P WMA 12/T30/00/5212/9

water & sanitation

Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

DIRECTORATE: OPTIONS ANALYSIS

FEASIBILITY STUDY FOR THE MZIMVUBU WATER PROJECT

IRRIGATION DEVELOPMENT

OCTOBER 2014

FEASIBILITY STUDY FOR THE MZIMVUBU WATER PROJECT APPROVAL

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Authors:	*Sub-Consultants: MBB Consulting Engineers (PMB), Oscar Ashton* *Final Review: A Pepperell and Simon Johnson*
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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*

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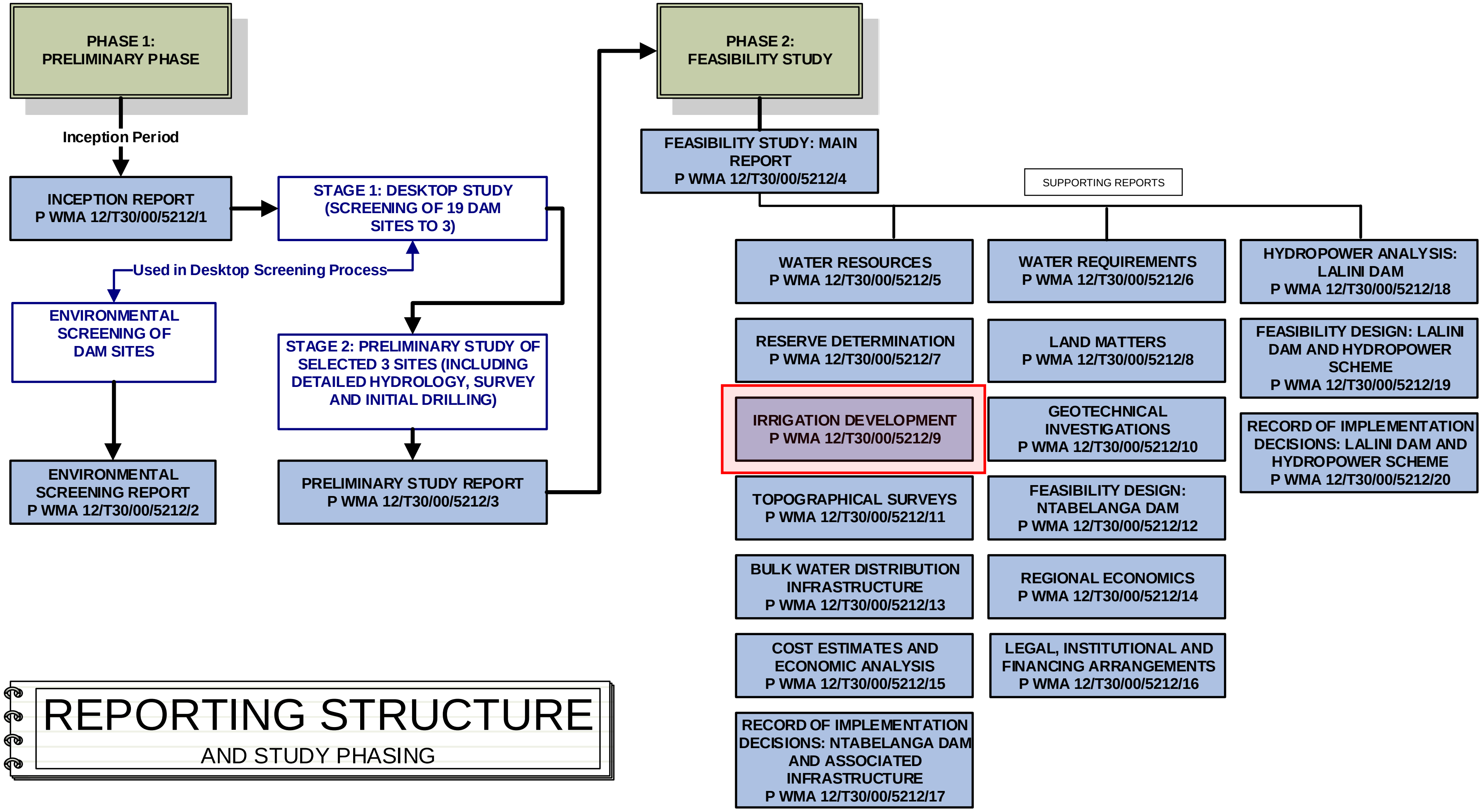
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AND STUDY PHASING

REFERENCE

This report is to be referred to in bibliographies as:

Department of Water and Sanitation, South Africa (2014). ***Feasibility Study for the Mzimvubu Water Project: Irrigation Development***

DWS Report No: P WMA 12/T30/00/5212/9

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 Province 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:

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

As a result of this the Department of Water and Sanitation (DWS) 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 was completed by October 2014 in three stages as follows:

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

The purpose of this study was 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.

Report numbers P WMA 12/T30/00/5212/2 to 20 describe the feasibility study processes undertaken to select a preferred dam site that would be developed to meet the development goals and social benefits described above.

PURPOSE OF REPORT

The purpose of this report is to present the findings of studies undertaken to investigate the irrigation development potential and associated infrastructure requirements of the preferred dam site as determined under the feasibility study.

IDENTIFICATION OF HIGH IRRIGATION POTENTIAL LANDS

Following a screening and ranking process undertaken in Phase 1, the three dam sites selected for further consideration and study were Somabadi, Thabeng, and Ntabelanga. This process is described in detail in the Preliminary Study Report No. P WMA 12/T30/00/5212/3.

An initial desktop GIS exercise was carried out to identify high potential irrigable soils according to certain criteria, for purposes of comparison of these dam sites.

The criteria were:

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

A field verification exercise was carried out and the verified land areas meeting these criteria were 504 ha for Ntabelanga Dam, and 1 062 ha for each of Thabeng and Somabadi dams.

The three dams were compared using the above data as well as several other selection criteria, and Ntabelanga Dam emerged as the top ranked dam, when all factors were taken into account. This was the dam selected at the end of Phase 1 of the study for further investigation.

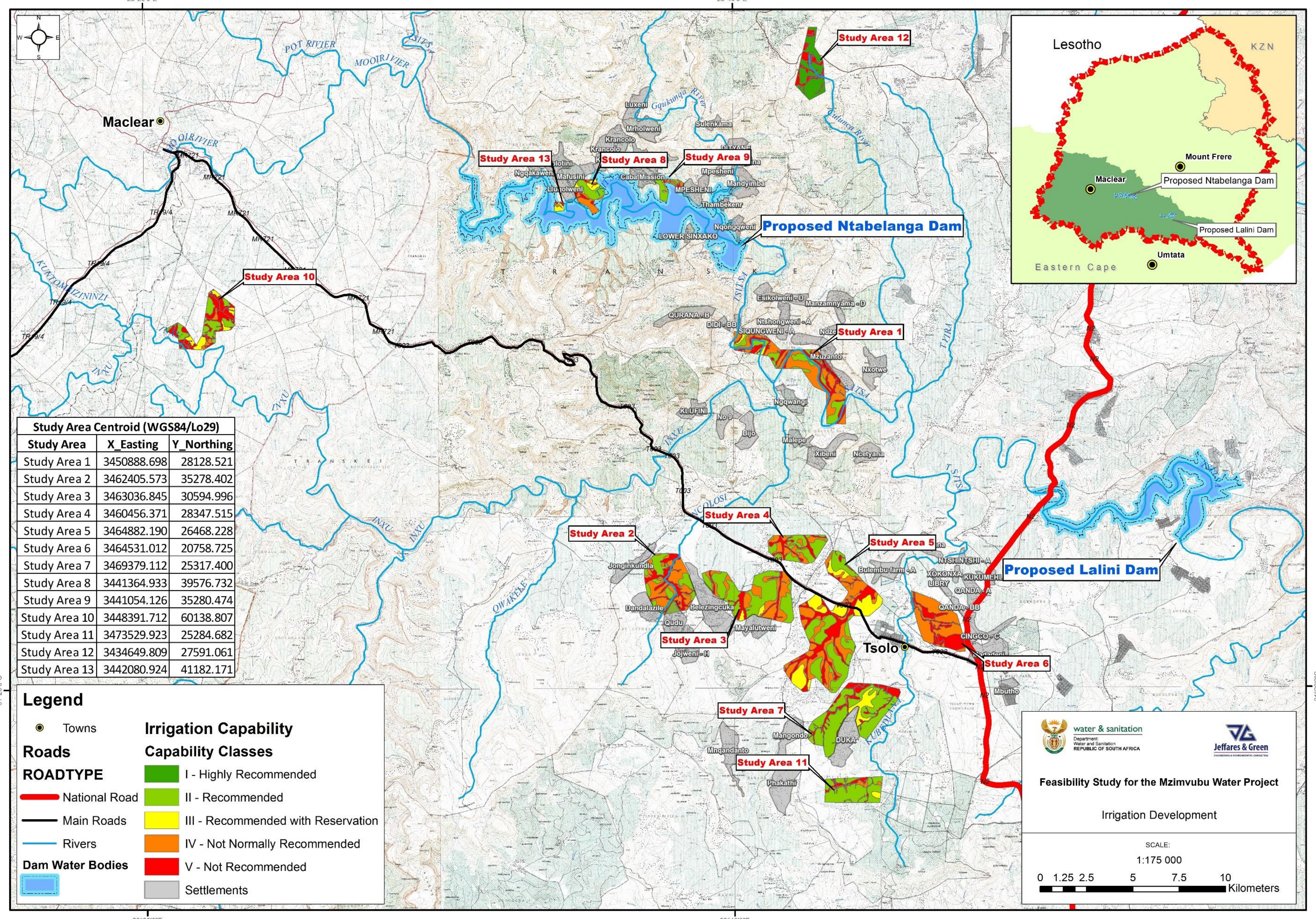
In Phase 2 of the study, the focus was on the area to be supplied with water by the Ntabelanga Dam, and in this case the economic criteria of distance from the water source and elevation above the water source were adjusted in the GIS analysis, to cast the net wider and to find more potentially suitable agricultural land for irrigation. This relaxation of criteria took into account the social upliftment purpose of the project and was implemented to widen the area and the number of people that could benefit from the scheme.

Further analysis and fieldwork was undertaken, and 7 708 ha of high potential soils were identified in the Ntabelanga supply area, as modified for existing land use. Much of the land was situated around the town of Tsolo to the south east of the dam. This more detailed field verification exercise was carried out as described in Appendix A, following which 3 675 ha of suitable irrigable lands were confirmed.

A critical review of where these lands lay relative to the dam, and forming contiguous soils bodies together resulted in a final estimate of 2 868 ha of irrigable land which could be supplied with water from the Ntabelanga Dam. This involved an extensive soils augering and testing exercise to determine the soil profiles, types and locations of these higher potential irrigable land areas.

These high potential areas are shown in Figure 1.

Two remote "outlier" areas 10 and 12 were noted. Area 10 is far from the proposed raw water source and has a low proportion of the higher soil classes. Area 12 has a significant area of high class soils but is at a straight line distance of 12 km, and at an elevation some 440 m above the raw water pumping station. The terrain between the pump station and area 12 is particularly mountainous and highly problematical for pipeline construction. An intermediate booster pumping station would also be required. This area is not consider viable with regard to being supplied with water from the Ntabelanga Dam.



Study Area Centroid (WGS84/Lo29)		
Study Area	X_Easting	Y_Northing
Study Area 1	3450888.698	28128.521
Study Area 2	3462405.573	35278.402
Study Area 3	3463036.845	30594.996
Study Area 4	3460456.371	28347.515
Study Area 5	3464882.190	26468.228
Study Area 6	3464531.012	20758.725
Study Area 7	3469379.112	25317.400
Study Area 8	3441364.933	39576.732
Study Area 9	3441054.126	35280.474
Study Area 10	3448391.712	60138.807
Study Area 11	3473529.923	25284.682
Study Area 12	3434649.809	27591.061
Study Area 13	3442080.924	41182.171

Figure 1: Land Identified as Having High Irrigation Potential

Areas 1, 8, 9 and 13 are close enough to the dam and river, and could be irrigated directly from source using local "quick-fit" abstraction and distribution infrastructure.

Most of the high potential farming units are located in and around the urbanised centre of Tsolo, at a distance of some 17 km away from the Tsita River, and at an elevation between 130 and 220 m above the river level at that nearest point.

This means that raw water supply to the lands in the Tsolo area would need to be conveyed via pipeline and pumped from the source, which will have significant operation, maintenance and energy cost implications.

This is analysed in detail in the Bulk Water Distribution Infrastructure Report No. P WMA 12/T30/00/5212/13, and the Cost Estimates and Economic Analysis Report No. P WMA 12/T30/00/5212/15.

AGRICULTURAL WATER REQUIREMENTS

The climate of the Tsolo area is characterised by mean daily maximum temperature of 22°C, a mean minimum temperature of 9°C, and a mean temperature of 16°C. Mean annual precipitation is 780 mm, total annual evapotranspiration is 1659 mm and mean humidity 65%. Frost does occur and occasional snow on the higher lying areas cannot be ruled out. Crops tolerant of a cool climate must be considered.

A list of crops suited to the climate is presented in the body of the report, together with expected yields per crop.

For a mixed enterprise farming operation, a range of crops could be planted on the selected potential farming units. A typical irrigation water use was determined for a typical planting scenario. This is 619 mm/a. An upper limit of irrigation demand was also determined by considering a reference crop with a crop factor of 1 planted year round. The upper limit is 1 141 mm/a for this reference crop.

High potential irrigable soils of up to 2 868 ha have been identified, of which 2 451 ha is located in the areas adjacent to Tsolo, and the remaining 417 ha are located on the north shore of the future impoundment basin of the Ntabelanga Dam, and close to the Tsitsa River channel downstream and close to the Ntabelanga Dam itself.

*For a total irrigated area of 2 868 ha, the water demand from the dam would be a maximum of 32.7 million m^3/a (i.e. using the application rate of 1 141 mm/a). For the purposes of determining the average raw water requirements on the Ntabelanga Dam for irrigation purposes, an average application rate of 880 mm/a was applied to the above irrigable areas, which, including an allowance of 10% for losses, gave an annual average irrigation raw water requirement of **27.8 million m^3/a**.*

BULK WATER SUPPLY

The irrigable areas that have been identified (Figure 1) adjacent to the water bodies (i.e. study Areas 1, 8, 9 and 13) can be supplied using portable abstraction pumps, and quick-coupling pipeline distribution and irrigation systems.

The other high potential irrigation areas located around Tsolo are of substantial area for which a bulk water supply could be justified. These land areas are, however, situated at elevations of between 140 m and 220 m above the Tsitsa River elevation, and between 17 and 32 km from the nearest point of the Tsitsa River, and the Ntabelanga Dam, respectively. This would therefore require significant pumping and conveyance systems to deliver raw water in bulk to these lands.

Applying an average irrigation application rate of 880 mm/yr, and a peak of 1 141 mm/yr, to these Tsolo irrigation areas totalling 2 451 ha, and allowing for up to 20 hours per day pumping to eliminate peak period energy usage, this produces the following water transfer pumping rate requirements (used to size and optimize pipelines and pumping systems):

- *Peak daily pumping rate: 1.06 m^3/s*
- *Average pumping rate: 0.82 m^3/s*

The identified higher potential farming units to be irrigated at Tsolo are located at elevations ranging from 930 to 1 090 m.a.s.l. A minimum residual head of 20 m is required in the bulk water system at the edge of field so that the sprinkler systems on all farming units can be supplied by gravity.

Figure 2 shows these areas around Tsolo which have been colour coded to show the elevation ranges that they fall within.

Two alternatives were investigated as raw water source locations.

- *Alternative 1: At the Ntabelanga Dam raw water outlet works.*
- *Alternative 2: At an abstraction weir and pumping station located in the Tsitsa River downstream of the dam, and as close to Tsolo as possible.*

Alternative 1 would have a raw water pumping station located near to the inlet works of the proposed Ntabelanga WTW, and this would have a suction elevation range at a minimum of 915.0 m.a.s.l., and an average of approximately 937.0 m.a.s.l.

Alternative 2 abstracts raw water from the Tsitsa River downstream of the Ntabelanga Dam via an abstraction weir. This may require low lift pumps to transfer water from the river to a large settlement basin prior to high lift pumping onward to the Tsolo area. The river level at this location is 872.0 m.a.s.l., and this alternative therefore has between 43 and 65 m higher pumping head than Alternative 1.

Four options were investigated for irrigation water distribution:

Options 1 and 2 considered pumping raw water directly from the two alternative sources given above to a single command reservoir located at a strategic location and elevation, to control flow and maintain pressure along this single rising main. Branches off the rising main would then be fed to the edge of fields of the various irrigable land areas described above. Local distribution and sprinkler systems in-field would be provided by the farm unit operators.

One advantage of these options is the single pumping solution, but a disadvantage is that there will need to be pressure reduction on some branch lines and that all of the raw water is effectively being pumped to the maximum elevation. The end point command reservoir would also need to be an expensive reinforced concrete structure, as there is no suitable location at sufficient elevation for a simpler open, earth-bunded storage structure.

Options 3 and 4 considered breaking the delivery of the total bulk water transfer into a shorter rising main to an intermediate open-topped, earth-bunded storage tank, from where it gravitates flow to the distribution system supplying the majority of the land areas at elevations coded in green and blue on Figure 2. The intermediate storage structure will have a volume of one day's storage of the full system demand, allowing for some flexibility in selection of pumping tariff bands, as well as catering for power outages. This storage facility is located on a ridge en-route at an elevation of 1 068 m.a.s.l. Within this distribution system, two smaller booster pumping stations would be required to lift raw water further to the balancing tanks in those areas at higher elevation, shown in purple and red on Figure 2.

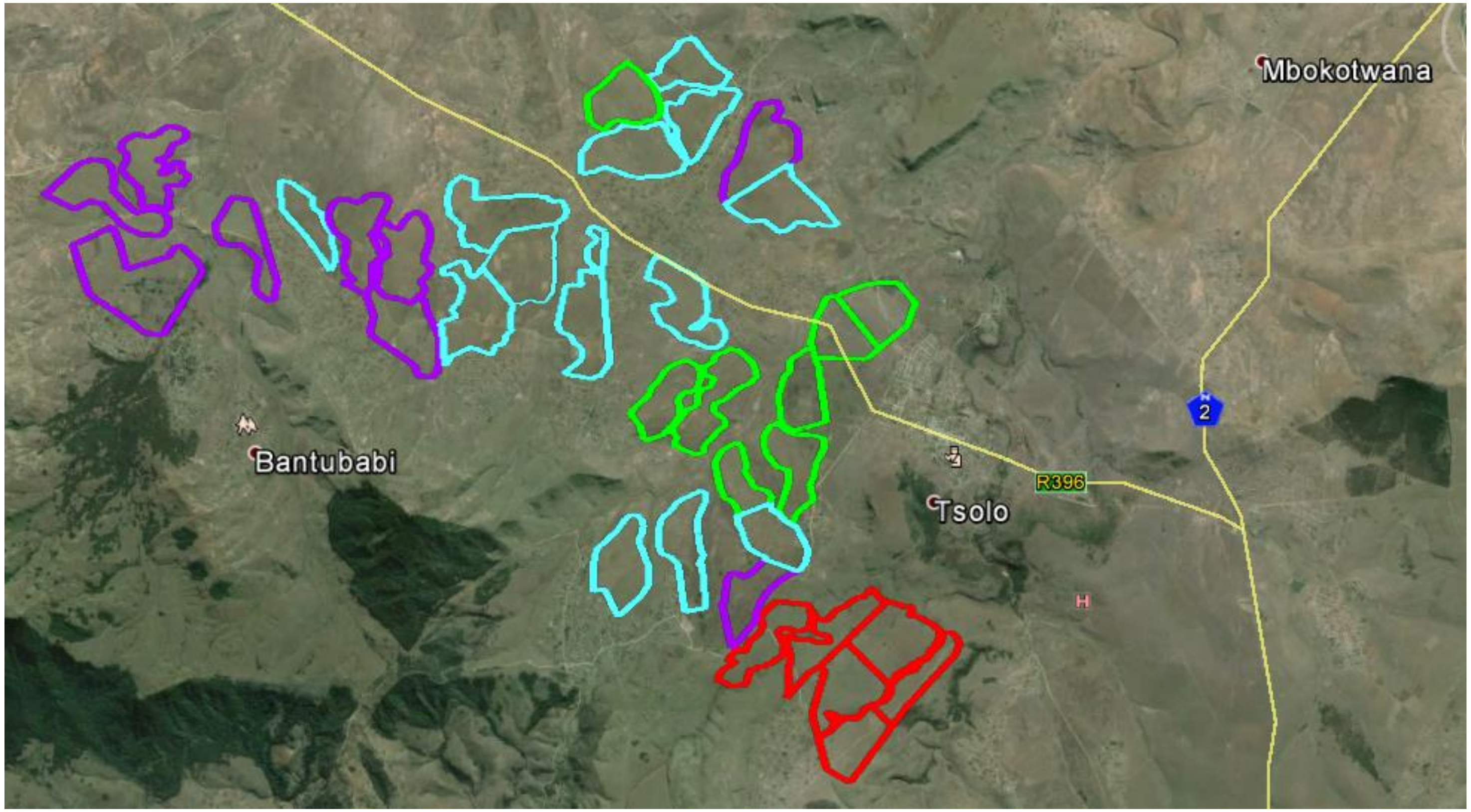


Figure 2: Elevations of Land with High Irrigation Potential

Key to Farm Unit Elevation Ranges:	
(green)	*930 to 1 000 m.a.s.l*
(light blue)	*1 000 to 1 040 m.a.s.l*
(purple)	*1 040 to 1 080 m.a.s.l*
(red)	*1 080 to 1 120 m.a.s.l*

A discounted cash flow/URV analysis was undertaken to optimally size the rising mains and raw water pumping configurations of Options 1 to 4. Option 3 is recommended as it has the lowest unit cost of water delivered to edge of field (R1.14/m^3), but excluding capital redemption costs. The capital cost of the bulk water supply to edge of field was estimated to be R660 521 820 inclusive of VAT at 2014 price levels. This excludes in-field farm development costs. An overall layout plan of this preferred option is given in Figure 3.

As shown on Figure 4, smaller balancing storage tanks would be provided at the end points of the branch lines, which will effect pressure regulation and pump control, and have six hours storage to cater for short power outages. Thus each farming unit would be able to connect into the bulk water distribution system pipelines at "edge of field" as shown in white on Figure 4, which, supported by the elevated balancing tanks also shown on the same figure, would provide and maintain an adequate and consistent water pressure for irrigation of each farming unit through the in-field irrigation reticulation system to be installed on each farm.

AGRICULTURAL ECONOMICS

A Gross Margin Analysis (GMA) has been carried out for the crops that are suited to the area. The GMA per crop is presented in the report body. A typical crop planting scenario with a mix of vegetables, row crops and forage/fodder crops indicates that a Gross Margin of around R580 000 is realistic per 60 ha farming unit. It is stressed that this is a gross margin on directly allocable costs, and not a measure of profit. This calculation, however, is based upon a unit cost of water delivered to edge of field of R0.40/m^3, which is significantly less than the R1.14/m^3 cost of supply given above.

Clearly some subsidization of this unit cost of raw water as well as capital costs must be made if the irrigation schemes are to be viable and sustainable. The Department of Rural Development and Agrarian Reform suggests that a figure of R0.25/m^3 would be a reasonable target to ensure that gross margins are attractive enough to encourage investment into commercial irrigated agriculture. This emphasizes the need to subsidize the Ntabelanga scheme with revenue gained from the energy sales generated by the Lalini Dam and hydropower scheme.

The Eastern Cape Wild Coast Development initiative includes a proposal to develop a Special Economic Zone (SEZ) in the area adjacent to the Mthatha Airport. The focus of this SEZ would be agri-processing, and if implemented this offers a major opportunity for the Tsolo area to become a main supplier of fresh produce to this SEZ. If this opportunity is realised, then the choice of crops to be grown on the proposed farming units could be matched with the market requirements of the Mthatha SEZ.

In terms of the market potential of crops grown in the Tsolo area, it was the Department of Rural Development and Agrarian Reform's opinion that demand would greatly exceed supply in this regard.

Clearly the farms should be of a size which can grow irrigated field crops and irrigated pastures, with a small area of around 10 hectares set aside for vegetable crops. The market potential will control the size of the vegetable crops. A mixed farming enterprise is therefore indicated. A possible employee structure per 60 ha mixed enterprise irrigation farming unit is presented, comprising 75 permanent employees per unit and 20-30 seasonal employees per unit. Based on 45 farming units, this would result in 3 375 permanent direct jobs, and up to 1 350 seasonal direct jobs.

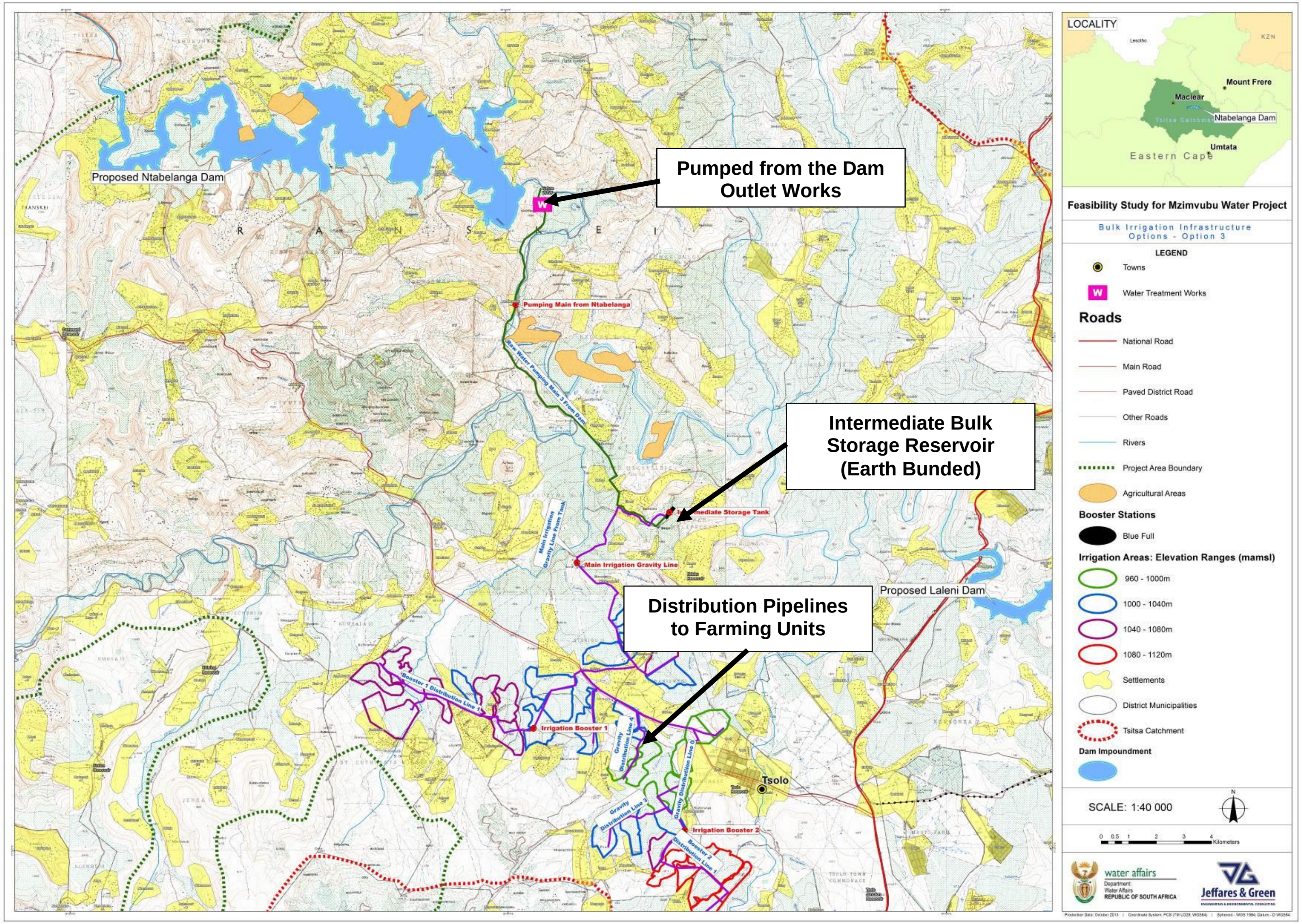


Figure 3: Overall Layout Plan of Option 3

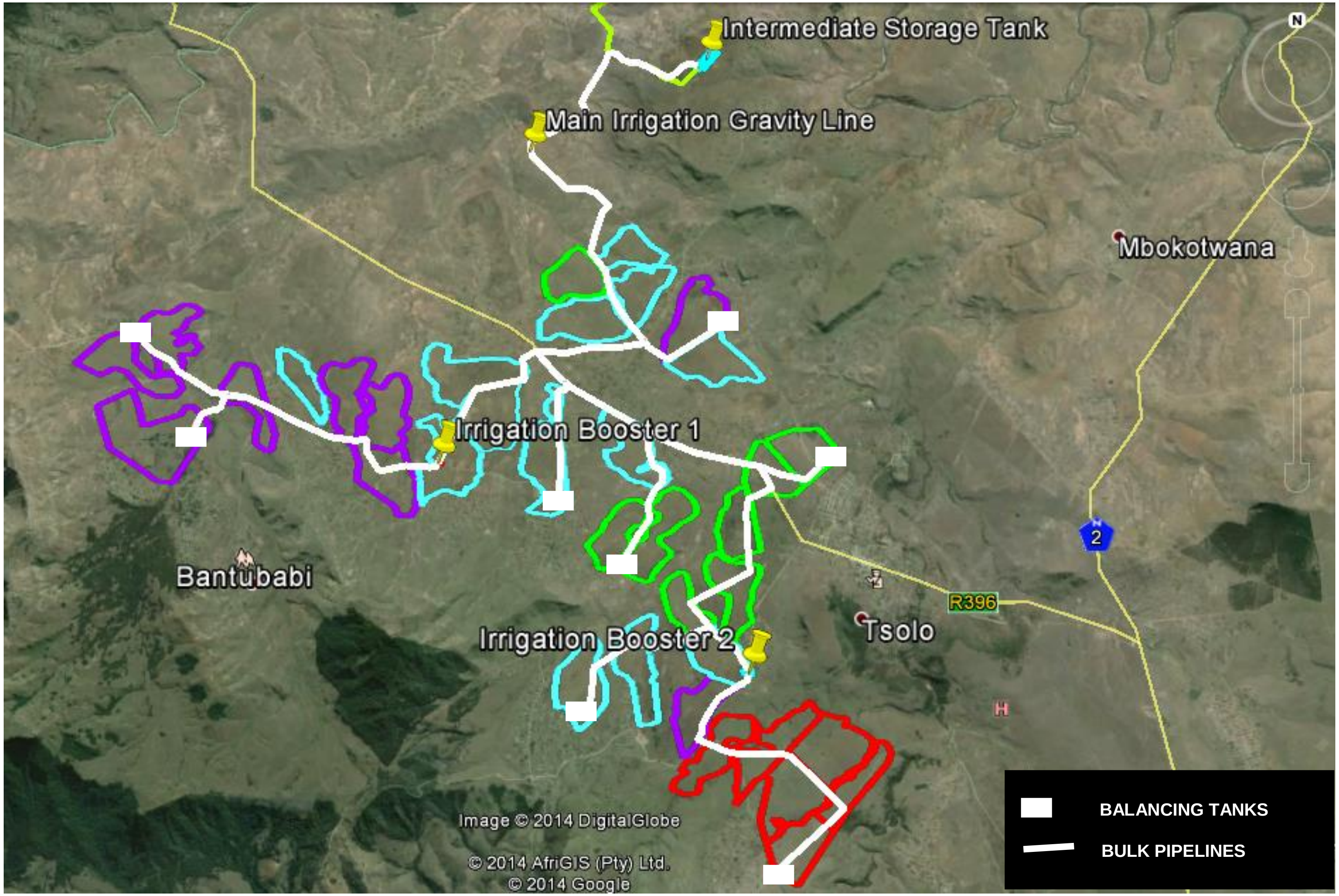


Figure 4: Detail of Bulk Distribution to Edge of Field

LAND MATTERS

The farming enterprises are proposed to be developed as commercially run irrigation farming units. This would provide the incentive for each farm to be economically viable and sustainable, which has been a key problem with existing irrigation schemes in the past. It would require the introduction of new technology to the area, and would also require an overhaul of the current system of communal farming currently in place in the area.

Extensive public consultation with the community, traditional leaders and government officials would be required. It is important that a land register of current land use is set up so that land claims and disputes can be properly addressed and managed.

Determination of farming unit size has been made on the premise that each farming unit should own their own tractor and farming implements, and the appropriate farm size to economically justify this approach. This has been determined as an average of 60 ha per farming unit. The 2 868 ha of irrigable land around the Ntabelanga Dam can thus be reasonably grouped into 45 farming units.

Whilst every pocket of land that has been identified as being of high irrigation potential has a different shape and topography, a generic farm layout was developed to show a typical setup arrangement and mix of crops that could be grown. This is shown in Figure 5.

Irrigation of land used to graze livestock is not consider a viable option. However, as shown on Figure 5, it may be viable to grow high nutritional lucerne and/or ryegrass as forage crops under irrigation for sale to livestock owners.

The current system of land tenure is communal dry-land farming on State-owned land. It is suggested that commercial leases of at least 20 years be entered into with prospective farmers, with leases being conditional upon proper and effective use of the land.

Technical training and support structures do exist in the area. The Department of Rural Development and Agrarian Reform is well positioned to provide training and extension services in the area. Tsolo Agricultural College and Jongiliswe Agricultural College for Traditional Leaders are local resources that could be used to train, mentor and support developing farmers. Business training will need to be a focus area for the farmers, as the farms need to be economically sustainable. A typical average 60 ha farming unit will potentially have a turnover of some R2 million per annum.

CONCLUSION

*2 868 ha of high potential irrigable land has been identified which could be supplied with water from the Ntabelanga Dam. This land can be reasonably grouped into 45 farming units of approximately 60 ha each. Depending on what crop mix is planted to what area, the water demand from the dam will be between 17.8 million m^3/a and 32.7 million m^3/a. An average application rate of 880 mm/a/ha was applied to the above irrigable areas, after allowing 10% for losses, which gives an annual irrigation raw water requirement of **27.8 million m^3/a**.*

Introduction of a commercial irrigation farming model is recommended. However this will constitute a major change from the current system of land use. Extensive community consultation will be required. Failure to garner broad community support for the proposal will constitute the biggest risk to failure of the scheme, both in the short and long term. An annual Gross Margin of around R580 000 per farming unit is realistic for a typical mix of vegetables, row crops and fodder crops.

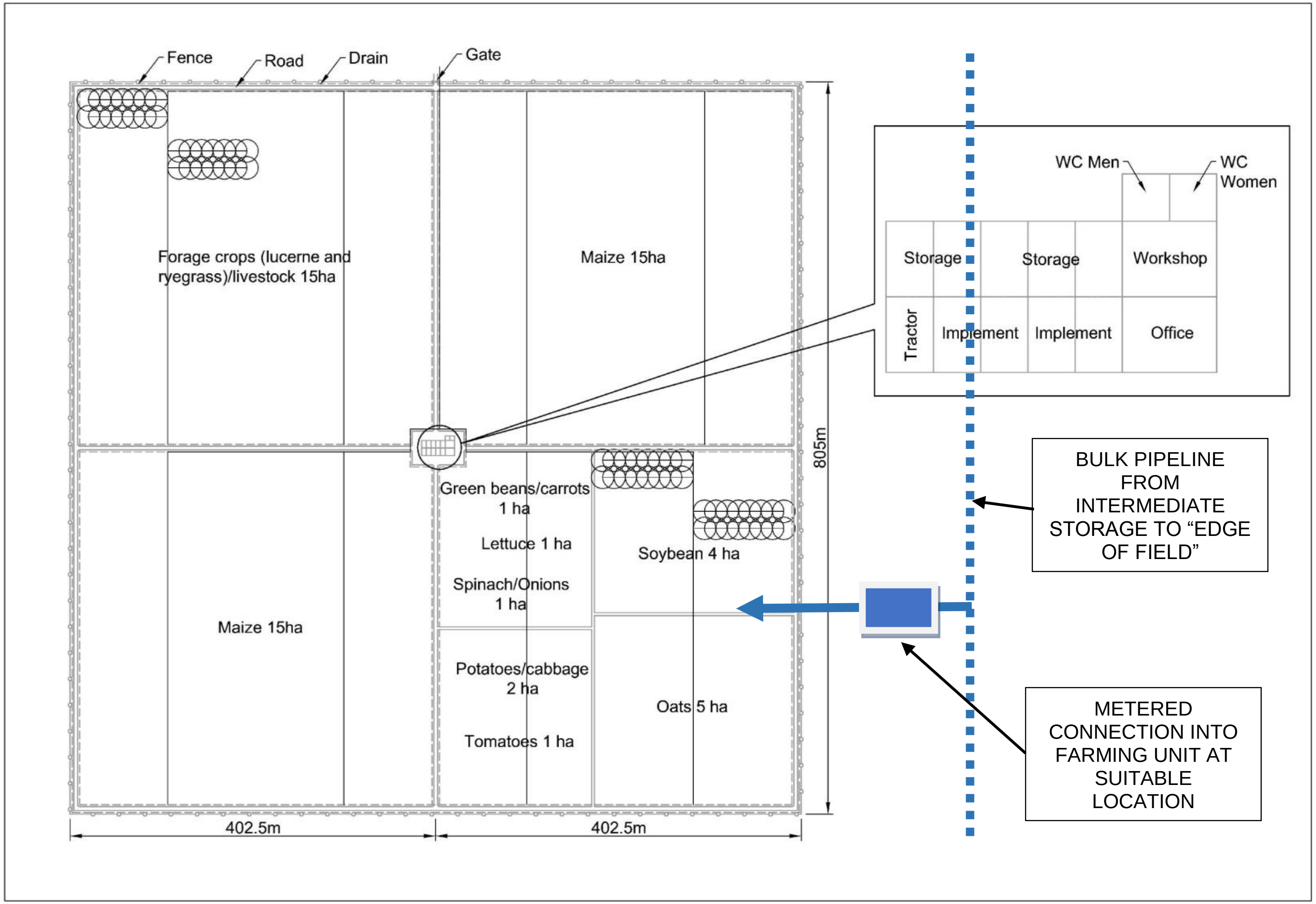


Figure 5: Typical Arrangement of a 60 ha Farming Unit

Up to 3 375 permanent direct jobs, and up to 1 350 seasonal direct jobs could be created on the farming units.

The capital cost of the bulk water supply infrastructure to edge of field is estimated to be R661 million inclusive of VAT at 2014 price levels. This excludes in-field farm development costs, which for all areas could total another R180 to 200 million.

Key issues that will need to be resolved are:

- *land reform and a change of mind set as regards agrarian practices and land tenure;*
- *the need for extensive consultation with Traditional Leaders and the affected people in the areas to be developed; and*
- *extensive investment in training, facilitation, and support services.*

The economics of the identified development option are based upon:

- *grant funding of the bulk water supply infrastructure to ensure that the water supplied is affordable;*
- *reduction of power, operation and maintenance costs through the beneficial usage of the hydropower revenue generated by the Lalini Dam and hydropower scheme; and*
- *the maximising of the potential market opportunities, if the SEZ is developed at the Mthatha Airport.*

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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 to Company
CV	Coefficient of Variability
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
IAPs	Invasive Alien Plants
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

MAP	Mean Annual Precipitation
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
SAWS	South African Weather Service
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 a.s.l.
Height	m
Distance	m, km
Dimension	mm, m
Area	m^2 , ha or km^2
Volume (storage)	m^3
Yield, Mean Annual Runoff	m^3/a
Rotational speed	rpm
Head of Water	m
Pressure	Pa
Diameter	mm or m
Temperature	ºC

Description	Standard unit
Velocity, speed	m/s, km/hr
Discharge	m^3/s
Mass	kg, tonne
Force, weight	N
Gradient (V:H)	%
Slope (H:V) or (V:H)	1:5 (H:V) or 5:1 (V:H)
Volt	V
Power	W
Energy used	kWh
Acceleration	m/s^2
Density	kg/m^3
Frequency	Hz

1. INTRODUCTION

The Mzimvubu River catchment in the Eastern Cape Province 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-Eastern 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:

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

As a result of this the Department of Water and Sanitation (DWS) 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 was completed in October 2014 in several stages as follows:

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

The purpose of this study was 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.

Report numbers P WMA 12/T30/00/5212/2 to 20 describe the feasibility study processes undertaken to select a preferred dam site that would be developed to meet the development goals and social benefits described above.

The purpose of this report is to present the findings of studies undertaken to investigate the irrigation development potential and associated infrastructure requirements of the preferred dam site as determined under the feasibility study.

2. DETERMINATION OF POTENTIAL IRRIGABLE SOILS

2.1 Phase 1

Phase 1 of the study required the screening of dam site options and the selection of a shortlist of three dam sites that made best possible use of the water resources of the Mzimvubu River catchment. The focus of the irrigation development task in this stage was to objectively identify the potential for developing irrigated agriculture around or below these three screened and shortlisted dam site options. This formed one of the criteria for decision making in terms of selecting the best dam site for further study in Phase 2 of the project.

The following factors were used to evaluate the irrigation potential of land surrounding the candidate dams, with a view to forming viable commercial farming units:

- irrigable soil quality, as determined by soil classification, soil depth and soil texture;
- slope: commercially viability will require mechanisation, and therefore slopes need to be within the limit that can be mechanically farmed;
- proximity to water source: commercial viability requires that the water source should be located within certain horizontal and vertical distance of the irrigable lands;
- natural rainfall: areas with high natural rainfall would not respond as well to irrigation when compared to areas with a medium to low occurrence of natural rainfall, and
- water availability within the proposed dams.

All of the identified sites were analysed, so that they could be objectively ranked against each other in terms of irrigation potential. For this preliminary stage analysis, a desktop study was undertaken using GIS analysis techniques.

The criteria were analysed per dam site as described below:

- Soils – Soils across the catchment were classified on a 1 km x 1 km raster grid basis as either “high”, “medium” or “low” potential, based on an algorithm which took into account the soil series, depth and texture.
- Slope – Slope across the catchment was calculated from existing elevation data, and slopes less than 12% were considered suitable for mechanised farming operations.
- Proximity to water source – For economic viability reasons, the areas considered were limited to those within 60 m vertical of the river at the proposed dam wall location or in the river below a proposed dam, and 5 km horizontal 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.
- 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.

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

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

Across the catchment, the soil potential relative to the identified dam sites is as shown in Figure 2-1.

Table 2-1: Mzimvubu Land Area Categorisation by Soil Potential

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

As shown in Table 2-1, 15% of the land area, or 301 400 ha, is identified as being high potential soil. However, a low proportion of this land area lies within a reasonable distance of the potential dam sites.

Across the catchment, water stress is shown in Figure 2-2.

Table 2-2: Mzimvubu Land Area Categorisation by Water Stress

Water Stress	Area identified (ha)
High	2 816
Medium	1 368 060
Low	4 416
Total	**1 975 272**

As shown in Table 2-2, 69% of the land area, or 1 370 876ha is identified as having high or medium water stress.

The above GIS coverages were further analysed for the slope, elevation and distance criteria, and the results per dams site are as shown in Table 2-3.

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.

