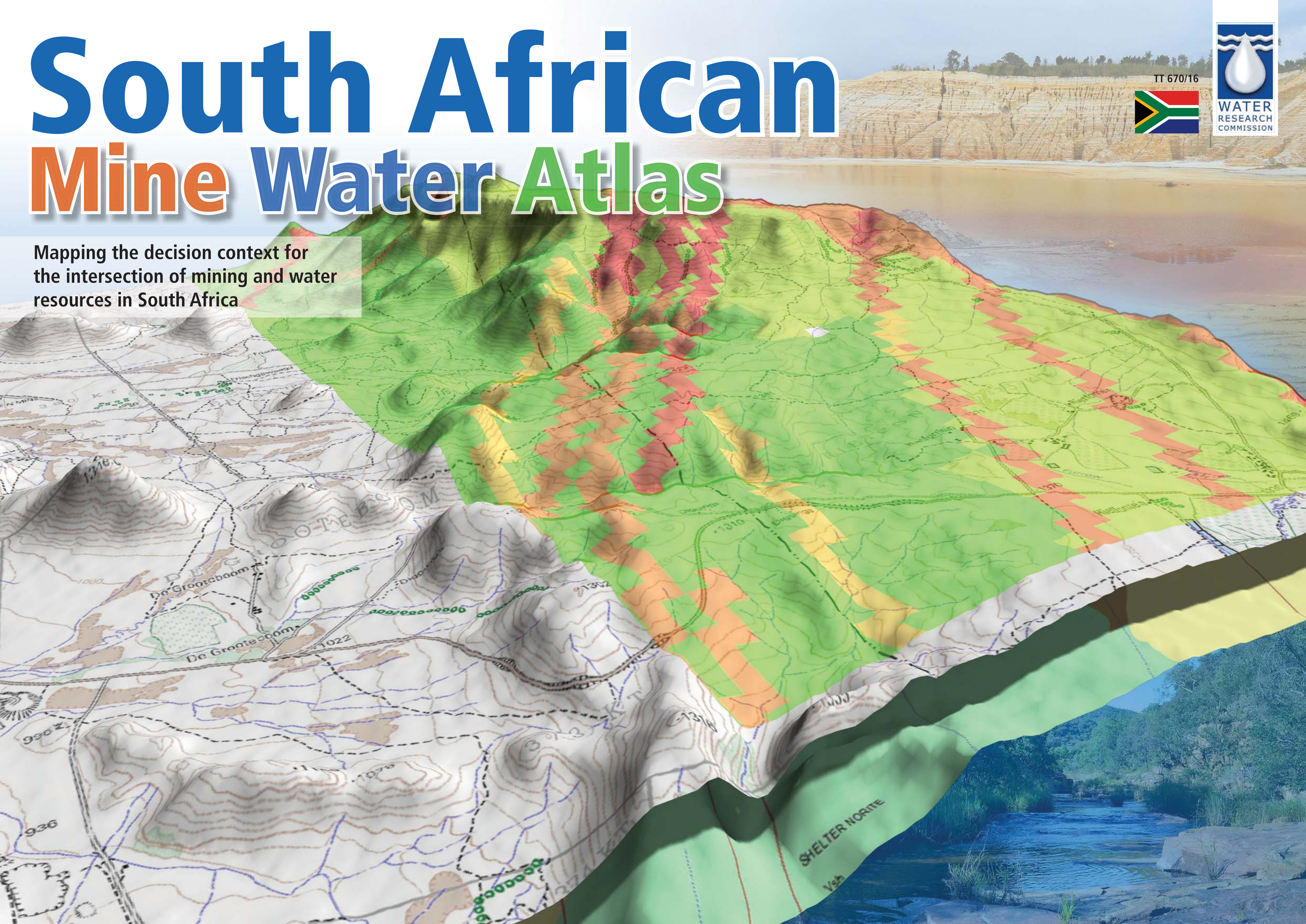
South African Mine Water Atlas

Mapping the decision context for the intersection of mining and water resources in South Africa

TT 670/16

WATER RESEARCH COMMISSION



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The South African Mine Water Atlas.
(WRC Project No. K5/2234//3).

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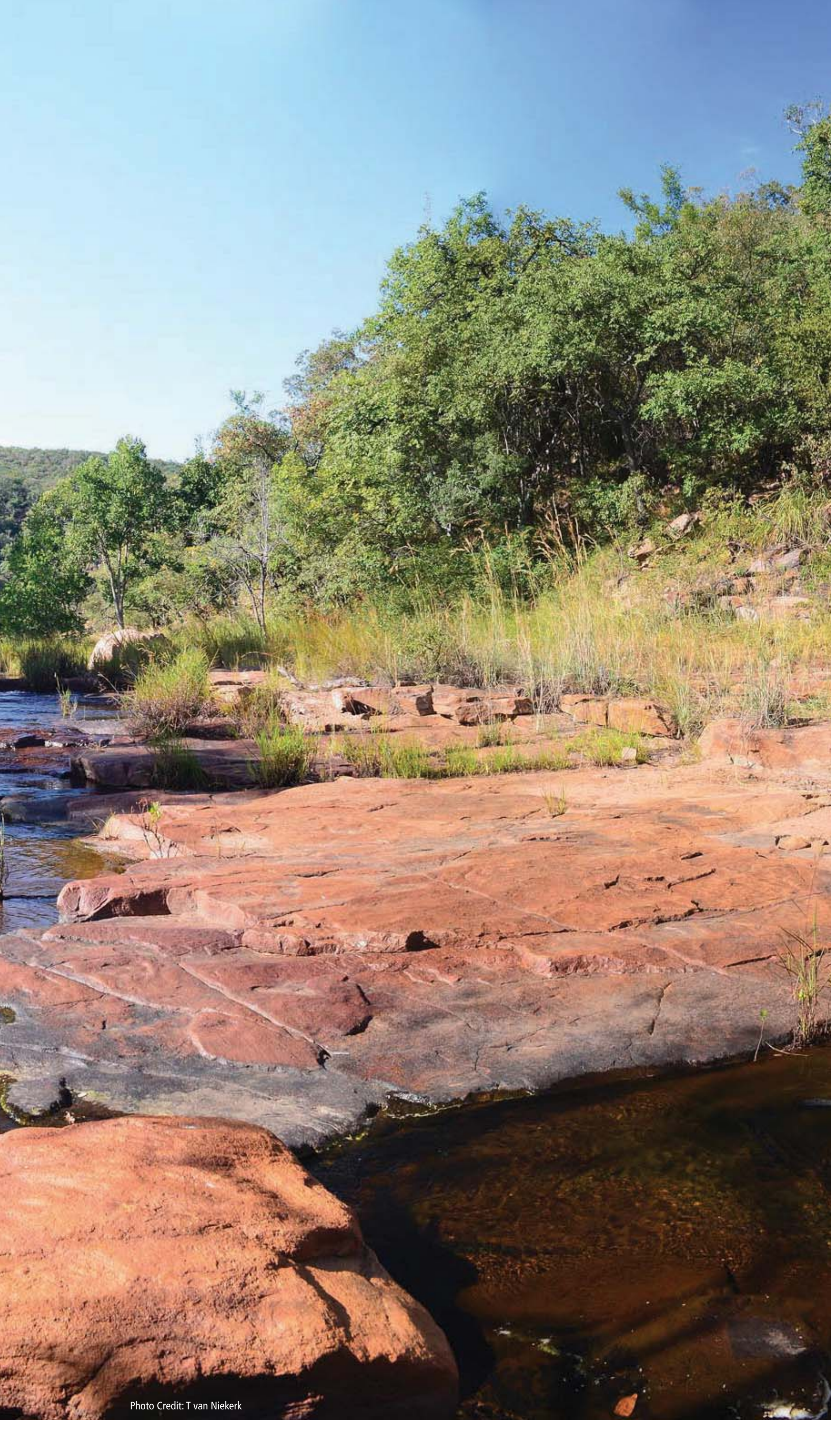
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Limitations

The Atlas, its contributing risk rating models, and other spatial models, were designed from the outset to handle varying levels of data availability. Considering the scope and geographic scale of the project, limitations in the availability of key data assets are to be expected. Nevertheless, the project team committed that in both data-rich and data-poor areas the tool should provide an assessment of water vulnerability or threat considering the un-mitigated impact of mining in each locality. To this end the pre-cautionary principle was applied such that a lack of confidence or certainty in information increases the risk rating.

- No use of the sub-ordinate control of climate in the geo-environmental model.
- The extent and delineation of mineral resources across South Africa relies heavily on the work and data published by the Council for GeoScience. The public domain GIS data assets in respect of mineral regions were found to be inadequate in terms of spatial resolution and completeness for several mineralised areas or minerals. Golder closed this gap to the extent possible by delineating mineralised zones to the appropriate resolution and scale, supported largely by the Council's own publication.
- The extent and mapping of active and non-active mines (point data in the mapping) is not complete, and relies heavily on the data supplied by the SNL Mining Database.
- Resource Quality Objectives (against which to base assessment of compliance against specific measurables) have not yet been set for several water management areas across South Africa.
- Water quality and flow monitoring stations are not established across all quaternary catchments.
- There is limited access to acid base accounting or leach test and other mineralogical or quality data for certain mineral provinces;
- Limited knowledge of the likely mining extraction methods in the more marginal mineralised zones, also linked to a lack of knowledge of the specific depth to mineral resource.
- There is no provision for the linkage of groundwater and surface water systems. This work was deemed beyond the scope of this project.

List of definitions

Acronym	Definition
ABA	Acid Base Accounting
AQ	Aquifer
ARD	Acid Rock Drainage
BIC	Bushveld Igneous Complex
BYC	Borehole Yield Class
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EC	Electrical Conductivity
EI	Ecological Importance
EMP	Environmental Management Plan
ES	Ecological Sensitivity
GARD (Guide)	Global Acid Rock Drainage
GIS	Geographic Information System
GW	Groundwater
NGA	National Groundwater Archive
OC	Open Cast Mining
PES	Present Ecological State
RQO	Resource Quality Objective
RQS	Resource Quality Services
RWQO	Resource Water Quality Objective
SW	Surface Water
TDS	Total Dissolved Solids
TSG	Transvaal Supergroup
UG	Underground Mining
WMA	Water Management Area
WMS	Water Management System
WRC	Water Research Commission

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WATER RESEARCH COMMISSION

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Photo Credit: Golder Associates

Table of Contents

1 WHAT IS THE MINE WATER ATLAS?

The mine Water atlas is a resource that is intended to map the un-mitigated threat of mining to water resources across South Africa. The Atlas essentially maps the broad, high-level decision context for the intersection of mining and water resources in South Africa.

What is the primary objective?

The primary objective is to consolidate existing but fragmented data (pertaining mostly to mineralogy, water quality, flow, present ecological state, hydrogeological information), to provide a national overview of what is happening across the country. This it is hoped will help water resource managers from all sectors to understand where the vulnerabilities are, which should lead to more coordinated decision making.
The Atlas is meant to be:

- An educational resource for water users – incl. legislators and the public;
- A tool to facilitate decision-making and the setting of key questions both for investors and developers, and for regulators and water management planners.

How is this information portrayed?

That atlas presents maps in a regional context, handling each Water Management Area (WMA) in separate sections and focussing on the key issues presented in each. The Atlas's information products are in printed or print ready form, in digital spatial (GIS) datasets; and presented in interactive form through online web portal resources, allowing anyone access to interactive map data.

What the Atlas is not:

The Atlas does not present where a developer can or cannot mine, but rather what risks or threats there are to South Africa's water resources in an un-mitigated scenario. This is intended to present the key questions intuitively and graphically, and facilitate understanding the issues from a broader geographic context. From a mine developer's perspective, for example, this could pertain to the expected liabilities in terms of level of mitigation.

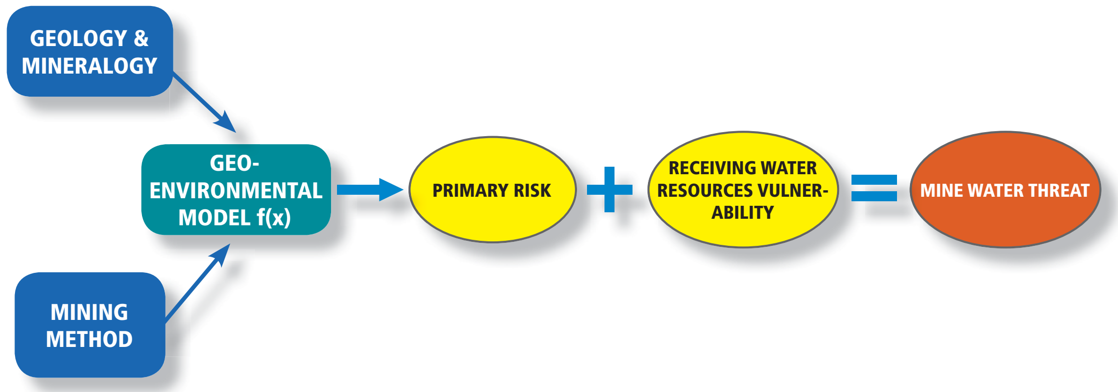
The Atlas also does not in any way replace the need for site-specific specialist study and impact assessment in the determination of risk, impact assessment, and specific mitigation strategies in respect of mining and water management.

How has the mapping of risk, vulnerability and threat been produced?

The Mine Water Atlas is based primarily on a **geo-environmental model** approach, whereby it is accepted that mineral-deposit geology, along with geochemical and biogeochemical processes, are fundamental controls on the environmental behaviour of mineral deposits (GARD Guide (INAP) and Blowes, Geoffrey, Plumlee, Thomas). Mineral-deposit geology fundamentally controls the environmental conditions that result from mining. The project implemented a geo-environmental model for environmental prediction that also considers the sub-ordinate control of mining method. The mineral deposit risk profiles were then considered against the receiving water resource's vulnerability. The geographic intersection of risk ratings from the geo-environmental model approach and vulnerability ratings of the receiving water resource creates the final mine water threat rating. Each of the component risk profiles in the model can be mapped and understood individually (groundwater vulnerability, primary mineralogical risk, surface water vulnerability), or threaded together to be understood in the Mine Water Threat mapping.

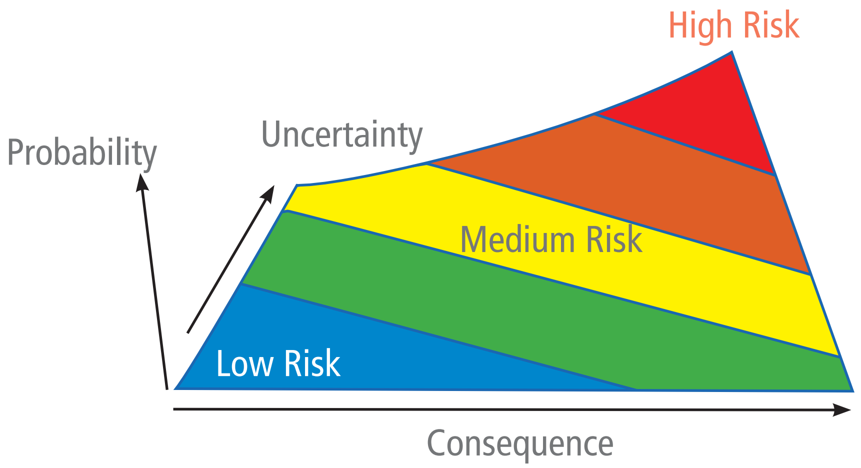
Mine Water Threat is mapped using cumulative scores of risk and vulnerability in the geographic intersection of mineral regions (known in the Atlas as mineral provinces) and their respective receiving water resources. Ultimately the threat rating is built from two key aspects:

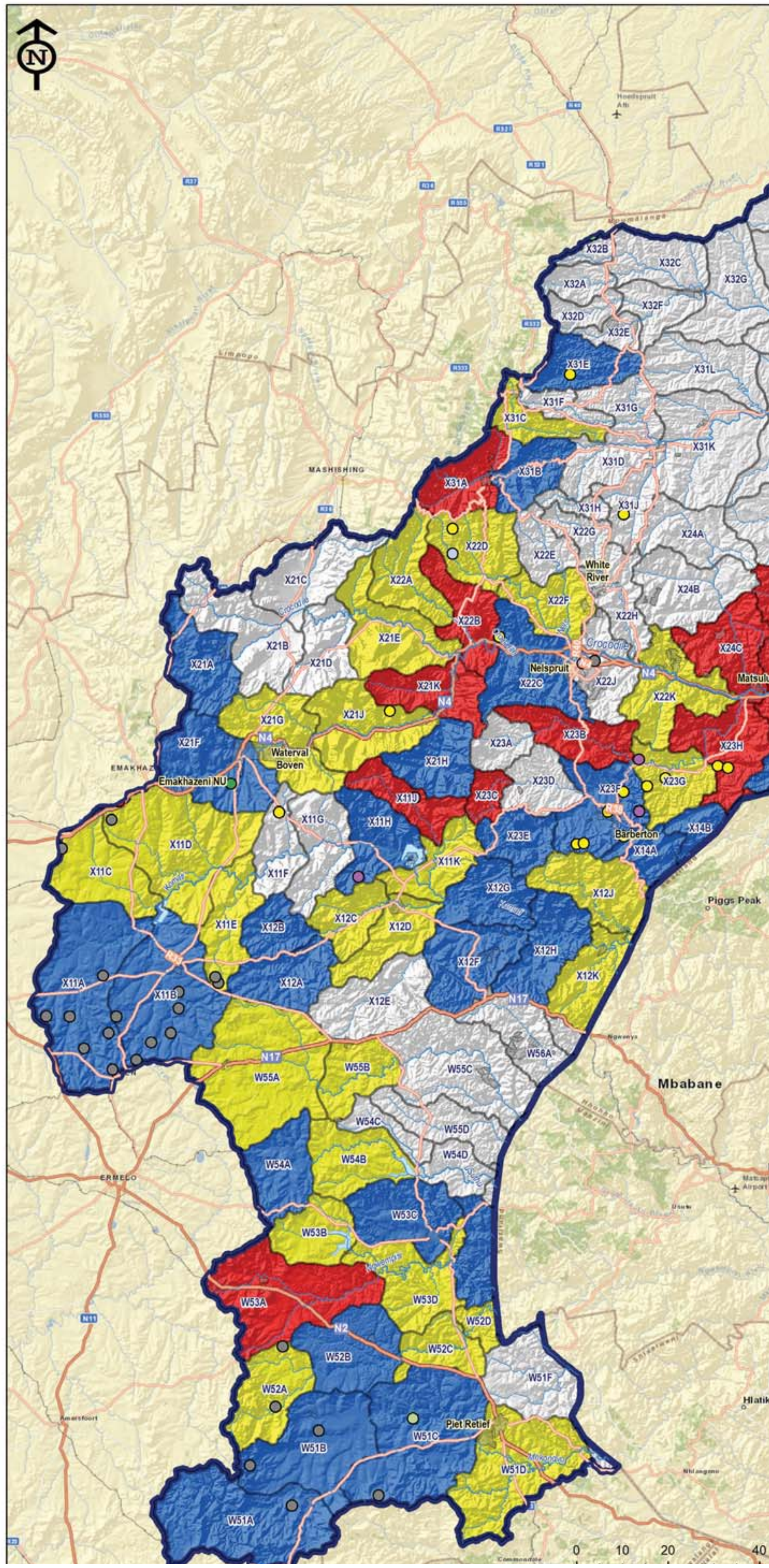
- Geo-environmental Risk, made up of:
    - Mineralogical risk: Mined materials and host rock geology and mineralogy; and
    - Mining Activities: What characterises the dominant in situ mineral extraction process for any "mineral province", those activities typically within the mine lease area (excluding downstream processing or manufacturing);
- Receiving Water Resource vulnerability: the surface and ground water resource, its vulnerability, assimilative capacity and aspects of consequence for local water resources.



Dealing with uncertainty

The project team anticipated varying levels in the completeness and resolution of data to inform the national atlas. The risk assessment model was built to specifically handle this issue, and specifically within the geo-environmental model component, a lack of data or knowledge drives up uncertainty, which translates to an increase in risk. This is explained further in section 3.1 titled "Understanding the Model".

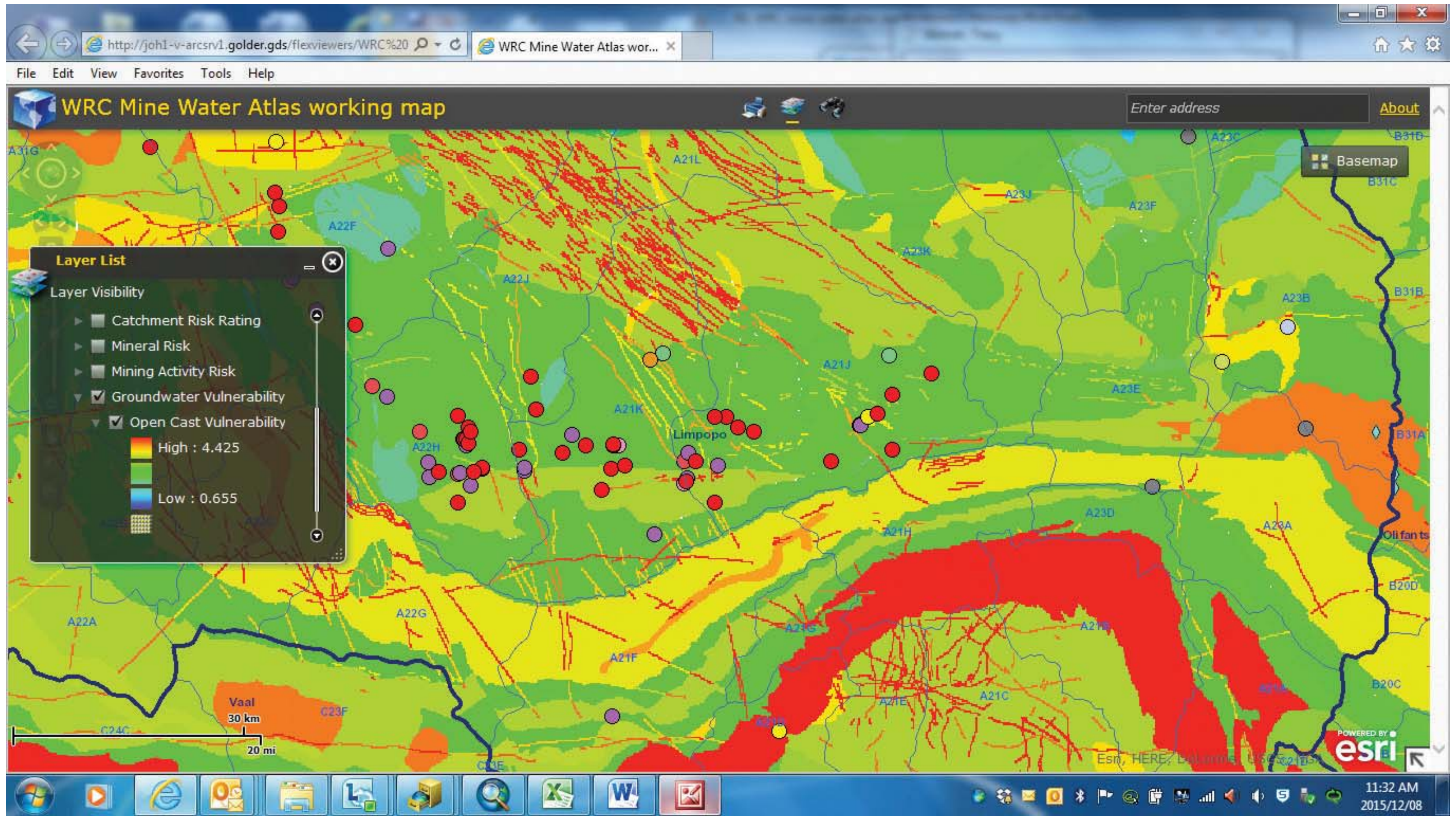




Information resources and data products supplied

The Mine Water Atlas in its entirety is an information package of the following information resources:

- The Printed hardcopy or print-ready A3 Atlas in high definition .pdf format;
- A consolidated GIS database of spatial information assets consolidated in the production of the Atlas, or derived from the Atlas project, pertaining mostly to water resources and mining; and
- The online web map portal providing users interactive access to all the spatial data assets and mapping consolidated and developed during the production of the Atlas; and
- The collection of models and rating matrices developed during the production of the Atlas.

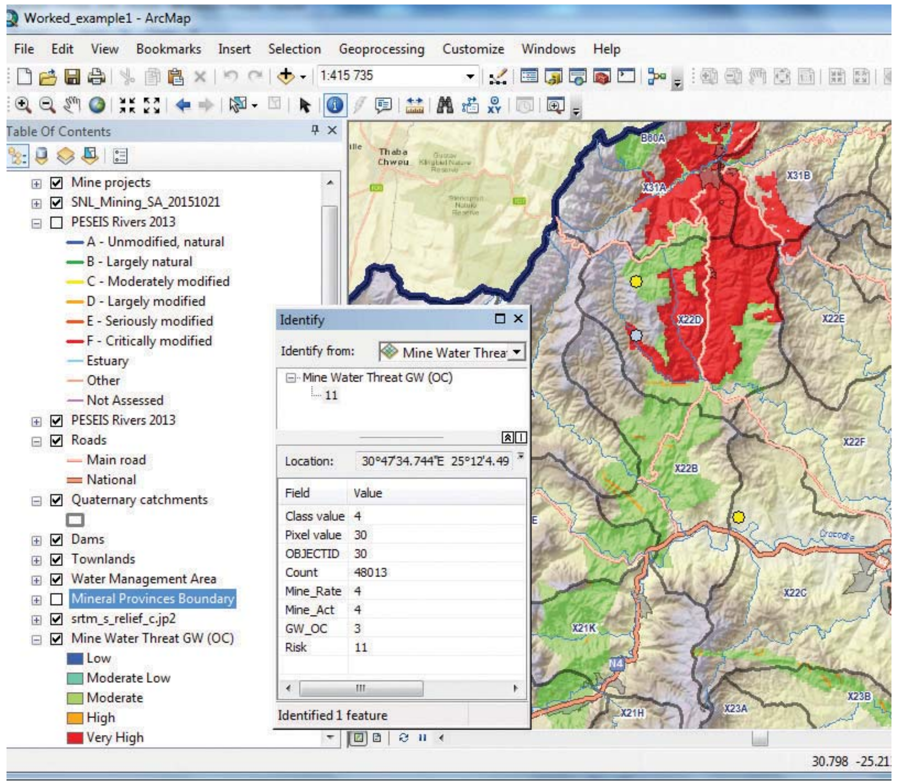


Web map portal

The web map service allows non-GIS users to browse the datasets, control scale and layers and perform basic attribute queries.

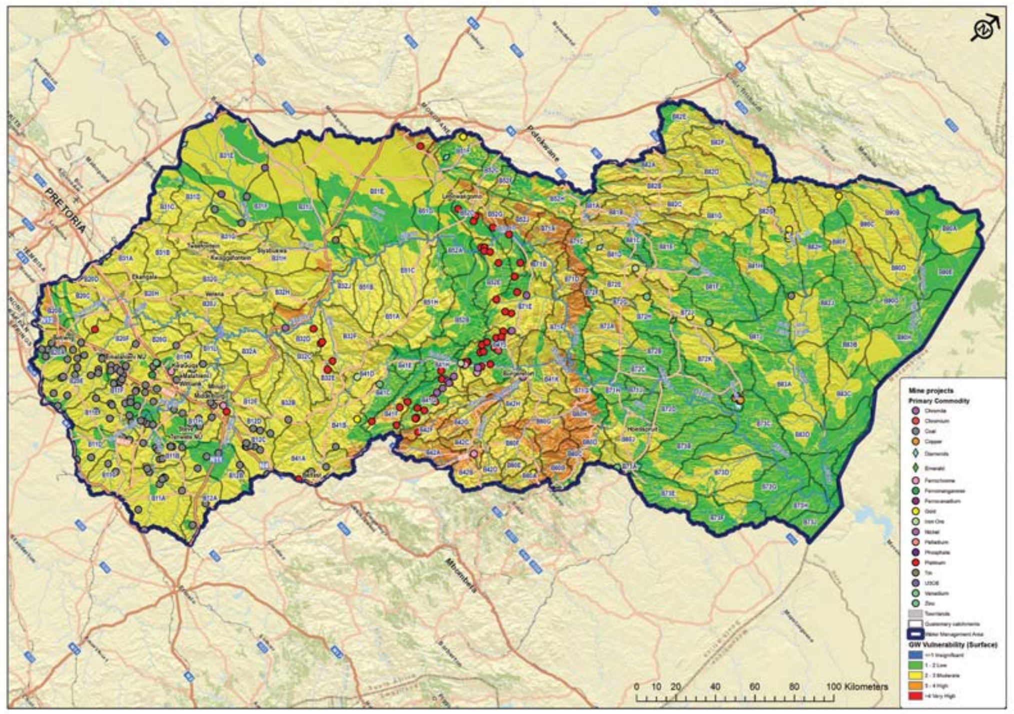
Digital spatial (GIS) data

The GIS data used to generate the map products of the Atlas are supplied in ArcGIS native formats. Datasets generated by the Atlas project are supplied with full metadata, accessible through ArcGIS software and in .pdf summary format. ArcGIS native map file formats (.mxds) are supplied to ease the use and interrogation of maps using ArcGIS.



Hardcopy and softcopy map publications

These maps are static and present the limitation of fixed scales, and mapping large regions of South Africa on A3 page sizes in the printed Atlas. The softcopy A0 maps per WMA supplied in the data package provide more detail and resolution in the mapping of water vulnerability and threat from mining. The WMAs are each mapped at individual scales to maximise the use of page space and the presentation of detail. Each WMA is mapped in a series of nine thematic maps showing the various component parts of the Mine Water Threat assessment. The hardcopy and softcopy maps do not provide the user with the ability to interrogate the attributes are various risk=rated or vulnerability rated geographic areas. This level of interaction with the data is only possible via the other two information access channels listed below.



2 WATER IN THE NATIONAL CONTEXT

South Africa is water scarce, being the 29th driest of 193 countries and having an estimated 1 110 m³ of water per capita in 2005. Moreover, its rainfall varies dramatically from season to season, and the limited available water is distributed unevenly across the country. The South African economy and its urban settlements developed largely in response to mining opportunities, hence much of the demand for water comes from inland areas, far from major rivers or other sources of water. This limited endowment has not prevented society from harnessing the water supply that is available. It is used to support social and economic activities in thriving urban areas, as well as in extensive, water-dependent mining operations. The water resource base also underpins extensive commercial agriculture and sustains an environment sufficiently attractive to generate significant tourism activity (Water Scarcity in South Africa, DBSA, 2009).

Surface water

Surface runoff is the main water source in South Africa. The average total mean annual runoff of South Africa under natural (undeveloped) conditions is estimated at a little over 49 000 million m³/a, which includes about 4 800 million m³/a and 700 million m³/a of water originating from Lesotho and Swaziland respectively, which naturally drains into South Africa.

Water Quality

To meet the country's growing water requirements, water resources are highly developed in large parts of the country. As a result of the many control structures (dams and weirs), the abstraction of water and return flows to rivers, as well as the impacts of land use, the flow regime in many rivers has also been significantly altered. This has significantly changed the quality of water and the integrity of aquatic life in many rivers.

South Africa's surface and groundwater resources show pronounced regional differences and changes in water quality. The changes in those areas where water quality has deteriorated significantly are due to anthropogenic activities. Exceptions are the ambient salinity levels of certain rivers of the eastern (e.g. Great Fish and Sundays Rivers) and western Cape (e.g. lower Berg River) where natural salinisation is of geological origin. Currently much of the water quality of the country's water resources is influenced by wastewater discharges and land-based activities. Major impacting sources include agricultural drainage and wash-off (irrigation return flows, fertilisers, pesticides and runoff from feedlots), urban wash-off and effluent return flows (bacteriological contamination, salts and nutrients), industries (chemical substances), mining (acids and salts) and areas with insufficient sanitation services (microbial contamination).

The quality of groundwater is influenced by mining activities, leachate from landfills, human settlements and intrusion of sea water.

Water transfers

Due to the spatial imbalances in the availability of and requirements for water in the country, inter-catchment transfer of water is a necessary reality in South Africa. In particular some water quality implications for inter-basin transfer schemes in South Africa include the transfer of more salinity which has been rising dramatically in recent years for example in the Vaal and Orange River Systems.

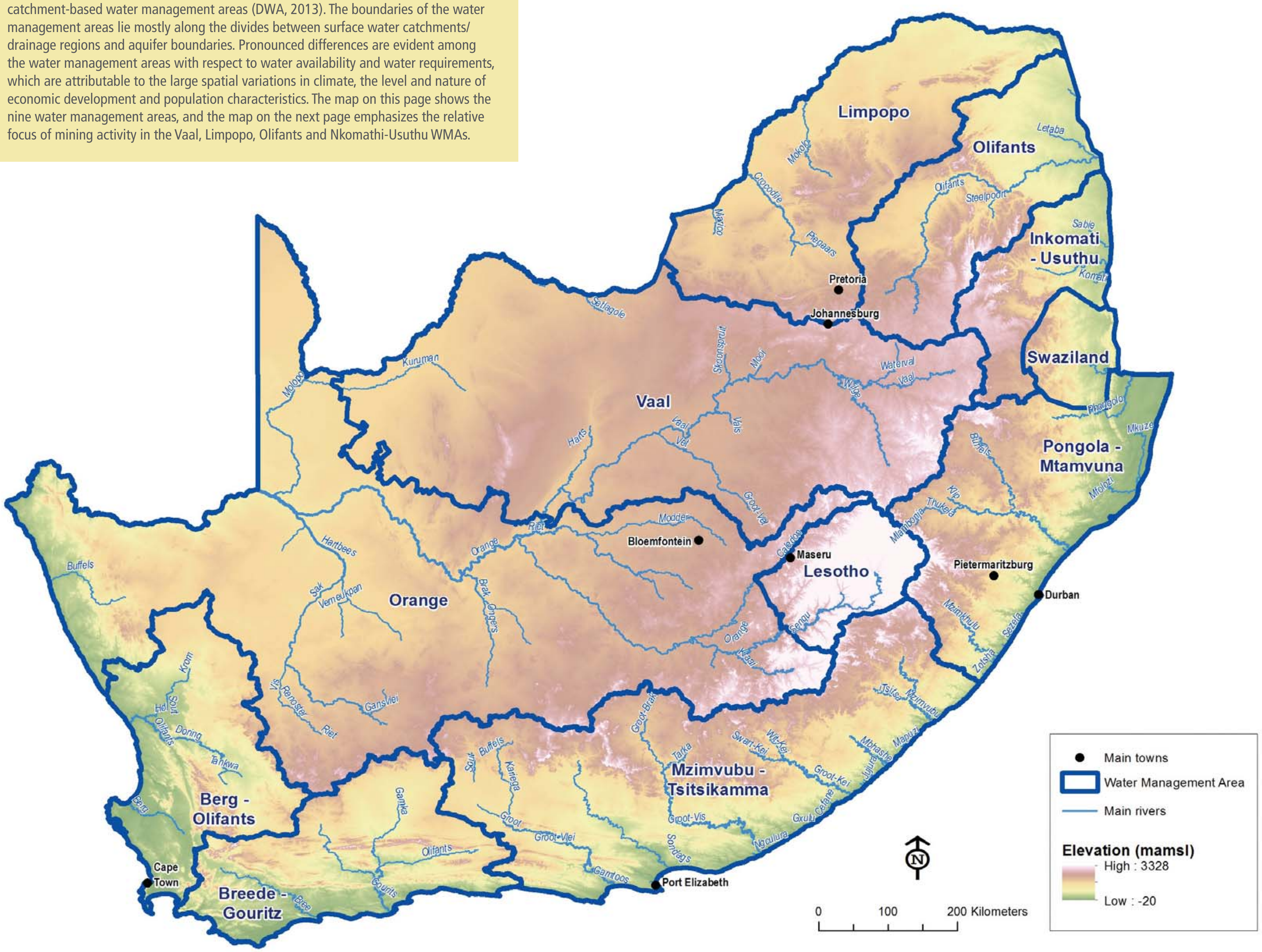
Groundwater

Groundwater occurs widely, and a significant portion of South Africa's population depends on it for their domestic water needs. The value and vulnerability of groundwater represents a strategic component of water resources of South Africa. Security of groundwater supplies is thus essential and protection of groundwater has become a national priority. The major reason for poor management of groundwater has been a lack of a structured approach to management and a lack of knowledge and information about groundwater (DWA, 2010b).

