Department of Water and Sanitation

Report No: P WMA 03/000/00/6923/5

WP11393

CROCODILE EAST WATER PROJECT (CEWP)

MODULE 1: TECHNICAL FEASIBILITY STUDY

Pre-Feasibility Study: Geotechnical and Material Investigations Report

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DOCUMENT INDEX

This report forms part of the series of reports issued as part of the project Crocodile East Water Project (CEWP) Module 1: Technical Feasibility Study.

A document index is provided below.

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CEWP	Crocodile East Water Project
D: NWRP	(DWS) Directorate: Integrated Water Resource Planning
D: NWRP	(DWS) Directorate: National Water Resource Planning
D: SWRP	(DWS) Directorate: Strategic Water Resource Planning
D: WRDP	(DWS) Directorate: Water Resource Development Planning
DM	District Municipality
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
FS	Feasibility Study
FSL	Full Supply Level
LM	Local Municipality
RL	Reduced Level
WC/WDM	Water Conservation and Water Demand Management

LIST OF UNITS AND SYMBOLS

°	Degrees
H:V	Horizontal versus Vertical Gradient
km	Kilometre
m	Metres
m³	Cubic Metres
m²	Square Metres
no	Number

1 INTRODUCTION

1.1 Background to Study

The water of the Crocodile (East) River Catchment in Mpumalanga has been fully allocated, yet the water requirements, especially domestic water requirements, continue to grow. The system is under stress, and it cannot fully meet the environmental water requirements as well as the reliability / assurance of supply for both the agricultural and municipal water uses.

The situation will worsen in the short term if water conservation and water demand management (WC/WDM) measures are not fully implemented. In the medium to long term, WC/WDM measures will not be sufficient to provide for the increase in domestic water requirement. The yield of the water resource will have to be increased by means of **additional storage**.

Both public and commercial sectors have requested development of **additional yield** through **storage** within the **Crocodile (East) River Catchment**. Due to the long lead-time required in developing new dams, the construction of an additional dam in the Crocodile River Catchment has to be investigated without delay.

Taking cognisance of the above-mentioned and based on previous studies and investigations carried out in the past, the following **four proposed dams** within the **Crocodile (East) River Catchment** were recommended for further study as part of this Study (WP11393: Module 1: Technical Feasibility Study):

- Mountain View Dam on the Kaap River.
- Montrose Dam on the Crocodile East River.
- Boschjeskop Dam on the Nels River.
- Strathmore Off-Channel Storage Dam, near the confluence of the Kaap and Crocodile rivers.

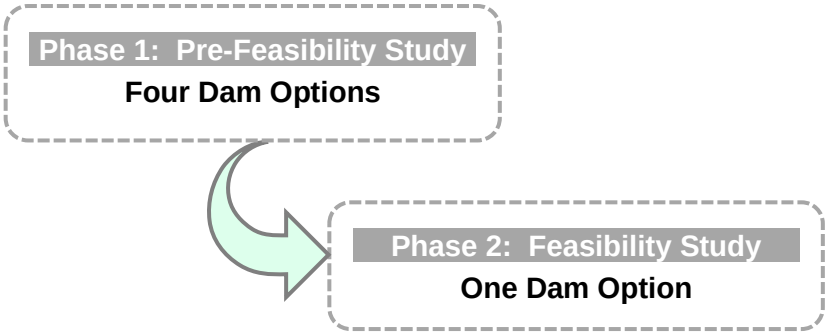
This Technical Feasibility Study will be undertaken in two separate phases, as follows:

Phase 1: Pre-Feasibility Study

The Pre-Feasibility Study (Phase 1) will be undertaken for the above-mentioned **four** proposed dams within the Crocodile (East) River Catchment

Phase 2: Feasibility Study

Under the Phase 1: Pre-Feasibility Study, **one** of the possible four dam options will be selected and recommended for further study and development to a **feasibility level** of detail in the Phase 2: Feasibility Study.



1.2 Study Area

The Crocodile (East) River Catchment in Mpumalanga is located in the north-east of the country and forms part of the larger Inkomati River Basin. The water of the Inkomati River Basin is shared between Mozambique, South Africa and Eswatini. A map of the Study Area is included in **Figure 1-1**.

Engineering investigations and studies for the respective dams and associated infrastructure will **each** have their **specific focus** and **study area** and will also apply to dam access, advanced infrastructure for the dam and the possible relocation of services (roads, rail, etc).

However, with respect to the Water Resources task (water demands, yield analysis, future water balance, the development of short-term stochastic yield reliability curves, updating of the water resources planning model, etc.) of the Study, the study area will cover the **whole** of the **Crocodile (East) River Catchment** (see **Figure 1-1**).

The Crocodile (East) River Catchment comprises of the following four tertiary catchments as indicated in **Figure 1-2**:

- Upper Crocodile Catchment (X21)
- Middle Crocodile Catchment (X22)
- Lower Crocodile Catchment (X24)
- Kaap Catchment (X23)

Important tributaries of the Crocodile River include the following:

- Kaap River
- Elands River
- Nels River
- White River

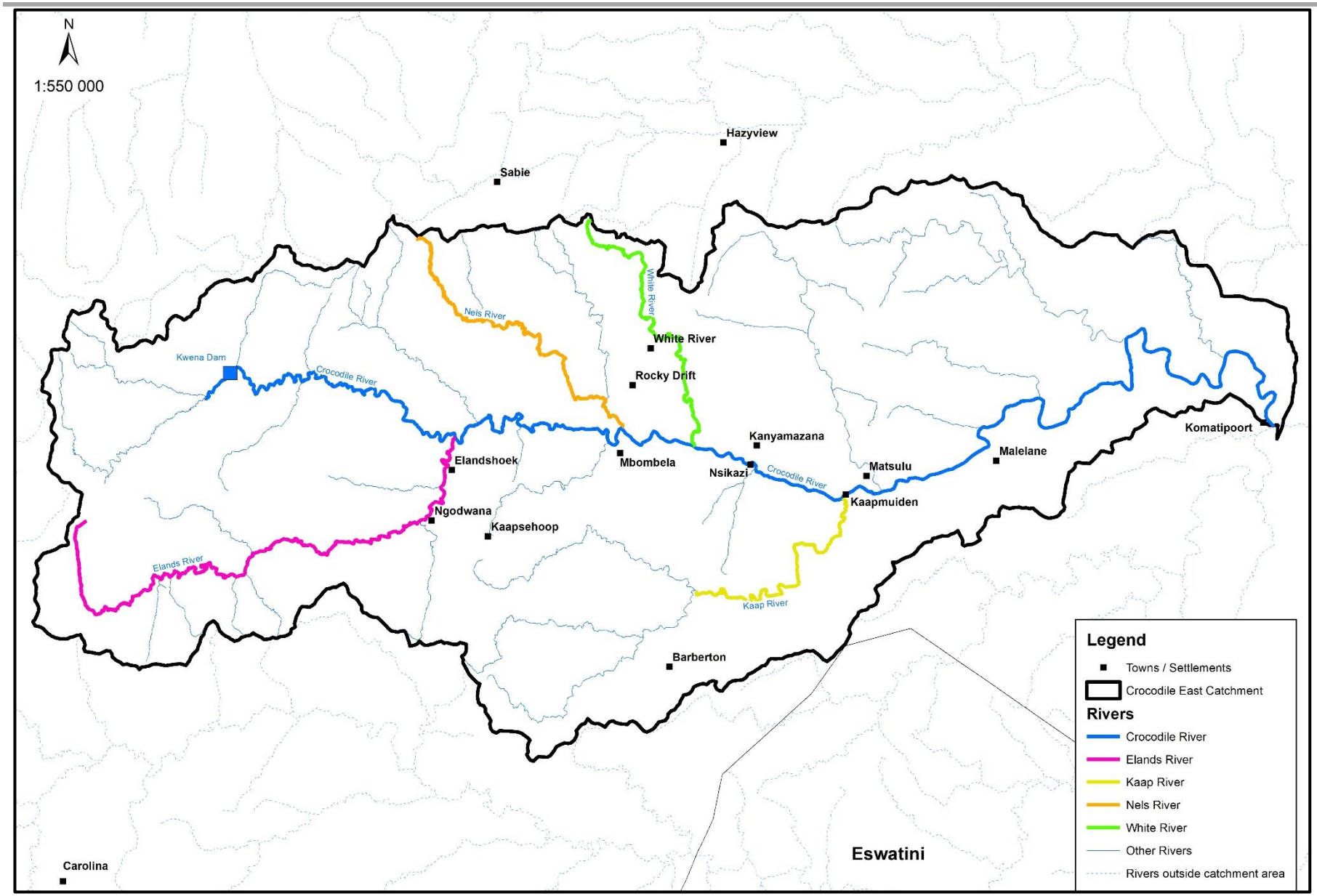


Figure 1-1: Crocodile River Catchment

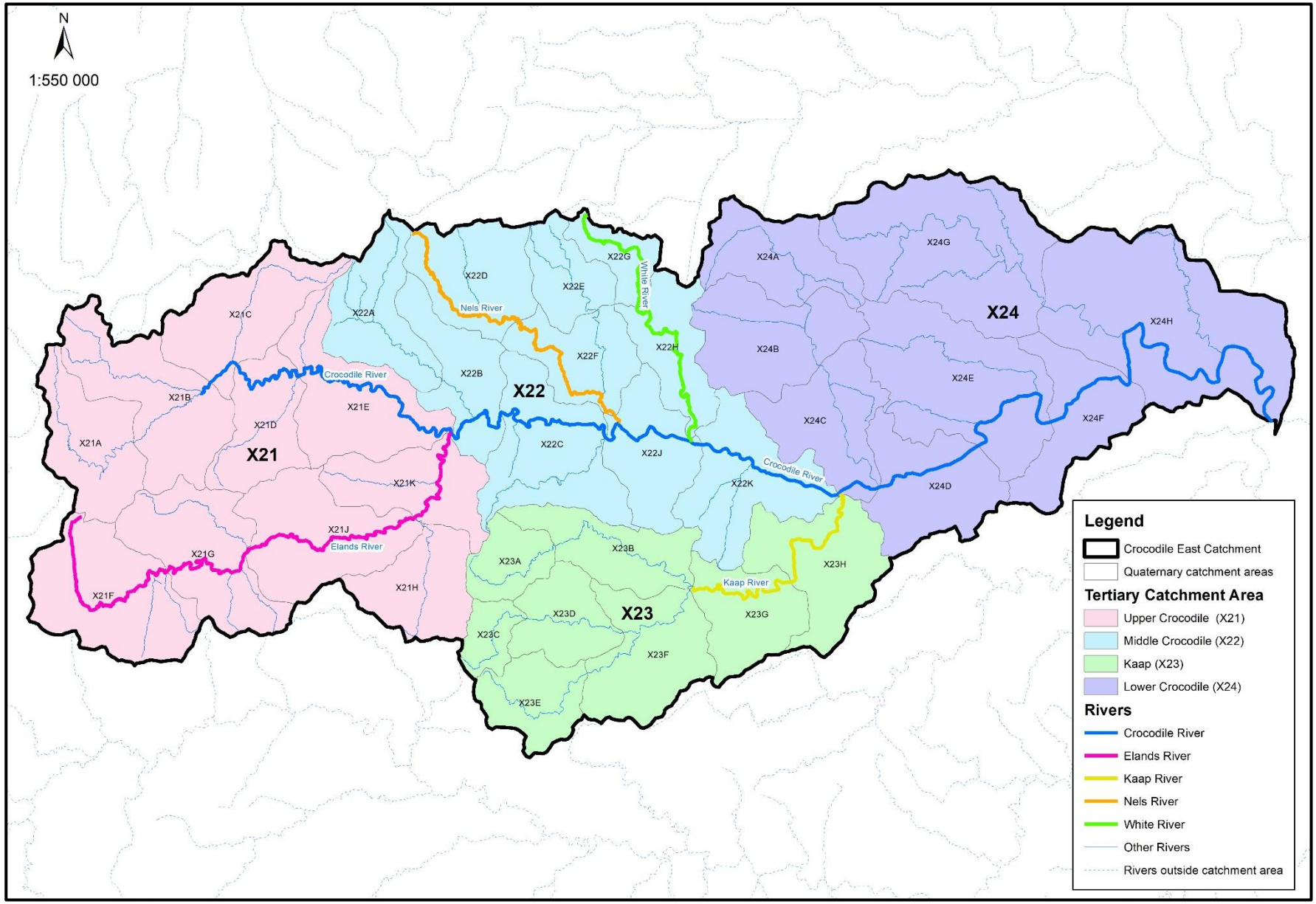


Figure 1-2: Crocodile East River: Tertiary Catchments

The following District and Local Municipalities fall within the Crocodile (East) River Catchment:

- Ehlanzeni District Municipality
  - Bushbuckridge Local Municipality
  - City of Mbombela Local Municipality
  - Nkomazi Local Municipality
  - Thaba Chweu Local Municipality
- Gert Sibande District Municipality
  - Chief Albert Luthuli Local Municipality
- Nkangala District Municipality
  - Emakhazeni Local Municipality

The Crocodile River Catchment is rural in nature, with agriculture being the main economic activity. The high rainfall escarpment catchments of the Upper and Middle Crocodile and Kaap catchments have significant areas of commercial forestry.

The Upper Crocodile Catchment is relatively undeveloped with small domestic and irrigation demands. The Middle Crocodile Catchment has large areas of controlled irrigation and urban demands in the Mbombela LM. The Kaap River Catchment is dominated in the lower eastern part by significant areas of controlled irrigation. Water is transferred into the Kaap River Catchment from the Lomati and Shiyalongubo dams for urban users (Umjindi Local Municipality which was disestablished and merged with Mbombela Local Municipality to establish the City of Mbombela Local Municipality) and agriculture (Louw's Creek Irrigation Board). The Lower Crocodile Catchment has large areas of controlled irrigation and smaller urban/domestic demands for the Nkomazi LM.

The only major dam in the catchment is the Kwena Dam in the Upper Crocodile River Catchment. The dam is approximately 60 km west of Mbombela on the main stem of the Crocodile East River or in the upper reaches of the Crocodile East Catchment. The dam is far from the water demand centers and therefore makes it difficult to regulate and manage water distribution to supply demands as required by the users.

1.3 Proposed Dams

Four proposed dams (listed below) will be investigated during the Pre-Feasibility Phase (Phase 1) of this Study. Only **one** will be selected and recommended for further study in the Feasibility Phase (Phase 2) of the Study. It is, however, possible that the second-best option could be taken forward at a later stage.

- Mountain View Dam on the Kaap River.
- Montrose Dam on the Crocodile East River.
- Boschjeskop Dam on the Nels River.
- Strathmore Off-Channel Storage Dam, near the confluence of the Kaap and Crocodile Rivers.

The regional orientation of the **four proposed dam sites** is indicated in **Figure 1-3**.

1.4 Purpose of Report

This report deals with the geological and geotechnical considerations of each of the four dam sites at pre-feasibility investigation level. This involved a desk study assessment of the available information, a walk-over site visit and a review of the information. The results of each of the dam sites are discussed in the subsequent sections, while additional descriptions and site photos are contained in the Site Visit Report (refer to **Appendix A**).