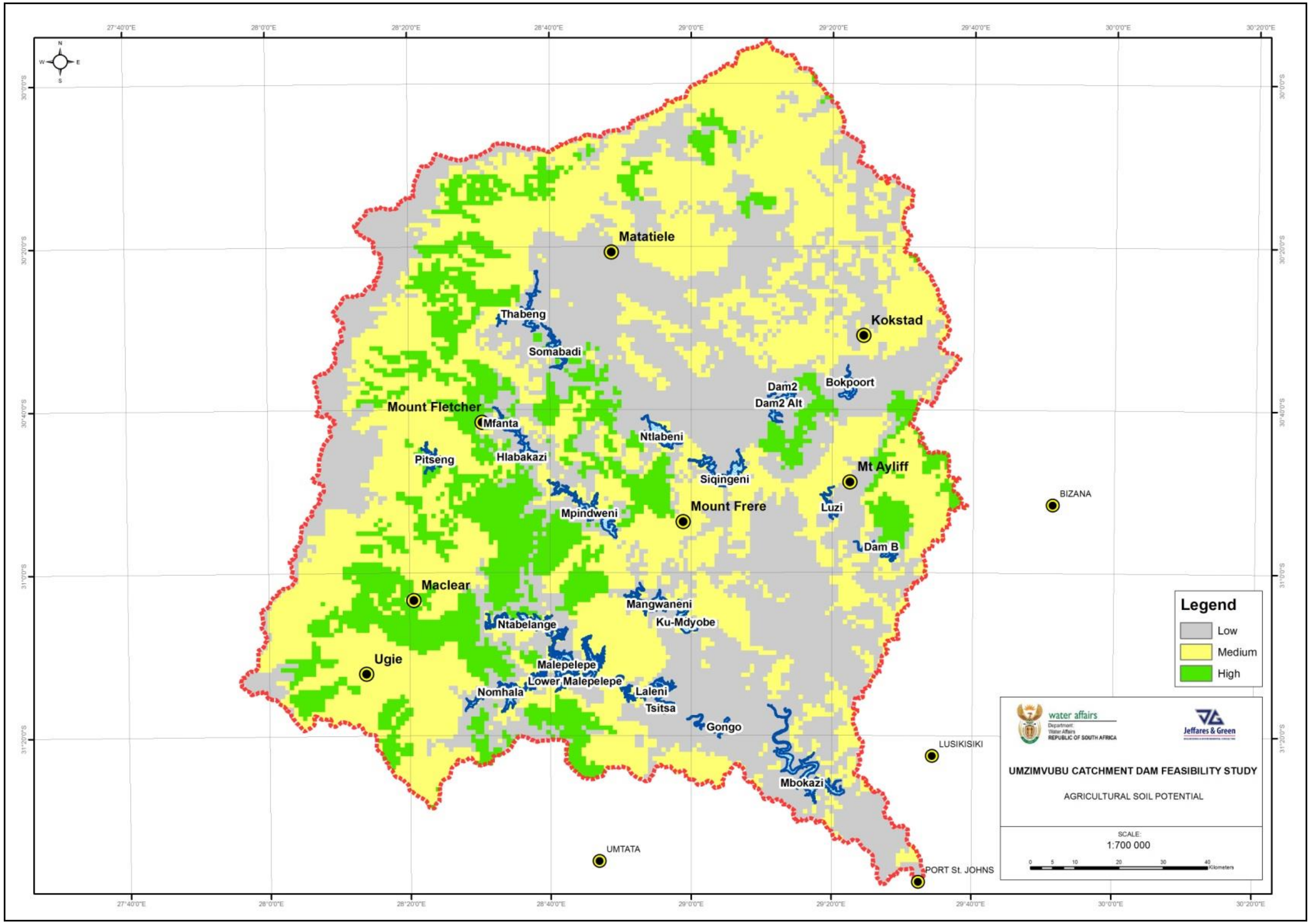


Figure 2-1: High, Medium and Low Potential Soils in Mzimvubu Catchment

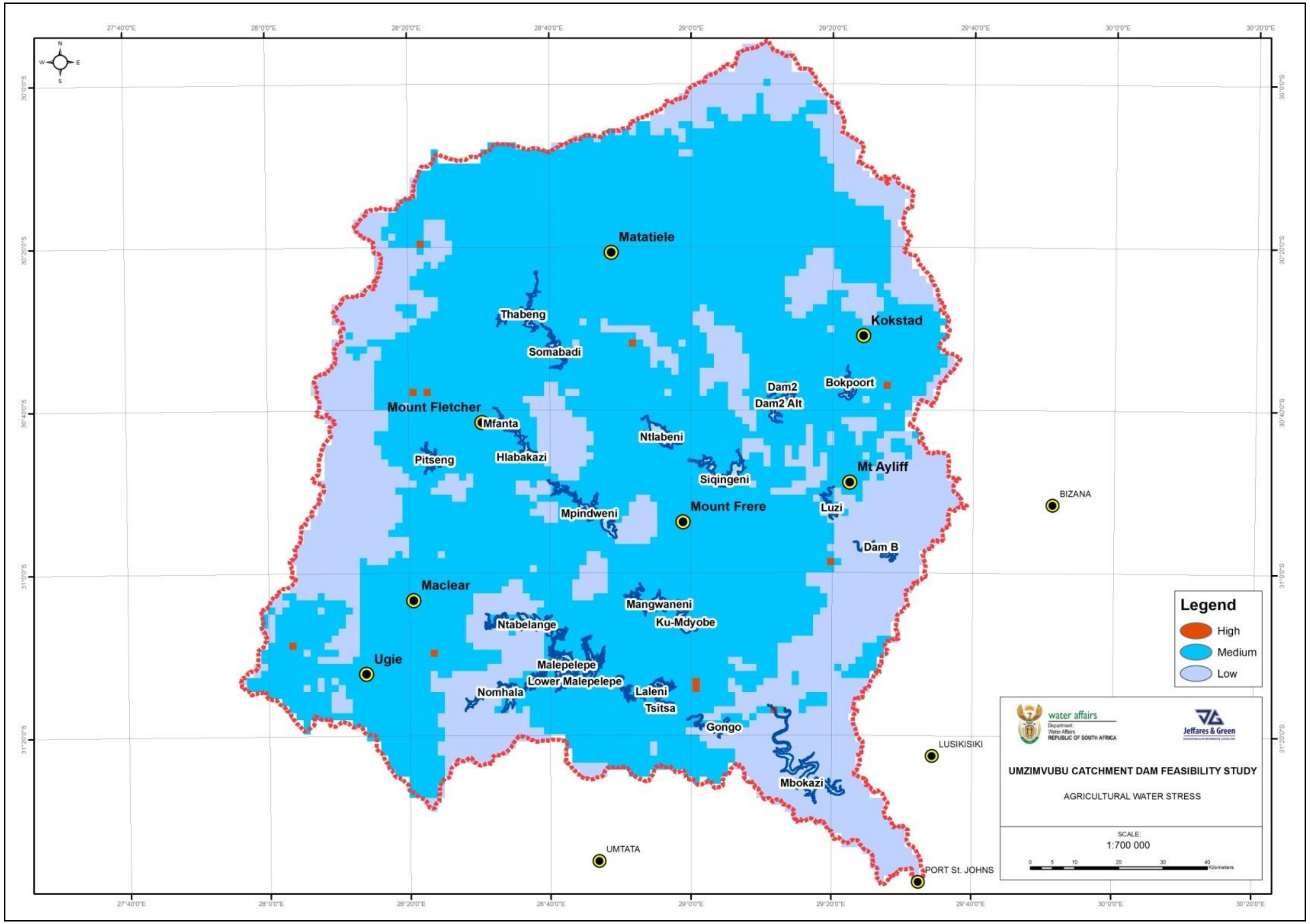


Figure 2-2: High, Medium and Low Water Stress Areas in Mzimvubu Catchment

Table 2-3: High Potential Agricultural Land Meeting Selection Criteria

No	Catchment	Total Catchment Agric Land (ha)	Dam	High Potential Area (ha)
1	T31	8 561	Siqingeni	0
2			Dam2	0
3			Dam2 Alt	0
4	T32	957	Dam B	0
5			Bokpoort	0
6			Luzi	0
7	T33	22 647	Ntlabeni	0
8			Somabadi	1 261
9			Thabeng	1 553
10	T34	31 976	Mangwaneni	0
11			Ku-Mdyobe	0
12			Mfanta	0
13			Mpindweni	0
14			Hlabakazi	0
15			Pitseng	1 476
16	T35	57 953	Ntabelanga	1 247
17			Nomhala	747
18			Malepelepe	22
19			Lower Malepelepe	22
20			Lalini	0
21			Tsitsa	0
22			Gongo	0
23	T36	0	Mbokazi	0

2.1.1 *Phase 1 Field Review*

The three candidate sites were reconnoitred to verify the desktop information as derived above. It was also important that ground-truthing of the desktop information took place, to ensure that decisions were being made on reliable and accurate information. Budgetary constraints did not allow for extensive soil sampling and testing at this initial high level stage of the study.

Another visit was organised over a two day period 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 selection 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 was therefore modified to some extent prior to the visit. The final areas assessed per dam were as follows in Table 2-4.

Table 2-4: Areas of High Potential Agricultural Land (Initial Criteria)

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

Selective and representative sampling was undertaken 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 and stones.

Other recorded field data were effective root depth, ameliorated root depth, topsoil organic carbon, outcrops and total available moisture. Soil samples were taken for laboratory analyses to test for salinity and sodicity hazards.

The area to be evaluated was very large (in excess of 3 500 ha) and, and therefore at this preliminary stage, only rapid (and limited) sampling was undertaken to gain an understanding of typical soil types in the area, and to guide the study team in planning the further sampling undertaken in Phase 2 of the study. Figure 2-3 shows an example of good and bad soils identified in this region during this preliminary fieldwork.

2.1.2 Phase 1 Results

a) Ntabelanga

It was estimated that 60% of the screen study 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 a 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) are expected to be in the range of 5 to 15 cmol+/Kg with moderate cation exchange capacity (CEC) 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.

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

Figure 2-3: Soil Sampled for Classification and Depth Marking

It was estimated that the remaining 40% of the studied Ntabelanga 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.

b) Somabadi

It is estimated that 80% of the screened study area (1 062 ha) has Hutton 2200 salm and Hutton 2100 salm soil types. Orthic topsoils overlie red apedal subsoils. Effective root depth ranges from 40 cm 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 a 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 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. Increased 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.

c) 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) occur.

It is estimated that 1 062 ha has Hutton 2200 salm and Hutton 2100 ha salm soil types. Orthic topsoils overlie red apedal subsoils. Effective root depth ranges from 40 cm 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 a luvic character as clay has moved from top to subsoil. Textural transition from topto 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 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. Increased salinity and sodicity levels may occur at these sites.

These soils present limiting conditions for irrigation.

2.1.3 Summary Phase 1 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
- Class VIII: very low potential

Classes I to IV are generally considered suitable for irrigation, while Classes V to VIII are generally considered unsuitable. As shown in Table 2-5, no Class I and II soils were found.

Table 2-5: 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
Ntabelenga	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

Phase 1 of the study concluded with the selection of Ntabelanga as the preferred dam site, considering all of the criteria being evaluated, which included technical, economic, environmental, potable water supply and irrigation considerations.

2.2 Phase 2

In Phase 2 of the study, following a decision to maximise the potentially irrigable agricultural land in the area around Ntabelanga Dam, the two economic criteria of elevation < 60 m above the river at the dam site or in the river below the dam site, and distance < 5 km from the dam wall or either side of the river below the dam site, were removed from the criteria.

This resulted in more agricultural land being included for consideration without being constrained by economic factors, and this was deemed important in order to maximize the potential for economic development and social upliftment in the study area.

The land identified around Ntabelanga Dam now met the following criteria:

- high irrigation potential soils,
- slope < 12%, and
- water deficit – medium to high water stress (shortage of natural rainfall).

A total area of over 8 000 ha was identified, the largest increase in area coming from the land in and around the town of Tsolo, approximately 20 km due south-east of the proposed dam wall. This land was reviewed for existing land use, particularly existing settlements constructed on the land, and the specific areas to be investigated were thus trimmed down to 7 708 ha of land potentially available for irrigated agriculture.

2.2.1 *Phase 2 Field Review*

As in Phase 1, it was necessary to visit the 7 708 ha, to review the soils on site, to physically assess the identified lands from an agricultural perspective, and to correlate physical observations on the ground with the desktop mapping carried out in the GIS.

The resulting more detailed soils assessment was carried out over 17 days and resulted in:

- 249 augered soil samples and observations,
- 12 modal soil profiles, and
- laboratory analyses of various soil parameters, including salinity and sodicity.

The full report on this fieldwork and observations therefrom is presented in Appendix A.

2.2.2 *Phase 2 Results*

In summary, the soils were classified as shown in Table 2-6.

Table 2-6: Summary of Irrigable Soils Suitability: Ntabelanga Dam

Irrigability Class	Irrigability Class Description	Extent (ha)	Extent (%)
I	Highly recommended	255	3
II	Recommended	2 796	36
III	Recommended with reservation	624	8
IV	Not normally recommended	2 131	28
V	Not recommended	1 906	25

Thus, the findings were as follows:

- irrigation classes I, II and III are recommended for irrigation, and this totalled 3 675 ha or 47% of the study area;
- irrigation class IV is not normally recommended for irrigation, whilst irrigation class V is totally unsuited to irrigation. These sites total 4 033 ha or 53% of the study areas, and
- limitations to irrigation in classes IV and V are either slope gradients more than 12%, shallow soils, duplex soils, sodic soils or soils with rocky outcrops.

Based on this reconnaissance soil assessment to determine the irrigation capability of soils for agriculture in the Ntabalenga area, a general recommendation and conclusion of the irrigation capability of soils and sites was made as follows:

- Soil bodies recommended for irrigation
  - 3 675 ha or 47% of the study area
  - Oxidic soils of the Hutton, Griffin, Clovelly and Inanda forms
  - These soils are generally located on midslope and some crest terrain units.
- Soil bodies not recommended for irrigation
  - 4 037 ha or 53% of the study area
  - Duplex, hydromorphic and lithic soils of the Swartland, Estcourt, Klapmuts, Katspruit, Westleigh, Glenrosa and Mispah soil forms
  - Generally located on footslopes, valley bottom and some crest terrain units.

The land generally rises towards the north, south and west of the dam and the issue of economic viability was again raised, as some of the identified lands were in excess of 300 m static lift above the proposed dam. These areas were excluded on the basis that no economically feasible irrigation farming would be possible on these lands considering the vertical pumping lift required to get the water to these lands and consequent high costs.

The final step in the process was a critical review of the remaining areas of identified high potential soils. In some cases, patterns or trends that had been established in the field could be used to further interpret and calibrate the soil polygons on the GIS.

A particular example is that the poorer soils not recommended for irrigation were generally found in the valley bottoms and in the drainage lines. The upslope portions, and areas without obvious drainage problems are generally good for irrigated farming, provided they contain a good soils form. A final interrogation of the identified good soils polygons from the field verification exercise, allowed some truncated polygons to be reasonably extended according to the principles above.

Thus, the final estimate of potentially irrigable land that could be supplied with water from the Ntabelanga dam was established as 2 868 ha, of which 2 451 ha is located in the areas adjacent to Tsolo, and the remaining 417 ha are located on the north shore of the future impoundment basin of the Ntabelanga Dam, and close to the Tsitsa River channel downstream and close to the Ntabelanga Dam itself.

The locations of these areas of higher agricultural potential land are shown in Figure 2-4.

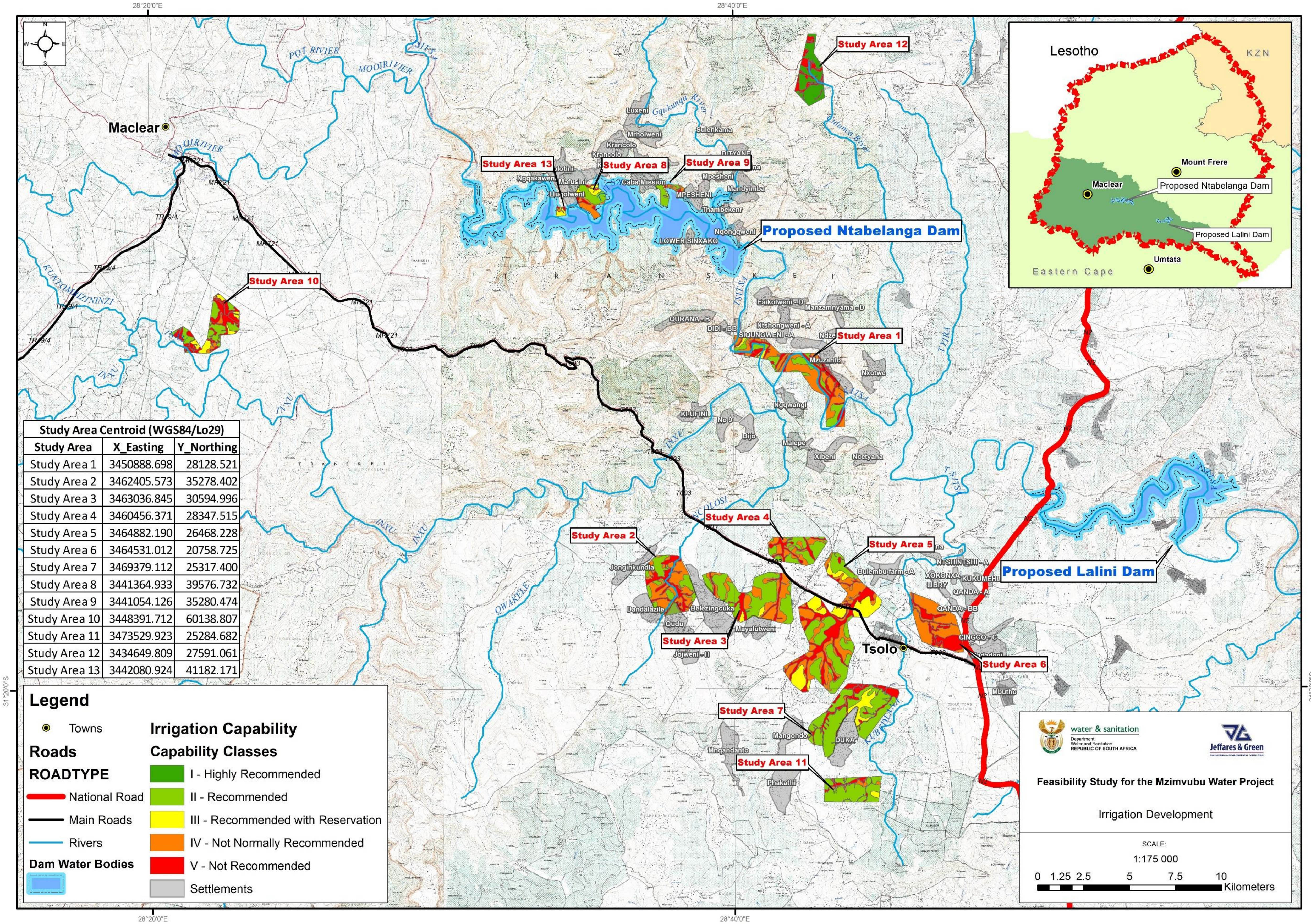
Two remote “outlier” areas 10 and 12 were noted. Area 10 is far from the proposed raw water source and has a low proportion of the higher soil classes. Area 12 has a significant area of high class soils but is at a straight line distance of 12 km, and at an elevation some 440 m above the raw water pumping station. The terrain between the pump station and area 12 is particularly mountainous and highly problematical for pipeline construction. An intermediate booster pumping station would also be required. This area is not consider viable with regard to being supplied with water from the Ntabelanga Dam.

Most of the proposed farming units are located in and around the urbanised centre of Tsolo, at a distance of some 17 km away from the Tsita River, and at an elevation between 130 and 220 m above the river level at that nearest point.

This means that raw water supply to these areas would need to be conveyed via pipeline and pumped from the source, which will have significant operation, maintenance and energy cost implications.

This is analysed in detail in the Bulk Water Distribution Infrastructure Report No. P WMA 12/T30/00/5212/13, and the Cost Estimates and Economic Analysis Report No. P WMA 12/T30/00/5212/15.

Details of this bulk water supply system are given in a later section herein.



Study Area Centroid (WGS84/Lo29)		
Study Area	X_Easting	Y_Northing
Study Area 1	3450888.698	28128.521
Study Area 2	3462405.573	35278.402
Study Area 3	3463036.845	30594.996
Study Area 4	3460456.371	28347.515
Study Area 5	3464882.190	26468.228
Study Area 6	3464531.012	20758.725
Study Area 7	3469379.112	25317.400
Study Area 8	3441364.933	39576.732
Study Area 9	3441054.126	35280.474
Study Area 10	3448391.712	60138.807
Study Area 11	3473529.923	25284.682
Study Area 12	3434649.809	27591.061
Study Area 13	3442080.924	41182.171

Figure 2-4: Higher Potential Irrigable Soils - Ntabelanga Dam

3. LAND MATTERS

3.1 Proposed Farming Model

A number of farming models are possible on the identified land. The land is currently communally farmed and un-irrigated, and any move towards modern, commercial irrigation farming will almost certainly be met with strong resistance from those who perceive they may:

- lose land they have farmed for years;
- lose a historical or spiritual link to the land;
- lose power, through not being able to freely allocate land, and/or
- have new technology forced upon them.

Resolution of these issues will require broad community consensus, without which the development of the proposed farms will almost certainly fail. In obtaining such consensus widespread and inclusive community consultation must be the starting point during the implementation phase of the development.

Right from the start a view needs to be taken on whether the irrigation project is to be developed according to a social benefit model, maximising the number of people that will benefit irrespective of profitability, or according to an economically sustainable model whereby the farms can be individually profitable and sustainably farmed.

The social benefit model to maximise the number of people benefitting from the irrigation scheme will be the most palatable politically. However, it is likely to have a number of serious shortcomings, inter alia:

- plot sizes that are too small to be economically farmed as standalone enterprises;
- low turnover and low profit on small farms means the farms will generate supplementary income only, reducing incentive and interest in the enterprise;
- small farm sizes will result in losses of economies due to scale, unless cooperative farming schemes or centralised farming committees are established;
- small farms that rely on shared resources often do not have the resources and implements available when required for critical planting or harvesting operations;
- small farms that are subject to communal management structures often battle to farm effectively. As soon as decision-making is removed from the individual farmer and is vested in a committee, accountability and responsibility are likewise removed from the individual farmer, and the basis for sound and sustainable decision-making is weakened;
- commercial banks are reluctant to lend money to communal farming collectives that do not have a commercially viable business plan, and
- long-term subsidisation of farms creates false economies and also creates dependencies, which are counterproductive.

For irrigation farms to be feasible they need to be economically viable, implying that they can be operated as stand-alone farms with net profits that exceed operating costs. This will empower each farming unit investor to have their own implements, make independent decisions, and will encourage them to become sustainable contributors to the local economy and to become employers within the community.

The above view will hinge on a radical shift in farming methods currently being practiced in the area, and will require the support and buy in from Government at large, applicable Government Departments (such as the Department of Rural Development and Agrarian Reform, Department of Rural Development and Land Reform) and other agencies (e.g. Eastern Cape Rural Development Agency) that will assist with support, training, land administration matters and getting community consensus, traditional leaders that currently administer the land under the communal farming system, the community who currently reside on and farm the land, and local training institutions that will be required to train and support the farmers.

If support is withdrawn from any of the above sections of the community, the venture will almost certainly fail as a commercial proposition.

Consultations have been held with various sectors of Government, and Government Departments have been involved with the process and contributed throughout the study. Specifically, the Eastern Cape Department of Rural Development and Agrarian Reform have committed themselves, in a presentation to the Working Group on 13 October 2014, to the following:

- carrying out consultation on the preferred farming model to be adopted;
- carrying out detailed soils investigations;
- providing advisory support on the production of crops;
- preparing budgets for suitable crops, and
- planning and design of on-farm infrastructure.

They have further suggested the Eastern Cape Rural Development Agency as the implementing agent for the irrigation development.

3.2 Determination of Farm Size

The viability of the proposed approach hinges on the determination of an economically viable farm size. There are a number of aspects to be considered.

3.2.1 Crop Yields and Gross Margin Analyses (GMA's)

Vegetable crops will produce the best GMAs. These crops have very high production costs and demand the highest management inputs. This means they can produce the biggest losses if management is inadequate.

More important however is that the market for such crops is finite and prices drop radically if there is over-production. Most vegetable crops have a limited shelf life.

If the choice of crops for the project is based on those with the highest GMA's then all the farms will produce vegetables. This will produce an oversupply of vegetables which will flood the market and drive prices down.

The Eastern Cape Wild Coast Development initiative includes a proposal to develop a Special Economic Zone (SEZ) in the area adjacent to the Mthatha Airport. The focus of this SEZ would be agri-processing, and, if implemented, this offers a major opportunity for the Tsolo area to become a main supplier of fresh produce to this SEZ.

If this opportunity is realised, then the choice of crops to be grown on the proposed farming units could be matched with the market requirements of the Mthatha SEZ. In terms of the market potential of crops grown in the Tsolo area, it was the Department of Rural Development and Agrarian Reform's opinion that demand would greatly exceed supply in this regard.

The farms should be of a size which can grow irrigated field crops and irrigated pastures, with a small area of around 10 hectares set aside for vegetable crops. The market potential will control the size of the vegetable crops. A mixed farming enterprise is therefore indicated.

3.2.2 Farm Sizes Relative to Tractors and Machinery

Timing of the agricultural processes, especially planting, is critical to obtaining optimum yields. The reasons for this relate mainly to weather conditions. Late planting can take a mature crop into cold conditions in winter thus reducing yields. Early planting when soil temperatures are too low can lead to poor stands and thus reduced yields. Preparing land well before planting can lead to having to repeat the operations if rain falls and weeds germinate.

This is expensive and reduces the time available to achieve optimal planting dates. The optimal planting dates for most field crops are in the rainy season and field operations are interrupted not only on the rainy day but for some days afterwards while the fields dry out. All the above must be catered for in equipping a farm with tractors and implements.

3.2.3 Ownership of Tractors and Implements

It is sometimes suggested that to obtain best utilization of tractors and implements in a project that implements should be pooled and that farmers should be able to draw from the pool as they need machinery. However, this approach has generally not met with success when it has been tried in the past in South Africa.

The reason for this is that all the tractors and equipment are generally required at the same time over the optimum planting season which is over a very short time (4 – 5 weeks). Planting during the optimum planting season is critical for farm viability. It is proposed that individual ownership of the basic equipment is essential, and that farms be sized to justify this individual ownership of equipment.

3.2.4 Basic Farm Tractor and Equipment

Table 3-1 summarizes the basic implements required to work a farming unit.

Table 3-1: Basic Implements Required to Work a Farm

Implement	Number Required	Work rate
50kw Tractor	1	
Plough	1	6 ha/day
Disc	1	15 ha/day
Planter	1	15 ha/day
Cultivator	1	20 ha/day

The time available to carry out the land preparation and planting exercise is 4–5 weeks, less any non-working time during rainy spells.

The time required to prepare and plant 60 hectares would therefore be as follows:

- Plough: 10 days
- Disc: 4 days
- Plant: 4 days
- Cultivate: 3 days

This is a total of 21 days, which would allow 14 non-working days for rainy spells and mechanical breakdowns.

Furthermore, a typical 60 ha farming unit could provide for the following economic production:

- an area to grow more lucrative vegetables relative to the market conditions;
- an area for the growing of field crops, and
- an area for growing livestock feed or growing irrigated pastures for the introduction of an animal factor to the farm.

From the above, and given the distribution of the higher potential land identified above, it is suggested that a 60 ha irrigated farming unit is developed for the establishment of economically sustainable and viable commercial farmers.

3.3 System of Tenure

The current system of tenure is communal farming. Under this system the State owns the land, but it is managed and allocated to community members by traditional leaders. Although the system is relatively stable, without title to the land, farmers cannot easily raise loans to invest in the farming enterprise.

It is proposed that the farming units are established as economically viable commercial irrigation farms. The most reasonable system of land tenure would be a medium-term lease entered into between the State and the farming unit investor.

This lease needs to be long enough that the investors can establish themselves on the land, establish a number of enterprises, invest in the farm, and repay any loans raised to finance the investment. The lease should also be long enough that the farmer can take a medium-term view in developing the farm. This may entail a few lean years in the early stages of farm development, with more profitable years to follow once the farm has been well established.

A lease period of 20 years should be considered for the system of land tenure. It is important that the lease is linked to agricultural performance, with cancellation of the lease being an option if the farmer fails to establish any agricultural production within (say) 3 years, or if the land is used for non-agricultural purposes.

It is critical that the land allocation under the current system of communal farming is audited and that a land register is set up. This should be done early on in the implementation phase of the project, and should form part of the community consultation process. This will establish a benchmark for the current land use in terms of who has been allocated which land, since what date, what land area, if it is currently being farmed, how much land in total has been allocated, and how much land remains unallocated.

This will form the basis of any discussions around land rights, any compensation payable, any offset arrangements, or any land trading system. Without such a system being set up early on, the process will quickly become mired in squabbles by community members who feel they are being disenfranchised or unfairly removed from their land.

3.4 Training and Support Resources

Irrigation farming is not common in the communal areas and communities surrounding the town of Tsolo. It will be viewed as new technology, and it is important that there is appropriate training and extension support of new and emerging farmers if the technology is to be successfully implemented.

A number of resources are available which will be important for the training of new farmers, the support and guidance of farmers as they become established, and the continued support of farmers through extension and advisory services:

- Tsolo Agricultural College;
- Jongiliswe Agricultural College for Traditional leaders, and
- Eastern Cape Department of Rural Development and Agrarian Reform.

Feedback has been provided during consultative meetings held as part of this study that the technical support in terms of agricultural training and extension support does exist within these institutions listed above.

However, no formal business skills training exists. Farms that are 60 ha in size (as proposed) would be expected to have an initial minimum annual turnover of around R2 million (2014 price levels) according to the Gross Margin Analysis presented further in this report, and appropriate business skills will be as important as agricultural skill development for the farms to be sustainable.

Business courses either need to be developed and offered as courses/modules within the existing training facilities, or new business skill training facilities need to be established in the area.

3.5 Beneficiary Selection

It has been strongly advocated from the consultative meetings held to date that the process of beneficiary selection needs to be designed to succeed. That is, prospective farmers to be settled on the plots need to have demonstrated:

- agricultural skills and knowledge to enable them to farm effectively;
- business skills to be able to farm profitably and sustainably, and to enable them to contribute to the local economy through becoming primary producers and providing employment opportunities;
- aptitude to become farmers, to work hard, and to remain enthusiastic, and
- willingness to embrace new technology, and to continue learning as new agricultural technologies evolve.

This process should be initiated through formal training progress where suitable applicants are firstly trained in the theory, then provided with practical training and experience, then monitored and supported, and finally placed on the farming plots where continuing support and extension services are available when and where required. Throughout the process, prospective farmers unable or unwilling to make the grade should rather focus on the other employment opportunities that will arise.

This “incubation” of farmers that show aptitude, ability and willingness is far preferable to a placement based on a “first come first served” basis, or placement based on who is currently occupying the land.

Commercially successful farmers will not only make best use of the land and the irrigation investment, but will contribute to food security in the area, to the regional economy, and will generate up to 3 375 permanent jobs and up to 1 350 seasonal jobs on the 45 proposed farming units. By contrast, failed farming units would make poor use of the available land, reduce food security, and diminish the leveraging effect that job creation can have on the local economy.

It is recommended that the Provincial Department of Rural Development and Agrarian Reform, and the Department of Rural Development and Land Reform be assigned responsibility for the undertaking of this land reform and irrigated agriculture development initiative as they have the best experience, understanding, and capabilities of the consultative and mentoring approaches required.

This process should begin as soon as possible in order than the future irrigated agriculture and associated raw water requirements be confirmed, so that the dam and associated infrastructure development can be finalized accordingly during the detailed design and implementation stage.

4. IRRIGATION WATER DEMAND

4.1 Climate

The ultimate determination of annual water use for the irrigation of this land first requires the selection of suitable crops for the prevailing climate, and finally the determination of a monthly irrigation regimen, taking into account the rainfall and evapotranspiration of the area.

There is no reliable, long-term recorded climate data available for the study area, hence the climate data presented below is modelled data[1]. 89% of the study area is located in the Tsolo vicinity, and hence climate data is presented for this location.

Tsolo receives 780 mm mean annual precipitation (MAP) and has a mean annual temperature (MAT) of 16°C. The mean annual evaporation (A pan) is high at 1 659 mm. Frost occurs in winter. Snow cannot be ruled out on high-lying ground.

The climate dictates that crops tolerant of cool conditions and frost be established. The somewhat low MAT suggests that crop growth will be retarded (due to low heat units) to some extent and that subsequent crop yields will be somewhat restricted. Irrigation will supplement soil moisture deficits during the dry winter months and will provide a significant yield increase compared to current rain-fed agricultural practice.

Table 4-1: Climate of the Tsolo Area

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Mean
Mean monthly rainfall (mm)	129	108	108	46	18	5	8	14	36	69	105	101	**780**
Mean daily maximum temperature (°C)	26	26	25	22	21	18	18	20	21	22	23	25	**22**
Mean daily minimum temperature (°C)	14	14	13	10	7	4	4	5	8	10	11	13	**9**
Mean daily temperature (°C)	20	20	19	16	14	11	11	13	15	16	17	10	**16**
Mean Evapotranspiration (mm)	184	149	149	111	102	89	98	126	138	158	164	191	**1 659**
Humidity (%)	69	69	68	65	62	62	60	60	63	67	68	68	**65**

4.2 Suitable Crops and Expected Yields

Based on the climate data presented (particularly mean annual temperature and frost occurrence), soil types and soil properties, and assuming a medium level of irrigation management input, a variety of possible crops recommended for irrigation in the Tsolo area are presented in Table 4-2.

[1] *Schulze, R.E. 2007. Preface and Executive Summary. In: Schulze, R.E. (Ed). 2007. South African Atlas of Climatology and Agrohydrology. Water Research Commission, Pretoria, RSA, WRC Report 1489/1/06, Section 1.1.*

Table 4-2: Suitable Crops and Expected Yields for Irrigation Classes I, II and III

Crop	Uses	Suitability	Expected Yield
Cabbage	Food	Moderate	50 tons/ha
Carrot	Food	High	30 tons/ha
Green Bean	Food	High	8 tons/ha
Italian Ryegrass	Nutritious grazing	High	10 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
Potato	Food	High	30 tons/ha
Soya bean	Food, oil seed, animal feed	Moderate	3 tons/ha
Spinach	Food	High	20 tons/ha
Tomato	Food	Moderate	35 tons/ha

4.3 Irrigation Water Requirements

Estimating the irrigation water use of a potential farm in the Tsolo area depends on a number of factors, including what crop is planted to what area, historical rainfall, planting and harvesting dates, whether crops are perennial or seasonal, whether double cropping occurs for seasonal crops, and management factors.

These factors make it impractical to predict the multitude of crop types, areas and planting combinations that might occur in practice.

However, a theoretical maximum water use per hectare can be determined by studying the water demand of a reference crop. This is a crop with a crop factor of 1 all year round, and assumes that irrigation is supplied where evapotranspiration (ETo) > rainfall, i.e. irrigation is calculated as the difference between evapotranspiration and historical rainfall for a crop with a crop factor of 1 in all months.

This has been modelled in the SAPWAT model, and the results are presented in Table 4-3.

While this is a theoretical water demand based on a reference crop it is useful in that it provides an upper limit of irrigation requirement, irrespective of the crop mix, or areas under crops that will be grown. Any crop mix should require less than this in practice.

Table 4-3: Irrigation Water Demand for a Reference Crop

Water use (mm @ 80% assurance of supply)												Water use	Water use
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(m^3/ha/a)	(mm/a)
96	84	74	75	82	80	91	116	118	110	97	118	**11 410**	**1 141**

Another approach would be to develop the water requirements for a "realistic" crop mix that might be grown on a 60 ha farming unit, as is presented in Table 4-4.

Table 4-4: A Realistic Crop Mix for a 60 ha Farm Unit

Cropped area (ha)	Crop 1	Crop 2	Water use (mm @ 80% assurance of supply)												Water use
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	(m^3/a)
1	Green beans											43	42	81	**1 660**
		Carrot		81	69	54	60								**2 640**
1	Lettuce										87	68	92	87	**3 340**
		Lettuce	92	64	75	65									**2 960**
2	Potatoes		109	0								37	56	164	**7 320**
		Cabbage			81	41	60	82	36						**6 000**
10	Lucerne		92	74	45	18	18	41	21	36	73	96	91	114	**71 900**
5	Oats						41	21	40	81	111	127	29		**22 500**
1	Spinach		112	96								84	67	128	**4 870**
		Onion			136	68	80	62	60	40	91				**5 370**
4	Soybean		148	113	69								181	76	**23 480**
5	Ryegrass							182	41	80	164	187	49		**35 150**
1	Tomatoes		118	101	64							73	48	100	**5 040**
30	Maize		166	89	44							125	29	145	**179 400**
Total = 60														**Total**	**371 630**

This would provide for a mixed enterprise, economically viable irrigated farm with a manageable mix of row crops, vegetable cash crops, and pasture/forage crops suitable for livestock farming.

The above total estimate consumption per year is equivalent to an average of 619 mm/year of irrigation. The above two methods thus give a range of irrigation from 619 to 1 141 mm/year.

As the occurrence frequency of such "maximum" and "realistic" irrigation requirements cannot be predicted with any degree of certainty, a figure of an average of this range was used to determine the likely average annual irrigation water demand upon the Ntabelanga Dam, which, including allowance for wastage and losses) amounted to some 880 mm/year of irrigation applied over the total areas to be irrigated.

5. BULK RAW WATER SUPPLY SYSTEM

5.1 Introduction

Figure 2-4 shows the locations of high potential land that have been identified as being suitable for irrigation development.

It is proposed that these be developed as approximately 45 farming units with sizes ranging from 45 to 65 hectares. The total area of land that would be developed in this way has been estimated as 2 868 ha, of which 2 451 ha is located around the Tsolo area, and the remainder is located adjacent to the river downstream of the dam, and along the shoreline of the inundated area upstream of the dam.

The irrigable areas that have been identified adjacent to the water bodies (i.e. study Areas 1, 8, 9 and 13) can be supplied using mobile abstraction pumps, and quick-fit coupling pipeline distribution and irrigation systems. Areas 10 and 12 are considered to be too small and remote from the water source to justify a long and expensive bulk water supply system.

However, the other high potential irrigation areas located around Tsolo are of substantial area for which a bulk water supply could be justified. These land areas are, however, situated at elevations of between 140 m and 220 m above the Tsitsa River elevation, and between 17 and 32 km from the nearest point of the Tsitsa River, and the Ntabelanga Dam, respectively. This will therefore require significant pumping and conveyance systems to deliver raw water in bulk to these lands.

Applying an average irrigation application rate of 880 mm/yr, and a peak of 1 141 mm/yr, to these Tsolo irrigation areas totalling 2 451 ha, and allowing for up to 20 hours per day pumping to eliminate peak period energy usage, this produces the following water transfer pumping rate requirements:

- Peak daily pumping rate: 1.06 m^3/s
- Average pumping rate: 0.82 m^3/s

5.2 Bulk Raw Water Transfer Options

The identified higher potential farming units to be irrigated at Tsolo are located at elevations ranging from 930 to 1 090 m.a.s.l.. A minimum residual head of 20 m is required in the bulk water system at the edge of field so that the sprinkler systems on all farming units can be supplied by gravity.

Figure 5-2 shows these areas in more detail. They have been colour-coded to show the elevation ranges that they fall within.

5.3 Raw Water Source Alternatives

Two alternatives have been investigated as raw water source locations.

1. Alternative 1: At the Ntabelanga Dam raw water outlet works.
2. Alternative 2: At an abstraction weir and pumping station located in the Tsitsa River downstream of the dam, and as close to Tsolo as possible.

Alternative 1 would have a raw water pumping station located near to the inlet works of the proposed Ntabelanga WTW, and this would have a suction elevation range at a minimum of 915.0 m.a.s.l., and an average of approximately 937.0 m.a.s.l.

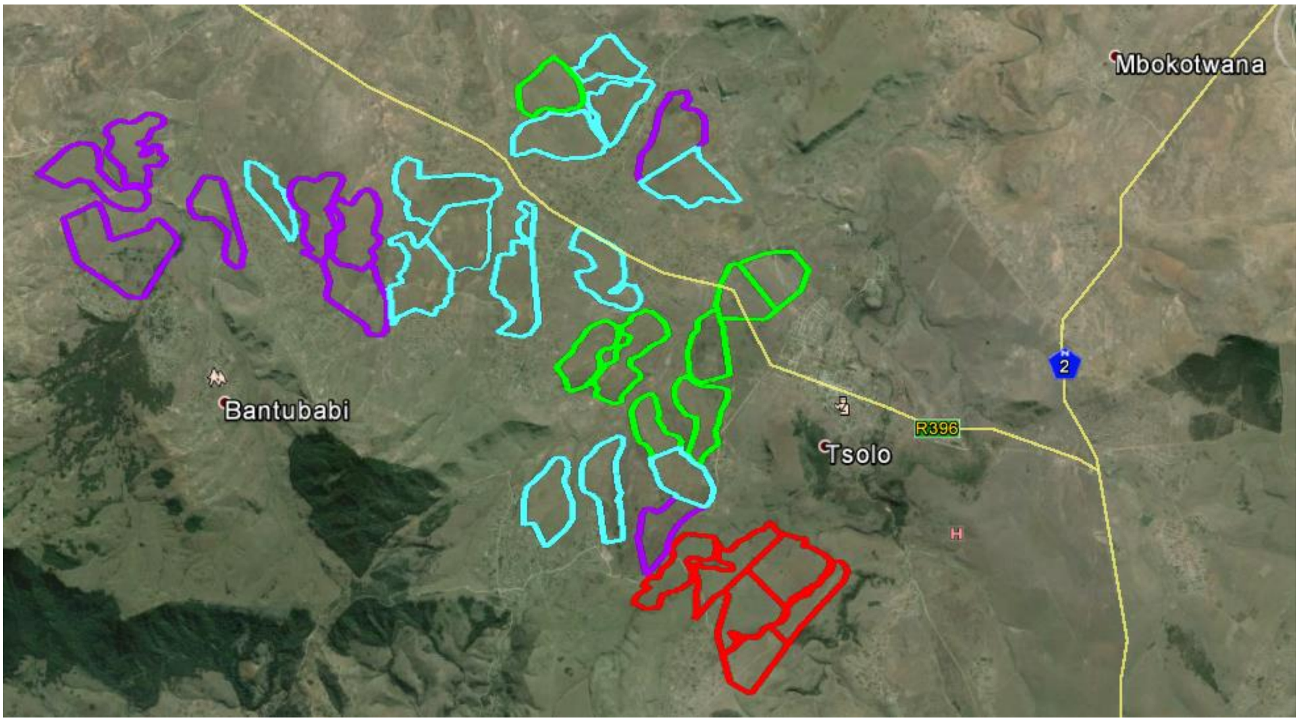


Figure 5-1: Elevations of Land with High Irrigation Potential

Key to Farm Unit Elevation Ranges:	
	930 to 1 000 m.a.s.l
	1 000 to 1 040 m.a.s.l
	1 040 to 1 080 m.a.s.l
	1 080 to 1 120 m.a.s.l

Alternative 2 abstracts raw water from the Tsitsa River downstream of the Ntabelanga Dam via an abstraction weir. This may require low lift pumps to transfer water from the river to a large settlement basin prior to high lift pumping onward to the Tsolo area. The river level at this location is 872.0 m.a.s.l., and this alternative therefore has between 43 and 65 m higher pumping head than Alternative 1.

5.4 Irrigation Water Distribution Options

Four options were investigated for irrigation water distribution:

Options 1 and 2 considered pumping raw water directly from the two alternative sources given above to a single command reservoir located at a strategic location and elevation, to control flow and maintain pressure along this single rising main. Branches off the rising main would then be fed to the edge of fields of the various irrigable land areas described above. Local distribution and sprinkler systems in-field would be provided by the farm unit operators.