Groundwater pollution and over-abstraction are serious problems in certain parts of South Africa. Poor and deteriorating groundwater quality is widespread and can be attributed to diverse sources in various sectors such as mining, industrial activities, effluent from municipal wastewater treatment works, storm water runoff from urban and especially informal settlements (where adequate sanitation facilities are often lacking), return flows from irrigated areas, effluent discharge from industries, etc.(DWA, 2010b)

Water Management Areas

To facilitate the management of water resources, the country has been divided into nine catchment-based water management areas (DWA, 2013). The boundaries of the water management areas lie mostly along the divides between surface water catchments/ drainage regions and aquifer boundaries. Pronounced differences are evident among the water management areas with respect to water availability and water requirements, which are attributable to the large spatial variations in climate, the level and nature of economic development and population characteristics. The map on this page shows the nine water management areas, and the map on the next page emphasizes the relative focus of mining activity in the Vaal, Limpopo, Olifants and Nkomathi-Usuthu WMAs.



MINING IN THE NATIONAL CONTEXT

Mining in South Africa has been the main driving force behind the history and development of Africa's most advanced economy.

Diamond and gold production may now be well down from their peaks, though South Africa is still number five in gold, but South Africa remains endowed with mineral riches. It is the world's largest producer of chrome, manganese, platinum, vanadium and vermiculite. It is the second largest producer of ilmenite, palladium, rutile and zirconium. It is also the world's third largest coal exporter. South Africa is also a huge producer of iron ore; in 2012, it overtook India to become the world's third biggest iron ore supplier to China, who are the world's largest consumers of iron ore.

With the growth of South Africa's secondary and tertiary industries, the relative contribution of mining to South Africa's gross domestic product (GDP) has declined over the past 10 to 20 years. Nonetheless, the industry is continually adapting to changing local and international world conditions, and remains a cornerstone of the economy, making a significant contribution to economic activity, job creation and foreign exchange earnings. Mining and its related industries are critical to South Africa's socio-economic development.

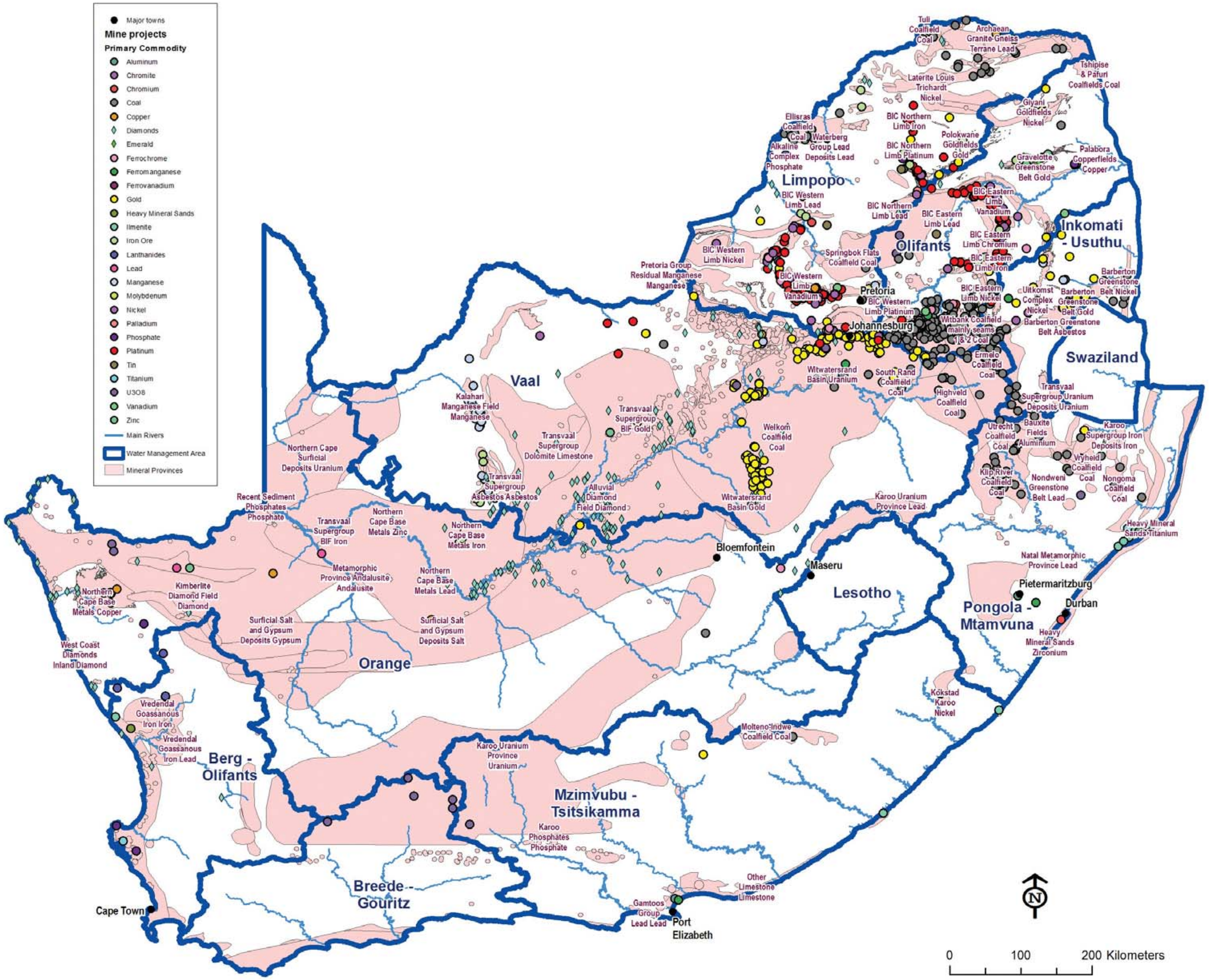
The sector accounts for a significant portion of the market capitalisation of the JSE, and continues to act as a magnet for foreign investment in the country.

Key mining facts from the Chamber of Mines:

- In 2014 the mining sector contributed R18 billion to the South African fiscus
- A total of 495,568 people were employed in the mining sector in 2014
- Each person employed in the mining sector supports up to nine indirect dependents
- The mining sector has, for many years, attracted valuable foreign direct investment to South Africa

The major mining commodities in South Africa are:

- Gold
- Coal
- Platinum
- Diamonds



3.1 GROUNDWATER VULNERABILITY MODEL

Methodology

The Groundwater vulnerability model was created using a composite overlay of hydrogeological criteria, using raster modelling in GIS and a simple numerical summation algorithm, based on ratings to known associated hydrogeological attributes.
Six different hydrogeological criteria are applied based on the groundwater information available nationally in South Africa, sourced principally from:

- the national groundwater archive (Dept. Water and Sanitation–NGA);
- groundwater assessment phase 2 (Dept. of Water Affairs, 2005);
- borehole yield classifications (1:500 000 Geohydrological Map Series of South Africa, 2003); and
- the attributes of the national geological map series of South Africa CGS.

Vulnerability ratings were applied for six hydrogeological components available in GIS format for groundwater that were collated during several decades of geological and hydrogeological mapping, consisting of aquifer lithology, hydro-lithological yield, secondary geological structures, borehole yield classes and groundwater quality. Each component contains several attributes for which a unique vulnerability rating between 1 and 5 has been allocated depending on the characteristics of the attribute. The allocation of the vulnerability ratings is based on a ranking of each attribute against the rest of them. For example, calcareous rocks (under surface mining) will have a vulnerability rating of 3, whilst shales are allocated a value of 1 and an alluvial aquifer a rating of 5. For the water quality element fresh water (<70 mS/m) has a rating of 5 and saline water (>300 mS/m) a rating of 1.

The relationships between the six hydrogeological components are expressed by weighting factors. Weighting factors have been allocated to each of the hydrogeological components to generate a weighted groundwater vulnerability rating in terms of the un-mitigated risk that mining may have on the local groundwater resources. For example, Borehole Yield Class and Water Quality will have a higher weighting factor than aquifer type due to their importance for sustainable yield and potability.

The vulnerability rating of groundwater resource is finally based on the type of mining activity. In terms of the impact on aquifer systems, the depth of mining is considered a major differentiator in the assessment. Thus the groundwater vulnerability ratings are separated into:

- surface mining (<100 m below ground level); and
- underground mining (>100 m below ground level).

This separation is based on the fact that groundwater systems have a tendency to become less "regionally linked" to surrounding systems with depth compared to shallow, surface mining where subsurface groundwater fluxes are more pronounced due to specific weathering patterns.

Many of the existing GIS attributes do not describe deeper groundwater conditions consistently across South Africa, however, a rating system for deeper mining activities is presented based on geological differentiations, viz. hard-rock and soft-rock occurrences. Surface mining activities were addressed first and a general depth of 100 m was assumed to be the maximum depth that the majority of open pits reach before the activity ceases or changes over to underground workings. It was also presumed that 100 m is the maximum depth at which most aquifer systems can be classified as "weathered and fractured". These aquifer systems largely represent the productive shallow aquifers in South Africa and interaction between them and surface water resources may occur during post-mining operations when rewatering of the surface and underground workings takes place.

Surface Mining

The surface mining groundwater vulnerability model applies the following thematic GIS overlays:

Lithology_AQTYPE (aquifer type):

- This attribute provides a package of geological formations (lithologies) that originates from the 1:500 000 Geohydrological Maps Series. A unique numerical coding is attached to each different lithology, for example dolomite is coded as 26, arenaceous rocks (sandstone, arkose and orthoquartzite) as 24 and undifferentiated rocks and mixed lithologies as 40. This approach provided an applicable selection of hydro-lithologies as much work has been spent on transforming baseline formation geology to the concept of hydro-lithological groundwater units during the development of the 1:500 000 Geohydrological Map Series of South Africa by the Department of Water and Sanitation.
- This lithological based differentiation provides a good demarcation of aquifer systems on a national scale and is based on the 1:500 000 Geohydrological Maps Series.
- A rating (1-5) was applied to each of the lithological codes based on an original (primary) groundwater unit's effective storage/storativity. Secondary features such as folds, faults, dykes, fracturing or karst development are included under the category Local/Regional Secondary Structures. Alluvium has a rating of 5 and argillaceous rocks (shale, claystone, mudstone and siltstone, including diamictite) a rating of 1.
- Large, uniform occurrences of acid, mafic, ultra-mafic rocks and large intrusive bodies (sills and lava flows) have been allocated lower ratings due to their "hard rock" nature and absence of secondary fracturing, weathering and insignificant aquifer potential.

A weighting factor of 0.15 for this attribute based on the hard rock nature of a large group of the aquifer systems in South Africa.

Hydro-Lithology Yield

- Rating based on aquifer replenishment/sustainability and aquifer/aquiclude/aquitard transmissivity excluding any secondary features (fracturing, dykes, lineaments and folding).
- Aquifer systems in South Africa are grouped in four basic categories based on the character of the water bearing features of the formation material, i.e.,
  - Intergranular (mostly unconsolidated formation material), rating of 3;
  - Intergranular and Fractured (also fractured and weathered), rating of 2;
  - Fractured (typical hard rocks with limited primary water bearing status), rating of 1; and
  - Karst (weathered, decomposed carbonate rocks, caverns and underground lakes), rating of 4.
- Karstification of dolomite/limestone formations has been included under the Hydro-Lithology Yield attribute; although no GIS layer describing karst aquifer areas is available. The potential contribution to a water resource due to karstification is significant (much higher recharge and storativity), but difficult to apply in this GIS application since these areas are not mapped specifically and is therefore based on local information.

A weighting factor of 0.20 for this attribute due to its impact on the migration of fluids through hard rock aquifers.

Regional Secondary Structures >5 km^2:

- GIS based regional structural information is available based on geological mapping of folds, jointed formations (mostly those with bedding planes) and potential weathered & fractured and fractured groundwater units such as mafic/ultra mafic extrusive rocks, granite, sandstone, dolomite, quartzite, and ironstone.
- Syncline and anticline folding as provided by the structural geological criteria have a low rating value of 1 and 2 respectively.
- Overturned folding is expected to create significant fracturing in near surface conditions (say <300 m depth) and is therefore allocated a higher rating value of 4 compared to normal folds.
- A wide spectrum of lineaments has been mapped initially by the Council for Geoscience (1:250 000 Geological Map Series) but their impact on the vulnerability relating to mining is regarded as local (<5 km^2). These features have been allocated a different category (Local) and grouped together with dykes, veins and marker layers (see Local Secondary Structure discussion below).
- Intense folded formations where jointing/shearing has developed due to over-folding and shearing have a rating of 3 due to the development of secondary jointing/fracturing, e.g. the Kraaipan Group and Wolkberg Group Dolomites.

A weighting factor of 0.1 is allocated for this attribute due to the regional context.

Local Secondary Structures <5 km^2:

- Lineaments have been mapped by the (1:250 000 Geological Map Series) in detail over the whole of South Africa based on satellite imagery, air photos, airborne surveys and geological field mapping. These are included in the GIS platform for lineaments/intrusive contact zones with an applicable description of each feature, i.e., Karoo Dolerite (dykes and sills), Kimberlite dykes, diabase dykes, etc.; each with its own unique lithology code.
- Intersections between lineaments of different ages, e.g., a Karoo Dolerite dyke and a diabase dyke or fault zone, are allocated a rating of 5. These have higher groundwater fluxes along the feature, especially in areas with higher relief and deeper incised drainage channels.
- The rating for local lineaments/contact zones varies from individual Kimberlite, granite, granophyre, pyroxenite and carbonatite dykes with a rating value of 1 to individual Karoo Dolerite dykes, faults and fractures with a rating value of 3. Where dyke swarms occur, a space-delimited measure has been introduced in the rating model to identify dykes within a specified distance from each other. A maximum rating of 5 is allocated in the case of Karoo dolerite dykes, basalt dykes, diabase dykes and brecciated quartz-porphyry dykes within 100 m from each other.
- Other features such as quartz veins and brecciated quartz veins have been coded as well and programmed into the rating model (ratings of 2 and 3 respectively).

A weighting factor of 0.16 is allocated to attribute due to its contribution to groundwater movement on local scale, i.e. <5 km^2.

Groundwater (Borehole) Yield Classes (BYC):

- The borehole yield is an indicator of the hydraulic conductance of aquifers. This is considered to be the most significant factor of the groundwater risk rating since it is related to the permeability of water bearing groundwater units.
- On a national scale this attribute differentiates between an aquifer's potential as a regional productive aquifer system or an aquifer with limited potential, i.e., rating the results of mining activities in a low yield shale/diamictite aquifer against a higher yielding sandstone aquifer.
- This GIS platform is introduced into the rating model based on the five different yield classes as mapped for the development of the 1: 500 000 Geohydrological Map Series of South Africa by the Department of Water Affairs. The Borehole Yield Class layer is applied on a simple sliding scale with the lowest yield (insignificant or <0.1 l/s) allocated 1 increasing to a rating of 5 for high (>5 l/s).

A weighting factor of 0.23 for this attribute due to the importance of groundwater yield.

Groundwater Quality:

- Based on the 1: 500 000 Geohydrological Map Series (Department of Water Affairs) information, this GIS layer provides a good indication of the groundwater quality,

i.e., electrical conductivity (EC, mS/m) obtained from borehole hydrocensus surveys in the past. Electrical conductivity is a measure for the salinity of water at the origin and can be obtained without having the water quality analysed.

- The map unfortunately does not include a most recent, national coverage of the groundwater quality of the country.
- The risk rating is based on five water quality classes as per Department of Water and Sanitation 1998 Guideline (WRC Report No. TT 101/98). Only the uneven values 1, 3 and 5 are used in this rating to emphasise the importance of retaining good quality groundwater resources where present.
- The risk rating for groundwater quality is based on the fact that all water resources should be protected against any water quality deterioration from a specific standard. A risk rating of 5 is therefore allocated for a Class 0 and 1 (EC <150 mS/m), a rating of 3 for a Class 2 (EC >150 to 370 mS/m) and a rating of 1 for Class 3 and 4 (EC >370 mS/m).

A weighting factor of 0.23 is allocated for this attribute based on the importance of retaining groundwater quality in its natural state.

Deep (>100 m) Underground Mining

The risks rating procedure for underground mining operations is based on the same rating principles as the surface mining. Due to the decrease in aquifer potential in terms of lower permeabilities and having only a fractured type hydraulic character at these depths, rating measures for the following attributes have been decreased due to the fact that the activity is deep underground and the main risk is the position of uncapped shafts from where decant from flooded underground workings may develop.

Lithology_AQTYPE:

- Alluvium and unconsolidated formations are inactive;
- The rating values will remain as for surface mining; and

A weighting factor of 0.15 for this attribute based on the hard rock nature of a large group of the aquifer systems in South Africa.

Hydro-lithology Yield

- Intergranular (alluvium and other unconsolidated formation) are inactive;
- Intergranular and fractured rocks and karst rocks rating decreased to 1 due to the activity being below the average weathered depth of 45 m in South Africa; and
- Fractured rock rating decreased to 2 due to limitations on water bearing fracture occurrences deeper than 150 m in South Africa.

A weighting factor of 0.15 for this attribute due to its impact on the migration of fluids through hard rock aquifers.

Regional Secondary Structures >5 km^2:

- The rating values increased due to the larger potential for underground dewatering that may occur over areas where fracturing along fold axis (anticlines and synclines) may have developed.
- Over folding/jointing has been increased to 4 and 5 respectively due to the higher head involved with dewatering in these areas and potential impact on overlying shallow aquifer systems.

A weighting factor of 0.3 is allocated for this attribute due to the regional context.

Local Secondary Structures <5 km^2:

- The rating values are decreased in relation to surface mining due to the reduced fracturing and lower permeability of the contact zones of these structures (i.e. fractures, veins, dyke/sill contact zones) with depth.
- It is, however, anticipated that these local structures will play a significant role in the groundwater potential of underground mine workings (see discussion below – borehole yield classes).

A weighting factor of 0.25 is allocated to this attribute due to its contribution to groundwater movement on local scale, i.e. <5 km^2

Groundwater (Borehole) Yield Classes:

It is a known fact that water strikes and their potential yields decrease with depth and below 100m only occasional fractures may be intercepted. The water bearing properties of groundwater units in underground mine workings are significantly lower than at shallower depths (<100 m depth).

- In hard rock groundwater units secondary structures play a significant role and terms such as occasional interceptions of "fissure water zones" are quite common for describing water-bearing zones by underground miners.
- The Borehole Yield Class information is an accumulation of water strikes over the depth of a borehole and covers an estimated depth of ~80 m based on the borehole information in the NGA. Therefore the available BYC cannot be used for deep mining. The weighing factor is therefore reduced to 0.1
- Sandstone groundwater units mined at 300 m below ground level are generally allocated a rating value of 3, however a higher rating up to 4 can be allocated where deep sandstone exhibits primary features e.g. the Tshipise sandstone in the Limpopo Province. A shale formation mined at 300 m below ground level is allocated a rating value of 1 (lower permeability). Massive hard rock groundwater units consisting of meta-calcareous rocks, acid-alkaline intrusive rocks, mafic intrusive rocks and undifferentiated metamorphic rocks are allocated a value of 1 (only secondary water bearing features prevails at depth).
- A deep seated, fresh dolomite for example is allocated a rating value of 1 due to its low primary hydraulic parameters (T & S) – however, if this formation is overlain by a developed karst aquifer, the rating for karst groundwater units in the secondary structure category will increase the overall rating value with 5 points.

A weighting factor of 0.1 is used for this attribute.

Groundwater Quality:

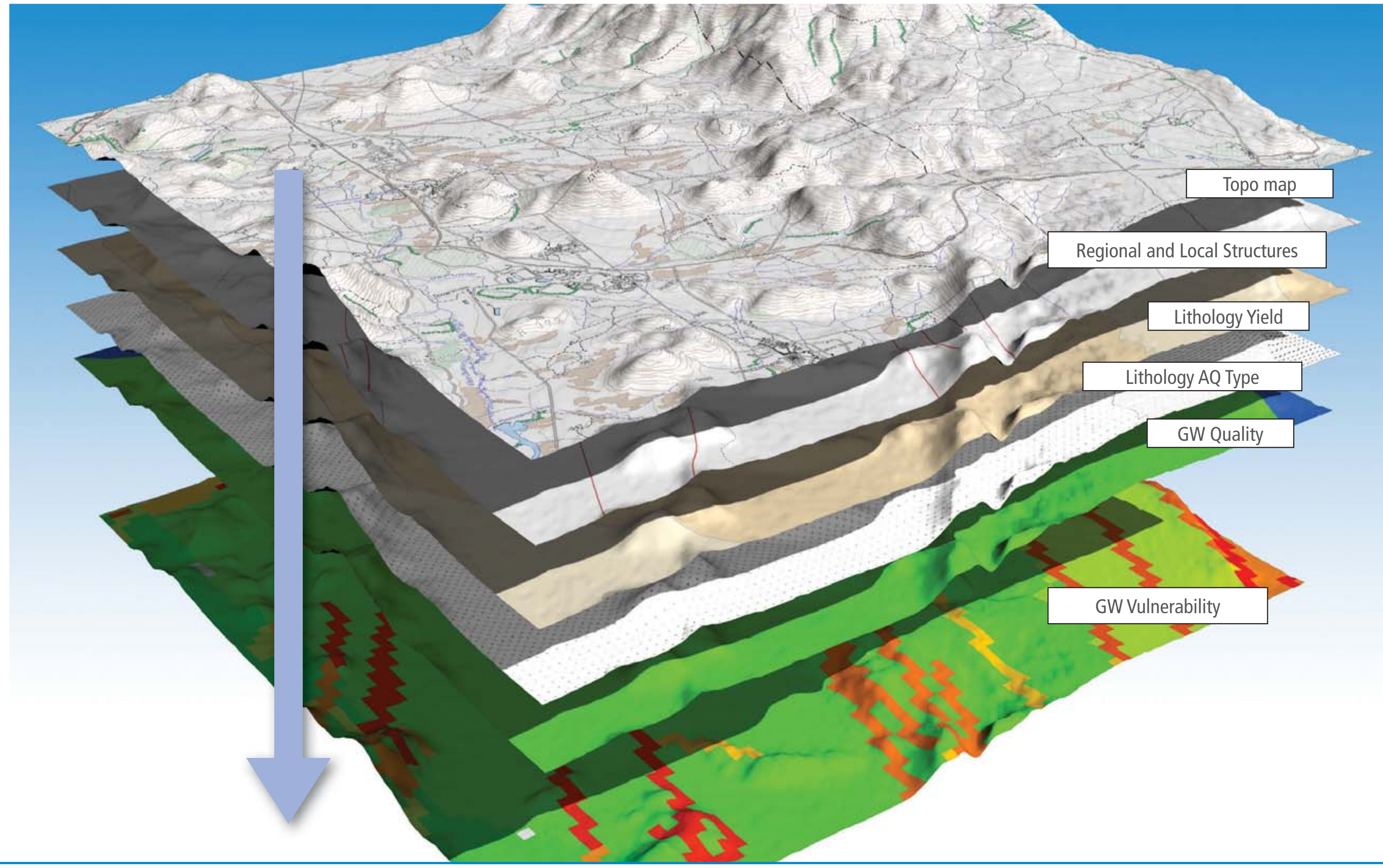
The same rating for surface mining is applied. Deep mining penetrates deeper water bearing zones that generally contain poorer water quality. It is therefore applicable to use the same water quality rating criteria as for the surface mining activity (see explanation above.)

A weighting factor of 0.3 is allocated for this attribute based on the importance of retaining groundwater quality in its natural state.

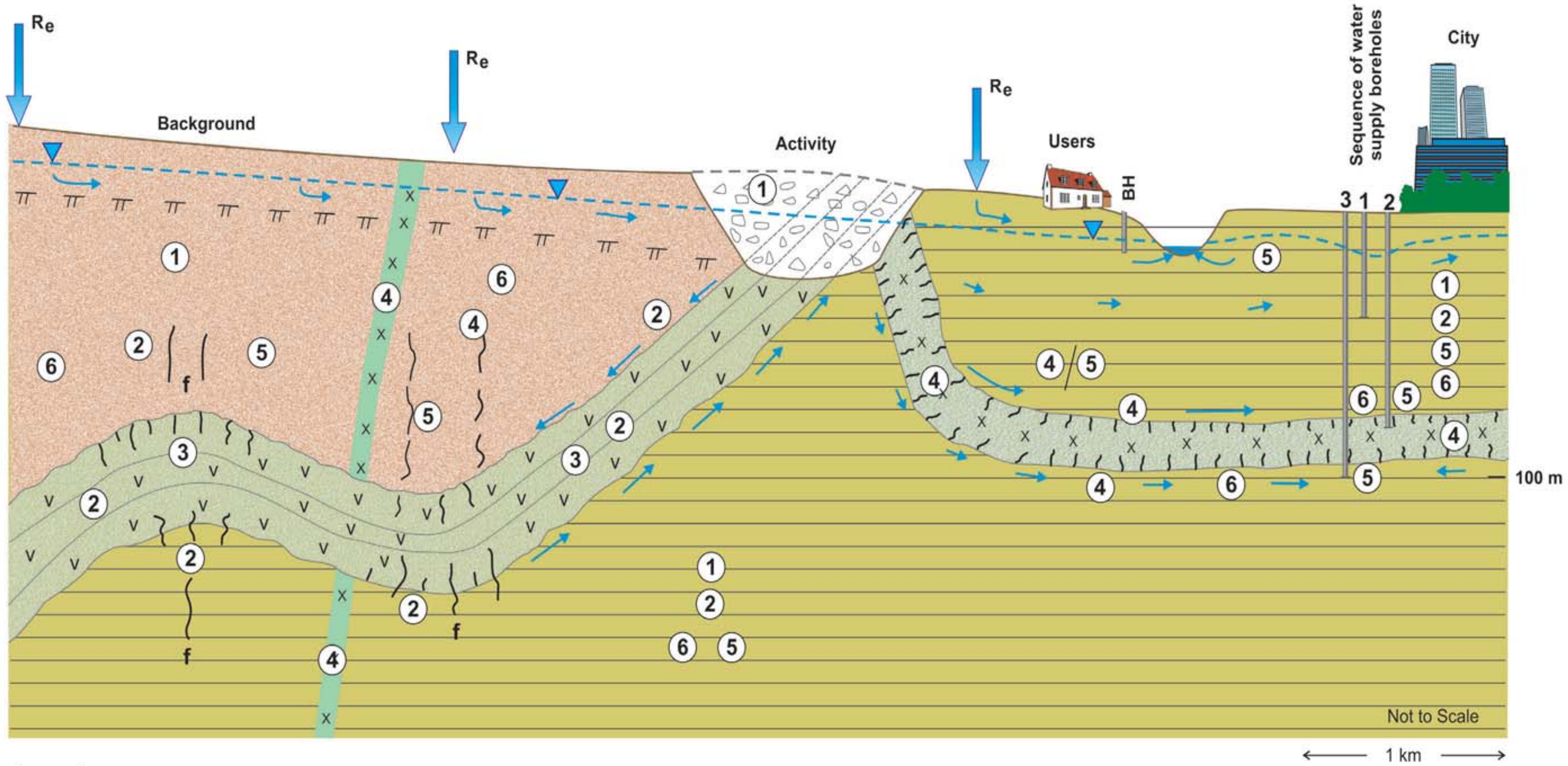
Conclusion

The approach described in this document has been tested by using data from existing mines to check the veracity of the methodology.

The rating results confirm high-risk values do occur in certain areas where mining activities are impacting on the local groundwater, and ultimately the surface water resources. Mapping methodology applied here can be used to support mitigation decisions.



SURFACE MINING

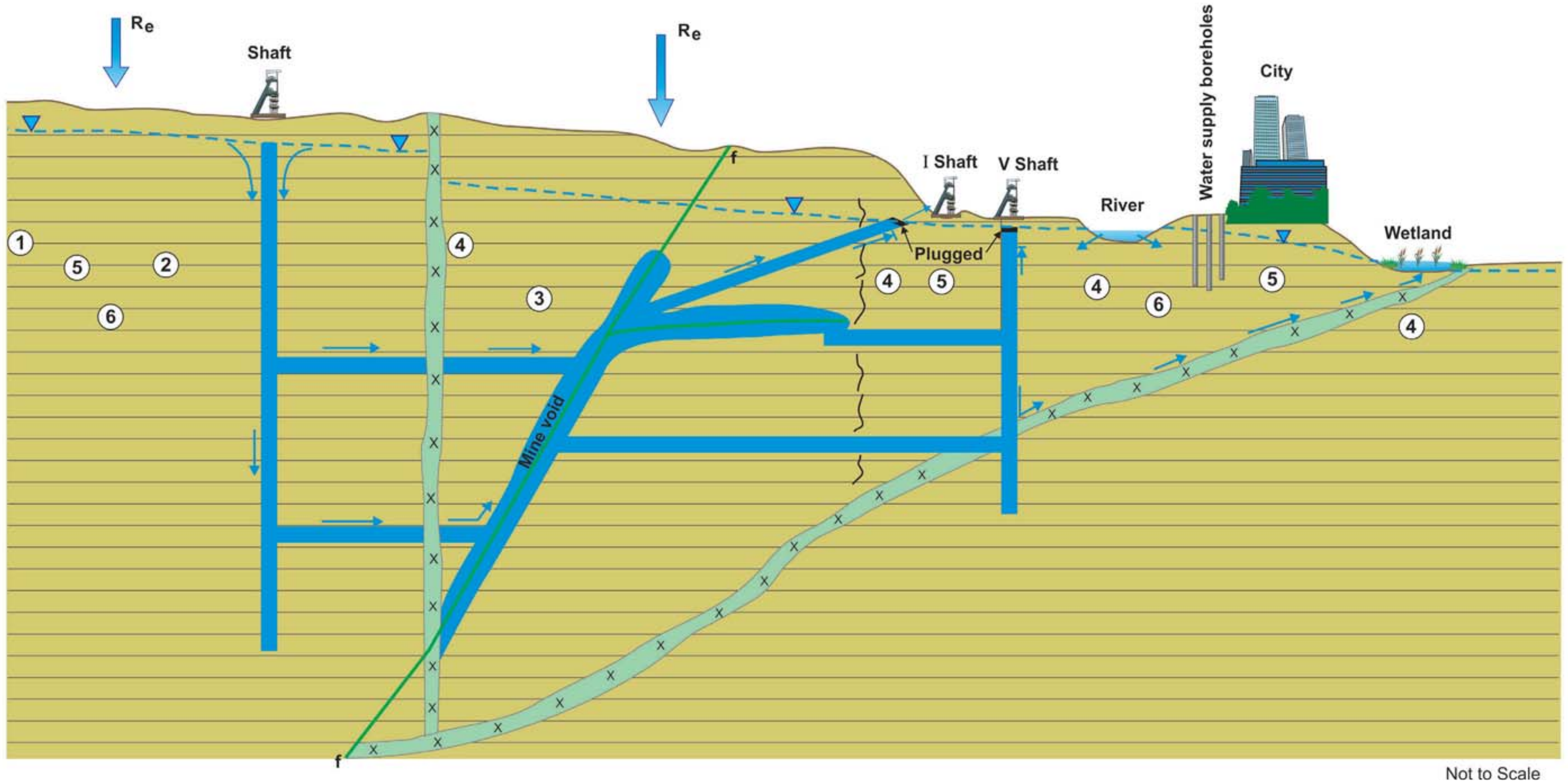


GROUNDWATER ATTRIBUTE, RANKINGS AND RATINGS		
Attribute	Description (Rank)	Rating (Count out of 1[lowest] to 5[highest]
1 – LITHOLOGY_AQuifer TYPE	Based on the primary rock type (storage/storativity) with no secondary features. Contains the saturated fractured and weathered rock profile. [Linked to specific Lith_Codes]	Alluvium = 5 Unconsolidated formations = 4 Arenaceous rocks = 3 Arenaceous/argillaceous = 2 Argillaceous rocks = 1 Diamictite = 1
2 – Hydro-Lithology Yield	Rating based on aquifer replenishment/sustainability and aquifer/ aquiclude/aquitard transmissivity excluding any secondary features (fracturing, dykes, lineaments and folding).	Intergranular = 3 Intergranular and fractured = 2 Fractured = 1 Karst = 4 [Linked to specific Lith_Codes]
3 – Secondary structures – Regional (>5 km²)	Folded formations, Joint development on bedding planes and regional fracturing. (These are regional features which may have joint, fracturing and slipping development along primary bedding planes). [Linked to Lith_Code/Structures Codes]	No regional features = 0 Over folding = 4 [specific structural codes mapped]; Jointed formations = 3 [specific structural codes mapped]; Anticlinal Folds = 2 [specific structural codes mapped]; Synclinal folds = 1 [specific structural codes mapped]
4 – Secondary structures – Local (<5 km²)	Lineaments, dolerite/diabase dykes/sills, faults/fracture zones and shear zones.	No local features = 0 Dyke/fault swarms (<100 m/>100 m apart) = 5/4; Single dykes/faults/fractures, (>750 m apart) = 3 Quartz porphyry/quartz syenite dykes = 2 Kimberlite/Carbonatite dykes = 1 Dolerite/diabase sils = 3
5 – Borehole yield class	Borehole yields based on tests during drilling operations.	Ratings from 5 (>5.0 l/s) to 1 (<0.1 l/s)
6 – Water quality	Recorded as electrical conductivity.	Ratings of 5 (<70 mS/m), 3 (70 to 300 mS/m) and 1 (>300 mS/m).

The schematic presentation of a rehabilitated surface mine illustrates a typical scenario where an ore body was mined in a shallow groundwater region and the original pit has been filled with mine waste material. The numbers indicate the six hydrogeological components that are contributing to a summarised vulnerability rating of this activity and where in the schematic presentation of the hydrogeological conditions in the area they are effective. For example, two secondary sill-like intrusions are present and both have secondary fracturing, thus contributing the regional groundwater flow and migration of groundwater residing in the rehabilitated pit; thus indicating a high vulnerability rating under the local geological features component. Migration of contaminated water from the pit to a well field is possible and the area will therefore have a relatively high vulnerability rating.