1.5 Structure of Report

The following is addressed in the relevant sections of this Report:

- **Section 1** provides a background of the Study, an overview of the Study Area, including the purpose and structure of this Report.
- **Sections 2 to 5** include the geotechnical and material investigations in terms of the following for the dam sites:
  - Geology
  - Dam Basin Stability and Watertightness
  - Materials Availability

The scope of geotechnical investigations required during the Phase 2: Feasibility Study is also provided for each dam site.

- **Section 6** provides the geotechnical ranking of the dam sites based on basic geological and geotechnical parameters.
- **Section 7** indicates the Study references.

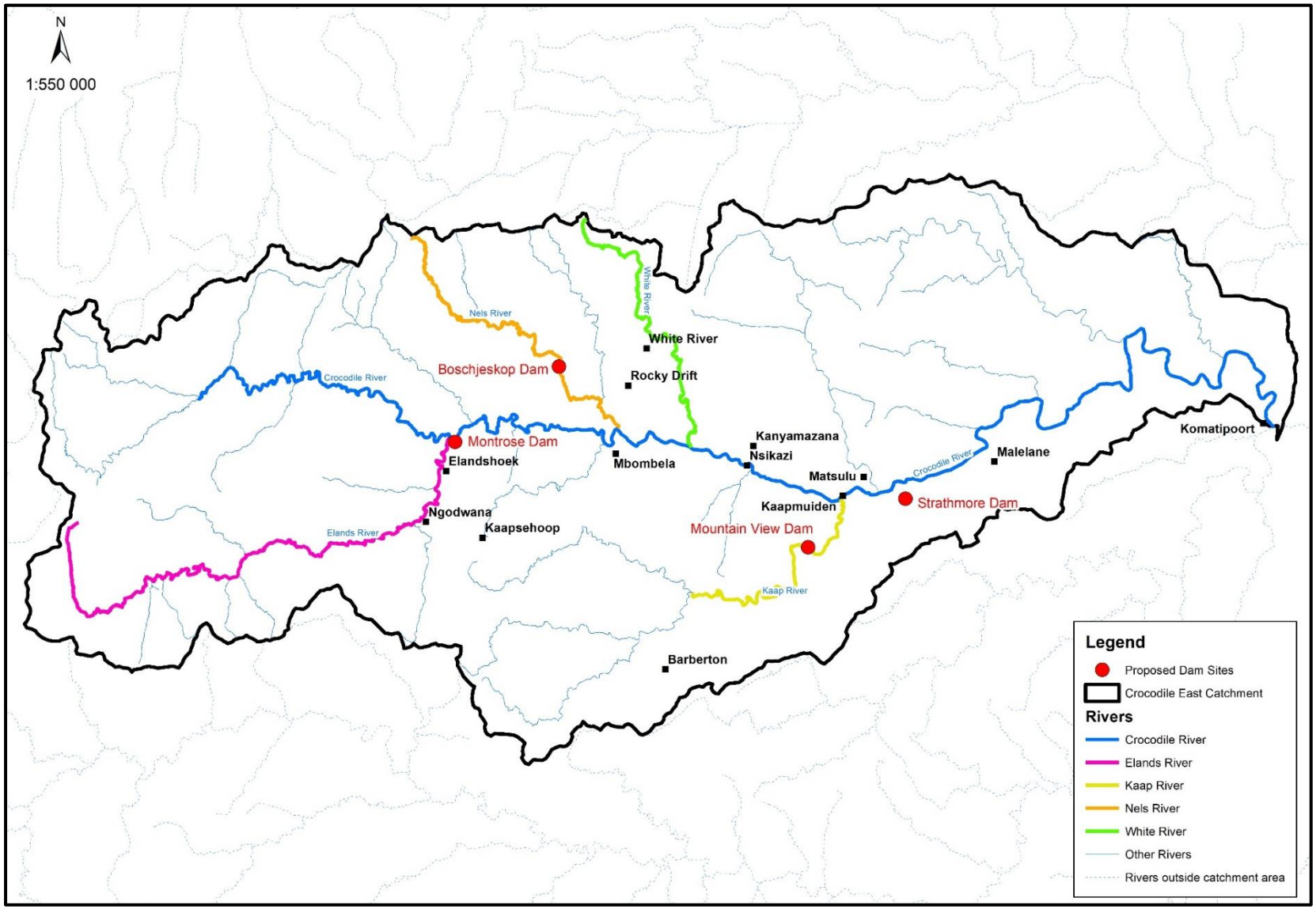
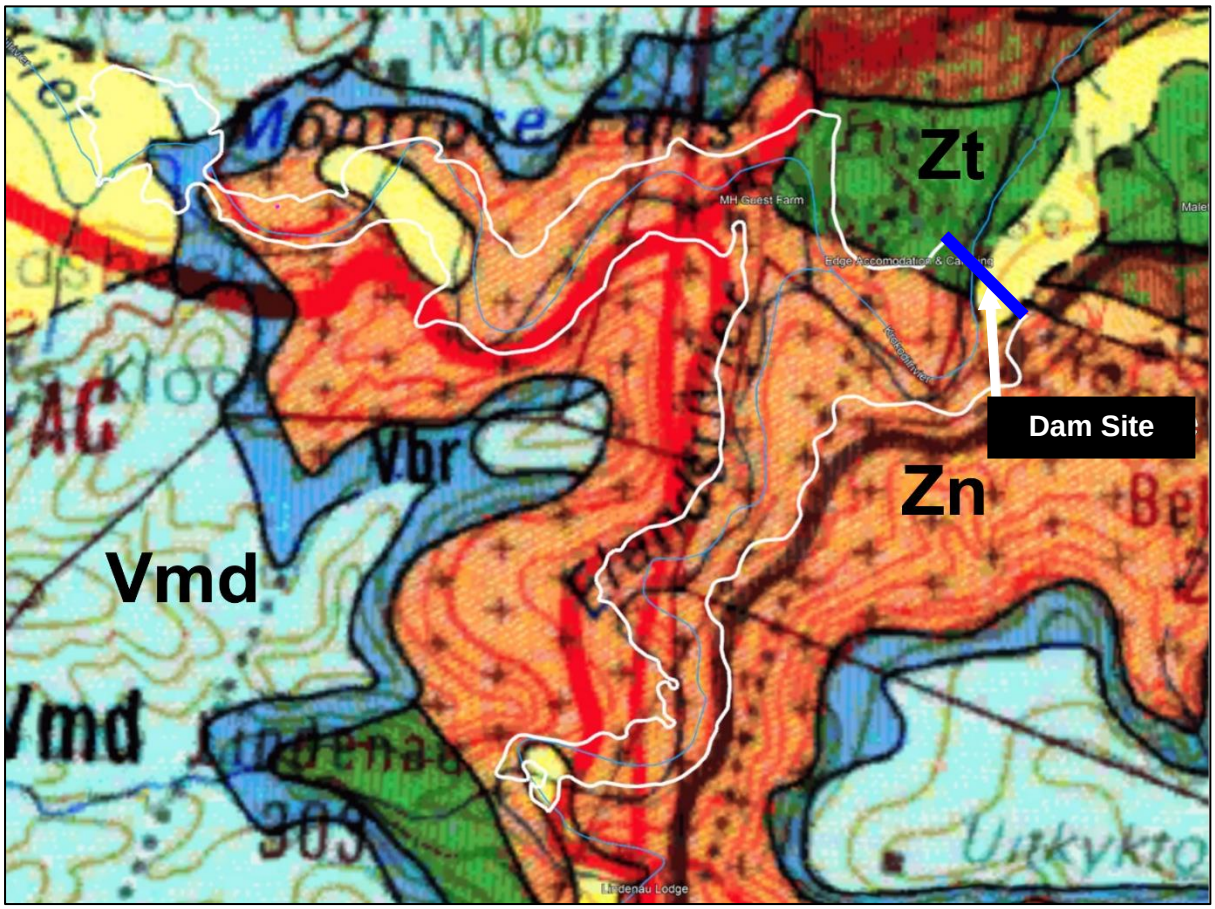


Figure 1-3: Regional Context of Four Proposed Dam Sites

2 MONTROSE DAM SITE

2.1 Geology

The Montrose Dam site is situated near the lower edge of the Great Escarpment, which is composed of sedimentary and volcanic succession of rocks belonging to the Chuniespoort and Pretoria Groups, Transvaal Supergroup. These rest unconformably on the granitic rocks of the Nelspruit Suite, which have a large distribution in the lowveld areas of Mpumalanga. Ancient rocks of the Barberton Supergroup occur sporadically in the area and particularly along a wide north-east striking band of up to 20 km wide along the southern portions of Mpumalanga. The regional geology of the dam site is shown in **Figure 2-1**.



Geological Legend:				
	Vmd	Dolomite	Chuniespoort Group	Transvaal Supergroup
	Vbr	Quartzite	Blackreef	Transvaal Supergroup
	Zn	Biotite Granite		Nelspruit Suite
	Zt	Schist, komatitite, volcanics		Barberton Supergroup

Figure 2-1: Montrose Dam Site: Geological Map

The dam site is located on the Crocodile River downstream of the Elands River confluence. The well-known Montrose waterfall occurs in the Crocodile River just downstream of the N4 river crossing. The dam site is underlain by biotite gneiss and biotite granite of the Nelspruit Suite (Basement Complex), with highly metamorphosed rocks of the Barberton Supergroup (schists, banded iron formation and various volcanic rocks) occurring on the downstream portion of the left flank. A wide band of granular alluvium is present in the river section at the dam site, becoming wider downstream of the dam site.

The dam site and adjacent areas are distinctly hilly with deeply incised river channels and a dendritic drainage pattern. The rivers are generally meandering, probably controlled by the orientation of geological structures. The gradient of the Crocodile River below the confluence with the Elands River is somewhat flatter than higher up in the catchment, where it has drained along the escarpment slopes.

There are two main orientations of structural features in the area, viz. north-north-west (340°) and west-south-west (070°). These are associated with shear zones, dolerite dyke intrusions and faults.

The climatic N-value as defined by Weinert is considerably less than 5, which implies that chemical weathering is the dominant mode of weathering (Weinert HH,1980). Relatively thick residual soils can therefore be expected with the residual soils partially disintegrated to silty and clayey sand.

2.2 Engineering Geological Evaluation

The location of the Montrose Dam site was chosen midway along a relatively straight portion of the river, approximately 1,8 km below the Elands River confluence in a relatively narrow, steep-sided valley. The shape of the valley at the site is somewhat asymmetrical with the left flank steeper than the right flank. The exact position of the dam is sensitive from a geological point of view, since a geological contact occurs on the left flank between granitic rock (upstream portion) and metamorphosed rocks of the Barberton Group (downstream portion). The current position of the dam was chosen such that the entire left flank is underlain by the Barberton metamorphosed rocks (except perhaps for the far upper portion).

The **left flank** is relatively steep, but convex. The gradient of the lower slope (up to 40 m above riverbed level) is about 1H:2V, while the average slope of the upper portion is 1H:7V. The left flank is characterised by the presence of widespread rock outcrops, including large

areas of relatively widely jointed rock. It is therefore expected that the depth to suitable foundations for a mass concrete structure should be relatively shallow on this flank, possibly ranging from <1 m to 3 m on the lower steeper portion to 3 m to 5 m on the upper flatter slope. Only the upper 1 m will be possible with mechanical excavation methods, whilst the remainder of the excavations will require controlled blasting techniques to avoid foundation damage and side wall stability problems.

The **river section** (river channel plus alluvial terraces) is over 70 m wide at the dam site and covered by granular alluvium. The thickness of the alluvium is not known but is estimated to be up to 5 m thick in places. The underlying rock will most likely be similar to the left flank, viz metamorphosed rock of the Barberton Group, with a possible geological contact with the Nelspruit granites buried under the alluvium. The rock profile will most likely be very undulating due to river scouring and selective erosion.

The **right flank** is overall somewhat flatter than the left flank but also has a convex shape. The lower portion of the flank from the riverbed level to approximately 30 m above riverbed level has a gradient of 1H:2,5V whilst the upper portion has a gradient of 1H:6,5V. The lower steep portion of the right flank is characterised by shallow granitic rock and sporadic large rock outcrops. The depth to rock here is expected to be on average 3 m, while the upper flank is covered by a thicker mantle of residual granite soils. The expected depth to rock foundations suitable for a concrete structure or cutoff core trench will range between 3 m and up to 7 m (upper flank zones).

The metamorphosed rock on the left flank and river section will most likely have moderate to high secondary coefficients of permeability. The dam also straddles a geological contact zone, possibly somewhere in the river section. A grout curtain combined with a foundation drainage will be required along the full length of the dam wall. Curtain depths of 50 m can be assumed in the river section, gradually tapering down to 10 m on the upper flank portions.

2.3 Dam Basin Stability and Watertightness

The dam basin is situated in a hilly terrain and steep slopes occur at the dam site and in the reservoir, extending up to 100 m above the FSL in places. The natural slopes above the dam do not show any signs of instability but the influence on the stability due to the raised water level and associated elevation of phreatic levels on the flanks will have to be investigated.

Existing infrastructure in the basin includes the following:

- Significant portions of the N4 including the R539/N4 interchange and Crocodile River bridge are currently being upgraded.
- The railway line appears to be just above the full supply level (FSL) on the right flank of the Crocodile/Elands Rivers but will have to be checked for flood levels. The possible effect of the elevated groundwater level on the stability of the railway line will have to be considered.
- Pending the FSL, portions of the village of Elandshoek may be inundated.

The following concerns were identified which could lead to water seepage from the reservoir area:

- A prominent north-south striking dolerite dyke intersects both the Crocodile and Elands Rivers legs of the basin. This could in theory lead to seepage and leakage into the nearby dolomite, but the dolomite occurs at an elevation that is much higher than the FSL and this is not considered to present a problem.
- Likewise, the dolomite that occurs both to the east and west of the Elands River portion of the reservoir occurs at elevations much higher than the FSL and leakage into the highly pervious dolomite is not considered possible.
- The dolomite in the vicinity of the basin does not underly it except at the far upstream portion of the Crocodile River where dolomite occurs in the upper reaches of the basin, pending the FSL.

2.4 Materials Availability

This section deals with the availability of natural construction materials for the construction of the dam and associated infrastructure. Generally, the following materials are required:

- Hard rock quarry for the manufacturing of concrete aggregate (coarse and fine).
- Impervious soils for embankment construction.
- Semi-pervious soils for embankment construction.
- Structural fill for platforms and access roads.

The areas on both sides of the Elands River at the confluence with the Crocodile River comprise scattered granitic rock outcrop with continuous rock exposed on the sides of the valley near the river. This area is underlain by biotite granite and is identified as a possible rock quarry site. A large area of approximately 200 000 m² was identified at the confluence for the development of a quarry.

Natural sand for fine concrete aggregate is present in isolated alluvial terraces along both Elands and Crocodile Rivers. A significant deposit occurs e.g., at the dam site, but its properties and volumes will need to be determined. It is anticipated that the bulk of the fine aggregate will be provided by the crushing of unweathered granite, with natural sand possibly used as a filler to improve workability.

Residual granite soil on the right flank, including overburden soil on the quarry can potentially be suitable for embankment construction. Clayey soils for cutoff zone in the embankment are not likely to be present in significant quantities in the basin, although the upper zone of the residual granite may comprise clayey sand which can be used for homogeneous embankment construction.