One advantage of these options is the single pumping solution, but a disadvantage is that there will need to be pressure reduction on some branch lines and that all of the raw water is effectively being pumped to the maximum elevation. The end point command reservoir would also need to be an expensive reinforced concrete structure, as there is no suitable location at sufficient elevation for a simpler open, earth-bunded storage structure.

Options 3 and 4 considered breaking the delivery of the total bulk water transfer into a shorter rising main to an intermediate open-topped, earth-bunded storage tank, from where it gravitates flow to the distribution system supplying the majority of the land areas at elevations coded in green and blue on Figure 5-2.

The intermediate storage structure will have a volume of one day's storage of the full system demand, allowing for some flexibility in selection of pumping tariff bands, as well as catering for power outages. This storage facility is located on a ridge en route at an elevation of 1 068 m.a.s.l. Within this distribution system, two smaller booster pumping stations would be required to lift raw water further to those areas at higher elevation, shown in purple and red on Figure 5-2.

Smaller balancing storage tanks would be provided at the end points of the branch lines, which will effect pressure regulation and pump control, and have six hours storage to cater for short power outages. Figures 5-3 and 5-6 show the proposed alignments of these four options

A discounted cash flow/URV analysis was undertaken to optimally size the rising mains and raw water pumping configurations of Options 1 to 4. The results are summarized in Tables 5-1 to 5-4.

Table 5-1: URV Analysis of Raw Water Transfer – Option 1[2]

Raw Water - Option 1						
INTERNAL PIPE DIA (mm):>			**799**	**898**	**1000**	**1102**
MAX VELOCITY (m/s):			**2.11**	**1.67**	**1.35**	**1.11**
MAX HEAD: (m)			**349.30**	**277.86**	**237.80**	**218.98**
MAX POWER (kW):			**6 055**	**4 816**	**4 157**	**3 796**
URV (R/m^3)	4%		2.012	1.908	**1.906**	2.035
	6%		2.146	**2.085**	2.118	2.277
	8%		2.294	**2.279**	2.350	2.540
	10%		**2.451**	2.484	2.594	2.819

Table 5-2: URV Analysis of Raw Water Transfer – Option 2

Raw Water - Option 2						
INTERNAL PIPE DIA (mm):>			**799**	**898**	**1000**	**1102**
MAX VELOCITY (m/s):			**2.11**	**1.67**	**1.35**	**1.11**
MAX HEAD: (m)			**334.65**	**297.31**	**275.17**	**266.53**
MAX POWER (kW):			**5 801**	**5 153**	**4 809**	**4 620**
URV (R/m^3)	4%		1.630	1.576	**1.575**	1.642
	6%		1.690	**1.659**	1.676	1.759
	8%		1.758	**1.751**	1.787	1.887
	10%		**1.832**	1.849	1.907	2.024

[2] *NB: lowest URV for each discount rate marked in red*

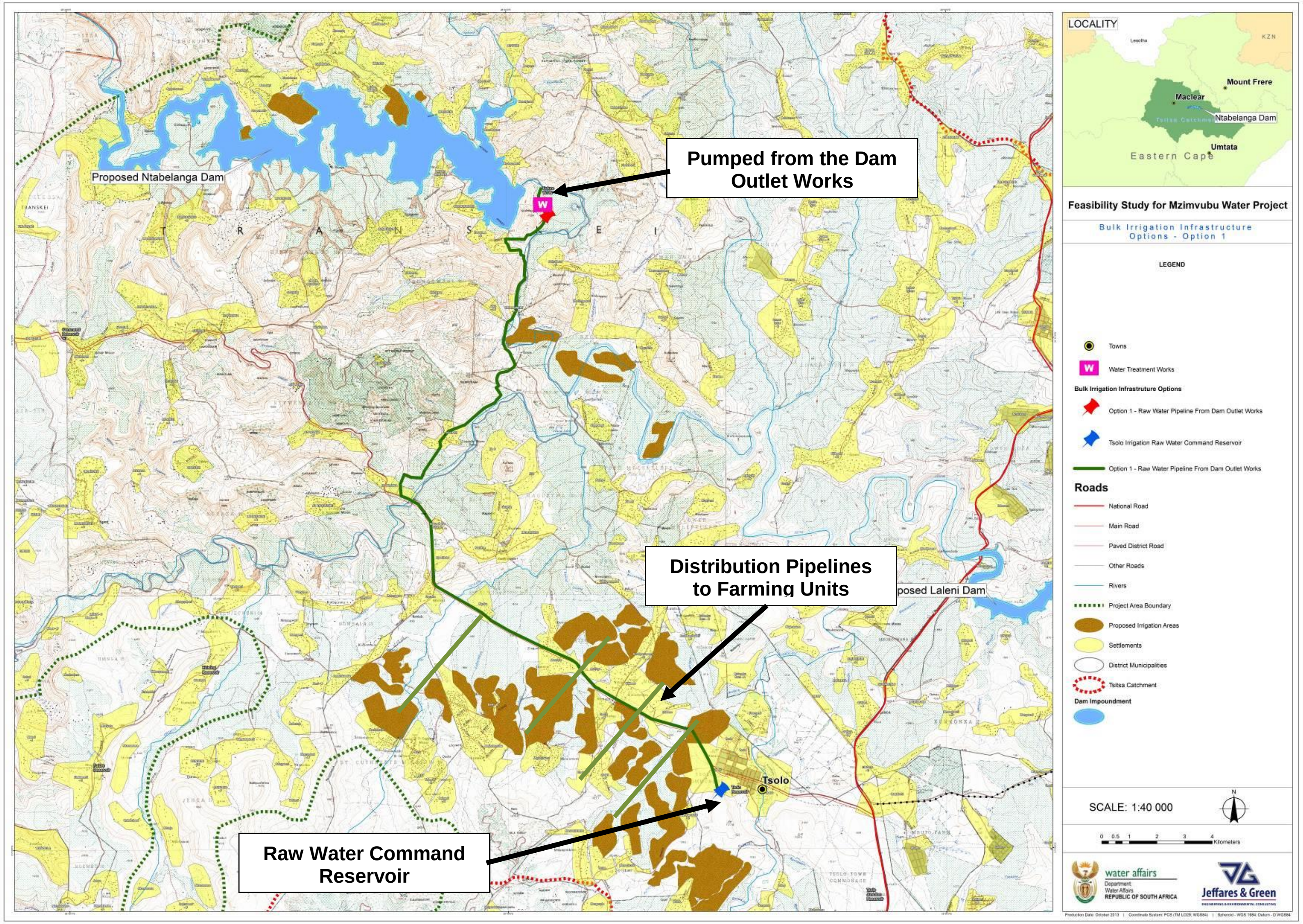


Figure 5-2: Overall Layout Plan of Option 1

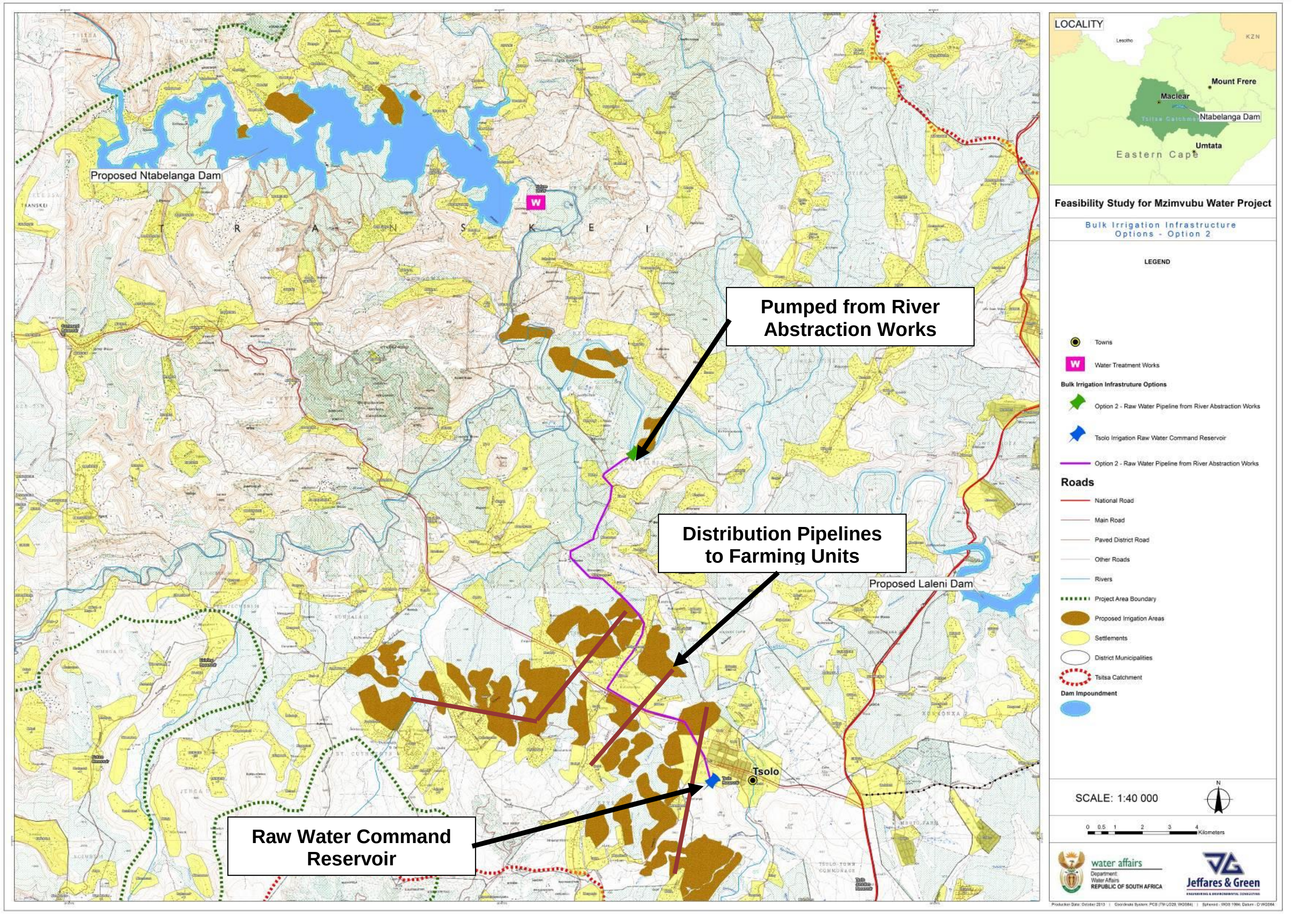


Figure 5-3: Overall Layout Plan of Option 2

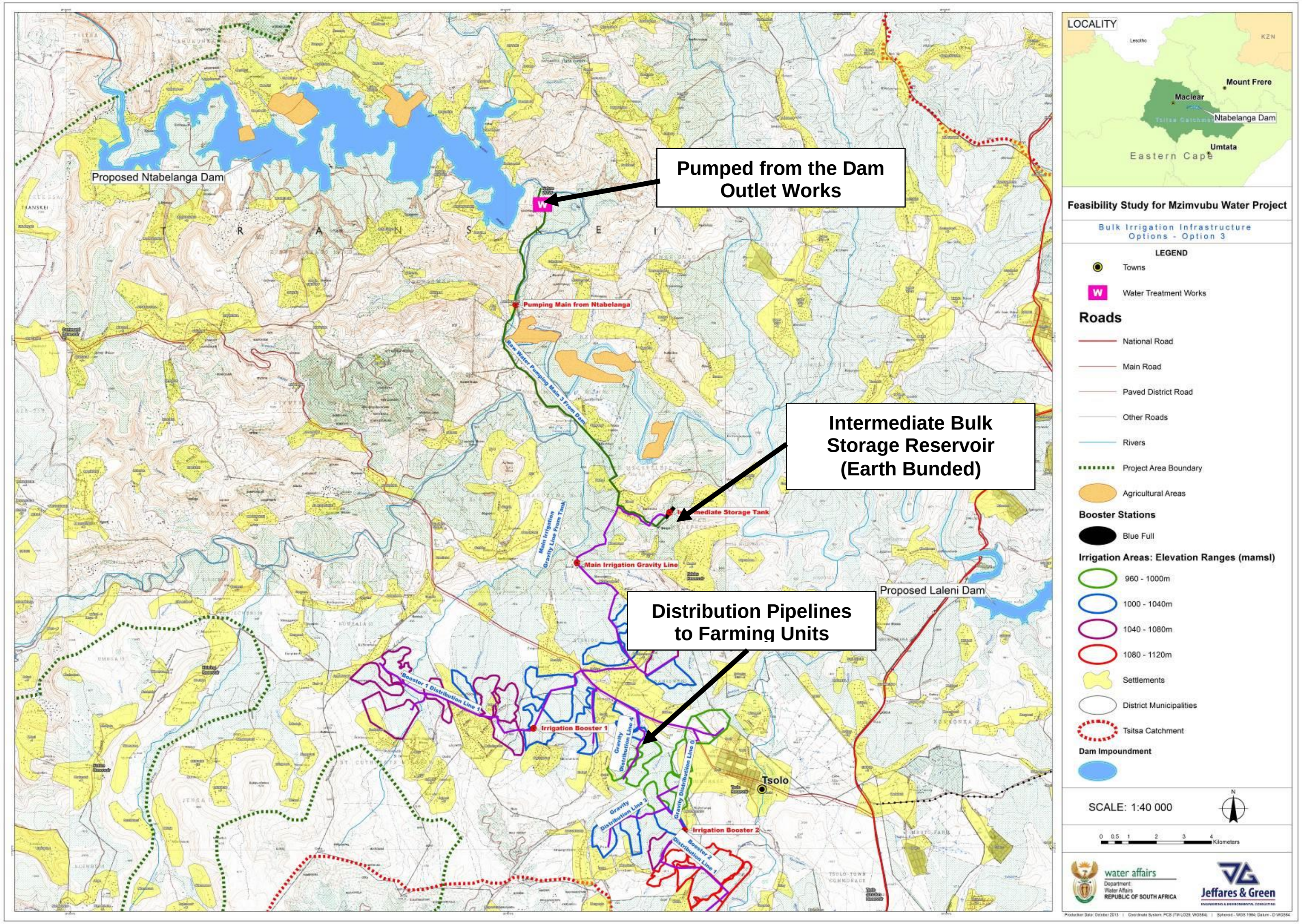


Figure 5-4: Overall Layout Plan of Option 3

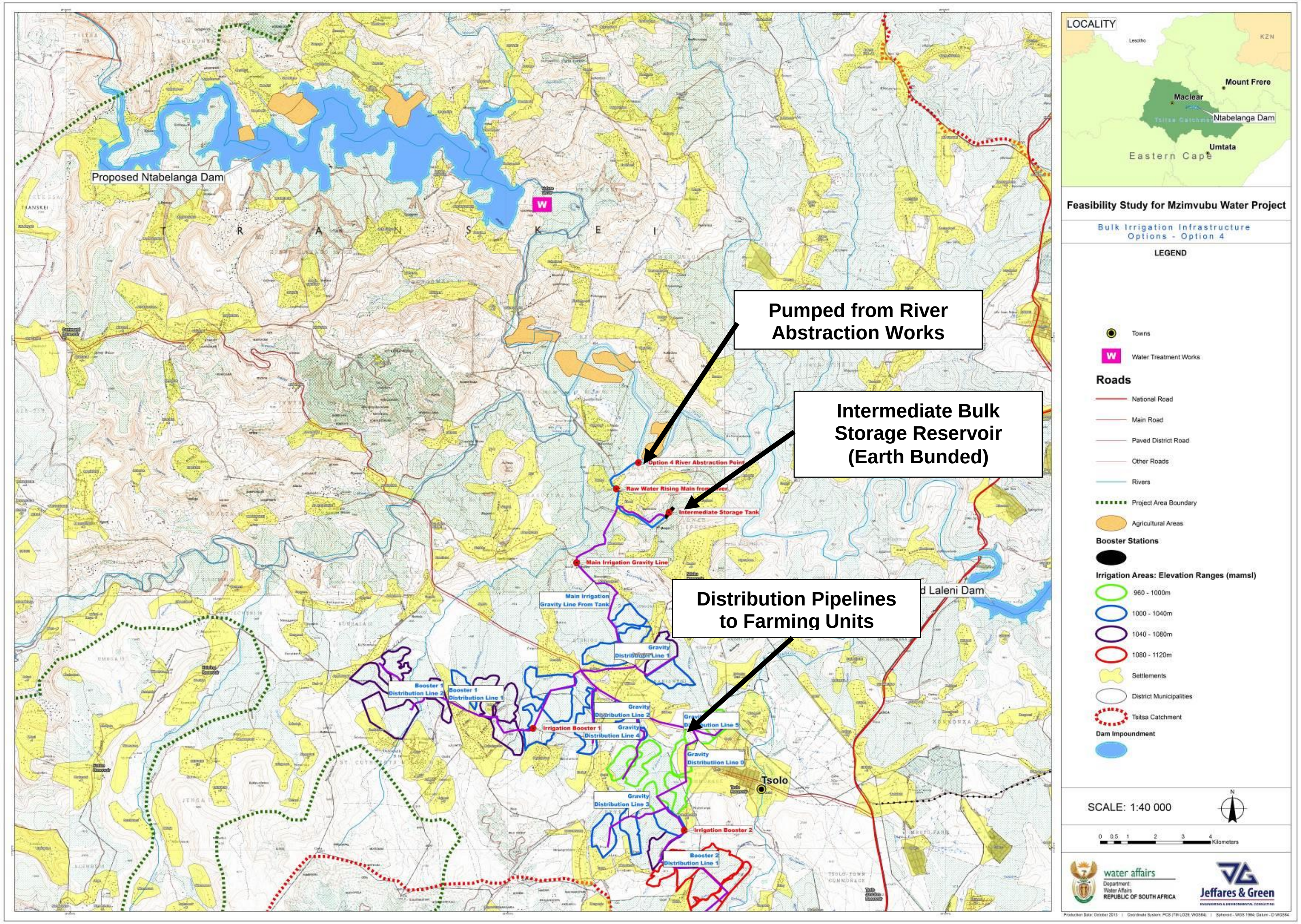


Figure 5-5: Overall Layout Plan of Option 4

Table 5-3: URV Analysis of Raw Water Transfer – Option 3

Raw Water - Option 3						
INTERNAL PIPE DIA (mm):>			**799**	**898**	**1000**	**1102**
MAX VELOCITY (m/s):			**2.11**	**1.67**	**1.35**	**1.11**
MAX HEAD: (m)			**232.65**	**197.04**	**178.07**	**167.69**
MAX POWER (kW):			**4 033**	**3 415**	**3 087**	**2 907**
URV (R/m³)	**4%**		1.225	1.174	**1.173**	1.237
	6%		1.289	**1.258**	1.275	1.354
	8%		1.359	**1.351**	1.386	1.482
	10%		**1.434**	1.450	1.505	1.617

Table 5-4: URV Analysis of Raw Water Transfer – Option 4

Raw Water - Option 4						
INTERNAL PIPE DIA (mm):>			**799**	**898**	**1000**	**1102**
MAX VELOCITY (m/s):			**2.11**	**1.67**	**1.35**	**1.11**
MAX HEAD: (m)			**230.24**	**220.82**	**215.80**	**213.05**
MAX POWER (kW):			**3 991**	**3 828**	**3 741**	**3 693**
URV (R/m³)	4%		1.105	1.092	**1.091**	1.108
	6%		1.117	**1.109**	1.113	1.134
	8%		1.132	**1.130**	1.139	1.164
	10%		**1.148**	1.153	1.167	1.197

Optimum pipe sizing lies between 914 mm and 1016 mm dia. and given that these URVs are within a few percent of each other, the recommendation would be made to opt for the larger sized pipeline, in order to reduce power costs and the risk of increased operating costs in the future.

In all options therefore, the 1016 mm dia pipeline is recommended.

5.5 Raw Water Pumping Configurations

The raw water pumping configurations for these options are based upon locally-available pumps suitable for the duties required and able to deal with sediment laden water.

5.5.1 Option 1

Table 5-5 summarises the Option 1 pump station and rising main characteristics.

Due to the high lift the *Curo* pumps were again used to give an example of the performance and pump arrangement that can be expected. This pump station would be located close to the Ntabelanga Dam WTW, and could either be a stand-alone pump station with layout as illustrated on other stations above, or could be integrated within the WTW clear water pump station structure but having a separate inlet and outlet stream.

Table 5-5: Option 1 Pump Station Characteristics

Raw Water Pump Station Option 1				
2050 capacity	1 060.00	l/s =	3 816	m^3/hr
Rising main				
Length	32900	m	Stat head	182.00
Diameter	1016	mm	Dyn head	55.80
Class			Total	237.80
Wall thk	8	mm		
ID	1000	mm		
ID	1	m		
A	0.785	m^2		
V	1.35	m/s		
Pumps				
Duty	Head	237.80		
	$^1/_5$ Flow	763.20	m^3/hr	
		212.00	l/s	
Pumps	5 x Curo 250/300 4-stage			

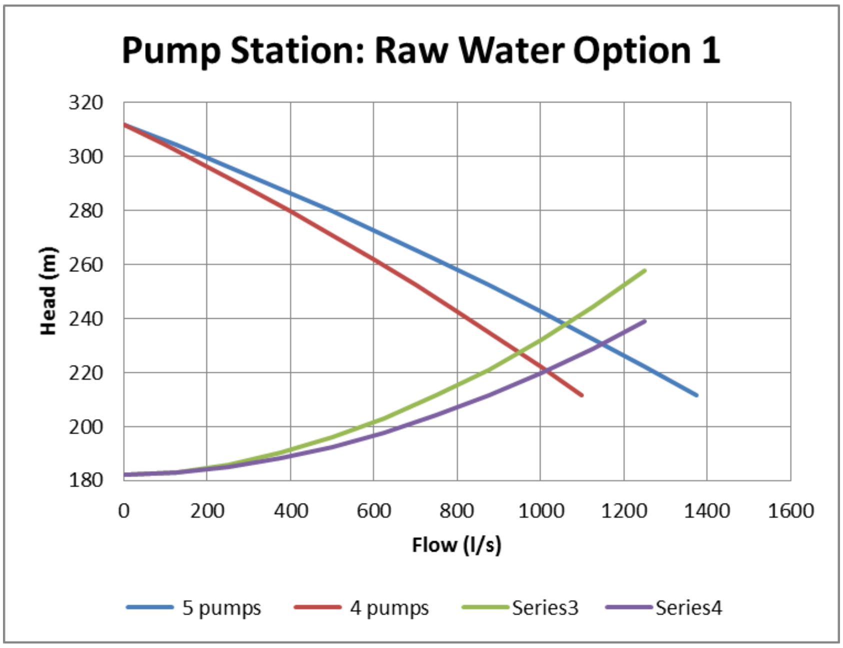


Figure 5-6: Option 1 – System Curve

5.5.2 Option 2

Table 5-6 summarises the Option 2 pump station and rising main characteristics.

Table 5-6: Option 2 Pump Station Characteristics

Raw Water Pump Station Option 2				
2050 capacity	1 060.00	l/s =	3 816	m³/hr
Rising main				
Length	17200	m	Stat head	246.00
Diameter	1016	mm	Dyn head	29.17
Class			Total	275.17
Wall thk	8	mm		
ID	1000	mm		
ID	1	m		
A	0.785	m²		
V	1.35	m/s		
Pumps				
Duty	Head	275.17		
	$^{1}/_{5}$ Flow	763.20	m³/hr	
		212.00	l/s	
Pumps	5 x Curo 250/300 4-stage			

Due to the high lift the *Curo* pumps were again used to give an example of the performance and pump arrangement that can be expected. The difference between Option 1 and Option 2 pumps would be the impellor sizes. This pump station would be located on the bank of the Tsitsa River at a suitable location as near as possible to the proposed Tsolo irrigated farming units. A river weir and intake works will also be required, and should be designed to reject sediment build-up.

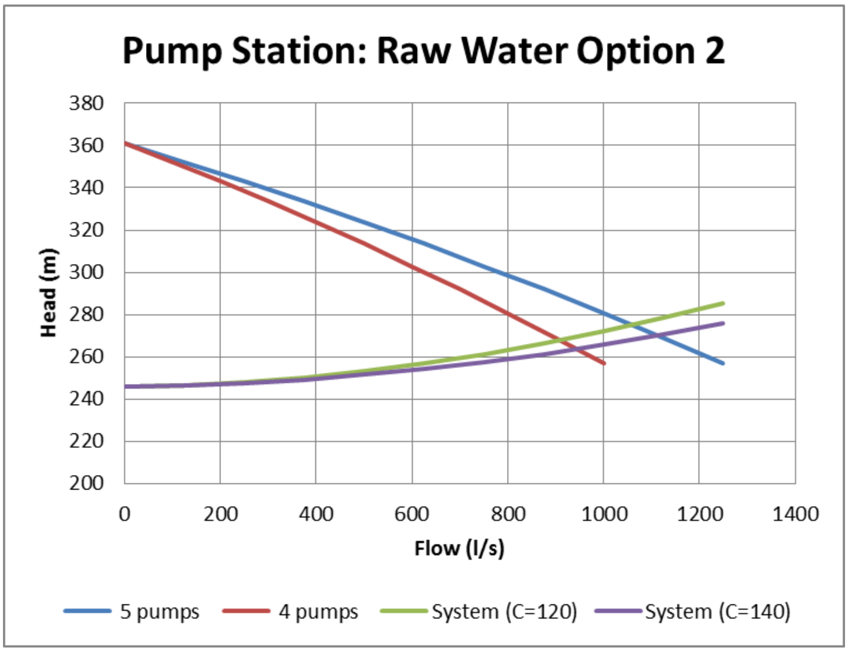


Figure 5-7: Option 2 – System Curve

5.5.3 *Option 3*

Table 5-7 summarises the Option 3 pump station and rising main characteristics.

Table 5-7: Option 3 Pump Station Characteristics

Raw Water Pump Station Option 3				
2050 capacity	1 060.00	l/s =	3 816	m^3/hr
Rising main				
Length	16400	m	Stat head	151.00
Diameter	1016	mm	Dyn head	27.82
Class			Total	178.82
Wall thk	8	mm		
ID	1000	mm		
ID	1	m		
A	0.785	m^2		
V	1.35	m/s		
Pumps				
Duty	Head	178.82		
	$^1/_5$ Flow	763.20	m^3/hr	
		212.00	l/s	
Pumps	5 x Curo 250/300 4-stage			

Due to the high lift the *Curo* pumps were again used to give an example of the performance and pump arrangement that can be expected. The difference between Option 1 and Option 3 pumps would be the impellor sizes.

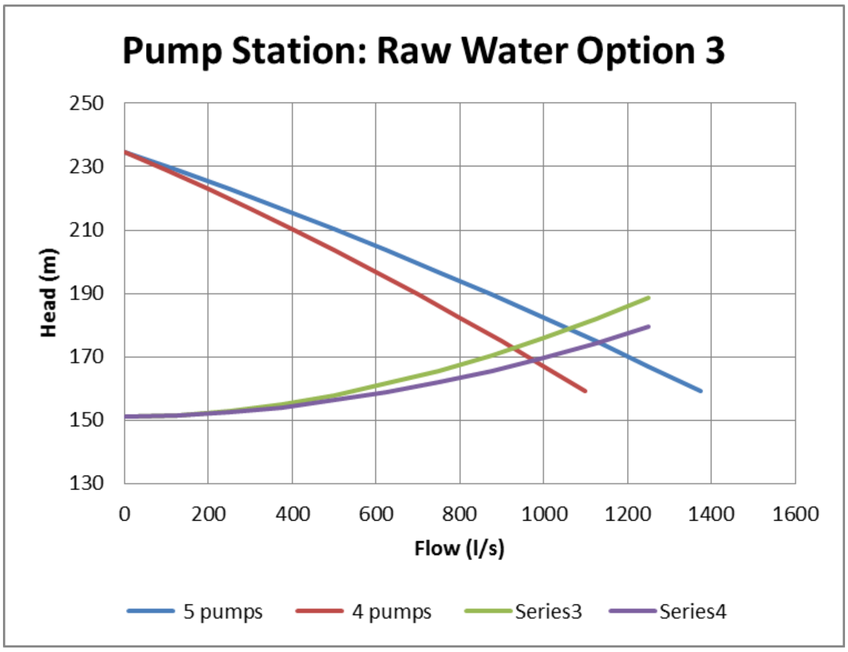


Figure 5-8: Option 3 – System Curve

5.5.4 Option 4

Table 5-8 summarises the Option 4 pump station and rising main characteristics.

Table 5-8: Option 4 Pump Station Characteristics

Raw Water Pump Station Option 4				
2050 capacity	1 060.00	l/s =	3 816	m³/hr
Rising main				
Length	4340	m	Stat head	208.50
Diameter	1016	mm	Dyn head	7.36
Class			Total	215.86
Wall thk	8	mm		
ID	1000	mm		
ID	1	m		
A	0.785	m²		
V	1.35	m/s		
Pumps				
Duty	Head	215.86		
	1/5 Flow	763.20	m³/hr	
		212.00	l/s	
Pumps	5 x Curo 250/300 4-stage			

Due to the high lift the *Curo* pumps were again used to give an example of the performance and pump arrangement that can be expected. The difference between Option 2 and Option 4 pumps would be the impellor sizes.

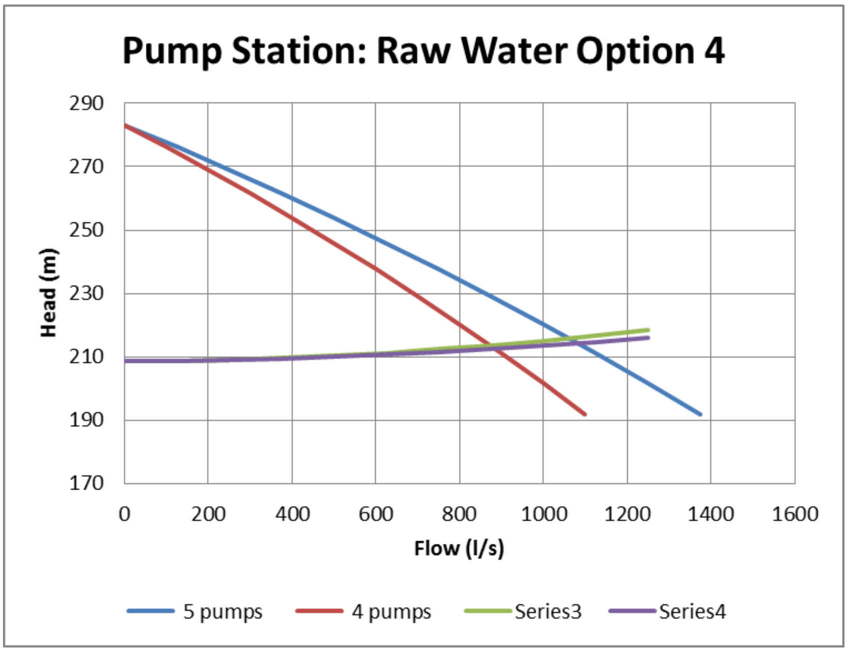


Figure 5-9: Option 4 – System Curve

In all options the duty point when using five duty pumps, each delivering 212 l/s was considered. Two additional pumps should be provided as standby/backup. The pumps are likely to be 2.0 m long and 1 m wide and high. Motors will be a similar size and a clear distance of 1.5 m between plinths has been allowed in the sizing of the building.

5.6 Bulk Distribution to Edge of Field

Figure 5-11 shows a conceptual layout of the bulk raw water distribution to the edge of each farming unit.

This has been developed based upon the possible farming units that could be developed but will need to be reviewed and optimized in more detail once the final configuration and approach taken farming units has been decided.

As shown on Figure 5-11, smaller balancing storage tanks would be provided at the end points of the branch lines, which will effect pressure regulation and pump control, and have six hours storage to cater for short power outages. Thus each farming unit would be able to connect into the bulk water distribution system pipelines at "edge of field" as shown in white on Figure 5-11, which, supported by the elevated balancing tanks also shown on the same figure, would provide and maintain an adequate and consistent water pressure for irrigation of each farming unit through the in-field irrigation reticulation system to be installed on each farm.

5.7 Bulk Raw Water System - Capital Works and Operating Costs

Full details of cost estimates for Options 1 to 4 are given in the Cost Estimates and Economic Analysis Report No. P WMA 12/T30/00/5212/15. All costs are based upon 2014 price levels, and this includes power tariffs.

In each case, the costs of both raw water pumping system and the distribution systems to deliver water to edge of field has been included.

In the case of Options 3 and 4, the distribution systems are identical.

These capital costs, and the estimated annual operation and maintenance costs are summarized in Tables 5-9 to 5-12.

Table 5-9: Annual Operation and Maintenance Costs: Option 1

OPTION 1 - IRRIGATION PIPELINE DIRECT FROM DAM						
ITEM	**DESCRIPTION**	**AMOUNT**		**O&M per year**		
1	Pipelines	R	373 932 964	0.50%	R	1 869 665
2	Abstraction works	R	15 000 000	0.25%	R	37 500
3	Pumpstations	R	19 313 896	4%	R	772 556
4	Reservoirs	R	45 000 000	0.25%	R	112 500
5	Electrical supply	R	30 000 000	4%	R	1 200 000
6	Contingencies	R	48 324 686	1%	R	483 247
7	Engineering fees	R	31 894 293			
	Allowance for M&E depreciation and replacement funding				R	1 931 390
	Total 1	**R**	**563 465 839**		**R**	**6 406 857**
	VAT	R	78 885 217		R	896 960
	Total	**R**	**642 351 057**		**R**	**7 303 817**
				Tot. Water		
O&M Cost for supply of raw water to edge of field excluding power				21 240 366		R 0.34
Power Cost per year		**R**	**20 063 277**	21 240 366		R 0.94
Cost for supply of raw water to edge of field including power				**R/m³**		**R 1.29**

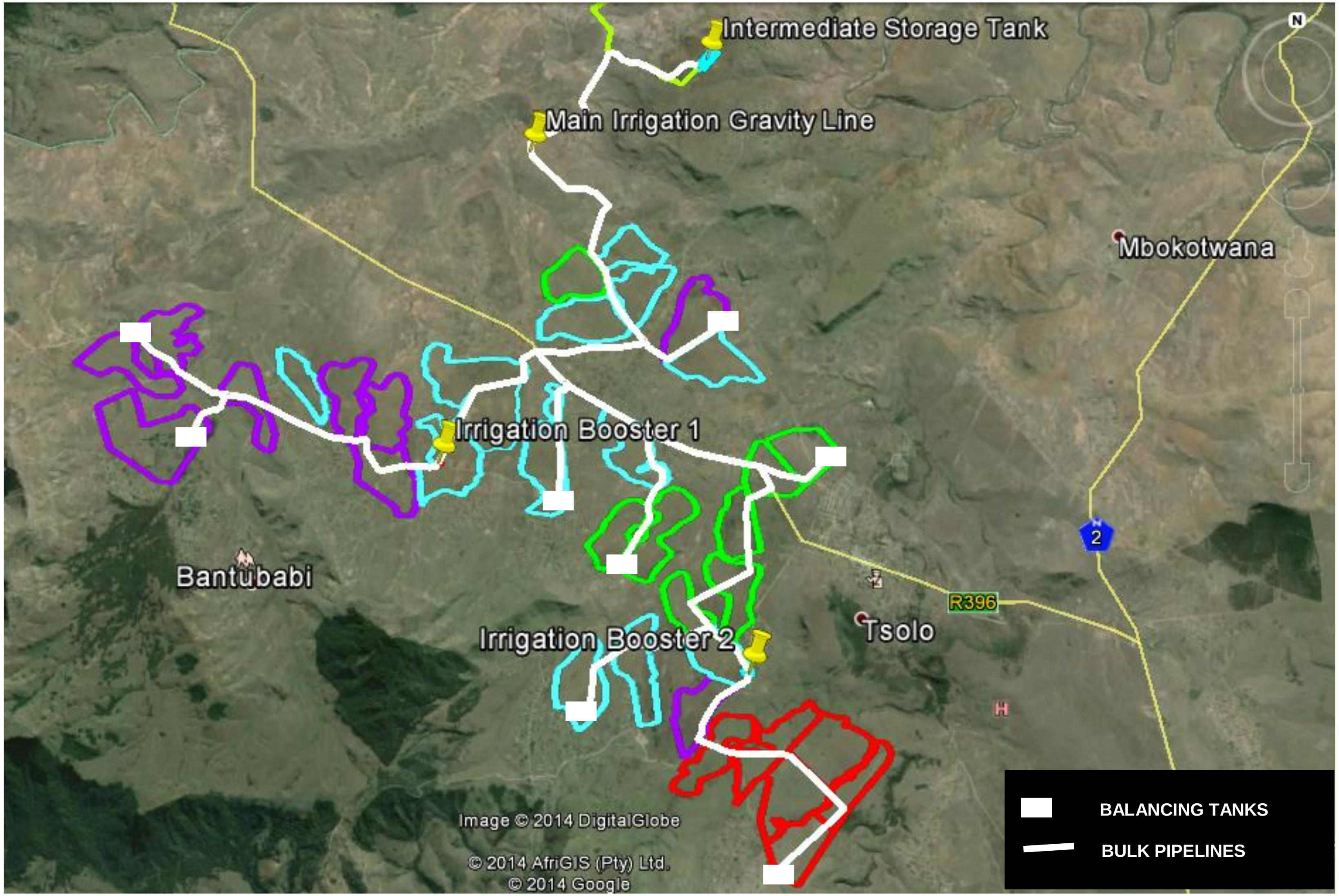


Figure 5-10: Detail of Conceptual Bulk Distribution to "Edge of Field"

Table 5-10: Annual Operation and Maintenance Costs: Option 2

OPTION 2 - IRRIGATION PIPELINE ABSTRACTED FROM RIVER						
ITEM	DESCRIPTION	AMOUNT		O&M per year		
1	Pipelines	R	212 117 272	0.50%	R	1 060 586
2	Abstraction works	R	25 000 000	0.25%	R	62 500
3	Pumpstations	R	21 910 061	4%	R	876 402
4	Reservoirs	R	45 000 000	0.25%	R	112 500
5	Electrical supply	R	30 000 000	4%	R	1 200 000
6	Contingencies	R	33 402 733	1%	R	334 027
7	Engineering fees	R	22 045 804			
	Allowance for M&E depreciation and replacement funding				R	2 191 006
	Total 1	**R**	**389 475 870**		**R**	**5 837 022**
	VAT	R	54 526 622		R	817 183
	Total	**R**	**444 002 492**		**R**	**6 654 205**
				Tot. Water		
O&M Cost for supply of raw water to edge of field excluding power				21 240 366		R 0.31
Power Cost per year		**R**	**22 760 173**	21 240 366		R 1.07
Cost for supply of raw water to edge of field including power				**R/m^3**		**R 1.38**

Table 5-11: Annual Operation and Maintenance Costs: Option 3

OPTION 3 - IRRIGATION PIPELINE DIRECT FROM DAM						
ITEM	DESCRIPTION	AMOUNT		O&M per year		
1	Pipelines	R	405 636 748	0.50%	R	2 028 184
2	Abstraction works	R	8 000 000	0.25%	R	20 000
3	Pumpstations	R	23 280 152	4%	R	931 206
4	Reservoirs	R	50 000 000	0.25%	R	125 000
5	Electrical supply	R	10 000 000	4%	R	400 000
6	Contingencies	R	49 691 690	1%	R	496 917
7	Engineering fees	R	32 796 515			
	Allowance for M&E depreciation and replacement funding				R	956 515
	Total 1	**R**	**579 405 105**		**R**	**4 957 822**
	VAT	R	81 116 715		R	694 095
	Total	**R**	**660 521 820**		**R**	**5 651 917**
				Tot. Water		
O&M Cost for supply of raw water to edge of field excluding power				21 240 366		R 0.27
Power Cost per year		**R**	**18 559 958**	21 240 366		R 0.87
Cost for supply of raw water to edge of field including power				**R/m^3**		**R 1.14**

Table 5-12: Annual Operation and Maintenance Costs: Option 4

OPTION 4 - IRRIGATION PIPELINE DIRECT FROM DAM				O&M per year		
ITEM	DESCRIPTION	AMOUNT				
1	Pipelines	R	281 337 560	0.50%	R	1 406 688
2	Abstraction works	R	33 000 000	0.25%	R	82 500
3	Pumpstations	R	25 044 951	4%	R	1 001 798
4	Reservoirs	R	50 000 000	0.25%	R	125 000
5	Electrical supply	R	30 000 000	4%	R	1 200 000
6	Contingencies	R	41 938 251	1%	R	419 383
7	Engineering fees	R	27 679 246			
	Allowance for M&E depreciation and replacement funding				R	1 132 995
	Total 1	**R**	**489 000 008**		**R**	**5 368 364**
	VAT	R	68 460 001		R	751 571
	Total	**R**	**557 460 010**		**R**	**6 119 934**
				Tot. Water		
O&M Cost for supply of raw water to edge of field excluding power				21 240 366		R 0.29
Power Cost per year		**R**	**21 309 869**	21 240 366		R 1.00
Cost for supply of raw water to edge of field including power				**R/m³**		**R 1.29**

It is clear that these irrigated farming units would not be viable should full capital redemption be taken into account. In the analyses undertaken, it has been assumed that all capital costs would be grant funded and will not have a capital redemption requirement. Whilst this is not in accordance with the current water pricing policy, the intention is to determine the annual costs of operating the scheme so that the impact of cross-subsidization on unit cost of water supplied can be understood. As is shown, the capital cost requirements for Options 2 and 4 are significantly less than for Options 1 and 2.

Operation and maintenance costs per annum have been estimated using the percentages of capital cost of the various components of the scheme as recommended in the DWS Technical Guidelines. An additional allowance has been made to set aside funds for recurrent depreciation/replacement on capital items such a pumps, valves, and similar equipment.

Dividing these annual operation and maintenance costs thus calculated by the average raw water supplied in the same period, produces a unit cost of between R0.27/m^3 and R0.34/m^3 with Option 3 having the lower operation and maintenance cost excluding energy consumption.

Power costs per annum were also calculated using the existing ESKOM Ruraflex tariff at a load factor of 75%, which uses an average tariff of R0.84/kWh.

Using this existing power tariff, and dividing total power cost by the raw water supplied in a year, the unit power cost of water ranges from R0.87/m^3 to R1.07/m^3, with Option 3 having the lowest unit power cost per m^3.

Overall Option 3 has the lowest unit water supplied cost of R1.14/m^3, excluding capital redemption but including funding of periodical capital infrastructure replacement.

Therefore, if the effective cost of power supplied to the scheme can be reduced through the benefits gained by generation of hydropower at Ntabelanga and Lalini, (i.e. cross-subsidized by grant-funding hydropower capital cost), the viability of irrigated agriculture development within the scheme could still be possible.

This key issue is discussed in more detail in the Cost Estimates and Economic Analysis

Report No. P WMA 12/T30/00/5212/15, where the overall viability of the multi-purpose scheme is analysed.

5.8 Conclusion

The above analyses shows Option 3 to be the preferred solution.

Whilst this has a higher capital cost than other solutions, the lower unit cost of water (assuming grant funding of CAPEX) puts this option as the highest ranked.

In addition, drawing water from the Ntabelanga Dam rather directly from the river will produce a pre-settled, lower sediment content, raw water that will not require additional settlement basins, and this will also reduce the risk of operation and maintenance problems within the new farming units.

Option 3 has the lowest energy requirement of the four options, with the main pumping station located at the same position as the Ntabelanga WTW, which simplifies the operational management at a single location, and confines the main input and output power supply lines to a common switching and transformer site.

The two smaller booster raw water pumping stations can be supplied with power by connection to the existing grid in the Tsolo Area.

The layout of the proposed raw water pump station located at the Ntabelanga Dam WTW site is shown overleaf in Figure 5-11.