Photo Credit: Golder Associates

UNDERGROUND MINING



GROUNDWATER ATTRIBUTE, RANKINGS AND RATINGS		
Attribute	Description (Rank)	Rating (Count out of 1[lowest] to 5[highest]
1 – LITHOLOGY_AQuifer TYPE	Based on the primary rock type (storage/storativity) with no secondary features. Contains the saturated fractured rock profile. [Linked to specific Lith_Codes]	Alluvium = 0; Unconsolidated formations = 0; Arenaceous/Quartzite = 3/2; Rudaceous rocks = 2; Mafic, intrusive rocks (sills) = 1; Arenaceous/argillaceous = 2; Argillaceous rocks = 1; Diamictite = 1.
2 – Hydro-Lithology Yield	Rating based on aquifer replenishment/sustainability and aquifer/aquiclude/aquitard transmissivity excluding any secondary features (fracturing, dykes, lineaments and folding).	Intergranular = 0; Intergranular and fractured = 1; Fractured = 2; Karst = 1. [Linked to specific Lith_Codes]
3 – Secondary structures – Regional (>5 km²)	Folded formations, joint development on bedding planes and regional fracturing. (These are regional features which include joint, fracture and shear development along primary bedding planes). [Linked to Lith_Code/Structures Codes]	No regional features = 0; Over folding = 4 [specific structural codes mapped]; Jointed formations = 5 [formations with thin bedding planes]; Anticlinal Folds/Domes = 3 [specific structural codes mapped]; Synclinal folds/Basins = 3 [specific structural codes mapped].
4 – Secondary structures – Local (<5 km²)	Lineaments, dolerite/diabase dykes/sills, faults/fracture zones and shear zones.	No local features = 0 Karoo dolerite dyke swarms (<100 m/>100 m apart) = 3/2; Basalt dyke swarm & brecciated faults = 2; Single dolerite/basalt dykes, (>750 m apart) = 1 Quartz porphyry/quartz syenite veins/dykes = 1 Kimberlite/Carbonatite dykes = 1 Dolerite/diabase sills = 3
5 – Borehole yield class	Borehole yields based on tests during drilling operations.	Ratings: 5 (>5.0 l/s), 3 (2.0 to 5.0 l/s), 2 (0.5 to <2.0 l/s), 1 (0.1 to <0.5 l/s) to 0 (<0.1 l/s).
6 – Water quality	Recorded as electrical conductivity.	Ratings of 5 (<70 mS/m), 3 (70 to 300 mS/m) and 1 (>300 mS/m).

The schematic presentation of an underground mining scenario (left) illustrates a typical scenario where mine tunnels intercept potential water bearing features linked to the surface. During Life of Mine, the mine void will act as a sink as the mine is operating in a "dewatering" phase. The numbering on the schematic presentation indicates the hydrogeological components as indicated on the attached table, i.e. Lithology-Aquifer Type (1), hydro-lithology yield (2), secondary geological features – regional extend (3), local geological features (4), borehole yield class (5) and groundwater quality (6). Each hydrogeological component has a specific weighting factor of which the regional and local geological features and water quality are the highest indicating. As indicated on the schematic presentation, where a mineshaft is penetrating a sill structure, migration of mine water along the contact zone may reach a distant wetland over time and thus impact on the groundwater status in that area. Similarly, large abstractions for a local well field may also cause up coning of mine water from deep water bearing zones.


Photo Credit: Golder Associates

3.2 SURFACE WATER METHODOLOGY

Methodology

The state of surface water resources can be described in terms of:

- water quality (including physical, chemical and biological characteristics of water),
- water quantity (pattern, timing, water level and assurance of in-stream flow),
- the composition, distribution and state of the aquatic life present in the water body, and
- the character and condition of the in-stream and riparian habitat.

These components of quantity, quality, aquatic ecosystem state and habitat are all interlinked and interdependent in a water resource and the influence of mine water results in a different response due to these interdependencies.

The surface water assessment maps indicate the threat that exists to receiving water resources at quaternary catchment level by representing the capacity of the water resource to assimilate potential impacts, in this case mine water generated in a mineral province. It is a high resolution picture that highlights stressed catchments that are under threat, but also areas where the surface water resources do have capacity available to accept degrees of impact. This mapping is intended to provide a broad overview perspective on the threat to the surface water resources within mining areas of South Africa and in doing so provides guidance on:

- The extent of management and/or interventions that may be required;
- An indication of the assimilative capacity available in the system;
- Prompting the level of investigation required;
- From a catchment perspective the extent of further development that may be permitted; and
- Highlighting areas that are ecologically important or with good water quality that may require a precautionary approach.

This is aimed at supporting catchment based management decision making of future mining developments in the context of sustainable fitness for use of surface water resources and for the protection of the integrity of aquatic ecosystems.

The assessment is driven by considering the threat to present state water quality and present ecological condition:

- For water quality: On a quaternary catchment basis the level of compliance to a generic set of Resource Quality Objectives or where available to Catchment based Resource Water Quality Objectives or Resource Quality Objectives;
- For Aquatic Ecosystem and Habitat health: For water resource/river reach the Present Ecological State (PES) that applies;

The threat posed to the surface water component is represented independently for (1) water quality (based on fitness for use – how good or bad water quality is) and (2) ecological condition (Present Ecological State), and then (3) includes an overall representation of the threat to surface water resources which integrates these two components.

The ecological condition is derived from the country wide database of Desktop Level Eco-classification of the surface water resources at a sub-quaternary scale which are classified in terms of Present Ecological State (PES) categories (DWA, 2013). This was a national project undertaken with the specific purpose of building up a national database of PES and Ecological Importance (EI) and Ecological Sensitivity (ES). This dataset was considered appropriate as it can be consistently applied to the surface water resource component of the Mine Water Atlas at an appropriate scale; and is available for the entire country.

The water quality present state of surface water resources was based on the assessment of the fitness for use of the water resources. The Department of Water and Sanitation's Resource Quality Services (RQS) water quality database, the Water Management System, was used as the source of the quantitative water quality data for this analysis. The threat to the present state is represented in terms of water quality variables considered indicative of mining related impact. In-stream water quality of surface water resources was assessed using chemical monitoring data at a range of monitoring sites throughout the country (in each of the mineral provinces per Water Management Area) which was compared to a generic set of conservative level resource water quality objectives (RWQOs) to determine compliance for the selected water quality variables. Where catchment specific RWQOs and Resource Quality Objectives (RQOs) are available these were applied in place of the generic set. Water quality variables of concern are highlighted as related to the state of water quality identified.

Scale of Reporting

The threat posed to surface water resources is represented at a quaternary catchment scale. Only quaternary catchments falling within the boundaries of the mineral provinces were assessed. This comprised 964 quaternary catchments that fall within areas where exploitable mineral resources are found (current and future).

Present Ecological State

The PES of a river is expressed in terms of various components, i.e. drivers (physico-chemical variables, geomorphology and hydrology) and biological responses (fish, riparian vegetation and aquatic macroinvertebrates), as well as in terms of an integrated state, the EcoStatus. Different processes are followed for each component to assign a category ranging from an A to an F category (where A represents a pristine natural state and F a critically modified state) (Table 1). Ecological evaluation against the expected reference conditions, followed by integration of the categories of each component, provides a description of the Ecological Status or EcoStatus of a river. Thus, the EcoStatus can be defined as the total of the features and characteristics of the river (instream and riparian zones) that influence its ability to support an appropriate natural flora and fauna. This ability relates directly to the capacity of the system to provide a variety of goods and services. (Modified from Kleynhans and Louw, 2007).

Table 1: Description of the Ecological categories

Ecological Category	Description
A	Unmodified, natural.
B	Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.
C	Moderately modified. Loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged.
D	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions has occurred.
E	Seriously modified. The loss of natural habitat, biota and basic ecosystem functions is extensive.
F	Critically / Extremely modified. Modifications have reached a critical level and the system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.

The PES is a very broad qualitative assessment of both the instream and riparian components of a river. In 2013, the DWS published a national database of the PES/EIS of Sub Quaternary (SQ) river reaches throughout the country that was based on a modified desktop level eco-classification. A combination of expert knowledge and available information on the sub-quaternary reach level were used to derive the Desktop Present Ecological State (PES). This PES/EIS database was used as the basis of the surface water maps to represent the ecological state component.

The final modelled information in the front end model for each primary catchment is available from the Directorate: Resource Quality Services (D:RQS), DWS. Information was extracted in a 'master spreadsheet' for each primary catchment that incorporates all the PES/EIS results.

PES Mapping

The ecological status of the surface water resources is represented in the atlas as:

- As a GIS layer of the PES of all sub-quaternary river reaches in the database (national);
- A threat to PES that exists per quaternary catchment. This was derived by the aggregation of the PES of the river reaches within a quaternary catchment; based on the proportional length present per ecological category. This was then rated in terms of a threat to the water resource based on the ecological category as follows:

PES	Threat
A	High
A/B	High
B	Moderate
B/C	Low
C	Low
C/D	Moderate
D	High
D/E	High
E	High

- The above threat ratings are represented as a map of PES in the mine atlas with the following colour coded shadings and associated threat as follows:

Threat - Impact of mine generated water	Threat
High Threat	Need to protect ecological integrity (High importance and/or sensitivity).
Moderate Threat	Capacity exists with more stringent management required
Low Threat	Capacity exists with management required
High Threat	Cannot deteriorate further to an unsustainable state.

Water Quality

Water quality is a driver that indicates that the ecosystem, and its associated organisms, is under stress or that the ecosystem has become unbalanced. It also influences the availability of the water for use. As a result there could be possible implications for the intended uses of the water.

Fitness for use is a scientific judgement, involving objective evaluation of available evidence, of how suitable the quality of the water is for its intended use. Water quality can therefore only be expressed in terms of fitness for use. Quality assessment to

determine fitness for use is generally based on assessment objectives that have been set for the water resource. For water to be regarded as "fit for use" for a number of different users in the same catchment, the water quality needs to satisfy the most demanding of those users. Typically this will be quantified in terms of individual water quality attributes. The present state water quality is represented in terms of the key water quality variables considered indicative for reporting of the threat to the water quality of surfaces water resources. Five parameters have been selected to provide an indication of the fitness for use of water resources. These variables were selected as they serve as suitable indicators of water quality sensitivity to potential mining related impacts within the present data constraints. The variables include Electrical Conductivity (EC), Total Dissolved Salts (TDS), Chloride (Cl^-), Sulphate (SO_4^-) and pH as they are representative constituents of salinity and acidity for which a sufficient data set is available.

In-stream water quality of surface water resources was assessed using chemical monitoring data at a range of monitoring sites throughout the country which was compared to a generic set of conservative level RWQOs; to catchment specific RWQOs or to RQOs to determine compliance for the selected water quality variables.

Water Quality Data

The data were extracted from the WMS (Water Management System) in November 2014 with a stipulated date range of 1st January 2011 to 11 November 2014. The monitoring sites selected were from the National Chemical Monitoring (Priority) Programme. This programme has a spatial resolution covering South Africa with approximately 330 sites that are situated predominantly on rivers and for which surface water quality samples are taken to analyse the levels of specific inorganic and physico-chemical attributes.

Data Analysis

The water quality status (fitness for use) of the surface water resources of a quaternary catchment within the mineral provinces at the selected monitoring points was assessed by determining compliance of the five selected water quality variables to a generic set of RWQOs (Table 2) applicable to all the rivers across the country, with the exception of the Olifants (Table 3) and Vaal (Table 4) catchments where RQOs apply (draft) and the Orange River catchment (Table 5) where specific catchment derived RWQOs apply.

The generic RWQOs used for the compliance assessment (Table 1) were derived using the Resource Water Quality Objectives (RWQOs) Model (Version 4.0) (DWAF, 2006) which uses as its basis the South African Water Quality Guidelines (DWAF, 1996), Quality of Domestic Water Supplies: Assessment Guide, Volume 1 (WRC, 1998) and Methods for determining the Water Quality Component of the Reserve (DWAF, 2008) and are based on the strictest water user criteria (thus represent fairly conservative limits).

To determine the present state of water quality the compliance of the EC, (sulphate), (chloride), (TDS) and pH to the applicable objectives was assessed based on the 50th, 75th and 95th percentile values calculated at the representative monitoring points within a quaternary catchment. The water quality status of a quaternary catchment is reported as a fitness for use category (either ideal, acceptable, tolerable or unacceptable) based on the status of the least compliant variable(s) of the five assessed within the catchment.

Table 2: Generic Resource Water Quality Objectives

Variable	Units	Bound	Ideal	Acceptable	Tolerable	Unacceptable
Cl	mg/l	Upper	40	120	175	>175
EC	mS/m	Upper	30	50	85	>85
pH	units	Lower	≥6.5	>6.5	-	<6.5
SO_4	mg/l	Upper	80	165	250	>250
TDS	mg/l	Upper	200	350	800	>800

Table 3: Olifants Catchment: Draft Resource Quality Objectives

Variable	Units	Bound	Olifants B11 G; B11J (upper portion)	Olifants B11L	Klipspruit B11K/L	Wilge B20J	Klein Olifants B12E	Olifants B32C Bottom of quat, outlet)	Witbank, Doornpoort, Loskop Flag Bashielo, Buffelskloof and Middelburg Dams
EC	mS/m	Upper	111	55	111		85	111	85
SO_4	mg/l	Upper	500	80	500	200	200	500	200

Table 4: Vaal Catchment: Draft Resource Quality Objectives

Variable	Units	Bound	C11J/11K, C70D, C70E, C70F, C70G, C70H	C12F, C21F, C22E, C22J, Outlet C23E Mooi-rivierloop, Harts C33C (EWR 17)	Tributaries C70C, C70J, C70K, Koppies Dam, Schoonspruit Eye C24C	C23L Vaal (EWR5)	Thembalihle Dam, Klipdrift Dam, Vaal Barrage, Taung Dam	C60B, C60C, C60D, C60E, C60F, C60H (Otterspruit tributary), Serfontein Dam, C24F,
EC	mS/m	Upper	70	111	55	85	85	65
SO_4	mg/l	Upper				200		

Variable	Units	Bound	C42J, C60G, C60J, at Douglas C92C, Vaalharts weir, Douglas weir	Koekermoer- spruit C24A (interim* -10yrs)	C24D, C24E, C42D, C42E	C24F Schoonspruit, Johan Neser Dam, C41A, C41B, C41C,C41D	Schoonspruit C24H	C42J Riet-spruit interim*	Allemans-kraal Dam C42E
EC	mS/m	Upper	85	110* (85)	75	70	75	185	30
SO_4	mg/l	Upper		400* (250)			200		

Table 5: Orange River: Catchment specific Resource Water Quality Objectives
Upper Orange

Variable	Units	Bound	Ash River Tunnel	Oranje-draai	Aliwal North	Gariep Dam	Roode-poort	Vanderkloof Dam	Doorien Kuilen	Marksdrift
Cl	mg/l	Upper	40	40	40	40	40	40	40	50
SO_4	mg/l	Upper	60	60	80	60	80	80	65	60
TDS	mg/l	Upper	260	260	260	260	260	260	260	360

Lower Orange

Variable	Units	Bound	Boege-berg	Neusberg	Upington	Pella mission	Vioolsdrift	Alexander Bay
Cl	mg/l	Upper	100	100	100	100	100	100
SO_4	mg/l	Upper	80	100	200	150	150	150
TDS	mg/l	Upper	400	450	450	550	550	550

SURFACE WATER METHODOLOGY (continued)

Water Quality Mapping

The water quality present state of the surface water resources is represented in the Atlas as:

- The threat to present water quality state within a quaternary catchment that is rated as follows:

Water Quality (Fitness for use)	Threat
Ideal	High
Acceptable	Low
Tolerable	Moderate
Unacceptable	High

- The water quality variable(s) that pose(s) the most threat is indicated per quaternary catchment is indicated together with the level at which the indicated compliance is achieved.

- The above threat ratings are represented as a map of water quality status in the mine atlas with the following colour coded shadings and associated threat as follows:

Threat of Future impact	
High	Ideal water quality that may need to be sustained
Low	Assimilative Capacity available with appropriate regulation
Moderate	Some capacity exists but with stringent regulation
High	No capacity available to accept impacts

Integrated Surface Water Map

An integrated surface water map that incorporates PES and present state of water quality per quaternary catchment is presented based on an integrated threat rating as follows. Where water quality status is not available per quaternary catchment the threat to the PES is used as the default rating.

Conclusion

The status mapping provides a broad overview perspective on the threat to the surface water resources within mining areas of South Africa and serves as an indicator only. The mapping represents present state of surface water resources, and will require an update within a reasonable time period (three years).

The majority of the compliance assessment is done based on the generic RWQOs which may also require revision within a reasonable time period (three years) as RQOs are determined and gazetted across catchments throughout South Africa.

PES	Water Quality (Fitness for use)	Threat
A	Ideal	High
A	Acceptable	Moderate
A	Tolerable	High
A	Unacceptable	High
A/B	Ideal	Moderate
A/B	Acceptable	High
A/B	Tolerable	High
A/B	Unacceptable	High
B	Ideal	High
B	Acceptable	Low
B	Tolerable	High
B	Unacceptable	High
B/C	Ideal	Moderate
B/C	Acceptable	Low
B/C	Tolerable	High
B/C	Unacceptable	High
C	Ideal	Moderate
C	Acceptable	Low
C	Tolerable	Moderate
C	Unacceptable	High
C/D	Ideal	Moderate
C/D	Acceptable	Low
C/D	Tolerable	Moderate
C/D	Unacceptable	High
D	Ideal	Low
D	Acceptable	Moderate
D	Tolerable	High
D	Unacceptable	High
D/E	Ideal	High
D/E	Acceptable	High
D/E	Tolerable	High
D/E	Unacceptable	High
E	Ideal	High
E	Acceptable	High
E	Tolerable	High
E	Unacceptable	High
A	PES is default	High
A/B	PES is default	High
B	PES is default	Moderate
B/C	PES is default	Low
C	PES is default	Low
C/D	PES is default	Moderate
D	PES is default	High
D/E	PES is default	High
E	PES is default	High

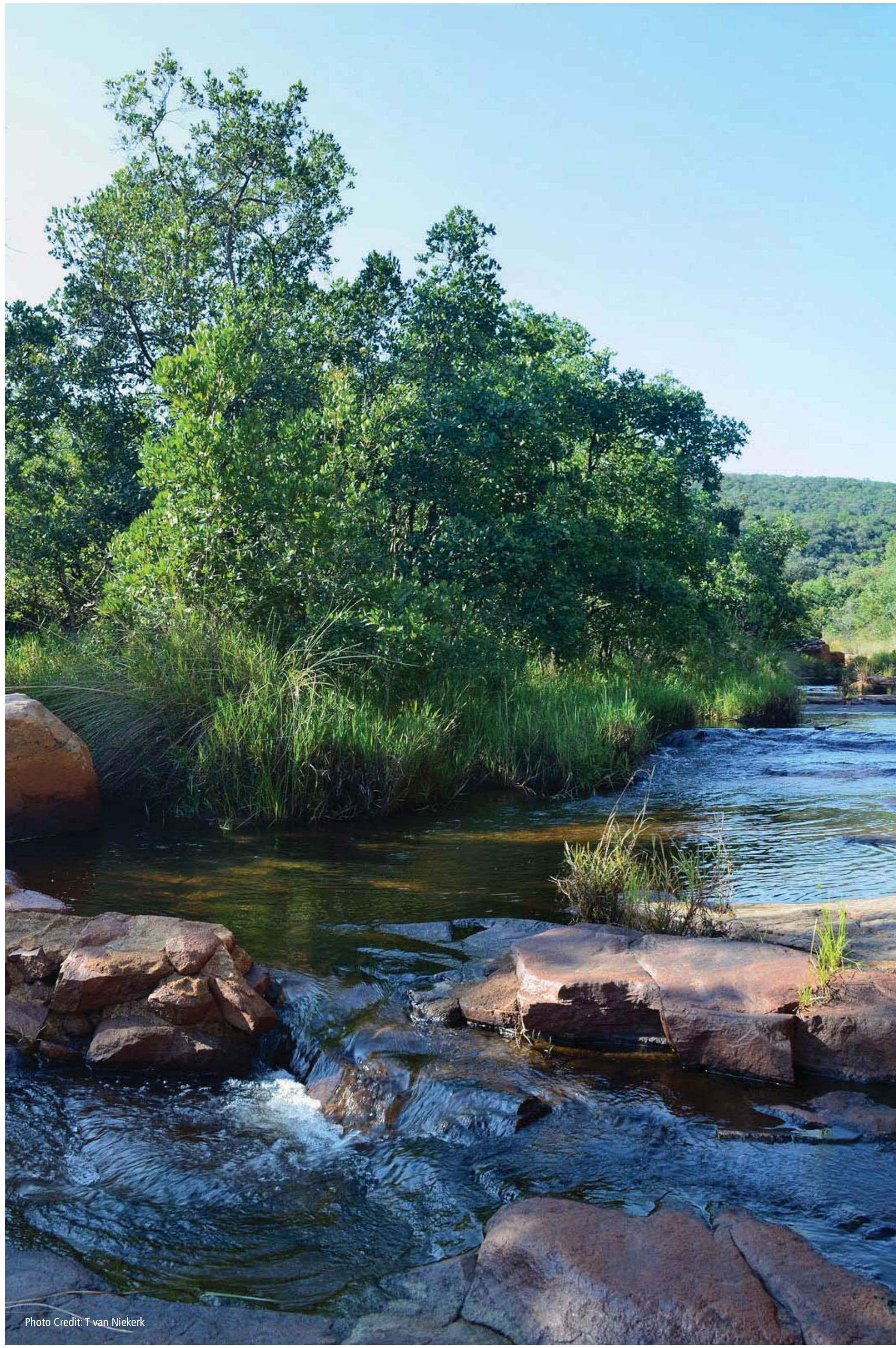


Photo Credit: T van Niekerk

3.3 GEO-ENVIRONMENTAL RISK MODEL

The mineral risk profiling or rating was developed based on any or all of the following data types, depending on availability, in the public domain:

- Existing geological data per mineral province
- Site specific geological data
- Site specific geochemical data, for example, from Acid Base Accounting (ABA), leach tests from:
    - Published papers
    - Integrated Water Use License applications
    - Evironemental Management Plans (EMPrs)
    - Dept. of Water & Sanitation databases

The precautionary principle plays a role such that the risk rating increases as the confidence or availability of data decreases.

1 Risk Question (weight)	Low Risk (1)	Medium Risk (2)	High Risk (3)
Is deposit acid-generating? (20%)	Not acid-generating (NAG)	Possibly acid-generating (PAG) or uncertain	Acid-generating (AG)
Are there neutralising minerals? (20%)	Yes, abundant	Limited	None
Are there minerals containing trace elements which are potentially toxic at low concentrations? (30%)	No	Yes but insoluble	Yes
Uncertainty (30%)	ABA database available	ABA data from less than 4 mines	Geological / theoretical information only

WMA	Mineral Province	Primary Commodity	Is deposit acid-generating? (20%)	Are there neutralising minerals? (20%)	Are there minerals containing trace elements which are potentially toxic at low concentrations? (30%)	Uncertainty (30%)	Total Score	Risk Assessment
Limpopo	Tuli Coalfield	Coal	2	2	2	2	2.0	Medium
	Tshipise & Pafuri Coalfields	Coal	3	2	2	2	2.2	Medium
	Ellisras Coalfield	Coal	3	2	3	1	2.7	High
	Springbok Flats Coalfield	Coal	3	2	3	3	2.8	High
	Witwatersrand basin	Gold, Uranium	3	2	3	1	2.7	High
	Transvaal Supergoup Gold	Gold	3	1	3	1	2.4	Medium
	Transvaal Supergroup BIF	Iron	2	1	3	1	2.1	Medium
	BIC Northern Limb	Platinum Group Elements, Chromium,	3	2	2	1	2.3	Medium
	Alkaline Complex	Lead, Phosphate	3	1	3	1	2.4	Medium
	Archaean Granite-Gneiss Terrane	Lead	3	2	3	3	2.8	High
	Beit Bridge Complex	Iron	1	2	1	3	1.8	Low
	BIC Phosphate Deposits	Phosphates	1	1	2	3	1.9	Low
	BIC Western Limb	Platinum Group Elements, Gold, Chromium, Iron, Lead,	3	2	2	2	2.2	Medium
	Giyani/Polokwane Greenstone BIF	Iron	3	2	3	2	2.5	High
	Kimberlite Diamond Field	Diamond	2	1	2	3	2.1	Medium
	Metamorphic Province Andalusite	Andalusite	1	1	1	3	1.6	Low
	Metamorphic Province Fluorite	Fluorspar	1	2	1	3	1.8	Low
	Other Limestone	Limestone	1	1	1	3	1.6	Low
	Pretoria Group Residual Manganese	Manganese	1	1	2	3	1.9	Low

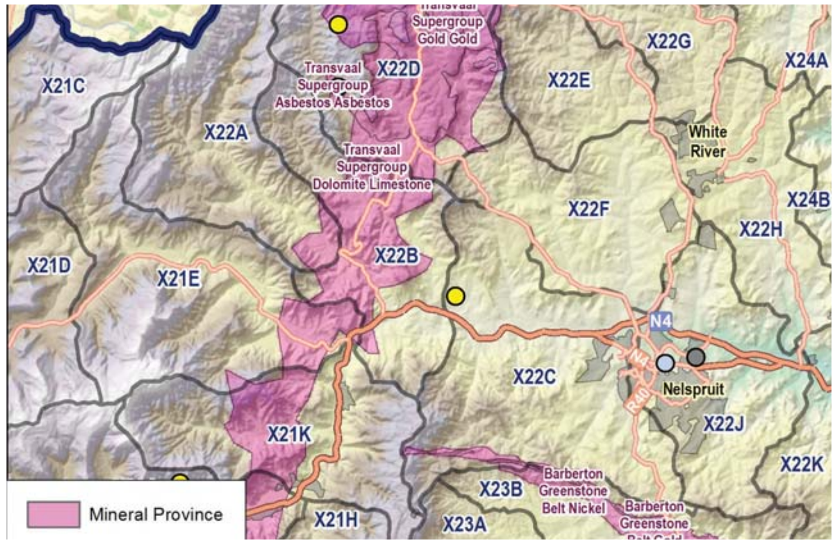
Photo Credit: Golder Associates

Summary description of the key thematic maps presented in the Atlas. Each of the component risk aspects in the Atlas's threat model is rated out of 5, with the general basis of scoring reflected in the table below, such that higher scores present relatively higher risk or vulnerability ratings.

Score	Relative Risk or Vulnerability descriptor
1	Low or insignificant
2	Moderate low
3	Moderate
4	High
5	Very High

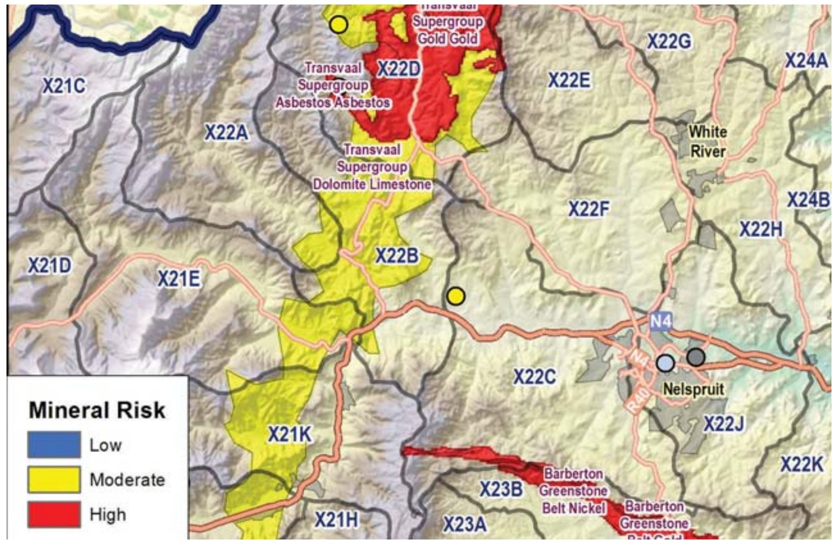
Mineral Provinces

"Mineral provinces" are mineralised zones that are broadly similar in terms of their host rock geology and mineralogy. This delineation is a key data asset in the Atlas, onto which an assessment of the risk of acid production and risks associated with likely mining activities are made. The mineral provinces also set the geographic limits of the final threaded Mine Water Threat rating.



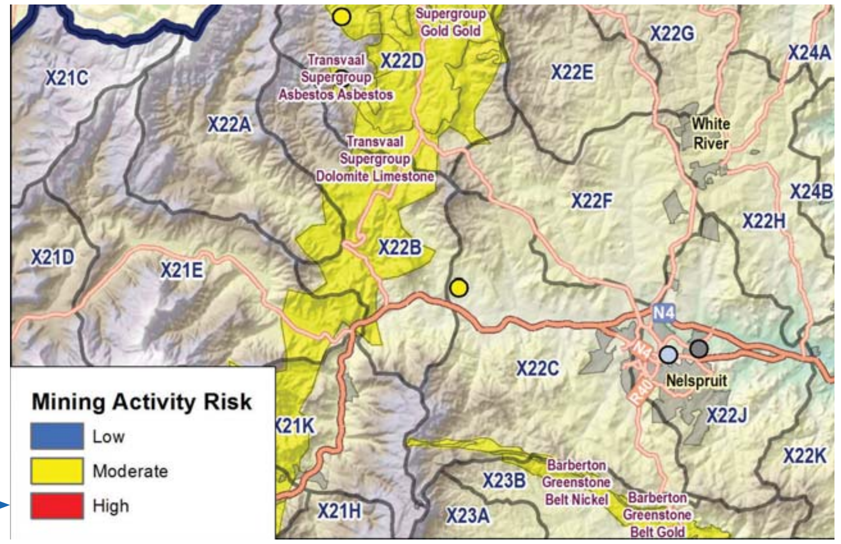
Mineral Risk

The mineral risk map reflects the assessed risk of acid production and/or leaching of constituents of concern into the environment. This basis of this assessment is detail in section **3, on page 17.**



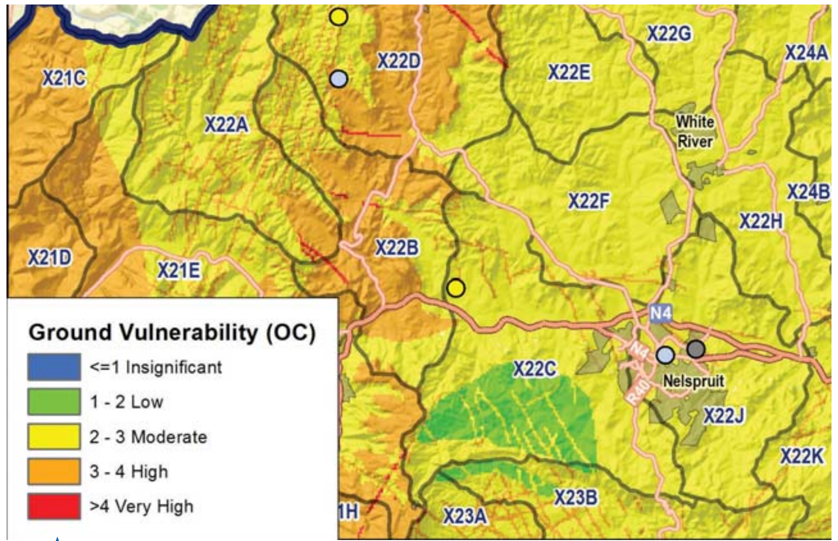
Mining Activity Risk

These maps reflect per mineral province the assessed relative risks against the likely dominant mining methods associated with mineral extraction, for the specific mineral province.



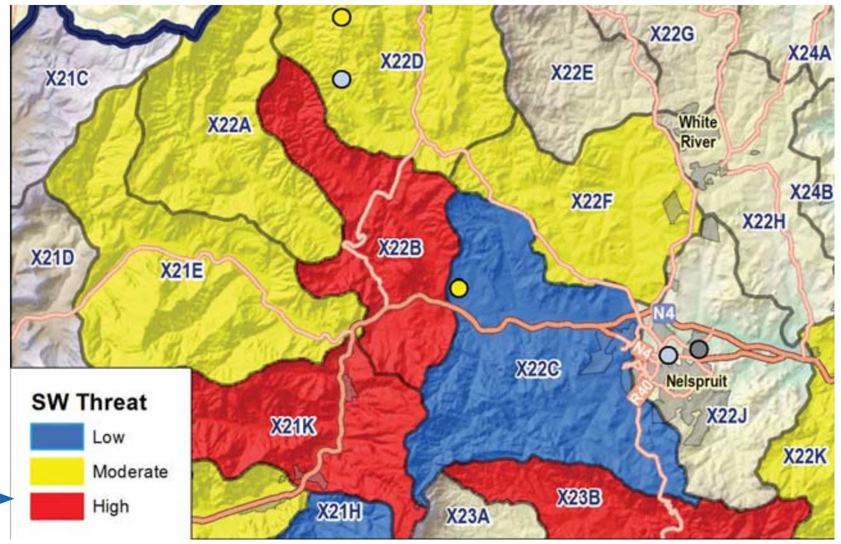
Groundwater Vulnerability

These maps present the vulnerability of groundwater resources to mining activity, considering separately the risk from surface mining activities and underground mining activities. The basis of this map is presented in detail in section **3 , on page 10**.



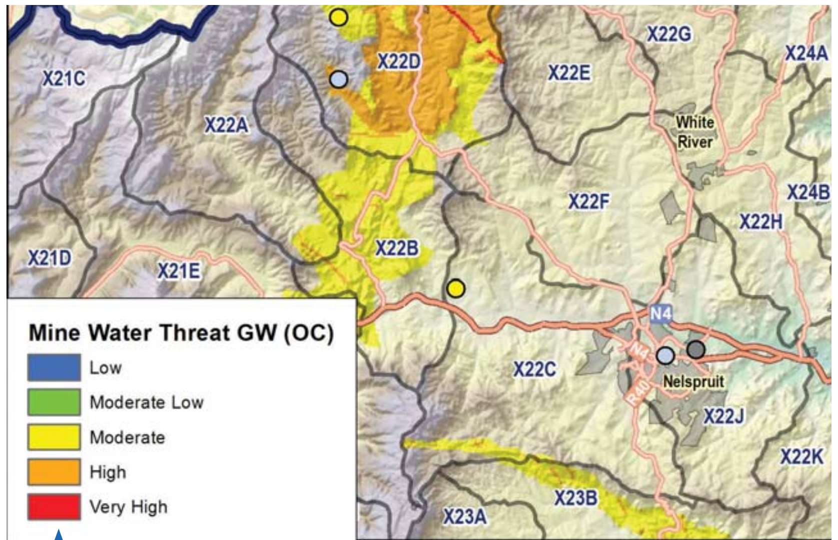
Surface Water Threat

This map reflects the assessment of the threat of mining to surface water resources at quaternary catchment level. The assessment is limited to those quaternary catchments that intersect mineral provinces across South Africa. Detailed in Section **3, page 14**.



Mine Water Threat

Mine Water Threat is the result of the threaded equation, summing the risk and vulnerability ratings of the mineral risk profile, mining activity risk and receiving water resource vulnerability. It presents three layers for groundwater (surface mining), groundwater (underground mining), and surface water. The mapping is limited to the extent of the mineral province delineations, focusing the assessment to those areas that either are being mined, or are likely to be mined.