Weathered granite from the overburden of the rock quarry will provide base course quality material for use as structural fill. Primary crushing and/or screening may however be required.

2.5 Feasibility Level Scope of Geotechnical Investigations

Feasibility level geotechnical investigations at the Montrose Dam site will involve a combination of the following investigation types:

- Geophysical surveys at the dam and rock quarry sites. Provision has been made for electrical resistivity surveys supplemented by seismic refraction surveys.
- Rotary core drilling will be conducted in the dam foundation footprint area as well as at the rock quarry site.
- Lugeon type water pressure tests will be required at most of the boreholes drilled in the dam site.
- Limited TLB test pits will be required on the right flank of the dam site, river section, the rock quarry site and potential borrow areas adjacent to the rock quarry (upstream).

- Laboratory testing will be conducted on foundation rock samples, representative quarry material samples and soils for embankment construction and sand for filters / fine concrete aggregate.

The scope of the feasibility level geotechnical investigation at the Montrose Dam site is as follows:

Rotary Core Drilling				
Left Flank	4 x 50 m		200 m	
River Section	4 x 50 m + 1 x 100 m		300 m	
Right Flank	8 x 30 m		240 m	
Rock Quarry	8 x 30 m		240 m	**Total: 980 m**
Geophysical Surveys				
Electrical Resistivity	River Section	4 x 100 m	400 m	
	Left Flank	1 x 250 m	250 m	
	Right Flank	1 x 400 m	400 m	
	Rock Quarry	1 x 800m 4 x 300 m	2 000 m	**Total 3 050 m**
Seismic Refraction	River Section	3 x 100m	300 m	
	Left Flank	1 x 100 m	100 m	
	Right Flank	1 x 300 m	300 m	**Total 700 m**
Laboratory Testing				
Rock Cores Dam Site	Uniaxial Compressive Strength		12 no	
	Deformation Tests		12 no	
Rock Cores Quarry	SANS 1083 Rock Sets		3 sets	
	Alkali-Silica Reactivity		5 no	
	Petrographic Analysis		5 no	
River Sand	SANS 1083 Sand Sets		5 sets	
Borrow Materials	Foundation Indicator		20 no	
	Standard Proctor Compaction		6 no	
	Triaxial CU		3 no	
Structural Fill	Foundation Indicator		10 no	
	Mod AASHTO compaction + CBR		4 no	

3 MOUNTAIN VIEW DAM SITE

3.1 Geology

The Mountain View Dam site was identified as early as 1967 when a dam site was investigated on the Kaap River by FC Truter under instruction of the then Department of Water Affairs. A walkover investigation was conducted initially on the farm Esperado Annex, but the site at the upstream end of a prominent gorge on Mountain View was identified as the preferred dam site. The results of that investigation were described in a short report, including a 1:50 000 scale geological map (Truter 1967). The site is underlain by granitic gneiss intruded by dolerite (diabase in the Truter report) that are orientated either east-west or north-south. The saddle on the upper left flank is associated with such a linear intrusion.

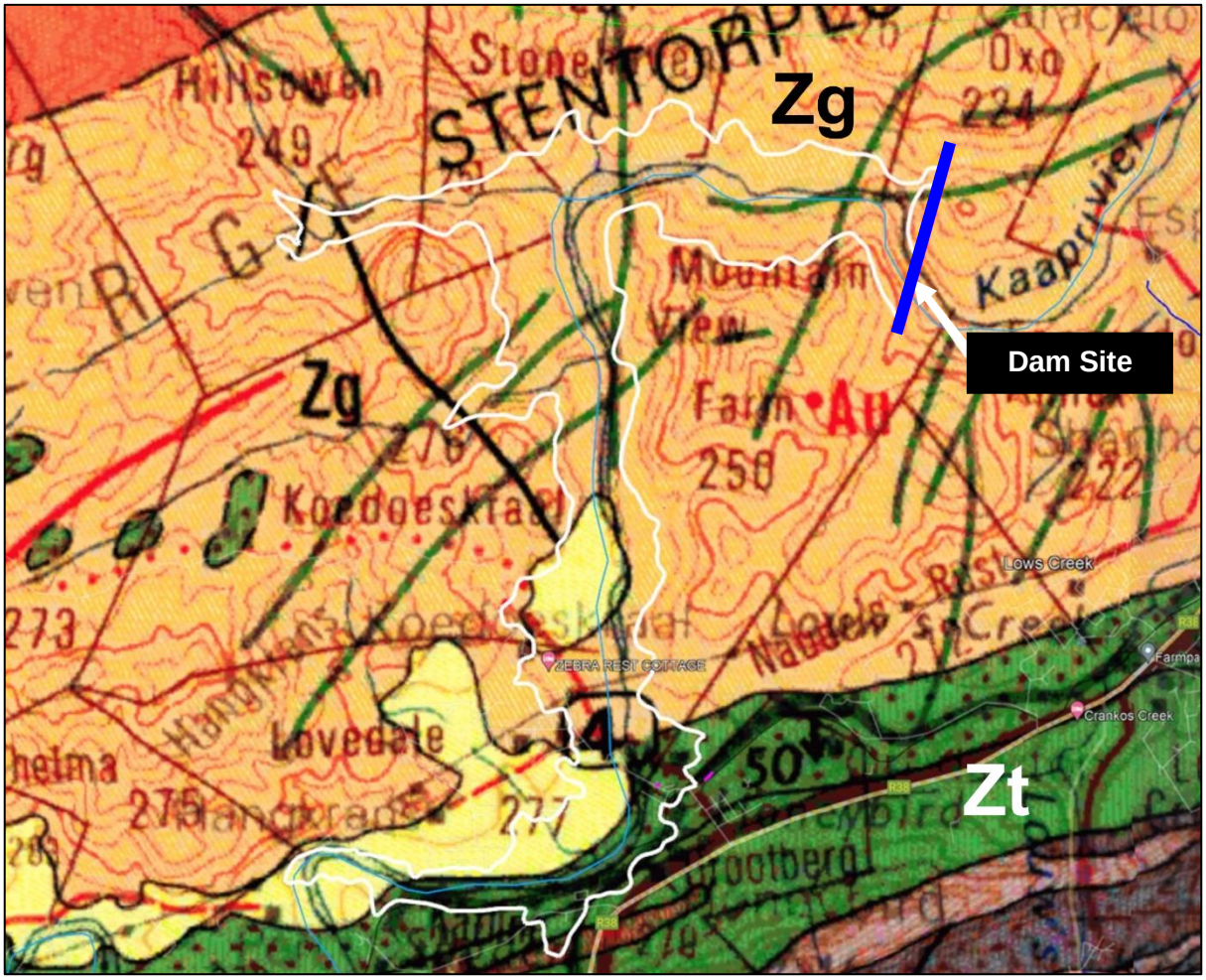
Truter mentioned the steep left flank with continuous rock outcrop while the right flank was somewhat flatter and possibly more weathered. He also mentioned that the site can be moved somewhat downstream where better right flank conditions may be expected (Truter 1967).

Truter also mentioned that the Mountain View Dam site is the only suitable site along the Kaap River for the construction of a large dam due to unfavourable topographical conditions further downstream. He also stated that the dam basin does not contain minerals of economic importance. He recommended that the dam site be investigated further by means of core drilling provided the results of a dam basin survey showed a favourable dam basin capacity. Drilling was undertaken at the upstream portion of the gorge, but the results thereof could not be found.

The proposed Mountain View Dam site is located on the Kaap River, which flows in a north-east direction to where it has its confluence with the Crocodile River at Kaapmuiden. The site is situated at the lower end of a mountainous area (Krokodilpoort Mountains) caused by granitic rocks of the Stentor Pluton (large-scale mass of igneous rock). Four main regional geological structural orientations are noted, viz.:

- North-east
- Almost north (just east of north)
- Almost east
- North-west

These are mainly manifested by dolerite dyke intrusions. The Stentor Pluton is remarkably massive with no significant evidence of shearing and/or faulting present. Some displacements may however be associated with dyke intrusions. The regional geology of the dam site is shown in **Figure 3-1**.



Geological Legend:

Zg	Biotite Gneiss	Basement Complex
Zt	Schist, komatitite, volcanics	Barberton Supergroup
	Dolerite Dyke Intrusions	

Figure 3-1: Mountain View Dam Site: Geological Map

The dam site was selected approximately midway along a relatively straight section of the river where both flanks are relatively steep and extend to heights in excess of 200 m above riverbed level. The rock type at the site is mapped as biotite-trondhjemite gneiss which will subsequently be referred to as gneiss in this report.

At least two east-west striking dolerite dykes occur on the upper left flank where these were responsible for a distinct saddle and possible soft ground conditions along the deeply

weathered dyke intrusion. Several north-east striking dykes intersect the site upstream and downstream thereof, but these do not influence the foundation conditions at the site.

A large section of the river channel is covered by water caused by a small weir at the lower end of the valley, but according to available information, extensive outcrops of gneiss are present in the river section. Bars of alluvium with thickness of up to one meter occur sporadically in the river section.

The climatic N-value as defined by Weinert is considerably less than 5, which implies that chemical weathering is the dominant mode of weathering (Weinert HH, 1980). Relatively thick residual soils can therefore be expected with the residual soils partially disintegrated to silty and clayey sand.

3.2 Engineering Geological Evaluation

The Mountain View Dam site was chosen approximately midway along a relatively straight portion of the river, in a relatively narrow, steep-sided valley. The site is situated 12,8 km upstream of the Crocodile River confluence. The shape of the valley at the site is somewhat asymmetrical with the right flank steeper than the left flank, particularly on the upper flank areas. The exact position of the dam site is not considered sensitive from a geological point of view, the valley shape and topography would rather dictate the dam site position. The level of the saddle on the left flank will determine the requirement to construct a saddle dam at this position, for the chosen FSL. This localized low point in the basin can also be utilized for a spillway.

Widespread relatively unweathered granite gneiss outcrops in the river section and on both flanks. The lower part of the river valley consists of prominent steep rock cliffs, whereas large portions of the upper flanks are covered by a superficial layer of talus material. The talus material consists of angular boulders of granite gneiss with gravel and silty sand, which have mainly been transported over relatively short distances by gravitational forces and surface runoff water. Some of the boulders are up to 3 m in size. Some degree of downslope rock movement (rock creep) has occurred on the steep sections of the flanks, resulting in large loose blocks of rock separated from the intact rock faces by wide, open subvertical cracks and joints.

At least two distinct sub-vertical joint sets occur at the site, namely a north-north-east/ south-south-west striking joint set which crosses the river at approximately 45° and a north-north-

west/south-south-east striking joint set running almost parallel to the river at the dam site. Distinction can be made between long continuous joints and joints which are short and discontinuous. The joint spacing of the continuous joints is highly variable, but mainly between 1 m and 3 m. However, the discontinuous joints have joint spacings of as close as 0,3 m. The sub-vertical joints exposed in the prominent rock outcrops in the river section are generally closed or very narrow. Erosion by water has occurred along some of the joints striking parallel to the river, but with depth these joints are expected to be closed.

A distinctive low angled joint set dipping approximately 30° downstream occurs at a spacing of about 10 m. These joints, as exposed on the flanks, are open and weathered to a width of up to 0,5 m in places. It is not known to what extent these joints are weathered with depth underneath the flanks and whether they also occur below the river section.

The **left flank** is relatively steep but becomes flatter approximately midway up the slope (at RL 450 m). The gradient of the lower slope (up to 60 m above riverbed level) is about 1H:1,7V, while the average slope of the upper portion is 1H:2,5V. The left flank is characterised by the presence of widespread rock outcrops, including large areas of relatively widely jointed rock. It is therefore expected that the depth to suitable foundations for a mass concrete structure should be relatively shallow on this flank, possibly ranging from 1 m to 3 m on the lower steeper portion, extending perhaps up to 5 m in places on the upper flatter slope. Foundation excavations would involve unconsolidated overburden and weathered rock. The latter will require controlled blasting to ensure a relatively smooth undamaged (due to blasting) foundation surface. Only the upper 1 m will be possible with mechanical excavation methods.

The **river section** (river channel plus alluvial terraces) is about 40 m wide at the dam site and mostly covered by water from the weir. The thickness of the alluvium is not known but is estimated to be less than 1 m in places. The underlying rock will most likely be similar to the flanks, viz medium to widely jointed gneiss. The rock profile will most likely be very undulating due to river scouring and selective erosion. Foundation excavations should extend at least 1 m into rock to create freshly blasted rough surfaces to increase shear strength on the rock-concrete interface.

The **right flank** has a constant slope of approximately 1H:1,8V. The flank is characterised by widespread gneiss rock outcrops and thin soil and vegetation cover. The depth to suitable foundation for a mass concrete dam is expected to be on average less than 2 m. Excavations would entail the removal of the overburden and weathered surface rock. Some localized deeper excavations may be required where weathering has extended along main joint zones.

The gneiss rock mass at the dam site may contain pervious joints and will most likely have moderate to (localized) high secondary coefficients of permeability. A grout curtain combined with foundation drainage will be required along the full length of the dam. Curtain depths of 60 m can be assumed in the river section, gradually tapering down to 7 m on the upper flank portions. The grout curtain on the left flank may have to be extended to cover the saddle, pending the dam type and FSL.

3.3 Dam Basin Stability and Watertightness

The dam basin is situated in a hilly terrain and steep slopes occur at the dam site and in the reservoir, extending in excess of 100 m above the FSL in places. The natural slopes above the dam do not show any signs of large-scale instability but large talus boulders and unconsolidated soil occur on steep slopes at or above the FSL, which will potentially be unstable under the influence of the raised water level and associated elevation of phreatic levels. A comprehensive slope stability assessment of the reservoir slopes will be required.

Existing infrastructure in the basin is very limited, but the following was identified:

- Cultivated lands in the far upstream extremity of the basin in the flat-lying areas.
- A railway line may become inundated in the far upstream portion of the basin, pending the FSL.
- Several farm steads, a lodge and localized access roads may become inundated in the far upstream portion of the basin.
- The integrity of portions of the R38 road between Kaapmuiden and Barberton will require attention.

Except for the saddle on the left flank near the dam site as mentioned and discussed in the previous section, no other potential zones of leakage from the basin were identified.

3.4 Materials Availability

This section deals with the availability of natural construction materials for the construction of the dam and associated infrastructure. The Mountain View reservoir area is characterised by a thin soil cover of mostly topsoil and granular talus and limited presence of granular residual gneissic soils. No large quantities of clayey soils are present in the basin, except in the

cultivated lands in the far upstream portion of the basin, approximately 9 km from the site. Embankment fill structures are therefore limited to concrete faced rockfill embankments.

The following materials are considered relevant for the Mountain View Dam:

- Hard rock quarry for the manufacturing of concrete aggregate (coarse and fine).
- River sand.
- Rockfill quarry site (possibly incorporated as spillway site next to saddle on left flank).
- Structural fill for platforms and access roads.

A potential rock quarry site was identified on the right flank approximately 700 m from the dam site, comprising an area of approximately 120 000 m^2. It follows that an in-situ volume of 1,8 x 10^6 m^3 rock can potentially be sourced with a 15 m quarry bench height.

Natural sand for fine concrete aggregate was not identified in the basin along the Kaap River. It is anticipated that the bulk of the fine aggregate will be provided by the crushing of unweathered granite, possibly blended with natural sand used as a filler to improve workability, provided such sources can be located.