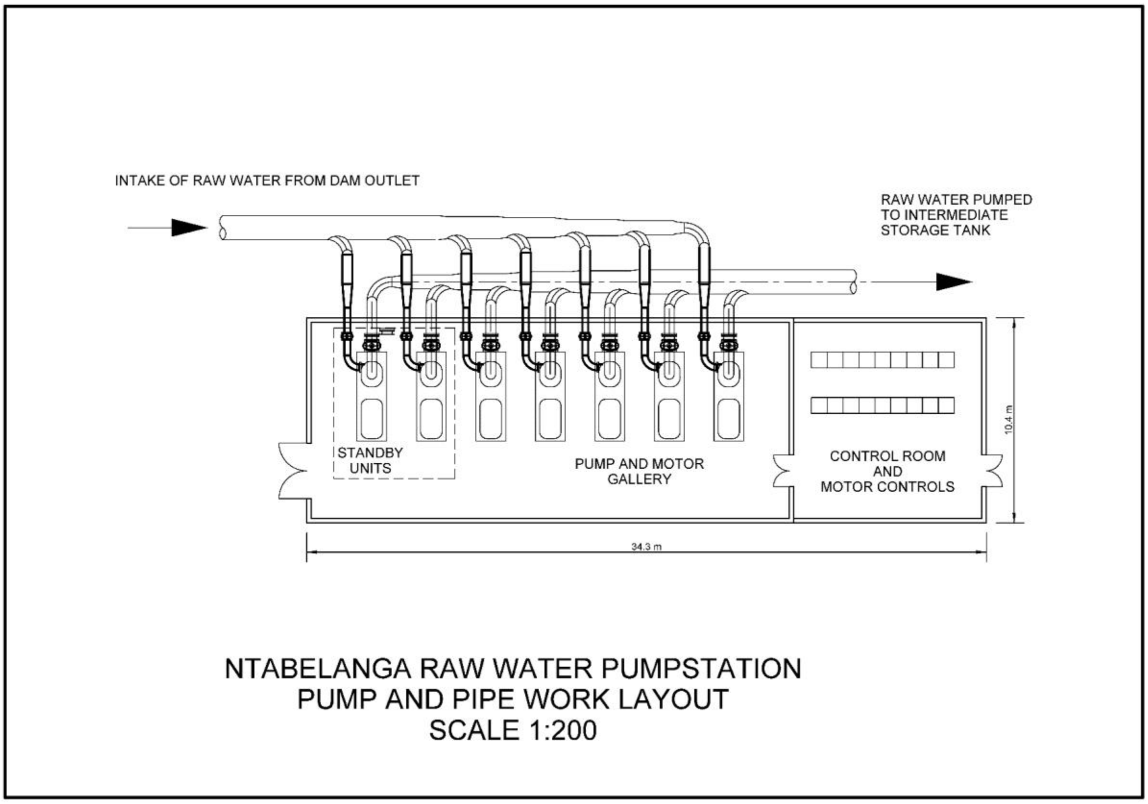


Figure 5-11: Ntabelanga Bulk Raw Water Pump Station Layout

6. AGRICULTURAL ECONOMICS

6.1 Gross Margin Analysis

Gross Margin Analysis (GMA) has been carried out for the sample crops listed in Table 4-2. This gives a good indication of the economic viability of the farms, given any crop mix from the options studied.

The definition of gross margin (GM) is the selling price of produce minus the direct cost of growing the produce. It excludes indirect costs, such as the cost of borrowing money and administrative expenses. The estimate yield and gross margin per crop type in the Tsolo area are given in Table 6-1:

Table 6-1: Estimated Yields and GMA per Crop

CROP	YIELD Tons/ha	GMA Rand
Cabbage	50	R 13 288.69
Carrot	30	R 55 839.86
Green Bean	8	R 32 173.90
Ryegrass	10	R 2 252.20
Lettuce	20	R 29 560.02
Lucerne	18	R 13 138.14
Lupin	3	R 6 657.16
Maize	8	R 4 034.35
Oats	7	R 7 953.00
Onion	25	R 12 127.34
Potatoes	30	R 11 741.47
Soya bean	3	R 4 741.99
Spinach	20	R 30 825.24
Tomatoes	35	R 16 819.57

6.2 Farm Output

The gross margin is the income over and above the direct costs of producing the goods, which include the costs of inputs such as seeds and fertiliser, the costs of planting and machinery, and the costs of labour, for example. From this, the farmer would need to draw a salary, pay the interest and capital redemption on any loans, and pay for any other services he may require such as crop insurance etc.

Based on the Gross Margin Analysis for various crops, being a reasonable mix of vegetables, row crops and pasture/forage crops, a typical 60 ha farm could produce the output in Table 6-2. Thus, in the Tsolo area, a gross margin of R580 737 could be realistically achievable for a 60 ha irrigated farm with the above mixed enterprise.

Table 6-2: Typical Annual Gross Margin for a 60 ha Mixed Enterprise Farm

Cropped area (ha)	Crop 1	Crop 2	GMA crop 1 (R/ha)	GMA crop 2 (R/ha)	Annual GM (R)
1	Green beans		R 32 173.90		R 88 013.76
		Carrot		R 55 839.86	
1	Lettuce		R 29 560.02		R 59 120.04
		Lettuce		R 29 560.02	
2	Potatoes		R 11 741.47		R 50 060.32
		Cabbage		R 13 288.69	
10	Lucerne		R 13 138.14		R 131 381.40
5	Oats		R 7 953.00		R 39 765.00
1	Spinach		R 30 825.24		R 42 952.58
		Onion		R 12 127.34	
4	Soybean		R 4 741.99		R 18 967.96
5	Ryegrass		R 2 525.20		R 12 626.00
1	Tomatoes		R 16 819.57		R 16 819.57
30	Maize		R 4 034.35		R 121 030.50
60					**R 580 737.13**

Whilst every parcel of land that has been identified as being of high irrigation potential has a different shape and topography, a generic farm layout was developed to show a typical setup arrangement and mix of crops that could be grown. This is shown in Figure 6-1.

General irrigation of pastures for the grazing of livestock is likely to be non-viable. However, the mix of crops can include a number of forage and pasture crops (lucerne, oats and ryegrass) from which high quality hay and animal feed could be produced and sold to livestock farmers.

In this economic analyses undertaken, the assumed total unit cost of raw water supplied to edge of field was approximately R0.40/m^3. This compares with the R1.14/m^3 total unit cost given for Option 3.

Given that a typical farming unit as described in this report is estimated to use some 371 600 m^3/per year, then a R0.71/m^3 increase in unit cost over the R0.40/m^3 figure used in the calculation would reduce the net surplus income per annum to some R305 460.

Such surpluses are required to repay loans, and refurbish equipment etc. and it must be questioned whether such a lower surplus income would provide enough return on the investment required on each farming unit.

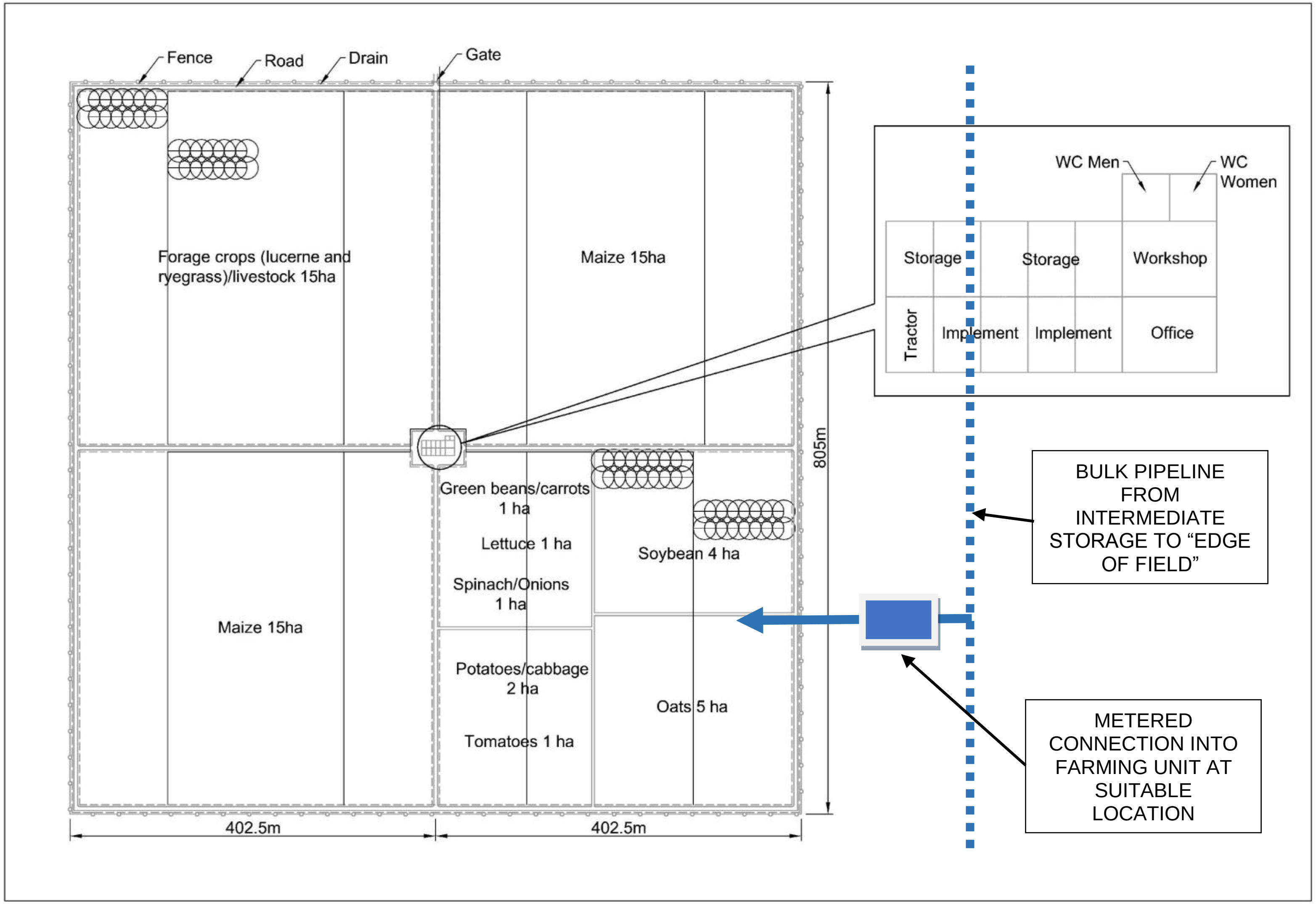


Figure 6-1: Typical Arrangement of a 60 ha Farming Unit

Clearly some subsidization of this unit cost of raw water must be made if the irrigation schemes are to be viable and sustainable. The Department of Rural Development and Agrarian Reform (DRDAR) suggested that a figure of R0.25/m^3 would be a reasonable target to ensure that gross margins are higher than that given above, and thus attractive enough to encourage investment into commercial irrigated agriculture.

It must also be noted that power tariffs will likely continue to increase at a greater rate than the escalation of prices of the produce sold by these farms, further reducing the surplus income available per farm.

This emphasizes the need to cross-subsidize the Ntabelanga scheme with revenue gained from the energy sales generated by the Lalini Dam and hydropower scheme.

6.3 Employees per Farming Unit

Based on a 60 ha farming unit, and a portable quick-coupling sprinkler system, the following employees are proposed per farming unit.

For this model, each farming unit would employ 75 permanent labour and between 20 and 30 seasonal labour, depending on what vegetables are grown and when they need harvesting. See Figure 6-2.

Based on the 45 farming units proposed (with an average size of approximately 60 ha per farm), some 3 375 permanent jobs would be created and up to 1 350 seasonal workers would be employed.

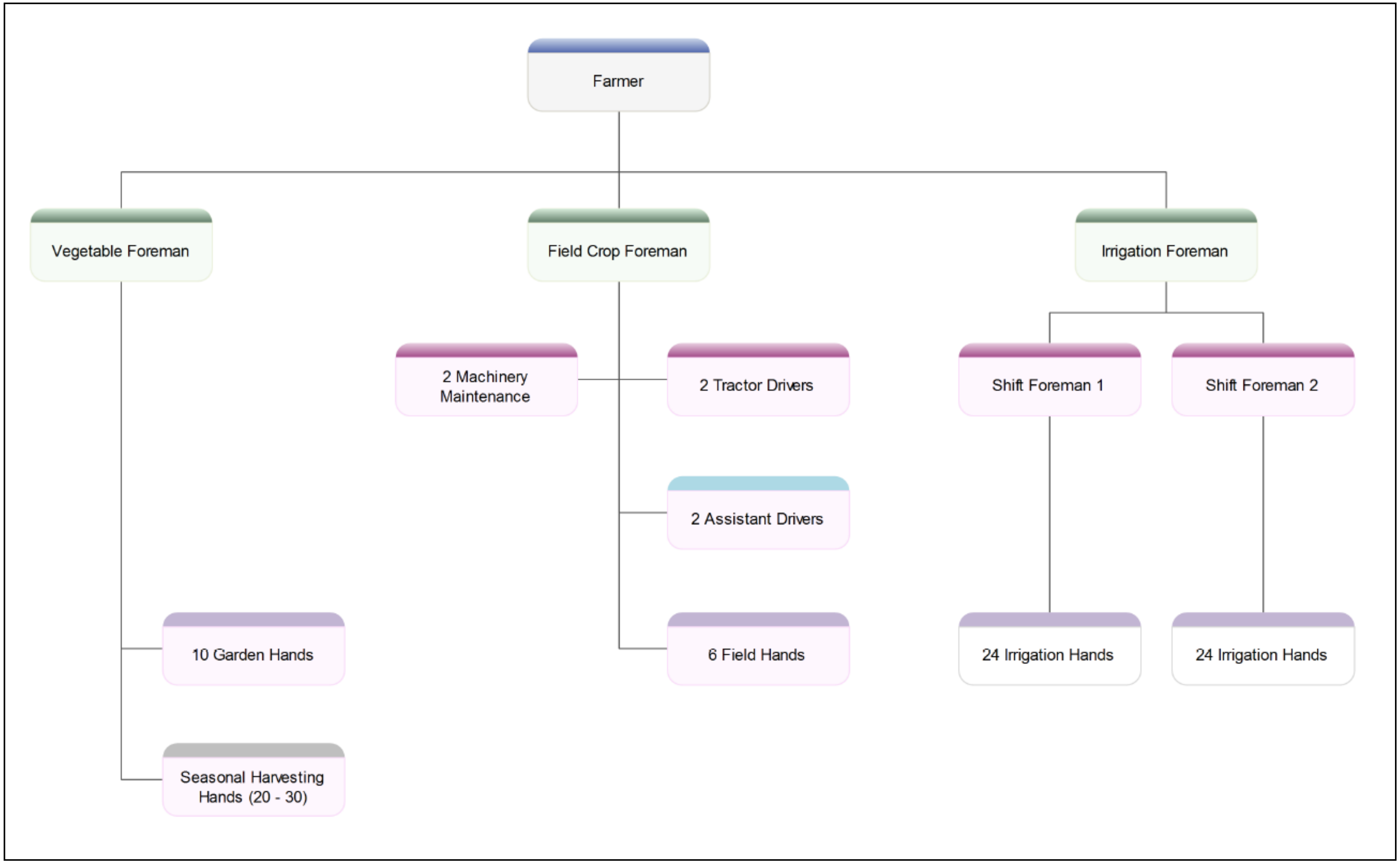


Figure 6-2: Typical Farming Unit Organogramme

7. CONCLUSIONS

7.1 Agricultural Water Use

2 868 ha of potential irrigable land has been identified which could be supplied with water from the Ntabelanga Dam. This land can be reasonably grouped into 45 farming units of approximately 60 ha each.

Depending on what crop mix is planted in each farming unit, the water demand from the dam is expected to be between a minimum of 17.8 million m^3/a and a maximum of 32.7 million m^3/a. An average application rate of 880 mm/a was applied to the above irrigable areas, which after allowing 10% for losses, gives an average annual irrigation raw water requirement of 27.8 million m^3/a.

7.2 Land Matters

A commercial model of irrigation farming has been proposed to ensure that the farms are economically sustainable and viable. This will require the introduction of new technology to the area, and will require a change from the traditional system of communal dry land farming administered by local Traditional Leaders, as currently in practice in the area. This will require extensive public consultation. Failure to get inclusive support from the community, local and Traditional Leaders and all spheres of Government, currently represents the greatest risk of failure to the irrigation project.

The size of farming units has been determined, based on each having the potential to be economically sustainable, and to justify the ownership of a farm tractor and implements per farming unit. This has been determined as 60 ha units. The available land has been realistically apportioned into 45 farming units with an average size of 63.7 ha each.

It is recommended that the Provincial Department of Rural Development and Agrarian Reform, and the Department of Rural Development and Land Reform be assigned responsibility for the undertaking of this land reform and irrigated agriculture development initiative as they have the best experience, understanding, and capabilities of the consultative and mentoring approaches required.

This process should begin as soon as possible in order than the future irrigated agriculture and associated raw water requirements be confirmed, so that the dam and associated infrastructure development can be finalized accordingly during the detailed design and implementation stage.

7.3 Regional Agricultural Economics

Gross Margin Analysis has been carried out for a range of suitable crops. On a typical mixed farming enterprise of 60 ha, a gross margin of R580 737 can be expected per farming unit. This margin could be increased if subsidy of the unit cost of water supplied can be achieved.

Up to 3 375 direct permanent jobs would be created and up to 1 350 seasonal workers would be directly employed on the farming units.

7.4 Key Issues to Resolve

Key issues that will need to be resolved are:

- Land reform and a change of mind set as regards agrarian practices and land tenure.
- This will require extensive consultation with traditional leaders and the affected people in the areas to be developed.
- Investment in training, facilitation, and support services.

The economics of the identified development option are based upon:

- Grant funding of the main bulk water supply infrastructure to ensure that the water supplied is affordable.
- Reduction of power costs through the beneficial usage of the hydropower generated by the Project Maximising the potential market opportunities, if the SEZ is developed at the Mthatha Airport.

APPENDIX A

SOILS INVESTIGATION FIELD REPORT:

NTABELANGA DAM

APPENDIX A
SOILS INVESTIGATION FIELD REPORT:
NTABELANGA DAM

EXECUTIVE SUMMARY

A reservoir dam is proposed in the Mzimvubu catchment, Eastern Cape. Earlier studies on the social and economic considerations as well as the irrigated agricultural potential, have identified the Ntabelanga area on the Tsitsa River, a tributary of the Mzimvubu River, as a preferred location for the development.

The essence of this natural resource agricultural assessment is to conduct a reconnaissance soil assessment of the Ntabelanga study area (7 708 ha). The study area consists of 13 spatially-separate parcels of land, identified earlier as having possible soil and site conditions suited to an irrigated agricultural sector.

The 13 study areas extend from Tsolo village in the east, to Maclear village in the west.

Study Area	***Topocadastral Map Nomenclature***	***Extent (hectares)***
1	*Junction Ferry*	*883*
2	*St Cuthberts*	*696*
3	*Bele*	*904*
4	*Ntshiqo*	*394*
5	*Ntabelanga*	*1 748*
6	*Model Farm 61*	*575*
7	*Upper Godwana*	*930*
8	*Skukuna*	*196*
9	*Caba Vale*	*87*
10	*Rusoord*	*483*
11	*Tikinki*	*402*
12	*Mtozelo*	*385*
13	*Gemfane*	*25*
Total		*7 708*

Current land use of the study areas is mostly livestock grazing with some subsistence rainfed maize cropping and vegetable production. Many of the already contoured fields have been lying fallow for some time. The study areas mostly have slope gradients less than 12%.

<u>Soils recommended for irrigation</u>
Deep (80 to >150 cm) mesotrophic oxidic soils of the Hutton, Griffin and Clovelly forms have clay loam to clayey textures, weak blocky to apedal structure and good infiltration and drainage. Soil hue is either red or yellow. Inherent soil nutrition is good with favourable calcium, magnesium, potassium and phosphorus contents. There is no salinity or sodicity hazard. These soils are mostly confined to midslopes and some crest terrain units.

<u>Soils not recommended for irrigation</u>
Shallow (less than 60 cm) soils of the gleyic group (Katspruit, Westleigh), lithic group (Glenrosa, Mispah) and duplex group (Swartland, Klapmuts, Estcourt) occur. Depth limiting material to rooting is soft plinthite, gley, saprolite, rock or strongly structured subsoils. Limitations to irrigation are soil depth, drainage, infiltration and high sodic (sodium) conditions at some sites. These soils are confined to footslope terrain units.

The irrigation capability of the Ntabelanga study area is as follows:

Irrigability Class	Irrigability Class Description	Extent (hectares)	Extent (percentage)
I	Highly recommended	255	3
II	Recommended	2796	36
III	Recommended with reservation	624	8
IV	Not normally recommended	2131	28
V	Not recommended	1906	25

The irrigation capability for the 13 individual study areas is as follows:

Study Area	Name on Topocadastral Map	Irrigation Capability Class	Hectares	Percentage of Study Area
1	Junction Ferry	I	0	0
		II	200	23
		III	22	2
		IV	417	47
		V	244	28
2	St Cuthberts	I	0	0
		II	204	29
		III	0	0
		IV	305	44
		V	187	27
3	Bele	I	0	0
		II	498	54
		III	23	3
		IV	277	31
		V	106	12
4	Ntshiqo	I	0	0
		II	194	49
		III	0	0
		IV	120	30
		V	81	21
5	Ntabelanga	I	0	0
		II	484	28
		III	334	19
		IV	510	29
		V	423	24
6	Model Farm 61	I	0	0
		II	0	0
		III	0	0
		IV	369	64
		V	205	36
7	Upper Godwana	I	0	0
		II	624	67
		III	100	11
		IV	4	0
		V	202	22
8	Shukuna	I	0	0
		II	73	37
		III	41	21
		IV	55	28
		V	28	14
9	Caba Vale	I	0	0
		II	47	53
		III	7	8
		IV	20	23
		V	14	16

Study Area	Name on Topocadastral Map	Irrigation Capability Class	Hectares	Percentage of Study Area
10	Rusoord	I	0	0
		II	166	35
		III	66	14
		IV	24	5
		V	227	46
11	Tikinki	I	0	0
		II	306	77
		III	14	3
		IV	27	7
		V	54	13
12	Mtozelo	I	255	66
		II	0	0
		III	0	0
		IV	0	0
		V	130	34
13	Gemfane	I	0	0
		II	0	0
		III	17	68
		IV	3	12
		V	5	20

Irrigation classes I, II and III are recommended for irrigation, totalling 3675 ha or 47% of the study areas.

Irrigation class IV is not normally recommended for irrigation, whilst irrigation class V is totally unsuited to irrigation. These sites total 4033 ha or 53% of the study areas. Limitations to irrigation in classes IV and V are either slope gradients more than 12%, shallow soils, duplex soils, sodic soils or soils with rocky outcrops.

Based on this reconnaissance soil assessment to determine the irrigation capability of soils for agriculture in the Ntabelanga area, a general recommendation and conclusion of the irrigation capability of soils and sites is as follows:

- ***Soil bodies recommended for irrigation***
  - *3675 ha or 47% of the study area*
  - *Oxidic soils of the Hutton, Griffin, Clovelly and Inanda forms*
  - *These soils are generally located on midslope and some crest terrain units.*

- ***Soil bodies not recommended for irrigation***
  - *4037 ha or 53% of the study area*
  - *Duplex, hydromorphic and lithic soils of the Swartland, Estcourt, Klapmuts, Katspruit, Westleigh, Glenrosa and Mispah soil forms*
  - *Generally located on footslopes, valley bottom and some crest terrain units.*

SOILS INVESTIGATION FIELD REPORT:
NTABELANGA DAM

A.1 INTRODUCTION

The Mzimvubu River catchment in the Eastern Cape has been identified as a priority zone for economic development and social upliftment. Construction of a dam on the Mzimvubu River, or on one of its tributaries, will contribute to meeting these objectives.

Studies by Government Departments and their appointed service providers have identified some suitable sites for construction of the reservoir, based on dam site suitability, need for potable water, hydroelectric power and agricultural development.

Agricultural development is the focus of this report, with emphasis on the extent and irrigation capability of soils to successfully support an irrigated agronomic enterprise. The following studies have been pursued over recent months to select suitable sites for an irrigated agricultural sector.

A.1.1 Desk Top Assessment

An initial desk-top[3] assessment of the greater Mzimvubu catchment determined the extent of suitable soils and sites for an irrigation project. Broad areas suitable for agricultural development under irrigation were delineated. A site assessment was not conducted.

A.1.2 Initial Field Investigations

A site assessment at exploratory level[4] in the Ntabelanga, Somabadi and Thabeng Districts where the irrigation potential of the sites, identified in the desk-top assessment, were assessed and suitable crops and their expectant yields identified.

A.1.3 Detailed Field Investigations

Based on findings of the earlier two agricultural studies (as well as other considerations), a decision was taken to construct the reservoir on the Tsitsa River. Attention would be on the Ntabelanga Area and its surrounds for the agricultural development project. A reconnaissance soil and irrigation capability assessment (the essence of this report) was commissioned. The reconnaissance study focuses only on selected sites in the Ntabelanga Area that meet requirements of an irrigation development – these being distance from the inundation area/downstream flow to the irrigation site, effort required to pump water to the sites, pumping costs and of course the irrigation capability of the soil.

This reconnaissance assessment of the soils and irrigation capability of selected sites in the Ntabelanga Area aims to:

- map soil types and soil properties;
- identify broad, relatively homogeneous sites for irrigation, and
- determine the irrigation capability for agriculture of each of the defined sites.

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[3] *Desk-top assessment of the agricultural potential of the Mzimvubu Catchment. F.Ellis and A.van Niekerk. Univ. Stellenbosch. May 2011.*

[4] *Exploratory assessment of the soils and irrigation capability at the proposed Ntabelenga, Somabadi and Thabeng agricultural development areas – Mzimvubu catchment. Keith Snyman & Associates. September 2012.*

This assessment of the irrigation capability of soils across 7 708 ha in the Ntabelanga area has been conducted at a feasibility level of study, which suffices for strategic agricultural planning.

Farm unit detailed design and operational planning would require intensive soil observations, via a more detailed soil survey.

This reconnaissance soil assessment and the subsequent deductions and recommendations contained in this report should therefore be considered in context.

A.2 STUDY AREAS

A.2.1 Selection and Delineation of Study Areas

The study areas were selected via a desktop GIS exercise which identified areas suitable for field investigation according to certain criteria. These criteria were developed to target areas that would be most suited to commercially viable mechanized irrigation farming. The criteria used are described below:

- 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.
- Slope – Slope across the catchment was calculated from existing elevation data, and slopes less than 12% were considered suitable for mechanised farming operations.
- Proximity to water source – For economic viability reasons, the areas considered were limited to those within 60m vertical of the river at the proposed dam wall location or in the river below a proposed dam, and 5km horizontal 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.
- Water deficit – Mean annual precipitation (MAP) was expressed as a ratio to mean annual evapotranspiration. 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.

GIS analysis methods were 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)

Later, the “proximity to water course” criteria was dropped at the request of the client to include more area, as this criteria set is essentially an economic feasibility criteria rather than a technical one. Greater areas could therefore be considered on a technical level, with the economic feasibility left to a later stage of study. Thus, using the above criteria and GIS analysis methods, in excess of 8 000 ha were identified relative to the Ntabelanga Dam. These were then divided into homogeneous land masses to be studied on the ground, which smoothed some irregular edges on the identified areas, and excluded areas that should not be assessed for obvious reasons, such as those already developed as townships within the Tsolo environs. In this manner, 13 distinct land areas totalling 7 708 ha were mapped and delineated.

A.2.2 Extent of Study Areas

The thirteen study areas identified as described above are spatially distant from each other. Their locations extend from the village of Tsolo in the east, to the village of Maclear in the west (see Figure A-1. Individual extents of the 13 study areas are shown in Table A-1.

Table A-1: Extent of the 13 study areas

Study Area	Topocadastral Map Nomenclature	Extent (hectares)
1	Junction Ferry	883
2	St Cuthberts	696
3	Bele	904
4	Ntshiqo	394
5	Ntabalenga	1 748
6	Model Farm 61	575
7	Upper Godwana	930
8	Skukuna	196
9	Caba Vale	87
10	Rusoord	483
11	Tikinki	402
12	Mtozelo	385
13	Gemfane	25
	Total:	**7 708**

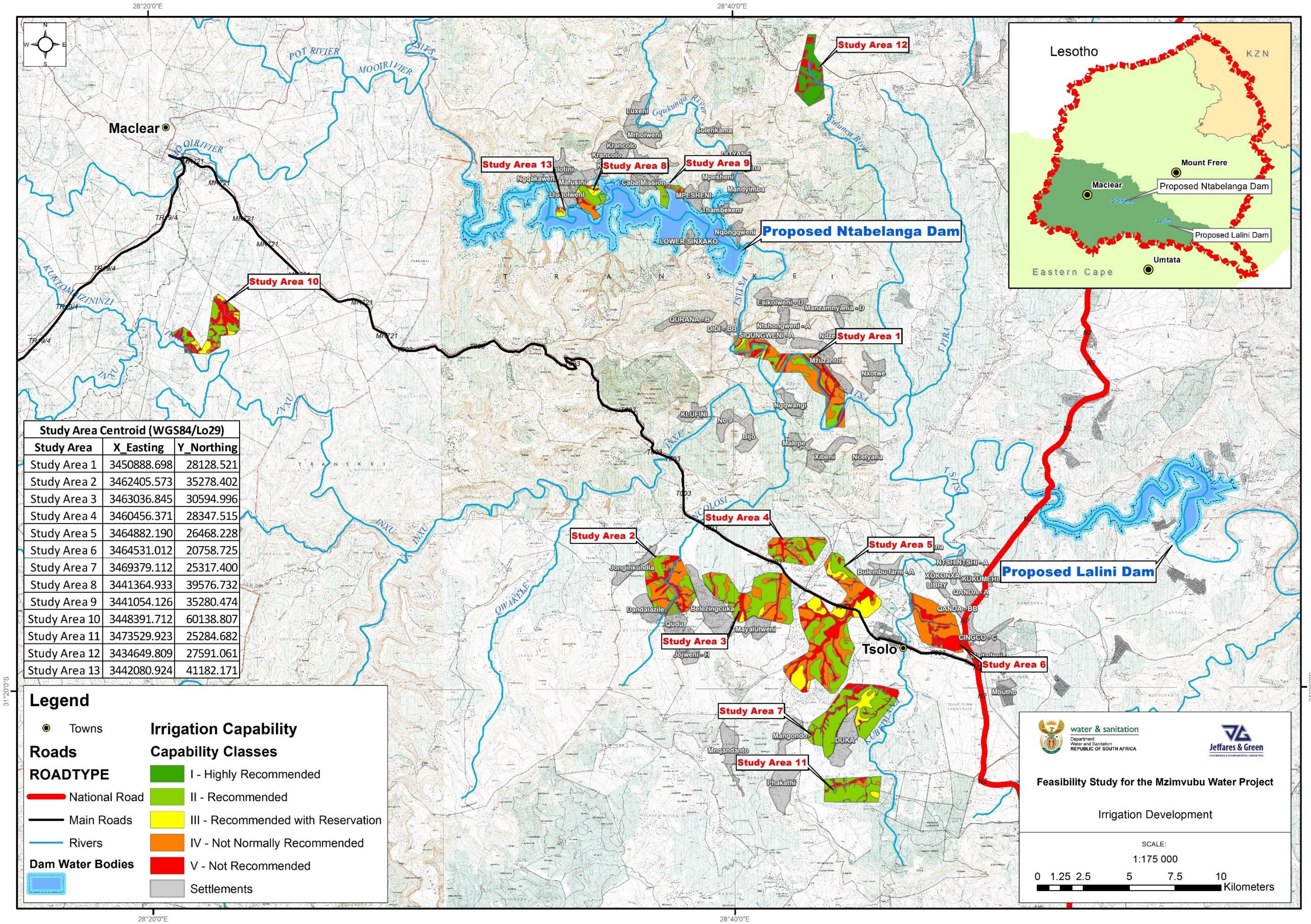


Figure A-1: Location of the study areas

A.3 CURRENT LAND USE

Some of the areas of interest are cultivated. It is however evident that many fields have not been planted in the recent past, evidence being rejuvenation of veld (Figure A-2). Maize grown under rain fed conditions occupies lesser extent (Figure A-3).

Figure A-2: Previously Cultivated Lands with Constructed Contour Banks

Figure A-3: Currently Cultivated Lands Less Prevalent

The remainder of the study area is covered by veld (Figure A-4) of the southern tall grassveld biome (highland and Dohne sourveld)[5]. Donga erosion is mostly confined to stream channel sections (Figure A-5), although other donga and surface erosion was noted.

Figure A-4: Veld Cover Across Some of the Study Areas

Figure A-5: Donga Erosion Occurs in Many Stream Channel Sections

[5] *Acocks. J.P.H. 1953. Veld Types of South Africa. Bot.Surv. S.Afr.Mem.28*.

A.4 BASELINE NATURAL RESOURCES

A.4.1 Topography

This reconnaissance assessment of the irrigation capability of selected sites focuses largely on areas having less 12% slope gradient. Consequently, most slopes within the study areas have level to strongly sloping land which is favourable for irrigation.

Altitude above sea level ranges from 850 to 1 325 m.a.s.l. Specifically, most of the study areas (i.e. areas 1, 2, 3, 4, 5, 6, 7, 8, 9, 11 and 13) in the Tsolo vicinity are 850 to 1098 m.a.s.l. Study area 12 in the far north is 1 250 m.a.s.l. whilst study area 10 near Maclear is 1 325 m.a.s.l.

A.4.2 Climate

There is no reliable, long term recorded climate data available for the study area, hence the presented climate data is modelled (Table A-2)[6]. As most of the study area (89%) is located in the Tsolo vicinity, climate data is presented for this location.

Tsolo receives 780 mm mean annual precipitation (MAP) and has a mean annual temperature (MAT) of 16 ºC. However, higher lying study areas 10 and 12 experience increased rainfall and decreased temperatures compared to the climate at Tsolo. The mean annual evaporation (A pan) is high at 1 659 mm. Frost occurs in winter. Snow cannot be ruled out on high-lying ground, and especially areas 10 and 12.

The climate dictates that crops tolerant of cool conditions and frost be established. The somewhat low MAT suggests that crop growth will be retarded (due to low heat units) to some extent and that subsequent crop yields will be somewhat restricted. Irrigation will supplement soil moisture deficits during the dry winter months and will provide a significant yield increase compared to current rain fed agricultural practice.

Table A-2: Climate data for the Tsolo area

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Mean
Mean monthly rainfall (mm)	129	108	108	46	18	5	8	14	36	69	105	101	**780**
Mean daily maximum temperature (°C)	26	26	25	22	21	18	18	20	21	22	23	25	**22**
Mean daily minimum temperature (°C)	14	14	13	10	7	4	4	5	8	10	11	13	**9**
Mean daily temperature (°C)	20	20	19	16	14	11	11	13	15	16	17	10	**16**
Mean Evapotranspiration (mm)	184	149	149	111	102	89	98	126	138	158	164	191	**1 659**
Humidity (%)	69	69	68	65	62	62	60	60	63	67	68	68	**65**

6 Schulze, R.E. 2007. Preface and Executive Summary. *In:* Schulze, R.E. (Ed). 2007. South African Atlas of Climatology and Agrohydrology. Water Research Commission, Pretoria, RSA, WRC Report 1489/1/06, Section 1.1.

A.4.3 Geology

The lithology consists of undifferentiated mudstone and sandstone of the Burgersdorp and Katberg Formations of the Beaufort Group. The weathering of the mudstone results in soils with clay loam to clayey texture, having red, greyish and pale hues. Weathering of the sandstone produces soils of yellowish red hues having medium/fine sandy loam to clay loam texture. Dolerite in the form of extended longitudinal dykes commonly intrudes the sandstone and mudstone, seen as boulder surface outcrops.
Weathering of the dolerite produces soils of red hue with heavier textures (clay loam to clay).

Alluvium (soils deposited by water) occurs within stream channels and on flood plains adjacent to rivers.

A.4.4 Soils

A.4.4.1 Reconnaissance Soil Survey

This study area is 7 708 ha in extent. 249 soil observations were conducted via soil auguring. Soil samples of some top- and subsoil horizons were taken and submitted to the laboratory[7] to determine salinity and salinity status. Diagnostic depth was 1.5 m. Soils were classified according to the accepted classification system used in this country[8]. The following properties were recorded per soil horizon: lower depth, clay content, sand grade, colour, structure, wetness hazard, gravel and stones.

Other recorded field data were effective root depth, ameliorated root depth, topsoil organic carbon, outcrops and total available moisture. The soil survey data is presented in Annexure 1 and the symbols used in this Appendix are explained in Annexure 2. Location of soil observations were recorded with a Trimble GPS instrument and are presented on Maps 1 to 13 in Annexure 4. Soil bodies and properties are presented in Section 5.4.2.

In addition 12 modal soil profiles were selected of common and representative soil forms within the dominant soil bodies. Soil profile faces were photographed, described in detail, sampled and submitted to an accredited soils laboratory[9] for routine soil analyses.

Georeferenced imagery[10] together with 5 m contours[11] at 1: 10 000 scale were used as base maps in the field.

[7] *SASRI – Mt Edgecombe*
[8] *Soil Classification. A Taxonomic System, for SA. Soil Class. Working Group. Dept. Agric. 1991.*
[9] *SASRI, Mount Edgecombe.*
[10] *Google Earth*
[11] *Surveyor General, Mobray.*

A.4.4.2Soil Bodies

a) Oxidic soils

See Maps 1 to 13 in Annexure 4.

Soil bodies:	*A1, A2, A3, A4, A5, A6, A7, A8*
Extent:	*3 746 ha or 49%*
Soil classification:	*Hu2200, Gf2200, Cv2200*
Effective root depth:	*80 - >150 cm*
Irrigation capability:	*Class I (254 ha or 3%) – highly recommended* *Class II (2802 ha or 36%) - recommended* *Class III (624 ha or 8%) – recommended with reservation* *Class V (66 ha or 1%) - not recommended*

A typical oxidic soil profile description of the Hutton form is:

A 0-20 cm	Brown red (5YR3/3), clay loam texture, apedal to weak blocky structure, hard when dry, firm when moist, sticky when wet, many pores, no coarse fragments, many roots, abrupt and/or gradual transition to:	**Orthic**
B2 20->150 cm	Red (25YR4/4), dry, clayey texture, weak block structure, hard when dry, firm when moist, sticky when wet, few pores, few roots.	**Red apedal**

Dominant soils are Hutton, Griffin and Clovelly forms. The deep effective rooting depth (80 - >150 cm) is favourable for cropping. Depth limiting material to rooting is saprolite, hard rock or occasionally soft plinthite. Sandy clay loam and clayey top- and sub-soil horizons respectively, provide good water storage and water holding capacities. Calculated profile TAM (total available moisture) ranges from 118 to 148 mm/m which is favourable for crop growth. Infiltration is moderately rapid and soil morphology indicates aeromorphic conditions to the depth limiting material.

There is no impeded drainage to result in a wetness hazard. Soil structure is apedal to weak blocky, becoming weak blocky to occasionally moderate blocky in the subsoil. Rooting will thus be somewhat impaired in the subsoil but under irrigated conditions the roots should be able to penetrate the moist subsoil. Profile gravel does not occur.

Soil analytical results of a typical Oxidic soil at Ntabelanga are presented in Table A-3.

Topsoils are brownish red in hue with a somewhat moderate organic carbon content (0.8%) indicating moderate nitrogen and sulphur mineralization potential. Cation exchange capacity is 36.5 and 56.4 cmol+/kg in the top-and subsoil respectively, indicating a low to moderate leaching soil environment due to reduced rainfall (Table A-2).

Exchangeable bases (Ca, Na, Mg, K) are in moderate concentration. It is therefore anticipated that fertilization for cropping will not be excessive. Soil pH (about 5 measured in water) indicates a slightly acidic soil environment. Phosphorus levels are low and will require attention. Salinity (salts) and sodicity (sodium) levels are well suited to cropping in that the EC, SAR and ESP measurements are well within tolerant norms for plant growth.

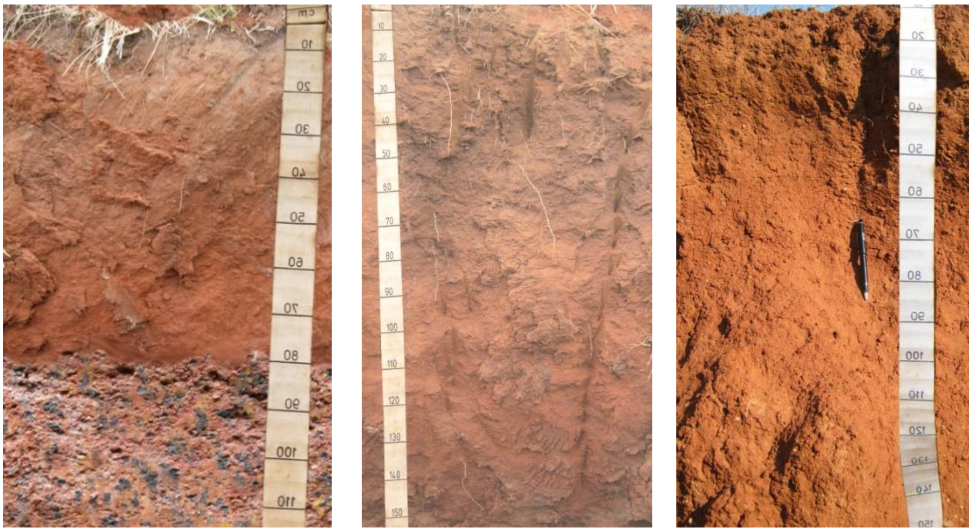


Figure A-6: Typical Oxidic Soils of the Hutton form

Table A-3: Nutrition and Analytical Properties of Sampled Oxidic Soil

Property	Depth cm	
	0-20	**20->150**
Clay %	25	42
Silt %	8	9
Sand %	67	49
Organic carbon %	0.85	0.50
Exch Ca (cmol+/Kg)	2.70	2.71
Exch Mg (cmol+/Kg)	1.28	2.68
Exch K (cmol+/Kg)	0.16	0.14
Exch Na (cmol+/Kg)	0.09	0.15
S Value (cmol+/Kg)	4,23	5.68
CEC (cmol+/Kg)	36.5	56.4
pH water	4.9	5.4
Soluble Ca (meq/l)	0.02	0.01
Soluble Mg (meq/l)	0.08	0.01
Soluble Na (meq/l)	0.34	0.32
ESP%	2.11	2.65
SAR **EC (mS/m)**	1.5 5	3.2 3
P Troug (mg/l)	1.5	3.2

b) *Gleyic soils*

See Maps 1 to 13 in Annexure 4.

Soil body:	*W1*
Extent:	*1 309 ha or 17%*
Soil classification:	*Ka2000, We2000*
Effective root depth:	*40*
Irrigation capability:	*Class V (1309 ha or 17%) - not recommended*

A typical gleyic soil profile description of the Westleigh soil form is:

A 0-40 cm	Dark brown (10YR3/3), clay loam texture, strong blocky structure, hard when dry, firm when moist, sticky when wet, many pores, no coarse fragments, some roots, wetness hazard, gradual transition to:	**Orthic**
B2 >40 cm	Dark brown grey (10YR4/2), dry, clayey texture, massive structure, hard when dry, firm when moist, sticky when wet, no pores, wetness hazard, no roots.	**Soft Plinthite**

Dominant soil forms are Katspruit and Westleigh. Soil Body W occupies depression areas, riparian habitats and wetlands.