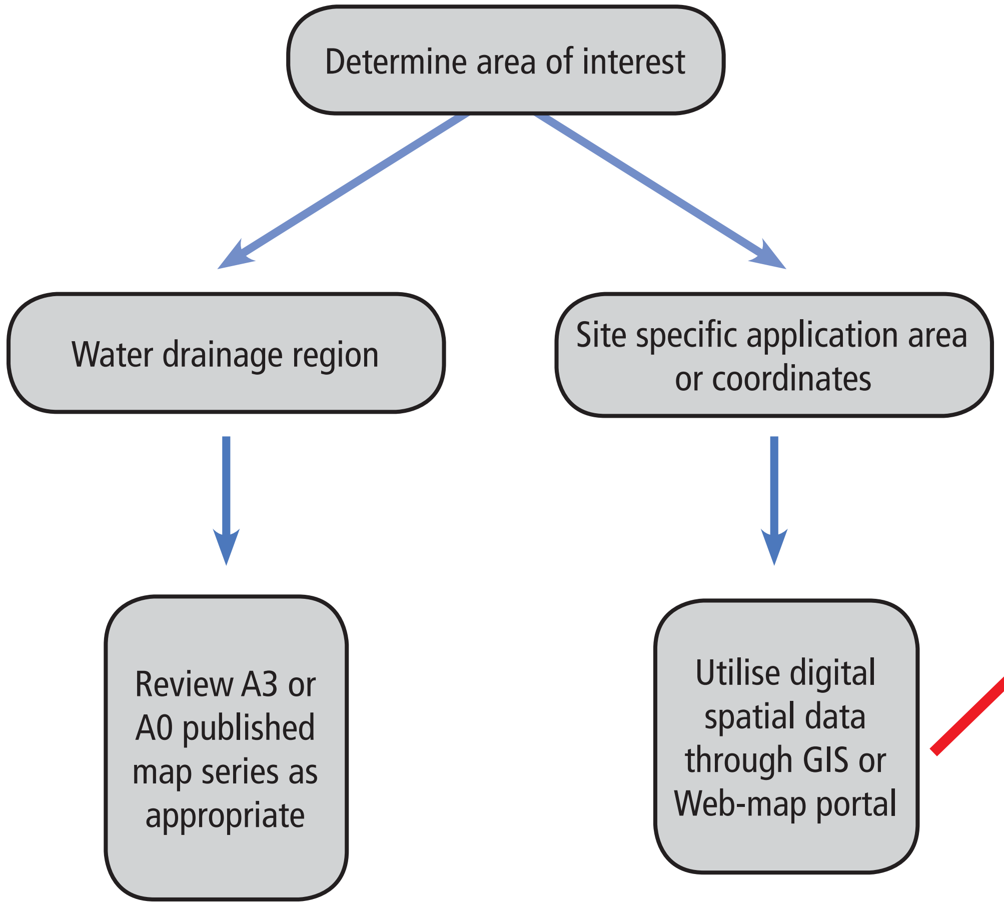


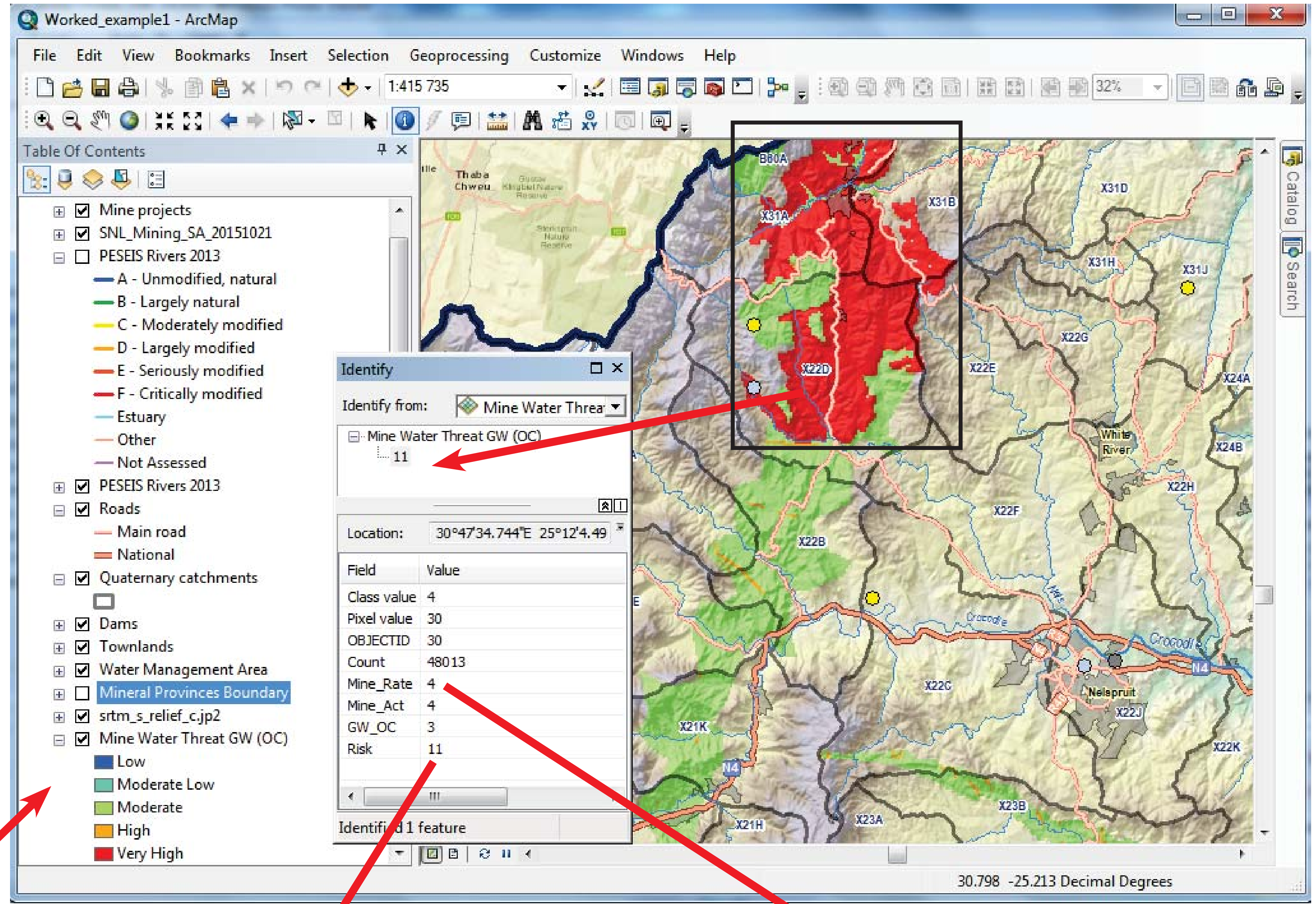
A worked example of using the Atlas:

Determine your area of interest, whether a specific mine application area or a catchment

Hard/Softcopy published maps – assess visually against the map series of different risk drivers, and/or the total Mine Water Threat result.

Using desktop GIS – upload a shapefile or coordinate, or zoom to a specific catchment area or mineral province. Using layer control to step through the various component risk criteria, or interrogate the Mine Water Threat layer in your specific area of interest to determine what the the drivers of threat to water resource are in situ.
Using the web portal, interrogate the data in much the same way as using desktop GIS





This GIS window has the **Mine Water Threat** layer for open cast mining loaded into the workspace. The Mine Water Threat layers are the cumulative unmitigated threat ratings summing the risk ratings from each of the three tiers of:

- mineralogy of each mineral province;
- the associated or likely mining activities in the same province; and
- the intersecting receiving water resource (groundwater in this example).

There is one such layer each for Surface Water, and Groundwater (both surface and underground mining scenarios).

The total threat score is **11** out of a possible 15, hence the high threat rating for this particular mineral province, represented in red. To understand how this score of 11 is achieved one can see the contributing scores of each of the three intersecting risk ratings. **These contributing components of threat can also be understood individually using the individual thematic mapping that is available for each, as is reflected by the layers depicted on page 11.**

The mineral risk rating of 4 out of 5 is high, and is a significant contributor to the overall high score of 11 in the Mine Water Threat thematic layer as is presented in this GIS interface.

Interpretation of this information might be:

- for a water manager or regulator: one of the likely key issues in specialist studies, impact assessment, and design of mitigation measures will be the apparent potential for acid generation in this mineral province - necessitating mineralogical and geochemical studies to confirm, and inform mitigation.
- for a mine developer: this information might inform what the likely liabilities or cost associated with mitigation might be, as well as facilitating a general understanding of environmental risk and the receiving water resource's vulnerability in the area.

WMA OVERVIEW

The Limpopo Water Management Area is a large and complex WMA comprising the Crocodile West, Marico, Limpopo and Luvuvhu catchment areas. Much of the area has low rainfall with significant inter-dependencies for water resources between catchments and with neighbouring WMAs.

Economic activity is mainly centred around game, livestock and irrigation farming, together with increasing mining operations. The main catchments are the Matlabas, Mokolo, Lephalala, Mogalakwena, Sand, Nzhelele and Nwanedi. Due to the aridity and flatness of the terrain few sites are available for the construction of major dams and the surface water potential has largely been developed. Relatively favourable formations for groundwater are found in the area and groundwater is therefore used extensively. However, over exploitation occurs in certain areas. Several inter-water management area transfers exist, all of which bring water into the catchment. A transfer from the Crocodile West catchment into the Mokolo catchment is being planned to support the expected growth in mining and power generation in the Lephalale area. The land use is agriculture, with private and provincial nature reserves as well as coal mining and platinum mining. The area is largely rural in nature.

The Luvuvhu River sub-catchment is situated in the north east of the WMA. The catchment is the only well-watered catchment in the Limpopo WMA. The main urban area is Thohoyandou with a large rural population scattered throughout the area. The economy is driven by irrigation and commercial forestry. The Mutale River is a major tributary of the Luvuvhu River. Other important tributaries of the Luvuvhu River include the Mutshindudi River and Dzondo River. There is also a relatively large groundwater resource in this catchment. Large scale utilization of the groundwater resource occurs mostly downstream of the Albasini Dam where it is used by irrigators and in the vicinity of Thohoyandou where it is used to provide water to rural communities. Several major dams have been developed to augment water supply. The control of alien vegetation is important in this catchment.

The Marico catchment borders Botswana to the northwest and the Vaal WMA to the south. The catchment is a large, relatively flat basin with low rainfall. Surface water is limited. Groundwater is important with springs and eyes providing river base flows and dolomitic aquifers providing water supply to the neighbouring Mafikeng area. The catchment is predominantly rural, with the main economic activity and water use being irrigated agriculture. Major towns include Zeerust and Marico. Some mining activity is present in the catchment but this is limited. Water supply is limited in the Marico, and sources are over exploited, with resources fully developed. The system is under stress.

The Crocodile West catchment lies to south eastern portion of the Limpopo WMA. The water resources of the Crocodile West catchment support major economic activities and a population of approximately five million people. It is the second most populous catchment area in the country with the largest proportionate contribution to the national economy, generating almost a third of the country's Gross Domestic Product. The area is highly altered by catchment development, with economic activity dominated by urban areas and industrial complexes of northern Johannesburg and Tshwane and with platinum mining north-east of Rustenburg. Extensive irrigation activities occur along the major rivers, with game and livestock farming occurring in other parts of the catchment. Development and utilisation of surface water occurring naturally in the water management area has reached its full potential. Large dolomitic groundwater aquifers occur along the southern part of the area. The aquifers are utilised extensively for urban and irrigation purposes. A substantial portion of the water used in the catchment is transferred from the Vaal River and further afield. Increasing quantities of effluent return flow from urban and industrial areas offer considerable potential for re-use, but the effluent is at the same time a major cause of pollution in some rivers. Population and economic growth, centred on the Johannesburg - Pretoria metropolitan complex and mining developments, are expected to continue strongly in this area.

Mining within WMA: Overview

The Mokolo catchment in the Limpopo WMA is the dominant coal mining area. The Mokolo River originates close to Modimolle and then drains to the north into the Limpopo. The Mokolo catchment is largely situated on the Waterberg coal fields. The major tributaries present in the catchment are the Tambotie River, Poer-se-Loop and the Rietspruit.

The Mokolo catchment is well developed in the Limpopo WMA. The large Mokolo Dam is situated in this catchment, which provides water for a multitude of uses. The main industrial development relates to Eskom's Matimba Power Station. Associated with this power station is the Grootgeluk Coal Mine which supplies coal to the power station, local users, as well as for export.

There are opportunities for further development of the substantial coal reserves and gas fields and other coal based industries and related development. The Waterberg coalfield is considered to hold more than 40% of South Africa's in situ mineable coal reserves. These vast resources are presently being mined at the large Grootegeluk coal mine. Other larger mining operations in the Limpopo WMA include the Venetia diamond mine and the Amandelbult, Northam, Mokopane, Messina, Lebowa, Marula and Modikwa platinum mines. Further expansion of mining is planned, particularly in the Mokopane area. The new thermal Medupi Power Station is currently under construction in the Mokolo Catchment.

The Murchison greenstone belt has yielded some 20% of the world's antimony and almost 30 t of gold, from the Consolidated Murchison Mines, as well as significant amounts of zinc and copper, mercury, gold (from non-antimonial deposits), paving and cladding stones and emeralds. The Venetia Kimberlite, west of Messina is currently South Africa's largest diamond producer and contributes the largest portion of the Limpopo province's mineral revenue.

There is limited coal mining in the Mutale catchment area (lower Luvuvhu catchment). The Tshikondeni Colliery is located approximately 71 km north east of the town of Thohoyandou in Limpopo Province. It is the only currently operating coal mine in the smaller Soutpansberg coalfield and yields high-grade coking coal for Iscor's steel mills. Magnesite mining is also undertaken in the lower Luvuvhu catchment area. The impact of coal and magnesite mining on the economy of this area is significant, as it is one of the only major industries offering employment in this remote area.

Within the Crocodile West catchment numerous mines occur mainly in a circular belt around the perimeter of the Bushveld igneous complex. These mines are mainly focussed on the Platina group of metals. Nine of the 14 producing Platinum group metal mines in South Africa are situated in the western limb of the Bushveld Complex. These mines have, for several decades, yielded the bulk of the total platinum group metal output from the world-famous Merensky Reef and UG2 chromitite layer of the Bushveld Complex, though the Eastern Limb and the Platreef are growing rapidly in importance. Substantial earnings also come from copper and nickel by-products. Mining activity is primarily concentrated in the Elands River catchment around Rustenburg. Mining water use amounts to approximately 8% of the total use in the catchment. These mines draw most of their water from the Vaal River System or from the Vaalkop Dam. Chromite production takes place in the lower portion of the Bushveld Complex in the Rustenburg area and immediately west of Pilanesberg in the Mankwe area. High-grade hematite is mined from the Penge Formation at Kumba Resources' Thabazimbi Iron Ore Mine in the southwest of the province. Acid and metallurgical grade fluorspar is currently produced from two mines hosted in dolomites in the vicinity of Zeerust and Marico, while limestone and dolomite are produced from two quarries in the Zeerust District.

SURFACE WATER PROFILE

Water Quality

Water quality monitoring of the surface water resources within the WMA is limited, with large percentage of the catchment area having no monitoring data available. Based on the data that is available, the present state of the salinity related water quality variables varies within the Crocodile West, Marico, Limpopo and Luvuvhu catchment areas. This is related to the development and associated impacts.

Within the Crocodile West catchment which is well monitored, the water resources are significantly impacted in terms of salinity, with the exception of the upper Elands catchment which has good quality water (ideal state). The water quality of the majority catchment area is predominantly in a tolerable state with respect to salinity, however the lower Crocodile River is in an unacceptable state. The Crocodile River and tributaries are impacted significantly by urbanisation, wastewater discharges and mining activities (platinum).

The water quality of the Upper Marico River is relatively good with water quality being in an acceptable state. The water quality of the lower Marico falls in the tolerable range in terms of salinity related water quality. High agricultural return flow is the major impacting activity. Water quality monitoring in the catchment is limited.

The water quality within the Limpopo and Luvhuvhu catchment area that is monitored is in an acceptable to ideal range for salinity. However, the salinity status is unacceptable in the upper Sand River catchment (A71A) and in Limpopo River at Musina. The Sand River is impacted by coal mining in the area, and the Limpopo River's water quality is driven by the seasonal flows from Botswana, intensive irrigated agriculture and mining activities. There is potential for further coal mining within the catchment area.

Ecological Condition

The present ecological condition of the rivers in the Limpopo WMA fall predominantly in a moderately modified state (category C) and largely modified state (category D) with a small percentage of smaller tributaries in less developed areas in the catchment in a natural to largely natural state (A and B present ecological condition). These are in less impacted areas of the catchment and fall largely within conservation areas. The modified river condition that is largely present in the WMA is due to impacts from agriculture, dams, mining and urban development. Within the Crocodile West catchment of the WMA, a number of river reaches in the A21 tertiary catchment (Johannesburg area), and parts of the A22 (Rustenburg) and A23 (Pretoria area) catchments are in a seriously modified state (E category) which is indicative of unsustainable systems, with a large loss of biota and ecosystem habitat.

Threat to the Surface Water Resources

Within the Limpopo WMA, of the 83% of the quaternary catchments assessed (with data available), 35% (5 rating red) of the catchment area includes stressed surface water resources that are under threat, 1% (5 rating green) that require the precautionary approach to management to maintain good condition, and 64% (rated 1 or 3) where the surface water resources do have capacity available to accept degrees of impact. Refer to the map on page 27.

MINERALOGY PROFILE

There are four major mineral provinces in the WMA:

- The Witwatersrand Basin produces gold and (historically) uranium and the mineralogical risk is high, due to high risk of acid rock drainage (ARD) and potentially toxic trace elements including uranium and lead.
- The BIC produces chrome and platinum, with medium mineralogical risk due to localised risk of acid rock drainage and potentially toxic trace elements, notably chrome. BIC phosphate deposits havelow risk.

- The Transvaal Supergroup (TSG) is a widespread mineral province from which gold, iron, dolomite and lead are produced. Generally the province has medium mineralogical risk, mainly due to potentially toxic trace elements, notably lead and zinc, which occur in minor/trace minerals within the dolomites. The TSG lead deposits are sulphide-rich and thus the risk of ARD results in a high mineralogical risk.
- The Karoo coalfields have significant risk of ARD, resulting in a medium mineralogical risk, or a high risk where there are potentially toxic trace elements, notably uranium in the Springbok Flats.

The remaining mineral deposits in the WMA include Greenstone Belt gold and iron (Polokwane) and various lead deposits, all of which have a high mineralogical risk rating due to ARD and potentially toxic trace elements, alkaline complexes and kimberlites with medium risk ratings and a variety of metamorphic- and sedimentary-hosted deposits with low risk ratings.

GROUNDWATER VULNERABILITY PROFILE

General aquifer profile (Lithology aquifer Type): there are four major aquifer systems in the WMA:

- Weathered hard rock, intergranular and fractured aquifers with borehole yields between 0.5 and 5.0 l/s and occasionally >5 l/s;
- Hard rock fractured aquifers with borehole yields of <2.0 l/s;
- Fresh water (<70 mS/m) karst aquifer systems with borehole yields >5.0 l/s; and
- Intergranular (alluvial) aquifer systems at major river courses with yields <5.0 l/s.
- Water quality varies from fresh (<70 mS/m) to saline (>300 mS/m), i.e. site/aquifer specific water quality aspects that should be considered.

Aquifer vulnerability rating:

Vulnerability rating varies between 1.4 (low, due to rock types, low-moderate yield classification and brackish water quality) and 4.4 (significant, due to dolomite water areas (Ramotswa-Dinokana-Zeerust and Tarlton-Pretoria-Irene) and the presence of diabase dykes causing preferential flow paths. There is a high presence of secondary geological features in the WMA which will contribute to a higher vulnerability rating due to preferential flow paths in the contact zones of these features. The remainder of the WMA fall in a low (1.9) to moderate (2.4) vulnerability rating. A few alluvial aquifer systems are present with moderate to high vulnerability ratings.

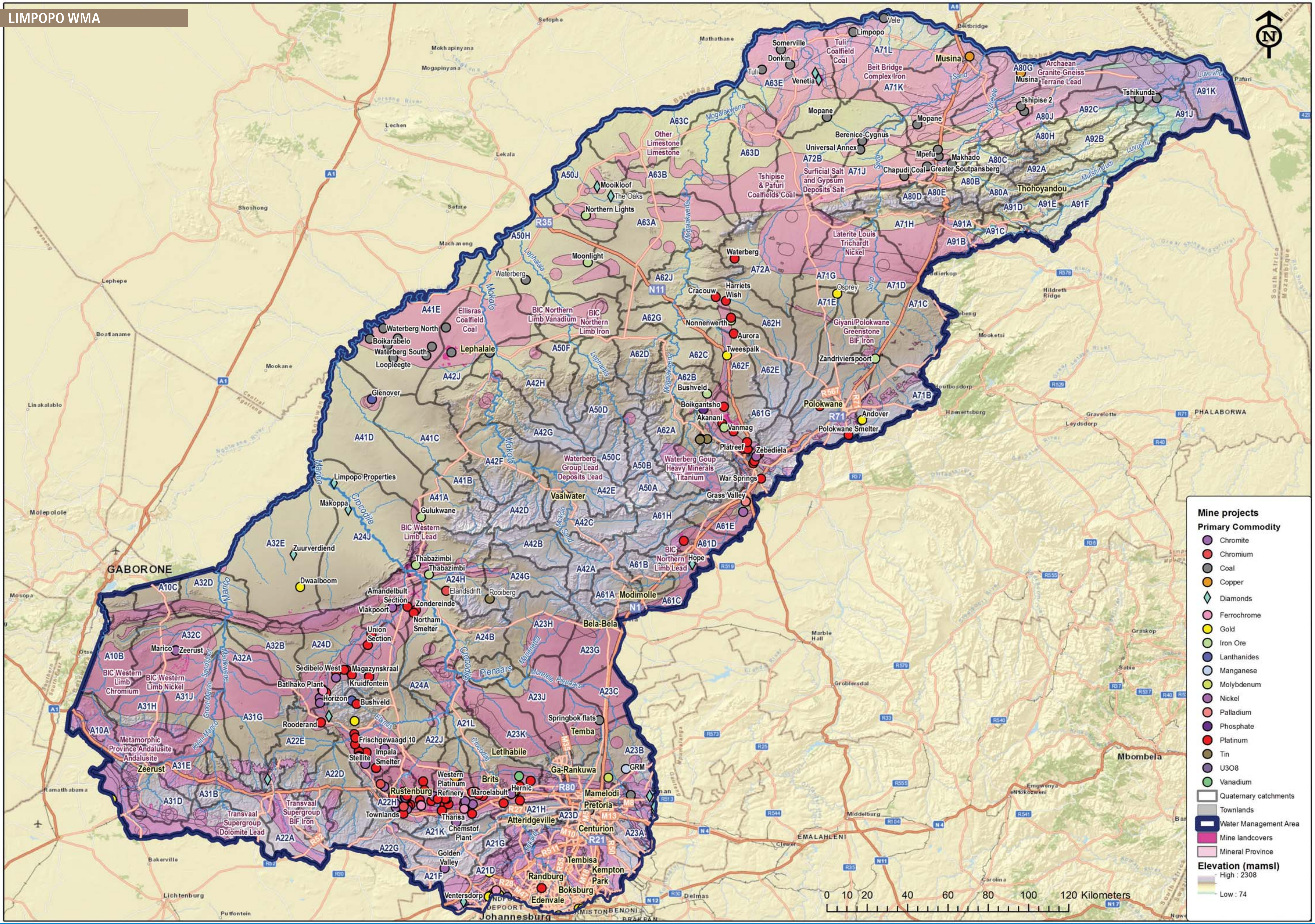
- Intergranular and fractured aquifer systems high (2.4 – Hout River Gneiss) to moderate (1.9 – Basement Granite-Gneiss) vulnerability rating;
- Fractured aquifer with low (1.6 to 1.9 – Rustenburg Layered Suite, Karoo sediments and Basement Granite-Gneiss) to moderate (2.1 – Waterberg sandstones);
- Fresh water karst aquifer systems with high to significant vulnerability rating: 3.5 and 4.4 where local dykes occur ;
- Intergranular (alluvial) aquifers with high vulnerability rating: 3.0 (Crocodile River alluvium) and 3.2 (Limpopo River alluvium);

Key areas of concern:

- Aquifer systems with fresh water quality;
- Several large secondary geological features (dykes, faults, foliations and unknown lineaments) which pose a high risk for localised fluid migrations – their presence in any local geological profile increases the aquifer vulnerability rating significantly;
- Karst aquifer systems; and
- Intergranular (alluvial) aquifer systems in river channel (Crocodile and Limpopo).

Locality map Limpopo WMA

LIMPOPO WMA


Mine projects
Primary Commodity
Chromite
Chromium
Coal
Copper
Diamonds
Ferrochrome
Gold
Iron Ore
Lanthanides
Manganese
Molybdenum
Nickel
Palladium
Phosphate
Platinum
Tin
U3O8
Vanadium
Quaternary catchments
Townlands
Water Management Area
Mine landcovers
Mineral Province
Elevation (mamsl)
High : 2308
Low : 74
0 10 20 40 60 80 100 120 Kilometers
GABORONE
Somerville
Donkin
Tuli
Tuli Coalfield Coal
Limpopo
Vele
Musina
Beit Bridge Complex Iron
Venetia
Archaean Granite-Gneiss Terrane Lead
Tshipise 2
Tshikunda
Mopane
Berenice-Cygnus
Universal Annex
Mpefu
Makhado
Chapudi Coal
Greater Soutpansberg
Surficial Salt and Gypsum Deposits Salt
Tshipise & Pafuri Coalfields Coal
Thohoyandou
Other Limestone Limestone
Mooikloof
The Oaks
Northern Lights
Laterite Louis Trichardt Nickel
Moonlight
Waterberg
Cracouw
Harriets Wish
Osprey
Ellisras Coalfield Coal
BIC Northern Limb Vanadium
BIC Northern Limb Iron
Waterberg North
Boikarabelo
Waterberg South
Loopleegte
Lephalale
Nonnenwerth
Aurora
Tweespalk
Giyani/Polokwane Greenstone BIF Iron
Zandrivierspoort
Glenover
Bushveld
Boikgantsho
Akanani
Vanmag
Polokwane
Andover
Polokwane Smelter
Platreef
Zebediela
Waterberg Group Lead Deposits Lead
Waterberg Goup Heavy Minerals Titanium
War Springs
Grass Valley
Vaalwater
Limpopo Properties
Makoppa
Gulukwane
BIC Western Limb Lead
Zuurverdiend
BIC Northern Limb Lead
Hope
Thabazimbi
Dwaalboom
Elandsdrift
Rooiberg
Modimolle
Amandelbult Section
Vlakpoort
Zondereinde
Northam Smelter
Bela-Bela
Union Section
Marico
Zeerust
BIC Western Limb Chromium
BIC Western Limb Nickel
Sedibelo West
Magazynskraal
Kruidfontein
Batlhako Plant
Horizon
Bushveld
Rooderand
Frischgewaagd 10
Impala Smelter
Stellite
Springbok flats
Temba
Metamorphic Province Andalusite Andalusite
Letlhabile
Ga-Rankuwa
GRM
Western Platinum Refinery
Brits
Rustenburg
Maroelabult
Hernic
Mamelodi
Pretoria
Townlands
Tharisa
Chemstof Plant
Atteridgeville
Centurion
Transvaal Supergroup BIF Iron
Transvaal Supergroup Dolomite Lead
Golden Valley
Randburg
Tembisa
Kempton Park
Boksburg
Edenvale
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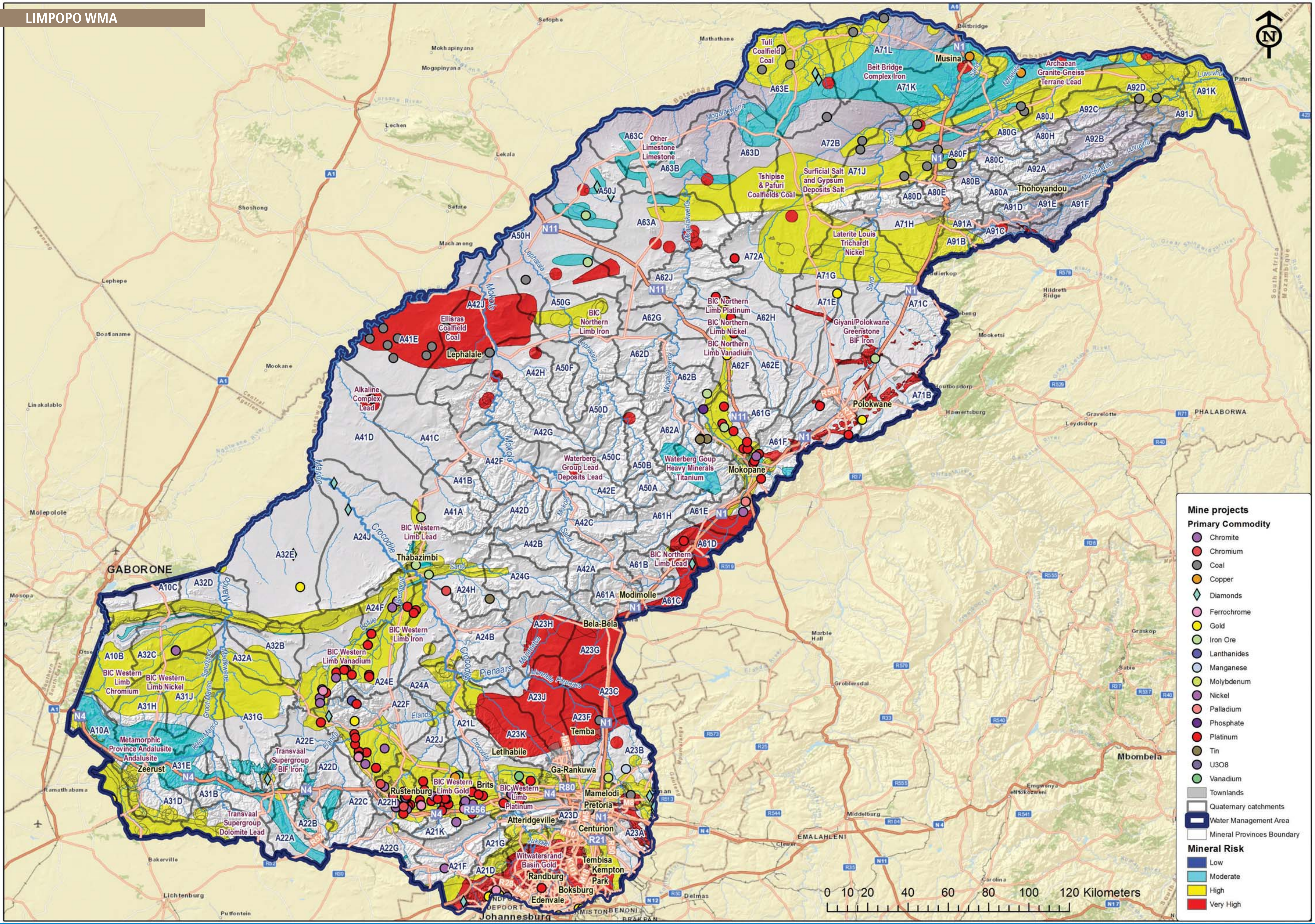
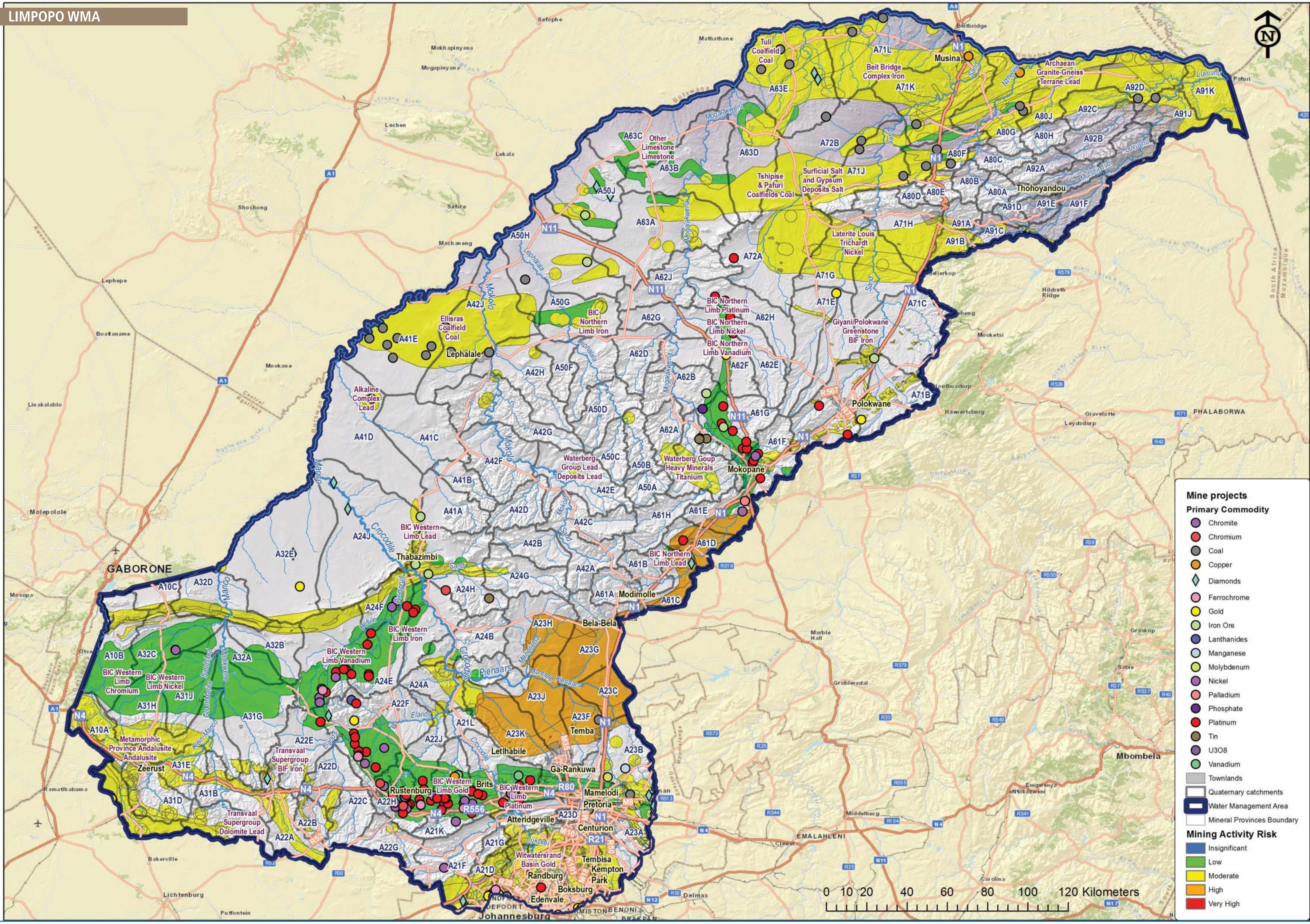
Mbombela
PHALABORWA
EMALAHLENI
Middelburg
Delmas
Lichtenburg
Mokopane


LIMPOPO WMA
Mine projects
Primary Commodity
Chromite
Chromium
Coal
Copper
Diamonds
Ferrochrome
Gold
Iron Ore
Lanthanides
Manganese
Molybdenum
Nickel
Palladium
Phosphate
Platinum
Tin
U3O8
Vanadium
Townlands
Quaternary catchments
Water Management Area
Mineral Provinces Boundary
Mineral Risk
Low
Moderate
High
Very High
0 10 20 40 60 80 100 120 Kilometers
GABORONE
Polokwane
Mokopane
Lephalale
Thabazimbi
Modimolle
Bela-Bela
Rustenburg
Pretoria
Johannesburg
Thohoyandou
Musina
Mbombela

