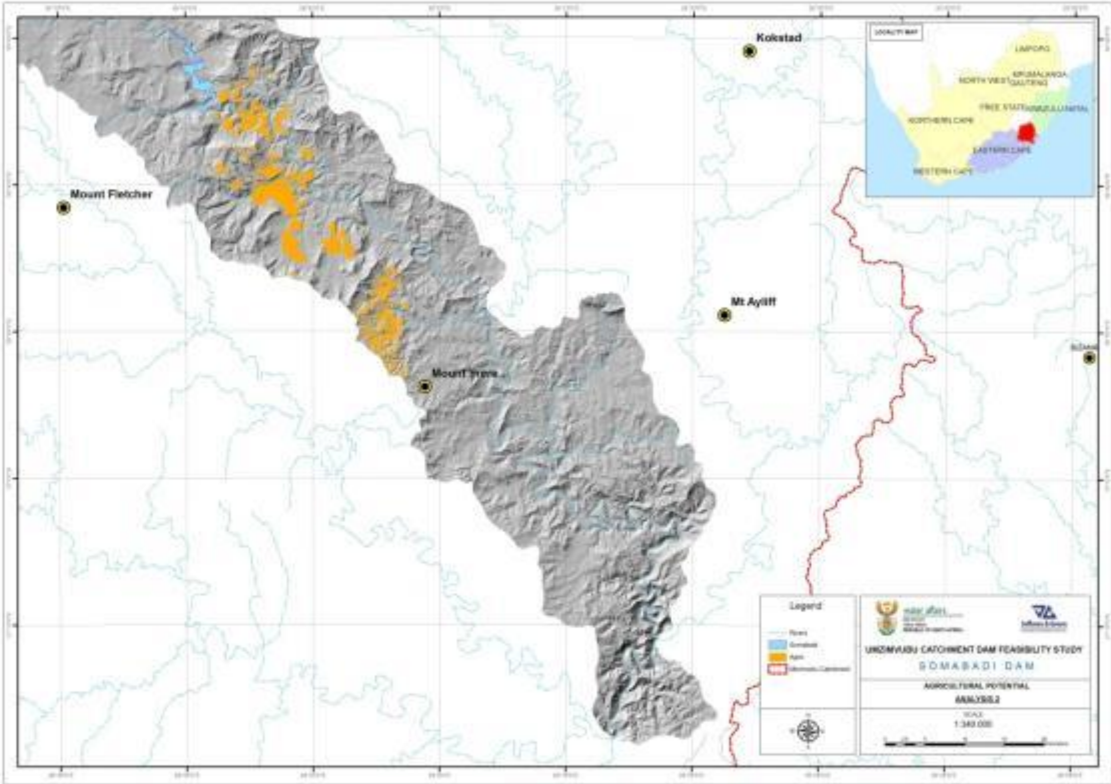


Figure 3-11: Maximum Potential Land that could be Irrigated by Somabadi Dam

In developing irrigation water demand projections for these areas thus identified, the following application rates were assumed for different potential crop types.

Table 3-20: Approximate Water Needs of Various Crop Types

Application Rate	Grains	Fodder	Winter Veg	Summer Veg
(mm/annum)*	260-300	250-400	300-350	240-360

***The above application rates are extra-over natural rainfall.**

As it is unknown as to what crops might be grown at this stage, once again, purely for the purposes of comparison of the three dams, a standard rate of 350 mm/a was used for all three dam site supply areas to calculate water requirements.

A further 20% was added to the overall irrigation water demand projections to allow for losses and over-application.

It is possible that a higher figure for application rates and losses might have been used, as irrigation water usage efficiencies above 75% are hard to achieve, however, the dam yield analyses undertaken below also assume higher assurances of supply than can be accepted by irrigation users, and therefore the lower losses quoted above would be balanced by these higher assurance of supply used for the basic purpose of comparing the three dams on a like-for-like basis.

In Phase 2, the irrigation efficiencies and differences in acceptable levels of assurance of supply between potable and irrigation water will be analysed to a much high level of detail.

Applying the criteria given above to the three dam supply areas, the total irrigation water demand projections for the BASE and HIGH scenarios described above, was as follows in Table 3-21.

Table 3-21: Irrigation Water Requirements Used for Comparative Analyses

	Summary: Estimation Of Irrigation Water Requirements					Potential Irrigation Water Requirement	
	Irrigatable Land (ha)			Typical Irrigation Rate (mm/a)		Base	High
	Limit Pumping Head & Distance from River	Area Identified when no Limits Applied	No Limits Applied, but 25% considered viable			million m^3/a	
Ntabelanga	504	10 536	2 634	350	+20% losses>	2.12	11.06
Thabeng	1 062	8 800	2 200	350	+20% losses>	4.46	9.24
Somabadi	1 062	7 733	1 933	350	+20% losses>	4.46	8.12

3.7.4 Combined Estimated Water Demands

In order to determine and compare the dam size and safe yield required for each option, the following total raw water demand projections to the year 2050 were used:

Table 3-22: Combined Water Requirements Used for Comparative Analyses

	Total Potable Water Demand		Irrigation Water Demand (incl 20% Losses)		Grand Total Water Demand	
	Base	High	Base	High	Base	High
	million m^3/a		million m^3/a		million m^3/a	
Ntabelanga	5.71	10.91	2.12	11.06	7.83	21.97
Thabeng	4.73	14.38	4.46	9.24	9.19	23.62
Somabadi	4.13	13.35	4.46	8.12	8.59	21.47

3.8 Is a Dam Required?

This question was raised at the December 2012 PSC meeting, when the estimated BASE case water demands were compared with the Mean Annual Runoffs (MAR) of the rivers at each of the three dam sites, and shown to be a very small proportion of the MAR.

However, such an approach is far too simplistic, and the need for a dam was further investigated by building a monthly simulation model for each dam site based upon the 1080 months of historical flow series that were generated under the hydrology task.

This is not as comprehensive as the full stochastic analyses undertaken in the WRYM modelling, but clearly illustrates the situation in a simple manner using historical flow series.

The results of this analysis are shown below, using Ntabelanga as an example. The first Table 3-23 shows the historical monthly flow series for the river without a dam or any abstraction at the dam site.

The second Table 3-24 shows the impact on monthly flows once the EWR is allocated as well as the **BASE** case monthly demands abstracted. Red cells show that the monthly flow would be inadequate to supply both EWR and raw water demand, and if 100% of EWR and 2050 demand is abstracted, there would be a deficit to supply in some 9% of the months. This equates very approximately to an assurance of supply of 91%.

The third Table 3-25 shows the impacts on monthly flows once the EWR is allocated as well as the **HIGH** case monthly demands abstracted. In this case, if 100% of EWR and the 2050 demand are abstracted, there would be a deficit to supply in some 20% of the months. This equates very approximately to an assurance of supply of 80%.

Whilst this simplistic model does not exactly mirror the way EWR releases are managed, it is sufficient to show that a regulating dam is required in order to provide a sufficient availability of supply to meet both BASE and HIGH demand scenarios.

Applying the same approach to the Thabeng & Somabadi dam sites produces even higher failure rates of up to 49% for the HIGH scenario, as this situation is affected by the higher EWRs required on the Kinira River. (See the section on hydrology in this regard).

This analysis clearly indicated that for all three sites a dam was required to regulate flow such that both EWR and raw water demand can be met with sufficient assurance levels.

Having used this historical model to demonstrate the need for these dams, all other dam yield analyses undertaken in Phase 1 were based upon a full stochastic approach using the WRYM yield modelling system, and detailed hydrology.

EWR's and the EWR release regime will also be reviewed in Phase 2 during the dam optimisation aspects of the study.

Table 3-23: Historical Monthly Flow Series for the Tsitsa River at Ntabelanga Dam

Tsitsa River at Ntabelanga Dam													
									BASE		HIGH		
MAR	319.81	Mm3/yr		EWR	52.82	Mm3/yr		Demands on Dam	7.83	Mm3/yr	21.97	Mm3/yr	
Distributed													Factor
Base Demand	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ntabelanga Historical Monthly Flows (Mm^3/mth) Minus EWR Minus BASE Demand												Fail Rate	%
Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1920	11.97	6.96	13.60	17.44	13.37	57.01	33.82	8.68	3.64	3.05	2.47	4.22	176.23
1921	12.22	70.39	57.53	15.89	8.04	4.41	2.01	32.37	18.66	15.26	24.73	10.95	272.45
1922	11.04	108.57	33.34	102.70	117.77	57.39	11.13	3.55	4.10	72.40	25.01	3.81	550.82
1923	4.25	4.44	17.32	19.03	41.37	29.45	6.04	3.82	4.22	3.44	4.30	6.34	144.01
1924	6.11	10.07	152.83	46.14	7.06	166.13	140.60	30.70	4.19	3.39	2.65	4.87	574.75
1925	3.71	16.56	8.60	9.85	13.32	69.87	21.70	7.06	12.19	6.68	3.03	9.94	182.51
1926	14.07	10.43	25.25	11.13	7.39	198.16	58.58	3.21	2.92	3.23	4.75	4.72	343.84
1927	10.55	4.41	88.92	126.87	43.20	12.11	4.63	4.66	4.06	3.38	6.73	3.87	313.38
1928	5.05	13.61	48.80	20.69	54.62	126.50	33.37	6.74	17.83	14.75	7.38	15.85	365.19
1929	64.02	50.18	59.81	82.16	21.58	64.69	30.45	5.98	5.02	5.05	10.70	7.24	406.89
1930	8.85	2.75	15.16	82.00	71.84	95.46	28.79	4.01	3.23	134.00	41.89	2.99	490.96
1931	7.45	12.48	20.02	11.62	102.57	35.30	3.39	5.12	4.64	6.10	3.92	36.88	249.47
1932	30.75	116.89	83.25	15.43	5.61	52.43	20.76	3.96	3.22	3.44	3.07	2.80	341.60
1933	2.66	149.94	128.18	233.52	66.58	81.02	26.20	3.94	4.25	22.31	8.98	2.54	730.12
1934	7.58	17.63	95.86	28.26	6.53	38.23	32.91	14.61	13.72	6.75	8.41	4.60	275.10
1935	5.07	2.94	1.06	3.51	136.42	54.41	6.77	29.56	12.42	7.72	3.80	4.08	267.77
1936	23.79	174.14	50.11	43.18	129.81	63.36	9.77	3.31	3.26	3.21	2.70	4.33	510.99
1937	6.74	2.92	14.27	65.59	84.91	27.62	70.57	22.95	6.12	7.63	7.74	3.51	320.57
1938	8.21	17.93	80.91	116.44	174.93	46.71	4.25	5.99	5.35	8.73	5.71	45.12	520.28
1939	29.89	18.39	8.74	12.77	52.28	31.04	10.17	16.10	8.26	3.54	2.99	5.63	199.80
1940	8.15	8.60	12.40	17.43	14.64	15.62	10.48	4.44	3.45	4.17	3.79	2.33	105.50
1941	5.36	4.59	1.87	16.72	54.34	77.25	30.51	9.50	4.23	2.78	5.75	6.65	219.55
1942	37.96	68.41	105.20	50.36	10.36	75.01	55.99	18.34	9.53	6.15	43.54	27.73	508.56

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1943	37.12	74.63	84.69	30.66	18.50	55.66	16.70	3.52	7.01	6.50	3.20	54.09	**392.30**
1944	25.13	3.52	1.38	7.30	59.39	55.62	13.24	4.08	3.48	2.99	2.33	2.10	**180.55**
1945	22.46	6.80	5.59	86.08	40.95	38.17	17.73	9.65	4.90	3.56	2.81	2.25	**240.94**
1946	3.97	14.41	8.49	32.43	50.40	62.10	36.86	8.52	18.34	9.33	3.15	6.21	**254.22**
1947	6.96	99.25	113.87	84.69	106.15	55.71	15.08	5.77	3.82	3.38	2.56	2.37	**499.62**
1948	19.01	7.75	7.12	6.52	22.75	14.02	7.06	5.16	3.13	3.65	3.29	3.69	**103.16**
1949	3.83	6.44	10.34	21.27	110.73	96.82	26.57	23.27	9.53	5.03	20.01	9.02	**342.86**
1950	14.25	6.07	104.05	43.46	15.32	11.61	5.16	3.38	3.03	2.69	5.35	6.31	**220.68**
1951	42.49	12.36	3.39	11.15	82.86	28.53	7.50	4.62	4.22	4.73	3.29	5.95	**211.08**
1952	5.65	8.95	13.36	10.33	53.99	23.85	21.61	7.47	2.62	2.43	3.94	10.22	**164.42**
1953	20.58	24.51	23.60	22.13	38.12	70.47	20.68	23.85	16.25	6.11	2.57	4.92	**273.79**
1954	17.91	14.23	8.68	142.94	127.91	39.09	18.58	7.95	6.67	4.54	2.48	3.87	**394.85**
1955	7.26	17.84	10.05	1.60	34.29	100.97	28.87	4.81	6.61	4.18	2.44	4.67	**223.58**
1956	5.56	57.90	107.09	45.65	11.69	138.23	52.30	7.06	3.93	4.60	9.42	18.47	**461.91**
1957	19.78	8.51	9.31	106.09	45.87	10.31	19.70	9.08	3.43	3.63	2.54	3.08	**241.31**
1958	3.45	70.33	37.28	7.93	10.57	13.74	33.97	61.60	18.89	8.78	6.90	5.13	**278.58**
1959	4.13	14.81	17.78	10.81	23.60	12.08	12.95	7.06	3.35	3.59	4.92	10.17	**125.25**
1960	6.52	28.89	49.85	33.71	17.22	37.43	32.26	13.84	4.73	2.94	3.36	3.43	**234.16**
1961	2.82	33.80	31.99	17.65	63.57	65.51	22.77	6.07	3.35	2.64	3.12	2.36	**255.65**
1962	10.01	61.05	47.07	133.65	66.89	166.92	52.18	5.20	3.33	7.58	3.92	1.96	**559.76**
1963	50.87	96.03	26.48	29.19	11.30	54.36	31.94	6.53	52.31	20.04	3.75	6.51	**389.32**
1964	47.61	14.38	9.00	10.23	68.03	20.14	5.72	4.18	100.79	35.56	10.09	5.74	**331.47**
1965	14.00	57.54	16.89	45.09	58.87	13.84	2.59	18.28	8.86	3.24	5.39	6.28	**250.88**
1966	4.57	5.58	10.75	27.05	76.46	129.68	73.39	16.91	8.51	8.16	3.97	1.90	**366.94**
1967	4.99	13.77	4.11	2.56	7.20	7.48	6.46	3.20	2.09	2.38	4.00	4.59	**62.82**
1968	5.69	7.36	3.62	2.40	16.12	111.64	32.76	5.53	3.99	3.68	2.90	2.63	**198.32**
1969	17.37	8.66	17.45	5.85	19.12	6.26	1.78	3.91	7.13	4.43	49.05	20.59	**161.60**
1970	51.73	18.14	5.97	13.39	15.61	12.95	8.63	13.67	8.21	8.22	22.39	10.07	**188.99**
1971	63.27	25.43	14.85	33.67	154.07	72.96	10.99	3.68	3.65	3.03	2.18	1.83	**389.61**
1972	3.71	55.12	17.49	6.00	97.80	85.62	25.04	5.10	3.00	3.66	4.54	4.28	**311.37**
1973	8.42	13.45	9.86	137.56	99.32	170.97	50.74	10.85	7.53	4.35	3.14	1.80	**518.00**
1974	2.46	36.13	17.73	9.19	6.85	27.78	10.60	2.59	2.23	2.63	2.06	35.37	**155.61**
1975	11.08	14.94	139.58	123.37	89.58	250.45	71.61	25.73	10.96	5.03	3.66	7.74	**753.74**
1976	128.05	39.27	4.83	12.32	29.67	20.08	9.70	3.55	2.51	4.48	4.69	17.88	**277.05**

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1977	12.37	19.69	16.14	16.84	7.74	14.96	235.11	71.74	3.78	2.84	4.02	9.43	**414.66**
1978	25.82	12.26	43.63	16.50	21.99	17.45	5.83	3.96	3.02	15.43	7.53	4.19	**177.62**
1979	6.78	4.10	4.99	7.38	8.37	13.27	5.62	2.40	1.97	2.46	1.87	27.01	**86.23**
1980	10.75	10.74	12.54	31.46	109.44	35.06	3.52	11.57	7.39	3.65	5.45	3.19	**244.76**
1981	2.20	4.14	11.47	17.68	9.26	109.68	35.32	3.58	5.06	7.20	3.50	3.83	**212.92**
1982	6.21	24.61	6.66	1.61	2.06	6.07	8.22	4.48	3.00	3.90	2.44	2.93	**72.18**
1983	9.19	59.36	74.49	31.60	22.35	72.75	32.99	7.67	6.86	7.38	4.24	3.05	**331.92**
1984	24.48	25.77	7.84	59.36	185.96	51.13	4.01	2.77	2.74	2.67	1.90	2.53	**371.17**
1985	80.45	66.90	86.98	40.65	33.85	27.59	7.31	2.70	2.66	3.77	8.27	9.90	**371.04**
1986	70.10	85.43	24.94	12.17	13.39	27.19	10.13	3.01	4.57	3.59	7.48	197.43	**459.42**
1987	82.45	25.87	17.86	20.36	205.79	120.98	25.97	9.18	5.86	5.23	5.14	6.62	**531.30**
1988	8.13	35.60	114.27	42.99	147.00	57.04	64.47	21.05	4.40	7.61	3.63	1.83	**508.03**
1989	16.14	189.36	60.53	30.42	8.41	66.20	28.20	5.19	4.62	3.73	10.11	5.13	**428.04**
1990	15.19	6.05	8.99	27.60	19.13	7.91	2.43	2.67	3.07	2.47	1.97	4.79	**102.27**
1991	86.77	42.47	105.64	33.45	13.45	7.45	6.13	2.92	2.20	2.05	2.20	3.99	**308.73**
1992	3.92	4.67	2.53	5.15	12.45	23.36	12.83	3.88	2.01	1.78	2.35	9.70	**84.63**
1993	68.09	33.27	51.00	70.50	91.91	130.86	33.29	3.43	3.82	6.62	6.14	2.26	**501.18**
1994	3.42	2.02	15.44	37.64	12.42	96.97	50.97	10.68	5.08	3.75	2.18	3.40	**243.96**
1995	9.76	10.75	156.02	190.23	114.62	35.89	7.32	4.22	3.46	4.78	3.16	2.69	**542.91**
1996	5.08	109.19	77.38	59.21	17.77	33.39	21.96	7.13	103.59	46.14	8.61	3.90	**493.36**
1997	13.32	18.42	10.65	84.12	168.32	166.86	46.33	11.02	5.69	6.42	7.40	4.89	**543.45**
1998	5.36	75.35	92.81	38.37	96.04	40.24	5.97	3.31	3.46	3.43	2.45	1.90	**368.69**
1999	27.03	15.64	60.69	153.18	150.88	155.07	85.30	24.12	7.08	4.26	2.77	6.30	**692.33**
2000	7.76	15.92	14.38	54.07	44.69	30.55	12.56	4.26	2.79	2.94	2.43	4.58	**196.96**
2001	19.59	143.54	87.05	59.63	20.98	36.47	13.30	8.25	6.97	11.97	27.01	13.29	**448.04**
2002	4.00	4.26	12.03	16.66	12.23	22.34	10.68	7.15	5.07	3.01	3.78	9.99	**111.19**
2003	4.04	6.47	4.52	78.29	36.91	106.83	36.03	4.21	3.47	11.73	6.40	55.49	**354.40**
2004	20.45	25.10	16.18	157.44	56.67	31.11	12.80	5.28	3.35	2.59	3.97	2.85	**337.79**
2005	5.31	32.95	11.23	44.32	49.76	29.79	38.70	17.99	5.83	3.96	35.26	35.11	**310.21**
2006	98.52	55.74	26.57	14.04	8.71	7.91	9.96	3.99	4.31	3.34	2.54	2.20	**237.83**
2007	32.21	18.21	9.54	20.56	51.29	42.91	32.06	9.90	9.41	5.45	3.90	2.90	**238.34**
2008	2.74	6.48	32.58	15.50	69.25	19.75	2.74	4.45	4.77	2.92	4.47	3.76	**169.43**
2009	34.66	12.85	3.51	88.41	35.06	8.25	6.21	3.43	4.33	3.40	2.05	1.37	**203.51**
													319.81