Effective rooting depth is continuously shallow and seldom exceeds 30 cm. Limiting material to plant rooting is hydromorphic material, identified as soft plinthite, gley or unconsolidated material with signs of wetness. Drainage is impeded, manifested by abundant grey profile hues. Profile conditions are anaerobic. Infiltration is slow.

Soil analytical results of a typical gleyic soil at Ntabelanga are presented in Table A-4. Apart from impeded soil profile drainage resulting in undesirable anaerobic conditions for plant growth, exceptionally high soil sodicity levels occur.

ESP (exchangeable sodium percentage) and SAR (sodium adsorbtion ration) are extremely high.

The high exchangeable sodium content on the cation exchange complex leads to clay dispersion in the soil, especially under wet conditions. Soils high in sodium result in severe crusting, low infiltration and retarded hydraulic conductivity, increased bulk density and increased erosion.

The gleyic soils of the study area have impeded drainage and high sodicity. Such soil conditions are not suited to irrigation.

Figure A-7: Typical Gleyic soil of the Westleigh From

Table A-4: Nutrition and Analytical Properties of Sampled Gleyic Soil

Property	Depth cm	
	0-40	**>40**
Clay %	17	21
Silt %	7	11
Sand %	76	68
Organic carbon %	0.55	0.51
Exch Ca (cmol+/Kg)	2.78	2.64
Exch Mg (cmol+/Kg)	1.99	1.98
Exch K (cmol+/Kg)	0.06	0.05
Exch Na (cmol+/Kg)	1.03	0.80
S Value (cmol+/Kg)	5.86	5.47
CEC (cmol+/Kg)	4.64	4.33
pH water	6.7	6.9
Soluble Ca (meq/l)	0.02	0.02
Soluble Mg (meq/l)	0.13	0.11
Soluble Na (meq/l)	1.23	1.20
P Troug (mg/l) **EC (mS/m)** **SAR** **ESP%**	1.97 17 4.6 17.8	3.40 16 4.8 14.7

c) *Duplex soils*

See Maps 1 to 13 in Annexure 4.

Soil body: *D1*
Extent: *2 131 ha or 28%*
Soil classification: *Se1220, Sw2122, Es1100*
Effective root depth: *20 -60 cm*
Irrigation capability: *Class IV (2131 ha or 28%) – not normally recommended*

A typical soil profile description of the Sepane soil form is:

A 0-30 cm	Brown (10YR4/2), clay loam texture, massive to moderate blocky structure, hard when dry, firm when moist, sticky when wet, some pores, no coarse fragments, some roots, abrupt transition to:	**Orthic**
B1 30-60 cm	Grey brown (10YR3/1), clayey texture, strong blocky and prismatic structure, very hard when dry, firm when moist, very sticky when wet, few pores, no roots to:	**Pedocutanic**
C >60 cm	Grey unconsolidated material with signs of wetness, wetness hazard.	**Hydromorphic material or saprolite**

Dominant soil forms are Sepane, Swartland and Estcourt. Effective rooting depth is 20 to 60 cm with either pedocutanic or prismatic structure limiting to root development. Deep ripping to improve profile depth is not recommended. Sandy clay loam and clayey top- and sub-soil textures occur.

Texture and structure change from top- to subsoil is commonly abrupt which is unsuited to root development. Calculated profile TAM (total available moisture) is about 30 mm/m which is low. Infiltration in the topsoil is moderately rapid, but very retarded in the subsoil. Lateral flow of soil water will occur with perched water on the subsoil.

Duplex soils are commonly associated with high salinity and sodicity. The duplex soils of the study area appear not to have a salinity problem, but high sodicity levels occur. This is evidenced by the high ESP and SAR measurements (>5%) recorded in top- and subsoils.

Associated soil conditions are resultant severe crusting, low infiltration, retarded hydraulic conductivity and increased bulk density. The excessive erosion dongas and surface erosion in the study area seen on foot slopes and valley bottom terrain units, where duplex soils occur, is testimony to this.

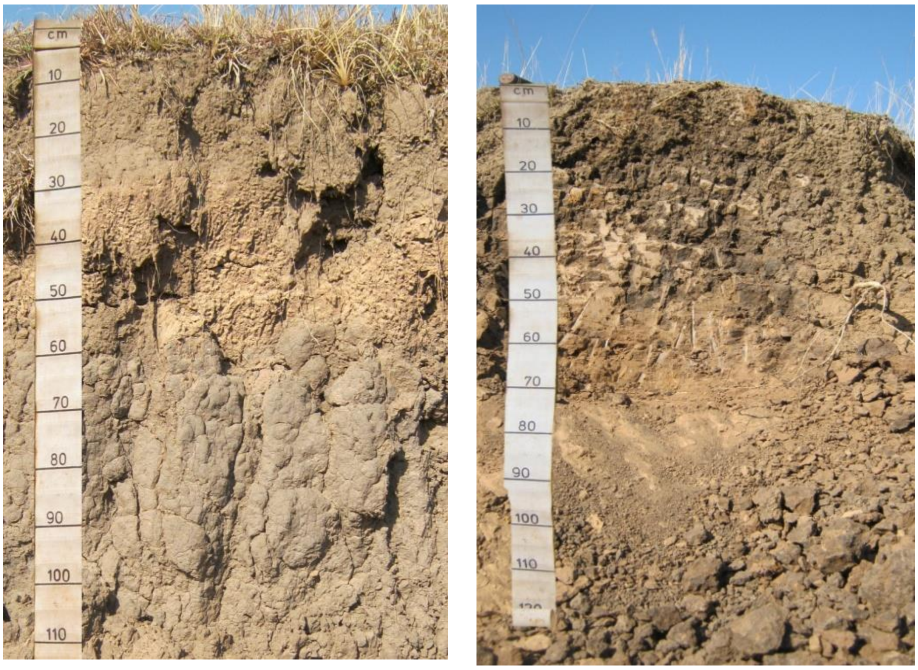


Figure A-8: Typical Duplex soils of the Estcourt and Valsrivier forms

Table A-5: Nutrition and Analytical Properties of Sampled Swartland Soil

Property	Depth cm	
	0-30	30-60
Clay %	27	47
Silt %	11	18
Sand %	62	35
Organic carbon %	0.92	0.90
Exch Ca (cmol+/Kg)	0.99	0.97
Exch Mg (cmol+/Kg)	1.12	1.04
Exch K (cmol+/Kg)	0.10	0.12
Exch Na (cmol+/Kg)	0.28	0.30
S Value (cmol+/Kg)	2.49	2.43
CEC (cmol+/Kg)	1.98	1.88
pH water	5.3	5.3
Soluble Ca (meq/l)	0.01	0.06
Soluble Mg (meq/l)	0.01	0.08
Soluble Na (meq/l)	0.94	1.67
EC (mS/m)	12	23
SAR	9.4	6.4
ESP%	11.6	2.4
P Troug (mg/l)	2.15	4.10

d) Lithic soils

See Maps 1 to 13 in Annexure 4.

Soil body: *C1*
Extent: *525 ha or 7%*
Soil classification: *Gs1212, Hu2200, Ms1100, Gs1111*
Effective root depth: *20 - 30 cm*
Irrigation capability: *Class V (525 ha or 7%) - not recommended*

A typical soil profile description of the Mispah soil form is:

A 0-20 cm	Brown red (5YR3/3), clay loam texture, apedal to weak blocky structure, hard when dry, firm when moist, sticky when wet, many pores, few coarse fragments, few roots, many outcrops on:	**Orthic**
B2 20-30 cm	Hard rock.	**Hard rock**

Dominant soils are Mispah, Glenrosa and Hutton forms. This soil body mostly occupies ridges associated with dolerite outcrops on the surface.

Occupancy of surface bounders is about 20 to 60% in places. Soil depth is shallow and seldom more than 30 cm deep.

Hard rock and saprolite is the depth limiting material. The site also often occurs on gradients more than 12%.

The site is not suited to irrigation due to shallow soils, surface outcrops and steep slopes.

A.5 IRRIGATION CAPABILITY

A.5.1 Site Criteria and Methodology

Irrigation capability was determined according to the following considerations:

- Topography
  - Gradient
  - Ground roughness (outcrops)

- Soils
  - Soil form
  - Effective rooting depth
  - Texture
  - Subsoil structure
  - Permeability and internal drainage
  - Soil water storage capacity (TAM)
  - Coarse fragments
  - Erosion hazard
  - Soil sodicity (ESP and SAR)
  - Soil salinity (EC)

The key to derivation of irrigability classes is shown in Table A-6.

Table A-6: Diagnostic Criteria and Key to Irrigation Classes

Characteristics	**Degree of Restriction**				
	1	**2**	**3**	**4**	**5**
Effective root depth cm					
<10% clay					
Permeable layer	>150	>90	60-90	30-60	<30
Impervious layer	>150	>120	60-120	30-60	<30
>10% clay					
Permeable layer	>90	60-90	30-60	20-30	<20
Impervious layer	>120	90-120	50-90	30-50	<30
Texture					
% clay	10-35	6-10	>45	<6	
Clay% top – clay % sub	20	35-45	>20		
Subsoil structure	Apedal	Moderate (dry)	Moderate (moist)	Strong	
Coarse fragments (% matrix)	<5	5-15	15-35	35-65	>65
Stones (>75 mm)	<15	15-35	35-55	55-70	>70
Gravel (2-75 mm)	>40	20-40	15-20	5-25	<5
Rock					
Sodium					
Topsoil	<0.5	<0.5	0.5-1	1-2	>2
Concentration (me%)	<5	<5	5-8	8-15	>15
ESP	<5	<5	5-8	8-15	>15
SAR					
Subsoil	<0.5	0.5-1	1-2	2-3	>3
Concentration (me%)	<5	5-8	8-15	15-20	>20
ESP	<5	5-8	8-15	15-20	>20
SAR					
Salts (conductivity mS/m)	<200	200-800	800-1200	1200-1600	>1600
General	<100	<100	<100	<100	<100
Poorly drained soils	<400	<400	<400	<400	<400
Well drained soils					
Slope %	0-4	4-8	8-12	12-20	>20
Erosion hazard	None	Low to moderate	Moderate to high	Very high	Very high
Internal drainage	Good	Moderate to good	Moderate	Moderate to poor	Poor
Extent of other restrictions	None	Slight	Moderate	High	Extreme
General description of capability class	No limitations	Moderate management requirements necessary	Insufficient management can cause problems	Severe limiting properties handicap yield	Unsuitable for irrigation
Irrigability class description	Highly recommended	Recommended	Recommended with reservation	Not normally recommended for irrigation	Not recommended
Irrigability class	**I**	**II**	**III**	**IV**	**V**

A.6 IRRIGATION CAPABILITY ASSESSMENT

A.6.1 Entire Study Area

The irrigation capability of the entire study area is shown in Table A-7.

Table A-7: Extent of Irrigable Land Classes in the Ntabelanga Study

Irrigability Class	Irrigability Class Description	Extent (hectares)	Extent (percentage)
I	Highly recommended	255	3
II	Recommended	2 796	36
III	Recommended with reservation	624	8
IV	Not normally recommended	2 131	28
V	Not recommended	1 906	25

A.6.2 Individual Study Areas

The irrigation capability for the 13 individual study areas is shown in Table A-8 and also on Maps 1 to 13 in Annexure 4.

Table A-8: Extent of Irrigable Land Classes in the Individual 13 Study Areas at Ntabelanga

Study Area	Name on Topocadastral Map	Irrigation Capability Class	Hectares	Percentage of Study Area
1	Junction Ferry	I	0	0
		II	200	23
		III	22	2
		IV	417	47
		V	244	28
2	St Cuthberts	I	0	0
		II	204	29
		III	0	0
		IV	305	44
		V	187	27
3	Bele	I	0	0
		II	498	54
		III	23	3
		IV	277	31
		V	106	12
4	Ntshiqo	I	0	0
		II	194	49
		III	0	0
		IV	120	30
		V	81	21
5	Ntabelanga	I	0	0
		II	484	28
		III	334	19
		IV	510	29
		V	423	24
6	Model Farm 61	I	0	0
		II	0	0
		III	0	0
		IV	369	64
		V	205	36
7	Upper Godwana	I	0	0

Study Area	Name on Topocadastral Map	Irrigation Capability Class	Hectares	Percentage of Study Area
		II	624	67
		III	100	11
		IV	4	0
		V	202	22
8	Shukuna	I	0	0
		II	73	37
		III	41	21
		IV	55	28
		V	28	14
9	Caba Vale	I	0	0
		II	47	53
		III	7	8
		IV	20	23
		V	14	16
10	Rusoord	I	0	0
		II	166	35
		III	66	14
		IV	24	5
		V	227	46
11	Tikinki	I	0	0
		II	306	77
		III	14	3
		IV	27	7
		V	54	13
12	Mtozelo	I	255	66
		II	0	0
		III	0	0
		IV	0	0
		V	130	34
13	Gemfane	I	0	0
		II	0	0
		III	17	68
		IV	3	12
		V	5	20

A.6.3 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, some crops recommended for irrigation are presented in Table A-9.

Irrigation is recommended on soil bodies A, and not on soil bodies W, D and C. Generally, this equates to the Oxidic soils (deep Hutton, Griffin and Clovelly) occurring on midslopes and crests being suited to irrigation. The remaining soils (hydromorphic, duplex and lithic) occurring on footslopes, valley bottom and steep land are not recommended for irrigation.

Table A-9: Some Suitable Crops for Irrigation Classes I, II and III

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

A.7 RECOMMENDATIONS AND CONCLUSIONS

Irrigation classes I, II and III are recommended for irrigation (Table A-8), totalling 3 675 ha or 47% of the study areas.

Irrigation class IV is not normally recommended for irrigation, whilst irrigation class V is totally unsuited to irrigation. These sites total 4 037 ha or 53% of the study areas.

Limitations to irrigation in classes IV and V are either slope gradients more than 12%, shallow soils, duplex soils, sodic soils or soils with rocky outcrops.

Based on this reconnaissance soil assessment to determine the irrigation capability of soils for agriculture in the Ntabelanga area, a general recommendation and conclusion of the irrigation capability of soils and sites is as follows:

- **Soil bodies recommended for irrigation**
    - 3 675 ha or 47% of the study area
    - Oxidic soils of the Hutton, Griffin, Clovelly and Inanda forms
    - Generally located on midslope and some crest terrain units.

- **Soil bodies not recommended for irrigation**
    - 4 037 ha or 53% of the study area
    - Duplex, hydromorphic and lithic soils of the Swartland, Estcourt, Klapmuts, Katspruit, Westleigh, Glenrosa and Mispah soil forms
    - Generally located on footslopes, valley bottom and some crest terrain units.

ANNEXURES

ANNEXURE 1. SOIL OBSERVATION DATA

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
1	Hu2100	A	20	50	F	5YR33	WB			151			D1	M	3		-31.334033
		B	151	55	F	2,5YR34	A										28.725100
2	Hu2200	A	40	35	F	5YR46	A			130	GL		D1	M	3		-31.331899
		B	130	55	F	2,5YR46	A										28.722832
3	We2000	A	40	23	F	10YR43	A			80	GL		S2	M	3	We/Oa	-31.328954
		B	60	40	F	10YR44	WB		10								28.720970
		C	90	45	F	10YR44	WB		80								
4	Hu2200	A	20	30	F	5YR33	A			90	GL		S2	M	3		-31.325588
		B	60	50	F	5YR46	A										28.720915
		C	110	55	F	5YR46	WB		60								
5	Dr2000	A	20	20	M	10YR43	A		30	20	HP		F	LM	4		-31.323501
																	28.719769
6	Hu2200	A	20	35	F	5YR33	WB			130	GL		D1	M	3		-31.326568
		B	130	50	F	2,5YR34	A										28.728763

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
		C	151														
7	Li2200	A	20	30	F	5YR46	A			50	HP		F	M	3	Li/Hu	-31.323290
		B	50	50	F	2,5YR46	A										28.727098
8	Bv2200	A	20	30	F	5YR33	A			130	GL		D1/S2	M	3		-31.321217
		B	120	50	F	5YR46	WB										28.726156
		C	151	55	F	2,5YR46	WB	W1	30								
9	Hu2200	A	20	28	F	5YR33	WB			140	GL		D1	M	3		-31.318175
		B	130	50	F	5YR46	WB										28.724472
		C	151	55	F	2,5YR46	WB		30								
10	Hu2200	A	30	25	F	5YR46	A			151			D1	M	3		-31.315670
		B	151	50	F	2,5YR46	WB										28.722389
11	Gs2111	A	20	18	M	10YR43	A			20	SO		T1	L	4		-31.311722
																	28.721560
12	Bv2200	A	30	35	F	5YR33	A			90	GL		D1	M	3		-31.318458
		B	90	55	F	2,5YR34	WB										28.732839

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
13	We2000	A	30	28	M	10YR43	WB			70	GL		T1	M	3		-31.315633
		B	70	35	F	5YR33	WB	W1	30								28.731257
14	Hu2200	A	40	28	F	5YR33	A			110	GL		D1	M	3		-31.312278
		B	110	50	F	2,5YR34	WB										28.732564
15	We2000	A	30	25	F	10YR44	A			60	SP		T1	M	3		-31.294480
		B	70	30	F	10YR46	WB	W1	20								28.73819053
16	Oa1220	A	40	30	F	5YR33	A			70	GL		T1	M	3	Oa/Tu	-31.29605407
		B	70	50	F	2,5YR34	WB										28.74257276
17	Tu2120	A	30	25	F	10YR43	A			90	GL		T1	L	3	Tu/We	-31.29576179
		B	90	30	F	10YR44	WB	W1									28.74659683
18	Se2220	A	30	20	M	10YR43	A			30	GL		T1	L	3		-31.29191911
		B	70	50	F	10YR44	SB	W1									28.74557398
19	Ka2000	A	30	20	M	10YR43	A	W3		0	GC		A	L	5		-31.28719297

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
																	28.74413766
20	Hu2200	A	25	35	F	5YR33	WB			130	GL		D1	M	3		- 31.27073049
		B	130	55	F	2,5YR34	WB										28.72070739
21	Ka2000	A	20	20	M	10YR43	A	W3		0	GC		A	L	5		- 31.27110433
																	28.72412008
22	Gs1111	A	30	40	F	10YR43	WB			30	GL		S1	MH	3		- 31.27400019
																	28.72603660
23	Hu2200	A	25	35	F	5YR46	WB			130	GL		D1	M	3		- 31.27675205
		B	130	55	F	2,5YR46	WB										28.72704629
24	Hu2100	A	35	45	F	5YR33	WB			100	GL		T1	M	3		- 31.27844679
		B	90	55	F	2,5YR34	WB										28.72550108
		C	110														
25	Hu2100	A	30	40	F	5YR33	WB			40	R	O2	D1	M	3	Loose boulder	- 31.26971762

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
		B	40	55	F	5YR44	WB										28.72694612
26	Hu2200	A	30	35	F	5YR33	WB			80	R	O1	D1	M	3	Loose boulder	-31.32795257
		B	80	55	F	5YR44	A										28.71274752
27	Gs1211	A	20	25	F	10YR43	WB			40	R		D1	M	3		-31.32457500
		B	40	35	F	10YR43	WB										28.71363156
28	Oa1120	A	20	40	F	35YR44	WB			110	SO		D1	M	3		-31.32118821
		B	110	55	F	5YR46	WB										28.71470980
29	Hu2200	A	40	30	F	5YR46	A			90	GL		T1	M	3		-31.32064313
		B	90	50	F	5YR44	WB										28.71115278
30	Hu2200	A	30	30	F	5YR44	A			130	GL		T1	M	3		-31.32313072
		B	130	50	F	2,5YR48	WB										28.69666784
31	Kd1000	A	10	25	F	10YR32	M			30	GC		T1	M	3		-31.31001589

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
		E	30	25	F	10YR53	M	W2									28.70903919
		B	50														
32	Ka2000	A	10	25	F	10YR42	M			10	GC		A	M	5		- 31.30943058
		G	30	50	F	10YR53	M	W3									28.71277275
33	Lo1000	A	30	25	F	10YR44	M			50	SP		T1	M	3		- 31.30745237
		E	50	25	F	10YR54	M	W2									28.71533593
		B	70	30	F	10YR54	M										
34	Oa2220	A	30	28	F	2,5YR33	A			70	SO		T1/S2	M	3	Oa/Gs	- 31.30403423
		B	70	38	F	5YR44	WB										28.71805913
35	Oa1120	A	40	25	F	10YR34	A			90	GL		S2	M	3		- 31.30106753
		B	90	35	F	7,5YR41	WB										28.71486093
36	Hu2200	A	20	30	F	5YR33	A			120	SO		T1	M	3		- 31.30197018
		B1	40	45	F	5YR46	A										28.71065992
		B2	120	50	F	5YR46	A		20								
37	Tu1110	A	30	25	F	10YR34	A			80	SP		T1	M	3		- 31.30374010

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
		B	70	30	F	10YR44	WB										28.70815448
		C	90	35	F	10YR44	WB	W1	20								
38	Ka2000	A	10	25	F	10YR33	M	W3		0	GC		A	H	5		-31.29672822
																	28.70416453
39	Hu2200	A	30	25	F	5YR33	A			60	GL		T1	M	3		-31.29788090
		B	50	30	F	5YR44	WB										28.70755509
		C	90	35	F	5YR44	WB		20								
40	Hu2200	A	20	40	F	5YR33	A			90	SO		S1	M	3		-31.29920013
		B	90	55	F	5YR44	WB										28.71033663
41	Ka2000	A	20	25	F	10YR42	M	W3		0	GC		T1	M	5		-31.29233091
																	28.71291063
42	Km1220	A	30	25	F	2,5YR32	A			30	VR		T1	M	3		-31.29495755
		E	50	25	F	7,5YR43	A	W2	30								28.71489479
		B	70				SB										
43	Oa1120	A	30	25	F	10YR33	A			60	GL		T1	M	3	Oa/Hu	-31.29660526

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
		B	60	30	F	7,5YR43	WB										28.71824848
44	Km1220	A	30	25	F	7,5YR33	A			40	VR		T1	M	3		-31.29895773
		GL	40	25	F				30								28.73431357
		B	60	50	F	5YR40	SB										
45	Ka2000	A	20	25	F	10YR33	M	W3		0	GC		T1	M	5		-31.14387869
																	28.37197765
46	Oa1220	A	30	28	F	5YR33	A			80	SO		T1	M	3		-31.15468246
		B	80	40	F	5YR46	WB										28.38130075
47	Va2122	A	25	28	F	10YR54	A			40	VR		T1	M	3		-31.15076954
		GL	40	28	F		A		60								28.37441936
		B	60	50	F	5YR44	SB										
48	Tu1220	A	30	25	F	10YR33	A			90	UW		T1	M	3		-31.15029269
		B	90	40	F	5YR44	WB										28.36961461
49	Hu2200	A	35	25	F	5YR33	A			150	SO		T1	M	3		-31.15857862

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
		B	110	30	F	5YR46	A										28.37857638
		C	151	45	F	2,5YR46	WB										
50	Hu2200	A	40	20	M	5YR46	A			100	SO		T1	M	3		-31.15697851
		B	100	30	M	2,5YR46	A										28.37243554
51	Hu2200	A	25	35	F	5YR33	WB			130	GL		D1	M	3		-31.16060310
		B	130	55	F	5YR44	WB										28.36842296
52	Ka2000	A	10	25	F	10YR42	M			0	GC		A	M	5		-31.16513628
		G	30	50	F	GRYM	M	W3									28.36754042
53	Gs1111	A	30	40	F	10YR42	WB			30	GL		S1	MH	3		-31.16169090
																	28.35449735
54	Ka2000	A	10	25	F	10YR42	M			O	GC		A	M	5		-31.28328541
		G	30	50	F	10YR42	M	W3									28.65296183
55	Ms2100	A	10	18	M	10YR44	A			10	R	O3	T1	M	3		-31.27804287

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
																	28.64917497
56	Cv1100	A	20	20	M	10YR44	A			40	R	O1	T1	M	3		-31.28780041
		B	40	24	M	10YR46	A										28.65587999
57	Hu2100	A	10	20	M	10YR44	A			151			T1	M	3		-31.28487336
		B	151	25	M	5YR46	A										28.66126972
58	Sw2121	A	30	20	M	10YR42	A			30	VP		T1	L	3		-31.28233314
		B	60	45	F	10YR33	SB										28.66111667
59	Hu2200	A	40	20	M	5YR46	A			100	SO		T1	M	1		-31.27993868
		B	100	30	M	2,5YR46	A										28.66141632
60	Hu2200	A	40	20	F	10YR43	A			80	SO		T1	M	3	Hu/Oa	-31.28145153
		B	70	30	F	7,5YR46	A										28.65683477
61	Hu2200	A	40	25	M	7,5YR44	A			150	SO		T1	M	3		-31.27938280

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
		B	150	35	M	5YR46	A										28.66391866
62	Ms2100	A	20	20	M	10YR33	A			20	R		T1	M	3		-31.28779714
																	28.66120049
63	Hu2200	A	25	25	F	5YR44	A			100	SO		T1	M	3		-31.28656859
		B	80	40	F	5YR44	A										28.66613642
		C	110														
64	Hu2100	A	50	25	M	7,5YR46	A			151			T1	M	3		-31.28363918
		B	151	33	M	5YR46	A										28.67958776
65	Ms2100	A	20	20	M	10YR42	A			20	R	O6	T1	M	3		-31.28952523
																	28.66154213
66	Ka2000	A	20	20	M	10YR32	M	W3		0	GC		T1	M	5		-31.29010359
																	28.66559219
67	Ms2100	A	10	20	M	10YR32	M			10	R	O7	T1	M	3		-31.29146900

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
																	28.66508726
68	Ms2100	A	10	20	M	10YR32	M			10	R	O7	T1	M	3		-31.29387628
																	28.66424505
69	Ms2100	A	20	20	M	10YR43	M			20	R	O6	T1	M	3		-31.29747731
																	28.66660053
70	Hu2200	A	40	35	F	5YR33	A			150	SO		D1	M	4		-31.29497045
		B	90	50	F	5YR44	A										28.66798036
		C	150	55	F	2,5YR44	A										
71	Hu2200	A	25	35	F	5YR33	A			90	GL		T1	M	3		-31.29463593
		B	80	45	F	5YR46	A										28.67372448
		C	120	50	F	2,5YR46	A		60								
72	Ka2000	A	20	25	F	10YR43	M	W3		0	GC		T1	M	5		-31.29444457
																	28.67799120
73	Hu2100	A	30	35	F	5YR33	A			60	SO		S2	M	3		-31.29533540

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
		B	60	45	F	5YR44	WB										28.68192944
74	Ms2100	A	20	25	M	10YR44	A			20	R		T1	M	3		-31.29590261
																	28.68626229
75	Hu2200	A	40	30	F	5YR33	WB			151			S2	M	3		-31.29727112
		B	151	45	F	2,5YR34	A										28.69111978
76	Hu2200	A	30	30	F	5YR33	WB			120	SO		S2	M	3		-31.29678346
		B	120	45	F	2,5YR34	WB										28.69531760
77	Hu2200	A	20	30	F	5YR33	WB			30	R	2	D1	M	3		-31.29512158
		B	30	45	F	2,5YR34	WB										28.69936958
78	Hu2100	A	40	45	F	5YR32	WB			140	SO		D1	M	3		-31.30004075
		B	140	55	F	2,5YR34	WB										28.68672866
79	Hu2200	A	40	30	F	5YR33	WB			150	SO		D1	M	3		-31.28968558

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
		B	150	45	F	2,5YR34	WB										28.67970153
80	Hu2200	A	30	35	F	5YR34	WB			151			T1	M	3		-31.28636192
		B	151	50	F	5YR64	WB										28.67654133
81	Gs2111	A	20	30	F	10YR53	WB			20	SO		S1	M	1		-31.28869794
																	28.69731987
82	Hu2200	A	40	35	F	5YR33	WB			130	SO		T1	M	3		-31.28534423
		B	130	48	F	5YR44	WB										28.68569763
83	Ka2000	A	20	25	F	10YR33	M	W3		0	GC		T1	MH	3		-31.27996698
																	28.69023086
84	Hu2200	A	40	35	F	5YR33	WB			90	SO		S2	M	3		-31.27251249
		B	110	50	F	2,5YR34	WB										28.70950095
85	Hu2200	A	40	35	F	5YR33	WB			90	SO		S2	M	3		-31.26933600

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
		B	90	50	F	2,5YR34	WB		10								28.70790076
86	Hu2200	A	40	35	F	5YR33	WB			100	SO		S2	M	3		- 31.26648230
		B	100	50	F	2,5YR34	WB										28.70618784
87	Ss2100	A	30	25	M	7,5YR42	A			30	PR		S2	M	3		- 31.26315619
		B	80	55	F	7,5YR54	SB										28.70439579
89	Ss2100	A	30	25	M	7,5YR42	A			30	PR		S2	M	3		- 31.26008321
		B	80	55	F	7,5YR54	SB										28.70207182
88	Hu2200	A	40	30	F	5YR33	WB			150	SO		S2	M	3		- 31.26951908
		B	150	45	F	2,5YR44	WB										28.69817331
90	Cf1100	A	40	35	F	7,5YR43	A			50	SO		S2	M	3		- 31.26417425
		E	50	25	F	7,5YR52	M	W2	40								28.71490083
91	Ka2000	A	30	28	F	10YR52	M	W3		30	GC		T1	M	5		- 31.26032790

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
																	28.71176209
92	Hu2200	A	40	30	F	2,5YR44	A			140	SO		S2	M	3		-31.27161604
		B	140	45	F	2,5YR34	WB										28.70022864
93	Hu2200	A	40	30	F	5YR33	WB			151			S2	M	3		-31.26340916
		B	151	45	F	2,5YR44	WB										28.69549982
94	Ss2100	A	50	28	F	10YR43	A			50	PR		T1	LM	3		-31.26971410
		B	70	50	F	10YR33	SB										28.69094200
95	Hu2100	A	30	30	F	5YR43	WB			60	GL		S2	M	3		-31.26551402
		B	60	40	F	5YR44	WB										28.68832642
96	Ka2000	A	30	28	F	10YR43	A	W3		0	GC		T1	L	5		-31.34526875
																	28.73280759
97	Hu2200	A	40	30	F	2,5YR34	WB			151			T1	M	3		-31.34218136

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
		B	151	45	F	2,5YR44	WB										28.73116298
98	Hu2200	A	30	30	F	5YR33	WB			110	SO		T1	M	3		-31.33944701
		B	110	45	F	5YR44	WB										28.72897790
99	Ka2000	A	20	30	F	10YR43	M	W3		20	GC		T1	M	3		-31.33967609
																	28.72601163
100	Hu2200	A	40	35	F	5YR33	WB			60	SO		S1	M	3		-31.34241144
		B	60	50	F	5YR44	WB										28.72450020
101	Hu2200	A	30	35	F	5YR33	WB			151			T1	M	3		-31.34893918
		B	151	50	F	2,5YR34	WB										28.71598737
102	Ka2000	A	20	30	F	10YR43	M			20	GC		T1	M	3		-31.35013637
																	28.71124389
103	Bv2200	A	20	30	F	5YR33	WB			40	SP		T1	M	3		-31.34453131

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
		B1	40	45	F	5YR44	WB										28.72044764
		B2	60	50	F	5YR52	M	W2	50								
104	Hu2200	A	30	30	F	5YR33	WB			90	GL		T1	M	3		-31.37789841
		B	90	45	F	5YR44	WB										28.73248480
105	Hu2200	A	30	30	F	5YR33	WB			110	SO		T1	M	3		-31.38007426
		B	110	45	F	5YR44	WB										28.73090959
106	Hu2200	A	40	30	F	5YR33	WB			140	SO		T1	M	3		-31.38314732
		B	100	45	F	5YR44	WB										28.73032554
107	Ka2000	A	20	25	m	10YR33	M	W3		20	GC		T1	M	5		-31.38636321
																	28.73026653
108	Hu2200	A	30	40	F	2,5YR33	WB			130	SO		T1	M	3		-31.38903678
		B1	70	55	F	2,5YR34	WB										28.72805161
		B2	130	55	F	2,5YR34	WB		30								
109	Ka2000	A	40	30	F	10YR42	M	W3		40	GC		T1	M	5		-31.38615668

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
																	28.74915079
110	Hu2200	A	50	25	F	2,5YR33	WB			100	SO		T1	M	3		-31.38547665
		B1	70	30	F	2,5YR34	WB										28.74584028
		B2	90	40	F	2,5YR34	WB		30								
		C	100														
111	Hu2100	A	40	30	F	2,5YR33	WB			110	GL		T1	M	3		-31.38884702
		B	110	40	F	2,5YR34	WB										28.74365469
112	Ka2000	A	20	25	M	10YR33	M	W3		0	GC		T1	M	5		-31.38399850
																	28.74770366
113	Ka2000	A	40	30	F	10YR42	M	W3		0	GC		T1	M	5		-31.38070936
																	28.74872935
114	Gs2111	A	40	35	F	10YR33	WB			40	LC		S1	M	3		-31.36710528
																	28.71988001
115	Ka2000	A	30	35	F	10YR31	WB	W3		0	GC		S1	M	5		-31.36416181

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
																	28.71788780
116	Hu2100	A	30	35	F	2,5YR34	WB			151			D1	M	3		-31.36096881
		B	151	45	F	7,5YR44	WB										28.71508833
117	Gs2111	A	60	35	F	10YR33	WB			80	LC		S2	M	3		-31.36325514
		B	90														28.72128574
118	Gs1111	A	70	45	F	10YR32	WB			80	LC	O1	D1	MH	3		-31.35971739
		B	90														28.71990172
119	Hu2100	A	50	40	F	5YR33	WB			151		O1	D1	M	3		-31.35669026
		B	151	55	F	2,5YR34	WB										28.71903151
120	Ka2000	A	30	35	F	10YR31	WB	W3		0	GC		S1	M	5		-31.34273506
																	28.73850494
121	Hu2100	A	30	35	F	2,5YR34	WB			151			D1	M	3		-31.33944634

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
		B	151	45	F	2,5YR44	WB										28.73982056
122	Hu2200	A	60	30	F	10YR33	WB			130	SO		D1	M	3		-31.33539185
		B	130	45	F	2,5YR46	WB		40								28.73960875
123	Hu2100	A	30	35	F	2,5YR34	WB			151			D1	M	3		-31.35632934
		B	151	45	F	2,5YR44	WB										28.73890056
124	Hu2200	A	50	40	F	7,5YR33	WB			151			D1	M	3		-31.35354303
		B	151	55	F	2,5YR46	WB										28.74218401
125	Gf1200	A	40	40	F	10YR32	A			151			S1	M	3		-31.35153606
		B1	100	45	F	10YR44	A										28.74570499
		B2	151	50	F	5YR46	A										
126	Gf1200	A	30	35	F	10YR32	A			130	R		D1	M	3		-31.34914923
		B1	80	45	F	10YR44	WB										28.74892163
		B2	130	55	F	5YR46	WB										
127	Hu2100	A	30	35	F	2,5YR34	WB			151			D1	M	3		-31.34648706

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
		B	151	45	F	2,5YR44	WB										28.75195295
128	Gf1200	A	30	40	F	10YR34	A			151			D1	M	3		-31.34339606
		B1	60	45	F	10YR44	WB										28.75454530
		B2	151	55	F	5YR46	WB										
129	Cv1100	A	30	40	F	10YR32	A			100	SO		S2	M	1		-31.33999083
		B	100	50	F	10YR44	A										28.75725291
130	Gf1200	A	30	35	F	10YR36	WB			151			S2	MH	3		-31.30865249
		B1	100	45	F	10YR44	WB										28.77351724
		B2	151	55	F	2,5YR48	WB										
131	Oa1220	A	40	30	F	10YR33	WB			80	SO		S2	M	3	Oa/Hu	-31.30668827
		B	70	40	F	5YR44	WB										28.77592477
		C	90														
132	Cv1100	A	40	28	F	10YR42	A			80	GL		S1	M	3		-31.30324641
		B	80	35	F	10YR54	A										28.77583307
133	Gf1200	A	25	30	F	10YR43	A			120	SO		S1	M	3		-31.30070904

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
		B1	70	35	F	10YR46	A										28.77286898
		B2	120	40	F	5YR38	A										
134	Gf1200	A	40	25	F	10YR42	A			110	SO		S2	M	3		-31.30745823
		B1	70	35	F	10YR46	A										28.77897520
		B2	110	40	F	5YR54	A										
135	We2000	A	40	20	F	10YR43	A			50	GL		S1	L	3		-31.31101333
		B	60	15	F	10YR32	M	W2	30								28.77653564
136	Gf1200	A	25	30	F	10YR43	A			120	SO		S1	M	3		-31.30359166
		B1	70	35	F	10YR46	A										28.79292084
		B2	120	40	F	5YR38	A										
137	Cv1200	A	30	30	F	10YR43	A			140	SO		S1	M	3		-31.30463496
		B	70	45	F	10YR44	A										28.78892745
		C	140	50	F	5YR45	A										
138	Cv1200	A	30	30	F	10YR43	A			110	SO		S1	M	1		-31.30547013
		B	60	45	F	10YR44	A										28.78432763
		C	110														
139	Gf1200	A	40	30	F	10YR43	A			151			S1	M	3		-31.29806271

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
		B1	70	35	F	10YR46	A										28.78899920
		B2	151	40	F	5YR38	A										
140	Cv1200	A	20	30	F	10YR33	A			90	SO		S1	M	3		-31.29983439
		B1	60	45	F	10YR44	A										28.78730496
		B2	90	50	F	5YR45	A										
141	Cv1200	A	40	30	F	10YR33	A			120	SO		S1	M	3		-31.29346666
		B1	70	45	F	10YR44	A										28.78281620
		B2	120	50	F	5YR45	A										
142	Gf1200	A	40	30	F	10YR33	A			151			S2	M	3		-31.29667944
		B1	100	40	F	10YR34	A										28.78056441
		B2	151	50	F	5YR46	A										
143	Cf1100	A	40	15	F	10YR42	A			90	SO		S1	M	3		-31.29828726
		E	90	12	F	10YR53	A	W2									28.77966151
144	Gs2111	A	60	28	F	10YR43	A			80	LC		S1	M	3		-31.27255339
		B	80			7,5YR44	A										28.61693666
145	Ms2100	A	20	40	F	10YR32	WB			20	R	O3	D1	M	4		-31.27486369

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
																	28.62063350
146	Hu2200	A	50	40	F	5YR33	WB			151			D1	M	3		-31.27674904
		B	151	55	F	2,5YR34	WB										28.62466746
147	Hu2200	A	60	40	F	5YR43	WB			151			T1	M	3		-31.27931851
		B	151	55	F	2,5YR44	WB										28.62787521
148	Hu2200	A	60	40	F	5YR33	WB			151			S2	M	3		-31.28110955
		B	151	55	F	2,5YR34	WB										28.63079824
149	Hu2200	A	50	40	F	5YR33	WB			151			S2	M	3		-31.28223432
		B	151	55	F	2,5YR34	WB										28.63494879
150	Hu2200	A	30	40	F	5YR46	WB			151			S2	M	3		-31.28292675
		B	151	55	F	2,5YR48	WB										28.63944761
151	Hu2200	A	30	45	F	5YR44	WB			100	SO		D1	M	3	loose rock @ 50	-31.29420292

OBS NO	SOIL CLASS	HOR- IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC- TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH- OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
		B	100	55	F	2,5YR46	WB										28.63936789
152	Gs2111	A	40	30	F	10YR33	A			50	SO		T1	M	3		-31.29120891
																	28.63988958
153	Hu2200	A	40	40	F	2,5YR33	WB			130	SO		S2	M	3		-31.28758105
		B	130	55	F	2,5YR34	WB										28.64340831
154	Sw2122	A	20	25	F	10YR34	A			20	VP		S1	M	3		-31.09044572
		B	40	55	F	10YR34	SB										28.63616743
155	Sw2122	A	40	25	F	10YR34	A			40	VP		S1	M	3		-31.08753830
		B	60	55	F	10YR34	SB										28.63735942
156	Se2220	A	30	20	M	10YR42	A			30	VP		T1	M	3		-31.09122399
		B	60	55	F	10YR34	SB										28.62623513
157	Se2220	A	30	15	M	10YR42	A			30	VP		T1	M	3		-31.08779756

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
		B	60	55	F	10YR34	SB										28.57955388
158	Se2220	A	20	15	M	10YR42	A	W2		20	VP		T1	M	4		-31.08752606 28.57888501
159	Se2220	A	20	15	M	10YR42	A	W2		20	VP		T1	M	4		-31.09008572 28.57698894
160	My1100	A	10	30	M	10YR32	A			10	R	O2	D1	H	3		-31.16160306 28.66748004
161	Gs2111	A	10	17	M	10YR42	A			10	SO		T1	M	3		-31.16673950 28.68522663
162	Se2220	A	30	35	F	10YR31	A			30	VP		D1	MH	3		-31.16775865 28.68310642
163	Gs2111	A	30	35	F	10YR31	AWB			30	SO		D1	H	3		-31.16951759

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
																	28.67960564
164	Mw1100	A	20	55	F	10YR31	SB			20	R	O2	D1	H	3		-31.17040540
																	28.70570806
165	Se2220	A	20	20	F	10YR42	A			20	VP		T1	H	3		-31.17289970
																	28.70406093
166	Hu2100	A	40	30	F	5YR34	WB			60	SO		D1	M	3		-31.17565146
		B	60	40	F	5YR44	WB										28.70285746
167	Mw1000	A	20	50	F	10YR33	SB			20	R	O3	D1	M	3		-31.18096937
																	28.70828549
168	Sw2122	A	40	25	F	10YR34	A			40	VP		S1	M	3		-31.02466649
		B	60	55	F	10YR34	SB										28.71177295
169	My1100	A	10	30	M	10YR32	A			10	R	O2	D1	H	3		-31.02122077

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
																	28.71170548
170	Ka2000	A	30	35	F	10YR31	WB	W3		0	GC		S1	M	5		-31.17563622
																	28.71948481
171	Oa1220	A	50	30	F	10YR42	WB			110	SO		T1	M	3		-31.18879043
		B	110	40	F	10YR34	WB										28.72726405
172	Hu2200	A	40	40	F	5YR34	WB			151			D1	M	3		-31.19224604
		B	151	55	F	2,5YR34	WB										28.72266716
173	Hu2200	A	40	35	F	5YR33	WB			70-120	SL-SO		D1	M	3		-31.19599242
		B	70	50	F	2,5YR44	WB										28.72328944
		SL	80														
		C	120														
174	Ar1200	A	70	55	F	10YR11	SB			70	UW		D1	H	5		-31.19982296
		G	90	55	F												28.72243272
175	Ms2100	A	10	20	F	10YR42	A			10	R	O1	S1	M	3		-31.20292769

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
																	28.72118935
176	Gs2111	A	40	25	F	10YR42	A			40	R		S1	M	3		-31.20563127
																	28.72120561
177	Hu2200	A	30	30	F	5YR33	A			30	SO		S1	M	3		-31.28589327
		B	80	45	F	2,5YR46	A										28.61774954
		C	120														
178	We2000	A	40	20	F	10YR43	A			40	SP		S1	L	3		-31.28308332
		B	60	22	F	10YR52	M	W2									28.62020778
179	Sw2122	A	15	30	F	10YR42	WB			15	VP		S1	L	4		-31.28132279
		B	20	50	F	10YR41	SB										28.62270635
180	Hu2200	A	30	30	F	5YR43	A			151			S1	M	3		-31.28011445
		B	151	45	F	2,5YR44	WB										28.62547640
181	Hu2100	A	20	40	F	5YR44	WB			20	R	O6	D1	M	3		-31.28037764