LIMPOPO WMA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Phosphate
Platinum
Tin
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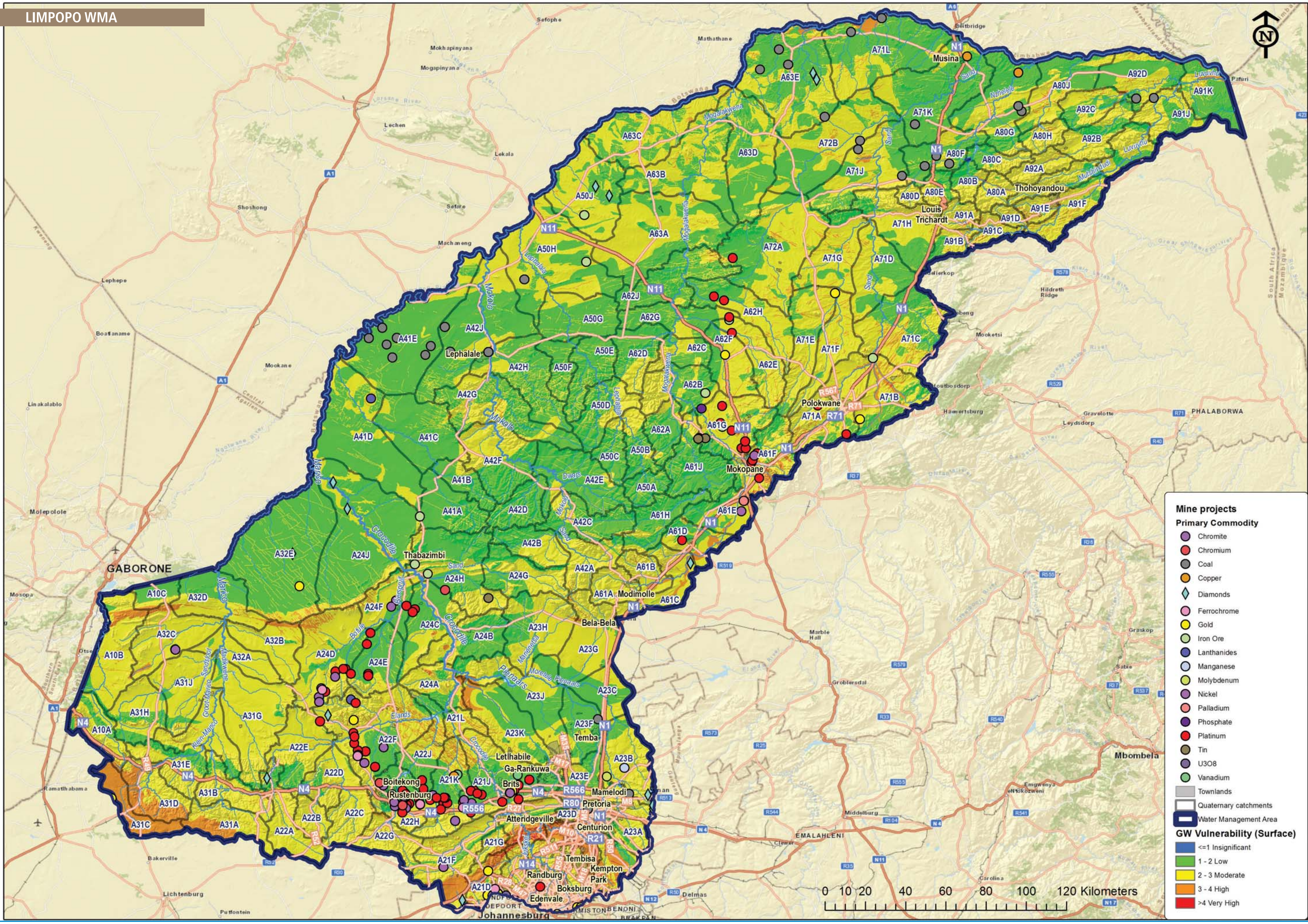
Vanadium
Townlands
Quaternary catchments
Water Management Area
Mineral Provinces Boundary
Mining Activity Risk
Insignificant
Low
Moderate
High
Very High
0 10 20 40 60 80 100 120 Kilometers
Tuli Coalfield Coal
Beit Bridge Complex Iron
Archaean Granite-Gneiss Terrane Lead
Other Limestone Limestone
Tshipise & Pafuri Coalfields Coal
Surficial Salt and Gypsum Deposits Salt
Laterite Louis Trichardt Nickel
Ellisras Coalfield Coal
BIC Northern Limb Platinum
BIC Northern Limb Nickel
BIC Northern Limb Vanadium
BIC Northern Limb Iron
Giyani/Polokwane Greenstone BIF Iron
Alkaline Complex Lead
Waterberg Group Lead Deposits Lead
Waterberg Goup Heavy Minerals Titanium
BIC Western Limb Lead
BIC Northern Limb Lead
BIC Western Limb Iron
BIC Western Limb Vanadium
BIC Western Limb Chromium
BIC Western Limb Nickel
Metamorphic Province Andalusite Andalusite
Transvaal Supergroup BIF Iron
Transvaal Supergroup Dolomite Lead
BIC Western Limb Gold
BIC Western Limb Platinum
Witwatersrand Basin Gold
Musina
Thohoyandou
Polokwane
Mokopane
Lephalale
Thabazimbi
Modimolle
Bela-Bela
Temba
Letlhabile
Ga-Rankuwa
Rustenburg
Brits
Mamelodi
Pretoria
Atteridgeville
Centurion
Tembisa
Kempton Park
Randburg
Boksburg
Edenvale
Johannesburg
Zeerust
GABORONE
PHALABORWA
Mbombela
EMALAHLENI

LIMPOPO WMA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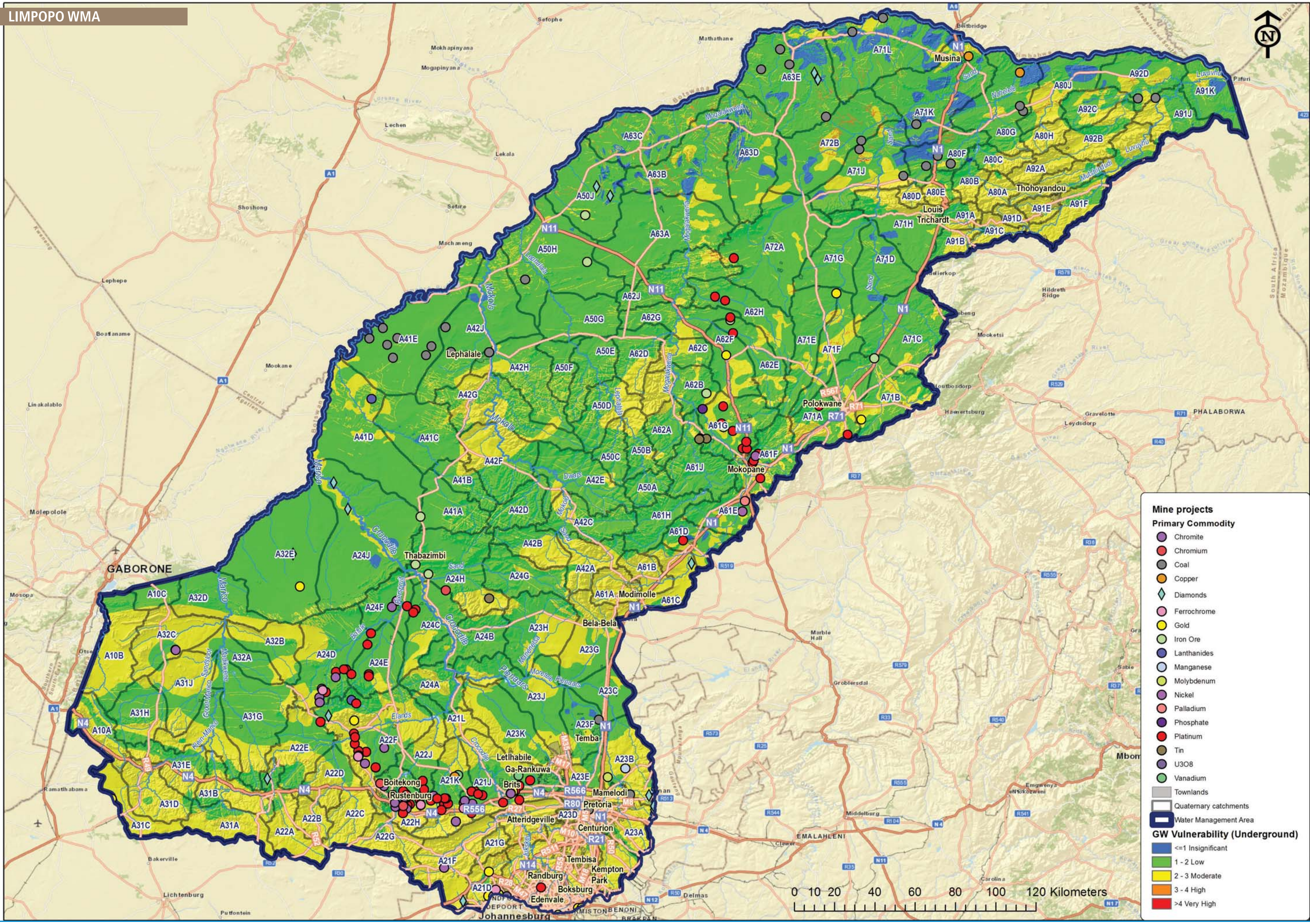
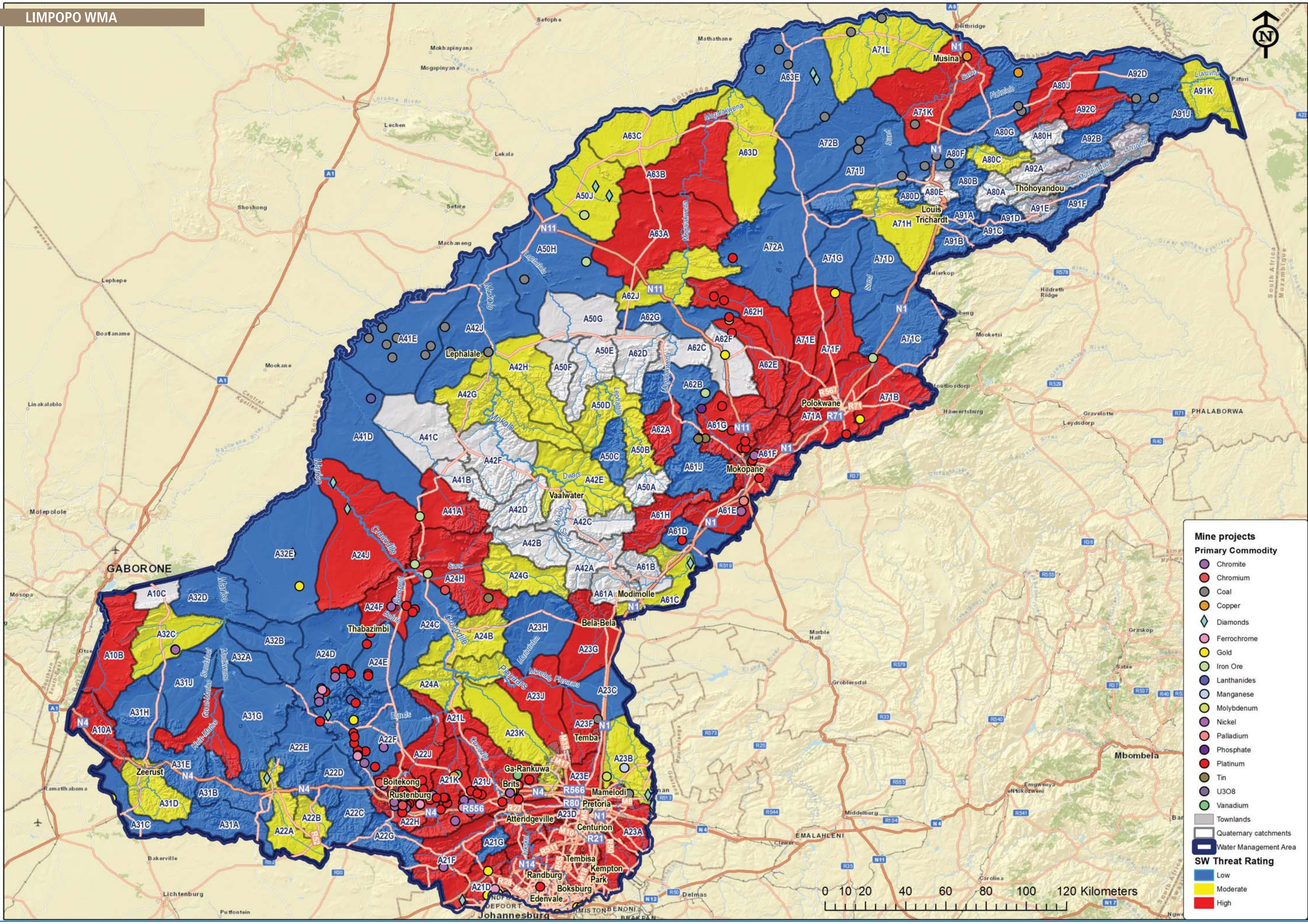
Molybdenum
Nickel
Palladium
Phosphate
Platinum
Tin
U3O8
Vanadium
Townlands
Quaternary catchments
Water Management Area
GW Vulnerability (Surface)
<=1 Insignificant
1 - 2 Low
2 - 3 Moderate
3 - 4 High
>4 Very High
0 10 20 40 60 80 100 120 Kilometers
GABORONE
Polokwane
Mokopane
Lephalale
Thabazimbi
Rustenburg
Pretoria
Johannesburg
Musina
Thohoyandou
Mbombela

GROUNDWATER VULNERABILITY - UNDERGROUND MINING

LIMPOPO WMA



LIMPOPO WMA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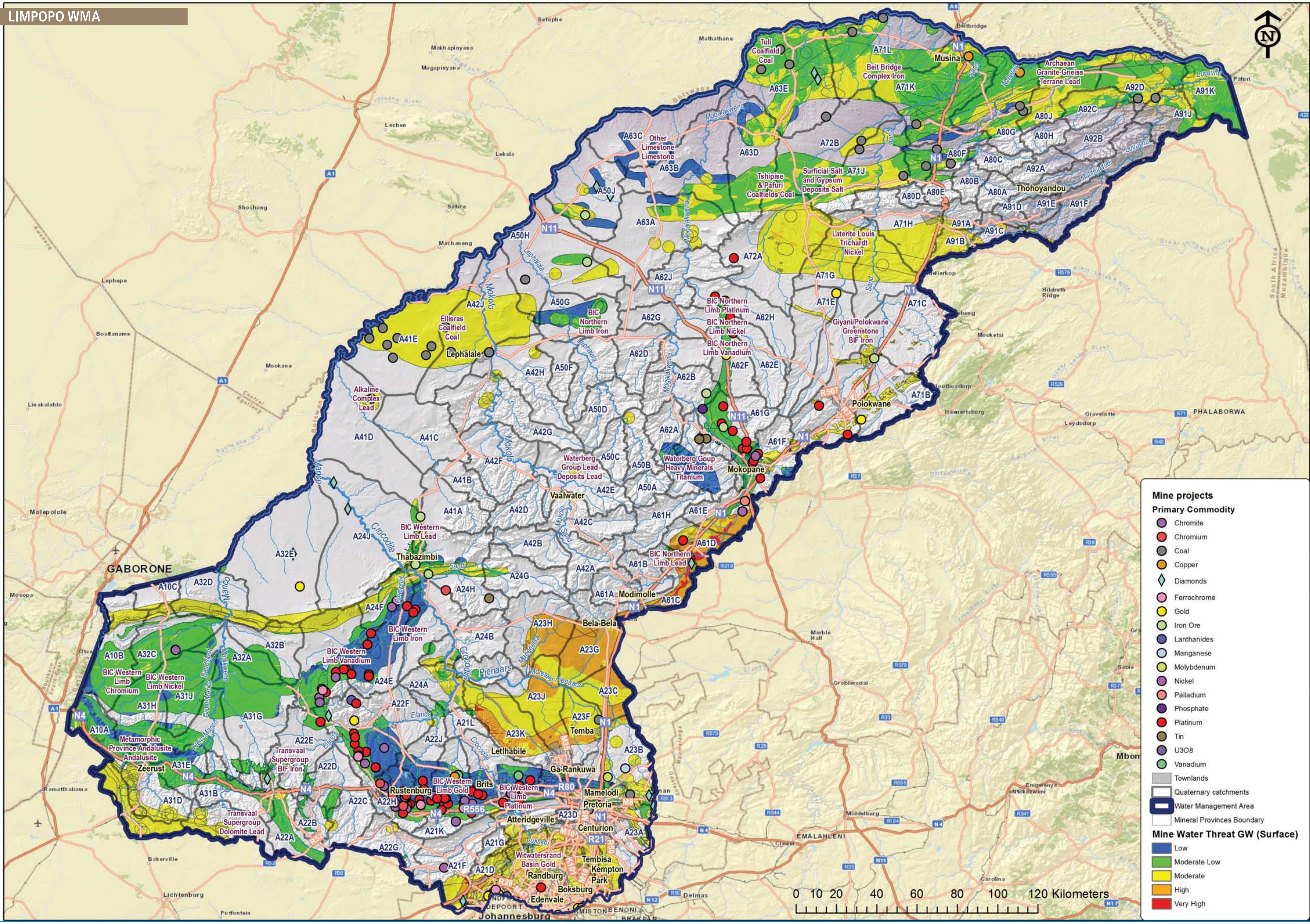
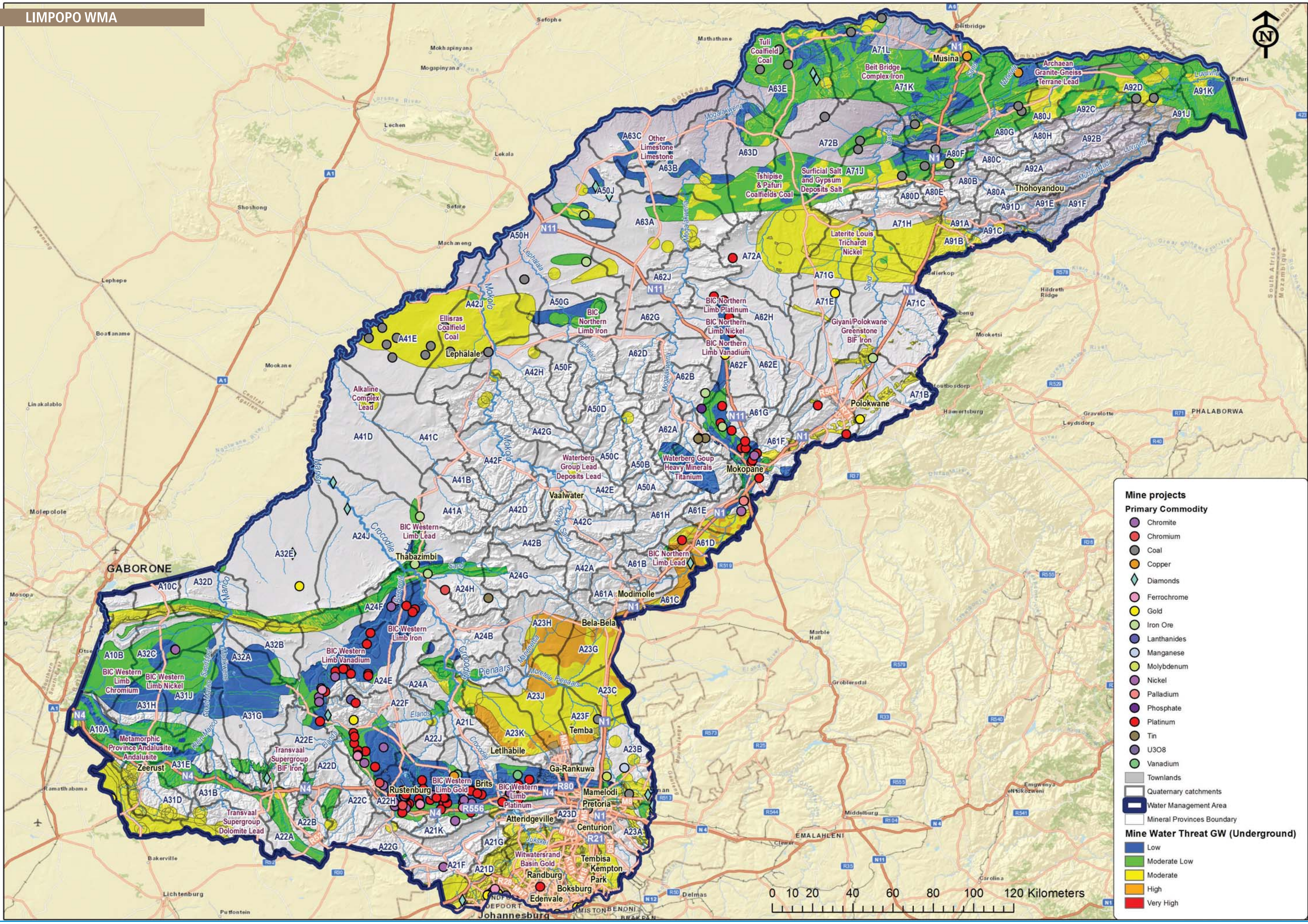
Phosphate
Platinum
Tin
U3O8
Vanadium
Townlands
Quaternary catchments
Water Management Area
SW Threat Rating
Low
Moderate
High
0 10 20 40 60 80 100 120 Kilometers
N
GABORONE
Musina
Louis Trichardt
Thohoyandou
Polokwane
Mokopane
Lephalale
Vaalwater
Modimolle
Bela-Bela
Thabazimbi
Zeerust
Rustenburg
Brits
Pretoria
Centurion
Johannesburg
Mbombela

MINE WATER THREAT GROUNDWATER - OPEN CAST

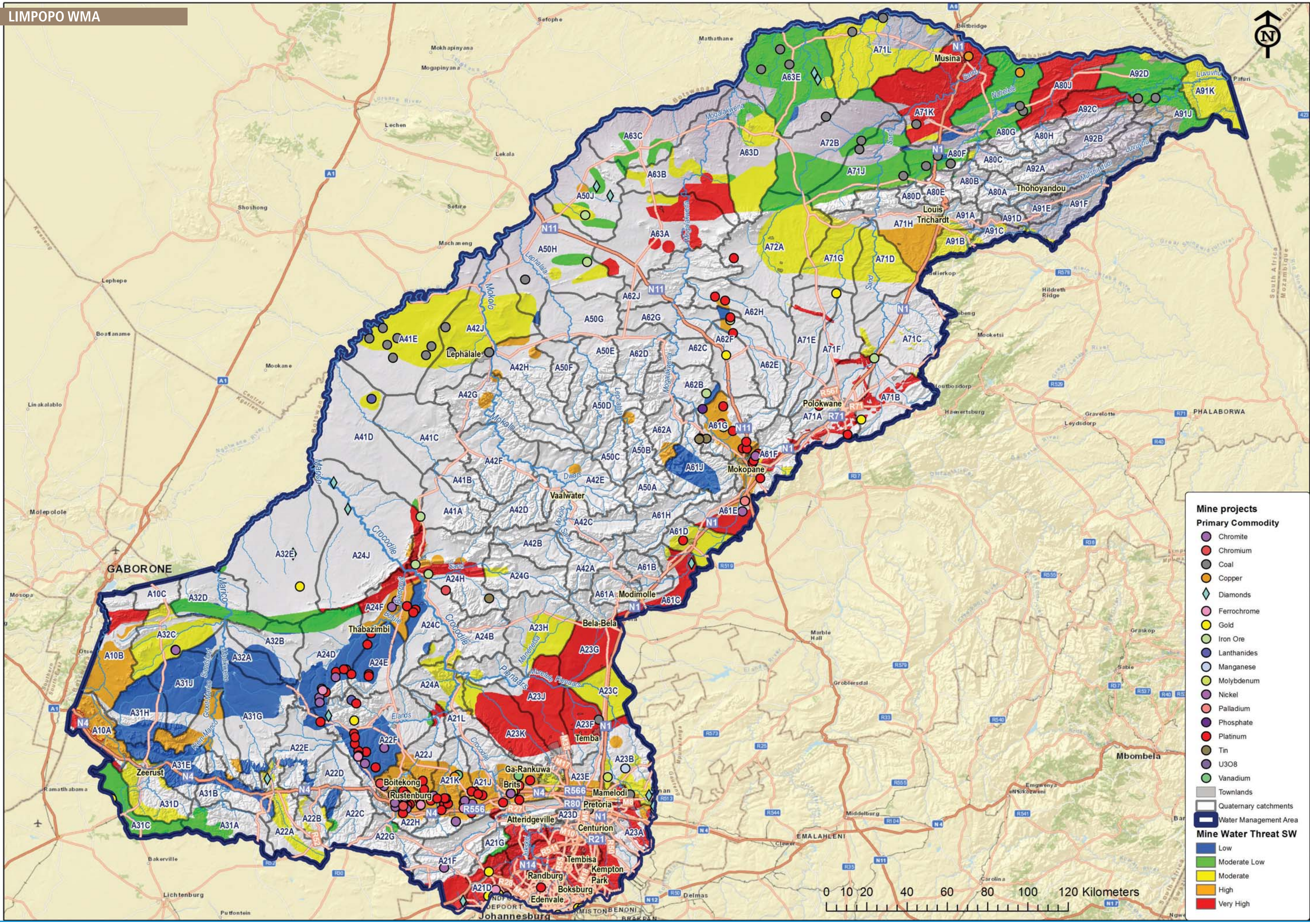
LIMPOPO WMA



MINE WATER THREAT GROUNDWATER - UNDERGROUND

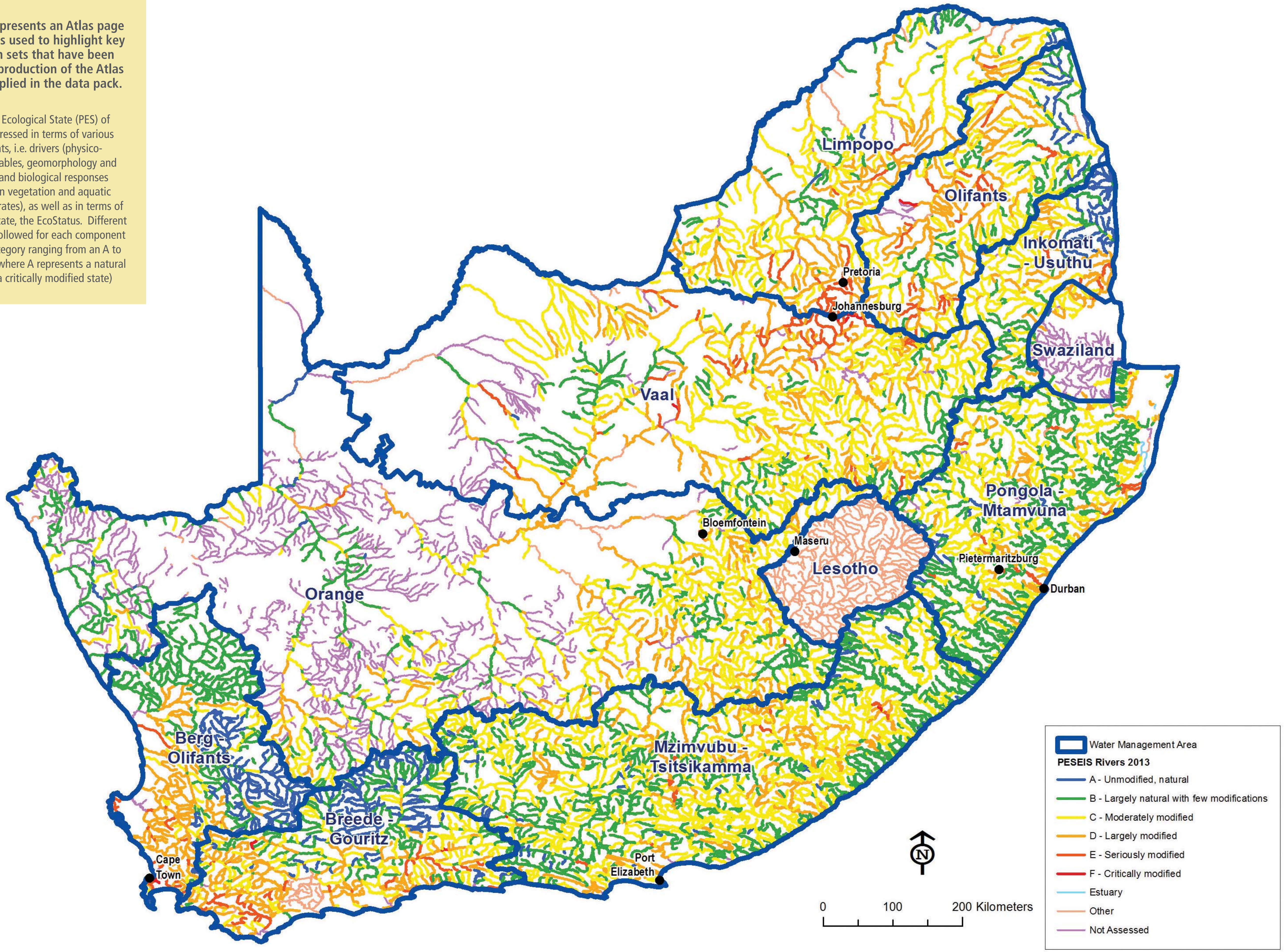


LIMPOPO WMA


Mine projects
Primary Commodity
Chromite
Chromium
Coal
Copper
Diamonds
Ferrochrome
Gold
Iron Ore
Lanthanides
Manganese
Molybdenum
Nickel
Palladium
Phosphate
Platinum
Tin
U3O8
Vanadium
Townlands
Quaternary catchments
Water Management Area
Mine Water Threat SW
Low
Moderate Low
Moderate
High
Very High
0 10 20 40 60 80 100 120 Kilometers
GABORONE
Lephalale
Thabazimbi
Vaalwater
Modimolle
Bela-Bela
Mokopane
Polokwane
Musina
Louis Trichardt
Thohoyandou
Rustenburg
Boitekong
Brits
Ga-Rankuwa
Temba
Mamelodi
Pretoria
Centurion
Atteridgeville
Tembisa
Kempton Park
Randburg
Boksburg
Edenvale
Johannesburg
Zeerust
Mbombela
PHALABORWA
EMALAHLENI
Middelburg
Delmas

This page represents an Atlas page holder that is used to highlight key foundation sets that have been used in the production of the Atlas and are supplied in the data pack.

The Present Ecological State (PES) of a river is expressed in terms of various components, i.e. drivers (physico-chemical variables, geomorphology and hydrology) and biological responses (fish, riparian vegetation and aquatic macroinvertebrates), as well as in terms of an integrated state, the EcoStatus. Different processes are followed for each component to assign a category ranging from an A to an F category (where A represents a natural state and F a critically modified state)



4.3 OLIFANTS WMA

WMA OVERVIEW

The Olifants WMA comprises the Olifants, Letaba and Shingwedzi River catchment areas. The WMA is highly stressed, fast growing in terms of population and development. There is limited opportunity for further water resource development and future development will need to rely on local sources of water.

The main tributaries of the Shingwedzi River include the Mphongolo, Phugwane, Shisha and Mashakwe Rivers. A large portion of the Shingwedzi River subcatchment (secondary catchment B9) falls within the Kruger National Park. Outside the park, land use is mainly subsistence agriculture and informal urban settlements. Several small gold mines were developed in the southwestern part of the Shingwedzi River catchment. The mines have limited impact on the local economy and have been closed down in recent years.

The Letaba catchment is located to the north of the WMA. The two main tributaries are the Klein and Groot Letaba Rivers. The Groot Letaba River catchment includes the main urban areas of Tzaneen and Nkowakowa and the Klein Letaba River catchment the town of Giyani. The rural population is scattered throughout the catchment area. The Letaba River catchment is highly regulated, particularly in the upper catchments where most of the runoff is generated. Surface water mainly originates in the mountainous areas and is regulated by several dams in the upper (Tzaneen, Magoebaskloof and Ebeneezer dams) and middle reaches of the river. The Letaba River is further regulated by a series of irrigation weirs that limit the flows of water into the Kruger National Park. There are further regulatory weirs and dams within the Kruger National Park (Mingerhout and Engelhardt dams). Intensive irrigation farming is practised in the upper parts of the Klein Letaba River catchment (upstream and downstream of the Middle Letaba Dam), and particularly along the Groot Letaba (downstream of the Tzaneen Dam) and Letsitele rivers. Vegetables, citrus and a variety of fruits are grown. The existing limited water resources in the catchment have been overexploited to meet the irrigation, afforestation, industry and rapidly increasing domestic water demands.

The Olifants system forms the major part of the WMA catchment area. Its main tributaries include the Wilge, Elands and Ga-Selati Rivers on the left bank and the Klein-Olifants, Steelpoort, Blyde, Klaserie and Timbavati Rivers on the right bank. The Olifants catchment is a highly utilised and regulated catchment and like many others in South Africa, its water resources are becoming more stressed due to an accelerated rate of development and the scarcity of water resources. The main economic activity in the catchment is related to mining. There are also large steel foundries located in Middelburg and eMalahleni. Extensive irrigation occurs in the vicinity of the Loskop Dam, along the lower reaches of the Olifants River, near the confluence of the Blyde and Olifants rivers, as well as in the Steelpoort valley and upper Selati catchment. Much of the central and north western areas of the catchment are largely undeveloped, with scattered rural villages where the people are mainly dependent on income generated by migrant workers in the Gauteng area, eMalahleni, Middelburg and Phalaborwa which are the largest urban centres. Land use in the area is characterised by rain-fed cultivation in the southern and north-western parts, with grain and cotton as main products. While most of the catchment area remains under natural vegetation for livestock and game farming as well as conservation, severe overgrazing is prevalent in many areas. Afforestation is found in some of the higher rainfall areas, with notable plantations in the upper Blyde River valley. The Kruger National Park is located at the downstream extremity of the Olifants catchment area. Most surface runoff originates from the higher rainfall southern and mountainous areas. There are nine major dams constructed in the Olifants River and the major tributaries which regulate the flow in the river system.

Mining within WMA: Overview

The main mining activities in the Olifants catchment are related to coal, platinum, vanadium, chrome, copper and phosphate. The coal mining is located in the upper reaches of the catchment around eMalahleni, Middelburg and Delmas, associated with large thermal power stations. The platinum, chrome and vanadium mines are located in the Steelpoort and Middle Olifants areas of the WMA while the copper and phosphate mining occurs in the lower Olifants around Phalaborwa.

All or part of the Witbank, Highveld, Eastern Transvaal, South Rand and KaNgwane coalfields are included in the Olifants catchment, as is the undeveloped Springbok Flats coalfield. A number of significant coal seams possessing diverse characteristics are present and have a variety of potential markets in the power generation, export, domestic, metallurgical, liquefaction and chemical sectors. This is the most important coal-producing area in South Africa and supports some 65 collieries working several seams in the Ecca coal belt. The Witbank coalfield contains a large and very important resource of high yield export quality steam coal, especially in the No. 4 seam.

The Phalaborwa Complex contains large deposits of copper, magnetite (iron ore) and apatite (phosphates), as well as the world's largest deposit of vermiculite (an expanding mica used in horticulture, agriculture and construction). It also hosts important concentrations of zirconium (in the form of baddeleyite), uranothorianite, nickel and precious metals. These deposits are successfully mined by the Palabora Mining Company and Foskor.

The Olifants catchment includes important ferrochrome, ferromanganese, ferrosilicon, and ferrovanadium production facilities. Some of the feedstock for these metallurgical plants is mined from silica, chromite and vanadiferous magnetite deposits in the Steelpoort area. The smaller Giyani (Sutherland) greenstone belt in the Klein Letaba catchment, in the area around Giyani, has yielded at least 10 t of gold from numerous small and six larger deposits (all closed at present), namely the Klein Letaba, Franke, Birthday, Fumani, Golden Osprey and Louis Moore mines. Large magnesite deposits were exploited here in the past. It is believed there is further potential for gold in this belt.

SURFACE WATER PROFILE

Water Quality

In terms of the salinity status of the WMA, the upper Olifants catchment is predominantly in an unacceptable state for the main stem Olifants River and many of the tributaries, but improves to a tolerable status at Loskop Dam. The salinity in the middle Olifants River falls in a tolerable range, and improves to an acceptable state in the Lower Olifants within the Kruger National Park. Many of the tributaries, including the Elands River, Wilge River, Steelpoort and the Ga-Selati, are in a good to acceptable status in the upper reaches of the catchments but deteriorate to unacceptable salinity ranges in the lower reaches before confluence with the Olifants River. The salinity related impacts are largely due to mining, irrigation return flows and wastewater discharges. The smaller tributaries, Grootspruit, Waterval, Treur, Blyde and Nwabitsi Rivers forming the headwaters of tributary catchments are in an ideal range, with respect to salinity status.