Weathered granite from the overburden of the rock quarry will provide base course quality material for use as structural fill. Primary crushing and/or screening may however be required.

3.5 Feasibility Level Scope of Geotechnical Investigations

Feasibility level geotechnical investigations at the Mountain View Dam site will involve a combination of the following investigation types:

- Geophysical surveys at the dam and rock quarry sites. Provision has been made for electrical resistivity surveys supplemented by seismic refraction surveys.
- Rotary core drilling will be conducted in the dam foundation footprint area as well as at the rock quarry site.
- Lugeon type water pressure tests will be required at most of the boreholes drilled at the dam site.
- Laboratory testing will be conducted on foundation rock samples, representative quarry material samples and soils for embankment construction and sand for filters / fine concrete aggregate.

The scope of the feasibility level geotechnical investigation at the Mountain View Dam site is as follows:

Rotary Core Drilling				
Left Flank	2 x 30 m + 1 x 100 m (inclined)		160 m	
River Section	2 x 50 m + 2 x 120 m (inclined)		340 m	
Right Flank	2 x 60 m + 1 x 100 m (inclined)		220 m	
Alternative spillway	3 x 30 m		90 m	
Rock Quarry	8 x 30 m		240 m	**Total: 1 150 m**
Geophysical Surveys				
Electrical Resistivity	River Section	2 x 200 m	400 m	
	Left Flank	1 x 250 m	250 m	
	Right Flank	1 x 250 m	250 m	
	Saddle	2 x 100 m	200 m	
	Rock Quarry	1 x 500m 4 x 300 m	1 700 m	**Total 2 800 m**
Seismic Refraction	River Section	2 x 100m	200 m	
	Left Flank	1 x 100 m	100 m	
	Right Flank	1 x 100 m	100 m	**Total 400 m**

Laboratory Testing		
Rock Cores Dam Site	Uniaxial Compressive Strength	12 no
	Deformation Tests	12 no
Rock Cores Quarry	SANS 1083 Rock Sets	3 sets
	Alkali-Silica Reactivity	5 no
	Petrographic Analysis	5 no
River Sand	SANS 1083 Sand Sets	2 sets
Structural Fill	Foundation Indicator	10 no
	Mod AASHTO compaction + CBR	4 no

4 BOSCHJESKOP DAM SITE

4.1 Geology

The Boschjeskop Dam site is located on the Nels River, which flows in a southern direction to where it has its confluence with the Crocodile River in the Lowveld Botanical Gardens. The site is situated in a relatively flat-lying area where a small hill forms the right flank. The left flank is flattish and covered extensively by transported and residual soils. Virtually the entire dam site and basin are underlain by biotite granite of the Nelspruit Suite (Basement rocks). Two distinct preferential orientations for structural geological features were noted, viz:

- North-north east
- North-north west

These are mainly manifested by shear zones and undifferentiated linear features, which could be dyke intrusions. The regional geology of the dam site is shown in **Figure 4-1**.

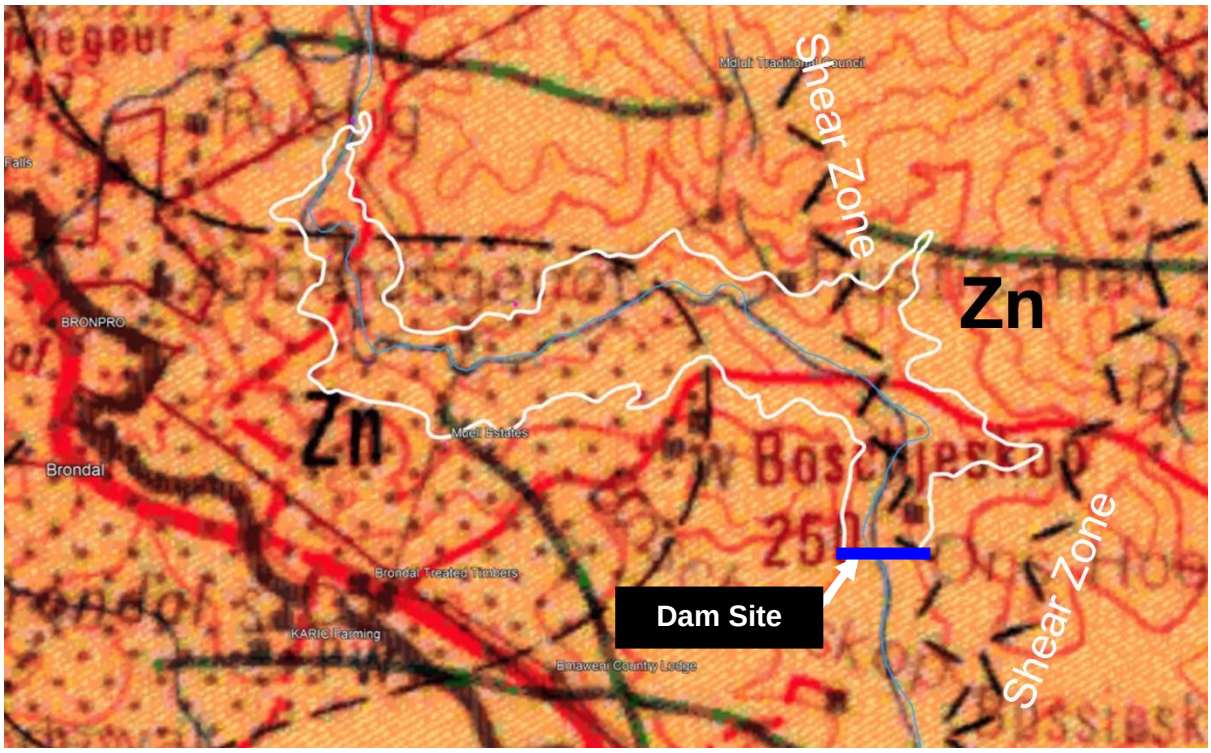


Figure 4-1: Boschjeskop Dam Site: Geological Map

The right flank of Boschjeskop Dam site comprises a relatively steep ridge and the left flank rises gently towards a localized hill, situated almost 1 km east of the site. The dam site is therefore strongly asymmetrical. The rock type at the site is mapped as white to grey biotite granite.

According to the published geological map, a north-north-west striking shear zone intersects the left flank of the dam. This feature could however not be identified during the site walkover or on satellite imagery due to the widespread presence of the transported soil cover at the left flank. The top of the ridge on the right flank comprises widespread occurrences of pegmatite, which is often associated with faulting, although not mapped as such on the geological map.

The river section is densely overgrown by large trees and shrubs, but isolated bars of sandy alluvium occur sporadically.

The climatic N-value as defined by Weinert is considerably less than 5, which implies that chemical weathering is the dominant mode of weathering (Weinert HH,1980). Relatively thick residual soils can therefore be expected with the residual soils partially disintegrated to silty and clayey sand.

4.2 Engineering Geological Evaluation

The Boschjeskop Dam site was chosen on topographical grounds at a unique position along the Nels River where topography was reasonably favourable for the construction of a large dam. The position of the dam is therefore not considered sensitive from a geological point of view, but the valley shape and topography would rather dictate the dam site position.

The **left flank** has a relatively flat but constant gradient of 1H:10,2V. The entire flank is covered by fine-grained reddish-brown hillwash, which overlies a thick mantle of residual granitic soil. Residual granite at the site consists of silty sand with minor clay, which gradually grades with depth to more granular soil. Depth to rock on the left flank is unknown, but it is safe to conclude at this stage that it probably follows riverbed level.

This flank is ideally suitable for a zoned earthfill embankment with a central clay core. Core trench depths will have to be determined from drilling results and permeability testing of the residual soils. For the purpose of this level of investigation, an average depth of 5 m can be assumed. Excavation depth for embankment shells can be taken as 1 m.

The **river section** (river channel plus alluvial terraces) is about 90 m wide at the dam site and covered by alluvial terraces and patches of sandy/gravelly soil. Widespread outcrops of widely jointed unweathered granite occur in the active river channel and on the riverbanks. The thickness of the alluvium is not known but is expected to be variable and less than 1 m in places. The underlying rock will most likely be very undulating due to river scouring and selective erosion. Foundation excavations should extend at least 1 m into rock to create freshly blasted rough surfaces to increase shear strength on the rock-concrete interface.

The **right flank** has a slight concave shape with an average slope of approximately 1H:2,8V. The flank is characterised by scattered weathered granite rock outcrops and a sandy soil cover. A large portion of the flank is covered by a eucalyptus tree plantation. Tree stumps and roots will have extended to a considerable depth. The expected depth to a suitable foundation for a mass concrete dam is expected to be reasonably deep, possibly up to 5 m. Excavations would entail the removal of the overburden and weathered surface rock. Some localized deeper excavations may be required where weathering has extended along main joint zones and along structural features such as shear zones/faults.

The granite rock mass at the dam site may contain pervious joints and will most likely have moderate to (localized) high secondary coefficients of permeability. A grout curtain combined with foundation drainage will be required along the full length of the dam wall. Curtain depths of 30 m can be assumed in the river section, gradually tapering down to 7 m on the upper flank portions. Localised deeper grouting may be required on the left flank where a shear zone is indicated on the published geological map. Drilling will have to confirm its presence and effect on the rock mass permeability.

4.3 Dam Basin Stability and Watertightness

The dam basin is situated in a flat-lying terrain without the presence of steep slopes. No basin instabilities should occur.

Existing infrastructure in the basin essentially comprises cultivation, but the following specific infrastructure was identified:

- A portion of the tarred access road.
- Several farm steads and localised access roads.

No potential zones of leakage from the basin were identified. The basin is lined with a well-developed layer of hillwash clayey soil, which provides a relatively impervious natural blanket that should ensure relatively watertight conditions.

4.4 Materials Availability

This section deals with the availability of natural construction materials for the construction of the dam wall and associated infrastructure. The Boschjeskop reservoir area is characterised by widespread soils. These will vary from fine-grained slightly plastic (hillwash) soils suitable for clay core as well as more granular residual granite for semi-pervious embankment zones. The following material sources will be required for the construction of the Boschjeskop Dam:

- Hard rock quarry for the manufacturing of concrete aggregate (coarse and fine) and riprap.
- River sand.
- Embankment construction material.
- Structural fill for platforms and access roads.

No potential rock quarry site was identified in the dam basin. Potential sites for a hard rock granite quarry occur on the high-lying portion of the right flank at elevations above RL 900 m and about 1 km from the dam site. Another potential rock quarry site outside of the basin occurs on the left flank approximately 1.2 km downstream of the dam.

No large deposits of natural sand for fine concrete aggregate and filters were identified in the basin along the Nels River. It is anticipated that the bulk of the fine aggregate will be provided by the crushing of unweathered granite, possibly blended with natural sand used as a filler to improve workability, provided such sources can be located.

Large quantities of both clayey and granular soils are present in the basin of the Boschjeskop Dam site. Potential sources occur on both flanks at the dam site up to the tarred road as well as upstream of the road, thus virtually across the entire basin area.

4.5 Feasibility Level Scope of Geotechnical Investigations

Feasibility level geotechnical investigations at the Boschjeskop Dam site will involve a combination of the following investigation types:

- Geophysical surveys at the dam and rock quarry sites. Provision has been made for electrical resistivity surveys supplemented by seismic refraction surveys.
- Rotary core drilling will be conducted in the dam foundation footprint area as well as at the rock quarry site.
- Lugeon type water pressure tests will be required in most of the boreholes drilled at the dam site.
- Test pit excavations in the dam basin to investigate embankment fill materials.
- Laboratory testing will be conducted on foundation rock samples, representative quarry material samples and soils for embankment construction and sand for filters / fine concrete aggregate.

The scope of the feasibility level geotechnical investigation at the Boschjeskop Dam site is as follows:

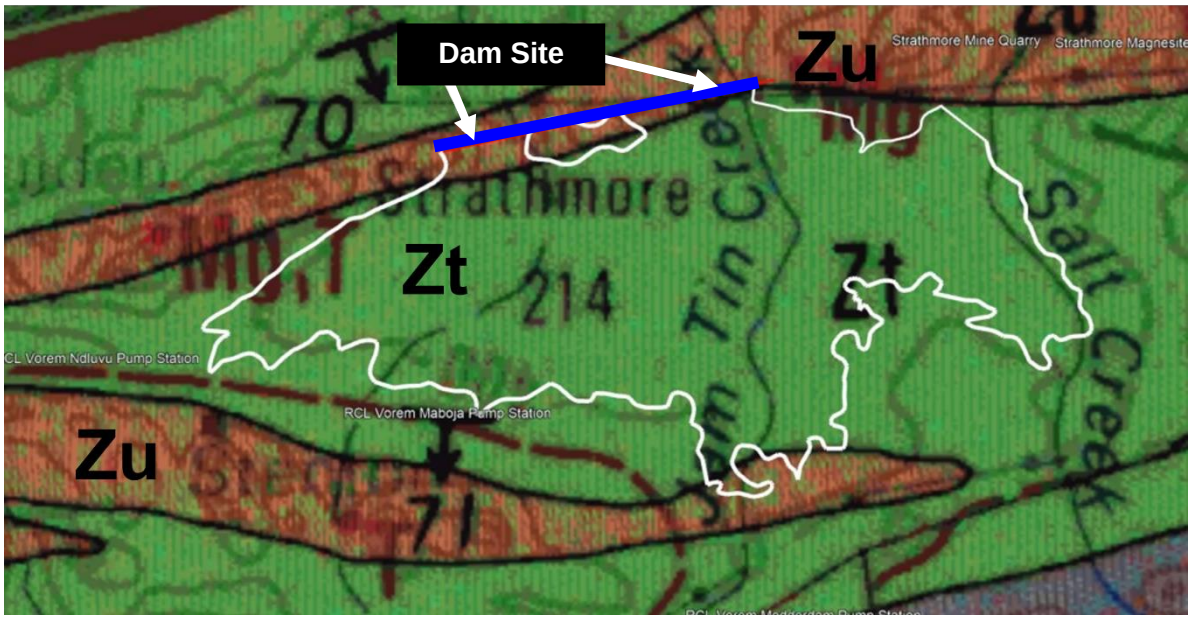
Rotary Core Drilling				
Left Flank	5 x 30 m		150 m	
River Section	4 x 50 m		200 m	
Right Flank	4 x 30 m		120 m	
Rock Quarry	8 x 30 m		240 m	**Total: 710 m**
Geophysical Surveys				
Electrical Resistivity	River Section	2 x 200 m	400 m	
	Left Flank	1 x 600 m	600 m	
	Right Flank	1 x 200 m	200 m	
	Rock Quarry	1 x 300m 4 x 100 m	700 m	**Total 1 900 m**
Seismic Refraction	River Section	2 x 100m	200 m	
	Left Flank	1 x 100 m	100 m	
	Right Flank	1 x 100 m	100 m	**Total 400 m**

Laboratory Testing		
Rock Cores Dam Site	Uniaxial Compressive Strength	8 no
	Deformation Tests	8 no
Rock Cores Quarry	SANS 1083 Rock Sets	3 sets
	Alkali-Silica Reactivity	5 no
	Petrographic Analysis	5 no
River Sand	SANS 1083 Sand Sets	2 sets
Structural Fill	Foundation Indicator	5 no
	Mod AASHTO compaction + CBR	2 no
Borrow Materials	Foundation Indicator	30 no
	Standard Proctor Compaction	10 no
	Triaxial CU	5 no

5 STRATHMORE DAM SITE

5.1 Geology

The Strathmore Dam site is an off-channel storage dam situated on two north-flowing streams, approximately 2,7 km south of the Crocodile River. The eastern stream is referred to as the Jam Tin Creek, while the western (smaller) stream is not named. Two embankment dams will be required in each of these streams to form this off-channel storage facility. The site is situated in a relatively flat-lying area where a localised east-west striking hill range was mainly formed by an undifferentiated group of metamorphosed rocks of the Barberton Supergroup, including komatitite, mafic and ultramafic schists, banded ironstone, and various meta-volcanic rocks. Basic and ultra basic rocks of the Basement Complex form distinct hilly terrain in these ancient rocks. These include serpentinised dunite, harzburgite, gabbro and anorthosite. Magnesite mineralisation is associated with these Basement Complex rocks. The Strathmore Magnesite Mine is situated to the north-east of the dam site, approximately in line with the embankments. The structural geology at the site is complex, but the main structural orientation of the foliation is east-west with a steep dip of 70° towards the south. The regional geology of the dam site is shown in **Figure 5-1**.