Table 3-24: Ntabelanga Dam Flow Series after Abstraction of EWR and BASE Demand

Ntabelanga Historical Monthly Flows (Mm^3/mth) Minus EWR Minus BASE Demand											FAIL RATE		9%
Year	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Total**
1920	7.94	0.67	6.71	9.37	3.82	46.79	28.82	6.40	1.60	1.02	0.64	1.80	**115.58**
1921	8.19	64.10	50.64	7.82	**-1.51**	**-5.81**	**-2.99**	30.09	16.62	13.23	22.90	8.53	**211.81**
1922	7.01	102.28	26.45	94.64	108.22	47.17	6.13	1.27	2.06	70.37	23.17	1.39	**490.17**
1923	0.22	**-1.86**	10.43	10.96	31.82	19.23	1.04	1.55	2.18	1.40	2.46	3.92	**83.36**
1924	2.08	3.77	145.94	38.08	**-2.48**	155.91	135.60	28.42	2.15	1.36	0.82	2.46	**514.10**
1925	**-0.32**	10.27	1.71	1.79	3.78	59.65	16.70	4.78	10.15	4.65	1.20	7.52	**121.86**
1926	10.04	4.14	18.36	3.07	**-2.16**	187.94	53.58	0.93	0.88	1.20	2.92	2.30	**283.19**
1927	6.52	**-1.88**	82.04	118.80	33.65	1.89	**-0.37**	2.38	2.02	1.35	4.89	1.45	**252.73**
1928	1.02	7.31	41.91	12.62	45.07	116.28	28.37	4.47	15.79	12.72	5.55	13.43	**304.54**
1929	59.99	43.89	52.92	74.10	12.03	54.47	25.45	3.70	2.98	3.02	8.87	4.83	**346.24**
1930	4.82	**-3.54**	8.27	73.94	62.29	85.24	23.78	1.74	1.19	131.97	40.05	0.58	**430.32**
1931	3.42	6.19	13.14	3.55	93.02	25.08	**-1.61**	2.84	2.60	4.07	2.09	34.46	**188.83**
1932	26.72	110.60	76.36	7.36	**-3.94**	42.21	15.76	1.68	1.18	1.41	1.23	0.38	**280.96**
1933	**-1.37**	143.64	121.29	225.46	57.04	70.80	21.20	1.66	2.21	20.28	7.15	0.13	**669.48**
1934	3.55	11.33	88.98	20.20	**-3.02**	28.01	27.90	12.33	11.68	4.72	6.58	2.19	**214.45**
1935	1.04	**-3.35**	**-5.82**	**-4.56**	126.88	44.19	1.76	27.29	10.38	5.68	1.97	1.66	**207.12**
1936	19.76	167.85	43.22	35.12	120.26	53.14	4.76	1.03	1.22	1.18	0.87	1.92	**450.34**
1937	2.71	**-3.37**	7.38	57.52	75.36	17.40	65.57	20.68	4.08	5.60	5.91	1.09	**259.93**
1938	4.18	11.63	74.02	108.37	165.38	36.49	**-0.75**	3.72	3.31	6.70	3.88	42.70	**459.64**
1939	25.86	12.09	1.85	4.70	42.73	20.82	5.17	13.82	6.22	1.51	1.16	3.21	**139.16**
1940	4.12	2.31	5.51	9.36	5.09	5.40	5.48	2.17	1.41	2.14	1.95	**-0.09**	**44.85**
1941	1.33	**-1.70**	**-5.02**	8.66	44.79	67.03	25.50	7.23	2.19	0.75	3.92	4.23	**158.90**
1942	33.93	62.12	98.31	42.29	0.81	64.79	50.99	16.06	7.49	4.12	41.71	25.31	**447.92**

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1943	33.09	68.33	77.81	22.59	8.96	45.44	11.70	1.25	4.97	4.47	1.37	51.67	**331.65**
1944	21.10	**-2.78**	**-5.50**	**-0.76**	49.84	45.40	8.23	1.80	1.43	0.96	0.49	**-0.31**	**119.90**
1945	18.43	0.50	**-1.30**	78.01	31.40	27.95	12.72	7.37	2.86	1.53	0.98	**-0.17**	**180.29**
1946	**-0.06**	8.12	1.61	24.37	40.85	51.88	31.86	6.24	16.30	7.30	1.32	3.80	**193.57**
1947	2.93	92.96	106.98	76.63	96.60	45.49	10.08	3.49	1.77	1.35	0.73	**-0.05**	**438.97**
1948	14.98	1.45	0.24	**-1.54**	13.20	3.80	2.06	2.88	1.09	1.62	1.45	1.28	**42.51**
1949	**-0.20**	0.15	3.45	13.21	101.18	86.60	21.57	20.99	7.49	3.00	18.17	6.60	**282.21**
1950	10.22	**-0.22**	97.16	35.39	5.78	1.39	0.16	1.10	0.99	0.66	3.51	3.90	**160.03**
1951	38.46	6.06	**-3.50**	3.09	73.31	18.31	2.50	2.34	2.18	2.70	1.45	3.53	**150.43**
1952	1.62	2.66	6.47	2.26	44.44	13.63	16.61	5.20	0.58	0.40	2.11	7.80	**103.77**
1953	16.56	18.22	16.71	14.07	28.57	60.25	15.67	21.57	14.21	4.08	0.74	2.50	**213.14**
1954	13.88	7.94	1.79	134.88	118.36	28.87	13.57	5.67	4.63	2.51	0.65	1.46	**334.21**
1955	3.23	11.55	3.16	**-6.46**	24.75	90.75	23.87	2.53	4.57	2.15	0.60	2.25	**162.93**
1956	1.53	51.61	100.20	37.59	2.14	128.01	47.30	4.79	1.89	2.57	7.59	16.06	**401.26**
1957	15.75	2.21	2.42	98.02	36.32	0.09	14.69	6.80	1.39	1.60	0.71	0.67	**180.67**
1958	**-0.58**	64.04	30.39	**-0.14**	1.03	3.52	28.97	59.32	16.85	6.75	5.07	2.71	**217.93**
1959	0.10	8.52	10.90	2.74	14.05	1.87	7.95	4.78	1.31	1.55	3.09	7.75	**64.60**
1960	2.49	22.59	42.96	25.64	7.67	27.21	27.26	11.56	2.69	0.91	1.52	1.02	**173.51**
1961	**-1.21**	27.50	25.10	9.58	54.02	55.29	17.77	3.80	1.31	0.61	1.29	**-0.05**	**195.00**
1962	5.98	54.76	40.19	125.58	57.34	156.70	47.17	2.92	1.29	5.55	2.09	**-0.46**	**499.11**
1963	46.84	89.73	19.59	21.13	1.75	44.14	26.94	4.25	50.27	18.01	1.92	4.10	**328.67**
1964	43.58	8.09	2.11	2.16	58.48	9.92	0.72	1.91	98.75	33.53	8.26	3.32	**270.82**
1965	9.97	51.25	10.01	37.03	49.32	3.62	**-2.41**	16.00	6.82	1.20	3.56	3.87	**190.23**
1966	0.54	**-0.71**	3.86	18.99	66.91	119.46	68.38	14.64	6.47	6.12	2.14	**-0.52**	**306.29**
1967	0.96	7.48	**-2.78**	**-5.50**	**-2.35**	**-2.74**	1.45	0.92	0.05	0.35	2.16	2.17	**2.17**

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1968	1.66	1.06	**-3.27**	**-5.66**	6.58	101.42	27.76	3.25	1.95	1.65	1.06	0.21	**137.67**
1969	13.34	2.36	10.56	**-2.21**	9.57	**-3.95**	**-3.23**	1.63	5.09	2.40	47.21	18.17	**100.95**
1970	47.70	11.85	**-0.92**	5.33	6.06	2.73	3.63	11.40	6.17	6.18	20.56	7.66	**128.34**
1971	59.24	19.14	7.96	25.60	144.52	62.74	5.99	1.40	1.61	1.00	0.34	**-0.58**	**328.96**
1972	**-0.32**	48.83	10.60	**-2.07**	88.25	75.40	20.03	2.82	0.96	1.63	2.70	1.87	**250.72**
1973	4.39	7.16	2.98	129.50	89.78	160.75	45.74	8.57	5.49	2.31	1.30	**-0.61**	**457.35**
1974	**-1.57**	29.83	10.85	1.13	**-2.70**	17.56	5.59	0.32	0.19	0.60	0.22	32.95	**94.97**
1975	7.05	8.65	132.70	115.30	80.03	240.23	66.61	23.45	8.92	3.00	1.83	5.33	**693.10**
1976	124.02	32.98	**-2.06**	4.25	20.12	9.87	4.70	1.27	0.47	2.45	2.86	15.47	**216.40**
1977	8.34	13.39	9.26	8.77	**-1.81**	4.74	230.11	69.47	1.74	0.81	2.19	7.02	**354.02**
1978	21.79	5.96	36.75	8.44	12.45	7.23	0.83	1.68	0.98	13.40	5.70	1.78	**116.97**
1979	2.75	**-2.20**	**-1.89**	**-0.69**	**-1.18**	3.05	0.61	0.12	**-0.07**	0.43	0.04	24.60	**25.58**
1980	6.72	4.44	5.65	23.40	99.89	24.84	**-1.49**	9.29	5.35	1.62	3.62	0.78	**184.11**
1981	**-1.83**	**-2.15**	4.58	9.61	**-0.28**	99.46	30.32	1.30	3.02	5.16	1.67	1.41	**152.27**
1982	2.18	18.31	**-0.23**	**-6.46**	**-7.49**	**-4.15**	3.22	2.20	0.96	1.87	0.60	0.51	**11.53**
1983	5.16	53.06	67.60	23.53	12.80	62.53	27.98	5.39	4.82	5.35	2.40	0.64	**271.27**
1984	20.45	19.48	0.95	51.29	176.41	40.92	**-0.99**	0.49	0.70	0.64	0.07	0.12	**310.52**
1985	76.42	60.60	80.09	32.59	24.30	17.37	2.31	0.42	0.62	1.74	6.43	7.49	**310.39**
1986	66.07	79.13	18.06	4.10	3.85	16.97	5.12	0.73	2.53	1.56	5.65	195.01	**398.77**
1987	78.42	19.57	10.97	12.29	196.24	110.76	20.97	6.90	3.82	3.20	3.30	4.20	**470.65**
1988	4.10	29.31	107.39	34.92	137.45	46.82	59.46	18.78	2.36	5.58	1.80	**-0.59**	**447.38**
1989	12.11	183.07	53.64	22.36	**-1.14**	55.98	23.20	2.92	2.58	1.70	8.27	2.71	**367.40**
1990	11.16	**-0.25**	2.10	19.53	9.58	**-2.30**	**-2.57**	0.40	1.03	0.44	0.13	2.38	**41.62**
1991	82.74	36.18	98.76	25.39	3.90	**-2.77**	1.13	0.65	0.16	0.02	0.36	1.57	**248.09**
1992	**-0.11**	**-1.62**	**-4.36**	**-2.91**	2.90	13.14	7.83	1.60	**-0.03**	**-0.25**	0.51	7.29	**23.98**

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1993	64.06	26.97	44.11	62.44	82.36	120.64	28.28	1.15	1.78	4.59	4.31	**-0.15**	**440.53**
1994	**-0.61**	**-4.28**	8.56	29.57	2.87	86.75	45.97	8.41	3.04	1.71	0.34	0.99	**183.32**
1995	5.73	4.45	149.13	182.16	105.08	25.68	2.32	1.94	1.42	2.75	1.33	0.28	**482.26**
1996	1.05	102.89	70.50	51.15	8.22	23.17	16.95	4.85	101.55	44.11	6.78	1.48	**432.71**
1997	9.29	12.13	3.76	76.06	158.78	156.64	41.32	8.74	3.65	4.39	5.56	2.47	**482.80**
1998	1.33	69.06	85.92	30.30	86.49	30.02	0.97	1.03	1.42	1.40	0.62	**-0.52**	**308.04**
1999	23.00	9.35	53.80	145.11	141.33	144.85	80.30	21.84	5.04	2.23	0.94	3.89	**631.68**
2000	3.73	9.62	7.50	46.00	35.15	20.33	7.56	1.99	0.75	0.91	0.60	2.17	**136.32**
2001	15.56	137.25	80.16	51.56	11.43	26.25	8.29	5.97	4.93	9.94	25.18	10.87	**387.39**
2002	**-0.03**	**-2.03**	5.15	8.59	2.68	12.12	5.68	4.87	3.03	0.97	1.94	7.57	**50.54**
2003	0.01	0.18	**-2.37**	70.22	27.36	96.61	31.02	1.94	1.43	9.70	4.57	53.07	**293.75**
2004	16.42	18.81	9.30	149.37	47.12	20.89	7.80	3.00	1.31	0.56	2.14	0.43	**277.15**
2005	1.28	26.66	4.35	36.25	40.21	19.57	33.69	15.71	3.79	1.93	33.43	32.70	**249.57**
2006	94.49	49.45	19.69	5.98	**-0.84**	**-2.31**	4.95	1.71	2.27	1.31	0.71	**-0.22**	**177.18**
2007	28.18	11.91	2.66	12.50	41.74	32.69	27.06	7.62	7.37	3.42	2.06	0.48	**177.69**
2008	**-1.29**	0.19	25.70	7.43	59.70	9.53	**-2.26**	2.18	2.73	0.89	2.64	1.34	**108.78**
2009	30.63	6.56	**-3.37**	80.34	25.51	**-1.97**	1.20	1.15	2.29	1.37	0.21	**-1.05**	**142.86**

(Blocks indicate Supply Deficit)

Table 3-25: Ntabelanga Dam Flow Series after Abstraction of EWR and BASE Demand

Ntabelanga Historical Monthly Flows (Mm^3/mth) Minus EWR Minus HIGH Demand											FAIL RATE		20%
Year	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Total**
1920	6.76	**-0.51**	5.53	8.19	2.65	45.61	27.64	5.22	0.42	**-0.16**	**-0.54**	0.62	**101.44**
1921	7.01	62.92	49.46	6.65	**-2.69**	**-6.99**	**-4.17**	28.91	15.44	12.05	21.72	7.35	**197.66**
1922	5.83	101.10	25.28	93.46	107.04	45.99	4.95	0.09	0.88	69.19	21.99	0.21	**476.02**
1923	**-0.96**	**-3.04**	9.25	9.78	30.64	18.05	**-0.14**	0.37	1.00	0.23	1.28	2.74	**69.21**
1924	0.90	2.59	144.76	36.90	**-3.66**	154.73	134.42	27.24	0.97	0.18	-0.36	1.28	**499.96**
1925	**-1.50**	9.09	0.53	0.61	2.60	58.47	15.52	3.60	8.97	3.47	0.02	6.34	**107.72**
1926	8.86	2.96	17.18	1.89	**-3.34**	186.76	52.40	**-0.25**	**-0.30**	0.02	1.74	1.12	**269.04**
1927	5.35	**-3.06**	80.86	117.62	32.47	0.71	**-1.55**	1.20	0.84	0.17	3.71	0.27	**238.59**
1928	**-0.15**	6.13	40.73	11.44	43.89	115.11	27.19	3.29	14.61	11.54	4.37	12.25	**290.39**
1929	58.82	42.71	51.74	72.92	10.85	53.29	24.27	2.52	1.80	1.84	7.69	3.65	**332.10**
1930	3.64	**-4.72**	7.09	72.76	61.11	84.06	22.61	0.56	0.01	130.79	38.87	**-0.60**	**416.17**
1931	2.24	5.01	11.96	2.37	91.84	23.90	**-2.79**	1.66	1.42	2.89	0.91	33.28	**174.68**
1932	25.54	109.42	75.18	6.18	**-5.12**	41.03	14.58	0.50	**0.00**	0.23	0.05	**-0.79**	**266.81**
1933	**-2.55**	142.46	120.11	224.28	55.86	69.62	20.02	0.48	1.03	19.10	5.97	**-1.05**	**655.33**
1934	2.37	10.16	87.80	19.02	**-4.19**	26.84	26.72	11.15	10.50	3.54	5.40	1.01	**200.31**
1935	**-0.13**	**-4.53**	**-7.00**	**-5.74**	125.70	43.01	0.58	26.11	9.20	4.51	0.79	0.48	**192.98**
1936	18.59	166.67	42.04	33.94	119.08	51.96	3.59	**-0.15**	0.04	0.00	**-0.31**	0.74	**436.19**
1937	1.53	**-4.55**	6.20	56.34	74.18	16.22	64.39	19.50	2.90	4.42	4.73	**-0.09**	**245.78**
1938	3.00	10.45	72.84	107.19	164.20	35.31	**-1.93**	2.54	2.13	5.52	2.70	41.52	**445.49**
1939	24.69	10.91	0.68	3.52	41.56	19.64	3.99	12.64	5.04	0.33	**-0.02**	2.03	**125.01**
1940	2.94	1.13	4.33	8.18	3.92	4.22	4.30	0.99	0.23	0.96	0.77	**-1.27**	**30.71**
1941	0.15	**-2.88**	**-6.19**	7.48	43.61	65.85	24.33	6.05	1.01	**-0.43**	2.74	3.05	**144.76**
1942	32.75	60.94	97.13	41.11	**-0.37**	63.61	49.81	14.88	6.31	2.94	40.53	24.14	**433.77**

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1943	31.92	67.16	76.63	21.41	7.78	44.26	10.52	0.07	3.79	3.29	0.19	50.49	**317.50**
1944	19.92	**-3.96**	**-6.68**	**-1.94**	48.66	44.22	7.06	0.62	0.26	**-0.22**	**-0.68**	**-1.49**	**105.75**
1945	17.25	**-0.68**	**-2.48**	76.83	30.22	26.77	11.54	6.20	1.68	0.35	**-0.20**	**-1.35**	**166.15**
1946	**-1.24**	6.94	0.43	23.19	39.67	50.70	30.68	5.06	15.13	6.12	0.14	2.62	**179.43**
1947	1.75	91.78	105.80	75.45	95.42	44.31	8.90	2.32	0.60	0.17	**-0.45**	**-1.23**	**424.82**
1948	13.80	0.27	**-0.94**	**-2.72**	12.02	2.63	0.88	1.70	**-0.09**	0.44	0.28	0.10	**28.36**
1949	**-1.38**	**-1.03**	2.27	12.03	100.00	85.43	20.39	19.81	6.31	1.82	17.00	5.43	**268.06**
1950	9.04	**-1.40**	95.99	34.22	4.60	0.21	**-1.02**	**-0.08**	**-0.19**	**-0.52**	2.33	2.72	**145.88**
1951	37.28	4.88	**-4.68**	1.91	72.13	17.13	1.32	1.16	1.00	1.52	0.27	2.35	**136.28**
1952	0.44	1.48	5.29	1.08	43.26	12.45	15.43	4.02	**-0.60**	**-0.78**	0.93	6.62	**89.62**
1953	15.38	17.04	15.53	12.89	27.39	59.07	14.50	20.39	13.03	2.90	**-0.44**	1.32	**198.99**
1954	12.71	6.76	0.61	133.70	117.18	27.69	12.39	4.49	3.45	1.33	**-0.53**	0.28	**320.06**
1955	2.05	10.37	1.98	**-7.64**	23.57	89.57	22.69	1.35	3.39	0.97	**-0.58**	1.08	**148.79**
1956	0.35	50.43	99.02	36.41	0.97	126.83	46.12	3.61	0.71	1.39	6.41	14.88	**387.12**
1957	14.57	1.03	1.24	96.84	35.14	**-1.09**	13.51	5.62	0.21	0.42	**-0.47**	**-0.51**	**166.52**
1958	**-1.76**	62.86	29.21	**-1.32**	**-0.15**	2.34	27.79	58.14	15.67	5.57	3.89	1.53	**203.78**
1959	**-1.08**	7.34	9.72	1.56	12.87	0.69	6.77	3.60	0.13	0.38	1.91	6.57	**50.45**
1960	1.31	21.41	41.78	24.46	6.49	26.03	26.08	10.38	1.51	**-0.27**	0.34	**-0.16**	**159.36**
1961	**-2.39**	26.32	23.92	8.40	52.84	54.11	16.59	2.62	0.13	**-0.57**	0.11	**-1.23**	**180.86**
1962	4.81	53.58	39.01	124.40	56.16	155.52	45.99	1.74	0.11	4.37	0.91	**-1.63**	**484.97**
1963	45.66	88.56	18.41	19.95	0.57	42.96	25.76	3.08	49.09	16.83	0.74	2.92	**314.53**
1964	42.40	6.91	0.93	0.98	57.30	8.74	**-0.46**	0.73	97.57	32.35	7.08	2.14	**256.68**
1965	8.79	50.07	8.83	35.85	48.14	2.44	**-3.59**	14.82	5.64	0.03	2.38	2.69	**176.08**
1966	**-0.64**	**-1.89**	2.68	17.81	65.74	118.28	67.20	13.46	5.29	4.95	0.96	**-1.70**	**292.14**
1967	**-0.22**	6.30	**-3.96**	**-6.68**	**-3.53**	**-3.92**	0.27	**-0.26**	**-1.13**	**-0.83**	0.99	0.99	**-11.98**

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1968	0.49	-0.12	-4.45	-6.84	5.40	100.24	26.58	2.07	0.77	0.47	-0.12	-0.97	123.53
1969	12.16	1.19	9.39	-3.39	8.39	-5.13	-4.41	0.45	3.91	1.22	46.03	16.99	86.80
1970	46.52	10.67	-2.09	4.15	4.88	1.55	2.45	10.22	4.99	5.01	19.38	6.48	114.19
1971	58.06	17.96	6.78	24.42	143.35	61.56	4.81	0.22	0.43	-0.18	-0.84	-1.76	314.81
1972	-1.49	47.65	9.42	-3.25	87.07	74.22	18.86	1.65	-0.21	0.45	1.53	0.69	236.58
1973	3.21	5.98	1.80	128.32	88.60	159.57	44.56	7.39	4.31	1.14	0.13	-1.79	443.20
1974	-2.75	28.65	9.67	-0.05	-3.88	16.38	4.42	-0.86	-0.99	-0.58	-0.96	31.77	80.82
1975	5.87	7.47	131.52	114.13	78.85	239.05	65.43	22.28	7.74	1.82	0.65	4.15	678.95
1976	122.84	31.80	-3.24	3.08	18.94	8.69	3.52	0.09	-0.71	1.27	1.68	14.29	202.26
1977	7.16	12.22	8.08	7.59	-2.99	3.56	228.93	68.29	0.56	-0.37	1.01	5.84	339.87
1978	20.61	4.78	35.57	7.26	11.27	6.05	-0.35	0.50	-0.20	12.22	4.52	0.60	102.83
1979	1.58	-3.38	-3.07	-1.86	-2.35	1.87	-0.57	-1.06	-1.25	-0.75	-1.14	23.42	11.44
1980	5.54	3.26	4.47	22.22	98.71	23.66	-2.66	8.11	4.17	0.44	2.44	-0.40	169.96
1981	-3.01	-3.33	3.40	8.43	-1.46	98.28	29.14	0.13	1.84	3.99	0.49	0.23	138.12
1982	1.00	17.14	-1.41	-7.63	-8.67	-5.33	2.04	1.02	-0.22	0.69	-0.58	-0.67	-2.62
1983	3.98	51.89	66.42	22.35	11.62	61.35	26.80	4.21	3.64	4.17	1.22	-0.54	257.13
1984	19.27	18.30	-0.23	50.11	175.23	39.74	-2.17	-0.69	-0.47	-0.54	-1.11	-1.06	296.37
1985	75.25	59.42	78.91	31.41	23.12	16.19	1.13	-0.76	-0.55	0.56	5.26	6.31	296.24
1986	64.89	77.95	16.88	2.92	2.67	15.79	3.94	-0.45	1.35	0.38	4.47	193.83	384.62
1987	77.25	18.39	9.79	11.11	195.06	109.58	19.79	5.72	2.64	2.02	2.12	3.03	456.50
1988	2.92	28.13	106.21	33.74	136.27	45.64	58.29	17.60	1.18	4.40	0.62	-1.77	433.23
1989	10.94	181.89	52.46	21.18	-2.32	54.80	22.02	1.74	1.40	0.52	7.09	1.53	353.25
1990	9.98	-1.43	0.92	18.35	8.40	-3.48	-3.75	-0.78	-0.15	-0.74	-1.05	1.20	27.47
1991	81.56	35.00	97.58	24.21	2.72	-3.95	-0.05	-0.53	-1.02	-1.16	-0.82	0.39	233.94
1992	-1.29	-2.80	-5.54	-4.09	1.73	11.96	6.65	0.42	-1.21	-1.43	-0.67	6.11	9.84