The water quality in the Letaba catchment is relatively good, falling in an ideal to acceptable state. The salinity of the Klein Letaba falls in the tolerable range, primarily due to impacts from agriculture and wastewater treatment works. Water quality monitoring in the catchment is fairly limited.

The salinity of the upper Shingwedzi River and the upper reaches of the Phugwane tributary are in the acceptable range. The salinity is impacted from runoff from the settlements in the catchment area. However the water quality monitoring within the catchment is very limited and further monitoring is required to confirm the status.

Ecological Condition

The present ecological condition of the rivers in the Olifants WMA falls predominantly in a moderately modified state (category C) and largely modified state (category D). A number of smaller tributaries in the upper reaches of the Olifants and within the Letaba and Shingwedzi catchment areas are in a natural to largely natural state (A and B present ecological condition). These are in less impacted areas of the WMA and fall largely within conservation areas, with the majority of A category rivers within the Kruger National Park. The modified river condition that is largely present in the WMA is due to impacts from mining, activities, agricultural activities and urban development. A small number of tributaries, in the Upper Olifants catchment, the Elands, Ga-Selati, Motse and Middle Letaba River catchment have been severely degraded and are in a seriously modified state (E category).

Threat to the Surface Water Resources

Within the Olifants WMA, of the 80% of the quaternary catchments assessed (with data available), 41% (5 rating red) of the catchment area includes stressed surface water resources that are under threat, 3% (5 rating green) that require the precautionary approach to management to maintain good condition, and 56%,(rated 1 or 3) where the surface water resources do have capacity available to accept degrees of impact. Refer to the map on page 39.

MINERALOGY PROFILE

There are five major mineral provinces in the WMA:

- The Witwatersrand Basin produces gold and (historically) uranium and the mineralogical risk is high, due to high risk of ARD and potentially toxic trace elements including uranium and lead.
- The BIC produces chrome and platinum, with medium mineralogical risk due to localised risk acid rock drainage and potentially toxic trace elements, notably chrome. BIC phosphate deposits are low risk.
- The TSG is a widespread mineral province from which gold, asbestos, dolomite and lead are produced. Generally the province has medium mineralogical risk, mainly due to potentially toxic trace elements, notably lead and zinc, which occur in minor or trace minerals within the dolomites. The TSG lead deposits are sulphide-rich and thus the risk of ARD results in a high mineralogical risk. The asbestos deposits have low mineralogical risk.
- The Karoo coalfields have significant risk of ARD, resulting in a high mineralogical risk where there is low neutralisation capacity (Highveld Coalfield and Seams 4 and 5 of the Witbank Coalfield) and medium risk where there is more neutralisation capacity (Seams 1 and 2 of the Witbank Coalfield). The Springbok Flats Coalfield has a high risk due to potentially toxic trace elements, notably uranium.
- The Giyani, Gravelotte and Polokwane Greenstone Belts have a generally high mineralogical risk rating due to ARD and potentially toxic trace elements, notably antimony, lead and nickel.

The remaining mineral deposits in the WMA include various lead deposits, all of which have a high mineralogical risk rating due to ARD and potentially toxic trace elements, alkaline complexes (including the Phalaborwa Copperfields) and kimberlites with medium risk ratings and a variety of metamorphic- and sedimentary-hosted deposits with mainly low risk ratings.

GROUNDWATER VULNERABILITY PROFILE

General aquifer profile (Lithology aquifer type): there are two major aquifer systems with limited river alluvium in the WMA:

- Intergranular and fractured aquifers with borehole yields between 0.5 and 5.0 l/s and occasionally >5 l/s;
- Fresh water (<70 mS/m) karst aquifer systems with borehole yields >5.0 l/s; and
- Intergranular (alluvial) aquifer systems confined to the lower stem of the Letaba and Singwidzi and middle sections of the Olifants with yields >5.0 l/s.

- Water quality varies from fresh (<70 mS/m) to saline (>300 mS/m), i.e. site/aquifer specific water quality aspects that should be considered.

Aquifer vulnerability rating:

Vulnerability rating varies from 1.4 (low, due to rock types, low-moderate yield classification and brackish water quality) to 3.9 (high, due to dolomite water areas (Delmas and Wolkberg areas) and the presence of diabase dykes causing preferential flow paths. The remainder of the WMA fall in a low (1.9) to moderate (2.4) vulnerability rating. There is a high presence of secondary geological features in the WMA which will contribute to a higher vulnerability rating due to preferential flow paths in the contact zones of these features.

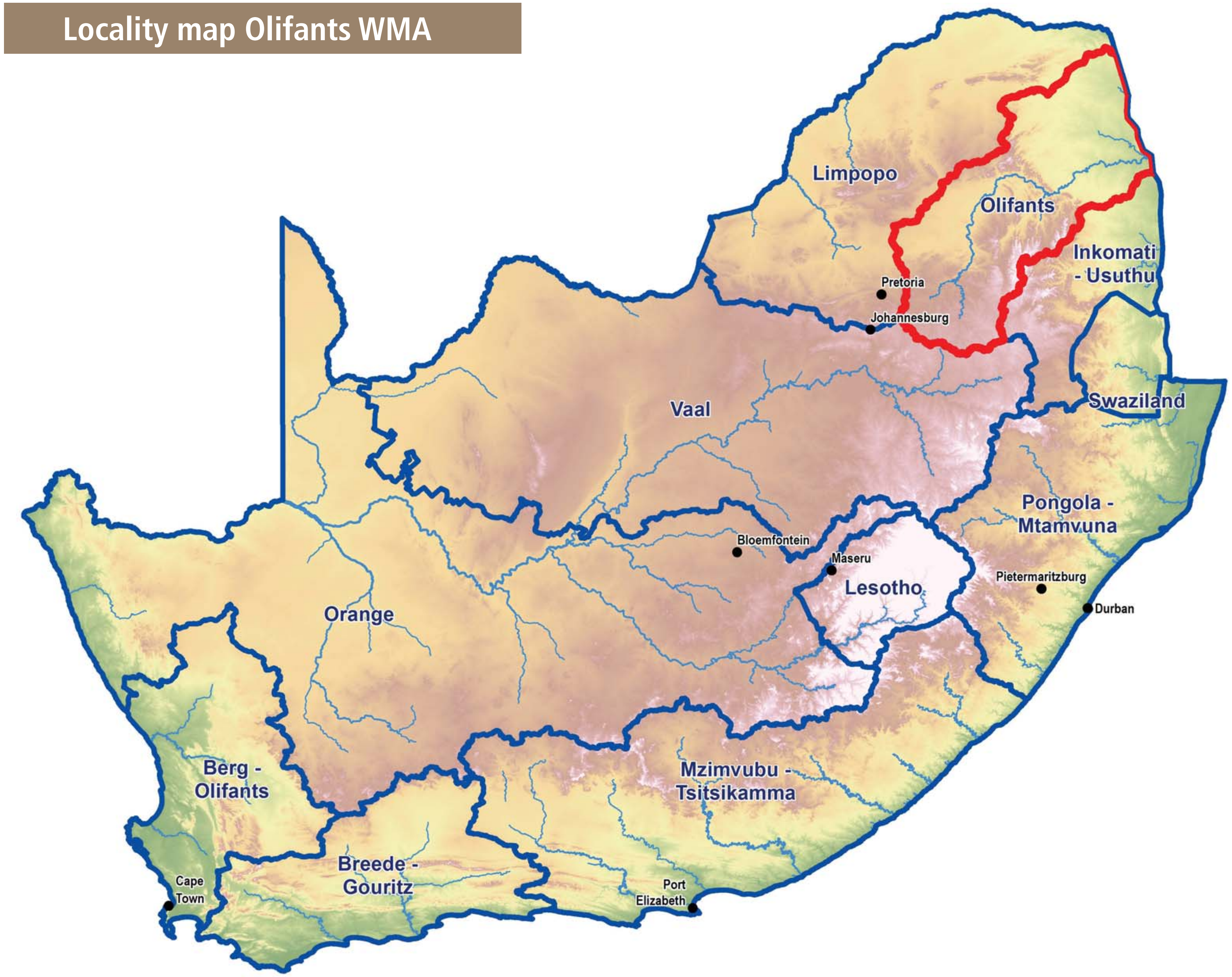
Intergranular and fractured aquifer systems:

- Goudplaat and other gneissiod rocks: low at 2.1, but moderate to high (2.6 to 3.2) where diabase and Karoo Dolerite dykes are present;
- Nebo Granite: Low at 1.9 to 2.4 where diabase and Karoo Dolerite dykes are present;
- Pretoria Group: Moderate at 2.9, but high (3.2 to 3.8) where Karoo Dolerite dykes are present;
- Ecca Group: Low at 1.8, but moderate to high (2.9 to 3.2) where Karoo Dolerite dykes are present.
- Fresh water Malmani Dolomite karst aquifer systems with high to significant vulnerability rating:3.3 and 4.4 with local dyke features;
- Intergranular (alluvial) aquifers with moderate (2.7) vulnerability for Letaba and Singwedzi River alluvium and high (3.2 to 3.4) for Olifants River alluvium aquifers.

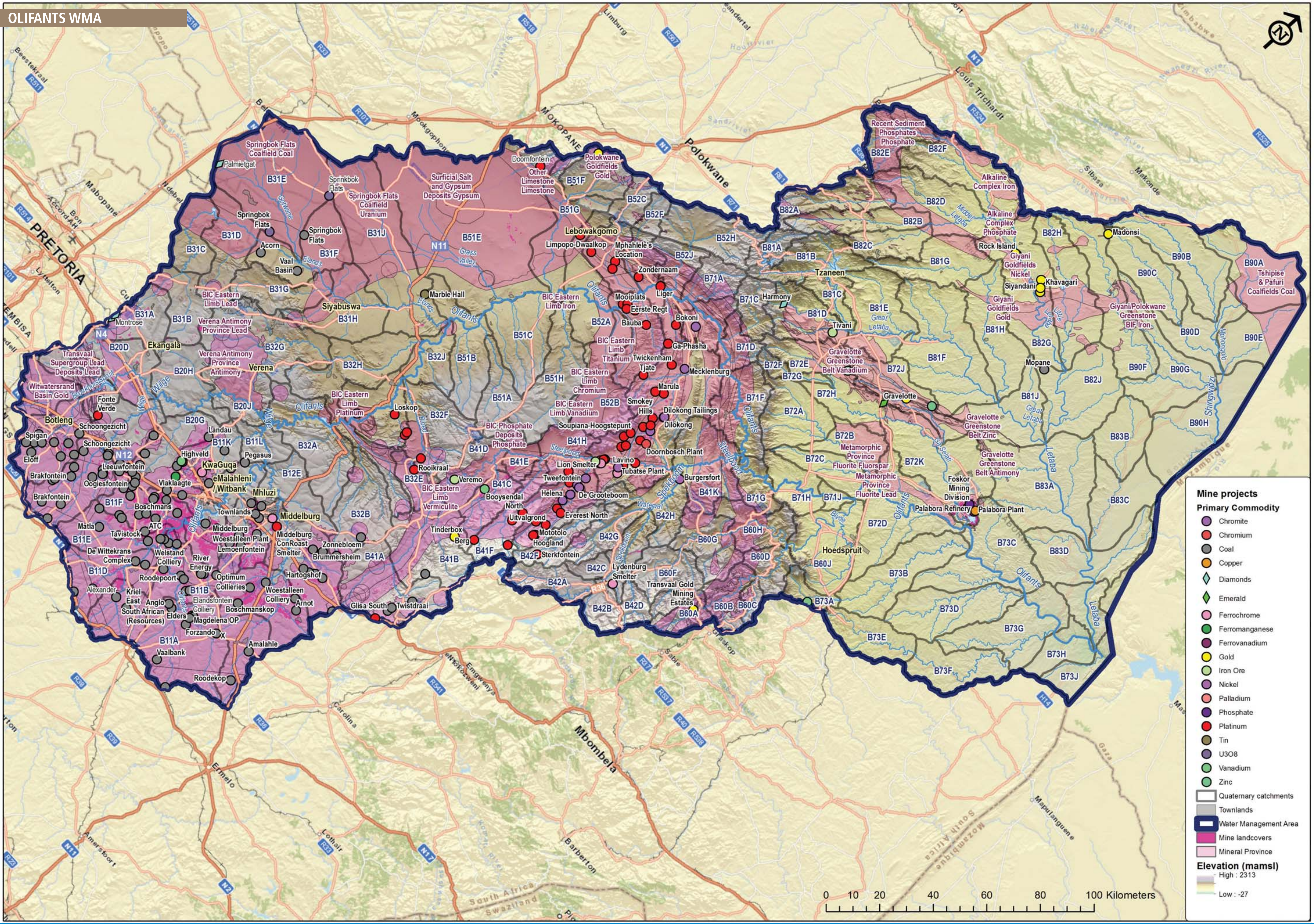
Key areas of concern:

- Aquifer systems with fresh water quality;
- Several large secondary geological features (dykes, faults, foliations and unknown lineaments) which pose a high risk for localised fluid migrations – their presence in any local geological profile increases the aquifer vulnerability rating significantly;
- Malamani Dolomite karst aquifer system in the Wolkberg Region supporting several large dolomite springs; and
- Intergranular (alluvial) aquifer systems in river channel (Olifants, Letaba and Singwidzi).

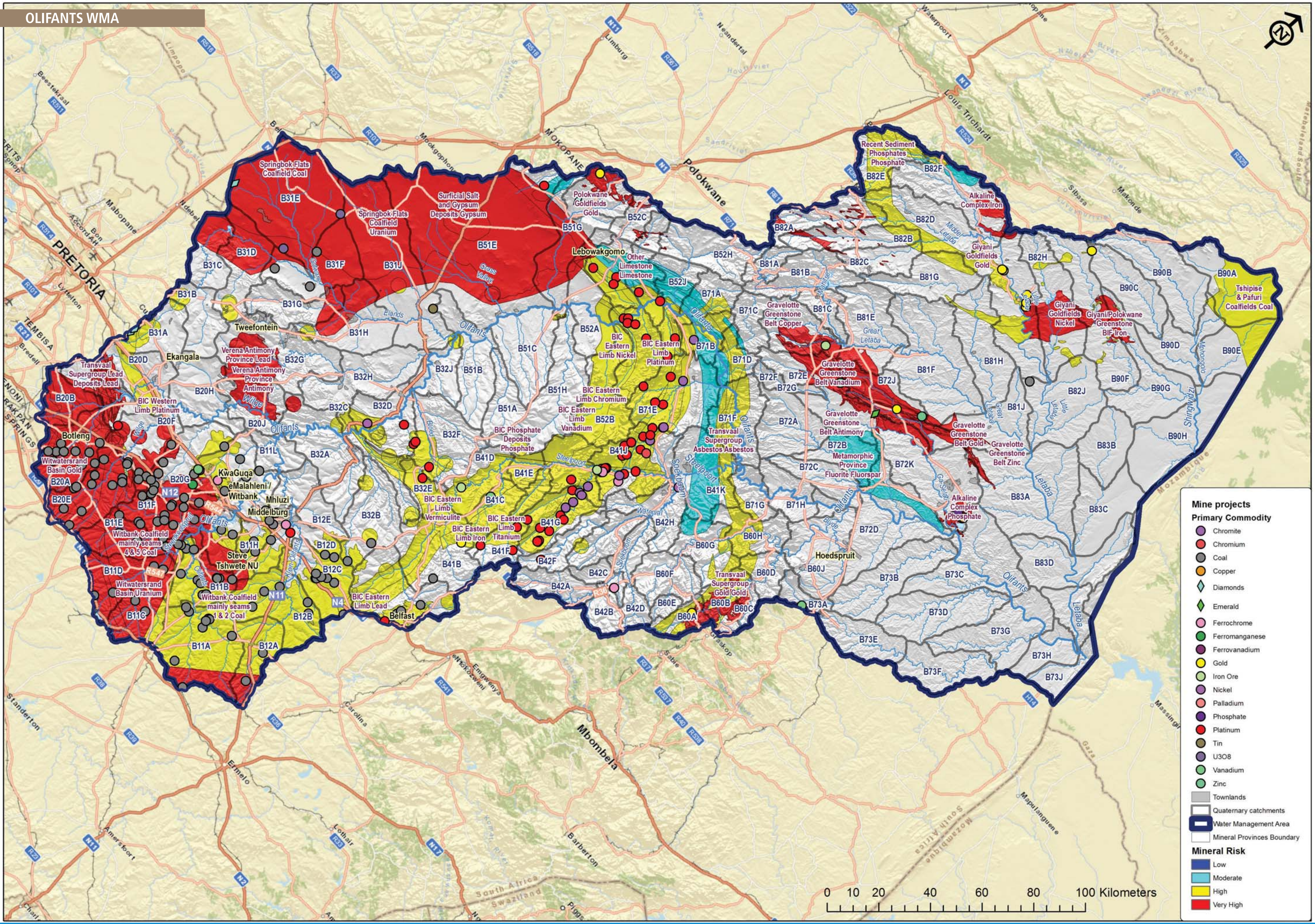
Locality map Olifants WMA



OLIFANTS WMA

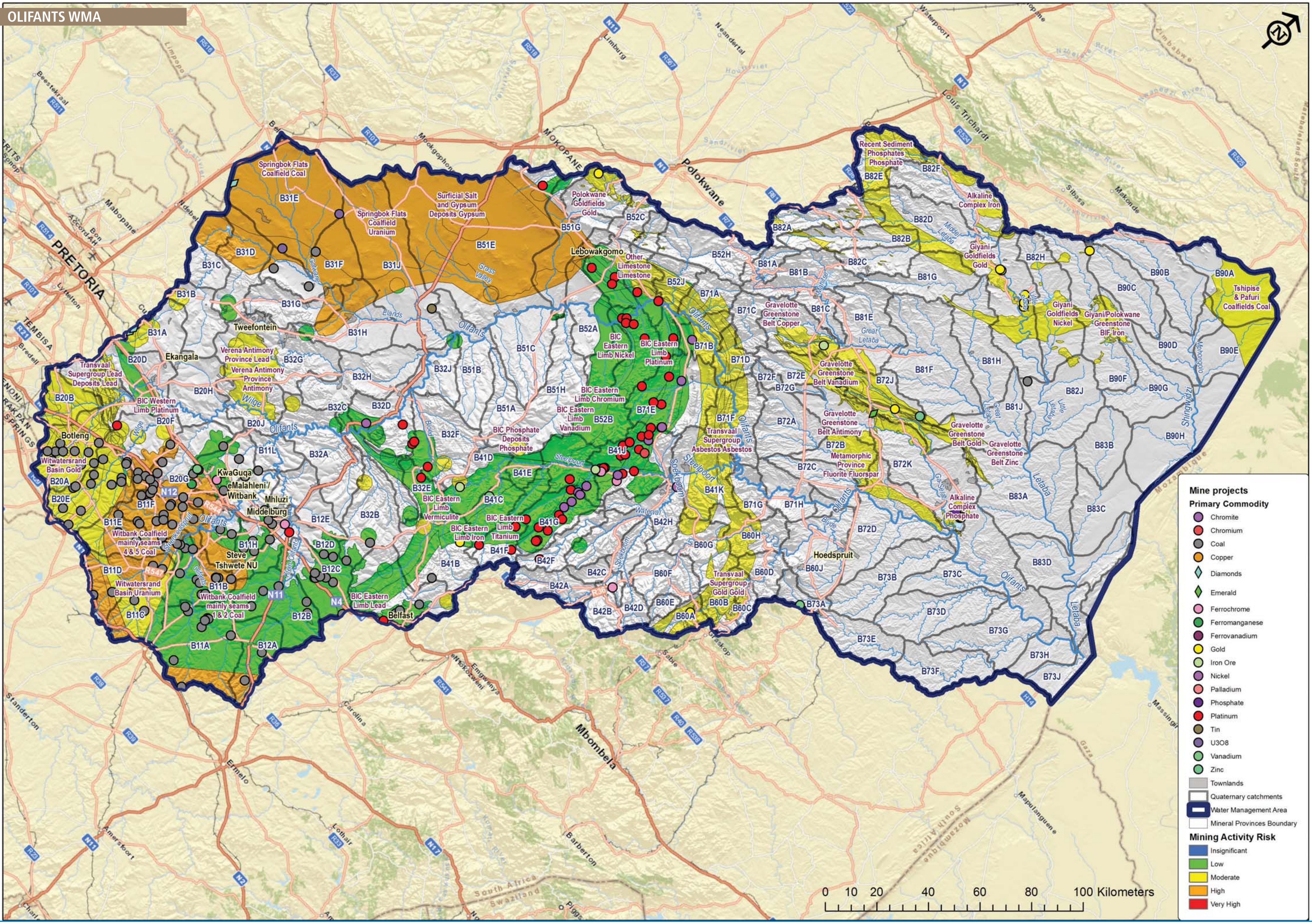


OLIFANTS WMA

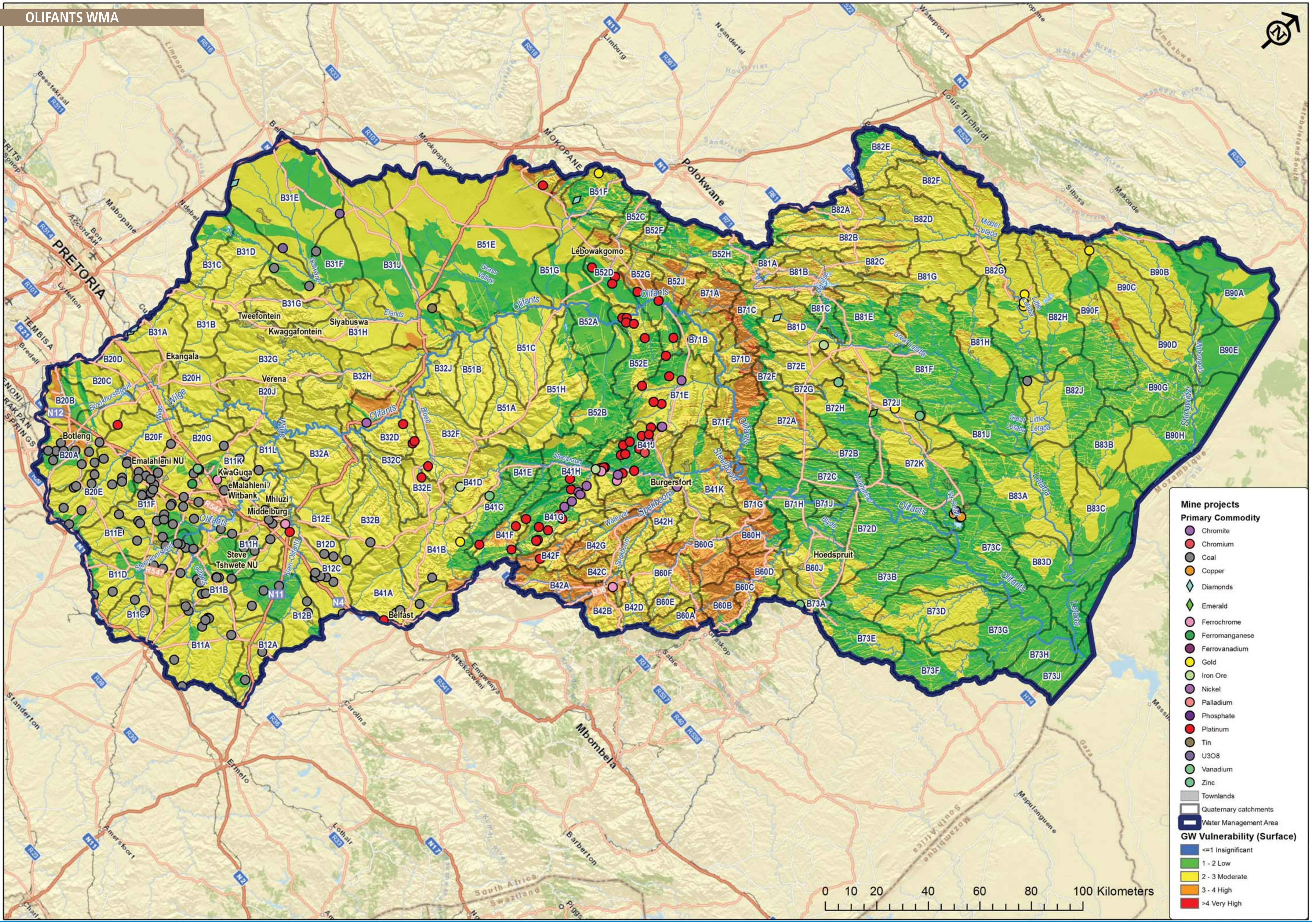


MINE ACTIVITY RISK RATING

OLIFANTS WMA



OLIFANTS WMA



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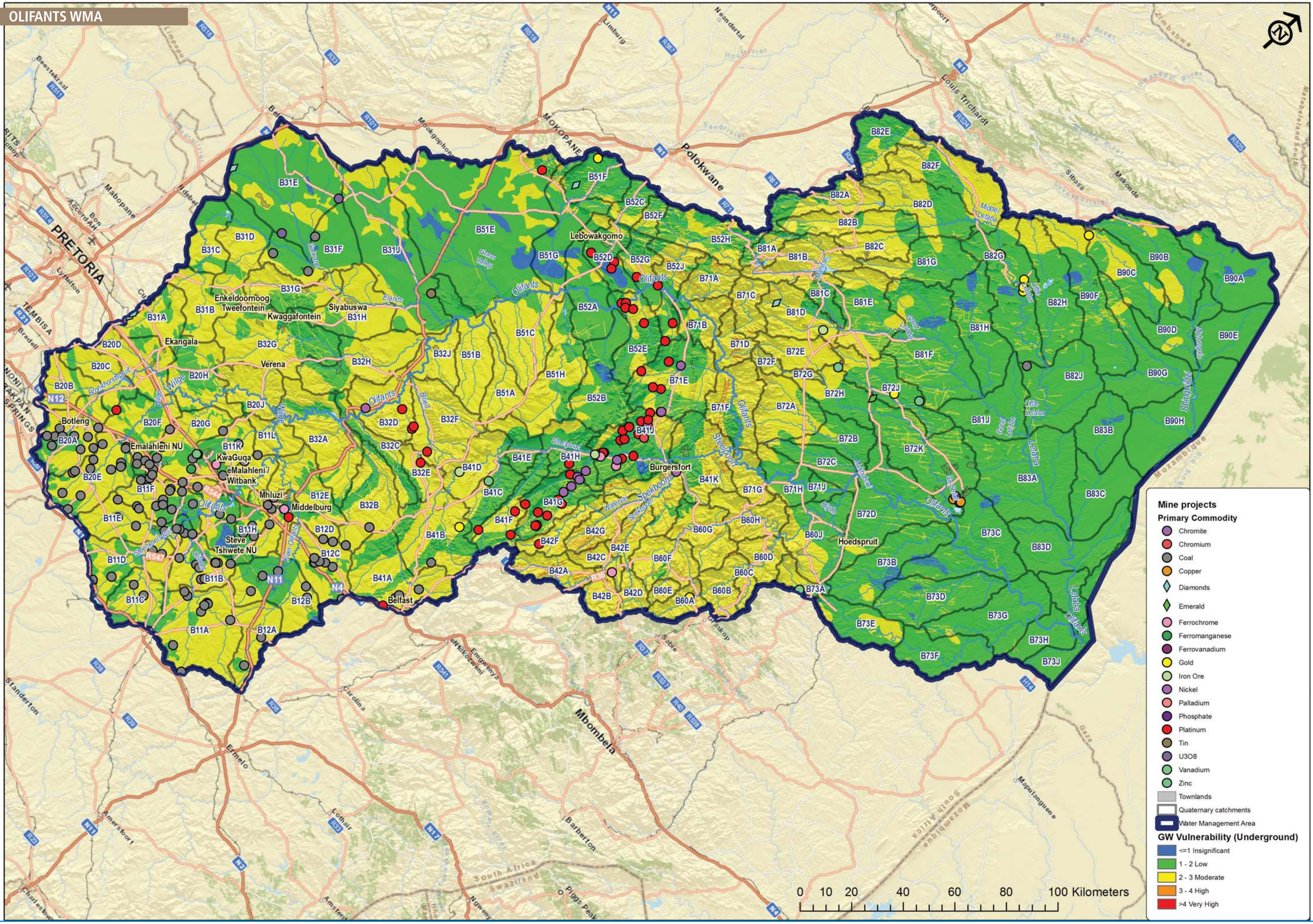
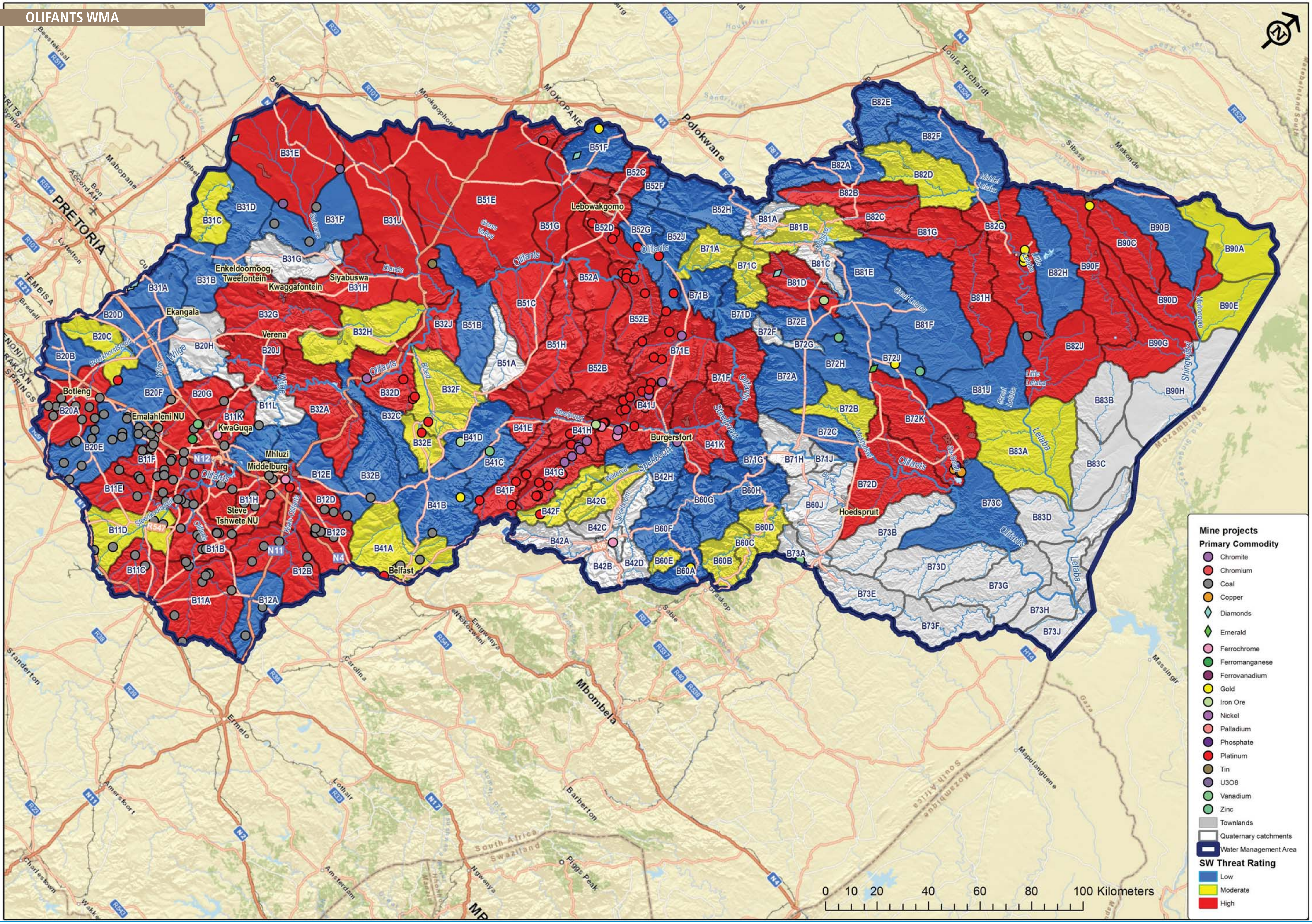