Geological Legend:

Zu	Serpentinised dunite, harzburgite, gabbro, anorthosite	Barberton Supergroup
Zt	Komatitite, schist, volcanics	Barberton Supergroup

Figure 5-1: Strathmore Dam Site: Geological Map

The dam site was selected where the east-west striking hill range provides relatively narrow river valleys where the north-flowing drainage features cut perpendicularly across the hill. The geology along the main portion of the hill which underlies most of the dam sites comprises ultra basic rocks of the Basement Complex, while most of the dam basin is underlain by the metamorphosed rocks of the Barberton Supergroup.

The river sections of both streams are densely overgrown by trees and shrubs, with narrow deposits of clayey alluvium present on the riverbanks. Granular alluvium is often present in the active river channel, but no large alluvial deposits were noted.

The entire basin is covered by dark brown to black clayey soils with intensive cultivation of mainly sugar cane.

The climatic N-value as defined by Weinert is considerably less than 5, which implies that chemical weathering is the dominant mode of weathering (Weinert HH,1980). Relatively thick residual soils can therefore be expected with the residual soils partially disintegrated to silty and clayey sand.

5.2 Engineering Geological Evaluation

The Strathmore Dam site was chosen on topographical grounds at a position where an off-channel reservoir can be created by constructing two embankment dams in two north-flowing streams. Water would be pumped from a weir in the Crocodile River. The position of the dam is therefore not considered sensitive from a geological point of view, but the valley shape and topography would rather dictate the dam site position.

The **East Embankment** dam has relatively steep flanks. Both flanks have average slopes of about 1V:3,7H, but the central flat section is 300 m long, which includes the river channel. The exact extent of the river section (channel plus alluvial terraces) is not known due to cultivated lands on the lower left flank. Depth to rock is not known. The entire site is covered by soil, but according to the excavations for the nearby syphon, weathered, highly jointed rock occurs from a depth of about 1 m on the flanks. For the purpose of this investigation, it can be assumed that the core trench depth to groutable rock will on average be 4 m to 5 m.

Excavations for a spillway on the upper right flank will be variable, but allowance should be made at this stage for 3 m to 6 m deep excavations to reasonably unweathered rock. The bedrock is considered to be highly jointed and accordingly pervious. Considering the value of

the (pumped) water, foundation grouting will be required to maximum depth of 50 m in the river section, gradually decreasing to 10 m on the upper flanks.

The **West Embankment** dam has an asymmetrical shape with the left flank relatively flat. The left flank has an average slope of about 1V:8H. The short right flank rises sharply up the steep slope with an average slope of 1V:2,5H. The central flat section is 125 m long, which includes the poorly defined river channel. The exact extent of the river section (channel plus alluvial terraces) is not known due to cultivated lands on the lower left flank and the presence of an existing farm dam just upstream of the site. Depth to rock is not known. The entire site is covered by soil, but according to the excavations nearby, weathered, highly jointed rock occurs from a depth of about 1 m on the flanks. For the purpose of this investigation, it can be assumed that the core trench depth to groutable rock should on average be 3 m to 5 m.

The bedrock is expected to be highly jointed and accordingly pervious. Considering the value of the (pumped) water, foundation grouting will be required to maximum depth of 50 m in the river section, gradually decreasing to 10 m on the upper flanks.

5.3 Dam Basin Stability and Watertightness

The dam basin is situated in a flat-lying terrain without the presence of steep slopes. No basin instabilities will occur.

Existing infrastructure in the basin essentially comprises cultivation, but the following specific infrastructure was identified:

- The eastern embankment intersects an electric high voltage power line.
- Several farm steads, associated structures and localised access roads.

No potential zones of leakage from the basin were identified. The basin is lined with a well-developed layer of clayey hillwash soil, which provides a relatively impervious natural blanket that should ensure relatively watertight conditions.

5.4 Materials Availability

This section deals with the availability of natural construction materials for the construction of the dam and associated infrastructure. The Strathmore reservoir area is characterised by widespread soils. These will vary from fine-grained slightly plastic (hillwash) soils suitable for clay core as well as more granular residual soils with depth for semi-pervious embankment

zones. Based on the uncertainty at this stage regarding the presence of semi-pervious embankment shell materials, a homogeneous embankment should be considered. The following material sources will be required for the construction of the Strathmore Dam:

- Hard rock quarry for the manufacturing of concrete aggregate (coarse and fine) and riprap.
- River sand.
- Embankment construction material.
- Structural fill for platforms and access roads.

No potential rock quarry site was identified in the dam basin or in close proximity to the dam site. The Barberton rock types are generally not considered suitable for the manufacturing of concrete, but certain formations may be suitable for riprap and filter materials provided it meets durability requirements. The prominent hill between the two embankments may be suitable for establishing a rock quarry for riprap subject to long-term durability compliance. Coarse concrete aggregate may have to be sourced from commercial sources, e.g., at Karino.

No large deposits of natural sand for fine concrete aggregate and filters were identified in the basin of the dam. It is anticipated that the bulk of the fine aggregate will be provided from commercial sources.

Large quantities clayey soils are present in the basin of Strathmore Dam site. Potential sources occur throughout the dam site, virtually across the entire basin area. The properties of the soils will have to be determined to ensure that their plasticity is not excessively high.

5.5 Feasibility Level Scope of Geotechnical Investigations

Feasibility level geotechnical investigations at the Strathmore Dam site will involve a combination of the following investigation types:

- Geophysical surveys at the dam and rock quarry sites. Provision has been made for electrical resistivity surveys supplemented by seismic refraction surveys.
- Rotary core drilling will be conducted in the dam foundation footprint area as well as at a potential rock quarry site.
- Lugeon type water pressure tests will be required in most of the boreholes drilled at the dam site.

- Test pit excavations in the dam basin to investigate embankment fill materials.
- Laboratory testing will be conducted on foundation rock samples, representative quarry material samples and soils for embankment construction and sand for filters / fine concrete aggregate.

The scope of the feasibility level geotechnical investigation at the Strathmore Dam site is as follows:

Rotary Core Drilling				
Eastern Embankment	6 x 30 m		180 m	
Western Embankment	5 x 50 m		250 m	
Spillway	6 x 30 m		180 m	
Rock Quarry	8 x 20 m		160 m	**Total: 770 m**
Geophysical Surveys				
Electrical Resistivity	Eastern Embankment	2 x 600 m	1 200 m	
	Western Embankment	2 x 600 m	1 200 m	
	Spillway	2 x 500 m	1 000 m	
	Rock Quarry	3 x 100 m	300 m	**Total 3 700 m**
Seismic Refraction	Eastern Embankment	1 x 500m	500 m	
	Western Embankment	1 x 500 m	500 m	
	Spillway	1 x 500 m	500 m	**Total 1 500 m**
Laboratory Testing				
Rock Cores Dam Site	Uniaxial Compressive Strength		3 no	
	Deformation Tests		3 no	
Rock Cores Quarry	SANS 1083 Rock Sets		2 sets	
	Alkali-Silica Reactivity		1 no	
	Petrographic Analysis		5 no	
River Sand	SANS 1083 Sand Sets		2 sets	
Structural Fill	Foundation Indicator		5 no	
	Mod AASHTO compaction + CBR		2 no	
Borrow Materials	Foundation Indicator		30 no	
	Standard Proctor Compaction		10 no	
	Triaxial CU		5 no	

6 GEOTECHNICAL RANKING OF DAM SITES

Basic geological and geotechnical parameters were used to rank the sites, based on current information. Some of these aspects need to be investigated before its actual effect on the site can be assessed. This ranking is therefore somewhat subjective at this stage but serves the purpose of differentiating between the sites.

Table 6-1: Geotechnical Ranking of Dam Sites

PARAMETER	MONTROSE	MOUNTAIN VIEW	BOSCHJESKOP	STRATHMORE
Geology				
Lithology	3	4	4	2
Structural Geology	3	3	3	3
Dam Site				
Rock outcrop distribution	3	4	2	1
River section conditions	2	3	3	1
Rock mass permeability	3	4	3	1
Basin				
Stability	3	3	4	4
Leakage	4	3	3	3
Materials				
Rock	3	4	1	1
Sand	2	2	2	1
Embankment/Rockfill	1	3	4	3
TOTAL	**27**	**33**	**29**	**20**

Explanation of geological parameter

1: Very Poor
2: Poor
3: Good
4: Very Good

The ranking system shows that Mountain View, Boschjeskop and Montrose dam sites, from a geotechnical/geological point of view, are reasonably similar. Strathmore has a relatively poor ranking based on the aggregated effect of several parameters which are clearly less positive compared to the other sites.

The results from the previous geotechnical investigations, supplemented by the current investigation were deemed sufficient for this pre-feasibility study level and no additional geotechnical investigations are therefore proposed at pre-feasibility level. Once the multi-disciplinary ranking of the sites has been completed and the results accepted by the team, it is proposed to commence immediately with the feasibility level geotechnical investigation of the selected site. This will commence with the finalising of the scope of the work.

7 STUDY REFERENCES

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APPENDICES

Appendix A Site Visit Report

Department of Water and Sanitation

Report No: P WMA 03/000/00/6923/1/1

WP11393

CROCODILE EAST WATER PROJECT (CEWP)

MODULE 1: TECHNICAL FEASIBILITY STUDY

Site Visit Report

June 2023

Final

water & sanitation
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APPROVAL

Project Name:	*Crocodile East Water Project (CEWP)* *Module 1: Technical Feasibility Study*
Report Title:	***Site Visit Report***
Author(s):	*Study Team*
Reviewer	*Lilene Louw & Evert Serfontein*
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Consultant:	*iX engineers, supported by WRP Consulting Engineers & Specialists*
Status of Report:	*FINAL*
First Issue:	*June 2023*
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Approved for the PSP by:

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Deputy Study Leader

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Mr Kobus Bester
Chief Engineer:
Water Resource Development Planning (East)

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Director:
Water Resource Development Planning

Prepared by:

iX engineers
Infrastructure Excellence

DOCUMENT INDEX

This report forms part of the series of reports issued as part of the project Crocodile East Water Project (CEWP) Module 1: Technical Feasibility Study.

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LIST OF ACRONYMS

CEWP	Crocodile East Water Project
CMF	Catchment Management Forum
D: NWRP	(DWS) Directorate: Integrated Water Resource Planning
D: NWRP	(DWS) Directorate: National Water Resource Planning
D: SWRP	(DWS) Directorate: Strategic Water Resource Planning
D: WRDP	(DWS) Directorate: Water Resource Development Planning
DWS	Department of Water and Sanitation
IUCMA	Inkomati Usuthu Catchment Management Agency
LM	Local Municipality
NOC	Non-Overspill Crest
OA	(DWS) Options Analysis
PFS	Pre-Feasibility Study

LIST OF UNITS AND SYMBOLS

km	Kilometre
m	Metres
°	Degrees
’	Minutes
”	Seconds

PREAMBLE

The Department of Water and Sanitation appointed iX engineers (Pty) Ltd for *WP11393: Crocodile East Water Project: Module 1: Technical Feasibility Study.*

The water of the Crocodile (East) River Catchment in Mpumalanga has been fully allocated, yet the water requirements, especially domestic water requirements, continue to grow. The system is under stress, and it cannot fully meet the environmental water requirements as well as the reliability / assurance of supply for both the agricultural and municipal water uses. The yield of the water resource will have to be increased by means of **additional storage**.

Taking cognisance of the above-mentioned and based on previous studies and investigations carried out in the past, the following **four proposed dams** within the **Crocodile (East) River Catchment** were recommended for further study as part of this Study (WP11393: Module 1: Technical Feasibility Study):

- Montrose Dam on the Crocodile East River.
- Mountain View Dam on the Kaap River.
- Boschjeskop Dam on the Nels River.
- Strathmore Off-Channel Storage Dam, near the confluence of the Kaap and Crocodile Rivers.

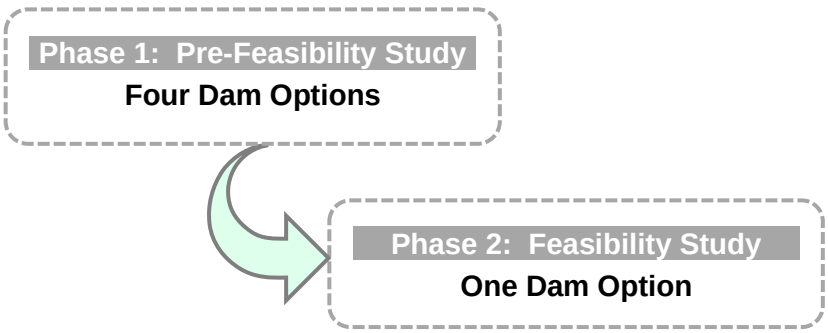
This Technical Feasibility Study will be undertaken in two separate phases, as follows:

Phase 1: Pre-Feasibility Study

The Pre-Feasibility Study (Phase 1) will be undertaken for the above-mentioned **four** proposed dams within the Crocodile (East) River Catchment

Phase 2: Feasibility Study

Under the Phase 1: Pre-Feasibility Study, **one** of the possible four dam options will be selected and recommended for further study and development to a **feasibility level** of detail in the Phase 2: Feasibility Study.



1 INTRODUCTION

1.1 Background to Study

The water of the Crocodile (East) River Catchment in Mpumalanga has been fully allocated, yet the water requirements, especially domestic water requirements, continue to grow. The system is under stress, and it cannot fully meet the environmental water requirements as well as the reliability / assurance of supply for both the agricultural and municipal water uses.

The situation will worsen in the short term if water conservation and water demand management (WC/WDM) measures are not fully implemented. In the medium to long term, WC/WDM measures will not be sufficient to provide for the increase in domestic water requirement. The yield of the water resource will have to be increased by means of **additional storage**.

Both public and commercial sectors have requested development of **additional yield** through **storage** within the **Crocodile (East) River Catchment**. Due to the long lead-time required in developing new dams, the construction of an additional dam in the Crocodile River Catchment has to be investigated without delay.