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1993	62.88	25.79	42.93	61.26	81.18	119.46	27.10	**-0.03**	0.60	3.41	3.13	**-1.33**	**426.39**
1994	**-1.79**	**-5.46**	7.38	28.39	1.69	85.57	44.79	7.23	1.86	0.54	**-0.84**	**-0.19**	**169.17**
1995	4.55	3.27	147.96	180.98	103.90	24.50	1.14	0.76	0.24	1.57	0.15	**-0.90**	**468.12**
1996	**-0.12**	101.71	69.32	49.97	7.04	21.99	15.78	3.67	100.37	42.93	5.60	0.30	**418.56**
1997	8.11	10.95	2.59	74.88	157.60	155.46	40.15	7.56	2.47	3.21	4.38	1.30	**468.65**
1998	0.15	67.88	84.74	29.13	85.31	28.84	**-0.21**	**-0.15**	0.24	0.22	**-0.56**	**-1.69**	**293.90**
1999	21.82	8.17	52.62	143.93	140.15	143.67	79.12	20.66	3.86	1.05	**-0.24**	2.71	**617.53**
2000	2.55	8.45	6.32	44.82	33.97	19.15	6.38	0.81	**-0.43**	**-0.27**	**-0.58**	0.99	**122.17**
2001	14.38	136.07	78.98	50.38	10.25	25.07	7.12	4.79	3.75	8.76	24.00	9.69	**373.24**
2002	**-1.21**	**-3.21**	3.97	7.42	1.51	10.94	4.50	3.69	1.85	**-0.20**	0.76	6.39	**36.39**
2003	**-1.16**	**-1.00**	**-3.55**	69.04	26.18	95.43	29.85	0.76	0.25	8.52	3.39	51.89	**279.60**
2004	15.25	17.63	8.12	148.19	45.94	19.71	6.62	1.82	0.13	**-0.62**	0.96	**-0.75**	**263.00**
2005	0.10	25.48	3.17	35.07	39.04	18.39	32.51	14.53	2.61	0.75	32.25	31.52	**235.42**
2006	93.31	48.27	18.51	4.80	**-2.02**	**-3.49**	3.77	0.54	1.09	0.13	**-0.47**	**-1.39**	**163.04**
2007	27.00	10.73	1.48	11.32	40.56	31.51	25.88	6.45	6.19	2.24	0.88	**-0.69**	**163.54**
2008	**-2.47**	**-0.99**	24.52	6.26	58.52	8.35	**-3.44**	1.00	1.55	**-0.29**	1.46	0.16	**94.63**
2009	29.45	5.38	**-4.55**	79.16	24.33	**-3.15**	0.03	**-0.03**	1.11	0.19	**-0.97**	**-2.22**	**128.71**

(Blocks indicate Supply Deficit)

4. PRELIMINARY STUDY - SITE SELECTION OF FINAL DAM SITE

4.1 Introduction

This section describes the process of further investigation of the three dam sites that were shortlisted following the site selection process described above in **Section 2** and the further investigations thereof as described in **Section 3**. These three sites have been compared on a common basis in terms of economics as well as other social and environmental factors. Conclusions are stated, and a recommendation is made for the final dam site which is to be investigated in more detail in Phase 2 of this study.

4.2 More Detailed Site Investigations Undertaken in Phase 1

As has been described above, following the inception period, and discussions held at PSC meetings in 2012, the study team agreed that it would be beneficial to undertake some more detailed hydrology, topographical survey, and some foundation core drilling at <u>all three</u> potential dam sites instead of only at the eventual single chosen site.

These are summarized below.

a) *Hydrology*

A detailed hydrological assessment was undertaken for the three shortlisted dams. This included yield modelling runs which were undertaken following the receipt of the detailed land survey information, which provided highly accurate depth verses surface area verses volume figures for each dam. This involved the stochastic hydrological modelling of the two Mzimvubu tributary rivers concerned (the Tsitsa and the Kinira), which allowed accurate and reliable yield assessments to be produced for each of the three dams, making the optimisation and economic comparison more robust.

Detailed flood hydrology was not done at this stage, as this will be undertaken on the selected single dam site in Phase 2. Preliminary flood figures were used for spillway capacity sizing purposes, as quoted in previous reports.

The hydrological analyses are described in the separate Water Resources Report Number P WMA 12/T30/00/5212/5 which will be a Phase 2 deliverable.

b) *Land Surveys (Topographical)*

Whereas, the original intention was to undertake detailed topographical surveys only in Phase 2, it was decided by the SMC to advance the initial topographical surveys into Phase 1 in order to enhance the accuracy of calculation of the area verses depth verses volume curves for each of the three dams, as well as the calculation of more accurate cost estimations for each dam, which improved the reliability of these Phase 1 analyses.

c) *Geotechnical Investigations*

A geotechnical reconnaissance in the vicinity of each dam was undertaken by the Study PSP to provisionally locate and “walk-over” each dam site, to check its potential suitability via an inspection of the visible surface geology, and to undertake an to investigate potential construction materials sources (clay, sand, random fill, rock, aggregates etc.) in the local area.

It was also decided by the SMC that the advancement of some of the geotechnical investigations into Phase 1 would also provide very important information regarding potential fatal flaws that might exist regarding the technical suitability of each dam site, (with particular reference to the founding conditions below the dam wall) as well as informing the decision-making on optimum dam type and materials usage. These investigations also provided very useful information regarding the further investigations that are required in Phase 2 for the single dam site selected in Phase 1.

The conclusions were that foundation conditions are reasonable at all three sites. Ntabelanga also appears to have adequate sources of rock, sand, clay (for core material), within the inundated basin upstream of the dam, whereas Thabeng's rock quarries lie more downstream, which could possibly have a higher environmental impact.

Once the full findings of these investigations have been considered, recommendations will be made as to what further drilling and materials sourcing investigations will be required for the selected dam site to be investigated in detail in Phase 2.

The results and conclusions from of all of the geotechnical investigations are to be contained in DWA Report Number P WMA 12/T30/00/5212/10 which is also a Phase 2 deliverable.

4.3 Capacity Requirements of the Three Dams

4.3.1 *Dam Sizing and Yield*

Following the receipt of the new survey data, new depth verses area verses volume tables and curves were generated for each dam, which data was then used in the WRYM models together with the updated and more detailed hydrological information also produced in Phase 1.

It was noted that the new surveys produced somewhat different curves for Ntabelanga and Somabadi to those used in the "BKS" report, but similar results for Thabeng. It was thought that a mismatch of 20m contour data with Google earth elevations might have been the cause of the previous error.

The new survey data was carefully cross-checked and is considered to be highly accurate. This new survey information was therefore used in the Phase 1 analyses.

4.3.2 *Sedimentation and Catchment Management*

Sedimentation was also reviewed, taking into consideration the latest figures available from the updated "Rooseboom" models, as well as in-depth analysis of the difference types of land use, and land degradation in the catchments above each dam. .

A parallel study being undertaken concurrently by the South African National Biodiversity Institute (SANBI) significantly enhanced the information available in this regard. Thanks to good co-operation with this study team, and knowing the locations of the three shortlisted dam sites, SANBI chose to study the upper catchments of the Kinira and Tsitsa rivers above these dams.

The SANBI study was based upon the following:

- The condition of a catchment can influence its ability to receive and deliver rainfall and runoff to a dam and its related infrastructure.
- The SANBI study assessed that condition of the two catchments in this regard and provided a measure of the risk to the proposed dams on the basis of this condition.
- The work was based on the fact that the nature, extent and condition of the various land cover types in a catchment will provide a quantitative indication of this risk and builds on the concept of nature delivering valuable services to people.

- Similar to the “working for water” initiative, actions taken to restore, improve and manage these heavily degraded catchments could produce significant benefits for the carrying capacity and productivity of the land, could reduce sedimentation, and could improve baseflow and water quality into the dams constructed in those catchments, as well as creating both temporary and permanent employment in the region.

Figures 4-1 and 4-2 show the situation in the Kinira and Tsitsa catchments above the shortlisted dam sites, as investigated in the SANBI study.

The conclusion of the SANBI study was that, taking into account the sedimentation vulnerability in each catchment, as well as the land use and conditions prevailing in the catchment areas above each dam, the Ntabelanga dam site has a higher ecosystem services potential and lower risk factors than the other two dam sites.

This means that an investment in catchment restoration and management could yield cost benefits in terms of increased land carrying capacity and productivity, reduced erosion and sedimentation, reduced flood peaks, improved water quality, and increased base flow in drier seasons.

Such an investment would mostly be in the form of labour-intensive activities which could increase the job creation in the area. However, such activities are something that should be undertaken as a matter of good practice rather than because a dam is being built in the catchment. Therefore, the cost of such activities and the job creation that results were not used as decision-making criteria when deciding which of the three dams should be implemented.

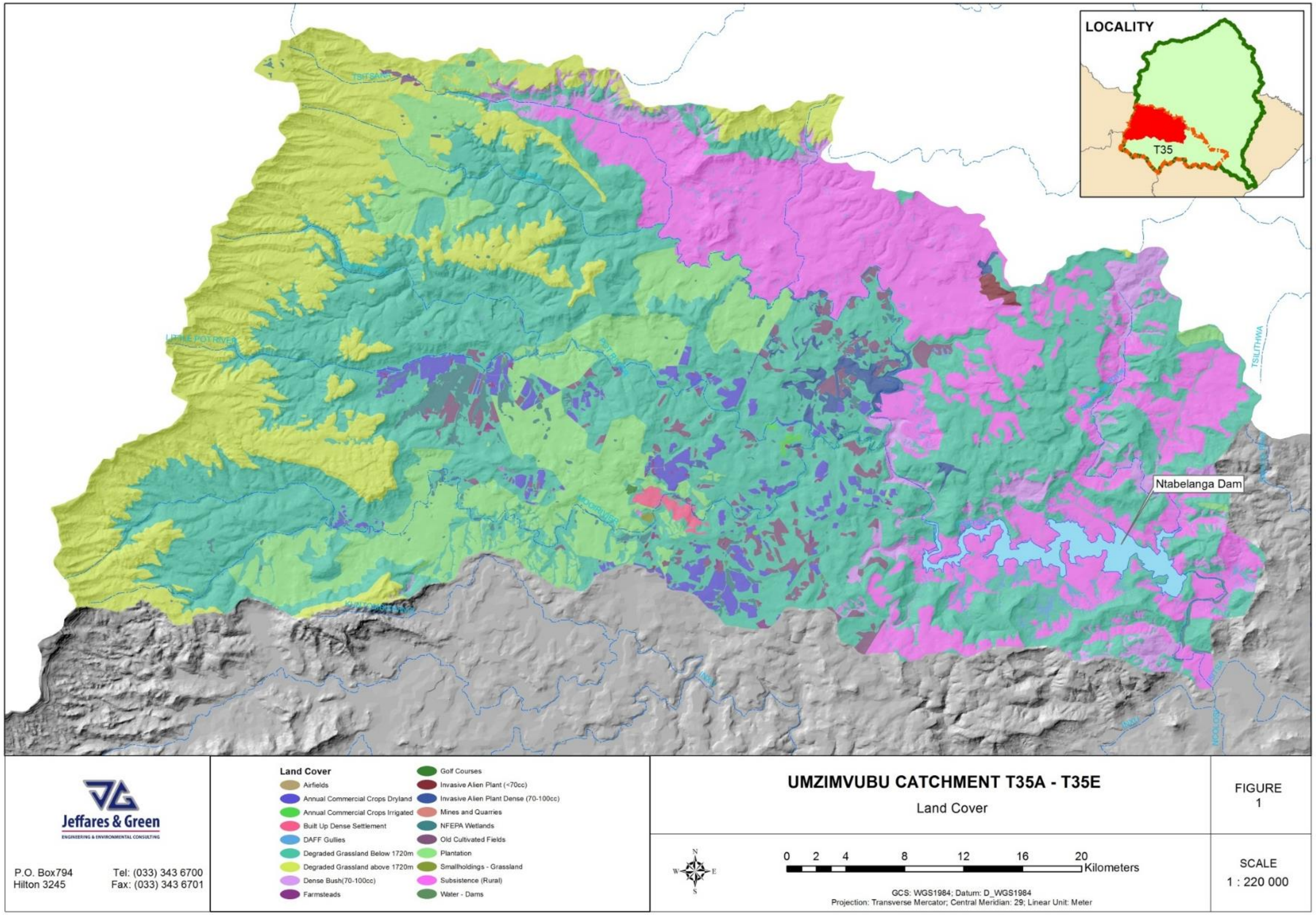


Figure 4-1: SANBI Study of the Tsitsa River Catchment above Ntabelanga Dam Site

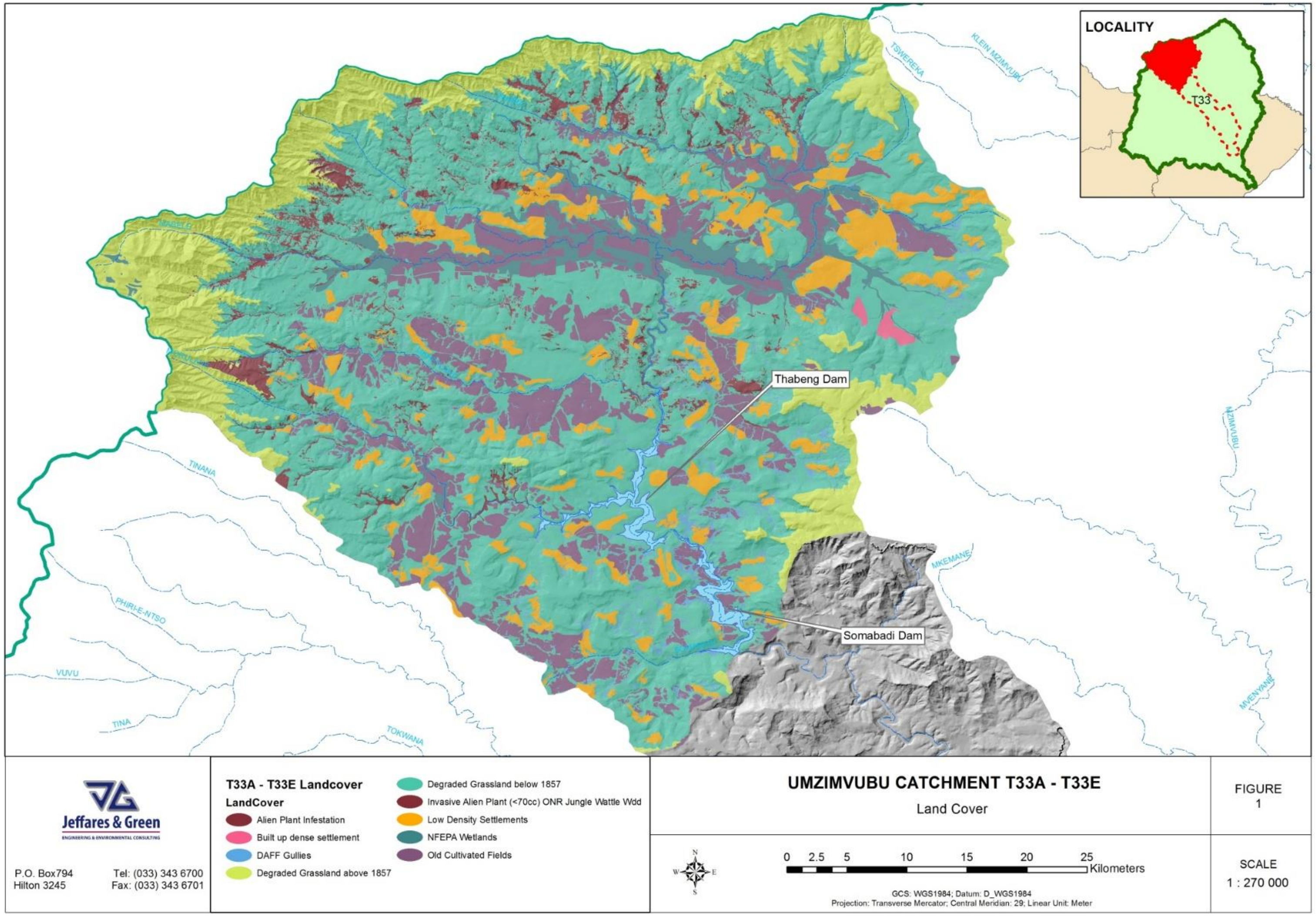


Figure 4-2: SANBI Study of the Kinira River Catchment above Thabeng/Somabadi Dam Sites

4.3.3 *Results of Yield Analyses*

As described above, updated EWR values as recommended by the Reserve Determination study team were also incorporated into the detailed hydrology WRYM models, and stochastic runs were undertaken to produce a series of depth/volume verses yield curves for each dam, at assurances of supply of 75%, 95% and 98%.

Results of these yield analyses are given in Figure 4-3 below, and the comparative economic analyses were undertaken using the 98% reliability yield figures.

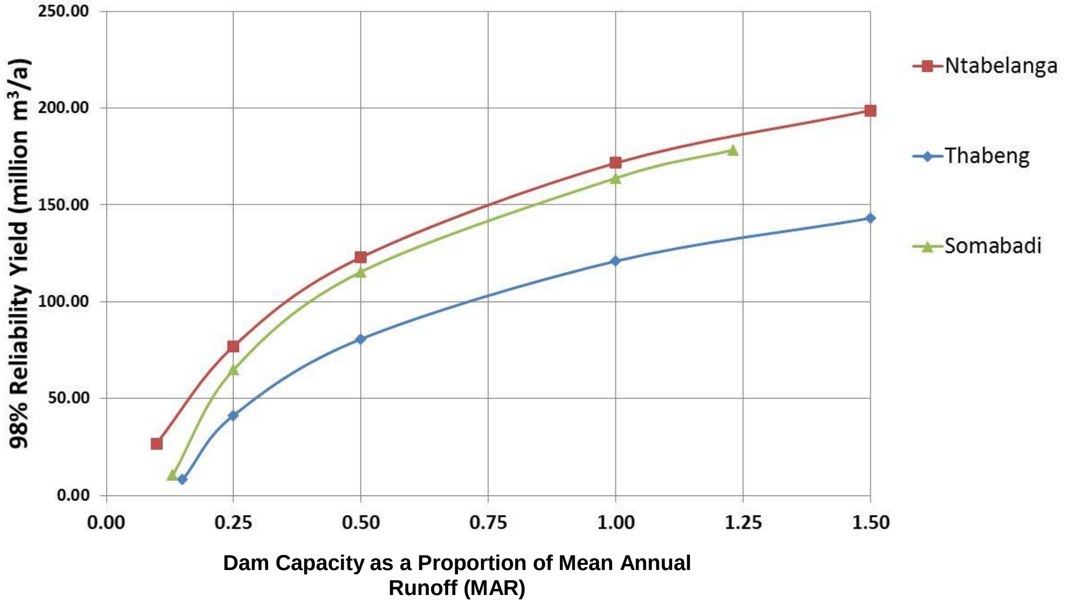


Figure 4-3: Comparison of Yield verses Capacity for the Three Dams

The range of sizes of dams analysed were equivalent stored volumes from 0.1 x MAR to 1.5 x MAR. Above this higher figure the yield curve significantly flattens and topography also becomes a constraint.

A dam size above 1.5 × MAR might be analysed if deemed necessary in Phase 2.

It can be observed that the Ntabelanga has the highest Yield verses Volume characteristic of the three dams. This does not mean that Ntabelanga is the best dam per se, as such comparisons should, inter alia, be based upon the economics aspects including unit cost of water produced.

Following this analysis, the raw water requirements, as described in the section above, were compared with the yields produced by this range of dam sizes.

In all three cases, the sizing of each dam having sufficient capacity to contain to the 50 year sedimentation accumulation volume, as well as supplying the HIGH scenario water requirements, and the EWR requirements, was relatively small at 10%, 20% and 15% of MAR for Ntabelanga, Thabeng and Somabadi dams respectively. This does not take into account any additional capacity requirement for hydropower generation however.

This is shown in Table 4-1 below.

Table 4-1: Size Statistics on the Three Dams

	GRAND TOTAL WATER DEMAND		98% Reliable Dam Yield	EWR	DAM SIZE (GROSS VOLUME INCLUDING SEDIMENT ALLOWANCE)		Dam FSL Water Depth	ESTIMATED CONT. HYDROPOWER THAT CAN BE GENERATED		ESTIMATED MAX PUMPING POWER NEEDED	
	BASE	HIGH						BASE	HIGH	BASE	HIGH
	million m^3/a		million m3/a	million m3/a	MAR x	million m3	m	MW	MW	MW	MW
NTABELANGA	7.83	21.97	26.80	52.82	0.10	33.00	31.00	0.27	0.27	0.61	1.71
THABENG	9.19	23.62	24.80	84.33	0.20	58.00	33.00	0.35	0.35	0.72	1.84
SOMABADI	8.59	21.47	21.32	104.98	0.15	54.15	44.53	0.40	0.40	0.67	1.67

Shows that each "minimum" capacity dam can reliably supply HIGH scenario demand as well as meeting EWR requirements

4.3.4 *Hydropower Potential*

A check was undertaken on each dam to ascertain the amount of reliable (continuous) hydropower that could be generated if a hydropower station were to be built immediately downstream of, or within, the dam wall, with average dam yield released through the turbines at 67% of the maximum head of the dam water depth. Whilst this is a simplistic approach and does not take into account variations in demand, it is considered adequate for Phase 1 comparison purposes.