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
																	28.62835567
182	My1100	A	10	50	F	10YR21	MB			10	R	O6	D1	H	3		-31.30999141
																	28.77768790
183	Hu2200	A	25	30	F	5YR46	A			100	SO	O1	S2	M	3		-31.29461892
		B	80	45	F	2,5YR48	A										28.73992424
		C	130														
184	Ka2000	A	60	30	F	10YR43	M			0	GC		S2	M	3	Bleached	-31.19117883
		B	80	40	F	10YR32	M	W3									28.71266555
185	Tu1220	A	30	23	F	10YR44	A			120	SO		S2	M	3		-31.18544552
		B	120	50	F	5YR46	WB										28.71349057
186	Hu2200	A	30	30	F	5YR43	A			110	SO		S2	M	3		-31.18163861
		B	110	45	F	2,5YR44	WB										28.71386200
187	We2000	A	40	25	F	10YR54	A			80	GL		T1	M	3		-31.17955241

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
		B	70	30	F	10YR56	M	W1									28.70559125
188	Se2220	A	50	35	F	10YR43	A			50	VP		T1	M	3		-31.17327861
		B				10YR34	SB	W1									28.70173617
189	Ia2200	A	50	30	F	5YR22	A			120	SO		S2	H	3		-31.16655543
		B	120	45	F	2,5YR44	WB										28.68057126
190	Ia2200	A	60	30	F	10YR32	A			151			S2	H	3		-31.09449586
		B	151	45	F	2,5YR44	WB										28.58869733
191	Hu2200	A	30	30	F	5YR34	A			151			S2	M	3		-31.29363117
		B	151	45	F	2,5YR34	A										28.63216546
192	Hu2200	A	30	30	F	5YR34	A			151			S2	M	3		-31.29255218
		B	151	45	F	2,5YR34	A										28.62035257
193	Ka2000	A	30	35	F	10YR31	WB	W3		0	GC		S1	M	5		-31.28983057

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
																	28.62735795
194	Ka2000	A	30	35	F	10YR31	WB	W3		0	GC		S1	M	5		-31.27677960
																	28.63541061
195	Hu2200	A	30	30	F	5YR34	A			151			S2	M	3		-31.27847187
		B	151	45	F	2,5YR34	A										28.63951358
196	Se2220	A	30	40	F	10YR32	SB			30	VP		T1	H	4		-31.02803063
																	28.71614788
197	Hu2100	A	40	45	F	5YR33	WB			151			D1	M	3		-31.02969535
		B	151	55	F	2,5YR34	WB										28.71428100
198	Hu2100	A	20	40	F	5YR33	WB			30	R	O1	D1	M	3		-31.02781174
		B	30	55	F	2,5YR34	WB										28.70607902
199	Ms2100	A	20	25	F	10YR42	A			20	R	O1	S1	M	3		-31.04296046

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
																	28.70531040
200	Du1110	A	20	25	F	10YR32	WB			151			A	M	4		- 31.01300480
		B	151	30	F	10YR31	WB										28.71334300
201	Hu2200	A	30	30	M	5YR44	A			151			T1	M	3		- 31.01699718
		B	151	45	M	2,5YR44	A										28.71344503
202	Se2220	A	50	35	F	10YR43	A			50	VP		S1	M	3		- 31.02499154
		B				10YR34	SB	W1									28.70795514
203	Wa1000	A	30	20	M	10YR43	A			50	HP		T1	LM	3		- 31.02615918
		E	50	10	M	10YR53	M	W2									28.71420740
204	Hu2200	A	30	28	M	5YR43	A			90	R	O1	D1	M	1		- 31.02428880
		B	90	45	F	2,5YR44	A										28.71423899
205	Hu2100	A	40	40	F	5YR33	A			100	SO		S2	H	3		- 31.02344797

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
		B	60	50	F	2,5YR45	A										28.70887023
206	Hu2200	A	40	30	F	5YR43	A			151			S1	M-H	3	Humic ?	-31.29104007
		B	151	45	F	2,5YR44	WB										28.69115050
207	Ia2200	A	50	40	F	5YR43	WB			151			S1	M	3		-31.27874922
		B	151	55	F	2,5YR44	WB										28.73272284
208	Ia2200	A	60	30	F	5YR43	A			151			S2	H	3	Humic ?	-31.28168935
		B	151	45	F	2,5YR44	WB										28.73809493
209	Hu2200	A	70	30	F	5YR43	A			151			S1	M-H	3	Humic ?	-31.29774805
		B	151	45	F	2,5YR44	WB										28.71444659
210	Ia2200	A	60	30	F	5YR22	A			130	SO		S2	H	3		-31.32915488
		B	130	45	F	2,5YR44	WB										28.69881234
211	Ia2200	A	50	30	F	5YR43	A			151			S2	H	3		-31.29908380

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
		B	151	45	F	2,5YR34	WB										28.72600131
212	Ia2200	A	80	30	F	5YR33	A			151			S1	H	3		-31.30175760
		B	151	45	F	2,5YR46	WB										28.72565984
213	Ia2200	A	50	30	F	5YR23	A			151			S2	H	3		-31.29272810
		B	151	45	F	2,5YR44	WB										28.73180382
214	Ka1000	A	12	15	M	10YR34	M	W1		0	GC		A	MH	W1		-31.28560714
		G	121	50	M	7,5YR44	M	W3							W3		28.73719984
215	Hu2100	A	40	40	F	5YR33	A			100	SO		S2	H	3		-31.28283542
		B	60	50	F	2,5YR45	A										28.69724818
216	Sw2122	A	15	30	F	10YR42	WB			15	VP		S1	M	4	Sw/Se	-31.10017770
		B	70	50	F	10YR41	SB										28.56718983
217	We2000	A	20	12	F	10YR53	A			20	SP		S1	M	3		-31.15881006

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
		B	40	20	F	7,5YR44	M	W2	20								28.35152496
218	Se2220	A	40	15	F	10YR34	A			40	VR		S1	M	3		-31.16404001
		B	70	50	F	7,5YR44	SB	W1									28.36008167
219	Hu2100	A	40	15	M	7,5YR46	A			90	SO		F	M	3	Hu/Bv	-31.16765934
		B	90	20	M	5YR46	A										28.36016257
220	Kd1000	A	40	12	M	10YR43	A			60	E		S1	M	3	Yellow	-31.14730854
		E	90	10	M	10YR53	M										28.37983031
		B	120	40	M	10YR64	M	W2									
221	Hu2200	A	60	20	M	5YR33	A			151			T1	M	3		-31.14039902
		B	151	30	M	2,5YR36	A										28.37404706
222	Du1110	A	20	25	F	10YR32	WB			151			A	M	4		-31.09733586
		B	151	30	F	10YR31	WB										28.58116930
223	Hu2200	A	30	30	F	5YR34	A			110	SO		S2	M	3		-31.09778273

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
		B	110	45	F	2,5YR34	A										28.58751032
224	Se2220	A	40	28	F	10YR43	A			40	PV		S2	M	3		-31.18623081
		B	80	50	F	10YR31	SB	W1									28.71872476
225	Hu2200	A	30	30	F	5YR34	A			151			S2	M	3		-31.17412725
		B	151	45	F	2,5YR34	A										28.71355179
226	Hu2200	A	30	30	F	5YR34	A			140	SO		S2	M	3		-31.17815062
		B	140	45	F	2,5YR34	A										28.69233131
227	Ms2100	AB	20	30	F	10YR32	MB			20	R	O6	D1	M	3		-31.17084525
																	28.71503930
228	Se2220	A	40	28	F	10YR43	A			40	PV		S2	M	3		-31.27091947
		B	80	50	F	10YR31	SB	W1									28.63405075
229	Km1220	A	40	25	F	10YR42	WB			60	VP		T1	M	3		-31.29103910

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
		E	60	20	F	10YR31	WB	W2									28.77491182
		B	151	45	F	10YR61	SB	W3									
230	Bv2200	A	30	30	F	7,5YR34	A			120	SP		T1	M	3		- 31.29362237
		B1	80	40	F	2,5YR34	A		65								28.77300479
		B2	120	45	F		M										
231	Ka2000	A	30	35	F	10YR31	WB	W3		0	GC		S1	M	5		- 31.31523269
																	28.79705039
232	Cv1100	A	30	40	F	10YR32	A			100	SO		S2	M	1		- 31.31311316
		B	100	50	F	10YR44	A										28.78686621
233	Gf1200	A	25	30	F	10YR43	A			120	SO		S1	M	3		- 31.30898991
		B1	70	35	F	10YR46	A										28.79402183
		B2	120	40	F	5YR38	A										
234	Ka2000	A	40	30	F	10YR42	M	W3		40	GC		T1	M	5		- 31.37956097
																	28.72087881
235	Oa1220	A	35	15	M	10YR42	A			121			A	M			- 31.38745885

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
		B	121	35	M	10YR41	A										28.72112781
236	Ka1000	A	12	15	M	10YR42	M	W1		0	GC	W1	A	MH	3		-31.32748220
		G	121	50	M	10YR41	M	W3				W3					28.70429296
237	Ka1000	A	12	15	M	10YR42	M	W1		0	GC	W1	A	MH	3		-31.31845194
		G	121	50	M	10YR41	M	W3				W3					28.70399549
238	Hu2200	A	30	20	F	5YR34	A			121			S2	M	3		-31.30849385
		B	121	35	F	2,5YR33	A										28.72964860
239	Hu2200	A	30	20	F	5YR44	A			121			S2	M	3		-31.34711829
		B	121	35	F	5YR44	A										28.71914859
240	Hu2200	A	30	20	F	5YR34	A			121			S2	M	3		-31.35413048
		B	121	35	F	2,5YR33	A										28.71168812
241	Hu2200	A	30	35	F	5YR44	WC			121			S2	M	3		-31.34753940

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
		B	121	45	F	5YR44	WC										28.72426600
242	Hu2200	A	30	30	F	5YR34	A			80	SO		S2	M	3		-31.37985743
		B	80	45	F	2,5YR33	A										28.74088252
243	Hu2200	A	25	20	F	5YR44	A			100	SO		T1	M	3		-31.18550824
		B	80	30	F	5YR44	A										28.72663852
		C	110														
244	Sw2122	A	15	30	F	10YR42	WB			15	VP		S1	M	4		-31.29070758
		B	70	50	F	10YR41	SB										28.74949561
245	Ka2000	A	10	25	F	10YR42	M			O	GC		A	M	5		-31.14190239
		G	30	50	F	10YR41	M	W3									28.37355958
246	Du1110	A	20	20	F	10YR33	WB			151			A	M	4		-31.37944168
		B	151	30	F	10YR32	A										28.72788852
247	Du1110	A	40	25	F	10YR33	A			151			A	M	4		-31.38541755

OBS NO	SOIL CLASS	HOR-IZON	LOWER DEPTH CM	CLAY %	SAND GRADE	COLOUR	STRUC-TURE	WETNESS HAZARD	GRAVEL	ERD	DEPTH LIM. MATERIAL	SURFACE FEATURES	LITH-OLOGY	TOPSOIL CARBON	TERRAIN	REMARKS	GPS LAT/LONG
		B	151	30	F	10YR31	A										28.72802109
248	Ms2100	AB	20	30	F	10YR32	MB			20	R	O6	D1	M	3		-31.38029542
																	28.73672359
249	Ka1000	A	12	15	M	10YR42	M	W1		0	GC		A	MH	W1		-31.27326771
		G	121	50	M	10YR41	M	W3							W3		28.62925607

ANNEXURE 2. KEY TO CODES USED IN ANNEXURE 1

HORIZON

OB = overburden
O = O-horizon
A = A-horizon
E = E-horizon
B = B-horizon
G = G-horizon
C = C-horizon
U = unconsolidated material
R = hard rock
SL = stoneline (includes gravel stone and rock line)
GL = concretion layer
MA = man-made soil horizon

SAND GRADE

F = fine
M = medium
C = coarse

SOIL COLOUR

G = Grey
B = Brown
Y = Yellow
R = Red
L = Black
P = Pale
D = Dark
S = Strong
I = Light
M = Mottled

WETNESS HAZARD

W1 = short periods (mottles on good background colour)
W2 = long periods (mottles on poor background colour)
W3 = almost year round (gleyed colours throughout, dark cutans, channel oxidation)

GRADE & TYPE OF STRUCTURE

sg = single grain (non-coherent)
A = apedal (coherent)
WB = weak blocky (indiscrete peds, some unaggregated material)
MB = moderate blocky (discrete peds, little unaggregated material)
SB = strong blocky (very discrete peds, no aggregated material)
WC = weak crumb (as for mb)
MC = moderate crumb (as for mb)
SC = strong crumb (as for sb)
M = massive (dense)

FACTORS AFFECTING CULTURAL PRACTICES

G = gravel or stones (2 - 2- mm)
R = rocks (2 -50 cm)
B = boulders (> 50 cm)
H = hardsetting horizon

Suffix 1-9 denotes 10% - 90% of soil volume

COMPACTION OR FIRMNESS

min = 30, max = 50 - compaction begins at 30 cm and ends at 50 cm
If maximum depth of compaction continues below 150 cm then enter value 151

EFFECTIVE ROOTING DEPTH

ERD is defined as the depth of soil above a restricting layer

AMELIORATED ERD

The depth limiting can be ameliorated by mechanical means such as ripping

SURFACE FEATURES

D = dongas
G = gullies
E = sheet erosion
S = surface capping
O = outcrops
R = rocks
B = boulders

Assesed for the area surrounding the auger point (75m radius)
Suffix 1-9 denotes 10% - 90% of surface area coverage

CARBON CONTENT

L = low	(<0.3% organic carbon)
LM = low to medium	(0.3% to 0.6% organic carbon)
M = medium	(0.6% to 1% organic carbon)
MH = medium to high	(1% to 1.4% organic carbon)
H = high	(1.4% to <1.8% organic carbon)
VH = very high	(1.8% to 3% organic carbon)
EH = extremely high	(>3% organic carbon)

DEPTH LIMITING MATERIAL

SO = weathering rock/saprolite
SL = stoneline
GL = gravel or concretion layer
VP = non-red structured horizon
VR = red structured horizon
PR = prismacutanic horizon
GC = gleyed material
SP = soft plinthite
HP = hard plinthite
VE = vertic horizon
NE = limiting neocutanic material
LC = lithocutanic horizon
C = compaction
WT = watertable
OO = organic topsoil
MA = limiting man-made horizon
UW = unconsolidated material with signs of wetness
UD = unconsolidated material without signs of wetness
R = hard rock
E = E-horizon
H = hardsetting horizon

LITHOLOGY

S = General fine sedimentry rock
S1 = shale
S2 = mudstone
T = General quartzitic rock
T1 = sandstone
T2 = quartzite
T3 = chert
D = General mafic rock
D1 = dolerite
D2 = basalt
D3 = gabbro
D4 = undifferentiated basic rock
D5 = undifferentiated ultrabasic rock
G = General acidic rock
G1 = granite
G2 = acid gneiss
G3 = undifferentiated acid igneous rock
L = General calcareous rock
L1 = limestone
L2 = dolomite
R = General sands
R1 = recent sand
R2 = weathering sand (eg Berea Sands)
E = tillite
F = ferricrete
A = alluvium
C = colluvium

ANNEXURE 3. MODAL PROFILE DESCRIPTIONS

	Survey: NTABELANGA																	
Observation		Horizon	Depth	Clay	Sand	Moist	Mottles		Lime		Structure			Coarse Frag.		Diagnos.	Bag	
No. **MP 1**				%	grade	colour	Occ.	Colour	Occ.	Type	Grade	Size	Type	Type	%	Hor.	nr.	
-31.16672315	Form: **Hu**	**A**	**40**	**45**	**fi**	**5YR33**	**f**	**BR**	-	-	**W**	**f-m**	**SB**	-	-	**ot**	**MP 1 T**	Parent Mat.: **DO**
28.68513771	Family: 2100	**B**	**151**	**55**	**fi**	**2.5YR34**	**f**	**BR**	-	-	**W**	**f-m**	**SB**	-	-	**re**	**MP 1 S**	Eff. Depth: **150+ cm**
	Text. Class: SaClLm	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Slope %: **7**
	Phase: -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Terrain Unit: **3**
Remarks: **This modal profile is situated in the better part of Area 1**																		Depth lim Mat.: -
Observation		Horizon	Depth	Clay	Sand	Moist	Mottles		Lime		Structure			Coarse Frag.		Diagnos.	Bag	
No. **MP 2**				%	grade	colour	Occ.	Colour	Occ.	Type	Grade	Size	Type	Type	%	Hor.	nr.	
-31.29442882	Form: **We**	**A**	**40**	**30**	**fi**	**10YR43**	**f**	**R**	-	-	**W**	**f**	**SB**	-	-	**ot**	**MP 2 T**	Parent Mat.: **SH**
28.67259745	Family: **1000**	**B**	**81**	**35**	**fi**	**10YR42**	**c**	**R Y**	-	-	-	-	**MA**	-	-	**sp**	**MP 2 S**	Eff. Depth: **60**
	Text. Class: **SaClLm**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Slope %: **5**
	Phase: -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Terrain Unit: **4**
Remarks: **Typical class IV soil for the area.**																		Depth lim Mat.: **sp**
Observation		Horizon	Depth	Clay	Sand	Moist	Mottles		Lime		Structure			Coarse Frag.		Diagnos.	Bag	
No. **MP 3**				%	grade	colour	Occ.	Colour	Occ.	Type	Grade	Size	Type	Type	%	Hor.	nr.	
-31.29419697	Form: **Hu**	**A**	**40**	**30**	**fi**	**5YR33**	**f**	**B**	-	-	**W**	**f-m**	**SB**	-	-	**ot**	**MP 3 T**	Parent Mat.: **MU**
28.67805599	Family: **2200**	**B**	**150**	**45**	**fi**	**2.5YR44**	**f**	**B Y**	-	-	**W**	**f-m**	**SB**	-	-	**re**	**MP 3 S**	Eff. Depth: **150**
	Text. Class: **SaClLm**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Slope %: **3**
	Phase: -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Terrain Unit: **3**
Remarks: **Free water at 120 cm+**																		Depth lim Mat.: **so**

No. **MP 4**		Horizon	Depth	Clay %	Sand grade	Moist colour	Mottles Occ.	Colour	Lime Occ.	Type	Structure Grade	Size	Type	Coarse Frag. Type	%	Diagnos. Hor.	Bag x nr.	
-31.29461892	Form: **Bv**	**A**	**30**	**30**	**fi**	**7.5YR33**	**f**	**B**	**-**	**-**	**W**	**f-m**	**SB**	**-**	**-**	**ot**	**MP 4 T**	Parent Mat.: **MU**
28.73992425	Family: **2200**	**B1**	**80**	**40**	**fi**	**2.5YR46**	**f**	**B Y**	**-**	**-**	**W**	**f-m**	**SB**	**-**	**-**	**re**	**MP 4 S**	Eff. Depth: **120**
	Text. Class: **SaClLm**	**B2**	**121**	**45**	**fi**	**2.5YR46**	**C**	**Y G**	**-**	**-**	**-**	**-**	**MA**	**-**	**-**	**sp**	**-**	Slope %: **3**
	Phase: **-**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Terrain Unit: **3**
Remarks: **Free water at 120 cm+**																		Depth lim Mat.: **sp**

Observation No. **MP 5**		Horizon	Depth	Clay %	Sand grade	Moist colour	Mottles Occ.	Colour	Lime Occ.	Type	Structure Grade	Size	Type	Coarse Frag. Type	%	Diagnos. Hor.	Bag nr.	
-31.31004296	Form: **Km**	**A**	**40**		**Ffi**	**10YR42**	**f**	**B**	**-**	**-**	**-**	**-**	**A**	**-**	**-**	**ot**	**MP 5 T**	Parent Mat.: **QS**
28.77763879	Family: **1110**	**E**	**60**		**fi**	**10YR31**	**c**	**G R**	**-**	**-**	**-**	**-**	**MA**	**-**	**-**	**gs**		Eff. Depth: **60 cm**
	Text. Class: **SaCl**	**B**	**151**		**fi**	**10YR61**	**m**	**G B R**	**a**	**NP**	**S**	**m**	**SB**	**-**	**-**	**vp**	**MP 5 S**	Slope %: **2**
	Phase: **-**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Terrain Unit: **3**
Remarks:																		Depth lim Mat.: **vp**

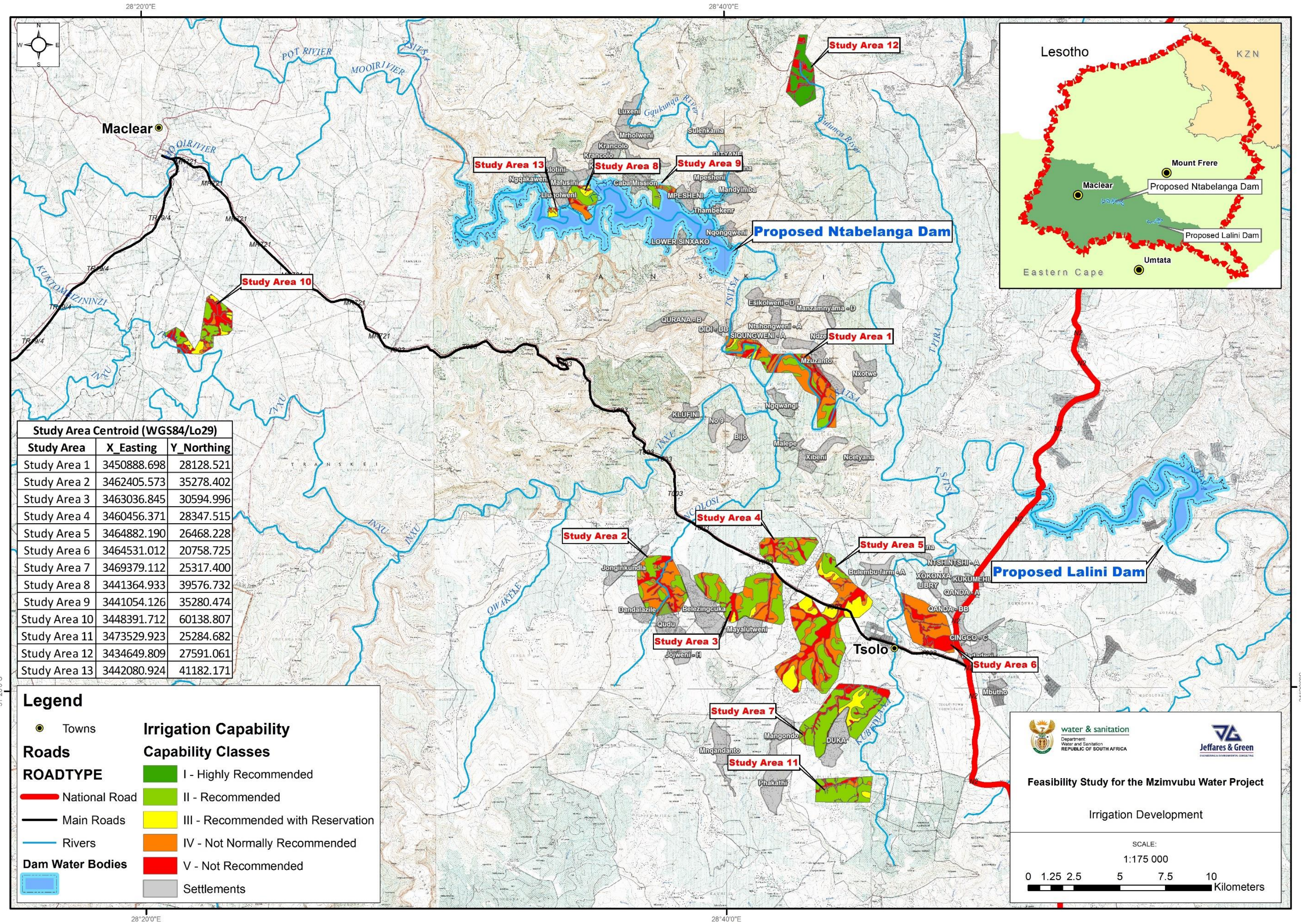
Observation No. **MP 6**		Horizon	Depth	Clay %	Sand grade	Moist colour	Mottles Occ.	Colour	Lime Occ.	Type	Structure Grade	Size	Type	Coarse Frag. Type	nr.	Diagnos. Hor.	Bag Nr.	
-31.34652402	Form: **Hu**	**A**	**30**	**45**	**fi**	**5YR44**	**f**	**B R**	**-**	**-**	**W**	**f-m**	**SB**	**-**	**-**	**ot**	**MP 6 T**	Parent Mat.: **DO**
28.75192042	Family: **2100**	**B**	**100**	**55**	**fi**	**2.5YR46**	**f**	**B R**	**-**	**-**	**W**	**f-m**	**SB**	**-**	**-**	**re**	**MP 6 S**	Eff. Depth: **100 cm**
	Text. Class: **SaCl**	-	-	-	-	-	-	-	-	-	-	-	-	-	-			Slope %: **4**
	Phase: **-**	-	-	-	-	-	-	-	-	-	-	-	-	-	-			Terrain Unit: **3**
Remarks:																		Depth lim Mat.: **so**

Observation		Horizon	Depth	Clay	Sand	Moist	Mottles		Lime		Structure			Coarse Frag.		Diagnos.	Bag	
No. **MP 7**				%	grade	colour	Occ.	Colour	Occ.	Type	Grade	Size	Type	Type	nr.	Hor.	nr.	
-31.37791599	Form: **Kp**	**A**	**50**	**30**	**fi**	**10YR32**	-	-	-	-	**A-WB**	**f**	**SB**	-	-	**ot**	**MP 7 T**	Parent Mat.: **S1**
28.73245912	Family: **1100**	**B1**	**100**	**45**	**fi**	**10YR44**	**f**	**BR**	-	-	**A-WB**	**f**	**SB**	-	-	**ye**	**Mp 7 S**	Eff. Depth: **150+ cm**
	Text. Class: **SaCl**	**B2**	**151**	**55**	**fi**	**5YR46**	**f**	**O**	-	-	**A-WB**	**f-m**	**SB**	**C**	**2**	**re**	-	Slope %: **10**
	Phase: -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Terrain Unit: **3**
Remarks: **Suspect dystrophic soils in Area 11**																		Depth lim Mat.: -
Observation		Horizon	Depth	Clay	Sand	Moist	Mottles		Lime		Structure			Coarse Frag.		Diagnos.	Bag	
No. **MP 8**				%	grade	colour	Occ.	Colour	Occ.	Type	Grade	Size	Type	Type	nr.	Hor.	nr.	
-31.33945326	Form: **Hu**	**A**	**30**	**35**	**fi**	**2.5YR34**	**f**	**B**	-	-	**W**	**f-m**	**SB**	-	-	**ot**	**MP 8 T**	Parent Mat.: **DO**
28.72898312	Family: **2100**	**B**	**151**	**45**	**fi**	**2.5YR44**	**f**	**B**	-	-	**W**	**f-m**	**SB**	-	-	**re**	**MP 8 S**	Eff. Depth: **150+ cm**
	Text. Class: **SaCl**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Slope %: **8**
	Phase: -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Terrain Unit: **3**
Remarks:																		Depth lim Mat.: **-**
Observation		Horizon	Depth	Clay	Sand	Moist	Mottles		Lime		Structure			Coarse Frag.		Diagnos.	Bag	
No. **MP 9**				%	grade	colour	Occ.	Colour	Occ.	Type	Grade	Size	Type	Type	nr.	Hor.	nr.	
-31.31974485	Form: **Hu**	**A**	**40**	**40**	**fi**	**5YR33**	**f**	**BR**	-	-	**W**	**f-m**	**SB**	-	-	**ot**	**MP 9 T**	Parent Mat.: **DO**
28.73374335	Family: **2200**	**B**	**151**	**55**	**fi**	**2.5YR44**	**f**	**BR**	-	-	**W**	**f-m**	**SB**	-	-	**re**	**MP 9 S**	Eff. Depth: **150+ cm**
	Text. Class: **SaCl**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Slope %: **3**
	Phase: -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Terrain Unit: **3**
Remarks:																		Depth lim Mat.: -

Observation		Horizon	Depth	Clay	Sand	Moist	Mottles		Lime		Structure			Coarse Frag.		Diagnos.	Bag	
No. **MP 10**				%	grade	colour	Occ.	Colour	Occ.	Type	Grade	Size	Type	Type	nr.	Hor.	nr.	
-31.29611660	Form: **Hu**	**A**	**40**	**40**	**fi**	**5YR43**	**f**	**BR**	-	-	**W**	**f-m**	**SB**	-	-	**ot**	**MP 10 T**	Parent Mat.: **DO**
28.69800048	Family: **2100**	**B**	**151**	**50**	**fi**	**2.5YR43**	**f**	**BR**	-	-	**W**	**f-m**	**SB**	-	-	**re**	**MP 10 S**	Eff. Depth: **150+ cm**
	Text. Class: **SaCl**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Slope %: **3**
	Phase: -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Terrain Unit: **3**
Remarks:																		Depth lim Mat.: -
Observation		Horizon	Depth	Clay	Sand	Moist	Mottles		Lime		Structure			Coarse Frag.		Diagnos.	Bag	
No. **MP 11**				%	grade	colour	Occ.	Colour	Occ.	Type	Grade	Size	Type	Type	nr.	Hor.	nr.	
-31.17563357	Form: **Sw**	**A**	**15**	**30**	**fi**	**10YR43**	**c**	**Y BR**			**W**	**f**	**SB**	-	-	**ot**	**MP 11 T**	Parent Mat.: **SH**
28.71941958	Family: **2122**	**B**	**70**	**55**	**fi**	**10 YR41**	**m**	**G BR**	**c**	**NP**	**S**	**m-c**	**AB**	-	-	**vp**	**MP 1**	Eff. Depth: **15 cm**
	Text. Class: **SaClLm**	**C**	**91**	-	-	-	-	-	-	-	-	-	-	-	-	**so**	**S**	Slope %: **12**
	Phase: -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Terrain Unit: **4**
Remarks:																		Depth lim Mat.: **so**
Observation		Horizon	Depth	Clay	Sand	Moist	Mottles		Lime		Structure			Coarse Frag.		Diagnos.	Bag	
No. **MP 12**				%	grade	colour	Occ.	Colour	Occ.	Type	Grade	Size	Type	Type	nr.	Hor.	nr.	
-31.27483468	Form: **Hu**	**A**	**40**	**40**	**fi**	**5YR34**	-	-	-	-	**W**	**f-m**	**SB**	-	-	**ot**	**MP 12 T**	Parent Mat.: **DO**
28.62064666	Family: **2100**	**B**	**151**	**55**	**fi**	**2.5YR34**	-	-	-	-	**W**	**f-m**	**SB**	-	-	**re**	**MP 12 S**	Eff. Depth: **150+ cm**
	Text. Class: **SaCl**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Slope %: **6**
	Phase: -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Terrain Unit: **3**
Remarks:																		Depth lim Mat.: -

ANNEXURE 4

SOIL AND IRRIGATION CAPABILITY MAPS



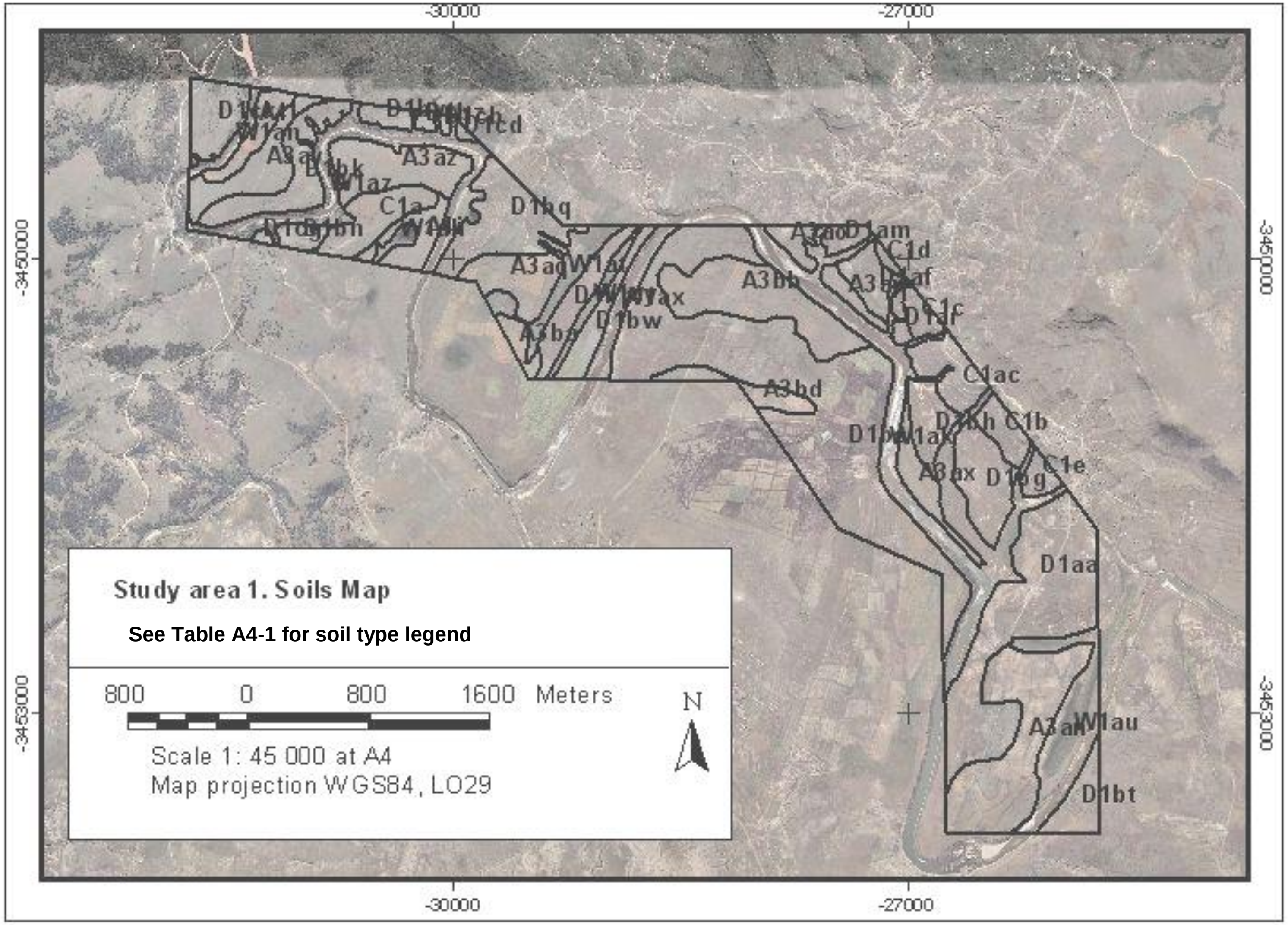
Study Area Centroid (WGS84/Lo29)		
Study Area	X_Easting	Y_Northing
Study Area 1	3450888.698	28128.521
Study Area 2	3462405.573	35278.402
Study Area 3	3463036.845	30594.996
Study Area 4	3460456.371	28347.515
Study Area 5	3464882.190	26468.228
Study Area 6	3464531.012	20758.725
Study Area 7	3469379.112	25317.400
Study Area 8	3441364.933	39576.732
Study Area 9	3441054.126	35280.474
Study Area 10	3448391.712	60138.807
Study Area 11	3473529.923	25284.682
Study Area 12	3434649.809	27591.061
Study Area 13	3442080.924	41182.171

Figure A4-1: Irrigation Capacity Study Area Locations and Co-ordinates

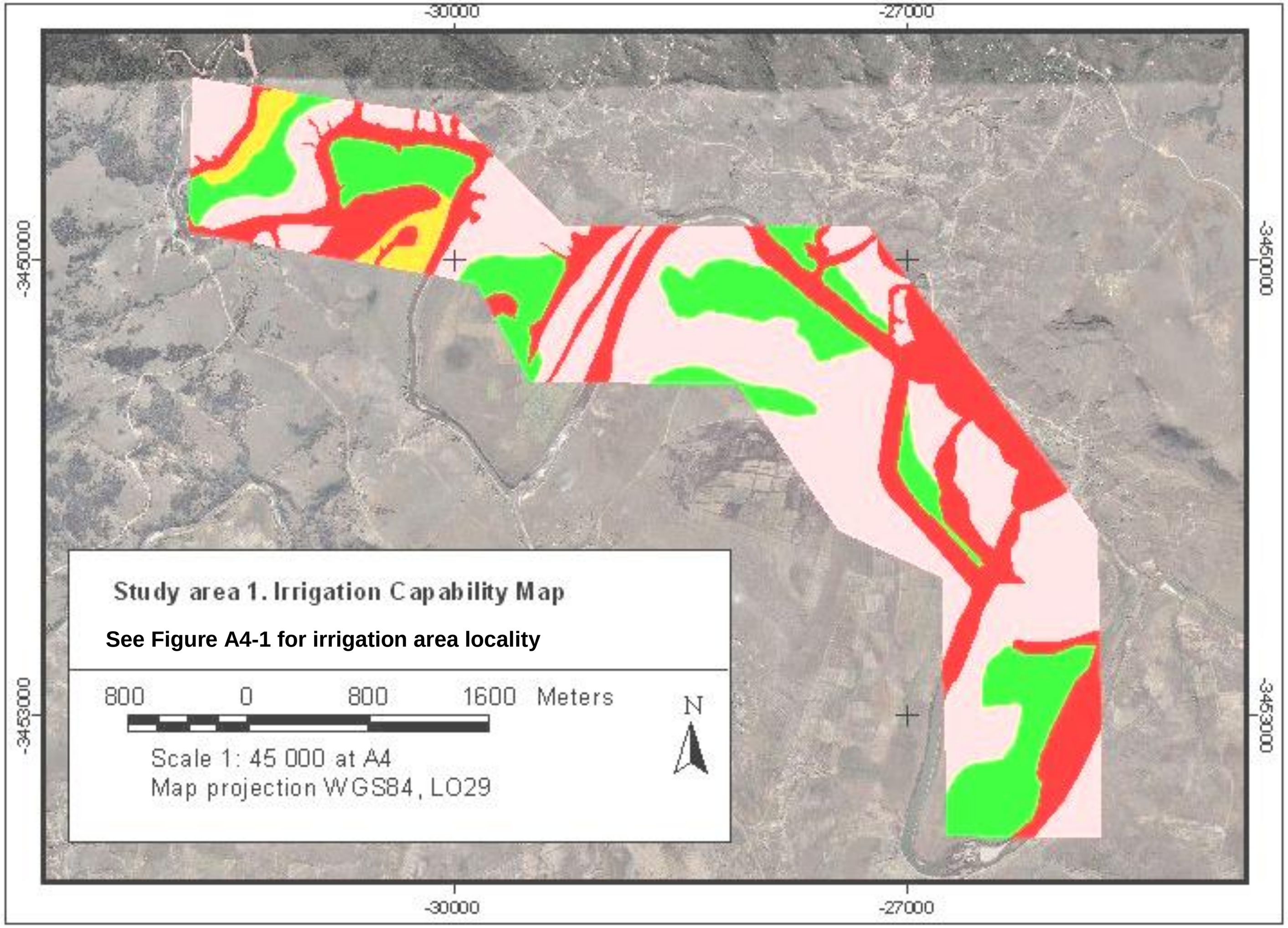
Table A4-1: Soils Maps: Legend of Soil Types and Classifications

Soil Body	Description of Soil Body	Soil Classification Dominant	Soil Classification Sub dominant	Effective Rooting Depth (cm)	Depth Limiting Material	Horizon Structure	Wetness Hazard Within Horizons	Topsoil Organic Carbon	Cultivation Factors	Surface Features	Lithology	Clay % A	Clay % E	Clay % B	Common Slope Gradient %	Irrigation Capability Class	Irrigation Capability Class Description	Limitations to Agriculture and Irrigation
A1 a-j 526 ha 7%	OXIDIC very deep yellow and /or red apedal luvic mesotrophic soils	Gf2200 Cv2200 Hu2200	Gf2100 Cv2100	100-150+	sapprolite	weak blocky - apedal A weak blocky - apedal B1 weak blocky - apedal B2	-	medium to high	-	10% outcrops	mudstone	30	-	40	0-8	II	Recommended	subsoil structure some outcrops
A2 a 14 ha <1%	OXIDIC deep yellow and /or red apedal luvic mesotrophic soils	Gf2200 Cv2200 Hu2200	Gf2100 Cv2100 Bv2200	80-100	sapprolite	weak blocky - apedal A weak blocky - apedal B1 weak blocky - apedal B2	-	medium to high	-	10% outcrops	mudstone	30	-	40	0-8	III	Recommended with reservation	subsoil structure some outcrops
A3 a-be 2110 ha 27%	OXIDIC deep red apedal luvic mesotrophic soils	Hu2200	Hu2100 Oa1120	120+	sapprolite	weak blocky - apedal A weak blocky - apedal B	-	medium	-	-	dolerite	40	-	50	0-8	II	Recommended	subsoil structure
A4 a-p 579 ha 8%	OXIDIC moderately deep red apedal luvic mesotrophic soils	Hu2200	Hu2100 Oa1120 Tu1120	80-120	sapprolite	weak blocky - apedal A weak blocky - apedal B	-	medium	-	10% outcrops	dolerite	40	-	50	0-8	III	Recommended with reservation	subsoil structure some outcrops
A5 a-i 166 ha 2%	OXIDIC deep red apedal luvic mesotrophic soils	Hu2200	Hu2100 Oa1120	120+	sapprolite	weak blocky - apedal A weak blocky - apedal B	-	medium	-	-	sandstone	20	-	30	0-8	II	Recommended	subsoil structure
A6 a-c 31 ha <1%	OXIDIC moderately deep red apedal luvic mesotrophic soils	Hu2200	Hu2100 Tu1120 Bv2200	80-120	sapprolite	weak blocky - apedal A weak blocky - apedal B	-	medium	-	-	sandstone	20	-	30	0-8	III	Recommended with reservation	subsoil structure
A7 a-f 255 ha 3%	OXIDIC deep red apedal luvic dystrophic soils	Hu2200 Ia2200	Hu2100	120+	sapprolite	weak blocky - apedal A weak blocky - apedal B	-	high	-	-	dolerite	40	-	50	0-12	I	Highly recommended	subsoil structure some steep gradients
A8 a-i 66 ha 1%	OXIDIC deep red apedal luvic dystrophic soils	Hu2200 Ia2200	Hu2100	120+	sapprolite	weak blocky - apedal A weak blocky - apedal B	-	high	-	-	dolerite	40	-	50	12+	V	Not recommended	subsoil structure gradient