Taking cognisance of the above-mentioned and based on previous studies and investigations carried out in the past, the following **four proposed dams** within the **Crocodile (East) River Catchment** were recommended for further study as part of this Study (WP11393: Module 1: Technical Feasibility Study):

- Montrose Dam on the Crocodile East River.
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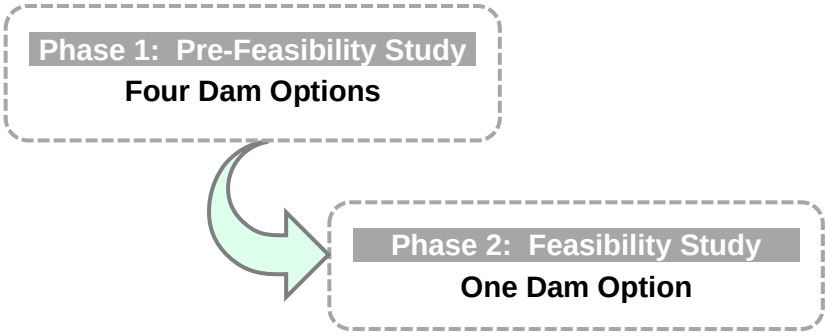

1.2 Study Area

The Crocodile (East) River Catchment in Mpumalanga is located in the north-east of the country and forms part of the larger Inkomati River Basin. The water of the Inkomati River Basin is shared between Mozambique, South Africa and Eswatini. A map of the Study Area is included in **Figure 1-1**.

Engineering investigations and studies for the respective dams and associated infrastructure will **each** have their **specific focus** and **study area** and will also apply to dam access, advanced infrastructure for the dam and the possible relocation of services (roads, rail, etc).

However, with respect to the Water Resources task (water demands, yield analysis, future water balance, the development of short-term stochastic yield reliability curves, updating of the water resources planning model, etc.) of the Study, the study area will cover the **whole** of the **Crocodile (East) River Catchment** (see **Figure 1-1**).

The Crocodile (East) River Catchment comprises of the following four tertiary catchments as indicated in **Figure 1-2**:

- Upper Crocodile Catchment (X21)
- Middle Crocodile Catchment (X22)
- Lower Crocodile Catchment (X24)
- Kaap Catchment (X23)

Important tributaries of the Crocodile River include the following:

- Kaap River
- Elands River
- Nels River
- White Rive

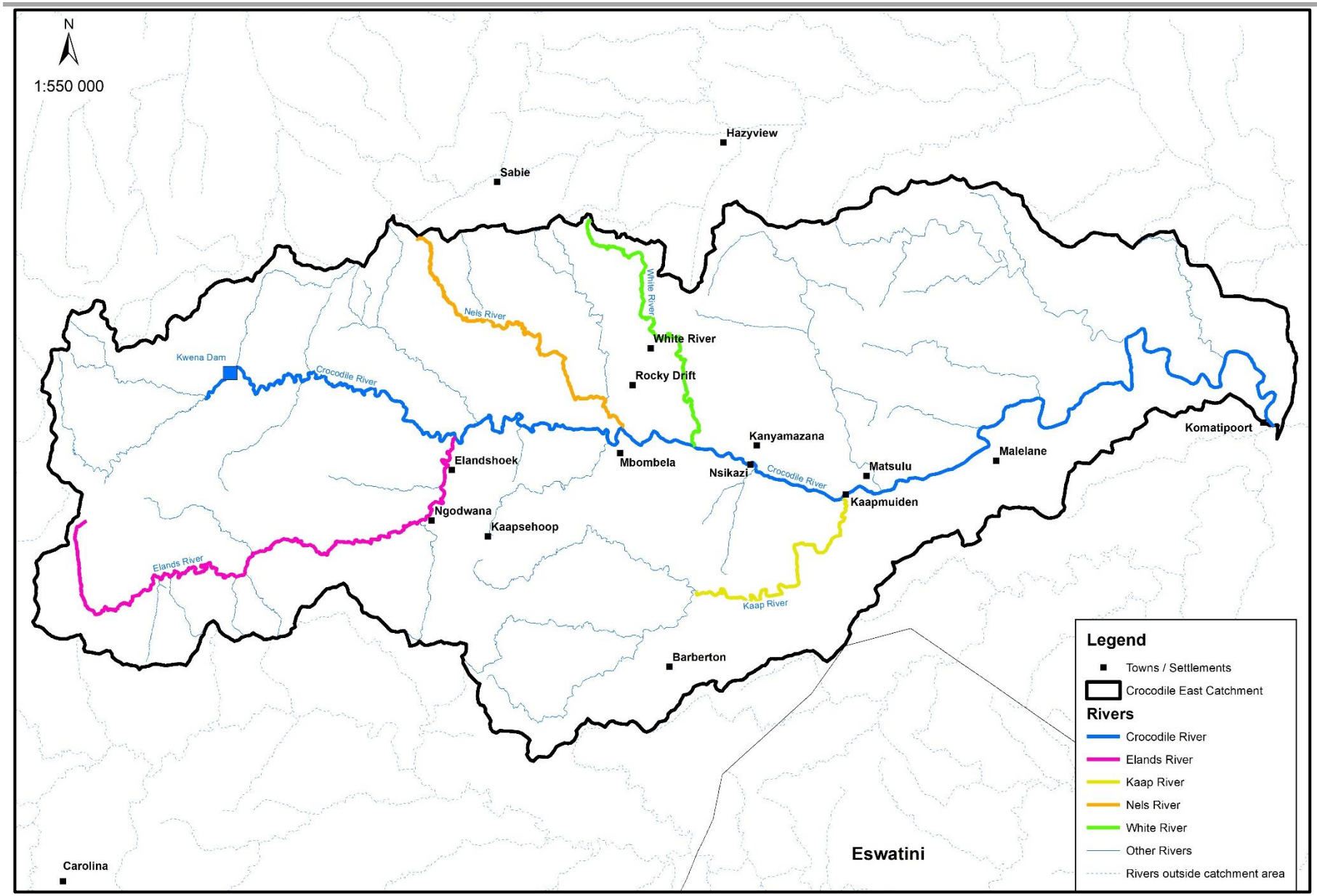

Figure 1-1: Crocodile River Catchment

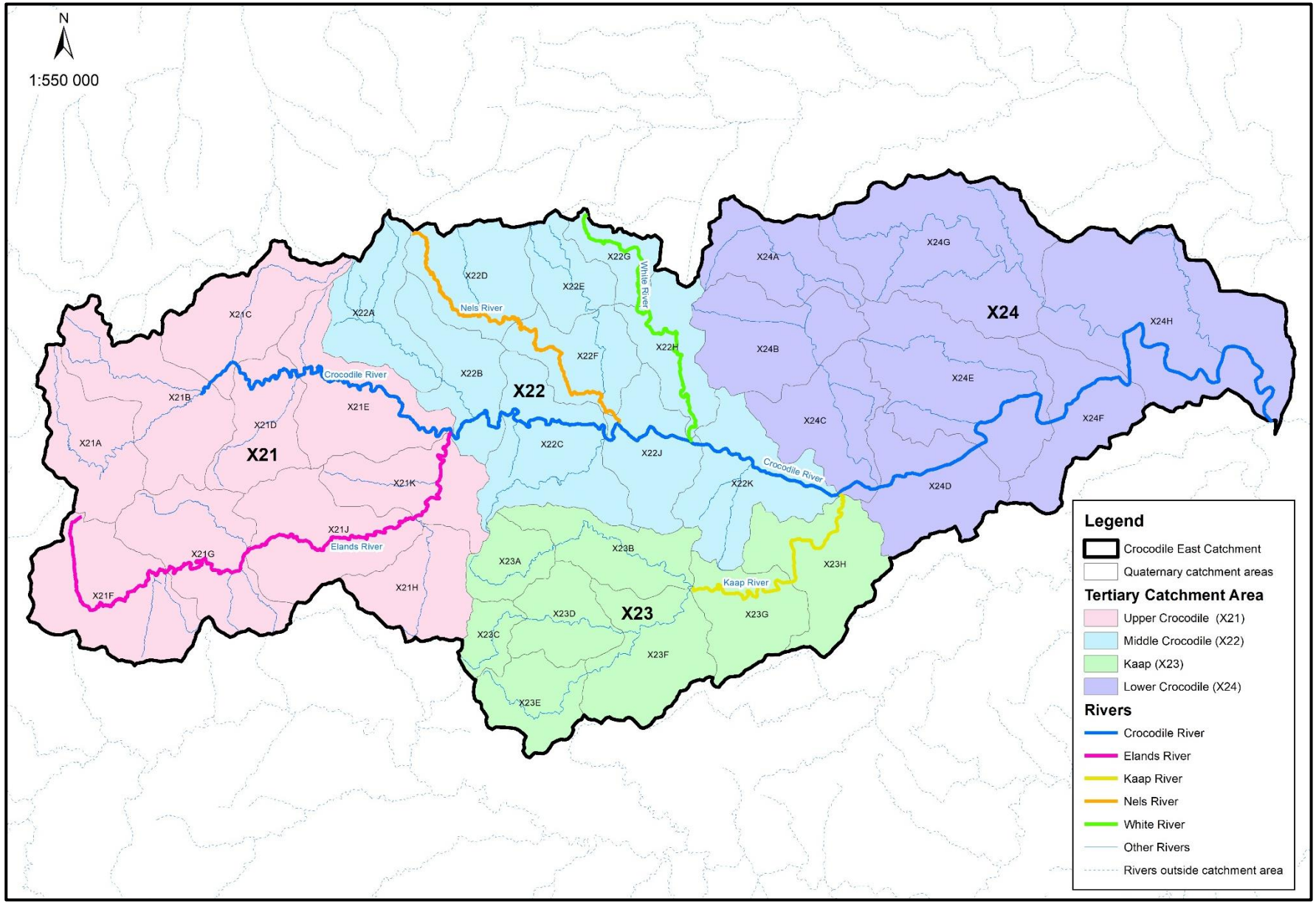

Figure 1-2: Crocodile East River: Tertiary Catchments

The following District and Local Municipalities fall within the Crocodile (East) River Catchment:

- Ehlanzeni District Municipality
  - Bushbuckridge Local Municipality
  - City of Mbombela Local Municipality
  - Nkomazi Local Municipality
  - Thaba Chweu Local Municipality
- Gert Sibande District Municipality
  - Chief Albert Luthuli Local Municipality
- Nkangala District Municipality
  - Emakhazeni Local Municipality

The Crocodile River Catchment is rural in nature, with agriculture being the main economic activity. The high rainfall escarpment catchments of the Upper and Middle Crocodile and Kaap catchments have significant areas of commercial forestry.

The Upper Crocodile Catchment is relatively undeveloped with small domestic and irrigation demands. The Middle Crocodile Catchment has large areas of controlled irrigation and urban demands in the Mbombela LM. The Kaap River Catchment is dominated in the lower eastern part by significant areas of controlled irrigation. Water is transferred into the Kaap River Catchment from the Lomati and Shiyalongubo dams for urban users (Umjindi Local Municipality which was disestablished and merged with Mbombela Local Municipality to establish the City of Mbombela Local Municipality) and agriculture (Louw's Creek Irrigation Board). The Lower Crocodile Catchment has large areas of controlled irrigation and smaller urban/domestic demands for the Nkomazi LM.

The only major dam in the catchment is the Kwena Dam in the Upper Crocodile River Catchment. The dam is approximately 60 km west of Mbombela on the main stem of the Crocodile East River or in the upper reaches of the Crocodile East Catchment. The dam is far from the water demand centers and therefore makes it difficult to regulate and manage water distribution to supply demands as required by the users.

1.3 Proposed Dams

Four proposed dams (listed below) will be investigated during the Pre-Feasibility Phase (Phase 1) of this Study. Only **one** will be selected and recommended for further study in the Feasibility Phase (Phase 2) of the Study. It is, however, possible that the second-best option could be taken forward at a later stage.

- Montrose Dam on the Crocodile East River.
- Mountain View Dam on the Kaap River.
- Boschjeskop Dam on the Nels River.
- Strathmore Off-Channel Storage Dam, near the confluence of the Kaap and Crocodile Rivers.

The regional orientation of the **four proposed dam sites** is indicated in **Figure 1-3**.

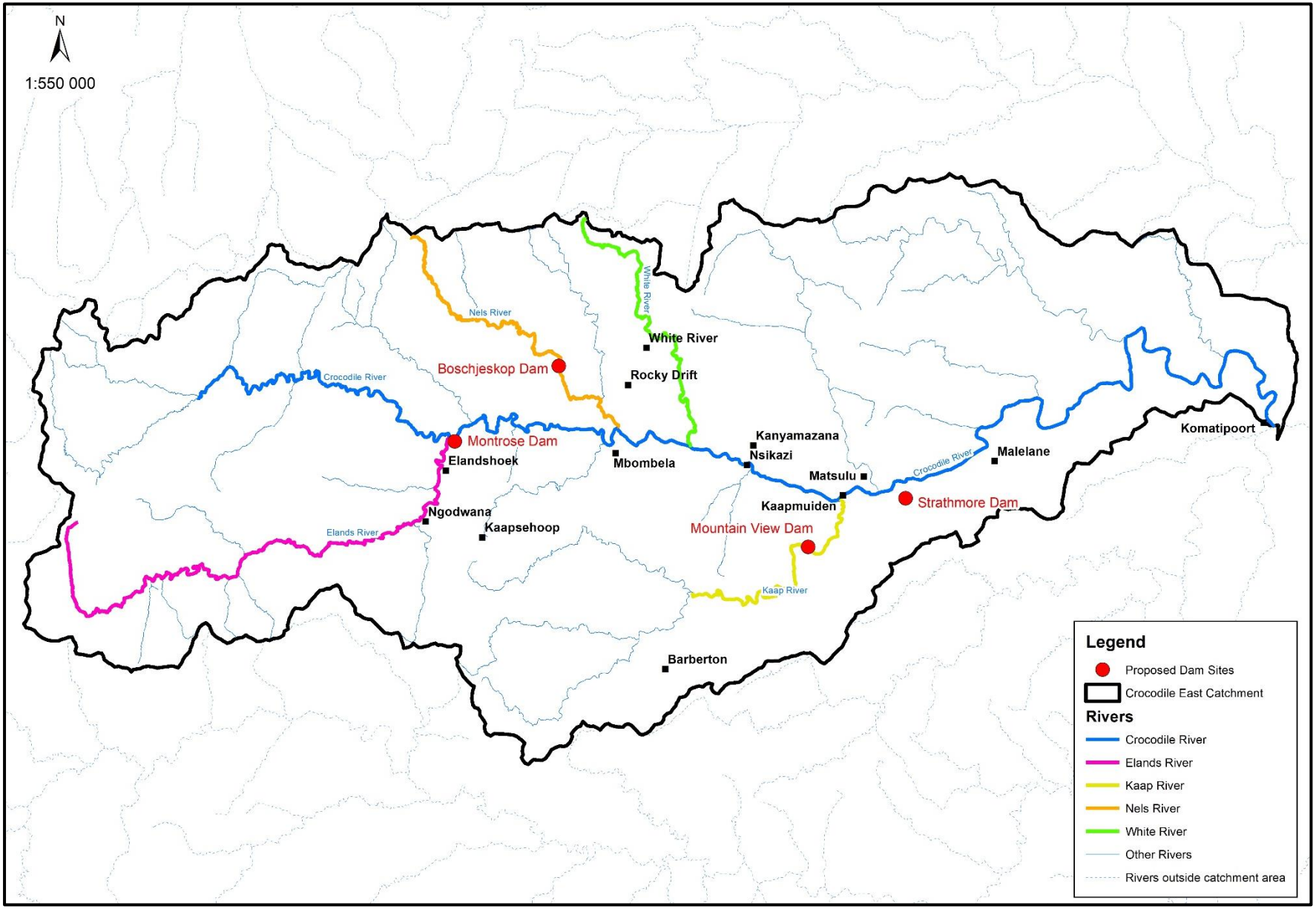

Figure 1-3: Regional Context of Four Proposed Dam Sites

2 OVERVIEW OF SITE VISITS

2.1 Site Visit Itinerary

Site visits of the four proposed dam sites (Montrose, Mountain View, Boschjeskop and Strathmore) were conducted from 1 to 4 November 2022.