The figures in Table 4-1 above show that, for the "minimum"-sized dams this output would range from 0.27 to 0.40 MW for the three dams.

Estimations were also made as to how much power would be required to transfer and treat the raw water and to pump potable water into the systems served by each dam. Whilst at this desk-top level this can only be a very approximate estimate, the power requirements for these bulk water supply systems totalled between 0.61 to 0.72 MW for the BASE demand case, to 1.67 to 1.84 MW for the HIGH scenario.

Clearly the requirements for a self-sufficient "hydro-powered" scheme cannot be met by these "minimum" dam sizes.

An analysis was therefore also undertaken to see how much larger and higher the three dams would need to be built to be able to generate the bulk water system power requirements given above. The incremental cost of raising the dam walls and installing hydropower plant for this latter scenario was thus calculated and included in the economic analyses described below.

4.4 Economic Comparison of the Three Dam Site Options

For each of the options described above, capital cost estimates were prepared so that a discounted cash flow analysis could be undertaken to compare the Unit Reference Value (URV[4]) of water supplied by each of the three dams.

It should be noted that in previous studies comparing dam site options, the URV was calculated on the basis of the full safe yield of the dam irrespective of whether that full yield was productively utilized for water supply or irrigation purposes. In this case the comparison has been made on the basis of the actual water delivered to potable water supplies and irrigation schemes. The URVs thus stated in this report will vary between the two different demand scenarios, but still provide a viable method for economic comparison of the three dam options.

Capital costs of each dam and dam size were calculated using a costing model which calculates major quantities of the various excavation and materials components, assuming that these dams would be random fill earth embankments, with a clay core, sand filters, rip-rap on the upstream face, upstream and downstream slopes of 1 in 3 and 1 in 2 respectively, using a standard depth of excavation to foundation level, and standard freeboard between FSL and NOC levels.

Figure 4-4 below shows a typical arrangement cross-section of such an embankment.

Each dam's geometry, and quantities thus generated, was based upon the more accurate centreline topographical information made available by the new LiDAR survey.

A standardized, conventional ogee uncontrolled concrete spillway and discharge chute was assumed and costed in each case, as well as a typical allowance for grouting.

Cost estimating unit rates for construction materials and works were developed using the latest Department of Transport Estimating Rates (April 2013) as well as other information taken from similar exercises undertaken recently on other projects.

These are considered representative of current market conditions, but will be further researched and updated in Phase 2.

Additional allowances were also made for the cost of advance infrastructure, temporary camps, laydown areas, mitigation costs, land acquisition, and other ancillary works, including temporary river diversions and cofferdams etc. These were allowed for in a "miscellaneous works" sum of 30%. A 10% general contingencies allowance was also included. P&G's were set at 30% for all options.

Costs for other downstream works such as water treatment works, pumping stations and bulk water supply systems are not included.

All unit rates were at April 2013 price levels, and CPA beyond 2013 was not included for this comparative analysis. These costs also exclude VAT.

[4] *URV is the Net Present Value of Capital and O&M costs over the lifespan of the scheme divided by the Net Present Value of raw water supplied over the same lifespan, and is expressed as Rand/m^3*

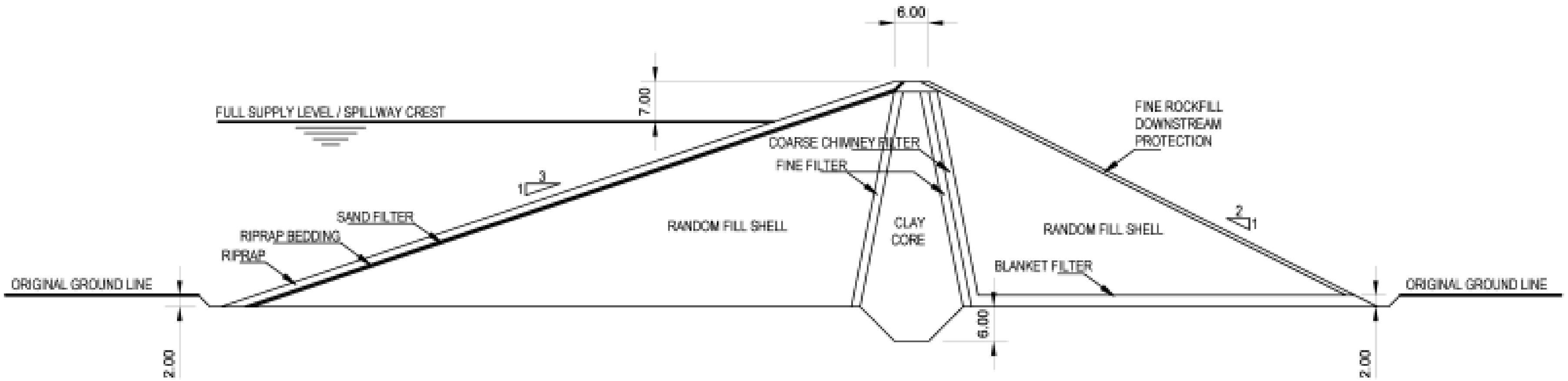


Figure 4-4: Typical Cross Section of Random Fill Clay Core Earth Embankment

(NB: For preliminary cost estimation only - Will be investigated in detail and optimized in Phase 2)

These cost estimate totals are summarized in Table 4-2 below.

Table 4-2: Capital Cost Estimates for the Three Dams of Various Sizes

Dam Size	Ntab Dam	Ntab Dam	Thabeng Dam	Thabeng Dam	Somabadi Dam	Somabadi Dam
MAR x	Vol (million m3)	Cost (Rm)	Vol (million m3)	Cost (Rm)	Vol (million m3)	Cost (Rm)
0.10	32.70	386.44	29.00	467.47	36.10	472.00
0.15	49.05	400.61	43.50	478.09	54.15	500.22
0.20	65.40	414.79	58.00	488.70	72.20	528.44
0.50	163.50	499.83	145.00	552.37	180.50	697.78
0.75	245.25	557.76	217.50	653.58	270.75	808.11
1.00	327.00	615.70	290.00	754.80	361.00	918.45
1.50	490.50	730.06	435.00	878.89	Limited by Terrain to 1.1 x MAR	

Costs are at 2013 prices, and exclude engineering and EIA costs and VAT

Calculating capital costs for the three dams and for various dam sizes enabled a "costing curve" to be produced for the given ranges of dam sizes, which was converted into a dam volume verses cost lookup table on the economic analyses models.

These curves are shown in Figure 4-5 below.

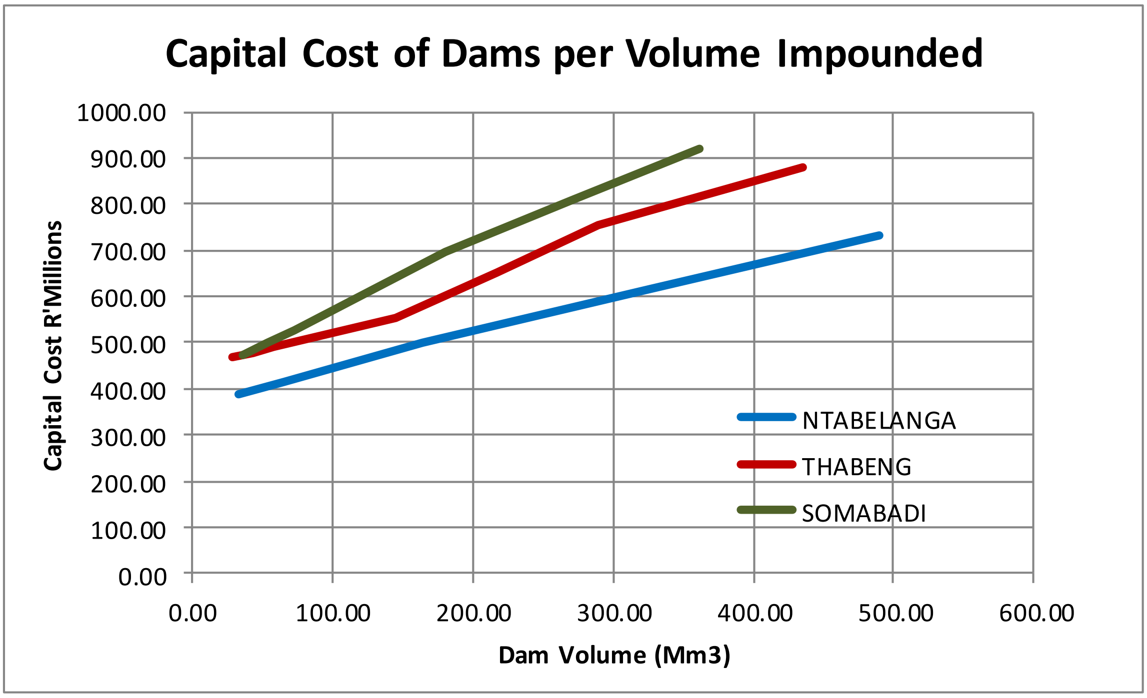


Figure 4-5: Dam Capital Cost Curves

The above chart this time illustrates that the Ntabelanga dam has a lower cost per million m^3 stored than the other two dam options.

Similar costings were derived for hydropower plant and associated infrastructure using various sources, including the ESKOM Eastern Cape Hydropower Options Report of 2004, costings undertaken by BKS in the 2010 Mzimvubu Report, and with some cross-checking by requesting new budget quotations from suppliers[5]. These were also based on April 2013 price levels.

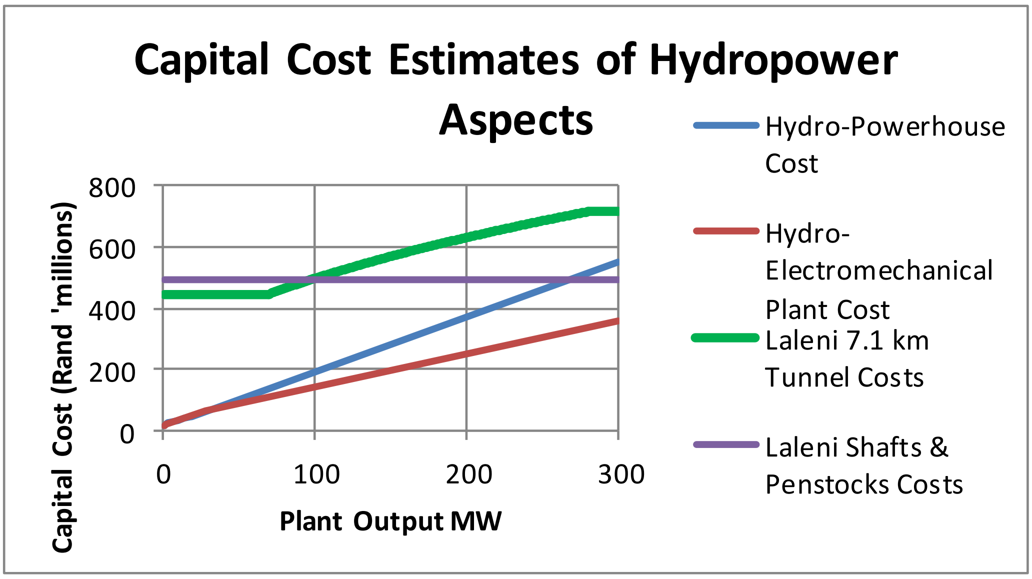


Figure 4-6: Hydropower Aspects Capital Cost Curves

All cost estimates have thus been derived on a common basis for the options investigated, and are considered sufficiently accurate for the purposes of economic comparison of these three dams.

4.4.1 *Options for Water Supply Purposes Only*

Scenarios were investigated firstly for dams that supplied raw water only to meet the above range of potable and irrigation demands, with no hydropower component.

Other scenarios were then run which included raised dams with hydropower plant installed to both deliver the require quantity of raw water to meet the projected demands, as well as generating sufficient hydropower to meet the energy needs of the water supply systems in the supply area served by the dam.

Annual O&M costs were allowed for on the basis of a 1% p.a. of the capital costs.

The National Treasury guidelines have recommended that discount rates of between 6% and 10% should be used when investigating projects funded from the national fiscus.

For this high level comparison of the three dam site options, discounted cash flow models were built and URVs of raw water supplied were calculated at a discount rate of 8% for the scenarios described above.

An allowance of 15% of capital cost was also added during the design and construction stage to cover engineering, construction supervision, and environmental management processes.

A summary of key outputs from the above analyses is given below for the two demand scenarios and the “with” and “without” hydropower options.

[5] *(NB: In the case of the Laleni/Tsitsa falls option described below, tunnelling unit costs were derived from previous tunnel estimating studies undertaken by Hatch/Mott MacDonald, as well as the figures used in the 2010 BKS Report, all duly updated for price escalation to April 2013.)*

For the water supply only options, and for the BASE and HIGH demand scenarios, the resulting URVs were as follows on Table 4-3:

Table 4-3: Summary of "Water Supply Only" Options

	Ntabelanga	Thabeng	Somabadi
Minimum Dam Size (MAR x)	0.10	0.20	0.15
Sufficient for HIGH Demand Scenario?	Yes	Yes	Yes
Dam Volume (million m^3)	33.00	58.00	54.15
Dam Wall Height (m)	38.00	40.00	51.53
98% Reliable Yield Available (million m^3/yr)	26.80	24.80	21.32
BASE Raw Water Demand (million m^3/yr)	7.83	9.19	8.59
HIGH Raw Water Demand (million m^3/yr)	21.97	23.62	21.47
	URVs of Raw Water Supplied*		
	R/m^3	**R/m^3**	**R/m^3**
BASE Demand Scenario	6.79	8.58	7.34
HIGH Demand Scenario	2.37	2.99	2.88

* At 8% discount rate

As can be seen in the above table:

a) Ntabelanga Dam has the lowest URV of water supplied
b) URVs for the BASE demand scenario are high for all dams

4.4.2 *Options for Self-Sufficiency in Hydropower*

In addition to the water-supply only case above, a further analysis was undertaken to investigate the incremental cost of upsizing these three dam options so that the dams and the water delivery infrastructure supplied by them could be self-sufficient in energy requirements by hydropower generation at each dam and distribution of the power produced into the supply zone.

In this case, each dam needed to be increased in size so that sufficient reliable yield and head was available to generate the amount of power required.

When undertaking economic analyses of power supply schemes a similar approach is taken to the URV analysis undertaken for water schemes. The difference is that instead of URV, the Levelized Cost of Energy is calculated, which is the Net Present Value of Capital and O&M costs over the lifespan of the scheme divided by the Net Present Value of energy supplied over the same lifespan, and is expressed as Rand/MWh.

Given that water supply is the basic reason for constructing these dams, only the incremental costs over these base costs of the minimum size dam is used to calculate the Levelized Cost of Energy produced by raising each dam and installing the necessary hydropower generation and distribution infrastructure.

Table 4-4 below summarizes the results of this analysis.

Table 4-4: Summary of Incremental Costs to Produce Hydropower Self-Sufficiency

	Power Supply to Base Demand Scenario Infrastructure		
	Ntabelanga	**Thabeng**	**Somabadi**
Dam Size With Hydropower (MAR x)	0.45	0.70	0.23
98% Reliable Yield Available (million m^3/yr)	114	97	54
Water Supply Only Dam Cost (R'million)	386	489	500
Incremental Costs for Hydropower (R'million)	219	278	270
	Levelized Cost of Power Produced*		
	R/MWh	**R/MWh**	**R/MWh**
BASE demand case	4 334	4 690	4 917

* At 8% discount rate

	Power Supply to High Demand Scenario Infrastructure		
	Ntabelanga	**Thabeng**	**Somabadi**
Dam Size With Hydropower (MAR x)	1.50	1.50	1.00
98% Reliable Yield Available (million m^3/yr)	199	143	164
Water Supply Only Dam Cost (R'million)	386	489	500
Incremental Costs for Hydropower (R'million)	474	534	656
	Levelized Cost of Power Produced*		
	R/MWh	**R/MWh**	**R/MWh**
BASE demand case	3 245	3 418	4 777

* At 8% discount rate

Costs are at 2013 prices, excluding engineering and EIA costs and VAT

As can be seen above, the levelized cost of power thus produced is in the range of R 3 245/MWh to R 4 917/MWh, which is very high considering that current bench marking of what are considered to be viable schemes is normally at the R 1 000/MWh level.

It is therefore not considered to be a viable option to include hydropower generation if only a single "minimum-sized" dam solution is selected for further consideration in Phase 2 of this study.

4.5 Other Considerations for the Selection of a Single Dam Site

In addition to economic comparison, there are several other selection criteria that were investigated in Phase 1.

4.5.1 *Populations Served*

As has been described in the above section on water requirements, for the BASE demand case, Ntabelanga dam would potentially supply more people than the other two dams, and also has the characteristic of this population to be concentrated much closer to the dam than for the other two dams.

The situation changes for the HIGH scenario, where Thabeng can potential supply more people than either of the other two dams. However, considering an "average" scenario between the BASE and HIGH scenarios, brings the total population that could be supplied by each dam close to a similar number for each dam. The advantage of Ntabelanga dam option is that all of the identified population to be served under both scenarios are more concentrated within a 50km distance from the dam, rather than a much longer distance for the other two dams. For this reason, Ntabelanga could be given a slightly high ranking than the other two dams.

4.5.2 *Land Requirements*

Land requirements (using the footprint of backwater inundation) for the three dams are of a similar order if the minimum sized dams were to be developed, but Ntabelanga dam would inundate a significantly higher areas of land than both Thabeng and Somabadi, (depending upon the demand scenario) if the dams were to have been raised in order to be self-sufficient in scheme energy requirements. Given that this latter option is not considered to be cost beneficial, differing land requirements are not a decision criteria for these three dams.

4.5.3 *Irrigation Opportunities*

As described in the appropriate section of this report, the differences between the BASE and HIGH demand scenarios for irrigation water needs were the stringency of the criteria applied to the GIS modelling of land areas suitable for irrigated agriculture use.

The BASE case land areas thus identified favour the Thabeng & Somabadi dam options, whereas the HIGH case changes the ranking to favour Ntabelanga. Taking an average of the two brings the potential areas of land suitable for irrigated agriculture to a very similar figure for all three dam options. One observation for the high scenario shows that the area of irrigable land identified for Ntabelanga via the GIS analyses appears to show a more contiguous nature, rather than a large number of fragmented land parcels. Whilst it could therefore be argued, on the prima face evidence, that the Ntabelanga dam offers the best irrigation opportunities, only a more detailed investigation in Phase 2 would prove this conclusively.

4.5.4 *Job Creation Opportunities*

Given the conclusion in the above paragraph, there would not seem to be a significant difference between the three dam options regarding the potential for jobs creation in the irrigated agriculture sector.

The same goes for the temporary and permanent jobs created through the infrastructure construction process, and on the operation and maintenance of the other water supply aspects. Jobs created if the recommended catchment management activities are implemented would also be similar for all three dam options.

4.5.5 *Impacts on Existing Infrastructure*

Comparing each of the three dam sites options for the “minimum” sized dam (i.e. water supply only – no hydropower), indicate some differences in impacts on the existing infrastructure. The three Figures 4-7 to 4-9 overleaf demonstrate this by overlaying the impoundment shoreline under flood flow conditions over images of each dam site location.

Whilst there are no major fatal flaws in the impacts caused by any of the three dams, Thabeng has slightly higher an impact than the other two options in that the inundated area drowns the R56 national road as well as a new water treatment works which is currently under construction. The roads affected on the other two dams are mostly rural roads for local access.

The implications of raising any of the three dams to produce sufficient hydropower would proportionately increase these impacts, with the effects at Thabeng probably having the highest impacts on the national road, and with Ntabelanga also drowning more cultivated fields than the other two dams. However, as described above, this latter option is not recommended.