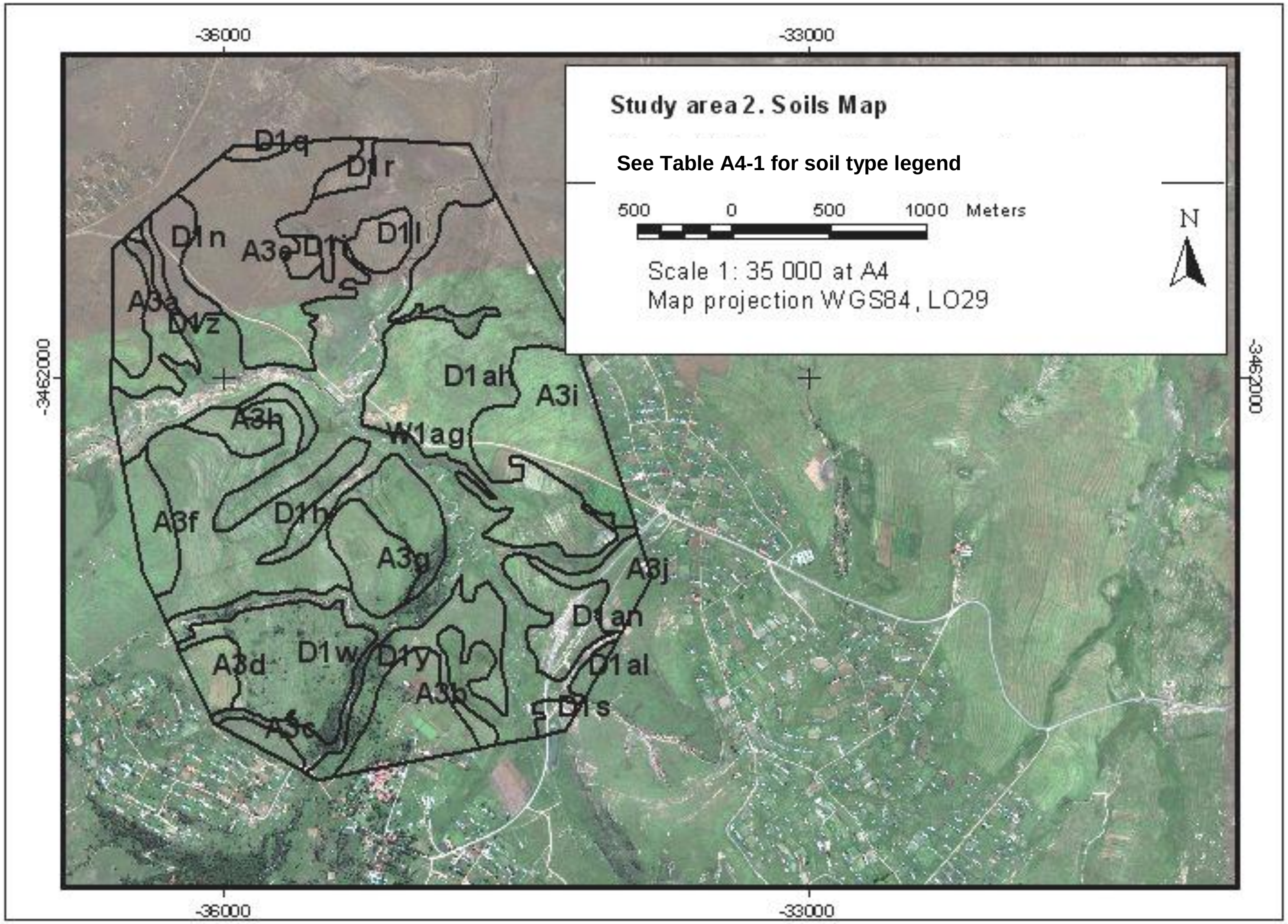
Soil Classification Sub dominant	Effective Rooting Depth (cm)	Depth Limiting Material	Horizon Structure	Wetness Hazard Within Horizons	Topsoil Organic Carbon	Cultivation Factors	Surface Features	Lithology	Clay % A	Clay % E	Clay % B	Common Slope Gradient %	Irrigation Capability Class	Description of Irrigation Capability Class	Limitations to Agriculture
Ka1000 Se1220 Se2220	0-30	gleyed clay	weak blocky - apedal A massive G	all year A all year G	medium to high	-	-	alluvium	25	-	50	0-5	V	Not recommended	wetness hazard drainage water courses wetlands sodicity
Sw2121 We2000 Gs2211 Es1100	20-60	non red structured horizons	weak blocky - apedal A strong blocky B	long B	low to medium	-	10% outcrops	mudstone dolerite	25	-	50	0-5	IV	Not normally recommended	wetness hazard subsoil structure drainage sodicity
My2100 Gs1111 Gs2211	20-30	hard rock or sapprolite	weak blocky - apedal A	-	low to medium	-	20-60% outcrops	dolerite sandstone mudstone	25	-	-	0-12	V	Not recommended	soil depth many outcrops steep gradients



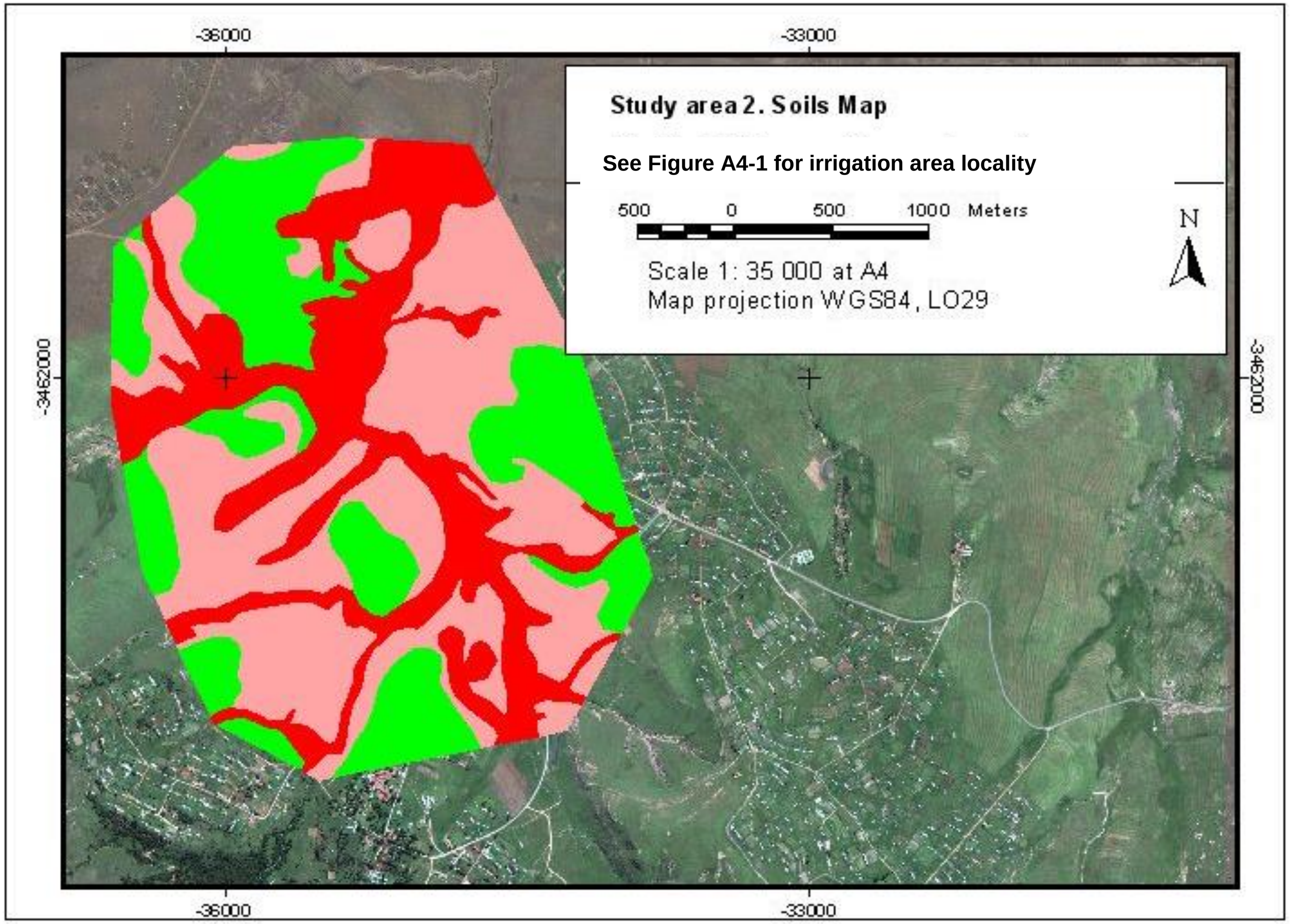
Map 1a: Soils Map for Study Area 1



Map 1b: Irrigation Capability Map for Study Area 1



Map 2a: Soils Map for Study Area 2



Map 1a: Irrigation Capability Map for Study Area 2

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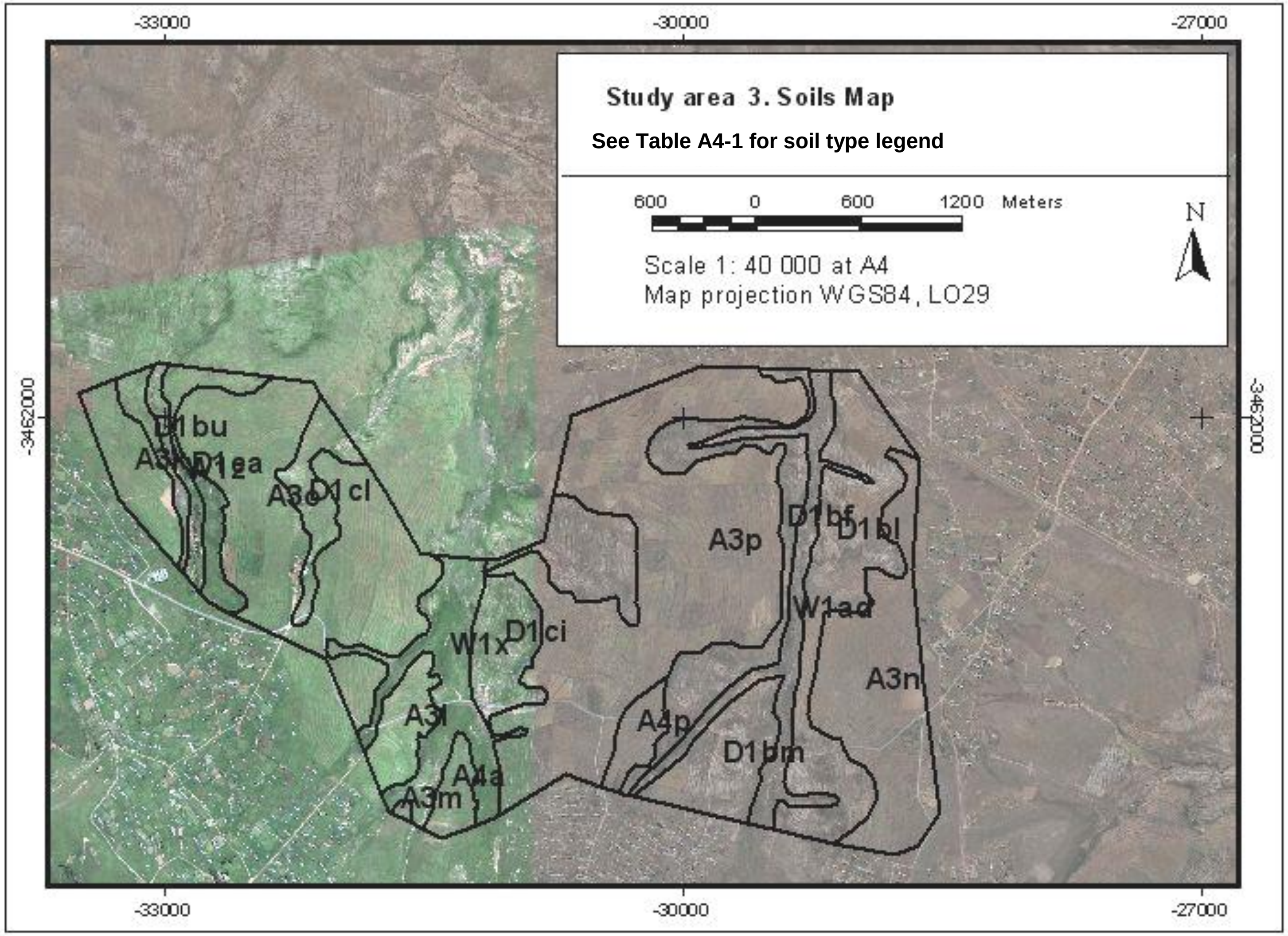
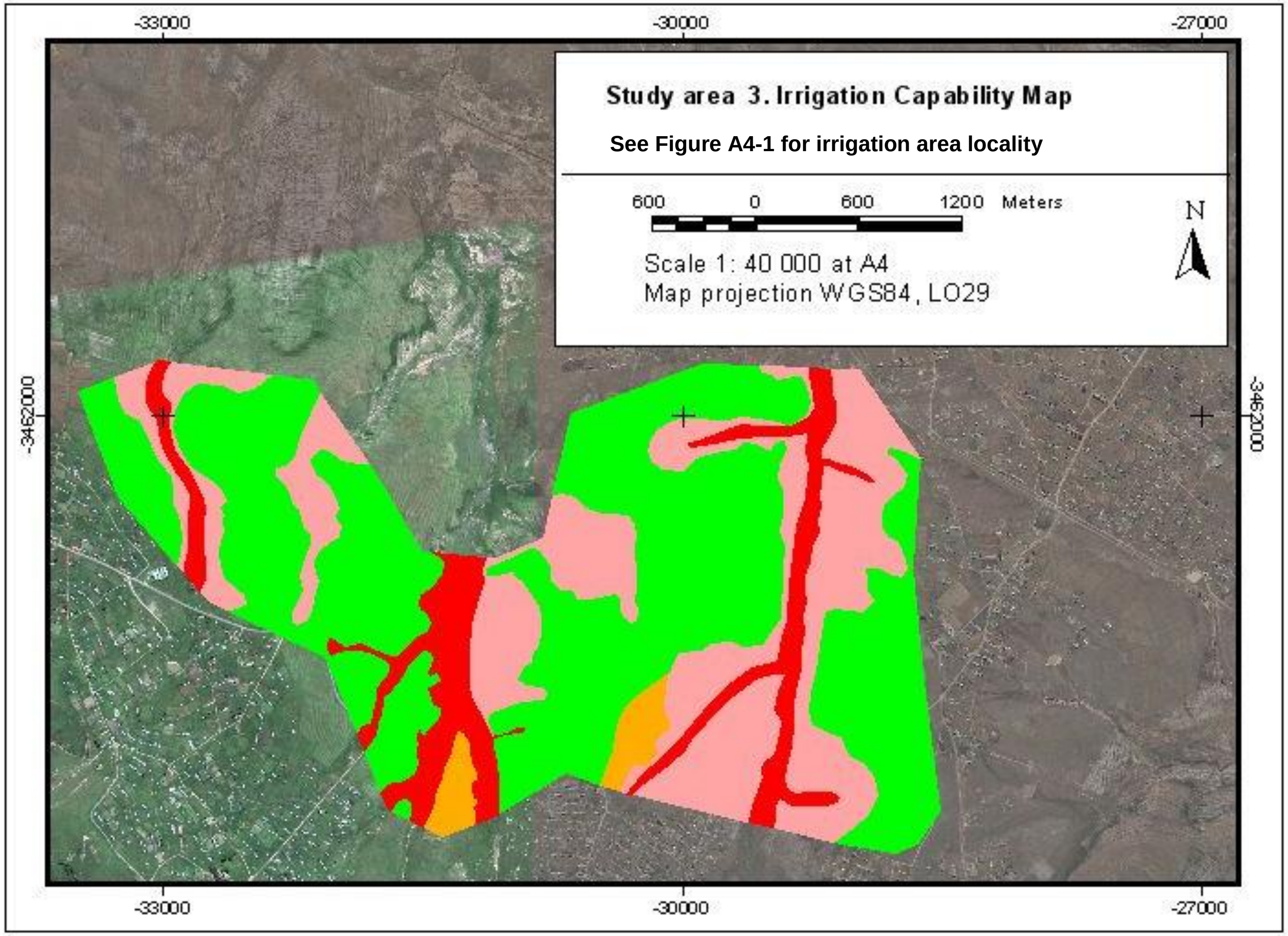
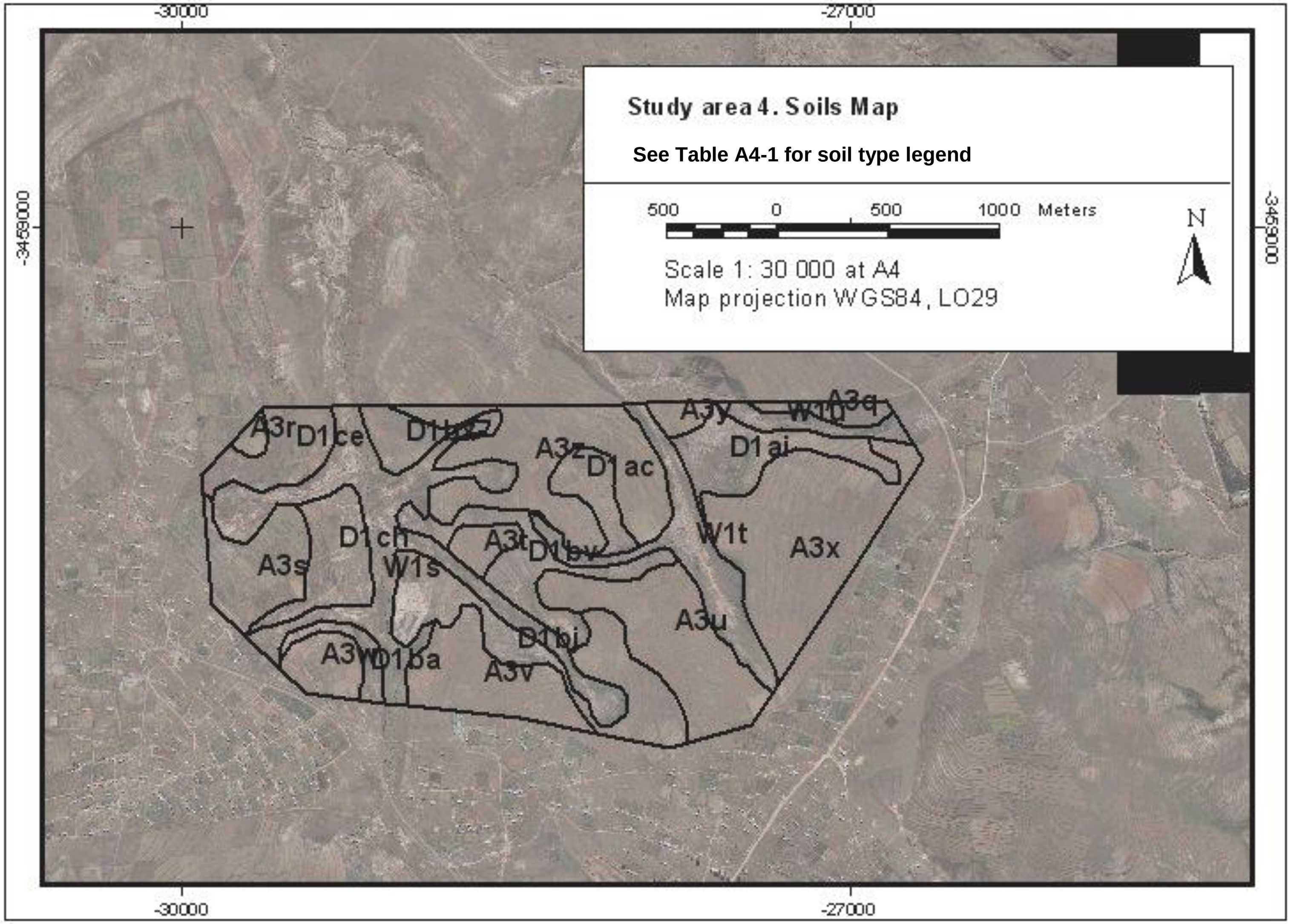


Map 3a: Soils Map for Study Area 3

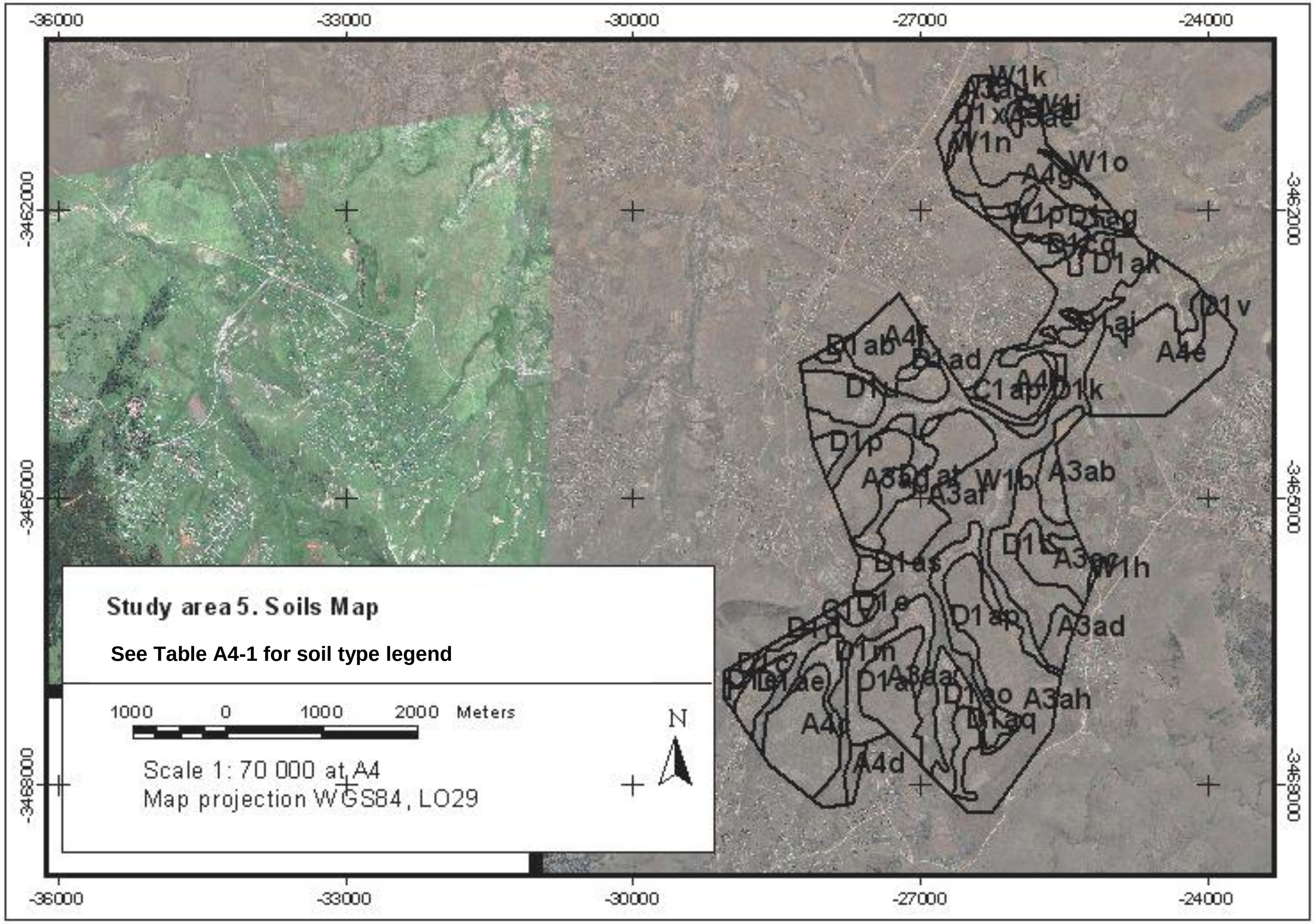


Map 3b: Soils Map and Irrigation Capability Map for Study Area 3.

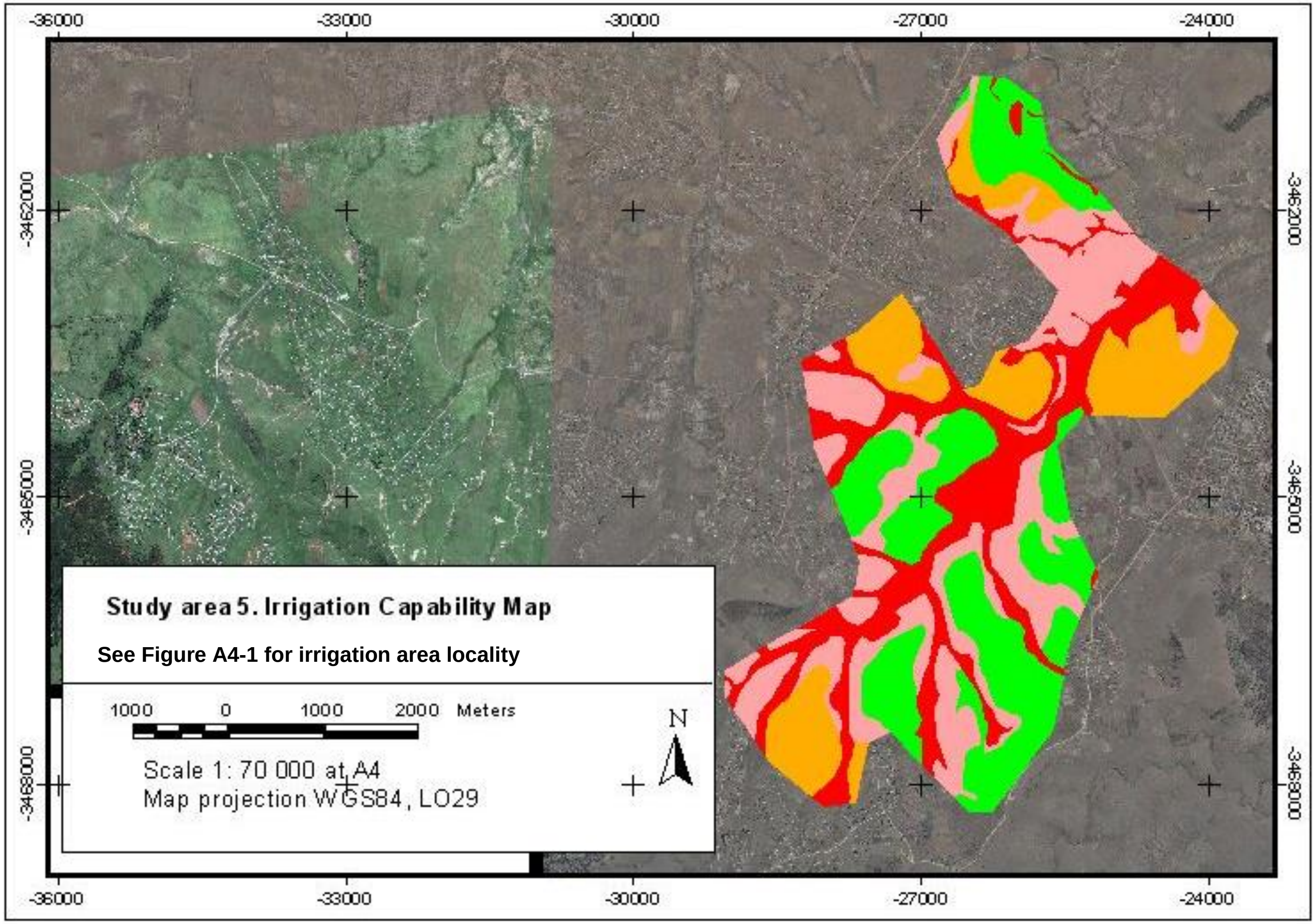


Map 4a: Soils Map for Study Area 4

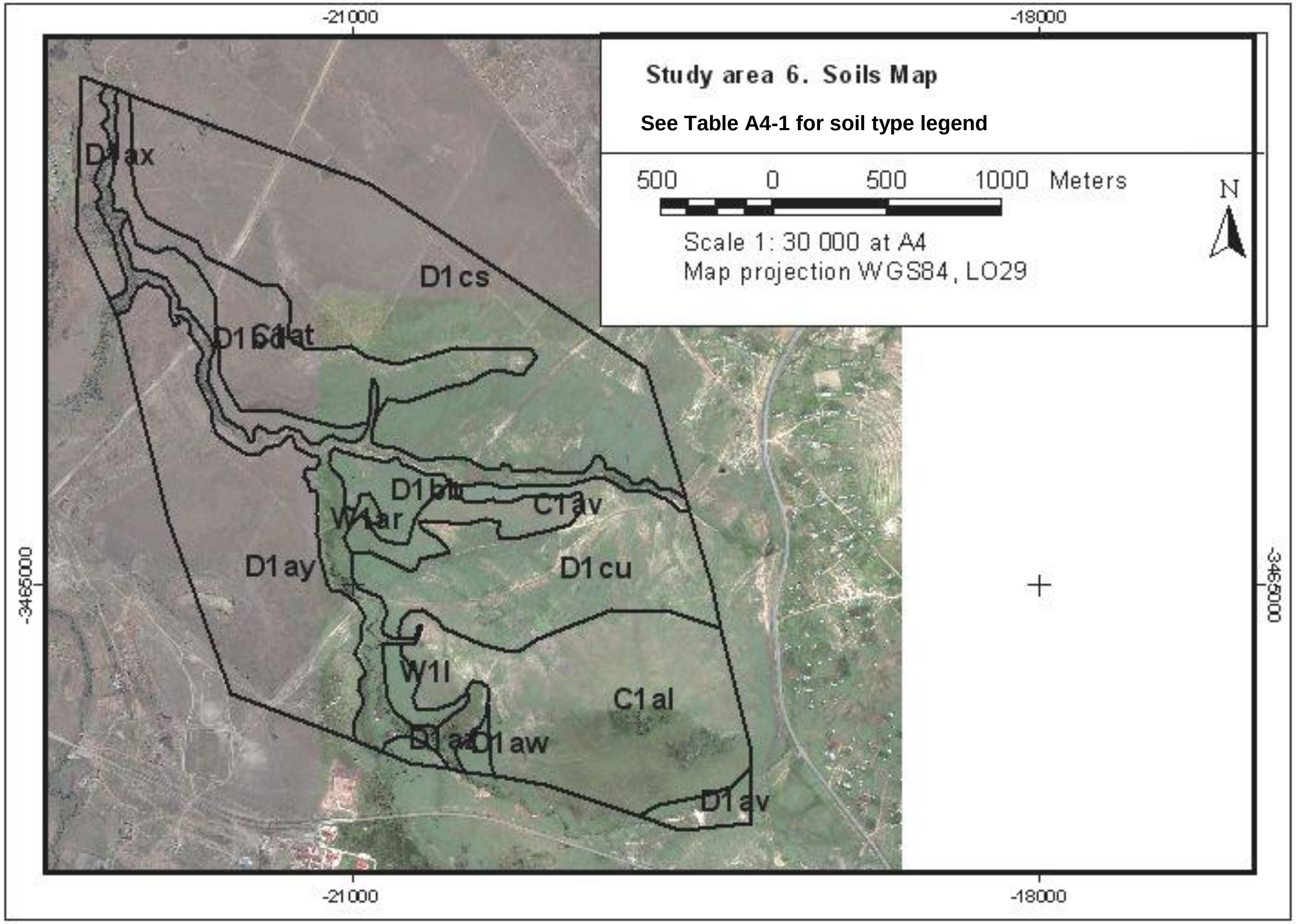
Map 4b: Irrigation Capability Map for Study Area 4



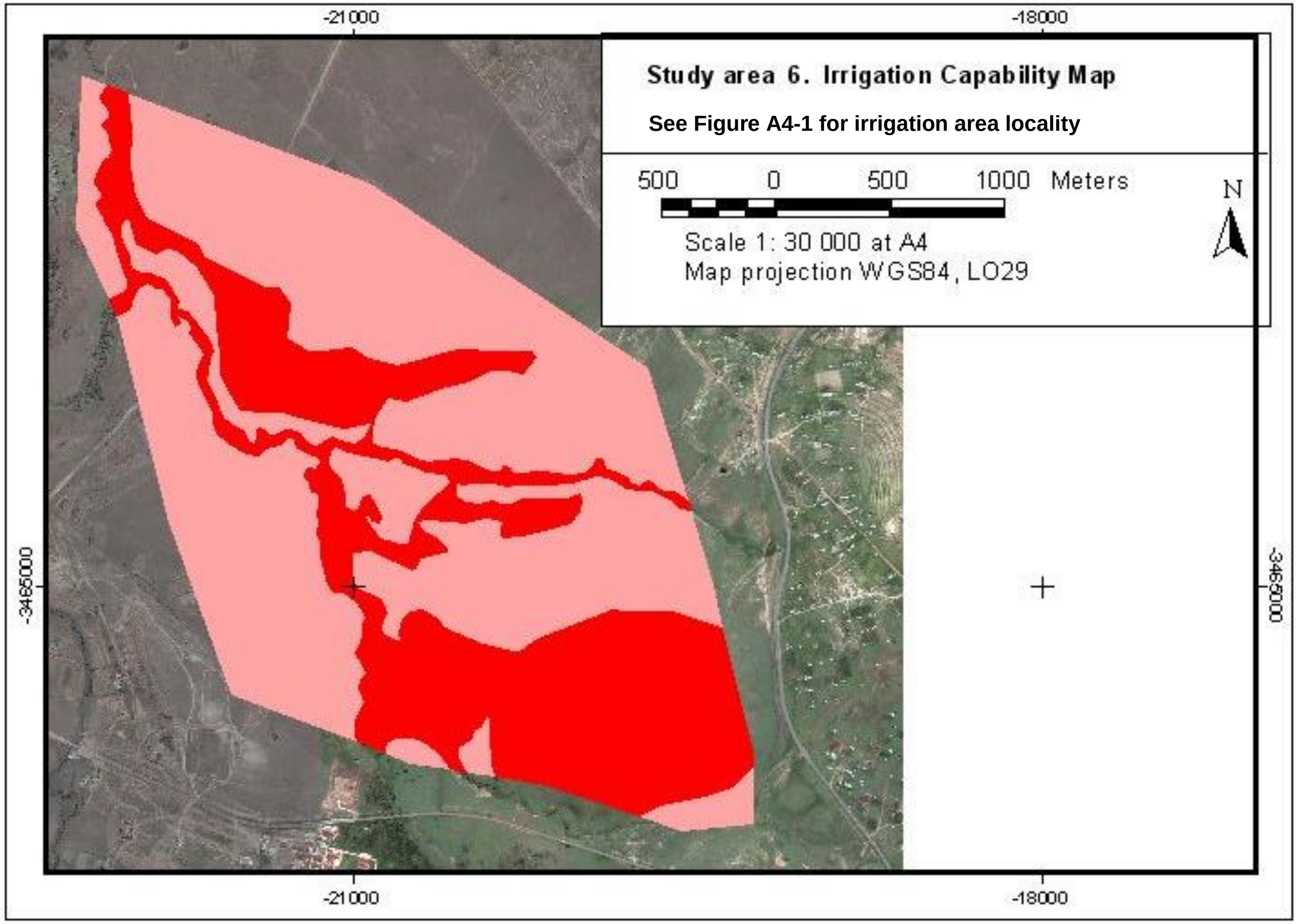
Map 5a: Soils Map for Study Area 5



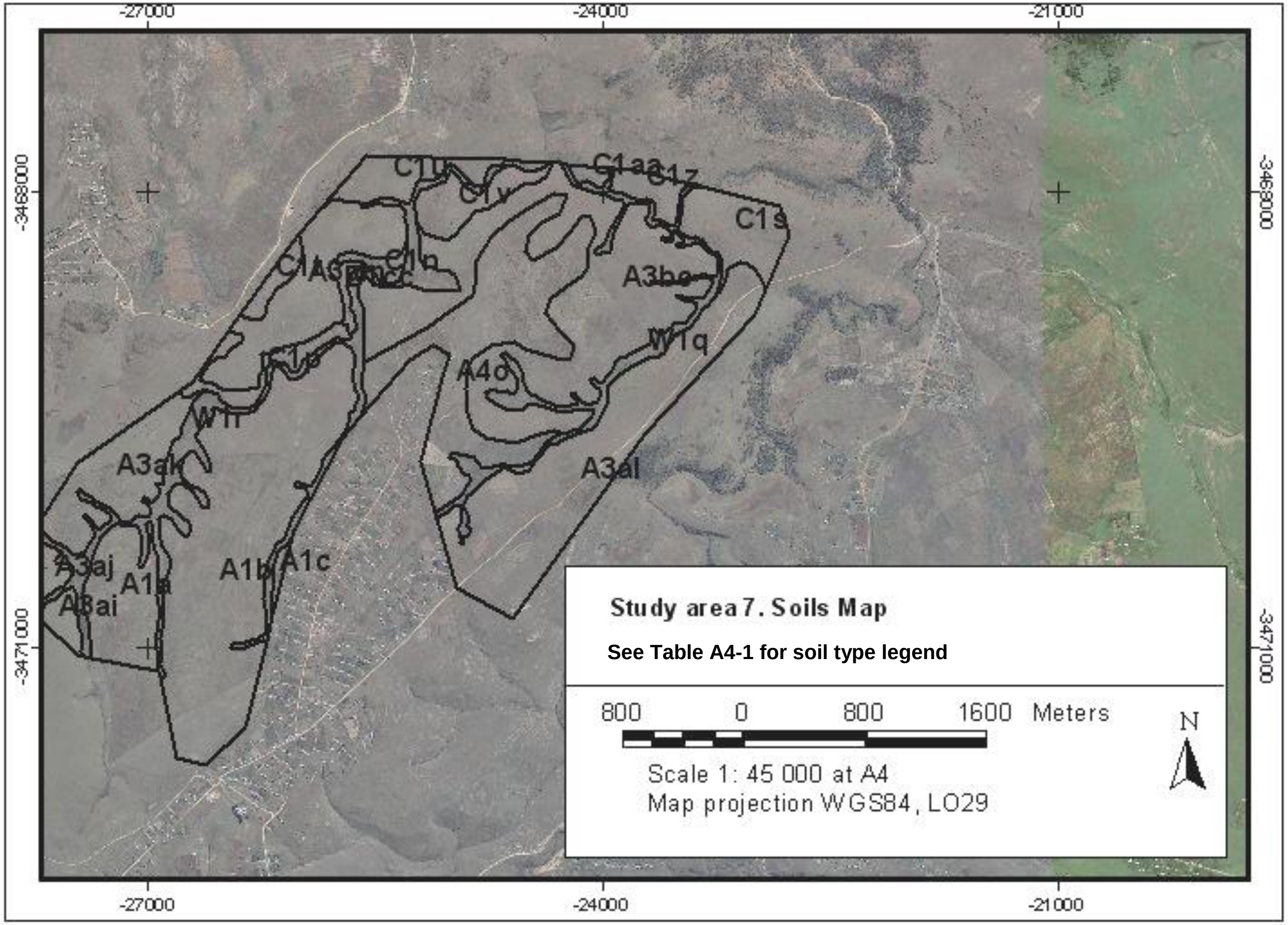
Map 5b: Irrigation Capability Map for Study Area 5



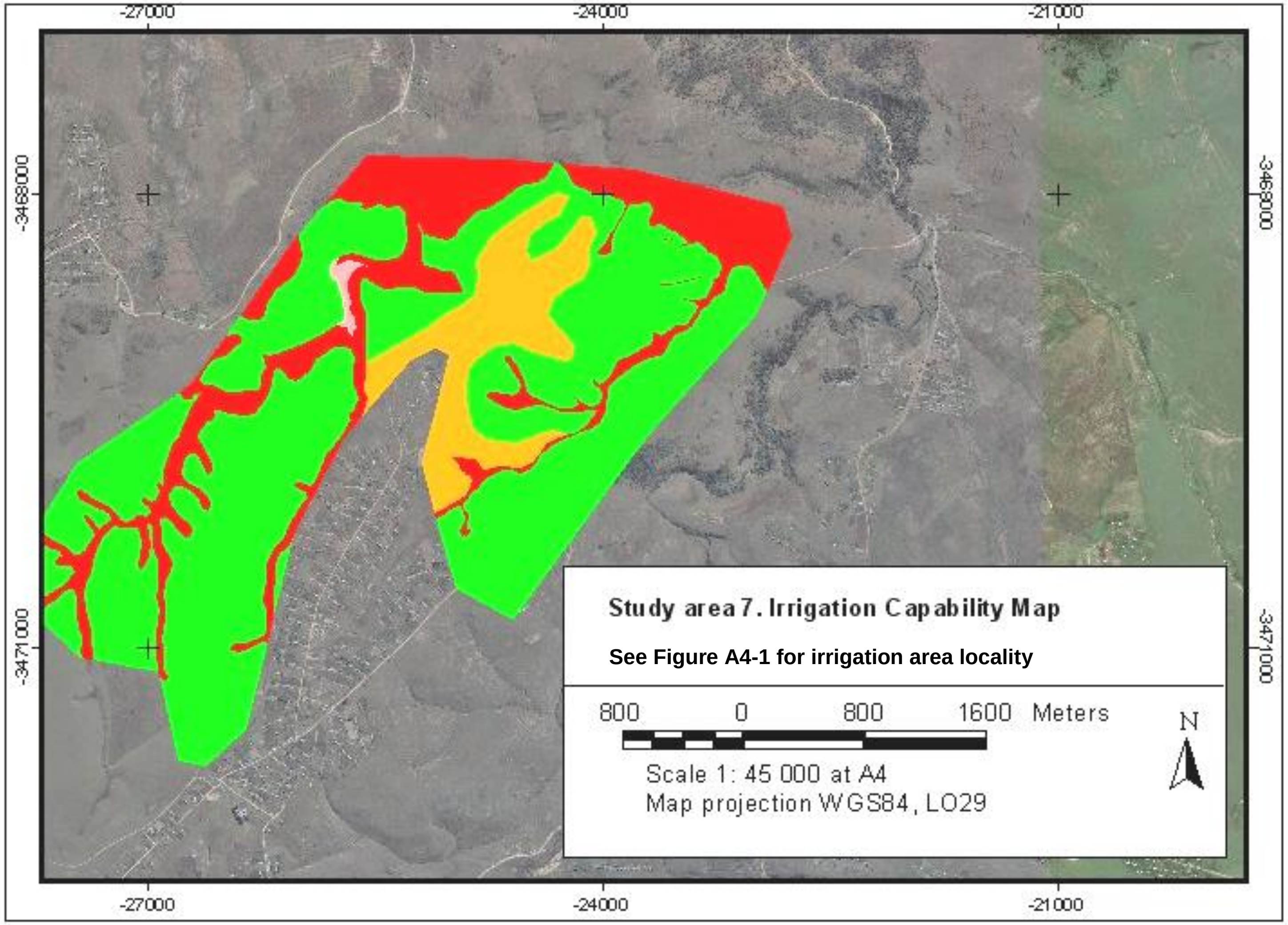
Map 6a: Soils Map for Study Area 6



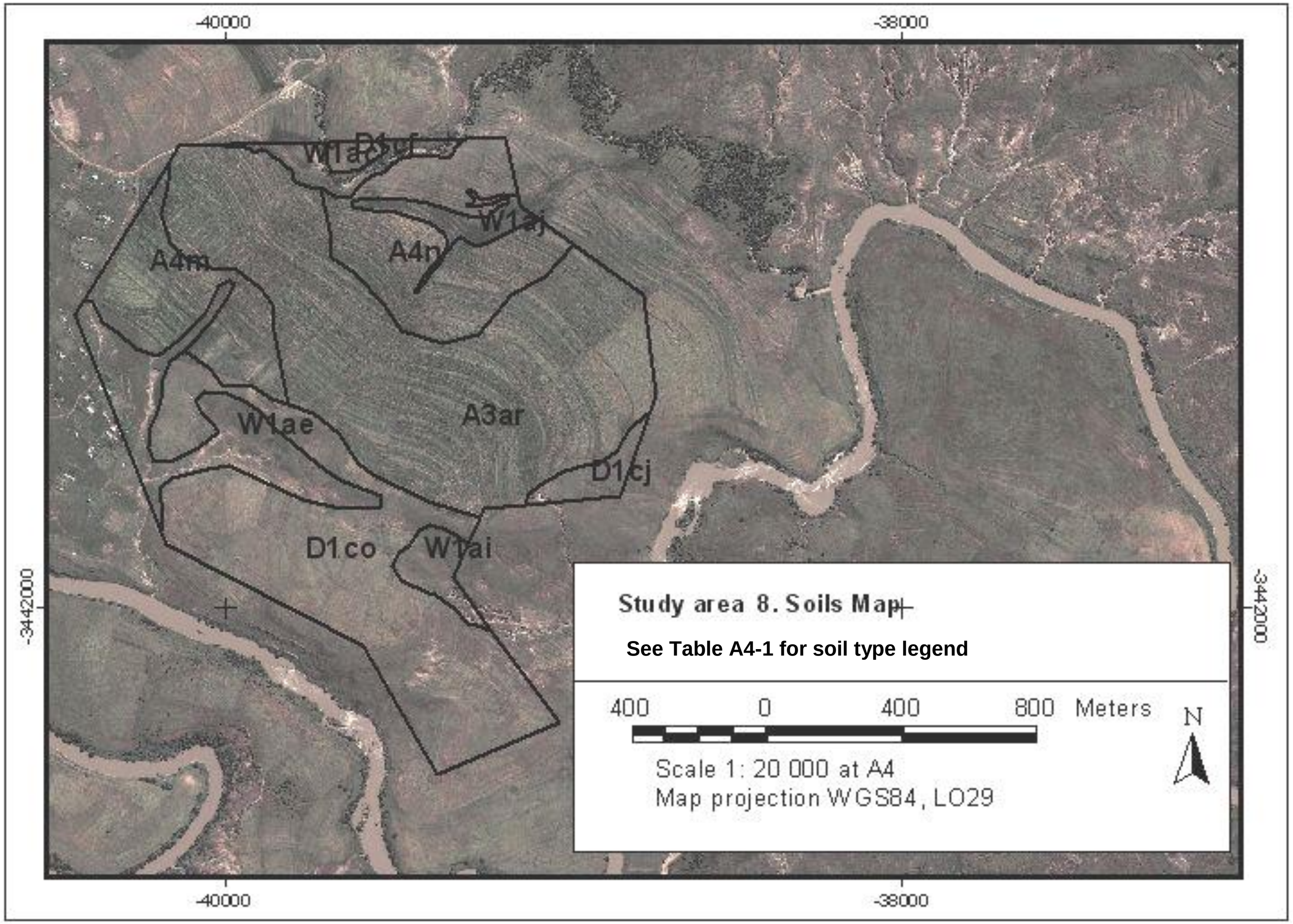
Map 6b: Irrigation Capability Map for Study Area 6