OLIFANTS WMA



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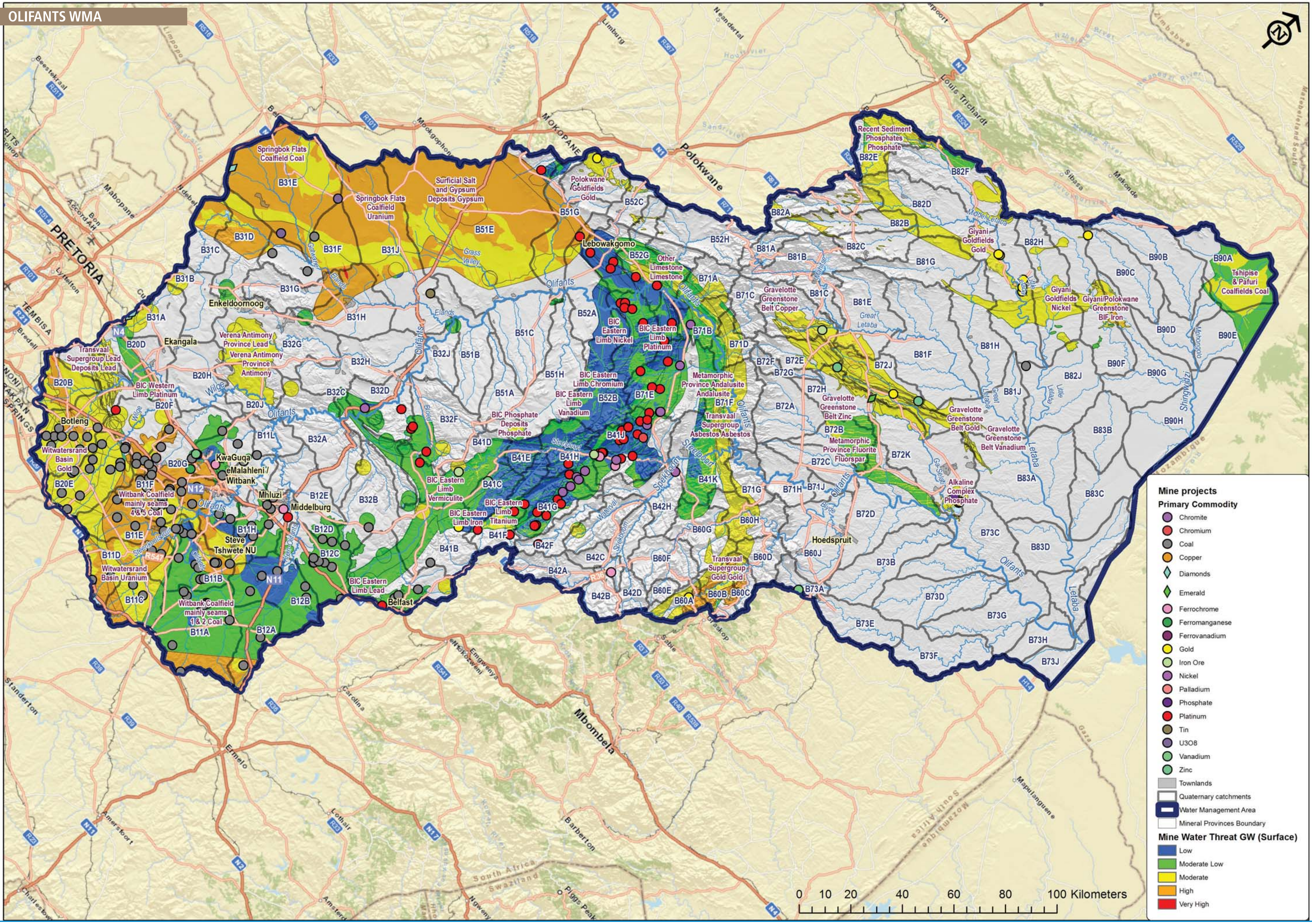
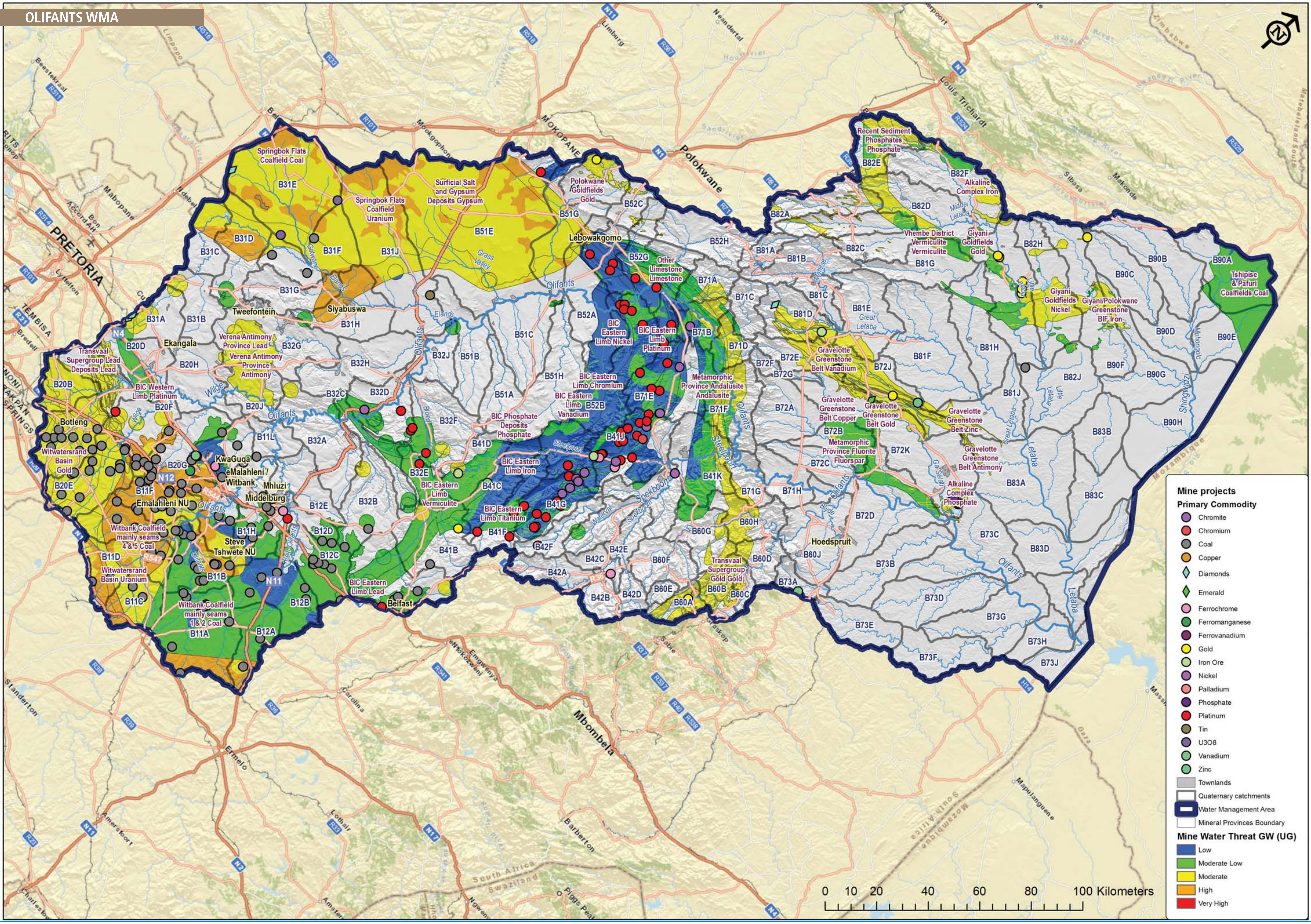
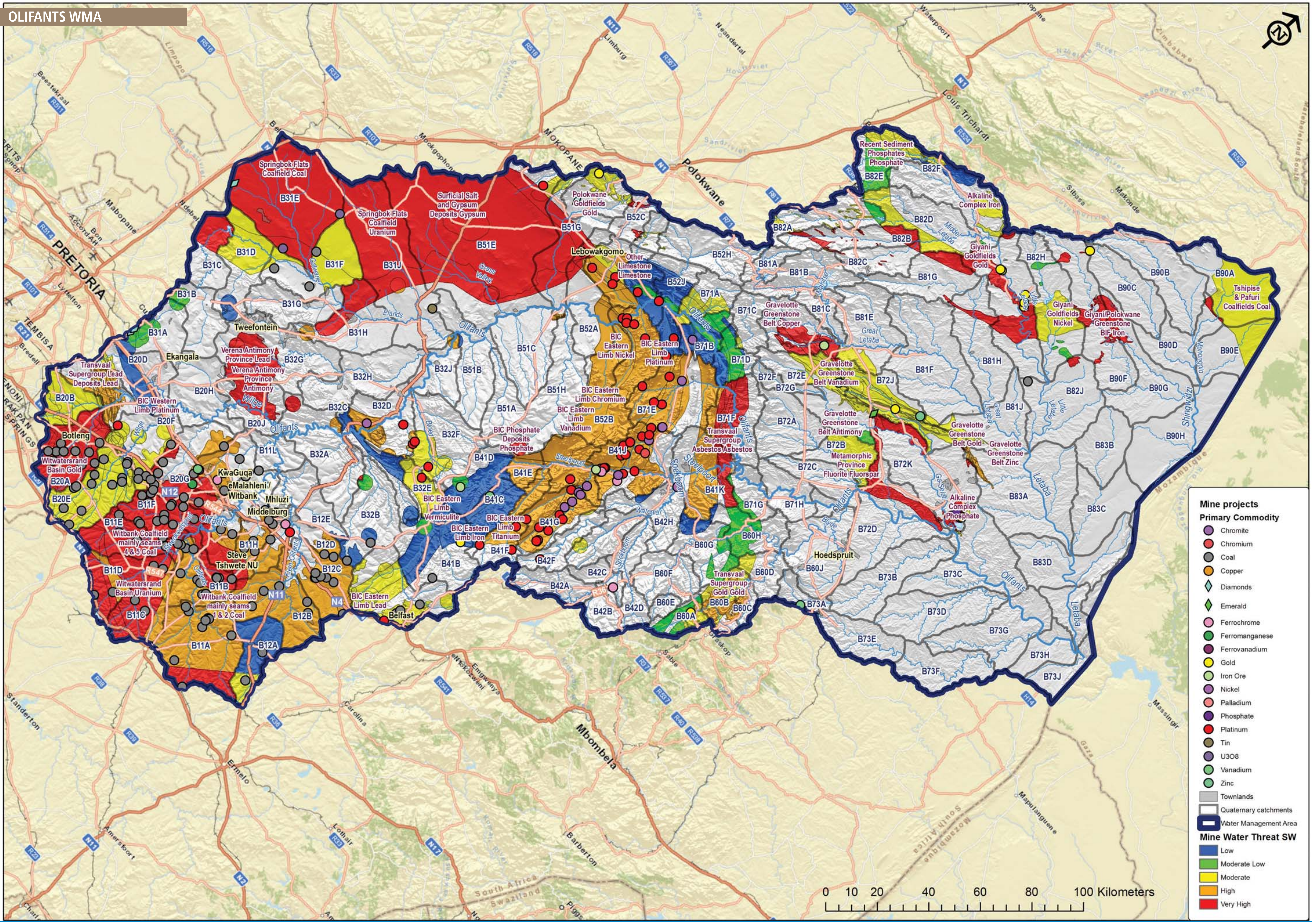


OLIFANTS WMA

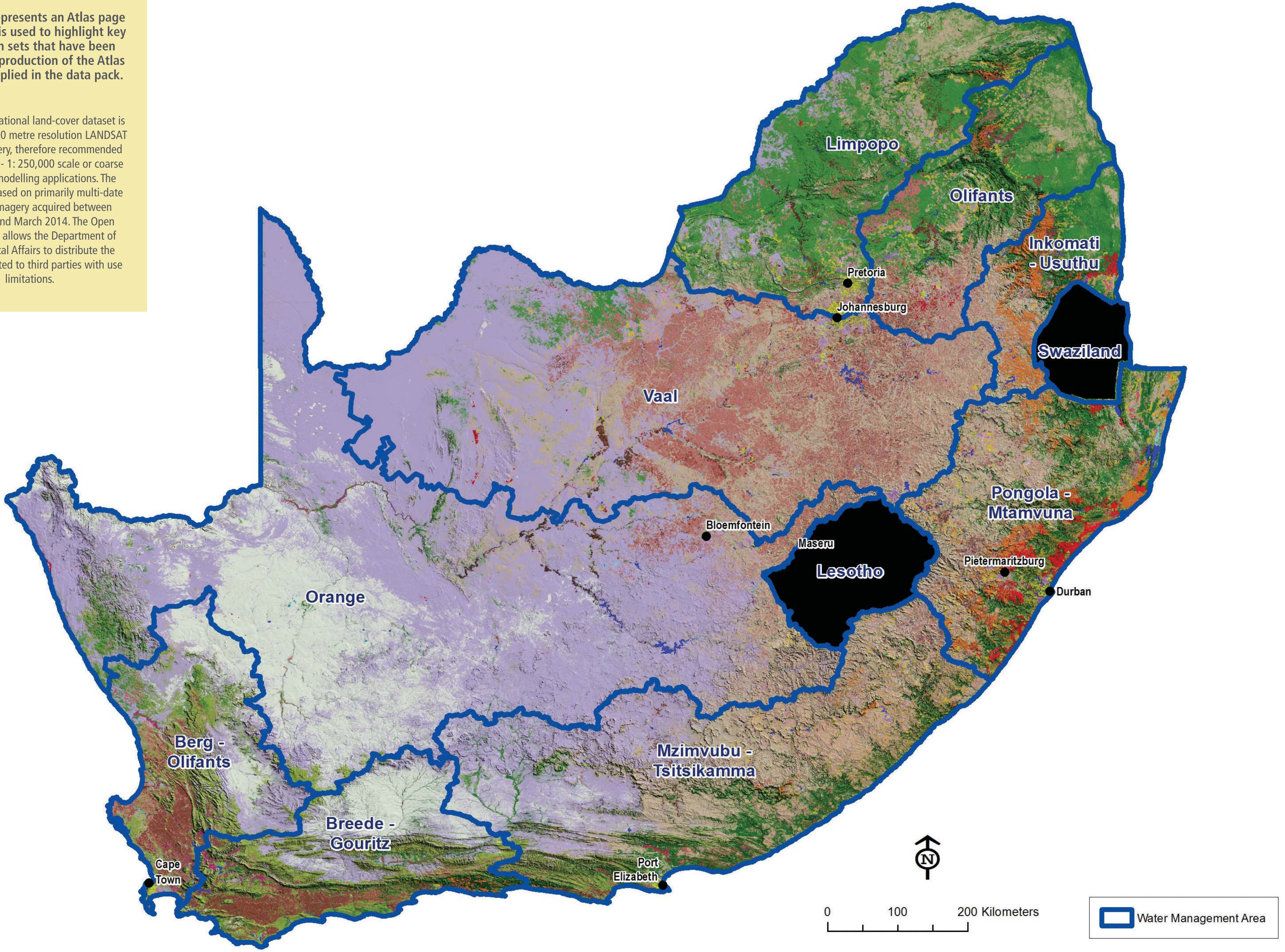


MINE WATER THREAT SURFACE WATER



This page represents an Atlas page holder that is used to highlight key foundation sets that have been used in the production of the Atlas and are supplied in the data pack.

The 2013-14 national land-cover dataset is mapped from 30 metre resolution LANDSAT satellite imagery, therefore recommended for ±1:75,000 - 1: 250,000 scale or coarse mapping & modelling applications. The information based on primarily multi-date Landsat 8 imagery acquired between April 2013 and March 2014. The Open Data License allows the Department of Environmental Affairs to distribute the data unrestricted to third parties with use limitations.



INKOMATI USUTHU WMA

WMA OVERVIEW

The Inkomati-Usuthu WMA is situated in the north-eastern part of South Africa and borders on Mozambique and Swaziland. All rivers from this area flow through Mozambique to the Indian Ocean. The WMA includes the Sabie-Sand River system, the Crocodile River (East) system, the Komati and Lomati system and the Usuthu River system. The Kruger National Park occupies almost 35% of the WMA.

Economic activity in the WMA is mainly centred on irrigation and afforestation, with related industries and commerce, and a strong eco-tourism industry. There is an emergence of increased coal mining in upper parts of the catchment. The Kruger National Park is a key feature of the WMA. The Sabie River which flows through the park is ecologically one of the most important rivers in South Africa. Important urban centres are Mbombela, White River, Komatipoort, Carolina, Badplaas, Barberton, Sabie, Bushbuckridge, Kanyamazan, Matsulu, Lothair, Piet Retief and Amsterdam.

Dams have been constructed on all the main rivers or their tributaries, and the water resource system (dams) in the WMA is generally well regulated. The water resources of the river systems are fully utilised or in balance, which requires reconciliation options for future water supply. An important feature is the joint management by South Africa and Swaziland of part of the water resources of the Komati Basin Water Authority (KOBWA). Because of the well-watered nature of most of the area, groundwater utilisation is relatively small. Most of the present yield from the Komati River west of Swaziland is transferred to the Olifants WMA for power generation. The Vygeboom and Nooitgedacht dams are used to supply this water. As in the case of the Komati, much of the available water from the Usuthu system is transferred out of the catchment (from Jericho, Westoe, Heyshope and Morgenstond dams) for use by the power stations on the Highveld. The Inkomati River is subject to an international cooperative agreement with Mozambique which obligates South Africa to have a minimum of 2 m^3/s supplied to Mozambique. Swaziland is also very dependent on the Usuthu River and relies on responsible upstream use by South Africa.

Large areas at several locations have been developed under irrigation. The crops grown include fodder, grain, tobacco, citrus, tropical fruits and sugar. Large areas of land have been developed under commercial forestry in the high rainfall escarpment and mountain areas. Much of the land outside the Kruger National Park also remains under natural vegetation for livestock and game farming as well as conservation. Overgrazing is prevalent in some of the densely populated rural areas. Dry land cultivation is found where good soils and favourable topography occur. Nelspruit is the largest urban centre in the water management area. Scattered rural villages with a high population density are characteristic of the area.

The upper catchment of the Sabie River is densely commercially afforested. The land use of the middle reaches is a mixture in sub-tropical fruits and dense informal settlements. The lower reach lies within the Kruger National Park. The upper Crocodile River catchment has intensive afforestation and agriculture of sub-tropical fruits and nuts. The flow of the Crocodile River is regulated by the Kwena Dam in the upper catchment. The upper Usuthu catchment is sparsely populated. Land use in the Usuthu system is dominated by afforestation, with some limited irrigation.

Currently the major stresses facing the WMA are the high water demands by Eskom, irrigation, afforestation and industry and rapidly increasing domestic water demands.

Mining within WMA: Overview

The major mining activity within the Inkomati catchment occurs in the Barberton and Mbombela areas, in the Crocodile River catchment (Kaap River). The mineral deposits in this region include gold, asbestos, iron, nickel, copper and manganese and a significant number of coal reserves. Gold and other minerals were widely mined, but have reduced to mainly small scale operations. Extensive coal mining is found in the south-west of the water management area, which is mainly used as fuel for large thermal power stations at the divide with the neighbouring Olifants WMA.

SURFACE WATER PROFILE

Water Quality

Water quality salinity status of the Komati River and Upper Crocodile River are in a good condition. The middle reaches of the Crocodile River are in a tolerable range for salinity with the lower reach being in an unacceptable state. The Lomati River is in a good to tolerable state, but is in the unacceptable range within Komati sub-catchment. The water quality of the Sabie River indicates generally good salinity status, with only a small tributary in the upstream catchment in the vicinity of Sabie in an unacceptable state. Water quality monitoring data are not available for the Usuthu catchment.

Ecological condition

The ecological condition of the rivers in the WMA is largely good to fair. Much of the system is in a natural to largely natural state (A and B present ecological condition) or moderately modified condition (C Category). The Kaap River in the Crocodile System and the lower reaches of the Crocodile River below the Kaap River confluence are in D present ecological state (largely modified). This is largely impacted by acid rock drainage originating from old gold mining areas. Smaller tributaries of the Upper Sabie River and the lower reaches of the Komati River out of Swaziland are also largely modified (D present ecological state). The Wit River, a tributary of middle Crocodile River, and the reaches within the lower Komati River have been severely degraded and are in a seriously modified state (E category).

Threat to the Surface Water Resources

Within the Inkomati-Usuthu WMA, of the 61% of the quaternary catchments assessed (with data available), 24% (5 rating red) of the catchment area includes stressed surface water resources that are under threat, 3% (5 rating green) that require the precautionary approach to management to maintain good condition, and 73%, (rated 1 or 3) where the surface water resources do have capacity available to accept degrees of impact. Refer to the map on page 50.

MINERALOGY PROFILE

There are three major mineral provinces in the WMA:

- Generally the TSG province has medium mineralogical risk, mainly due to potentially toxic trace elements, notably lead and zinc, which occur in minor/trace minerals within the dolomites. The TSG lead deposits are sulphide-rich and thus the risk of ARD results in a high mineralogical risk. The asbestos deposits have low mineralogical risk.
- The Karoo coalfields have significant risk of ARD, resulting in a high mineralogical risk where there is low neutralisation capacity (Ermelo Coalfield) and medium risk where there is more neutralisation capacity (Kangwane Coalfield and Seams 1 and 2 of the Witbank Coalfield).
- The Barberton Greenstone Belt has a generally high mineralogical risk rating due to ARD and potentially toxic trace elements, notably antimony, lead and nickel.

The remaining mineral deposits in the WMA include kimberlites with medium risk ratings and sedimentary-hosted deposits with mainly low risk ratings.

GROUNDWATER VULNERABILITY PROFILE

Water Quality

General aquifer profile (Lithology aquifer type): there are two major aquifer systems in the WMA:

- Intergranular and fractured aquifers with borehole yields between 0.5 and 2.0 l/s;
- Fresh water (<70 mS/m) karst aquifer systems with borehole yields >5.0 l/s; and
- Water quality varies from fresh (<70 mS/m) to saline (1000 mS/m), i.e. site/aquifer specific water quality aspects that should be considered.

Aquifer vulnerability rating:

Vulnerability rating varies between 1.0 (insignificant, due to rock types, low-moderate yield classification and brackish water quality) to 3.3 (high, due to dolomite water areas (Graskop-Sabie-Badplaas areas) and the presence of diabase dykes causing preferential flow paths. The remainder of the WMA fall in a low (1.9) to moderate (2.4) vulnerability rating. There is a high presence of secondary geological features in the WMA which will contribute to a higher vulnerability rating due to preferential flow paths in the contact zones of these features.

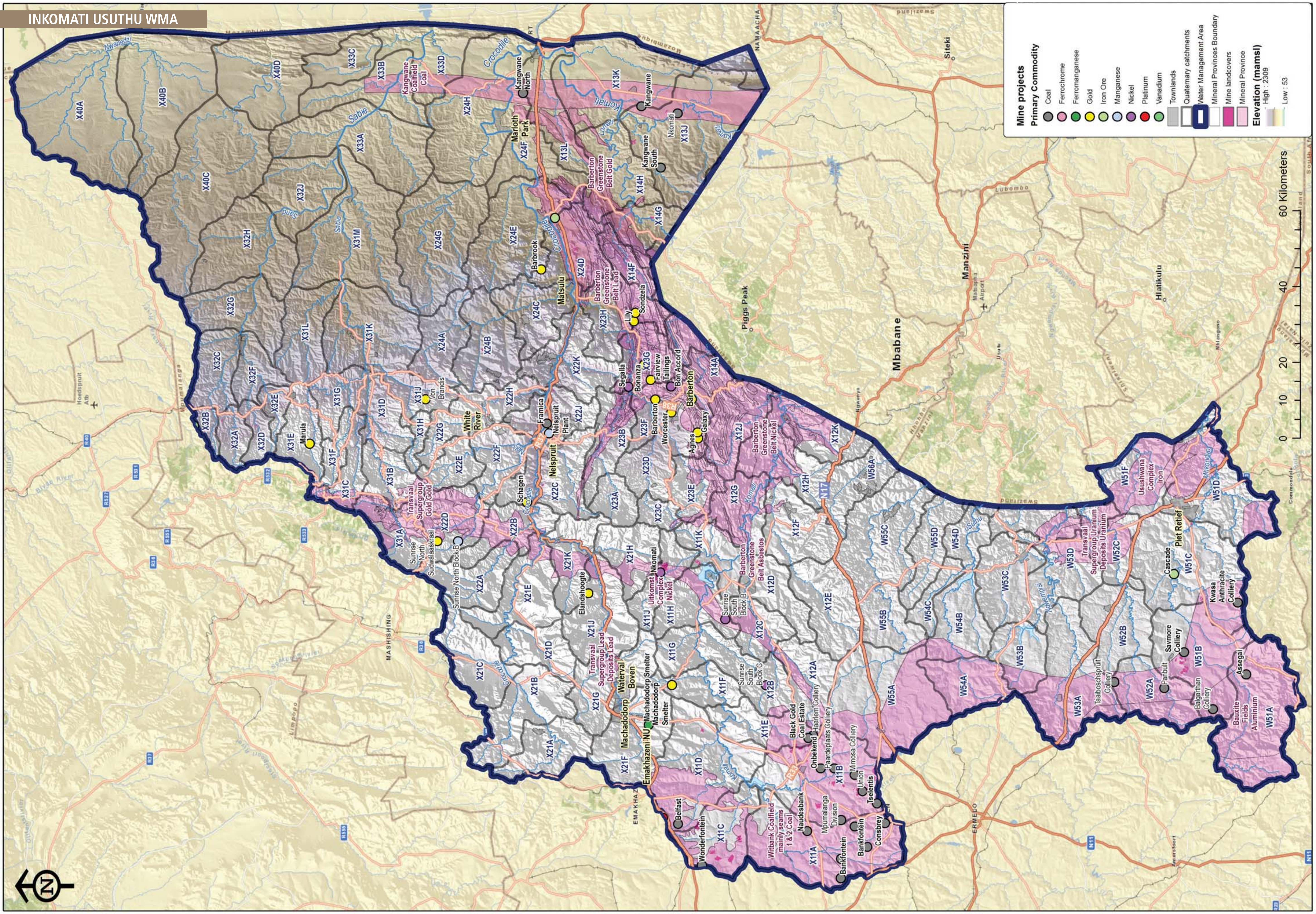
Intergranular and fractured aquifer systems:

- Karoo Supergroup Clarens arenate and Letaba basalt: insignificant (1.0) to low (2.1);
- Swazian Granites: low (1.9) to moderate (2.4) with limited impact on vulnerability due to unknown lineaments (2.3);
- Mpuluze Granite: Moderate (2.4) – vulnerability rating slightly elevated where diabase dykes occur, i.e. 2.8;
- Pretoria Group: Moderate at 2.5 to 28, but high (3.3 to 3.5) where Karoo Dolerite dykes are present; and
- Ecca Group: Moderate (2.5) to high (3.3) due to fresh groundwater quality (EC <70 mS/m).
- Fresh water Malmani Dolomite karst aquifer systems with high to significant vulnerability rating: 3.3 and 4.1 with local dyke features;

Key areas of concern:

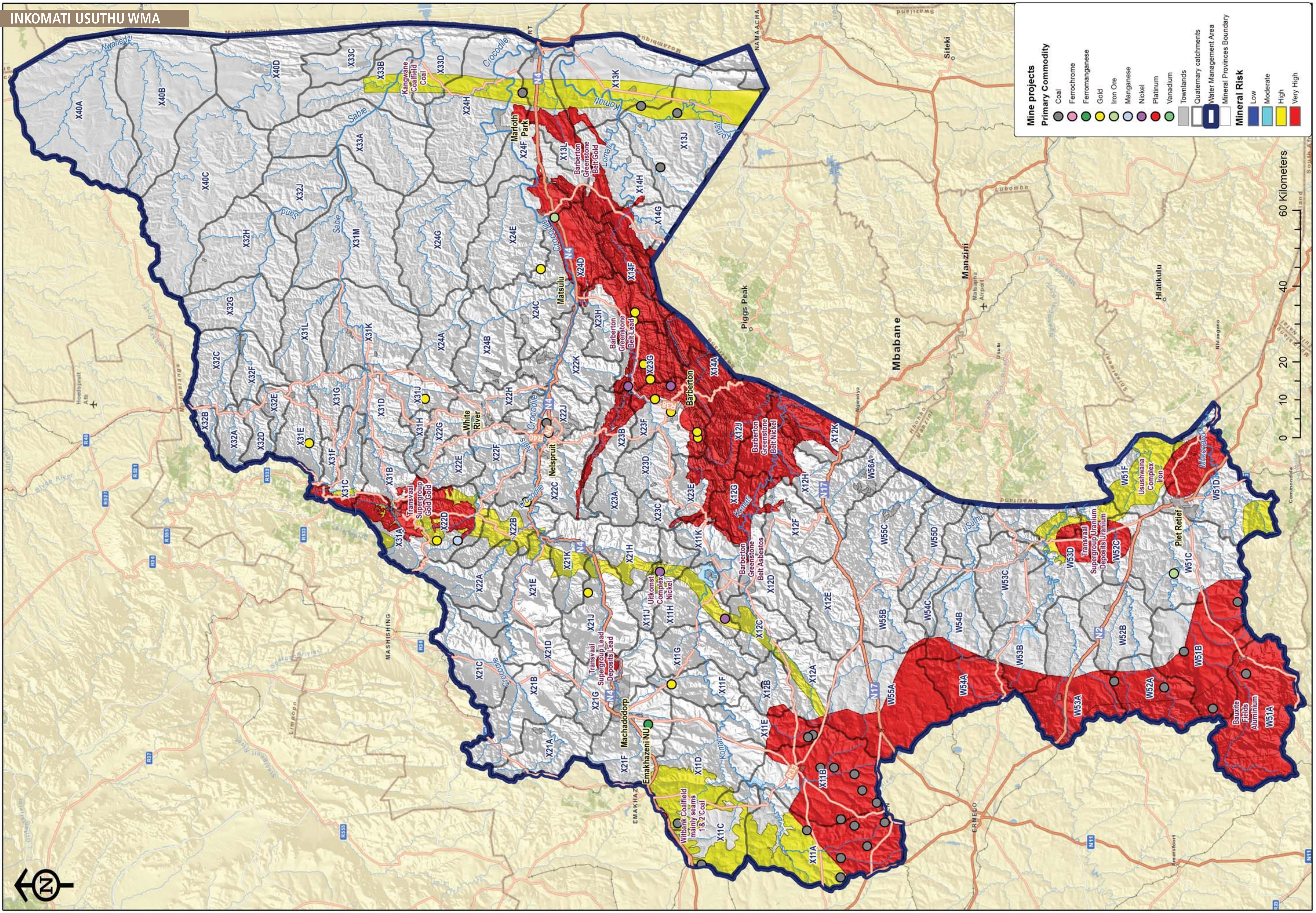
- Aquifer systems with fresh water quality (<70 mS/m), i.e. some areas on the Swazian Granites, Pretoria Group, Ecca Group and Mpuluze Granites.

INKOMATI USUTHU WMA

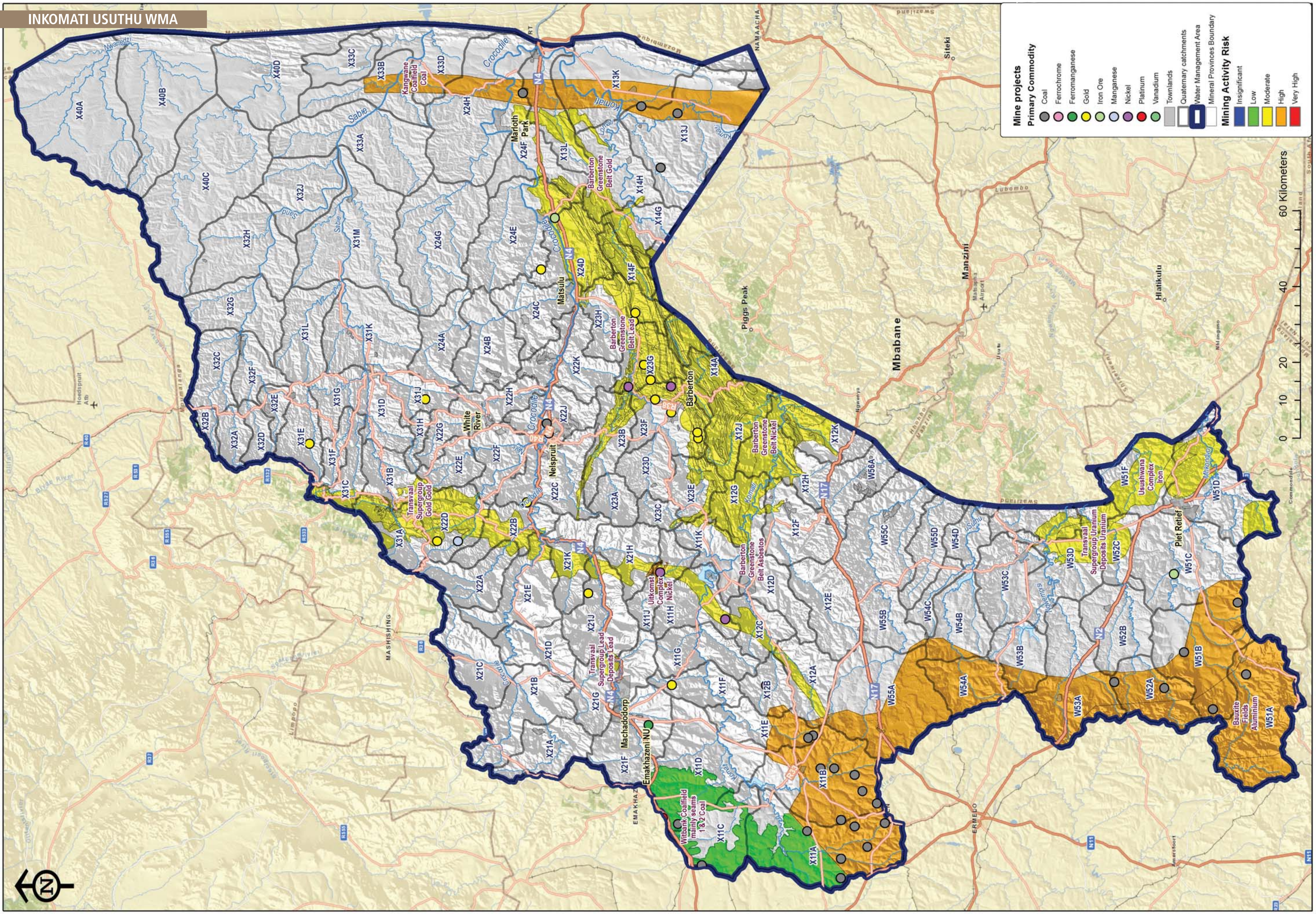


MINERAL RISK RATING

INKOMATI USUTHU WMA



INKOMATI USUTHU WMA



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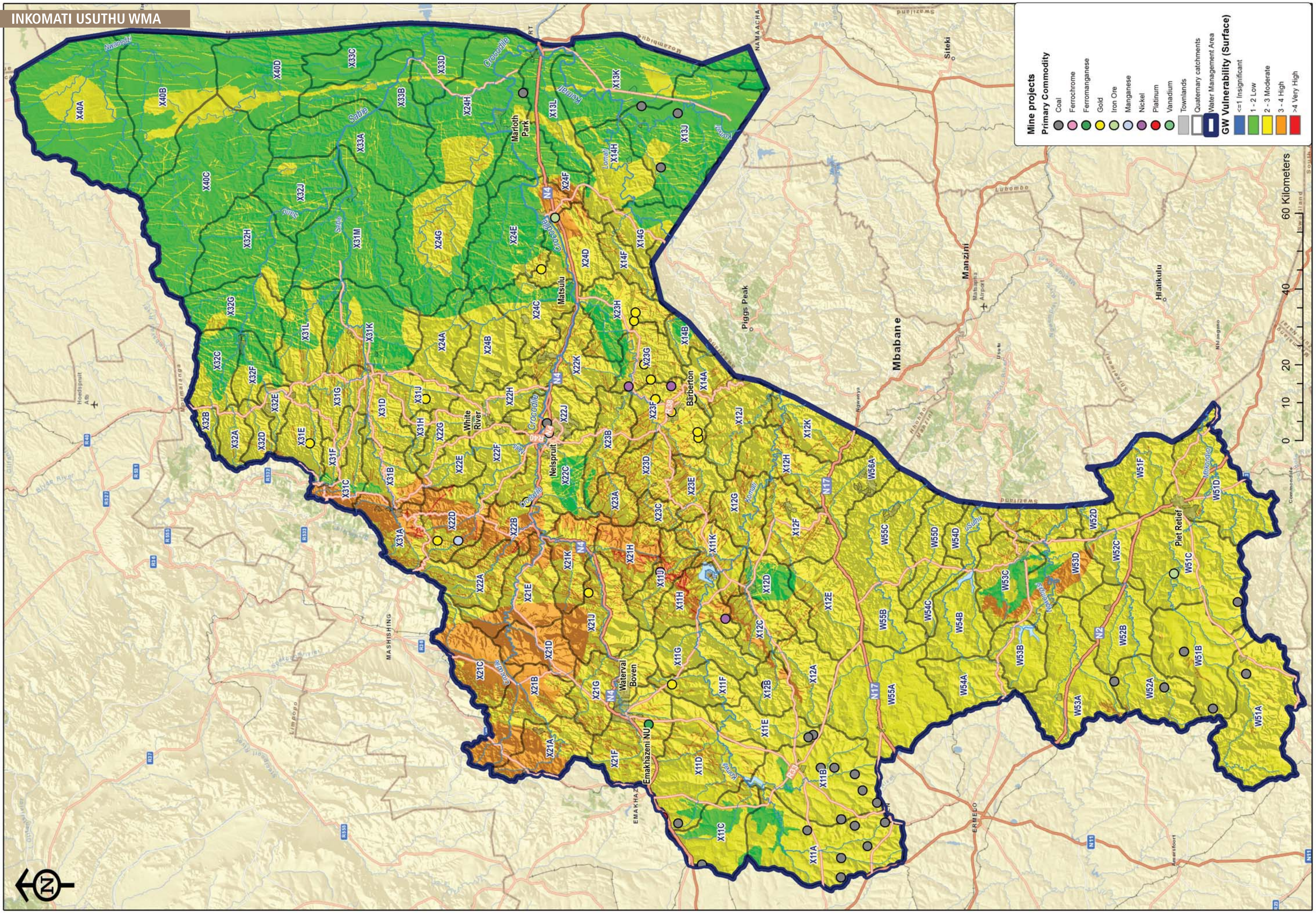