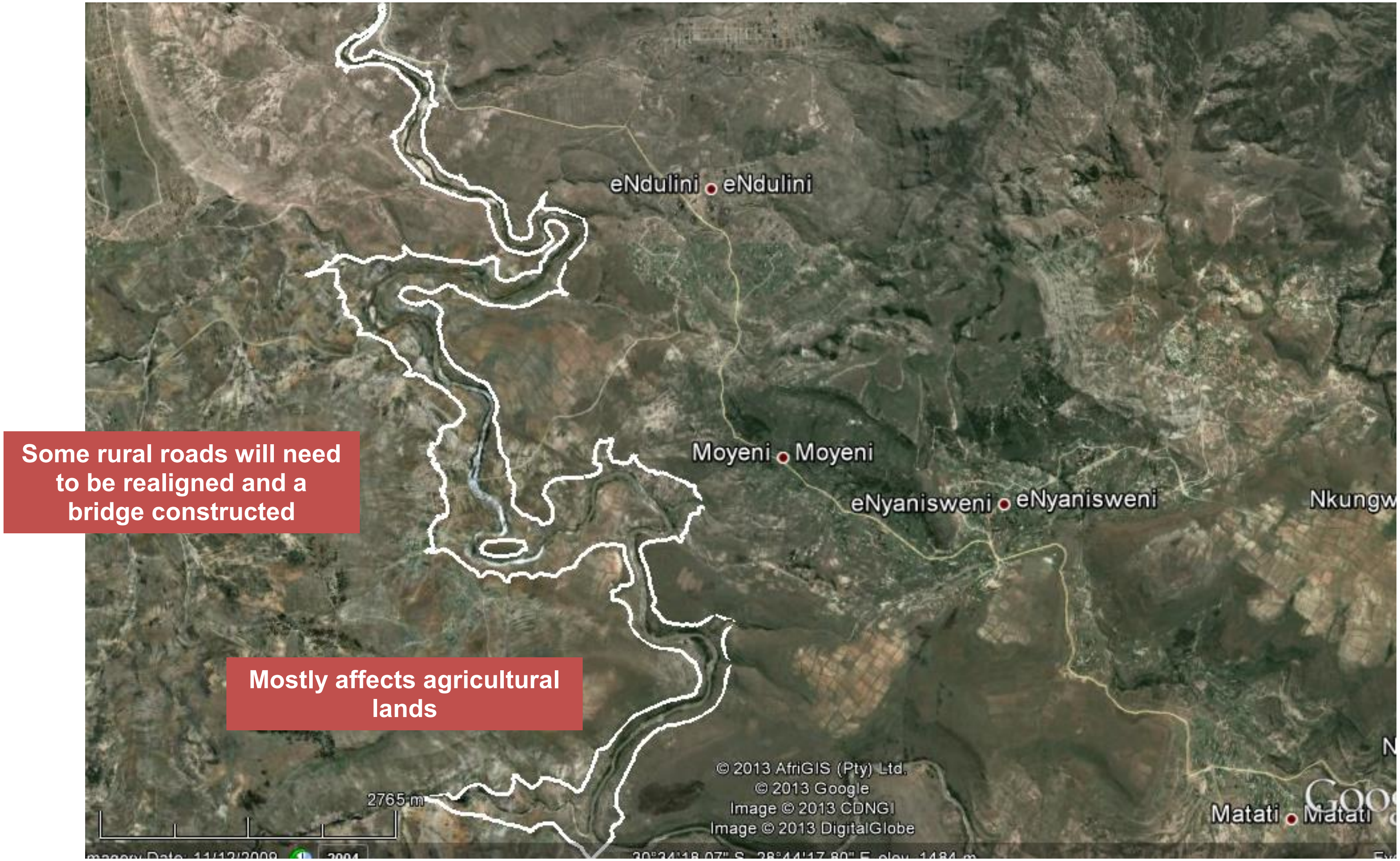


Figure 4-7: Impacts of Somabadi Dam Inundation Footprint on Existing Infrastructure

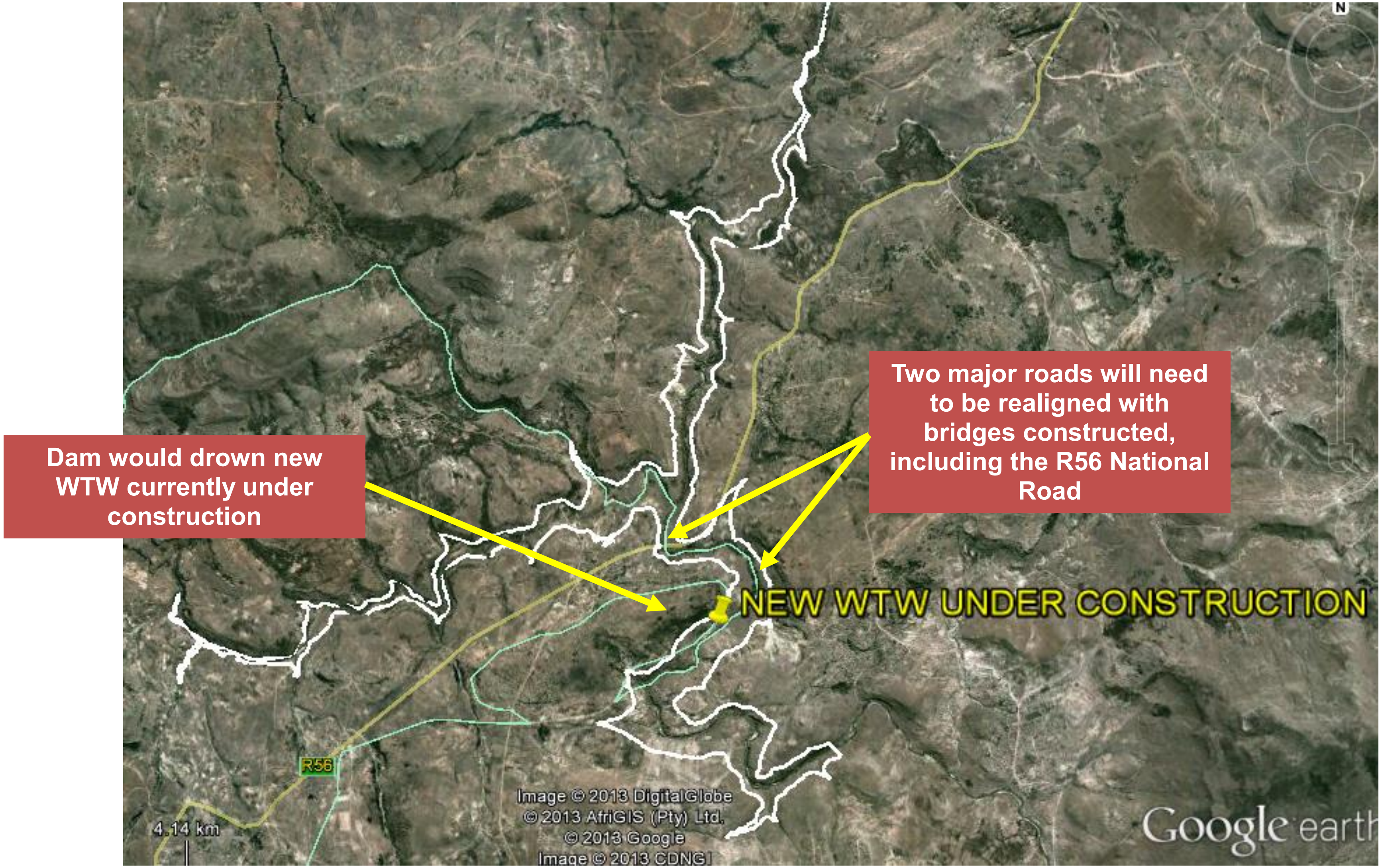


Figure 4-8: Impacts of Thabeng Dam Inundation Footprint on Existing Infrastructure

Figure 4-9: Impacts of Ntabelanga Dam Inundation Footprint on Existing Infrastructure

4.5.6 *Other Regional Water Supply Schemes Existing or Planned?*

Figures 4-10 & 4-11 show the footprints (red lines) of existing District Municipality water supply sources and schemes that have been identified to date in Phase 1.

Whilst the proportional coverage of these schemes to total population centres in the planning area are not dissimilar between the three dam site options, it can be seen that the areas close to the Thabeng & Somabadi dam sites are currently slightly better serviced than those close to the Ntabelanga dam site.

At this high level, it has not been possible to undertake extensive ground-truthing or detailed analyses of each and every existing scheme each supply area. However, as this criteria is also effectively covered under the category of total population served by each dam site, equal rating was given to all three dam site options.

4.5.7 *Able to Work Conjunctively with Other Major Schemes?*

This criteria is pertinent. This applies particularly to Ntabelanga, as this dam has the advantage over the other two in that it can be used conjunctively with a potential and significant hydropower scheme on the same river at Laleni/Tsitsa falls that was previously identified by ESKOM. This conjunctive hydropower option is discussed in more detail below.

Other options that have been considered for Ntabelanga dam include a potential longer-term (possibly only by 2050 or later) opportunity to effect inter-basin transfer to the Orange River system, and also to possibly augment the Mthatha water supply via inter-basin transfer to the neighbouring catchment.

However, both of these additional options would incur significant incremental conveyance costs as well as reducing the hydropower capacity of the conjunctive scheme. Being so long-term, the former option will not be considered further in this study, but the economic viability of the latter option will be investigated in Phase 2 of this study.

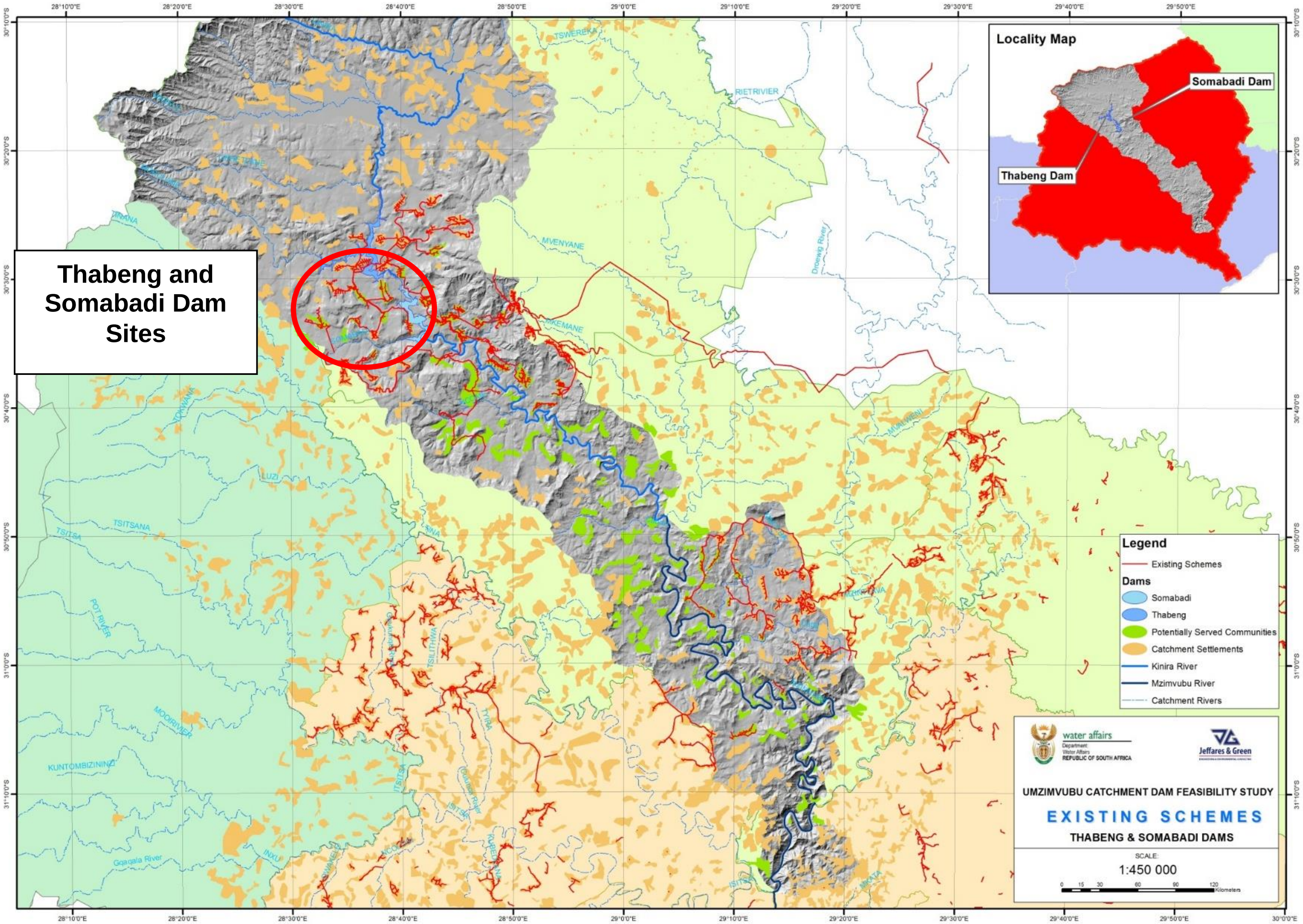


Figure 4-10: Areas in the Vicinity Which Have Existing Potable Water Schemes

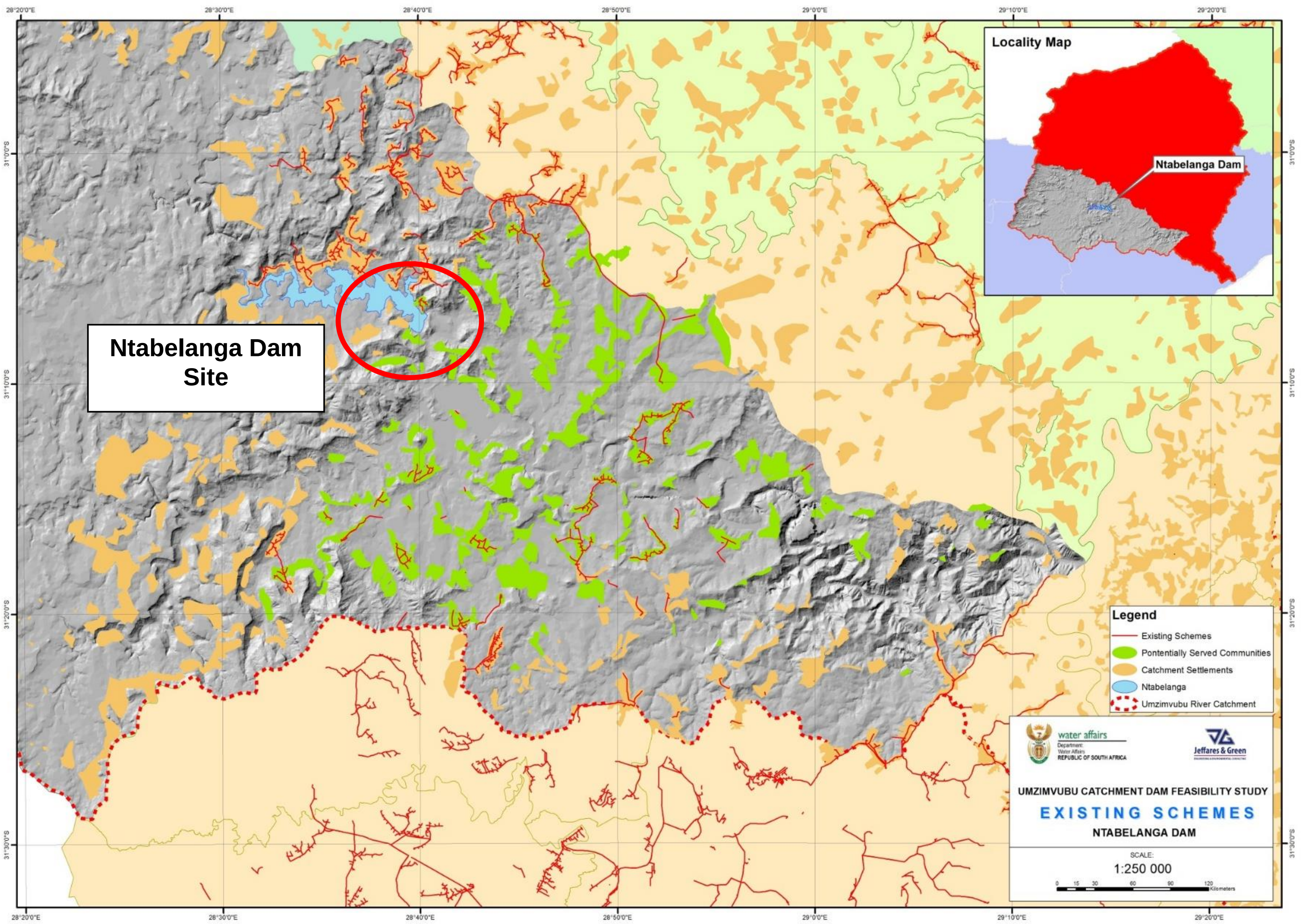


Figure 4-11: Areas in the Vicinity Which Have Existing Potable Water Schemes

4.6 Summary of Analyses and Decision Making Criteria

The "traffic light" colour coding method used in the tables below shows the simple ranking of the economic criteria between the three dams. No differential weighting was applied to these criteria as this requires qualitative rather than quantitive analysis to be undertaken, which can artificially skew results.

Table 4-5: Comparison of Dams by Numerical & Economics Analyses – Base Demand Case

BASE CASE CRITERIA			
Numbers and Economics	**Ntabelanga**	**Thabeng**	**Somabadi**
Population Served for this Scenario	**134 633**	**111 564**	**97 303**
Total Population within 50 Km of Dam	**223 686**	**94 666**	**116 337**
Irrigatable Areas within Limits Set (Ha)	**504**	**1062**	**1062**
Cost of Dam for Water Supply only (R'million)	**386**	**489**	**500**
Total Demand Supplied (Million M^3/A)	**7.83**	**9.19**	**8.59**
Total Water Available @ 98% (Million M^3/A) (Minimum Dam)	**26.80**	**24.80**	**21.32**
URV of Raw Water Supplied (No Hydropower) (R/M^3)	**6.79**	**8.58**	**7.34**
Is the above Dam Self-Sufficient for Hydropower?	**No**	**No**	**No**
Incremental cost of Raising Dam & Hydro-Plant (R'million)	**219**	**278**	**270**
Levelized cost of Energy Produced by Raising Dam (R/MWh)	**4 334**	**4 690**	**4 917**

Table 4-6: Comparison of Dams by Numerical & Economics Analyses – High Demand Case

HIGH CASE CRITERIA			
Numbers and Economics	**Ntabelanga**	**Thabeng**	**Somabadi**
Population Served For This Scenario	**223 686**	**294 784**	**273 743**
Total Population Within 50 Km Of Dam	**223 686**	**94 666**	**116 337**
Irrigatable Areas within Limits Set (Ha)	**2 634**	**2 200**	**1 933**
Cost of Dam for Water Supply only (R'million)	**386**	**489**	**500**
Total Demand Supplied (Million M^3/A)	**21.97**	**23.62**	**21.47**
Total Water Available @ 98% (Million M^3/A) (Minimum Dam)	**26.80**	**24.80**	**21.32**
URV of Raw Water Supplied (No Hydropower) (R/M^3)	**2.37**	**2.99**	**2.88**
Is the above Dam Self-Sufficient for Hydropower?	**No**	**No**	**No**
Incremental cost of Raising Dam & Hydro-Plant (R'million)	**474**	**534**	**656**
Levelized cost of Energy Produced by Raising Dam (R/MWh)	**3 245**	**3 418**	**4 777**

It should be noted that the above does not differentiate between potable water and irrigation water and the URVs are therefore actually an average figure for the whole demand. For both demand scenarios, the URVs are high and BASE case URVs are considered to be non-viable. Even the HIGH demand scenario URVs are high considering this relates to raw water production and does not include the additional treatment, bulk transfer and distribution costs.

Whilst this approach is considered acceptable for this high level comparison of options, the analysis will be undertaken at a much more detailed level of detail in Phase 2, where the differences in acceptable assurances of supply between potable and irrigation water, as well as the national policies on raw water pricing, will be taken into consideration.

As will be shown below, the sizing and operation of the selected dam conjunctively with the Laleni hydropower scheme provides cost benefits which changes the above non-viability into a viable situation.

Other criteria have also been evaluated for each dam and ranked in a similar manner, which are listed below.

Table 4-7: Comparison of Dams Based on Other Criteria – Both Demand Cases

Other Criteria (Environmental/Resettlement, Jobs, Etc)	Ntabelanga	Thabeng	Somabadi
Area of Land Inundated (Km^2) – No Hydropower	7.5	7.8	5.8
Impacts Existing Nat'l Road and Other Infrastructure?	Lower	High	Moderate
Other Regional Schemes & Sources Existing/Planned?	Yes	Yes	Yes
Able to Work Conjunctively with Other Major Schemes?	Yes	No	No
Sanbi Ecosystem Risk Assessment Results (Catchments)	Lower	Higher	Higher
Job Creation (Estimated Nos. Incl. Catchment Mang't)			
Temporary During Construction	200 to 300	200 to 300	200 to 300
Permanent Ws Operational Staff	30 to 50	30 to 50	30 to 50
Permanent on Irrigated Agriculture Schemes (Base Case)	50	106	106
Permanent on Irrigated Agriculture Schemes (High Case)	263	220	193

Whilst these other criteria show close rankings between the three dams, the significance of Ntabelanga being the only scheme able to work conjunctively with the potential Laleni hydropower makes it stand out above the other two dams.

4.7 Additional Alternative Options for Ntabelanga Dam

As mentioned above, another major option that has arisen during the Phase 1 investigations is the potential to build the Ntabelanga dam conjunctively with a hydropower scheme downstream on the same river, comprising a new dam at Laleni, located close to and above the Tsitsa falls. This latter scheme (then using Laleni dam only) was identified as a best option of many investigated by ESKOM in their study dated 2004.

This additional conjunctive use option has been discussed between DWA and ESKOM at a meeting held on 25 January 2013. The Department of Energy have also been informed and are considering information that has been sent to them by DWA.

Preliminary analyses undertaken to date, indicates that there could be economies of scale and other cost-benefits by constructing a "large" Ntabelanga dam to regulate flow to a "small" Laleni dam, and thence through the hydropower scheme tunnel and powerhouse.

The general arrangement of this conjunctive usage scheme is shown in Figures 4-12 and 4-13 overleaf.

Additional hydrological models were therefore run in Phase 1 and the hydropower module of the WRYM model was used to investigate two options:

a) *A stand-alone Laleni dam scheme with dam size 0.7 × MAR. This scheme could potentially produce some 27 MW continuous output (and possibly up to 180 MW peaking power at a load factor of 15%)*
b) *Using a raised Ntabelanga dam (1.5 × MAR) together with a small Laleni dam (0.18 × MAR). This scheme could potentially produce some 25 MW continuous output at Laleni and a further 2 MW continuous at Ntabelanga (again possibly up to 180 MW peaking power at the same load factor)*

High level cost estimations have been undertaken, and the incremental cost of implementing the conjunctive scheme b) over and above building the basic Ntabelanga dam for water supply only were calculated.