Attendees included representatives from the following organisations:

- DWS: Mr Kobus Bester (DWS study manager for the project, D:WRDP), Mr Silo Kheva (DWS, D:WRDP (Mpumalanga)) and other DWS staff that will be involved in the Study or that have an interest in the Study.
- iX engineers' Study Team
- IUCMA (Dr Tendai Sawunyama)
- Irrigation Boards
- Community Trust
- Landowners

Attendance Registers of the site visits of the dam sites are included in **Appendix A**.

The site visits presented an opportunity for the iX engineers' Study Team and others to familiarize themselves with the proposed dam sites and to obtain an overall and preliminary assessment of the sites from an engineering, geological and geotechnical, environmental and social perspective.

Photographs of some of the participants at the various dam sites are included below.


You are entering the
Croc River Conservancy.
This is private property.
Trespassers WILL be prosecuted.
Lena yindzawo lengakavunyelwa
kutsi kungene noma
ngabe ngubani.

An Itinerary for the site visits is included in **Table 2-1**.

Table 2-1: Site Visit Itinerary

Date	Time	Description
1 Nov 2022	**07:00**	**Depart from Pretoria**
	12:45	**Meet at Assembly Point 1:** Google Maps Co-ordinates: -25.42886 30.75477 (refer to map) Google Earth Co-ordinates: 25°25'44.01"S 30°45'16.78"E (see kmz file)
	12:45 - 13:00	Depart and travel as a Group to Montrose Dam site
	13:00 - 17:00	**Montrose Dam Site Visit:** · *Proposed Dam Wall Site and Dam Basin Area*
	±17:00	**Depart and Travel to Mbombela**
		Stay Overnight: Mbombela
2 Nov 2022	07:30	**Meet at Assembly Point 2:** Google Maps Co-ordinates: -25.47349 30.96795 (refer to map) Google Earth Co-ordinates: 25°28'25.38"S 30°58'4.53"E (see kmz file) (Nelspruit Crossing, parking area in front of Woolworths)
	07:30 – 08:30	Depart and travel as a Group to Mountain View Dam site
	08:30 - 17:00	**Mountain View Dam Site Visit:** · *Proposed Dam Wall Site and Dam Basin Area*
	±17:00	**Depart and Travel to Mbombela**
		Stay Overnight: Mbombela
3 Nov 2022	07:30	**Meet at Assembly Point 2:** Google Maps Co-ordinates: -25.47349 30.96795 (refer to map) Google Earth Co-ordinates: 25°28'25.38"S 30°58'4.53"(see kmz file) (Nelspruit Crossing, parking area in front of Woolworths)
	07:30 – 08:00	Depart and travel as a Group to Boschjeskop Dam site
	08:00 – 11:45	**Boschjeskop Dam Site Visit:** · *Proposed Dam Wall Site and Dam Basin Area*
	11:45 - 13:00	Depart and travel as a Group to Strathmore Dam site
	13:00 – 13:30	*Meet with Mr Mosa Chirwa the Chairperson of the Libuyile Community Trust. Mr Chirwa will travel with the team to meet the Chief – TL Dlamini. After the visit to the Chief, the team will be able to visit the land*.
	13:30 - 17:30	**Strathmore Dam Site Visit:** · *Proposed Dam Wall Site and Dam Basin Area*
	±17:30	**Depart and Travel to Mbombela**
		Stay Overnight: Mbombela

Date	Time	Description
4 Nov 2022	**07:30**	**Depart from Mbombela**
	11:30	**Arrive at Pretoria**
		Some of the Team Members may want to stay behind to visit some areas upstream or downstream of these proposed sites again, but not alone.

2.2 Brief Overview of Site Visits

The following sections provide a brief overview of the site visits undertaken to the respective dam sites.

2.2.1 Montrose Dam Site

The Montrose Dam site was visited on 1 November 2022.

The proposed dam is located in the Crocodile River some 2 km downstream of the confluence of the Elands and Crocodile rivers.

The approximate site co-ordinates of the proposed Montrose Dam (see **Figure 2-1**) are: Latitude 25°27'17" and Longitude 30°43'34".

Access was gained to the right flank via the Rivulets gravel road which eventually follows the railway track in a southern direction. The site is situated on the Crocodile River. It was accessed from the right flank on the farm of Loraine Dickens.

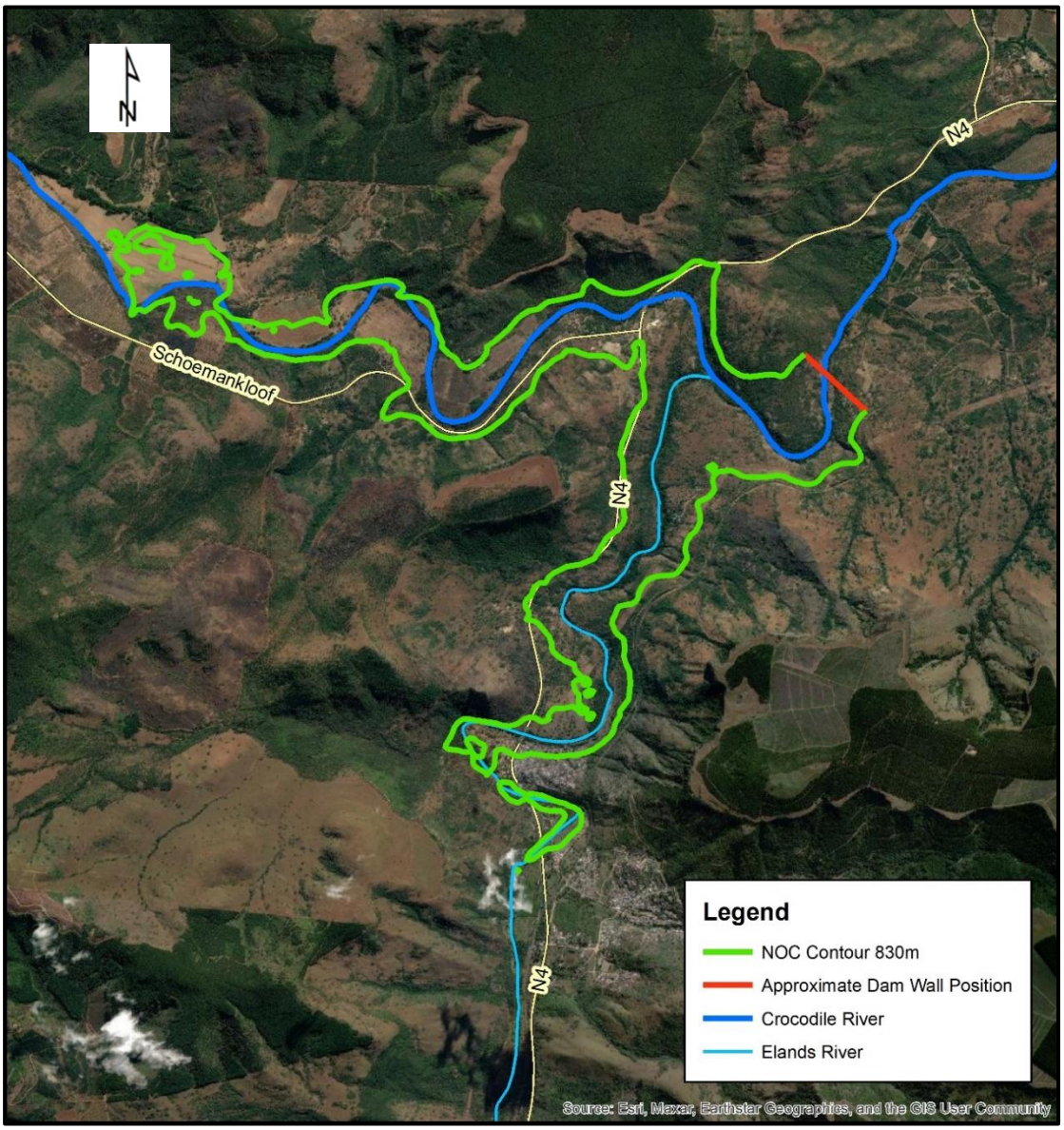

Figure 2-1: Montrose Dam Site

The dam site has an asymmetrical shape with the right flank significantly flatter than the left flank. Whilst vehicle access is possible from the right flank, the left flank access is difficult without any paths or tracks noticeable. It will be difficult to establish drilling equipment on the steep left flank. Widespread granite rock outcrops were however observed on the left flank.

The right flank has scattered granite rock outcrops and the rock weathering profile is clearly very irregular. The river section comprises a wide (approximately 50 m) alluvial terrace on the right bank with no rock outcrops visible in the river channel and rest of the river section.

Engineering geological investigations at Montrose will have to comprise a combination of geophysical surveys (electric resistivity on the flanks and seismic refraction in the river section) before drilling be commenced. The main objective of the geophysical surveys would be to identify the best location for a dam site in terms of founding. Potentially suitable area for a rock quarry was identified on the right flank approximately 600 m downstream of the Elands River confluence.

2.2.2 Mountain View Dam Site

The Mountain View Dam site was visited on 2 November 2022.

The Mountain View Dam site is situated on the Kaap River approximately 10 km south-west of Kaapmuiden and near the end of a steeply sided valley on the Kaap River (±)10 km upstream of the confluence with the Crocodile River.

The approximate site co-ordinates of the proposed Mountain View Dam (see **Figure 2-2**) are: Latitude 25°36'45" and Longitude 31°16'15".

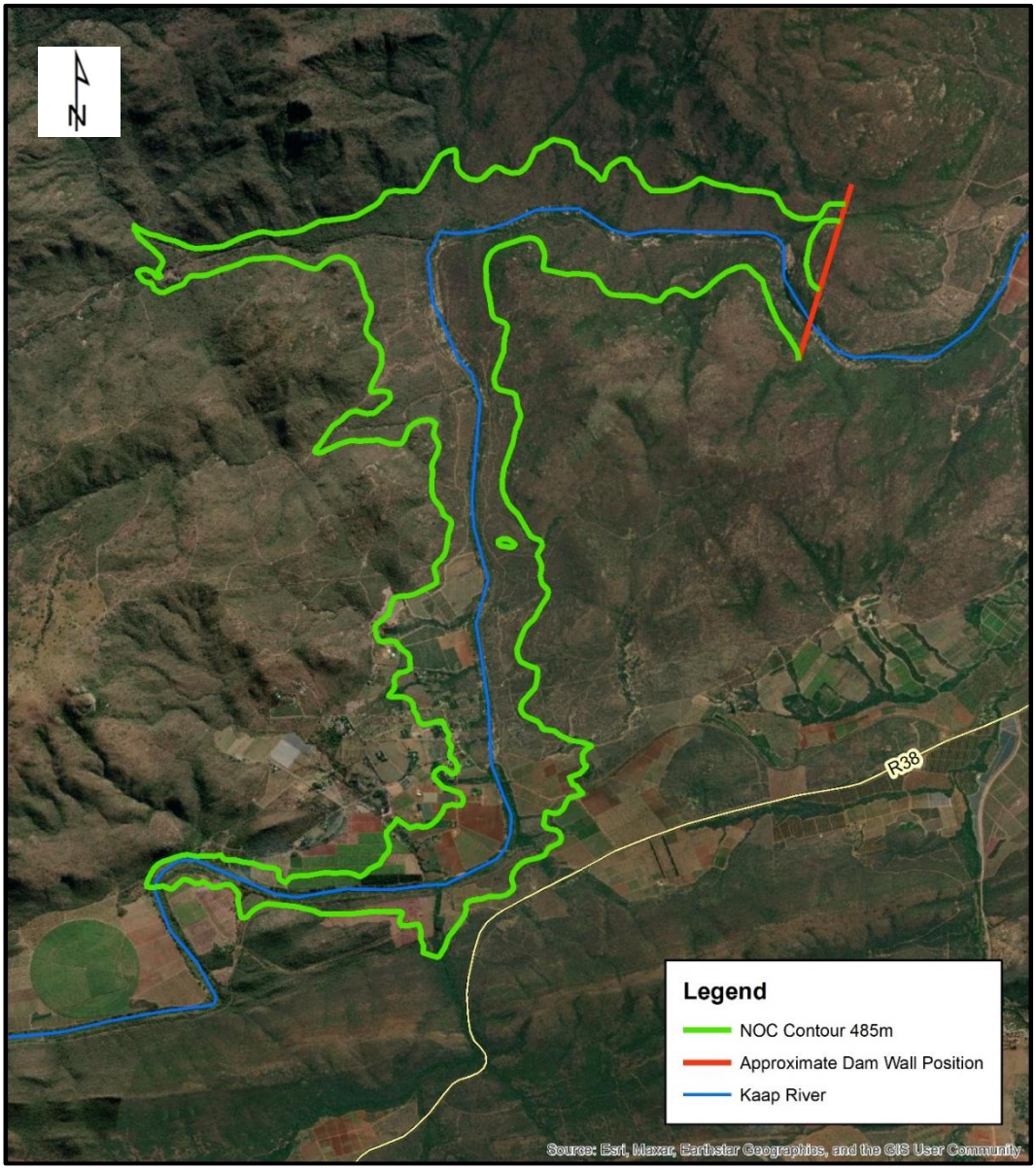

Figure 2-2: Mountain View Dam Site

Access was gained via the Esperado Road which turns off from the R38 Road to Barberton approximately 9.3 km from the N4. Access could be gained using a farm track that leads to the canal offtake on the left river bank, approximately 170 m below the small existing weir. Access to the upper left was possible by means of an existing track that was constructed as part of the exploration drilling programme in the nineteen seventies. The track extends all the way to the saddle on the upper left flank. Access to the upper left flank is reasonably easy, but the majority of the flank is steep and rugged with limited access for drilling equipment. It was confirmed during the site visit that the presence of the saddle is associated with a set of east-west striking dolerite dykes, possibly associated with faulting.

Water in the weir dams up within the river channel section for a distance of about 640 m where a very prominent granite rock outcrop forms an impressive continuous rock outcrop in the river section of approximately 250 m x 90 m, at the upstream end of the prominent gorge. Due to the presence of the weir and widespread water upstream of it, access for geophysical surveys and drilling operations is deemed very difficult.