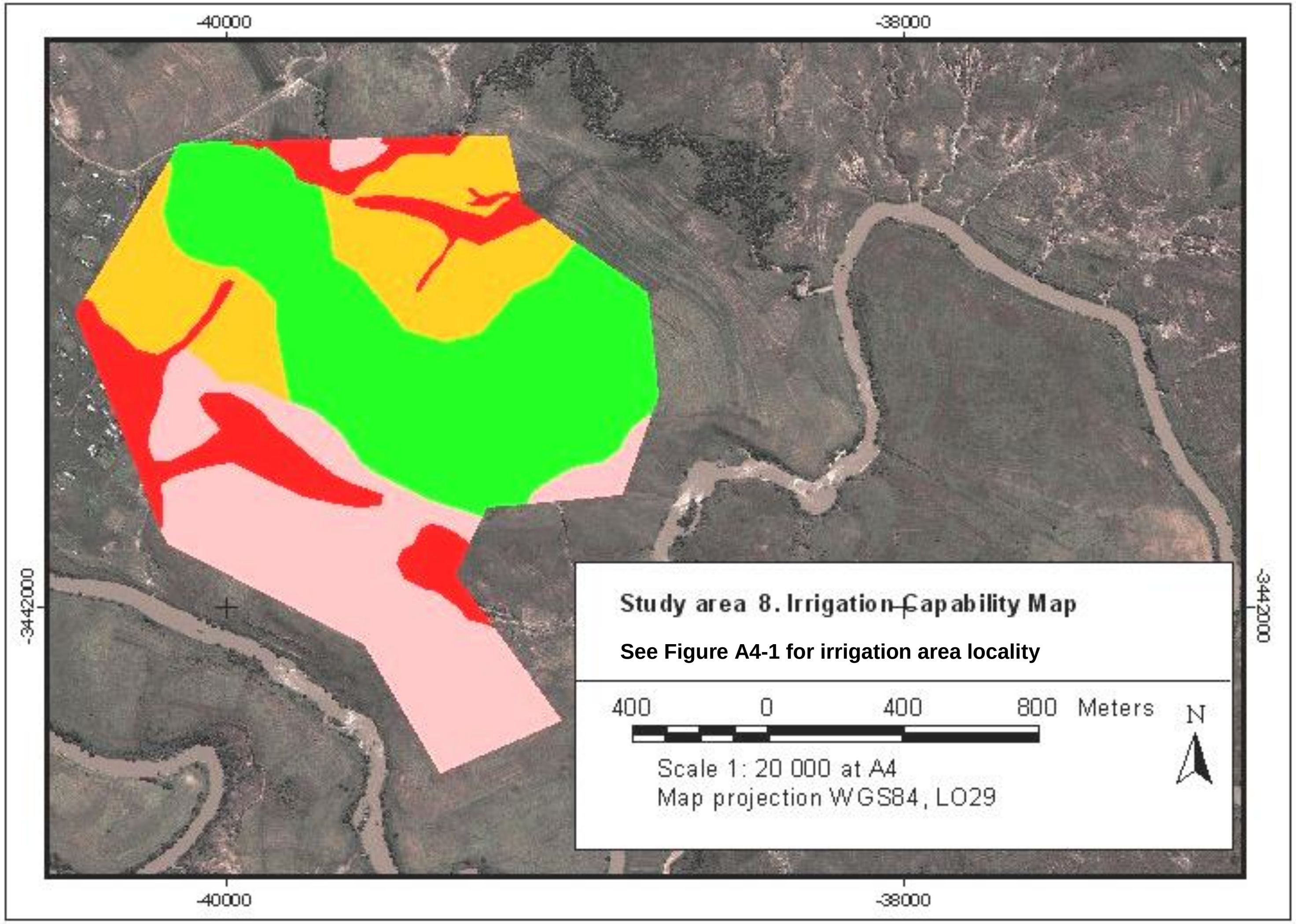
Map 7a: Soils Map for Study Area 7



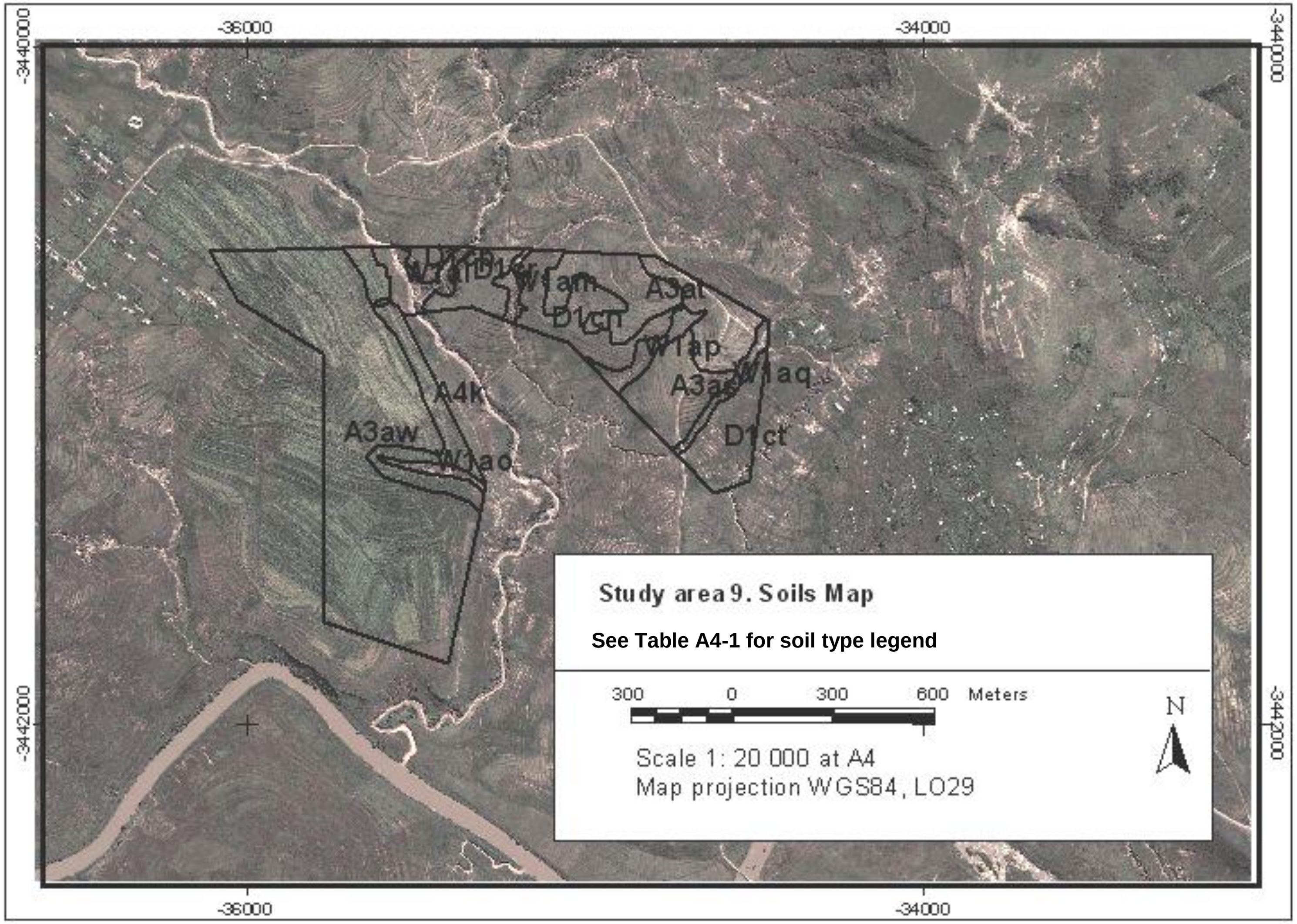
Map 7b: Irrigation Capability Map for Study Area 7



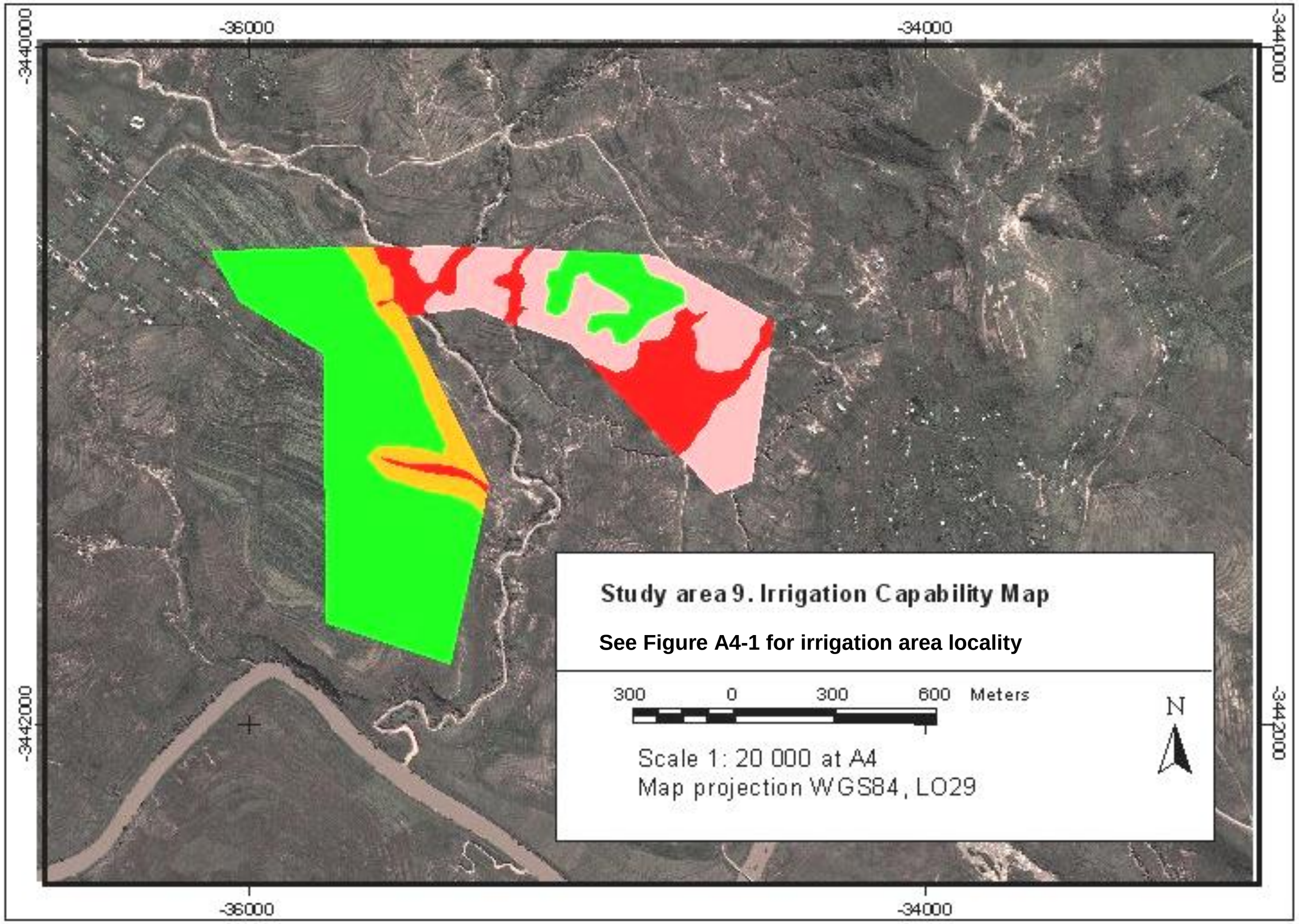
Map 8a: Soils Map for Study Area 8



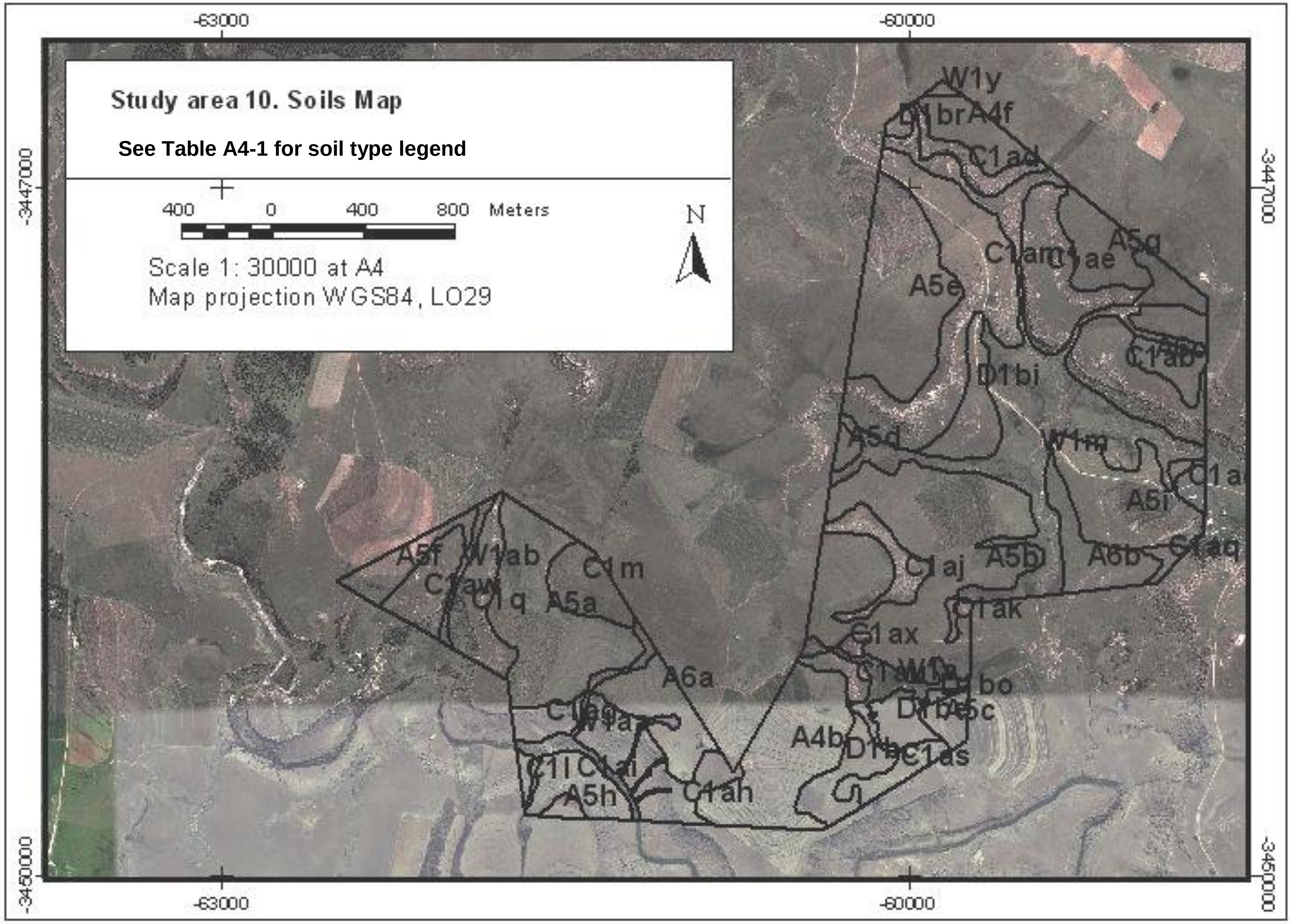
Map 8b: Irrigation Capability Map for Study Area 8



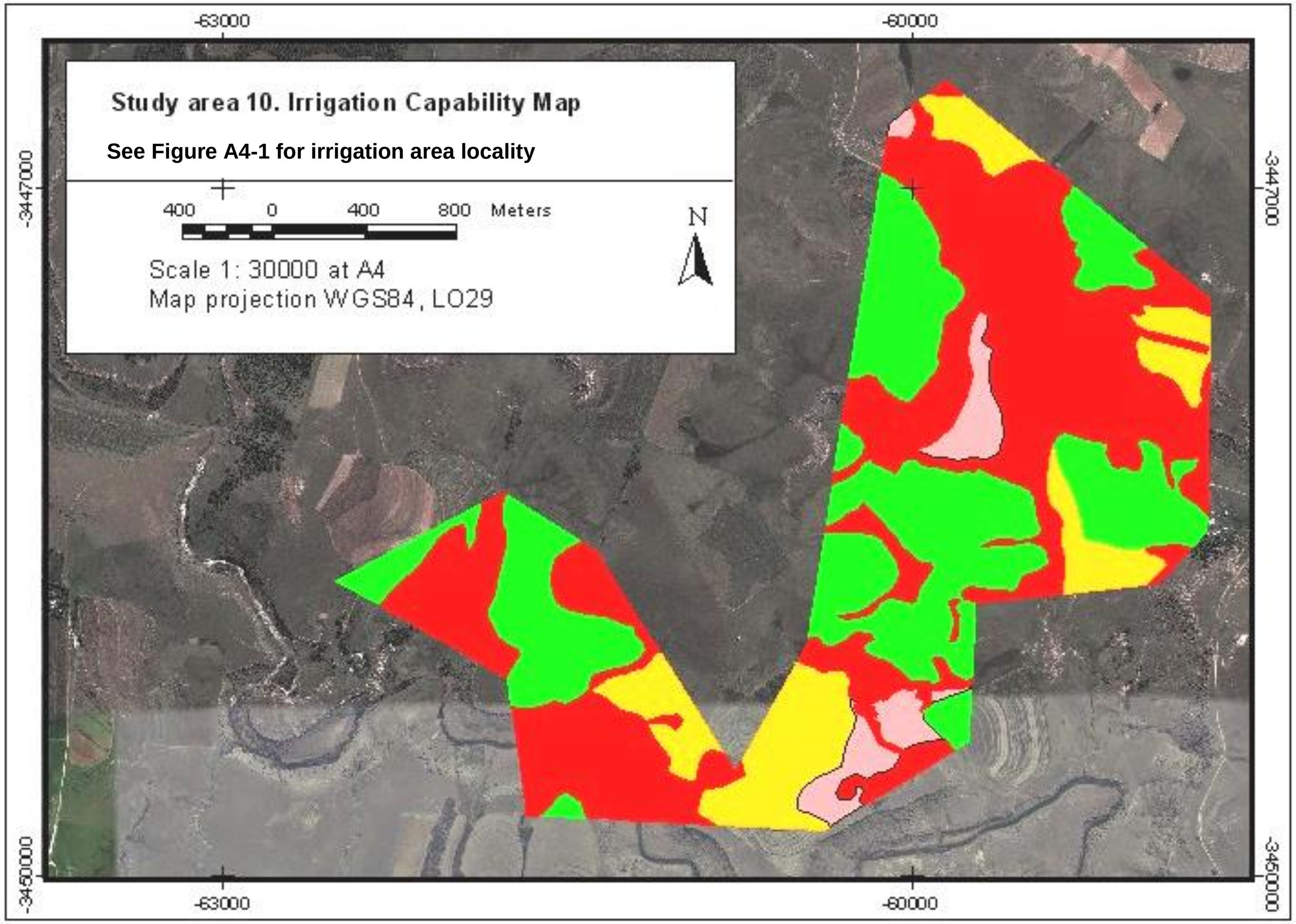
Map 9a: Soils Map for Study Area 9



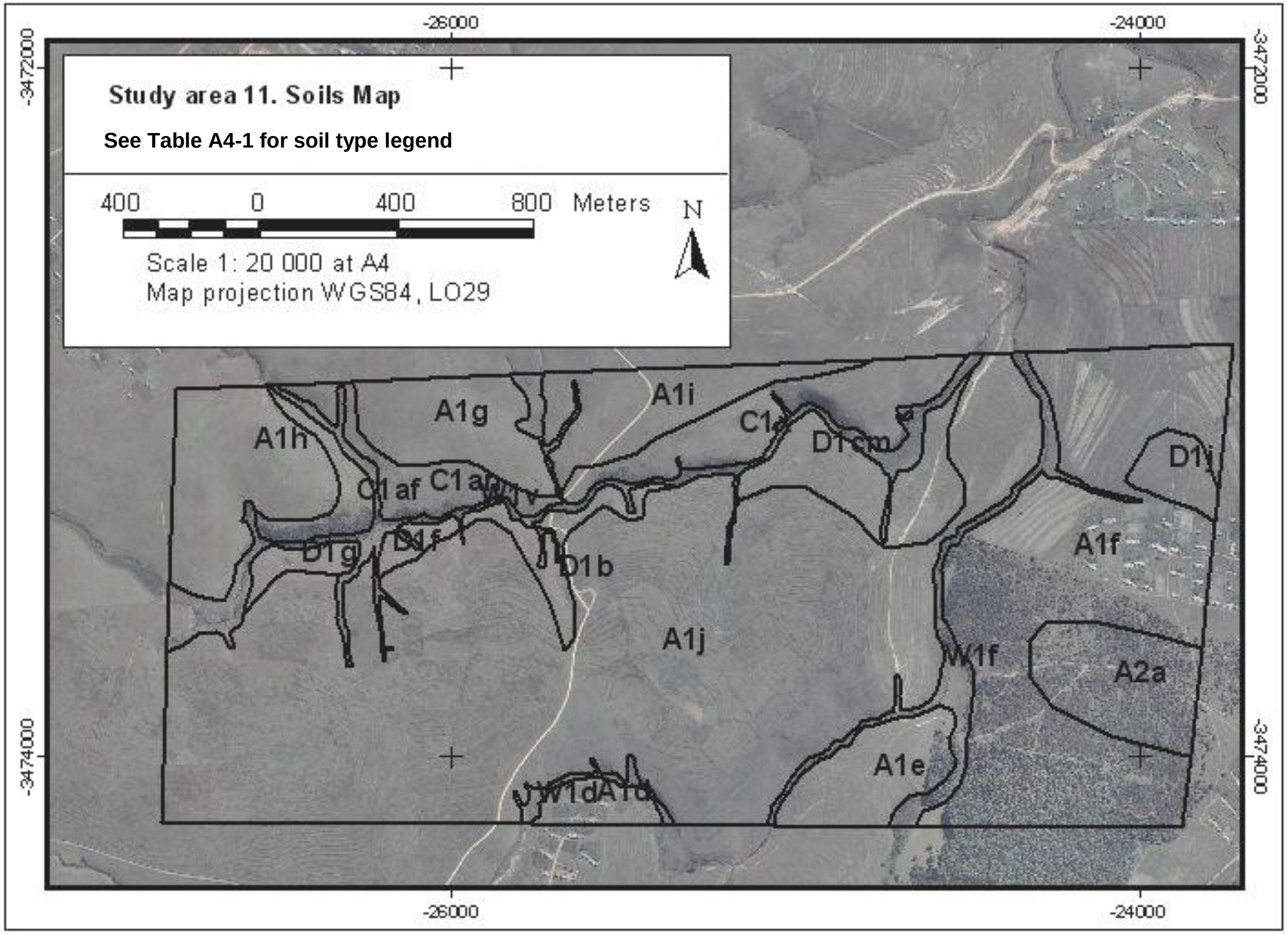
Map 9b: Irrigation Capability Map for Study Area 9



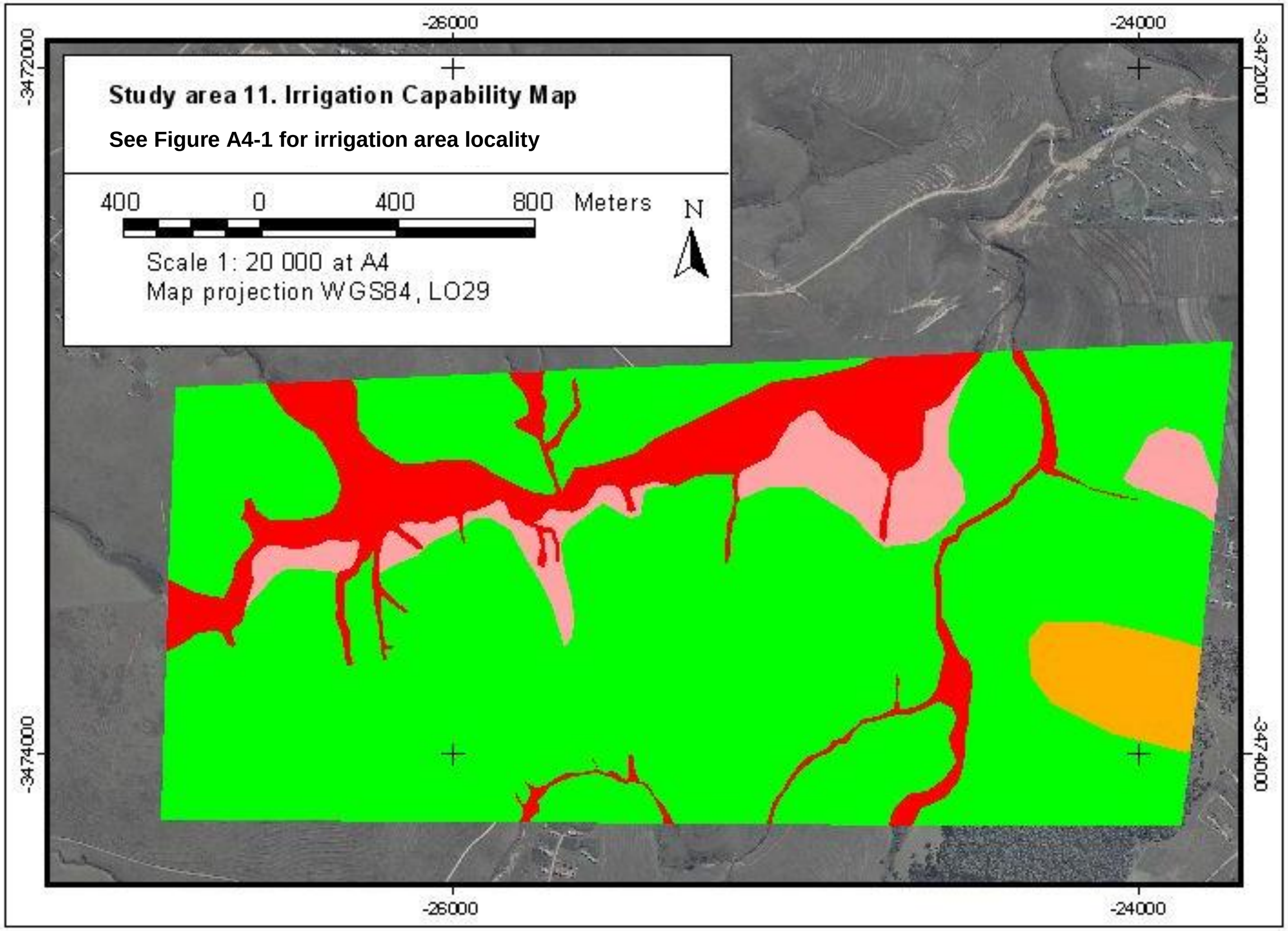
Map 10a: Soils Map for Study Area 10



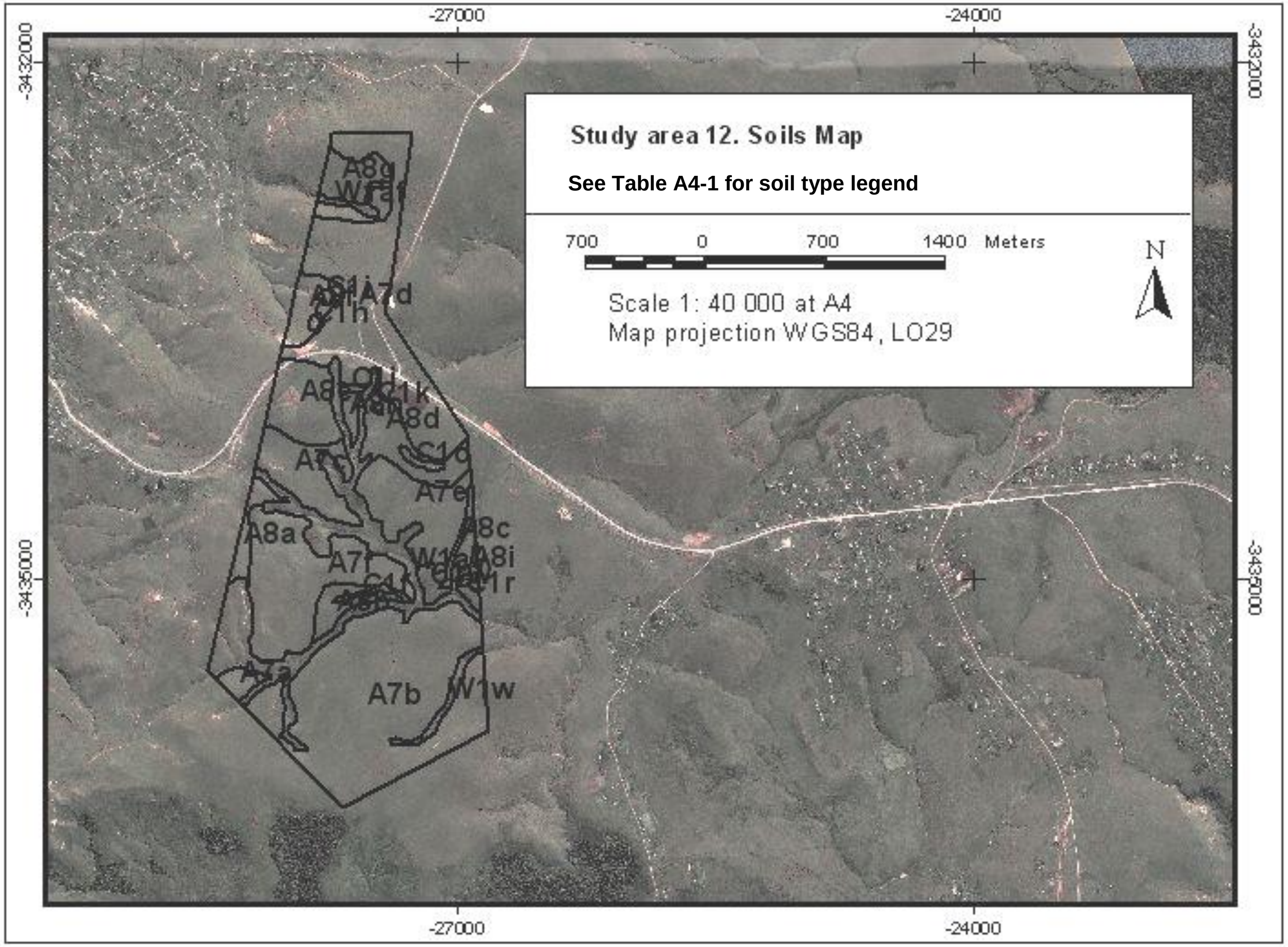
Map 10b: Irrigation Capability Map for Study Area 10



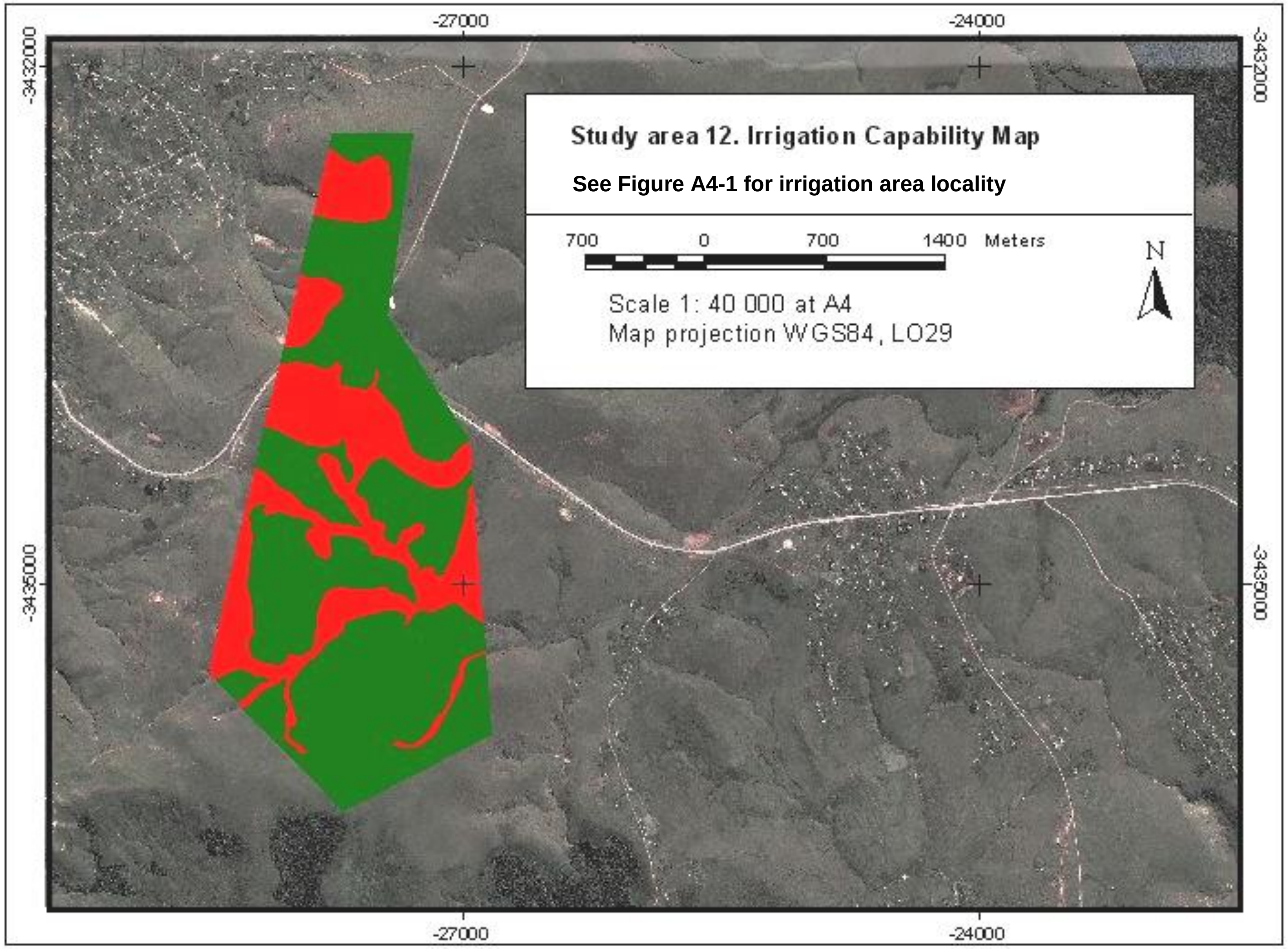
Map 11a: Soils Map for Study Area 11



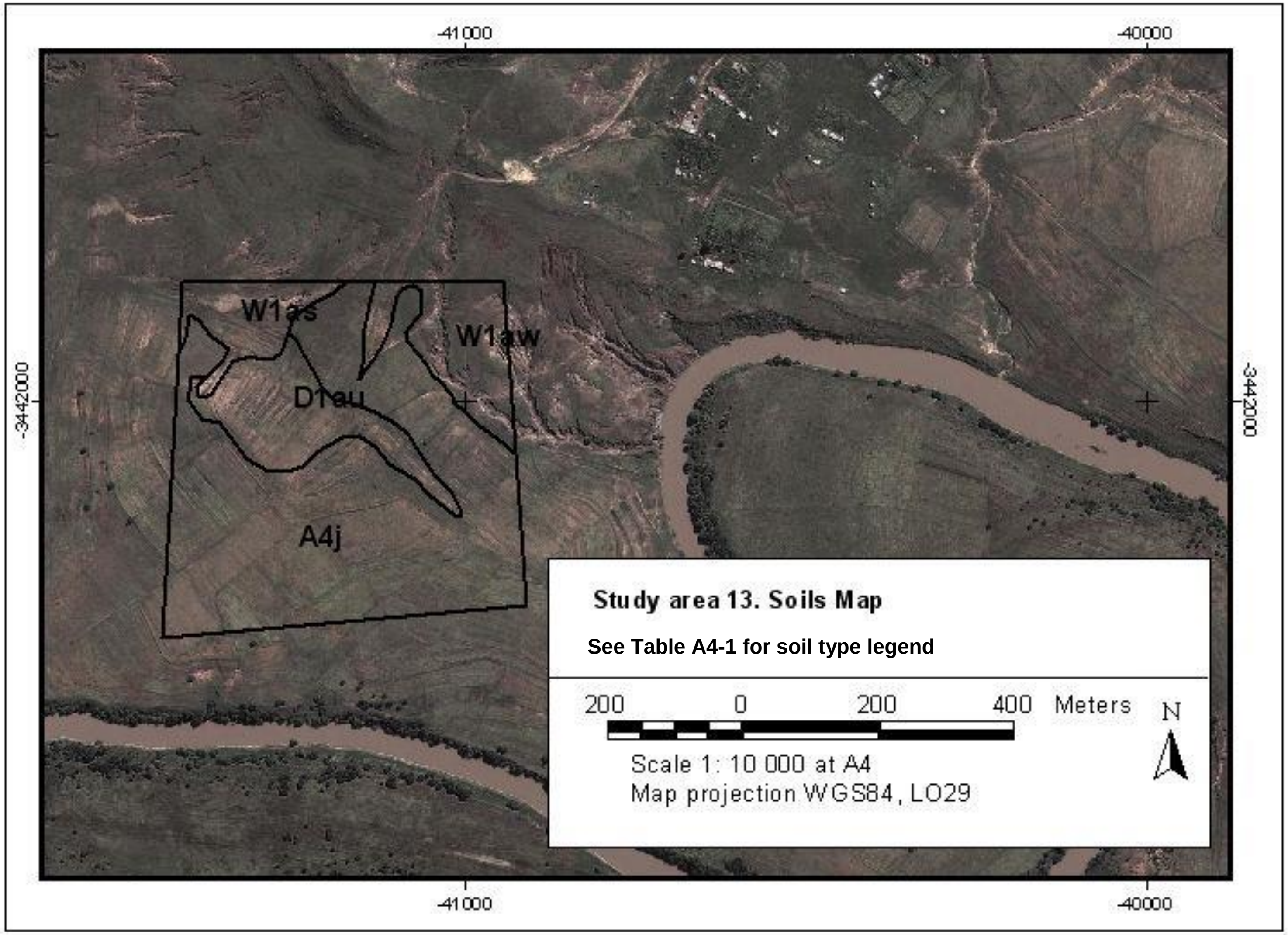
Map 11b: Irrigation Capability Map for Study Area 11



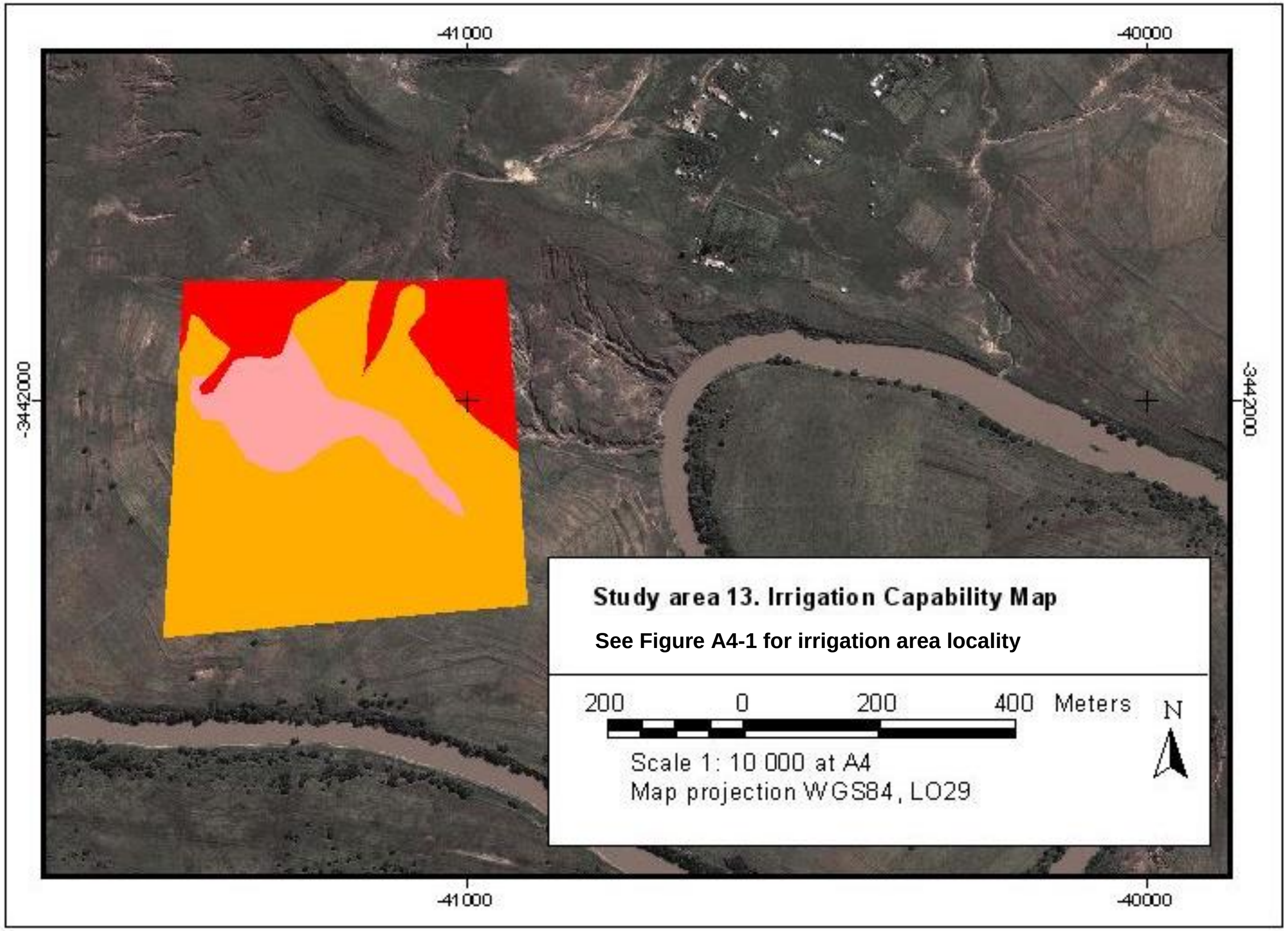
Map 12a: Soils Map for Study Area 12



Map 12b: Irrigation Capability Map for Study Area 12



Map 13a: Soils Map for Study Area 13



Map 13b: Irrigation Capability Map for Study Area 13