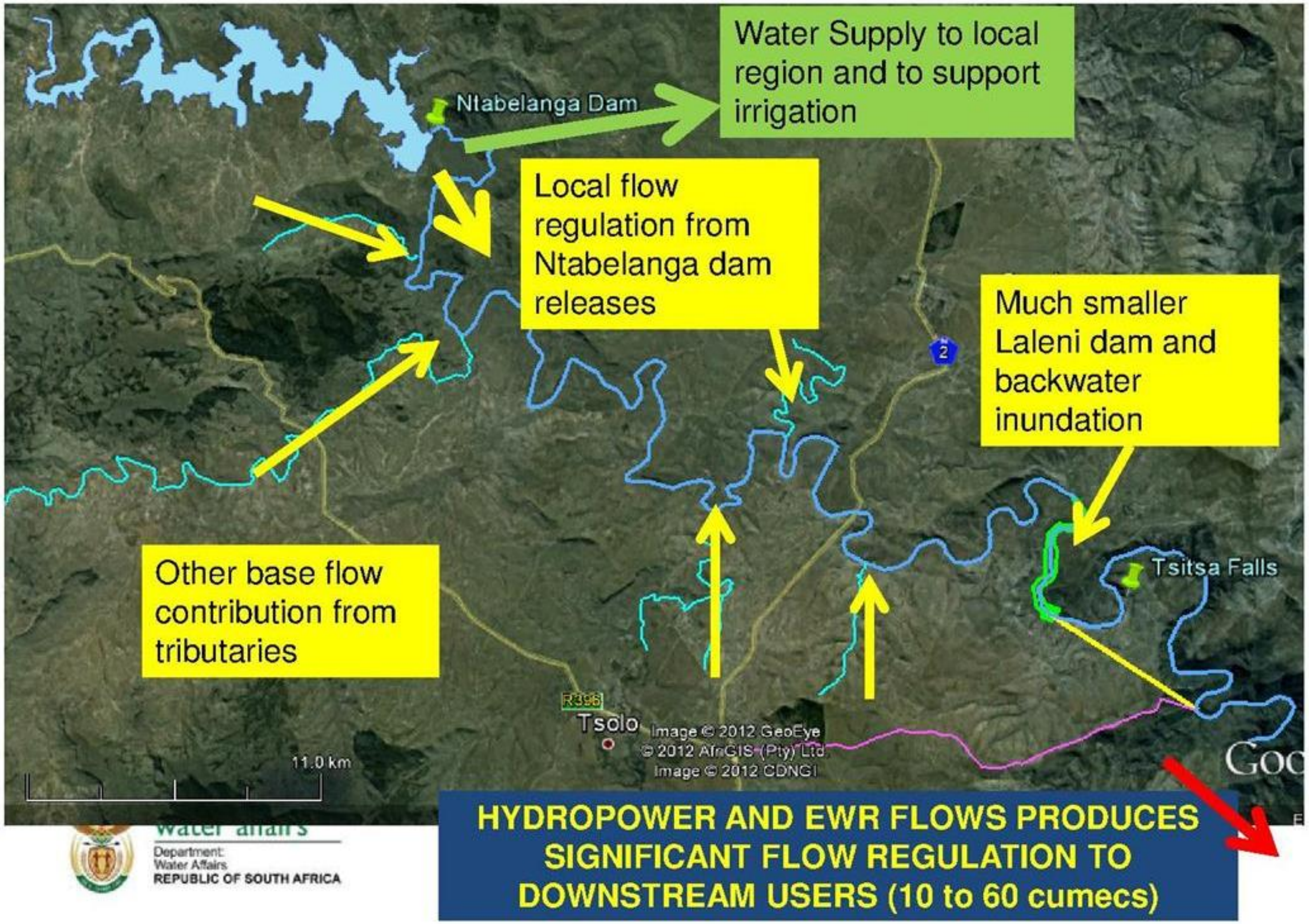


Figure 4-12: General Arrangement of the Potential Conjunctive Use of Ntabelanga and Laleni Dams

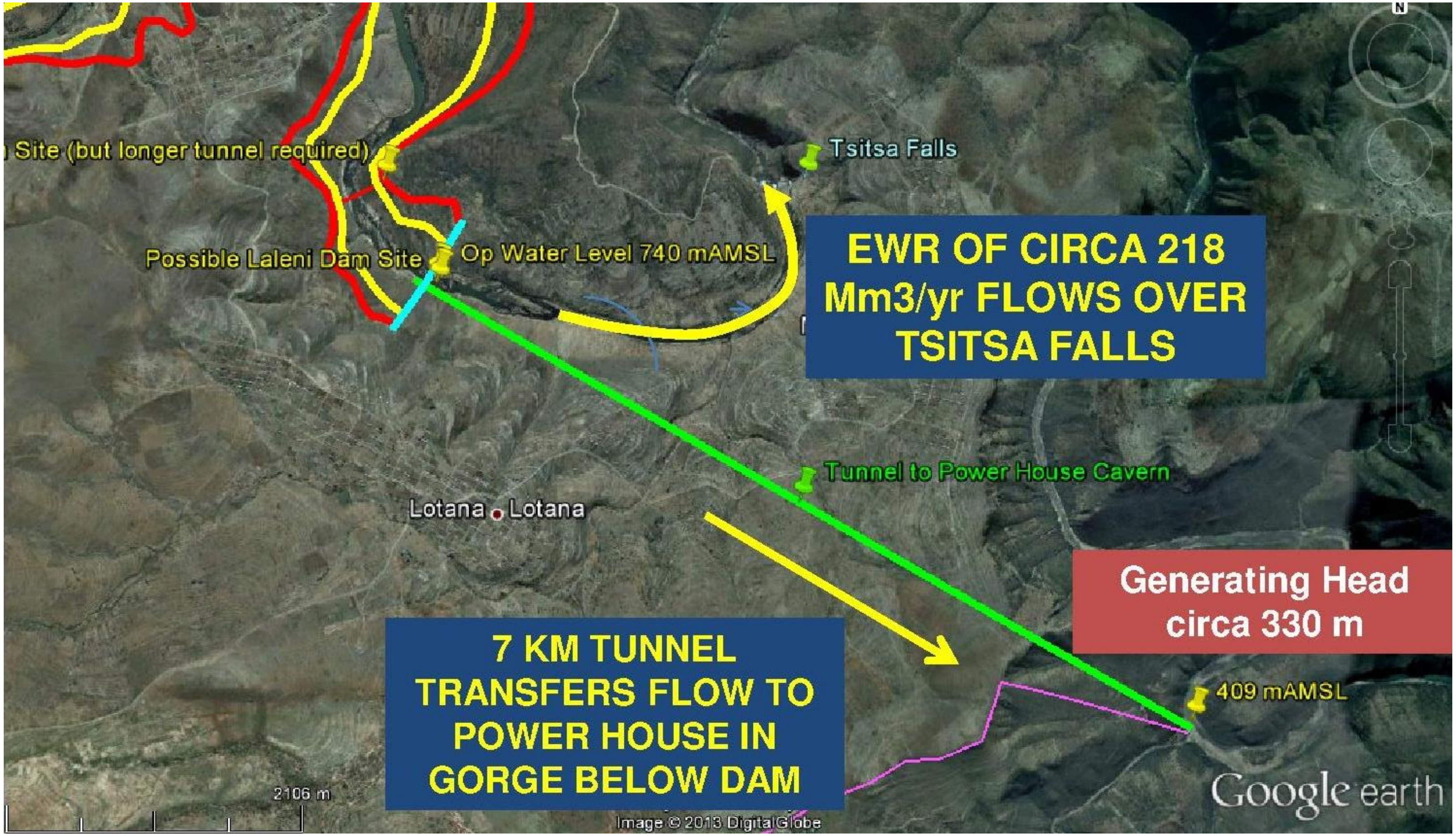


Figure 4-13: General Arrangement of the Potential Hydropower Scheme at Laleni

The chart in Figure 4-14 below shows the relatives costs of the Ntabelanga and Laleni dams showing the lower cost per volume impounded of the Ntabelanga dam.

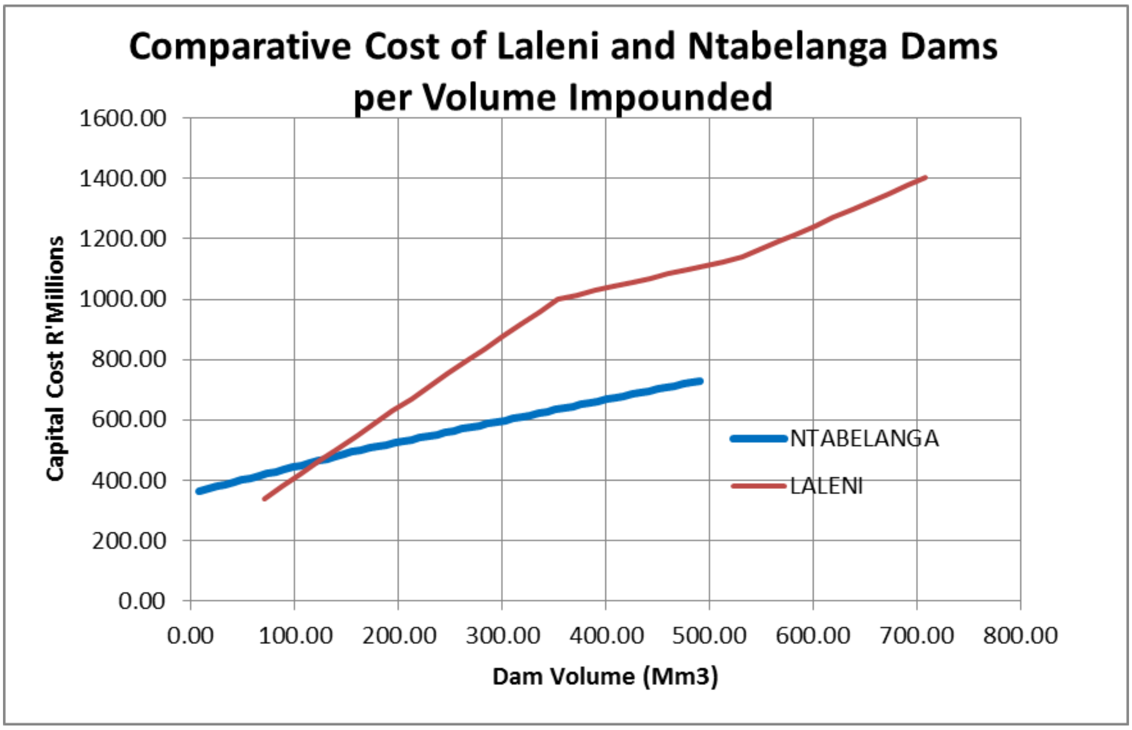


Figure 4-14: Comparison of Laleni & Ntabelanga Impoundment Costs

Using these incremental costs, the Levelized Cost of Energy produced was calculated at both 15% load factor and 100% (continuous power). The results in Table 4-8 show Comparison of a Laleni-only Hydropower Scheme with Conjunctive Usage of a Larger Ntabelanga Dam and a Smaller Laleni Dam (Incremental cost of hydropower components only)

Table 4-8: Comparison of a Laleni-only Hydropower Scheme

Options	Power Output Continuous		Power Output Max		Total Capex at Load Factors:		Levelized Cost of Energy	
	LF:100%	LF:15%	LF:15%	LF:100%	LF:15%	LF:100%	LF:15%	LF:100%
	MW	MW	Rand Millions	Rand Millions	Rand/ MWh	Rand/ MWh	Rand/ MWh	Rand/ MWh
					6% Discount Rate		8% Discount Rate	
a) Laleni only 0.7 MAR Dam	27	180	2 921	2 317	1 143	906	1 490	1 182
b) Laleni 0.18 Dam + Ntabelanga 1.5 MAR Dam	27	180	2 706	2 151	1 043	825	1 361	1 078
			Incremental cost of 27 MW hydropower scheme over water supply only scheme					

Whilst it must be emphasized that this analysis has been undertaken only at a high level at this stage, it is indicated that the conjunctive scheme could be built at a cost of some 7.5% lower than a stand-alone Laleni hydropower scheme, with the levelized cost of energy produced in the order of ± R 1000/MWh, which is understood to be the benchmark for a viable scheme. (Capital cost estimates for the full conjunctive scheme are given later in this section.)

The conjunctive scheme could produce major cost benefits, including potentially significant surplus revenues emanating from energy sales.

The hydropower generation potential of the scheme might also attract private sector interest which could result in a lower requirement for capital financing sourced from the Treasury. It must be reiterated, however, that this will depend upon the institutional, funding, and operational arrangements developed to implement such a conjunctive scheme.

In conclusion, there appears to be merit in further investigating the conjunctive use option as a part of Phase 2 of this study.

4.8 Conclusions & Recommendations

In terms of purely economic comparison of the three dam site options, Ntabelanga is clearly the highest ranked option, having the lowest capital cost and lowest URV of water produced for all configurations considered above.

Having said this, it should be noted that the URV's of raw water produced by all three dams (of "minimum size") are high if only potable and irrigation water requirements are taken into consideration.

Whilst the ranking is less clearly indicated when regarding the other impacts considered above, the overall conclusion and recommendation based upon the criteria considered above is that the Ntabelanga dam is the best single option to be taken forward into Phase 2 of this study.

The additional benefit that Ntabelanga has over the other two options is that it is well located so that it can be developed to work conjunctively and cost-beneficially with a potential large hydropower scheme on the same river.

If such additional use can be realised, then the URV of water produced could reduce accordingly and the economic viability of the dam itself could be realised.

This economic viability and financial sustainability of the selected dam will be investigated in more detail in Phase 2, which will revisit water requirements and existing water infrastructure in much more detail, as well as the cost-benefits of the scheme, including social upliftment, improved services, irrigated agriculture potential, and other job creation opportunities.

Following discussion and consideration of the above findings, the DWA study team concluded that a stand-alone dam at Ntabelanga on the Tsitsa river to supply potable and irrigation water requirements only would be unlikely to be economically viable, but if developed conjunctively with the potential Laleni/Tsitsa falls hydropower scheme, could deliver a viable solution meeting the multi-purpose social and economic upliftment objectives of the scheme.

It was therefore recommended that Phase 2 of this Feasibility Study focus on the development of the larger-sized Ntabelanga dam to be used conjunctively with the potential Laleni/Tsitsa falls hydropower scheme.

The full environmental and social impacts of the proposed Ntabelanga dam solution will also be investigated under the EIA study to be conducted by an independent PSP in parallel during Phase 2. The two study teams are required to work together in terms of planning and transfer of information.

At this Preliminary Study stage, the above analysis did not take into account the reserve requirements of the river systems downstream of the Ntabelanga and Laleni dams. These requirements will be a significant factor as regards how much water can be diverted through the hydropower plants and returned back to the river in any particular month, and this will be especially pertinent during low flow months, or particularly dry years.

These factors should be taken into account during the more detailed investigations of the conjunctive scheme.

4.9 Preliminary Cost Estimate for the Recommended Conjunctive Use Scheme

At this preliminary stage, the economic comparison of options has been undertaken by comparing dam infrastructure and associated works required to produce raw water at a satisfactory assurance of supply, and the incremental costs of the dams and associated infrastructure required to produce hydropower.

Water treatment and bulk water distribution costs were not included in such comparisons as the capital and operational unit cost per capita of domestic water supplied, and of raw water supplied to the identified areas of higher irrigation potential are considered to be very similar for all options, given the similar nature and topography of the supply areas and settlement distributions therein.

In preparing an overall preliminary cost estimate for the recommended conjunctive use scheme, these other costs have been included, but it must be emphasized that this is still at a very high level analysis only (ie low level of detail available).

Costs have also been included for the development of the irrigated agriculture schemes and their bulk water supplies.

Catchment management costs have also been included, and such activities should, if possible, commence well before the construction of the Ntabelanga dam to maximize the benefit thereof.

A preliminary estimate of other resettlement and mitigation costs are also included, but this will need to be revisited once the EIA study is underway.

Finally, the costs of further feasibility studies, site investigations, hydraulic modelling, detailed design, tendering, project management, supervision, and EIA have been added as a typical percentage of capital works cost.

Phase 2 will involve more detailed feasibility design of the Ntabelanga dam and water delivery systems which will greatly improve the level of accuracy of estimated costs of this component of the conjunctive use scheme.

Under the Terms of Reference of this ongoing Feasibility Study, the Laleni dam and associated hydropower aspects will not be investigated at such a level of detail, as this will be done under a separate Feasibility Study to be undertaken for that component of the conjunctive use scheme.

Caution should therefore be exercised when considering this preliminary cost estimate, which is as given in Table 4-9.

Table 4-9: Preliminary Cost Estimate of Overall Conjunctive Use Scheme

Preliminary Stage Cost Estimates - for Ntabelanga Conjunctive Scheme with Laleni Hydropower			
Component	**Description**	**Capital Cost R'millions**	**Basis of estimate**
Ntabelanga dam and associated works	1.5 MAR dam delivering raw water at dam wall	730	High level estimate - Dam cost estimating model
Ntabelanga dam hydropower works	Generating up to 1.6 MW continuous	40	ESKOM and other derived estimating curves
Ntabelanga water treatment works	50 Ml/day works	450	R9 million per Ml/day*
Ntabelanga bulk treated water distribution system	Distribution of raw water in bulk to supply area	1 124	R7 500 per capita served (cost derived from previous similar rural schemes)*
Ntabelanga irrigated agriculture developments	Raw water supply to edge of fields	450	R18000/m all-in cost x 25 km
Ntabelanga irrigated agriculture developments	Development and equipping of farms supplied with irrigation water	625	R250,000 x 2,500 ha
Ntabelanga land compensation/mitigation costs	Resettlement and other mitigations	80	Estimate only - no detailed info available
Tsitsa catchment management	Restoration and improvement of catchment above dam	300	First three years intensive activity - 600 jobs
Ntabelanga power transmission	New lines and transformers required to power infrastructure	90	Estimate for distribution lines
	Sub-Total	**3 889**	* These works overlap with projects being undertaken by OR Tambo DM
	Engineering and EIA Costs	**389**	10% of total capex
	Sub-Total Ntabelanga	**4 278**	
Laleni dam and associated works	0.18 MAR dam delivering raw water to hydropower plant	464	High level estimate - Dam cost estimating model
Laleni land compensation/mitigation costs	Resettlement and other mitigations	50	Estimate only - no detailed info available
Laleni water delivery tunnel, shafts and penstocks	Sized for 180 MW peak flows, 25 MW continuous	1 085	ESKOM and other derived estimating curves
Laleni hydropower E&M equipment	Sized for 180 MW peak flows, 25 MW continuous	213	ESKOM and other derived estimating curves
Laleni hydropower civil works	Sized for 180 MW peak flows, 25 MW continuous	309	ESKOM and other derived estimating curves
Laleni power transmission lines to grid	Sized for 180 MW peak flows, 25 MW continuous	148	18.5 km x R 8 million/km
	Sub-Total	**2 269**	
	Feasibility Study, Engineering and EIA Costs	**250**	11% of total capex
	Sub-Total Laleni	**2 519**	
	Grand Total Ntabelanga plus Laleni (R'Millions)	**6 797**	2013 Price levels

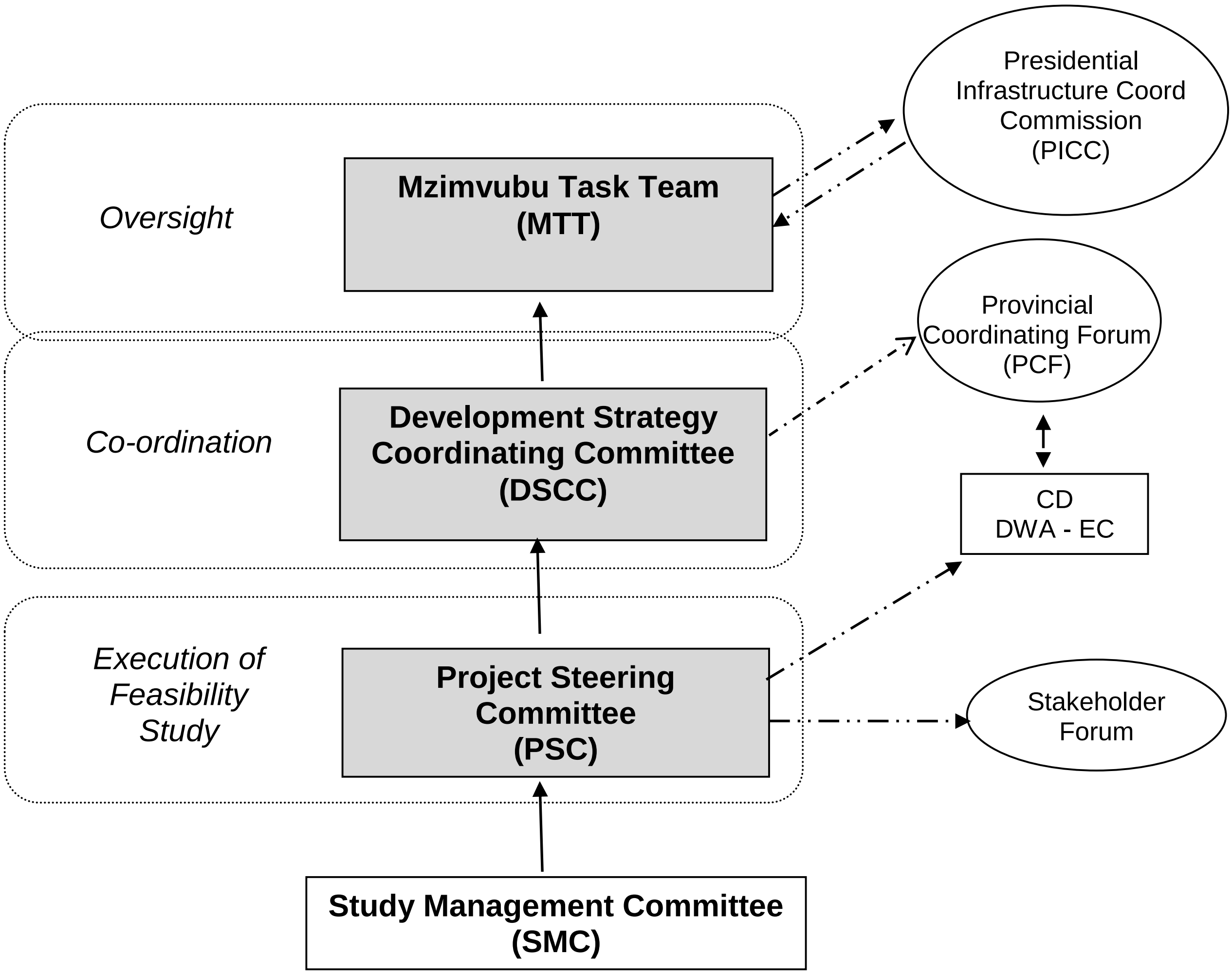
5. STAKEHOLDER INVOLVEMENT

Stakeholder involvement has been identified as an important component for the successful implementation of the Mzimvubu Water Project Feasibility Study. The involvement of as many spheres of both government and private business will ensure the maximum socio-economic benefits are obtained wherever the preferred dam site is decided to be developed.