The right flank is very steep and characterised by virtually continuous rock outcrops, giving rise to near-vertical rock cliff faces in places. The closest existing farm track to the upper parts of the right flank is more than 1 km. The right flank is not accessible for geophysical surveys except at the upper portions. The same goes for drilling.

Widespread rock in the dam basin offers several rock quarry site opportunities, particularly on the right flank.

The reservoir area contains steep valley slope of more than 1V:2H in places and reservoir slope stability will have to be investigated as part of the feasibility level studies.

2.2.3 Boschjeskop Dam Site

The Boschjeskop Dam site took place on 3 November 2022.

The proposed dam site is located 16 km to the north-west of Mbombela.

The approximate site co-ordinates of the proposed Boschjeskop Dam (see **Figure 2-3**) are: Latitude 25°21'07" and Longitude 30°52'21".

Access to the site is relatively easy via a secondary gravel road that turns off from the R37 heading northwards from Mbombela to Sabie.

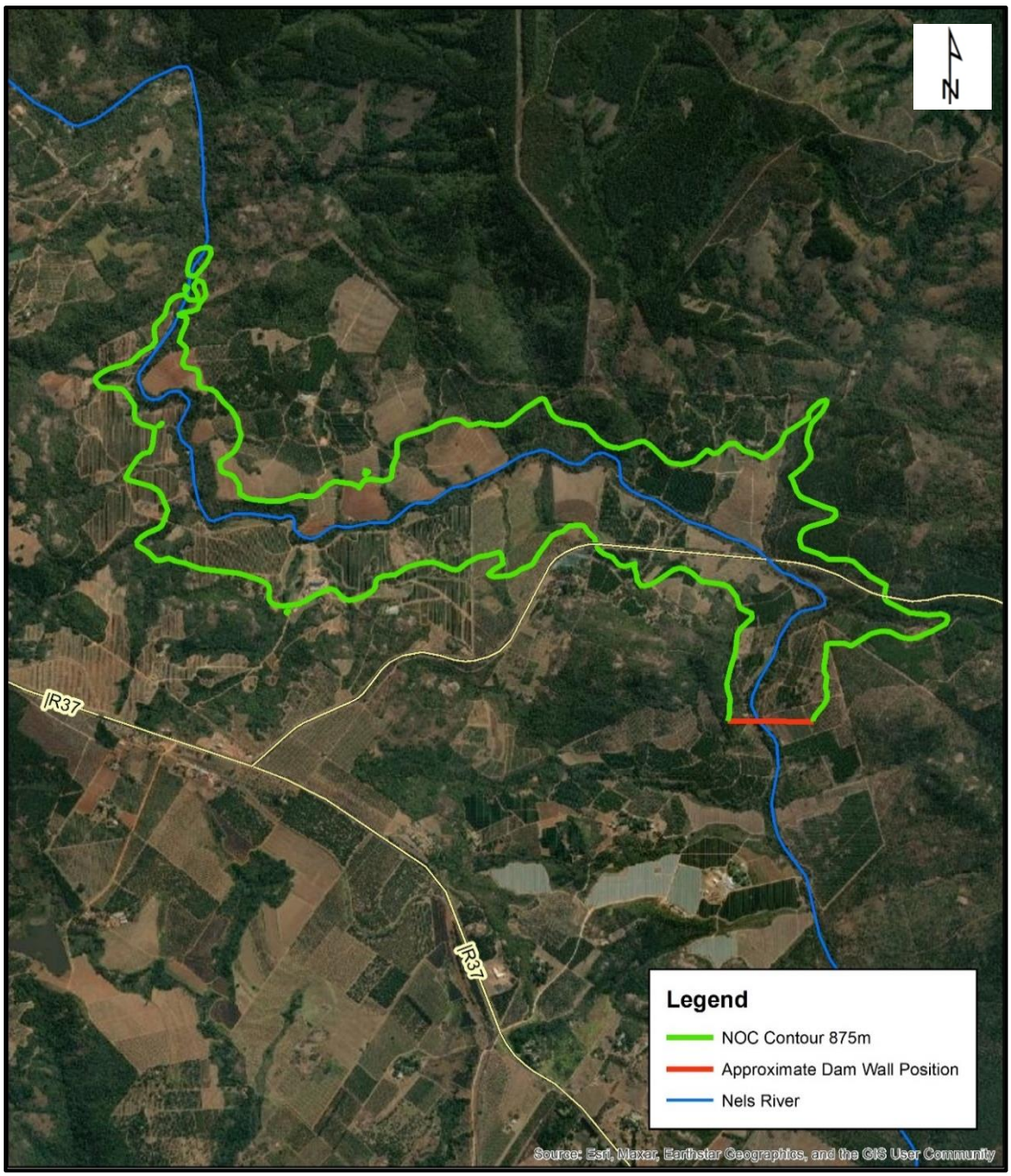

Figure 2-3: Boschjeskop Dam Site

The site has an asymmetrical shape with a steeper right flank that is covered by scattered granite gneiss outcrop. A distinct north-south striking shear zone intersects the upper right flank. This feature is easily recognised by widespread pegmatite and vein quartz which also form somewhat of a ridge.

The river section is densely vegetated mostly by large indigenous trees, but contains scattered prominent granite gneiss rock outcrops. Irregular rock profile is expected in the river section although mostly shallow rock.

The flat left flank is covered by a well-developed clayey sand surface layer (hillwash) underlain by deeply weathered granite.

Access to the entire site is good. Extensive use of geophysical surveys will be required to delineate the concrete spillway option. Earth embankment wall will be required for the flat right flank. The hillwash and residual granitic soils has a large distribution in the dam basin which should be well suited for embankment construction.

2.2.4 Strathmore Dam Site

The proposed dam site is located on the southern side of the N4 national highway halfway between Kaapmuiden and Malelane. The dam is to be constructed in a range of hills aligned more-or-less east-west and parallel to the N4 highway. The dam will require at least two separate dam walls.

The approximate site co-ordinates of the proposed Strathmore Off-Channel Dam (see **Figure 2-4**) are :

Latitude 25°36'45" and Longitude 31°16'15".

The approximate site co-ordinates of the second wall are:
Latitude 25°32'07" and Longitude 31°25'31".

Access to the site is easy via farm access road from the N4 road which occurs approximately 1.5 km north of the dam site.

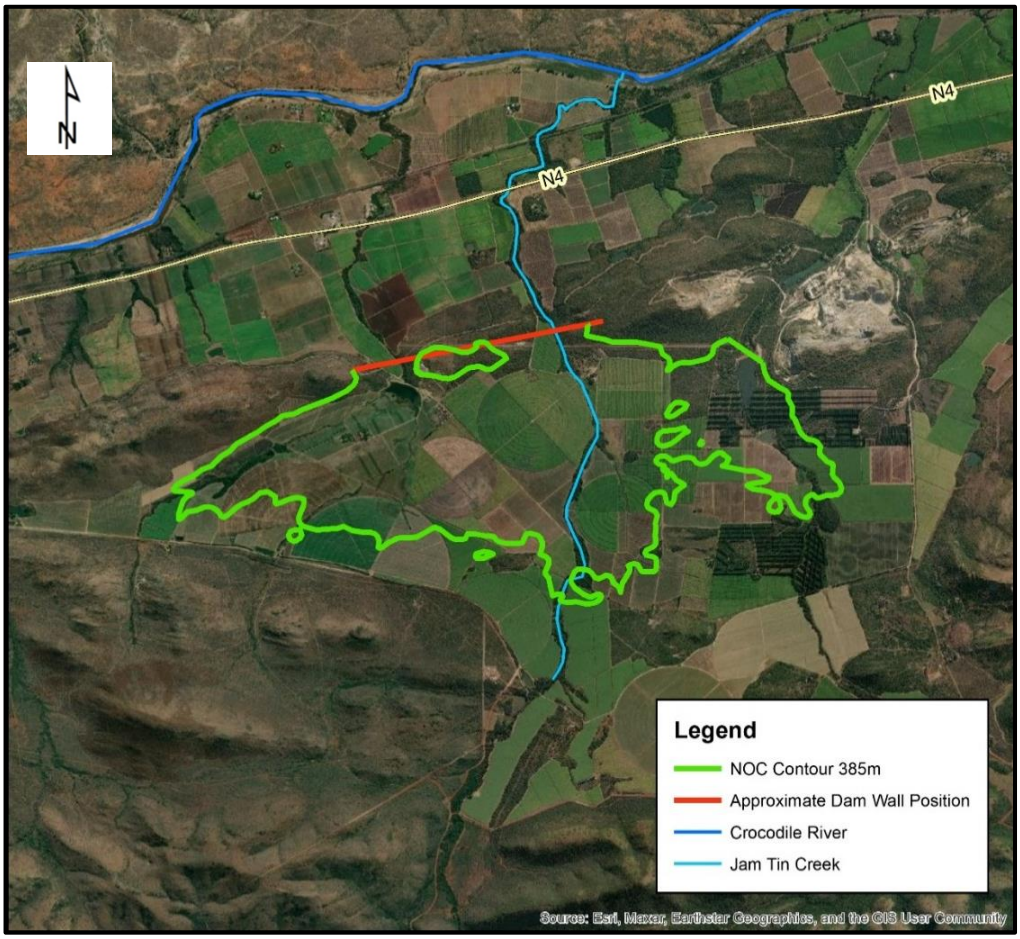

Figure 2-4: Strathmore Off-Channel Dam Site

Strathmore Dam Site is an off-channel dam straddling two north-flowing streams. These are separated by a low hill which forms part of a distinct almost east-west striking low hill range that is associated with the ancient so-called green belt rocks of the Swazian Group. These comprise highly metamorphosed rocks such as amphibolite and schist. A third stream flows northwards along the far eastern portion of the reservoir (Salt Creek) which will also require a saddle dam pending the reservoir level.

The entire reservoir area is under cultivation, mostly sugar cane.

The dam sites positions are not well defined and generally lack distinct rock outcrop, although some areas of shallow rock are expected. The rock mass is generally closely jointed and possibly highly pervious. Extensive foundation grouting is foreseen to render relatively impervious foundations.

A large magnesite mine is situated to the north-east of the dam. The presence of the old mining pits/mine concession area will limit the reservoir level. The possible leakage of reservoir water into the mine pit will have to be assessed.

Geotechnical foundations for this dam site will require geophysical surveys combined with rotary cored drilling particularly to determine rock mass permeability and grouting requirements. The presence of the nearby active mine will require further investigations of the extent and depths of the mine pits, mining lease boundaries and future mine extension planning. Large reserves of clayey soils are present in the basin for embankment construction.

Two of the dam sites may be affected by existing syphons and canal system.

APPENDICES

Appendix A Site Visit Attendance Registers

ATTENDANCE AND DISTRIBUTION LIST

SITE VISIT : MONTROSE DAM SITE

DATE : 1 NOVEMBER 2022

Name	Representing	Contact Details	Signature
E van As	Poplar Creek Farm	082-881 0592	
D van Rensburg	Poplar Creek farm	083 680 1023	
Silo Khewa	DWS	0663024058	
Bernard Chirwa	DWS	080 95 64 65 96	
GEDION SIZIBA	DWS	0656931826	
[illegible]	[illegible]	078 455 5286	
[illegible]	DWS	012 336 7670	
[illegible]	DWS	012 336 8160	
T. Mbili	DWS	012 336 8231	
S. Mamba	DWS	063 697 4588	
E Serfontein	iX	082 495 4815	
Lilene Louw	iX engineers	083 227 1692	
Kobus Beeter	DWS		

ATTENDANCE AND DISTRIBUTION LIST

SITE VISIT : BOSCHJESKOP DAM SITE

DATE : 3 NOVEMBER 2022

Name	Representing	Contact Details	Signature
J. PRETORIUS	Mooimaak	0835078997	
LP Marais	Nelspruit	083 264 5455	
JS Marais	"	0839408107	
Tolway Hopkins	IX Engineers	0828082693	
GEDION SIZIBA	DWS	0636931826	
Sakhile Mamba	DWS	0636974388	
Norman Chaka	SAFCOL	0788035410	
Bernard Chirenda	DWS	060 560 6960	
Thandekile Mbili	DWS	0781359140	
Khuthalo Tshindi	DWS	012 336 8160	
Kennedy Mandaga	DWS	012 336 7670	
OSCAR Martin	IX	082 585 8376	
Gawie Steyn	IX	0825658375	
Henriette Andersen	IX	0828074375	
J. WOLMARANS	DUNORA	0825576194	
AUD BERGH	SAPPI KRAFTEN SAWMILLS	0834008507	
J. Nesserman	Muell estates	0825423952	
A van Wyk	SAFCOL	078 8010487	
J. BARNARD	HIGHLAND NIGHT (FARMER)	0829457563	
E Serfontein	IX	082 495 4815	
Lilene Louw	iX engineers	083 227 1692	
Kobus Bester	DWS		

ATTENDANCE AND DISTRIBUTION LIST

SITE VISIT : MOUNTAIN VIEW DAM SITE

DATE : 2 NOVEMBER 2022

Name	Representing	Contact Details	Signature
DAWIE VAN SCHALKWYK	JINDILLI FARMS	066 680 9175 / 073 168 2780	
Johan St Leusburg	F J Botha Trust	0694043861 / 0825323156	
James van Merwe	Lake Kamo Irr. Board.	0825799020	
Marié le Roux	Kaapriver Majors	072 916 9256	
Stefan Lamprecht	Masfyn	slamprecht@masnya.co.za 0637073016	
SIPHO MASHINGA	LUCMA	072 810 5928	
Tolmay Hopkins	iX	0828082698	
David Morton	iX	0825658376	
Gavin Steyn	iX	0825658375	
Ewart Serfontein	iX	0824354815	
Charles Venter	Klipriversberg	0828781060	
Tendai Sawunyama	LUCMA	0826093043	
Silo Khoza	DWS	0663024058	
Bernard Chisendo	DWS	060 564 3696	
Tennocky Mandiya	DWS	082 005 9644	
Daniel Venter	Chairman Kaap River	0836797536	
Matthews Phoma	Morgenpoort	0825534065	
C Beale	"	0837058194	FJI
D.J. Bosman	OWNER	082 455 1752	
Thandekile Mbili	DWS	0731359140	
Vhutshilo Tshivhidzo	DWS	0123368160	
Eserfontein	iX	0824954815	
Lilone Louw	iX engineers	083 227 1692	
Kobus Bester	DWS		

ATTENDANCE AND DISTRIBUTION LIST

SITE VISIT : STRATHMORE DAM SITE

DATE : 3 NOVEMBER 2022

Name	Representing	Contact Details	Signature
R. Radley	Radley Landgoed	082 388 3643	
O. Mouton	IX	0825658578	
H ANDERSON	IX	0828074335	
MM CHIRWA	LIBERTY CC CONS	0721127870	
GEDION SZIBA	DWS	0636931826	
Benard Chirende	DWS	060 360 5696	
Kennedy Mundye	DWS	0823367670	
Tumay Hoffmann	IX	0828082693	
E Serfontein	IX	0824954815	
J.M MYAMBI	LIBERTY CONSULT	0824539244	
S.B Mamba	DWS	0636974388	
T. Mbili	DWS	0731359140	
Shiondi N	DWS	0711433 1785	
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E Serfontein	IX	0824954815	
Lilene Law	IX engineers	083 227 1692	
Kobus Bester	DWS		