5.1 Governance Structure

To assist in ensuring involvement of stakeholders at various levels a Governance Structure was adopted by the Project Steering Committee in the early parts of the study. This structure outlined three distinct levels at which differing types of input and involvement would be made by different parties. These three levels are oversight, coordination and execution of the Feasibility Study. Along with these three levels are important government bodies at both provincial and national level.

A diagrammatical representation of the adopted Governance structure is provided in Figure 5-1 below.



Direct reporting lines for decision and support
Information lines

Figure 5-1: Adopted Governance Structure for the Mzimvubu Water Project

The proposed frequency of meetings for each of the different bodies identified as part of the Governance Structure was as follows:

Frequency of meetings:

- MTT : 6 monthly or as advised;
- DSCC : 6 monthly or as advised;
- PCF : 6 monthly or as advised;
- PSC : Bi-monthly; and
- SMC : Bi-monthly or as required.

Examples of the likely attendees of the different forums are as follows:

- MTT : Ministers, MEC's and Premier;
- DSCC : Director-Generals, Municipal Managers, local councillors, CEO's of relevant government institutions (e.g. Water Boards, DBSA, IDZ);
- PCF : The Chief Director of DWA Eastern Cape is to represent the study and to provide feedback;
- PSC : Those directly involved with the reviewing or implementing the project; and
- SMC : Study leaders from DWA and Jeffares & Green and other key personnel from these two Parties.

5.1.1 *Mzimvubu Task Team*

The PICC Mzimvubu Task Team (MTT) is proposed to be setup for the Mzimvubu Water Project in the Eastern Cape. The overarching aim of the committee is a high level oversight of the implementation of the project and to ensure information related to progress and key decisions is transferred to the top spheres of government.

It is envisaged that the MTT will be attended by Ministers, MEC's and the Premier of the province and will meet regularly in order to stay informed about progress and developments on the project. It is envisaged that the PSP will make representation at this meeting in order to keep the body informed.

Meetings for this forum are proposed to be held in East London at the East London Golf Course conference facilities. Dates for the meeting will be distributed at least two months prior to the meeting.

5.1.2 *Development Strategy Coordinating Committee*

The overarching aim of the Development Strategy Coordinating Committee (DSCC) will be the coordination of the project and its findings and recommendations with the development plans of the province and relevant municipalities (both local and district). The aim of the committee will also be to ensure involvement and "buy in" from people at all levels of government starting from local councillors all the way up to Municipal Managers and Director-Generals.

The District Municipalities (DM) required to be involved in the DSCC are as follows:

- Sisonke DM;
- OR Tambo DM;
- Joe Gqabi DM; and
- Alfred Nzo DM.

It is proposed that this meeting will meet six monthly and will meet prior to the MTT. The appointed PSP will attend the DSCC meetings and will present the status quo of the project to the attendees.

Suggested representatives of the meeting are as follows:

- Director-Generals;
- Municipal Managers;
- Local Councillors;
- Project Manager from DWA;
- Chief Director: Integrated Water Resource Planning from DWA who is the Project Leader; and
- Study Leader from the PSP.

The Chief Director: Eastern Cape Regional Office of the DWA, will attend this forum and will provide a link between the DSCC and the Provincial Coordinating Forum (PCF).

Meetings for this forum are proposed to be held in East London at the East London Golf Course conference facilities. Dates for the meeting will be distributed at least two months prior to the meeting.

5.2 Project Steering Committee

A Project Steering Committee (PSC) was established during the Inception Phase of the study at the beginning of 2012. The first PSC Meeting was held in March 2012 and since then a further four meetings have been held in East London. The meetings that have been held are as follows:

- PSC Meeting 1: 15 March 2012;
- PSC Meeting 2: 17 May 2012;
- PSC Meeting 3: 26 July 2012;
- PSC Meeting 4: 27 September 2012;
- PSC Meeting 5: 11 December 2012; and
- PSC Meeting 6: 25 July 2013

The PSC is an important body in terms of Stakeholder Involvement and is involved in providing inputs into the execution of the Feasibility Study. It currently has representation from the following organisations:

- Department of Water Affairs – National;
- Department of Water Affairs – Eastern Cape (East London and Cradock);
- Eskom;
- Alfred Nzo District Municipality;
- OR Tambo District Municipality;
- Department of Rural Development and Agrarian Reform;
- Department of Agriculture, Forestry and Fisheries;
- Eastern Cape Department of Economic Affairs, Environment and Tourism;
- Office of the Premier;
- ASGISA – EC;
- TCTA;
- East London IDZ;
- Eastern Cape Planning Commission; and
- National Treasury.

5.3 Stakeholder Forum

A Screening Workshop (Stakeholder Forum) was held near Mthatha on 27 June 2012 with the intention of workshopping the 19 proposed dam development options along with the proposed selection criteria. The meeting was attended by 33 people and included representatives from the following organisations:

- DWA Pretoria;
- DWA Eastern Cape;
- DWA Cradock;
- The Nyandeni Local Municipality;
- The Kingdom of Pondoland;
- The South African Local Government Association;
- The National African Federated Chamber of Commerce;
- The Eastern Cape Socio Economic Consultative Council;
- The South African Social Security Agency;
- Coastal and Environmental Services (Environmental Consultants); and
- Jeffares and Green Pty Ltd (The PSP).

This was the first Stakeholder Forum which incorporated a wider group than that represented at the PSC Meetings. Further such meetings will be held to workshop the findings of Phase 1 and to advise on the way forward for Phase 2.

5.4 Stakeholder Newsletter

A Stakeholder Newsletter was issued as part of the Stakeholder Involvement on the project during Phase 1 of the study in August 2012. The newsletter provided an update of the progress made, selection criteria applied and key findings at that point in time. It was issued to all people registered on the Stakeholder Database and all recipients were encouraged to forward it to as wide a group of people as possible.

Further Stakeholder Newsletters will be issued at appropriate stages throughout the study when the need arises.

5.5 Other Relevant Liaisons with Key Stakeholders

A Liaison Meeting was held at the offices of DWA on 25 January 2013 with representatives of Eskom, TCTA, J&G and DWA. The Department of Energy (DOE) were invited but unfortunately did not attend. The aim of the meeting was to discuss the possibility of the Conjunctive Scheme as outlined in **Section 4** of this document.

5.6 Way Forward

Further Stakeholder Meetings will be held throughout Phase 2. In addition to this, once the Environmental Assessment PSP has been appointed, the study team will liaise extensively with them to ensure their Public Participation process is effectively linked to the involvement already started under this appointment.

6. RECOMMENDATIONS FOR PHASE 2

The first recommendation following the Preliminary Phase 1 of this Study is that the Ntabelanga dam has been selected as the best single dam site to be further investigated in Phase 2, where a full Feasibility Study will be undertaken. This will include the feasibility level design of the dam and its associated infrastructure.

Phase 1 findings have raised an additional option of conjunctive use of a larger Ntabelanga dam with the potential Laleni dam/Tsitsa falls hydropower scheme. This option was not provided for per se in the original scope of work for this Contract, but it has been agreed that this option will be the one to carry forward into the Phase 2 stage of the Feasibility Study.

In making this decision, it was recognized that the Terms of Reference, timescale and budget of Phase 2 of the Feasibility Study would allow for a detailed investigation and analysis of the Ntabelanga dam development, but that the Laleni dam and hydropower component of the conjunctive use scheme would only be undertaken at a lower level of detail.

It is therefore highly recommended that a fully detailed feasibility study on the Laleni dam and hydropower scheme be commenced as soon as possible, and be concluded before a final decision to construct the larger Ntabelanga dam is made.

6.1 Scope of Work

The Scope of Work as defined in the Terms of Reference for this project will involve the following tasks, for the selected Ntabelanga dam site:

- Detailed hydrology (over and above that undertaken in Phase 1), which will include the flood hydrology required to inform dam safety requirements, determine spillway capacity, and give a value to the requirements for dealing with river flow during construction;
- Reserve determination;
- Water requirements investigation (including agricultural and domestic water supply investigations);
- Topographical survey (over and above that undertaken in Phase 1);
- Geotechnical investigation (more detailed investigations than Phase 1;
- Dam type selection and feasibility level design;
- Land matters;
- Environmental & Social Impact Assessment (this will be undertaken in a separate study that will run in parallel to this one);
- Public participation;
- Regional economics; and
- Legal, institutional and financial arrangements.

Whilst the requirements of each of these tasks are already described in the Contract Agreement, the follow comments are made:

6.1.1 Detailed Hydrology

This has been completed in Phase 1 for the selected dam site. In Phase 2, this task will additionally comprise the rerunning of yield models taking on board the final operational requirements for the dam, as well as the agreed EWR values and release regime.

Flood studies will be undertaken to determine the Design Flood and Safety Evaluation Flood in order to optimize the dam design and its spillway.

A value will be determined for the 1:20 year return period flood, to determine the measures that will be required to deal with such river flows during construction.

A backwater analysis will be undertaken for the final dam design in order to provide information regarding Environmental & Social Impacts, resettlement and compensation, other land matters, and upstream infrastructure realignments, etc.

6.1.2 Reserve Determination

Site reconnaissance, sampling, and assessments of both Riverine and Estuarine aspects have been undertaken during Phase 1, and the second site visits are currently being completed in this regard,

A workshop will be held to discuss the results of these investigations, and recommendations will be made for the reserve in the Tsitsa River with specific reference to the Ntabelanga dam site and its proposed operational regime.

The ecological class of river thus determined will need to be agreed as early as possible as this will affect the EWR requirements, which in turn will affect the dam yield, sizing, operational regime, and associated outlet arrangements.

6.1.3 Water Requirements

This will involve a more detailed investigation of potable and agricultural water needs, and will include a high-level review of the potential for inter-basin transfer from the Ntabelanga dam, both to adjacent catchments and further afield, to the Orange-Vaal system.

In terms of agricultural water requirements, further ground-truthing and soil sampling will be undertaken.

6.1.4 Topographical Survey

There will be a need to extend the existing topographical surveys early on in Phase 2 with the focus on the selected dam site and its associated infrastructure, and other affected infrastructure (e.g. roads and bridges that might need to be realigned). Budget still remains within the sub-contract of Southern Mapping for this purpose.

6.1.5 Geotechnical Investigations

There will be a need to undertake further geotechnical investigations early on in Phase 2 with the focus on the selected dam site and its associated infrastructure, construction materials investigations, other affected existing infrastructure (e.g. roads and bridges that might need to be realigned).

Some budget still remains within the sub-contract of Weppelman Geotechnical Services specifically for the rotary core drilling aspects, and there is also an unallocated amount in the Provisional Sum which could also be used if required.

With regard to the latter, part of the Provisional Sums will also need to be used to undertake trial pitting for dam materials source investigations and soil sampling, as well as the associated laboratory testing, to provide the design parameters. These investigations will need to be undertaken early in Phase 2 in order to provide the design parameters prior to the optimisation and preliminary design of the dam itself.

Seismic refraction geophysical investigations will also be undertaken at the proposed dam site.

6.1.6 Dam Design

This will include further site reconnaissance and use of the hydrological, topographical and geotechnical information obtained in Phase 1, to “home in” on the best dam wall location. Access will be a key consideration as well as the optimum dam type and spillway arrangements. Several options will be investigated for dam type including RCC/mass concrete, earth core rock fill (ECRF), earth core random fill embankment, and concrete-faced rock fill (CFRD).

This optimisation process will be undertaken as a priority in Phase 2 so that recommendations can be made as to dam type as early as possible and preliminary design commenced. This reiterates the need to undertake the additional geotechnical investigations as early as possible in Phase 2 so that materials availability and physical parameters can be available to optimize the design.

This task is one of the most critical in Phase 2 as the outcome will provide the required information to the DWA Infrastructure Division, who will be preparing invitations for proposals for the detailed design and construction supervision of the dam and associated infrastructure, in parallel to the Phase 2 activities[6].

Given that this project is of high priority, the intention is that the detailed design contract be commenced no later than the end October 2013.

The task deliverables will be a Preliminary Design Report and accompanying drawings and other data that would provide sufficient information for the detailed design to be implemented.

6.1.7 Land Matters

As the scheme layouts and operational details begin to emerge, this task will investigate the land issues that will arise as a consequence. This will include identifying land ownership, assessing the needs for the acquisition of land for the infrastructure itself, and land requirements for the downstream infrastructure including water supplies and irrigation aspects.

The land aspects team will work closely with the independent EIA PSP who will identify the needs and impacts of land acquisition, servitudes, resettlement, as well as other mitigation and compensation matters.

6.1.8 Environmental & Social Impact Assessment (EIA) and EMP

This task will be undertaken by an Independent PSP. DWA are currently undertaking a procurement process for this PSP, who will be appointed as soon as possible. Obtaining approval for the EIA and subsequently the EMP will be a critical path activity from this point onward.

6.1.9 Public Participation

This task has been initiated by the Feasibility Study PSP during Phase 1, and has comprised:

- Regular meetings with the PSC
- Stakeholder meeting during the dams screening process
- The issuing of a stakeholders newsletter
- The compilation of a stakeholders register
- Various presentations at other regional workshops

In Phase 2, this activity will be taken over by the Independent EIA PSP, who will liaise closely with the Feasibility Study PSP.

[6] *Alternatively, the DWA Infrastructure Division may decide to undertake this design in-house*

6.1.10 Regional Economics

This task will investigate the opportunities in the region of the dam for economic and social development, which will inform the design team in its optimisation and design of the dam and its downstream works.

The cost benefits and social development opportunities will be a key factor in implementation policies, including potential subsidization of infrastructure considered to provide the intended economic and social development stimulus in this very poor region of South Africa.

6.1.11 Legal Issues

These issues span across many of the tasks being undertaking in Phase 2, but will include matters of land ownership acquisition and compensation, infrastructure ownership and operations, labour law, contract law, and similar.

6.1.12 Institutional & Financial Arrangements

This will be a key output from the Phase 2 studies. The interfaces between the dam, raw water systems, water treatment works and distribution systems have several potential institutional models that could be applied, and this will also affect, and be affected by, the financial arrangements for each element of the system.

Various institutional and financial models will be investigated, which process will need to be undertaken in close co-operation of Treasury, DWA, possibly the Department of Energy and ESKOM, as well as the relevant District Municipality and its infrastructure funding sources, which could include, inter alia, MIG, RBIG and the DBSA.

6.2 Programme

The Phase 2 programme is given overleaf in Figure 6-1, and is unchanged from that currently being followed in Phase 1.

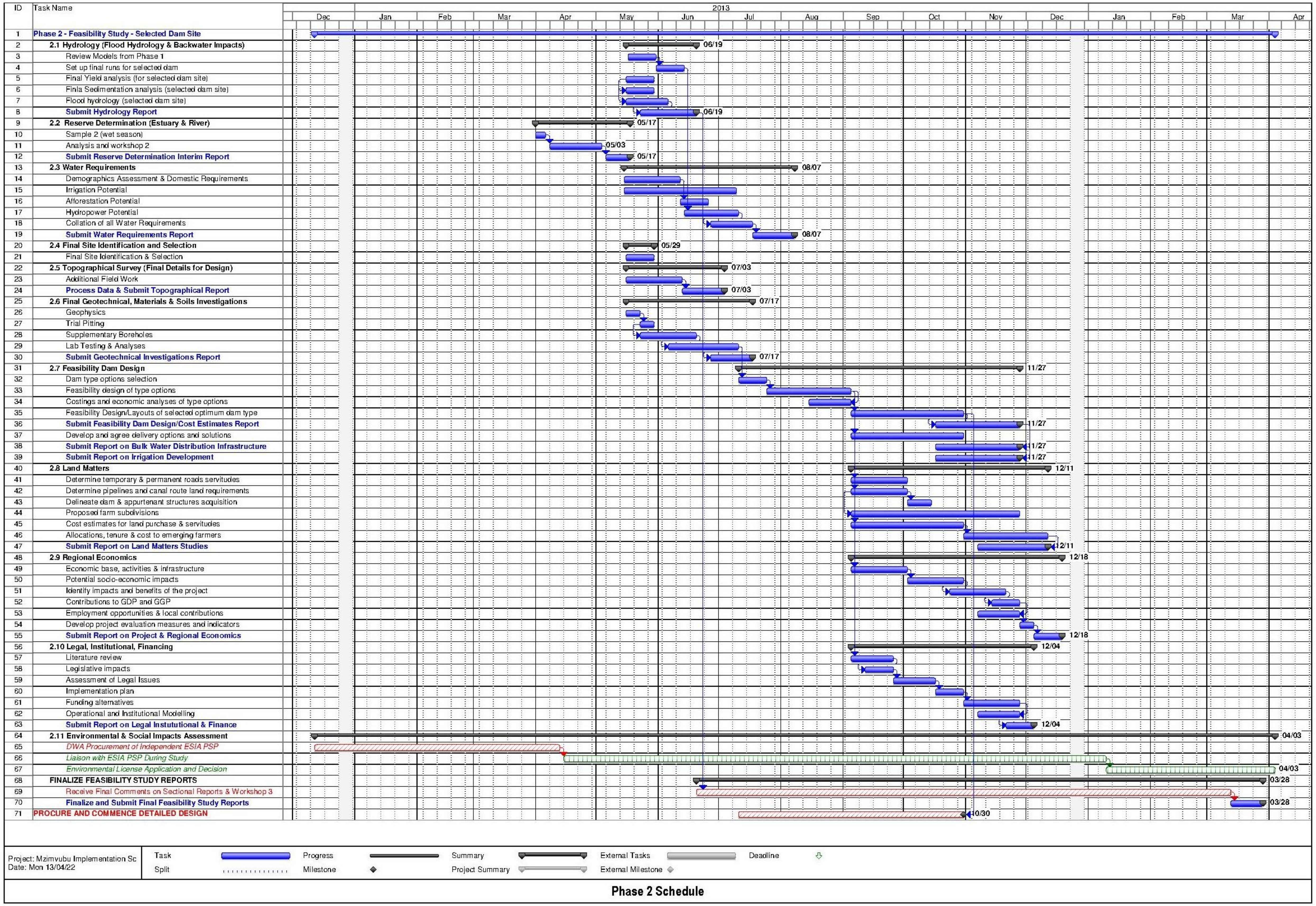


Figure 6-1: Phase 2 Implementation Schedule

7. REFERENCES

Republic of Transkei, 1987. Mzimvubu Basin Development

DWA, 2010. Assessment of the Ultimate Potential Future Marginal Cost of Water Resources in South Africa

DWA/BKS, 2010. DWA Report Number P WMA 12.000/00/3609 - Water Resources Study in Support of the ASGISA-EC – Mzimvubu Water Project.

Ingerop 2010. ASGISA-EC Business Case for Water Related Opportunities.

Ferreira, C. 2012. Gauged Rainfall and Streamflow data, via E-mail on 9 October 2012. Department of Water Affairs: Eastern Cape Region, Cradock.

Lynch, S. D. 2003. Development of A Raster Database of Annual, Monthly and Daily Rainfall For Southern Africa. Water Research Commission, Pretoria, South Africa, WRC Report 1156/1/03. pp 78.

SSI, 2006. WRSM2000 (Enhanced) User's Guide. May 2006. Draft final document compiled by SSI and TiSD, in association. Authors: Pitman WV, Kakebeeke, JP and Bailey, AK.

WRC. 2009. Executive Summary and Book of Maps. March 2009. WRC Report No. TT 380/08, Version 2 compiled by the WR2005 Consortium of SSI, SRK Consulting, Knight Piésold, Arcus Gibb, Ninham Shand, PD Naidoo & Associates and Umfula Wempilo Consulting as part of the Water Resources of South Africa 2005 Study for the Water Research Commission (WRC), Pretoria, South Africa. Authors: Bailey, AK and Middleton, BJ. Water Research Commission Report Number TT 512/11.

APPENDIX A:

KEY INFORMATION ON EACH OF THE 19 DAM SITE DEVELOPMENT OPTIONS

Option 1: Siqengeni

- River: Upper Mzimvubu;
- District Municipality: Alfred Nzo District Municipality;
- Nearest Town: Mount Frere;
- Catchment Size: 6 482 km^2;
- Mean Annual Runoff: 709 million m^3;
- Approximate Dam Wall Height (1MAR Dam): 80 m;
- Approximate Dam Surface Area (1 MAR Dam): 24 km^2;
- Estimated Historical Firm Yield (after EWR allowance): 289 million m^3/annum;
- 50 Year Sediment Figure: 113 million m^3 which is 15.9% of total storage volume;
- Environmental Impacts: High EIS and PES, code 2 NFEPA river, "vulnerable" vegetation type. Dam site considered unsuitable;
- Potential to be used for Water Supply: Medium to low potential for water supply due to locality of dam in relation to communities of need;
- Agricultural Potential: Limited to no potential;
- Hydropower Potential: Capex/MW is R237 million. Medium potential;
- Estimated Capital Cost (Indicative only): R1 470 million;
- URV of Water Produced (excl. distribution costs): 0.8 R/m^3;
- Proximity to Main Transport Infrastructure (Distance from N2): 5.14 km;
- Water Transfer Potential: Limited; and
- Forestry Potential: Very low potential.

Option 2: Dam "2"

- River: Upper Mzimvubu;
- District Municipality: Alfred Nzo District Municipality;
- Nearest Town: Mount Ayliff/Kokstad;
- Catchment Size: 2 680 km^2;
- Mean Annual Runoff: 240 million m^3;
- Approximate Dam Wall Height (1MAR Dam): 49 m;
- Approximate Dam Surface Area (1 MAR Dam): 11 $km^{2;}$
- Estimated Historical Firm Yield (after EWR allowance): 56 million m^3/annum;
- 50 Year Sediment Figure: 47 million m^3 which is 19.6% of total storage volume;
- Environmental Impacts: High EIS and PES, code 1 NFEPA river, "vulnerable" vegetation type. Dam site considered unsuitable;
- Potential to be used for Water Supply: Low potential for water supply due to locality of dam in relation to communities of need;
- Agricultural Potential: Limited to no potential;
- Hydropower Potential: Capex/MW is R825 million. Low potential;
- Estimated Capital Cost (Indicative only): R800 million;
- URV of Water Produced (excl. distribution costs): 2.1 R/m^3;
- Proximity to Main Transport Infrastructure (Distance from N2): 34.6 km;
- Water Transfer Potential: Limited; and
- Forestry Potential: Low potential.

Option 3: Bokpoort

- River: Mzintlava;
- District Municipality: Sisonke District Municipality;
- Nearest Town: Kokstad;
- Catchment Size: 1 379 km^2;
- Mean Annual Runoff: 130 million m^3;
- Approximate Dam Wall Height (1MAR Dam): 60 m;
- Approximate Dam Surface Area (1 MAR Dam): 7 km^2;
- Estimated Historical Firm Yield (after EWR allowance): 37 million m^3/annum;
- 50 Year Sediment Figure: 24 million m^3 which is 18.5% of total storage volume;
- Environmental Impacts: PES = B, also very highly stressed reach from irrigation, code 2 NFEPA river, "vulnerable" vegetation type. Dam site considered to be potentially suitable;
- Potential to be used for Water Supply: Medium potential for water supply due to locality of dam in relation to communities of need;
- Agricultural Potential: Limited to no potential;
- Hydropower Potential: Capex/MW is R1 314 million. Very Low potential;
- Estimated Capital Cost (Indicative only): R910 million;
- URV of Water Produced (excl. distribution costs): 3.7 R/m^3;
- Proximity to Main Transport Infrastructure (Distance from N2): 19.6 km;
- Water Transfer Potential: Limited; and
- Forestry Potential: Medium to high potential.

Option 4: Luzi

- River: Mzintlava;
- District Municipality: Alfred Nzo District Municipality;
- Nearest Town: Mount Ayliff;
- Catchment Size: 1 909 km^2;
- Mean Annual Runoff: 198 million m^3;
- Approximate Dam Wall Height (1MAR Dam): 63 m;
- Approximate Dam Surface Area (1 MAR Dam): 6.5 km^2;
- Estimated Historical Firm Yield (after EWR allowance): 72 million m^3/annum;
- 50 Year Sediment Figure: 33 million m^3 which is 16.7% of total storage volume;
- Environmental Impacts: Code 2 NFEPA river, "least threatened" vegetation type. Dam site considered suitable;
- Potential to be used for Water Supply: Medium potential for water supply due to locality of dam in relation to communities of need;
- Agricultural Potential: Limited to no potential;
- Hydropower Potential: Capex/MW is R845 million. Low potential;
- Estimated Capital Cost (Indicative only): R880 million;
- URV of Water Produced (excl. distribution costs): 1.8 R/m^3;
- Proximity to Main Transport Infrastructure (Distance from N2): 26.7 km;
- Water Transfer Potential: Limited; and
- Forestry Potential: Medium to high potential.

Option 5: Dam "B"

- River: Mzintlava;
- District Municipality: OR Tambo District Municipality;
- Nearest Town: Mount Ayliff;
- Catchment Size: 2 497 km^2;
- Mean Annual Runoff: 282 million m^3;
- Approximate Dam Wall Height (1MAR Dam): 93 m;
- Approximate Dam Surface Area (1 MAR Dam): 6.8 km^2;
- Estimated Historical Firm Yield (after EWR allowance): 125 million m^3/annum;
- 50 Year Sediment Figure: 43 million m^3 which is 15.2% of total storage volume;
- Environmental Impacts: Inundate NFEPA wetland pocket and code 2 river, "least threatened" vegetation type. Dam site considered suitable;
- Potential to be used for Water Supply: Medium potential for water supply due to locality of dam in relation to communities of need;
- Agricultural Potential: Limited to no potential;
- Hydropower Potential: Capex/MW is R687 million. Low potential;
- Estimated Capital Cost (Indicative only): R1 980 million;
- URV of Water Produced (excl. distribution costs): 2.4 R/m^3;
- Proximity to Main Transport Infrastructure (Distance from N2): 58.1 km;
- Water Transfer Potential: Limited; and
- Forestry Potential: Medium potential.

Option 6: Thabeng

- River: Kinira;
- District Municipality: Alfred Nzo District Municipality;
- Nearest Town: Matatiele;
- Catchment Size: 1 778 km^2;
- Mean Annual Runoff: 307 million m^3;
- Approximate Dam Wall Height (1MAR Dam): 53 m;
- Approximate Dam Surface Area (1 MAR Dam): 16 km^2;
- Estimated Historical Firm Yield (after EWR allowance): 144 million m^3/annum;
- 50 Year Sediment Figure: 31 million m^3 which is 10.1% of total storage volume;
- Environmental Impacts: NFEPA wetlands upstream important for Blue Cranes, "vulnerable" vegetation type. Dam site considered suitable;
- Potential to be used for Water Supply: Medium to high potential for water supply due to locality of dam in relation to communities of need;
- Agricultural Potential: Approximately 1 500 ha of potential agricultural land;
- Hydropower Potential: Capex/MW is R395 million. Medium potential;
- Estimated Capital Cost (Indicative only): R710 million;
- URV of Water Produced (excl. distribution costs): 0.7 R/m^3;
- Proximity to Main Transport Infrastructure (Distance from N2): 166 km;
- Water Transfer Potential: Limited; and
- Forestry Potential: Medium potential.

Option 7: Somabadi

- River: Kinira;
- District Municipality: Alfred Nzo District Municipality;
- Nearest Town: Matatiele;
- Catchment Size: 2 146 km^2;
- Mean Annual Runoff: 324 million m^3;
- Approximate Dam Wall Height (1MAR Dam): 59 m;
- Approximate Dam Surface Area (1 MAR Dam): 15 km^2;
- Estimated Historical Firm Yield (after EWR allowance): 150 million m^3/annum;
- 50 Year Sediment Figure: 37 million m^3 which is 11.4% of total storage volume;
- Environmental Impacts: High EIS, NFEPA wetlands upstream important for Blue Cranes, "vulnerable" vegetation type. Dam site considered to be potentially suitable;
- Potential to be used for Water Supply: Medium to high potential for water supply due to locality of dam in relation to communities of need;
- Agricultural Potential: Approximately 1 250 ha of potential agricultural land;
- Hydropower Potential: Capex/MW is R333 million. Medium potential;
- Estimated Capital Cost (Indicative only): R760 million;
- URV of Water Produced (excl. distribution costs): 0.8 R/m^3;
- Proximity to Main Transport Infrastructure (Distance from N2): 190 km;
- Water Transfer Potential: Limited; and
- Forestry Potential: Medium potential.

Option 8: Ntlabeni

- River: Kinira;
- District Municipality: Alfred Nzo District Municipality;
- Nearest Town: Mount Frere;
- Catchment Size: 2 685 km^2;
- Mean Annual Runoff: 396 million m^3;
- Approximate Dam Wall Height (1MAR Dam): 65 m;
- Approximate Dam Surface Area (1 MAR Dam): 16 km^2;
- Estimated Historical Firm Yield (after EWR allowance): 187 million m^3/annum;
- 50 Year Sediment Figure: 47 million m^3 which is 11.9% of total storage volume;
- Environmental Impacts: Inundate NFEPA wetlands, "vulnerable" vegetation type. Dam site considered to be potentially suitable;
- Potential to be used for Water Supply: Medium to high potential for water supply due to locality of dam in relation to communities of need;
- Agricultural Potential: Limited to no potential;
- Hydropower Potential: Capex/MW is R238 million. Medium potential;
- Estimated Capital Cost (Indicative only): R770 million;
- URV of Water Produced (excl. distribution costs): 0.6 R/m^3;
- Proximity to Main Transport Infrastructure (Distance from N2): 22 km;
- Water Transfer Potential: Limited; and
- Forestry Potential: Low potential.

Option 9: Pitseng

- River: Tina;
- District Municipality: Tina River forms the boundary between the Alfred Nzo and OR Tambo District Municipalities;
- Nearest Town: Mt Fletcher;
- Catchment Size: 300 km^2;
- Mean Annual Runoff: 55 million m^3;
- Approximate Dam Wall Height (1MAR Dam): 34 m;
- Approximate Dam Surface Area (1 MAR Dam): 4 km^2;
- Estimated Historical Firm Yield (after EWR allowance): 20 million m^3/annum;
- 50 Year Sediment Figure: 7 million m^3 which is 12.7% of total storage volume;
- Environmental Impacts: High EIS, "vulnerable" vegetation type. Dam site considered to be potentially suitable;
- Potential to be used for Water Supply: Medium to low potential for water supply due to locality of dam in relation to communities of need;
- Agricultural Potential: Approximately 1 500 ha of potential agricultural land;
- Hydropower Potential: Capex/MW is R2 050 million. Very low potential;
- Estimated Capital Cost (Indicative only): R380 million;
- URV of Water Produced (excl. distribution costs): 2.9 R/m^3;
- Proximity to Main Transport Infrastructure (Distance from N2): 127 km;
- Water Transfer Potential: Limited; and
- Forestry Potential: Medium potential.

Option 10: Hlabakazi

- River: Tina;
- District Municipality: Tina River forms the boundary between the Alfred Nzo and OR Tambo District Municipalities;
- Nearest Town: Mt Fletcher;
- Catchment Size: 1 618 km^2;
- Mean Annual Runoff: 248 million m^3;
- Approximate Dam Wall Height (1MAR Dam): 57 m;
- Approximate Dam Surface Area (1 MAR Dam): 9.2 km^2;
- Estimated Historical Firm Yield (after EWR allowance): 93 million m^3/annum;
- 50 Year Sediment Figure: 28 million m^3 which is 11.3% of total storage volume;
- Environmental Impacts: High EIS, "vulnerable" vegetation type. Dam site considered to be potentially suitable;
- Potential to be used for Water Supply: Medium to high potential for water supply due to locality of dam in relation to communities of need;
- Agricultural Potential: Limited to no potential;
- Hydropower Potential: Capex/MW is R425 million. Medium potential;
- Estimated Capital Cost (Indicative only): R640 million;
- URV of Water Produced (excl. distribution costs): 1.00 R/m^3;
- Proximity to Main Transport Infrastructure (Distance from N2): 118 km;
- Water Transfer Potential: Limited; and
- Forestry Potential: Medium to high potential.

Option 11: Mpindweni

- River: Tina;
- District Municipality: Tina River forms the boundary between the Alfred Nzo and OR Tambo District Municipalities;
- Nearest Town: Mount Frere;
- Catchment Size: 2 176 km^2;
- Mean Annual Runoff: 337 million m^3;
- Approximate Dam Wall Height (1MAR Dam): 56 m;
- Approximate Dam Surface Area (1 MAR Dam): 16 km^2;
- Estimated Historical Firm Yield (after EWR allowance): 125 million m^3/annum;
- 50 Year Sediment Figure: 38 million m^3 which is 11.3% of total storage volume;
- Environmental Impacts: High EIS, "vulnerable" vegetation type. Dam site considered to be potentially suitable;
- Potential to be used for Water Supply: Medium to high potential for water supply due to locality of dam in relation to communities of need;
- Agricultural Potential: Limited to no potential;
- Hydropower Potential: Capex/MW is R295 million. Medium potential;
- Estimated Capital Cost (Indicative only): R640 million;
- URV of Water Produced (excl. distribution costs): 0.8 R/m^3;
- Proximity to Main Transport Infrastructure (Distance from N2): 17.8 km;
- Water Transfer Potential: Limited; and
- Forestry Potential: Medium to low potential.

Option 12: Mangwaneni

- River: Tina;
- District Municipality: Tina River forms the boundary between the Alfred Nzo and OR Tambo District Municipalities;
- Nearest Town: Qumbu/Mount Frere;
- Catchment Size: 2 764 km^2;
- Mean Annual Runoff: 414 million m^3;
- Approximate Dam Wall Height (1MAR Dam): 55 m;
- Approximate Dam Surface Area (1 MAR Dam): 15.5 km^2;
- Estimated Historical Firm Yield (after EWR allowance): 140 million m^3/annum;
- 50 Year Sediment Figure: 48 million m^3 which is 11.6% of total storage volume;
- Environmental Impacts: PES, code 2 NFEPA river, "least threatened" vegetation type. Dam site considered suitable;
- Potential to be used for Water Supply: Medium to high potential for water supply due to locality of dam in relation to communities of need;
- Agricultural Potential: Limited to no potential;
- Hydropower Potential: Capex/MW is R705 million. Low potential;
- Estimated Capital Cost (Indicative only): R1 490 million;
- URV of Water Produced (excl. distribution costs): 1.6 R/m^3;
- Proximity to Main Transport Infrastructure (Distance from N2): 13.4 km;
- Water Transfer Potential: Limited; and
- Forestry Potential: Low potential.

Option 13: Ku-Mdyobe

- River: Tina;
- District Municipality: OR Tambo District Municipality;
- Nearest Town: Qumbu/Mount Frere;
- Catchment Size: 2 864 km^2;
- Mean Annual Runoff: 140 million m^3;
- Approximate Dam Wall Height (1MAR Dam): 50 m;
- Approximate Dam Surface Area (1 MAR Dam): 15.2 km^2;
- Estimated Historical Firm Yield (after EWR allowance): 140 million m^3/annum;
- 50 Year Sediment Figure: 50 million m^3 which is 35.7% of total storage volume;
- Environmental Impacts: PES, code 2 NFEPA river, inundate wetlands (none NFEPA), "least threatened" vegetation type. Dam site considered suitable;
- Potential to be used for Water Supply: Medium potential for water supply due to locality of dam in relation to communities of need;
- Agricultural Potential: Limited to no potential;
- Hydropower Potential: Capex/MW is R480 million. Medium potential;
- Estimated Capital Cost (Indicative only): R1 940 million;
- URV of Water Produced (excl. distribution costs): 2.1 R/m^3;
- Proximity to Main Transport Infrastructure (Distance from N2): 17.2 km;
- Water Transfer Potential: Limited; and
- Forestry Potential: Low potential.

Option 14: Nomhala

- River: Tsitsa;
- District Municipality: The Tsitsa River forms the boundary between the Joe Gcabi and OR Tambo District Municipalities;
- Nearest Town: Qumbu;
- Catchment Size: 1 405 km^2;
- Mean Annual Runoff: 206 million m^3;
- Approximate Dam Wall Height (1MAR Dam): 43 m;
- Approximate Dam Surface Area (1 MAR Dam): 11 km^2;
- Estimated Historical Firm Yield (after EWR allowance): 76 million m^3/annum;
- 50 Year Sediment Figure: 25 million m^3 which is 12.1% of total storage volume;
- Environmental Impacts: High EIS, code 2 NFEPA river, wetlands (none NFEPA), NB for Blue Cranes, "endangered" vegetation type. Dam site considered unsuitable;
- Potential to be used for Water Supply: Medium to high potential for water supply due to locality of dam in relation to communities of need;
- Agricultural Potential: Approximately 750 ha of potential agricultural land;
- Hydropower Potential: Capex/MW is R625 million. Low potential;
- Estimated Capital Cost (Indicative only): R620 million;
- URV of Water Produced (excl. distribution costs): 1.2 R/m^3;
- Proximity to Main Transport Infrastructure (Distance from N2): 26.8 km;
- Water Transfer Potential: Limited; and
- Forestry Potential: Medium potential.

Option 15: Ntabelanga

- River: Tsitsa;
- District Municipality: The Tsitsa River forms the boundary between the Joe Gcabi and OR Tambo District Municipalities;
- Nearest Town: Qumbu;
- Catchment Size: 2 017 km^2;
- Mean Annual Runoff: 403 million m^3;
- Approximate Dam Wall Height (1MAR Dam): 53 m;
- Approximate Dam Surface Area (1 MAR Dam): 36 km^2;
- Estimated Historical Firm Yield (after EWR allowance): 155 million m^3/annum;
- 50 Year Sediment Figure: 35 million m^3 which is 8.7% of total storage volume;
- Environmental Impacts: High EIS, inundate wetlands (none NFEPA), "vulnerable" vegetation type. Dam site considered to be potentially suitable;
- Potential to be used for Water Supply: High potential for water supply due to locality of dam in relation to communities of need;
- Agricultural Potential: Approximately 1 250 ha of potential agricultural land;
- Hydropower Potential: Capex/MW is R167 million. High potential;
- Estimated Capital Cost (Indicative only): R420 million;
- URV of Water Produced (excl. distribution costs): 0.4 R/m^3;
- Proximity to Main Transport Infrastructure (Distance from N2): 30.6 km;
- Water Transfer Potential: Limited, but due to the lower cost of water is considered the best option for a potential water transfer scheme into the Kraai River (headwaters of the Orange River); and
- Forestry Potential: Medium potential.

Option 16: Malepelepe

- River: Tsitsa;
- District Municipality: OR Tambo District Municipality;
- Nearest Town: Qumbu;
- Catchment Size: 3 934 km^2;
- Mean Annual Runoff: 696 million m^3;
- Approximate Dam Wall Height (1MAR Dam): 42 m;
- Approximate Dam Surface Area (1 MAR Dam): 65 km^2;
- Estimated Historical Firm Yield (after EWR allowance): 277 million m^3/annum;
- 50 Year Sediment Figure: 68 million m^3 which is 9.8% of total storage volume;
- Environmental Impacts: High EIS, code 2 NFEPA river, wetlands (none NFEPA), NB for Blue Cranes, "endangered" vegetation type. Dam site considered unsuitable;
- Potential to be used for Water Supply: High potential for water supply due to locality of dam in relation to communities of need;
- Agricultural Potential: Approximately 20 ha of potential agricultural land;
- Hydropower Potential: Capex/MW is R303 million. Medium potential;
- Estimated Capital Cost (Indicative only): R1 000 million;
- URV of Water Produced (excl. distribution costs): 0.5 R/m^3;
- Proximity to Main Transport Infrastructure (Distance from N2): 14.8 km;
- Water Transfer Potential: Limited; and
- Forestry Potential: Medium potential.

Option 17: Laleni

- River: Tsitsa;
- District Municipality: OR Tambo District Municipality;
- Nearest Town: Qumbu;
- Catchment Size: 4 324 km^2;
- Mean Annual Runoff: 755 million m^3;
- Approximate Dam Wall Height (1MAR Dam): 62 m;
- Approximate Dam Surface Area (1 MAR Dam): 24 km^2;
- Estimated Historical Firm Yield (after EWR allowance): 254 million m^3/annum;
- 50 Year Sediment Figure: 75 million m^3 which is 9.9% of total storage volume;
- Environmental Impacts: Inundate NFEPA wetlands, code 2 NFEPA river, "endangered" vegetation type. Dam site considered unsuitable;
- Potential to be used for Water Supply: High potential for water supply due to locality of dam in relation to communities of need;
- Agricultural Potential: Limited to no potential;
- Hydropower Potential: Capex/MW is R265 million. Medium potential;
- Estimated Capital Cost (Indicative only): R1 170 million;
- URV of Water Produced (excl. distribution costs): 0.7 R/m^3;
- Proximity to Main Transport Infrastructure (Distance from N2): 18.4 km;
- Water Transfer Potential: Limited; and
- Forestry Potential: Medium potential.

Option 18: Gongo

- River: Tsitsa;
- District Municipality: OR Tambo District Municipality;
- Nearest Town: Qumbu;
- Catchment Size: 4 774 km^2;
- Mean Annual Runoff: 800 million m^3;
- Approximate Dam Wall Height (1MAR Dam): 81 m;
- Approximate Dam Surface Area (1 MAR Dam): 6.8 km^2;
- Estimated Historical Firm Yield (after EWR allowance): Unknown at present;
- 50 Year Sediment Figure: 81 million m3 which is 10.1% of total storage volume;
- Environmental Impacts: Inundate NFEPA and non-NFEPA wetlands, code 2 NFEPA river, "least threatened" vegetation type. Dam site considered suitable;
- Potential to be used for Water Supply: Medium to low potential for water supply due to locality of dam in relation to communities of need;
- Agricultural Potential: Limited to no potential;
- Hydropower Potential: Capex/MW is R359 million. Medium potential;
- Estimated Capital Cost (Indicative only): > R2 010 million;
- URV of Water Produced (excl. distribution costs): - R/m^3;
- Proximity to Main Transport Infrastructure (Distance from N2): 45.6 km;
- Water Transfer Potential: Limited; and
- Forestry Potential: Medium potential.

Option 19: Mbokazi

- River: Mzimvubu;
- District Municipality: OR Tambo District Municipality;
- Nearest Town: Port St Johns;
- Catchment Size: 19 263 km^2;
- Mean Annual Runoff: 2 520 million m^3;
- Approximate Dam Wall Height (1MAR Dam): 100 m;
- Approximate Dam Surface Area (1 MAR Dam): 28 km^2;
- Estimated Historical Firm Yield (after EWR allowance): Unknown at present;
- 50 Year Sediment Figure: 328 million m^3 which is 13.1% of total storage volume;
- Environmental Impacts: Estuary will drive this PES/EIS classification. Estuary highly important (Score=81) and rank=31, "least threatened" vegetation type. Dam site unsuitable;
- Potential to be used for Water Supply: Low potential for water supply due to locality of dam in relation to communities of need;
- Agricultural Potential: Limited to no potential;
- Hydropower Potential: Capex/MW is R116 million. High potential;
- Estimated Capital Cost (Indicative only): > R2 070 million;
- URV of Water Produced (excl. distribution costs): - R/m^3;
- Proximity to Main Transport Infrastructure (Distance from N2): 84.2 km;
- Water Transfer Potential: Limited; and
- Forestry Potential: Low potential.