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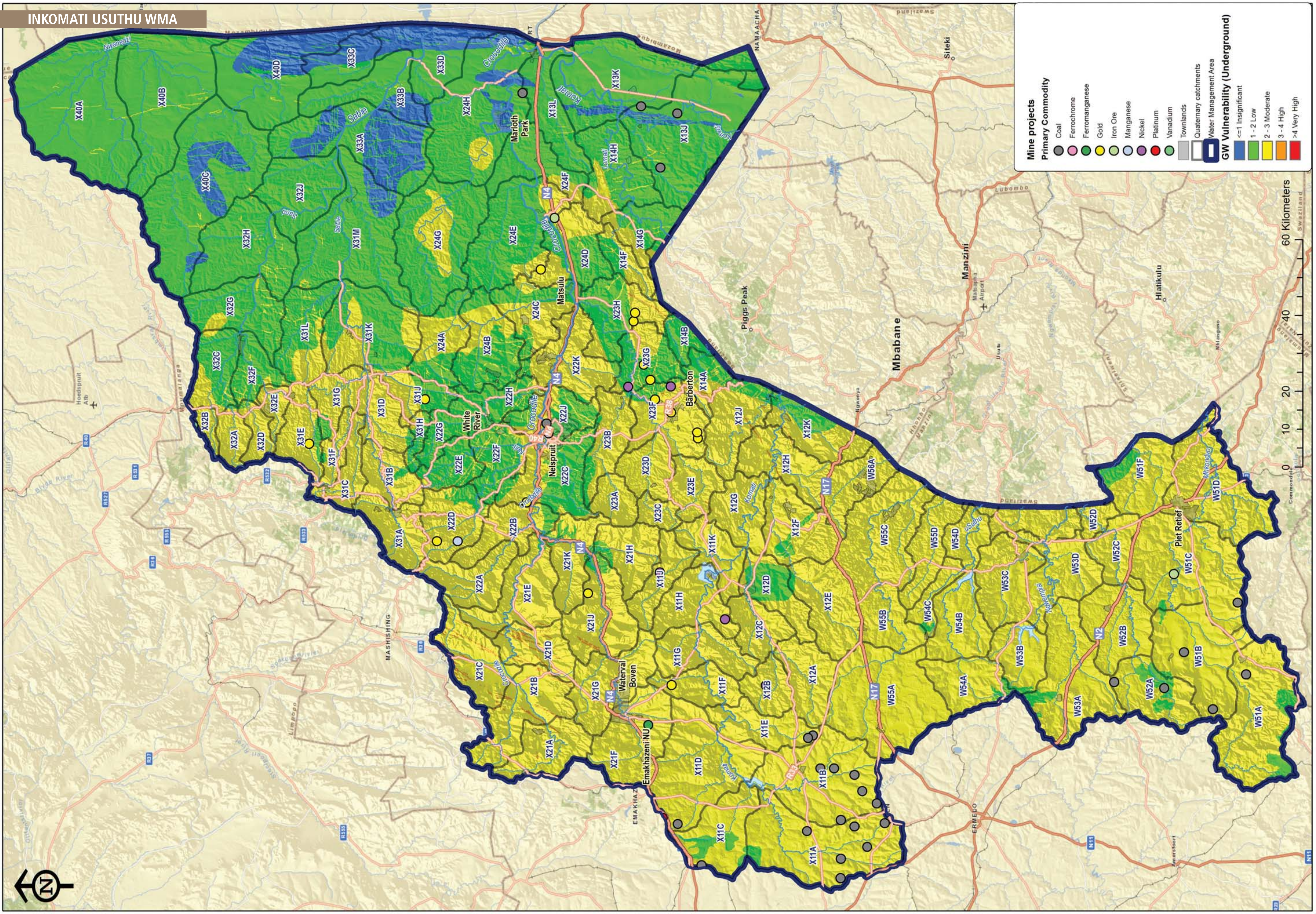

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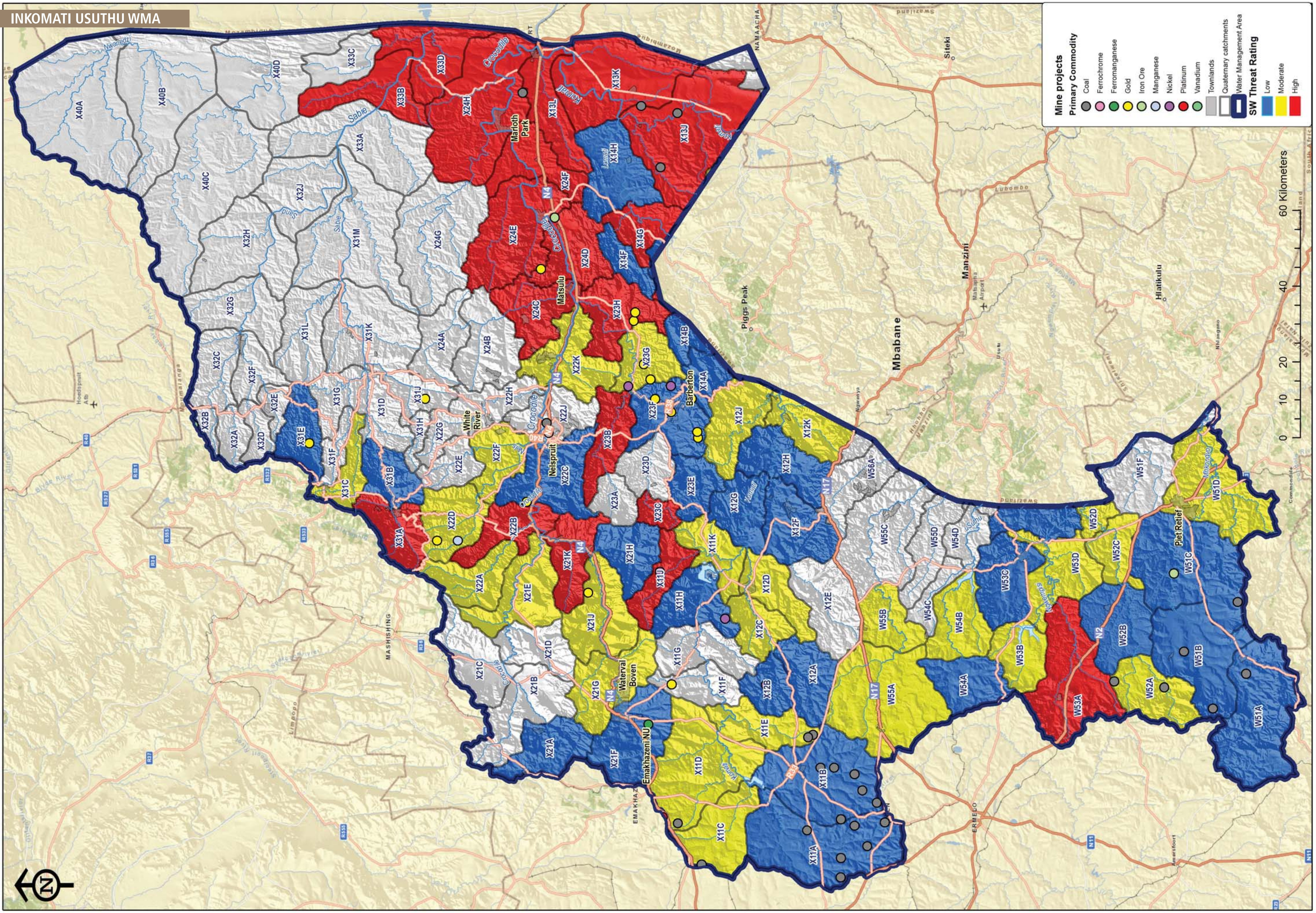

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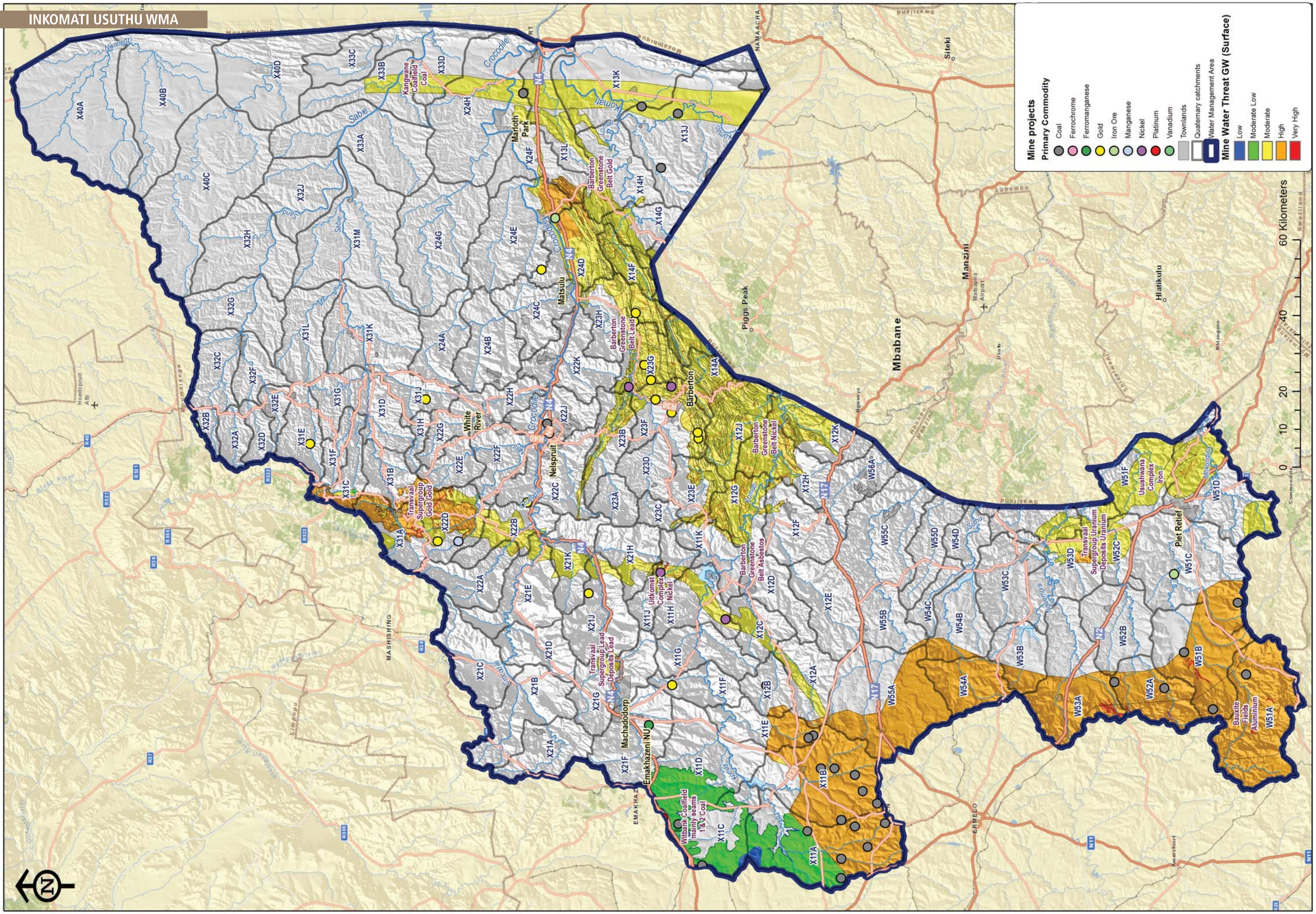
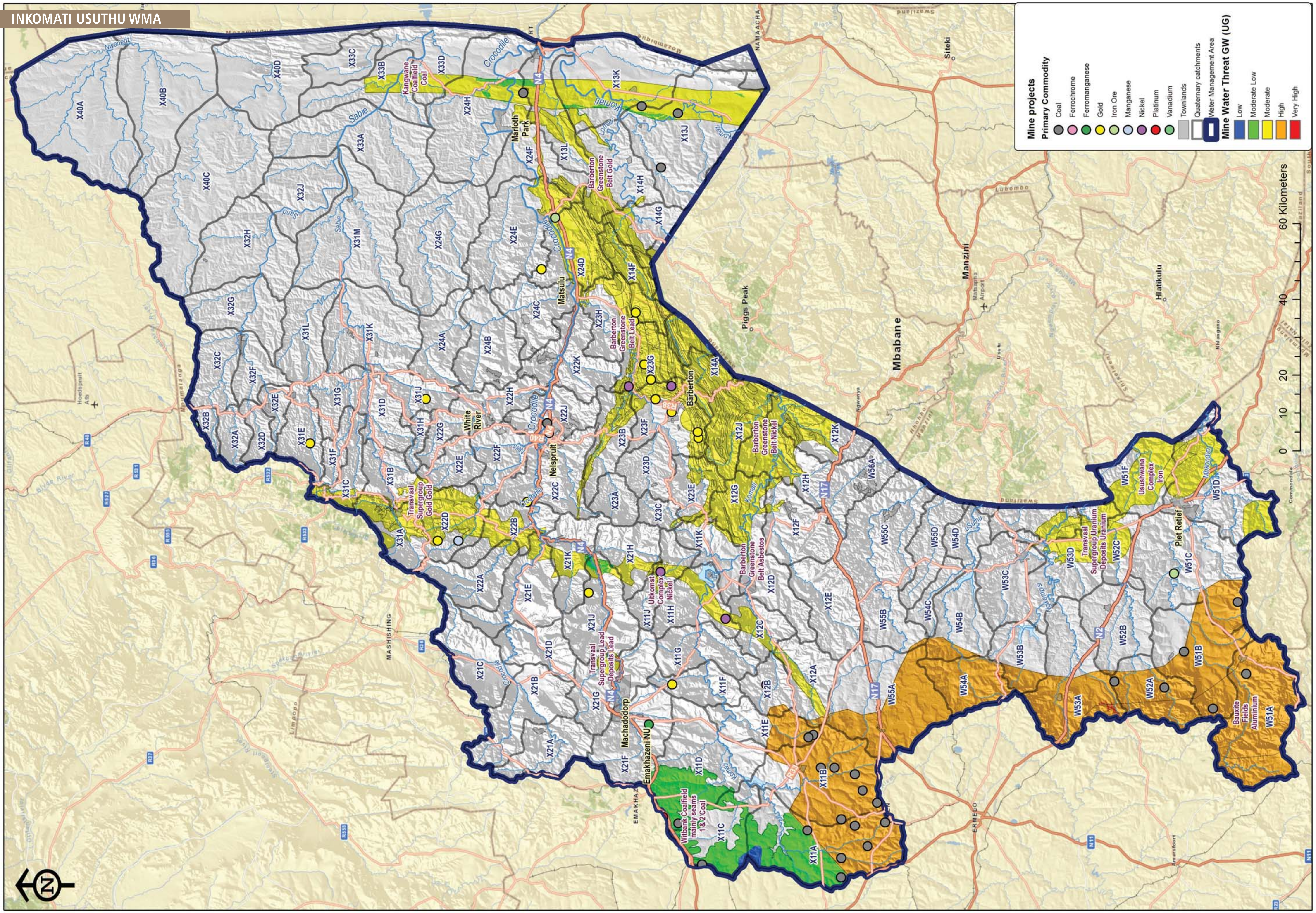
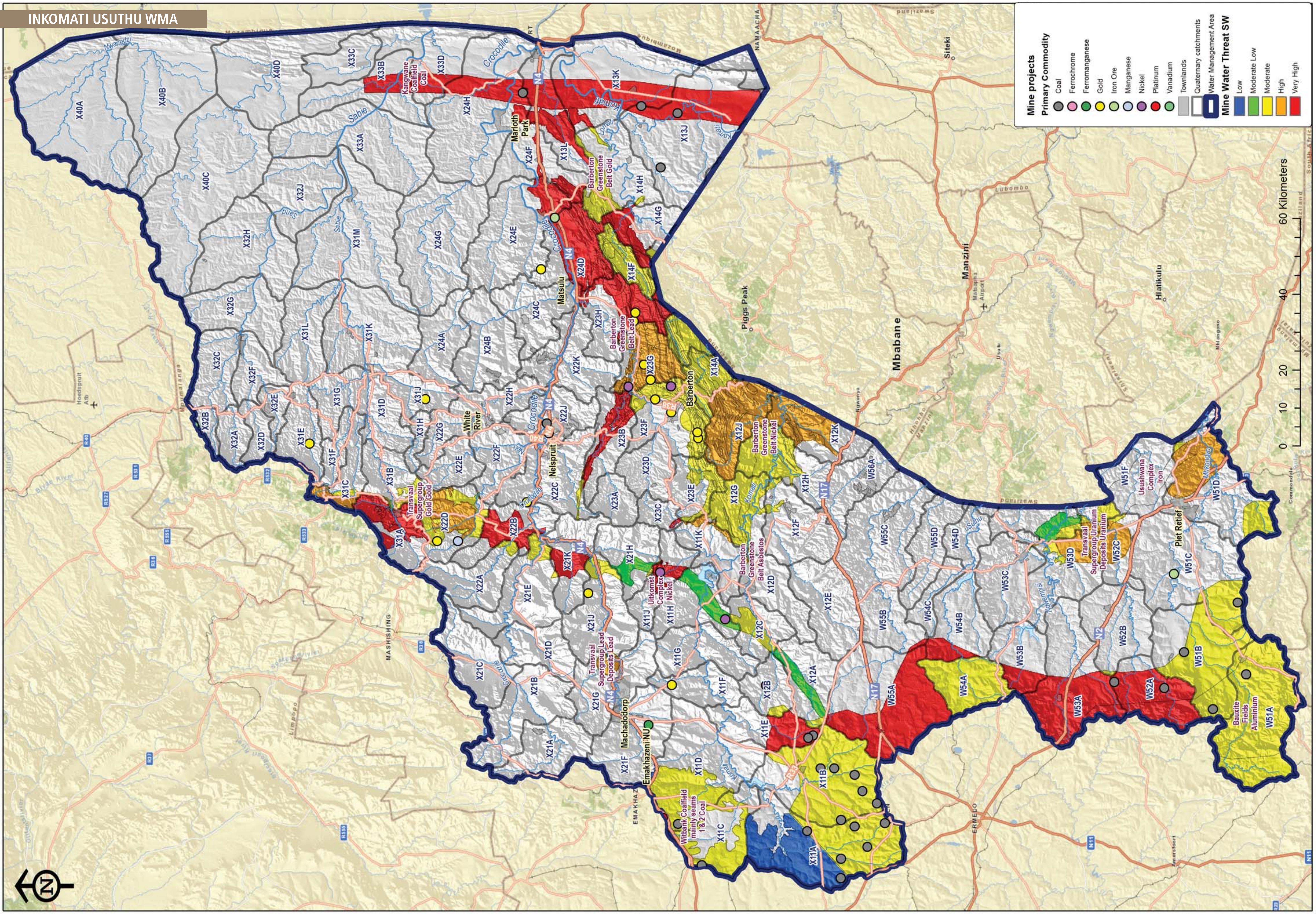


MINE WATER THREAT GROUNDWATER - UNDERGROUND

INKOMATI USUTHU WMA




Mine projects
Primary Commodity
Coal
Ferrochrome
Ferromanganese
Gold
Iron Ore
Manganese
Nickel
Platinum
Vanadium
Townlands
Quaternary catchments
Water Management Area
Mine Water Threat SW
Low
Moderate Low
Moderate
High
Very High
60 Kilometers

4.5 VAAL WMA

WMA OVERVIEW

The Vaal WMA includes the Upper, Middle and Lower Vaal catchment areas. The water resources of the Vaal River System are an important asset to the country and its people, supporting major economic activities and a population of about 12 million people. The Vaal River System catchment area stretches from Ermelo in the northeast to Vryburg in the northwest to Douglas in the southwest to Harrismith in the east. The Vaal River is the major water resource within the system with a number of significant tributaries along its length. Rising at Sterkfontein Beacon near Breyten, in Mpumalanga province, the Vaal River flows 1 415 km southwest to its confluence with the Orange River near Douglas. The Vaal River is probably the most developed and regulated river in Southern Africa – it has some 90 major man made impoundments situated on the main stem and its tributaries. The Vaal River System has extensive water resource infrastructure and is linked by substantial transfer systems to other water resource systems (Thukela, Usutu, Lesotho). There are also significant transfers out of the Upper Vaal catchment through the distribution system of Rand Water to the Crocodile West and Marico catchments. System supply reaches most of Gauteng, Eskom's power stations and Sasol's plants on the eastern Highveld, the North West and Free State Goldfields, the North West platinum and chrome mines, iron and manganese mines in the Northern Cape, Kimberley, several small towns along the main course of the river, as well as several large irrigation schemes. The water resources within the catchment are largely developed.

The Upper Vaal is highly altered by catchment development, with the Middle Vaal having a few major development centres with agriculture and mining being the main activities. The Lower Vaal is less developed with agriculture being the predominant land use. The significant development within the system includes both formal and informal urbanisation, industrial growth, agricultural activities and widespread mining activities. This development has led to deterioration in the water quality of the water resources in the system, requiring that management interventions are sought to ensure that water of acceptable quality is available to all users in the system, especially as land use activities continue to grow and intensify. Salinisation and eutrophication of the water resources in the Vaal River System appear to be the two major water quality problems being experienced.

Land use in the Upper Vaal is characterised by expansive urban, mining and industrial areas in the northern and western parts between the Grootdraai Dam and Mooi River catchments. This urbanised area is situated mainly in the province of Gauteng and extends beyond the WMA boundary. Other development in the catchment relates to dry land agriculture. The area includes several large towns located around the mining, industrial and agricultural development areas. The impact of mining on the economy of this area is significant.

The present character of land use in the Middle Vaal has been shaped by the discovery of diamonds in the north-western part of the catchment in the vicinity of Klerksdorp, Welkom and Virginia, with these areas now being dominated by gold mining. Current land use in the Middle Vaal is characterised by extensive dry land cultivation in the central parts of the catchment. The largest urban areas are Welkom, Klerksdorp and Kroonstad. Irrigation is practiced downstream of dams and along the main tributaries and at locations along the Vaal River.

Current land use in the Lower Vaal, due to the arid climate is characterised by extensive livestock farming as the main activity and large scale dry land cultivation in the north eastern part of the catchment. Intensive irrigation is practised at Vaalharts, as well as at locations along the Vaal River. The most significant urban area in the catchment is Kimberley to the South, which borders on the Upper Orange WMA as well. Several towns as well as scattered rural settlements are found mainly in the central and eastern part of the Lower Vaal.

The water balance reconciliation for the system does require that five core interventions be implemented to ensure that sufficient water is available to users in the short term. The interventions include eradication of the extensive unlawful water use, implementation of water conservation and water demand management measures, re-use of water, implementation of an integrated water quality management strategy and implementation of Phase 2 of the Lesotho Highlands Water Project.

MINING WITHIN WMA: OVERVIEW

The continued importance of the mining sector can be attributed to the coalfields in the northern parts and gold mining in the north-west of the Upper Vaal catchment area. Although the gold ore has been depleted in parts of the catchment, the largest unmined gold reserves in South Africa occur near Westonaria, with significant deposits also found at Carletonville and Randfontein. The increasing depth of gold mining, however, limits the economic viability of mining lower grade ore.

Products of the mining industry in the Upper Vaal include precious metals (gold, uranium) base metals, semi-precious stones, industrial minerals and coal. The contribution of mining to the economy of this area is significant. Coal mining occurs in the Bethal to Secunda area. Gold mining also occurs in the upper Waterval catchment (Secunda area). The area downstream of the Vaal Dam is also characterised by a large number of mining activities ranging from gold mining to quarrying. These mining activities occur in the Klipspruit, Suikerbosrand, Vaal Dam to Vaal Barrage and Mooi sub-catchments. Large gold mining operations are also located on the West Rand. Operating collieries are located in the Vereeniging-Vanderbijlpark-Sasolburg area adjacent to the Vaal River.

Within the Middle Vaal catchment numerous inactive mines are found in the north and west of the catchment, many of which were small diamond claims. The Middle Vaal is also characterised by a large number of gold mines (Free State Goldfields area and North West Goldfields area) especially in the KOSH area (Klerksdorp-Orkney-Stilfontein-Hartbeesfontein). There are five major gold mines active in the area and several diamond mine activities (varying from small scale one man operations to larger scale operations). The Klerksdorp goldfield, constituting seven producing mines, is part of the larger Witwatersrand goldfield. It is an important contributor to the South African gold, uranium and pyrite (sulphur) production. These mines still have a substantial reserve base of gold-bearing reef which, at the current rate of exploitation, is likely to last for many years to come. The economy of the Middle Vaal is dominated by the mining sector, particularly gold mining. The MidVaal Water Company (Stilfontein) is the main supplier of bulk water to urban areas in the North West Goldfields and Sedibeng Water (Bothaville) is the main supplier of bulk water in the Free State Goldfields.

Mining activities in the Lower Vaal area include diamonds, iron ore, manganese, lead, zinc and other minerals such as limestone and asbestos. The area includes the Kalahari manganese field. Kimberley remains an important centre for diamond mining and trade in diamonds, and is known for its high quality diamonds. The Sishen Mine, south-west of Kuruman, currently is the major supplier of iron ore in the country. Relatively little of the mining production is beneficiated locally. Diamonds are mined from Kimberlite fissures north of Swartruggens and from alluvial materials in the Lichtenburg-Ventersdorp and Schwizer Reneke areas, as well as along the Vaal River. Limestone and dolomite are produced from two quarries in the Lichtenburg District. The manganese and iron mines in the Lower Vaal have significant water requirements.

These are all situated in the dry north-west section of the catchment, and are supplied with water from the Vaal River System by the Vaal Gamagara Transfer Scheme.
The management of mining activities in the Upper Vaal is crucial to the management of water quality both in the short term to alleviate the current salt loads being released and long term to manage the impacts of mine closure and mine decants. Of further concern is the final decant points within the system once all the mines within this area close and pumping ceases. This is unknown at this stage but has future ramifications for all surrounding catchments. The water quality of the Grootdraai Dam is currently acceptable however, there are a number of operational and defunct coal mines in the catchment which need to be managed pro-actively. The post closure plans need to be finalized and implementation of the plans need to be managed. These mining areas of the Upper Vaal (which include the Eastern, Western and Central basins) have been identified by the inter-ministerial task group on mine water management in the Witwatersrand Goldfields formed in 2010, as areas requiring AMD intervention and management as a matter of urgency. The Upper Vaal is identified as a high priority catchment in terms of mining related water impacts.

The impacts from the gold mining activities within the Middle Vaal catchment on groundwater have been recognised as early as 1960 when localised dewatering became an issue at Stilfontein Gold Mine. Only more recently have the impacts on the quality of the groundwater and interaction with the Vaal River become a concern. The largest volumes are abstracted at Stilfontein Gold Mine's Margaret Shaft. Although Stilfontein's underground operations have ceased for more than ten years, pumping at Margaret Shaft continues for the safety of the downstream mines. The volume of water abstracted daily is estimated at 40 ML/d. The water is utilized by a number of users and any excess is discharged to the Koekemoerspruit. The mine water that is dewatered from Margaret shaft will in the foreseeable future be re-used by the mines for the re-working of old slimes dams. This project will go on for at least the next 15 to 20 years. Following this, if all underground mining ceases only then is it foreseen that the dolomites will fill up and decant. If the Margaret Water Company is established as per the DWS directives then it is foreseen that this additional water will be utilised in a sustainable manner, with a reduced and eventual minimum impact on the water resources and surrounding catchment (pers. comm DWS, Free State Regional Office).

SURFACE WATER PROFILE

Water Quality

The salinity status of the water resources within the Vaal WMA is predominantly in the tolerable to unacceptable range, which highlights that the water resources are under stress.

The water quality in the Vaal River in the upstream catchment (headwaters) is acceptable. There is poor quality water in the Witpuntspruit, X-spruit and Blesbokspruit tributaries of the Upper Vaal River. The water quality of the Grootdraai Dam falls in the acceptable range. The dam receives good water quality from the Usuthu system through catchment transfers. The water quality in the Grootdraai Dam is under threat in the long term unless the mine water is managed, in particular the mine closure situation. The water quality in the Vaal River from Grootdraai Dam to Vaal Dam is of acceptable quality. The lower reaches of the Waterval River are in an unacceptable range for salts. This is impacting on the Vaal River at the confluence at Villiers. The water quality of the Vaal River between Vaal Dam to the Mooi River confluence is in a tolerable range and is impacted by flows from the tributary catchments. Specific catchments in terms of unacceptable ranges for salinity include the Suikerbosrand, Klip River (Gauteng) and the Mooi River.

The water quality of the majority of the Middle Vaal is predominantly in a tolerable state with respect to salinity. The salinity status of the Rhenoster River is in the tolerable range in the upper reaches and improves to the acceptable range in the lower reaches. However the Koekemoerspruit and the Schoonspruit are in an unacceptable state for salinity. This salt load evidently results from the mining areas in these catchments. The available water quality data for the lower reaches of the Vals River also indicate unacceptable ranges for salts.

The Lower Vaal River is in the tolerable range for salinity from Bloemhof Dam, but deteriorates to an unacceptable quality below the Harts River confluence to Douglas. The impact of the Harts River on the salinity at Schmidtsdrift is significant. The salinity status of the Harts River is extremely poor (unacceptable) and contributes significant amounts of salts to the lower Vaal River. This is largely related to the irrigation return flows in the catchment.

Ecological Condition

The water resources of the Upper Vaal catchment are largely in a moderately modified condition (C present ecological state), with the exception of the water resources in the Vaal Barrage catchment area which are in a degraded condition (largely to seriously modified) (D and E present ecological state). Some smaller tributaries in the headwater catchments of the Upper Klip and Upper Wilge Rivers are in a good ecological condition, in a largely natural present ecological state (B Category).

Within the Middle Vaal area, the water resources fall predominantly in a moderately modified state (category C) and largely modified state (category D) with a small percentage of smaller tributaries in less developed areas in the catchment in a largely natural state (B present ecological condition). These tributaries are within the upper reaches of the Sand Vet catchments and the C25A catchment. Many reaches within the Schoonspruit and Koekermoerspruit catchments, and the lower reach of the Bamboespruit are in a seriously modified state (E category) which is indicative of unsustainable systems, with a large loss of biota and ecosystem habitat.

The lower Vaal River is in a largely modified ecological state (D category present ecological state) from Bloemhof Dam to Douglas. The main stem of the Harts River is in a moderately modified state (category C) and largely modified state (D category) with a many of its tributaries in a B category present ecological state. Many of the tributaries of the Molopo River are in a moderately modified state (category C) and largely modified (D category) present ecological state.

Threat to the Surface Water Resources

Within the Vaal WMA, of the 76% of the quaternary catchments assessed (with data available) 42% (5 rating red) of the catchment area includes stressed surface water resources that are under threat, 1% (5 rating green) that require the precautionary approach to management to maintain good condition, and 57%, (rated 1 or 3) where the surface water resources do have capacity available to accept degrees of impact. Refer to map on page 62.

MINERALOGY PROFILE

There are seven significant mineral provinces in the WMA:

- The Witwatersrand Basin produces gold and (historically) uranium and the mineralogical risk is high, due to high risk of ARD and potentially toxic trace elements including uranium and lead.
- The TSG is a widespread mineral province from which iron, gold, asbestos, dolomite and lead are produced. Generally the province has medium mineralogical risk, mainly due to potentially toxic trace elements, notably lead and zinc, which occur in minor/trace minerals within the dolomites. The iron and asbestos deposits (which overlie the dolomites) have low mineralogical risk. The TSG lead deposits are sulphide-rich and thus the risk of ARD results in a high mineralogical risk.
- The Karoo coalfields have significant risk of ARD, resulting in a high mineralogical risk where there is low neutralisation capacity (Highveld Coalfield) and medium risk where there is more neutralisation capacity (South Rand, Vereeniging-Sasolburg and Welkom Coalfields).
- The Karoo uranium province is a widespread, largely unexploited province with high mineralogical risk due to ARD and radionuclides.
- The Kalahari Manganese field has a medium mineralogical risk rating due to moderate ARD and potentially toxic trace element risk.
- The Northern Cape base metal deposits are massive sulphide deposits of copper, lead and zinc, with high mineralogical risk due to their substantial ARD potential and numerous potentially toxic trace elements.
- Quaternary sedimentary-hosted deposits are mainly diamonds, gypsum and heavy mineral sands – all are largely chemically inert and have low mineralogical risk ratings.

The remaining mineral deposits in the WMA include a variety of metamorphic- and sedimentary-hosted deposits with low risk ratings, and kimberlites with medium risk ratings.

GROUNDWATER VULNERABILITY PROFILE

General aquifer profile (Lithology aquifer type): there are four major aquifer systems in the WMA:

- Karst aquifers with borehole yields >5.0 l/s, supporting large fresh water dolomite springs;
- Intergranular and fractured aquifers with borehole yields between 0.1 and 2.0 l/s and water quality ranges <70 mS/m and 70-300 mS/m;
- Fractured aquifers with borehole yields between 0.1 and 2.0 l/s and water quality ranges <70 mS/m, 70 to 300 mS/m, 300 to 1000 mS/m and >1000 mS/m (hyper saline groundwater);
- Intergranular/alluvial (T-Qk deep seated (>50 mbgl) inland filled palaeo-drainage systems) with borehole yields between 0.1 and 2.0 l/s, but multi-layered aquifer systems (fresh, underlain by brackish/saline/hyper-saline groundwater).

AQUIFER VULNERABILITY RATING:

The overall vulnerability rating in the WMA varies from ~1.00 (insignificant, less than 10% of the WMA) to >4.3 (significant, ~5% of the WMA area) with the remaining part ranging from low to moderate (1.7 to 2.8).

Intergranular (alluvial):

- Semi-unconsolidated/semi-consolidated inland filled, palaeo drainage valleys of T-Q river systems – vulnerability ranges varies from low at 1.9 (Terra Firma area: 0.1 to 0.5 l/s, 300 to 1000 mS/m) to high at 3.3 (Tosca area: 0.5 to 2.0 l/s, <70 mS/m). Along the Gamagara River valley (Kathu-Van Zylsrus area), the vulnerability rating is at 3.0 (high) due to fresh water quality (<70 mS/m) and in the Lower Kuruman River (Van Zylsrus-Askham area) the vulnerability rating is at 3.2 (high) due to fresh water quality (<70 mS/m) and high yields (2.0 to 5.0 l/s)

Intergranular and fractured aquifer systems:

- Drakensberg Group Letaba basalt and underlying sedimentary formations (Clarens, Elliot and Molteno Formations) – vulnerability rating 2.5 (moderate) and high (>3.0) where dolerite dykes/sills occur;
- Central and Eastern Karoo Supergroup aquifers – Vulnerability ratings Beaufort Group Adelaide/Escourt Subgroups (mudstone and arenite) at 2.1 (moderate), Ecca Group Volksrust (shale) at 1.7 (low, brackish water quality) to 2.3 (moderate, fresh water quality);
- Western Karoo Supergroup aquifers – vulnerability rating for Dwyka Group (shale) at 1.3 (low) due to saline water quality (300 to 1000 mS/m);
- Karoo Dolerite dyke-aquifers in Karoo Supergroup formations – vulnerability rating from 2.5 (moderate) to 3.3 (high) at contact zone area along the strike of the dyke;
- Karoo Dolerite sill-aquifers in Karoo Supergroup formations – vulnerability rating at 3.1 (high) due to fresh water quality and moderate yields (0.5 to 2.0 l/s);
- Venterdorp Supergroup aquifers – vulnerability ratings from 1.7 (low) to 2.4 (moderate); and
- Basement Granite aquifers – vulnerability rating from 1.0 (insignificant, due to low yields and saline water quality) to 2.8 (moderate, due to 5.0 l/s yields and fresh water quality).

Fractured aquifers:

- Banded ironstone type aquifers (such as at Sishen-Postmasburg area) – vulnerability rating at 1.7 (low) due to low to moderate yields;
- Meta-arenaceous rock aquifers (west of Kaap-Vaal Craton and included in Namaqua-Natal Mobile Belt) – vulnerability rating at 1.5 (low yields and brackish water quality); and
- Namaqua-Natal Mobile Belt granitic, hard rock aquifers – vulnerability rating low (1.2 to 1.6) due to low yields and saline water quality.

Karst Aquifer Systems

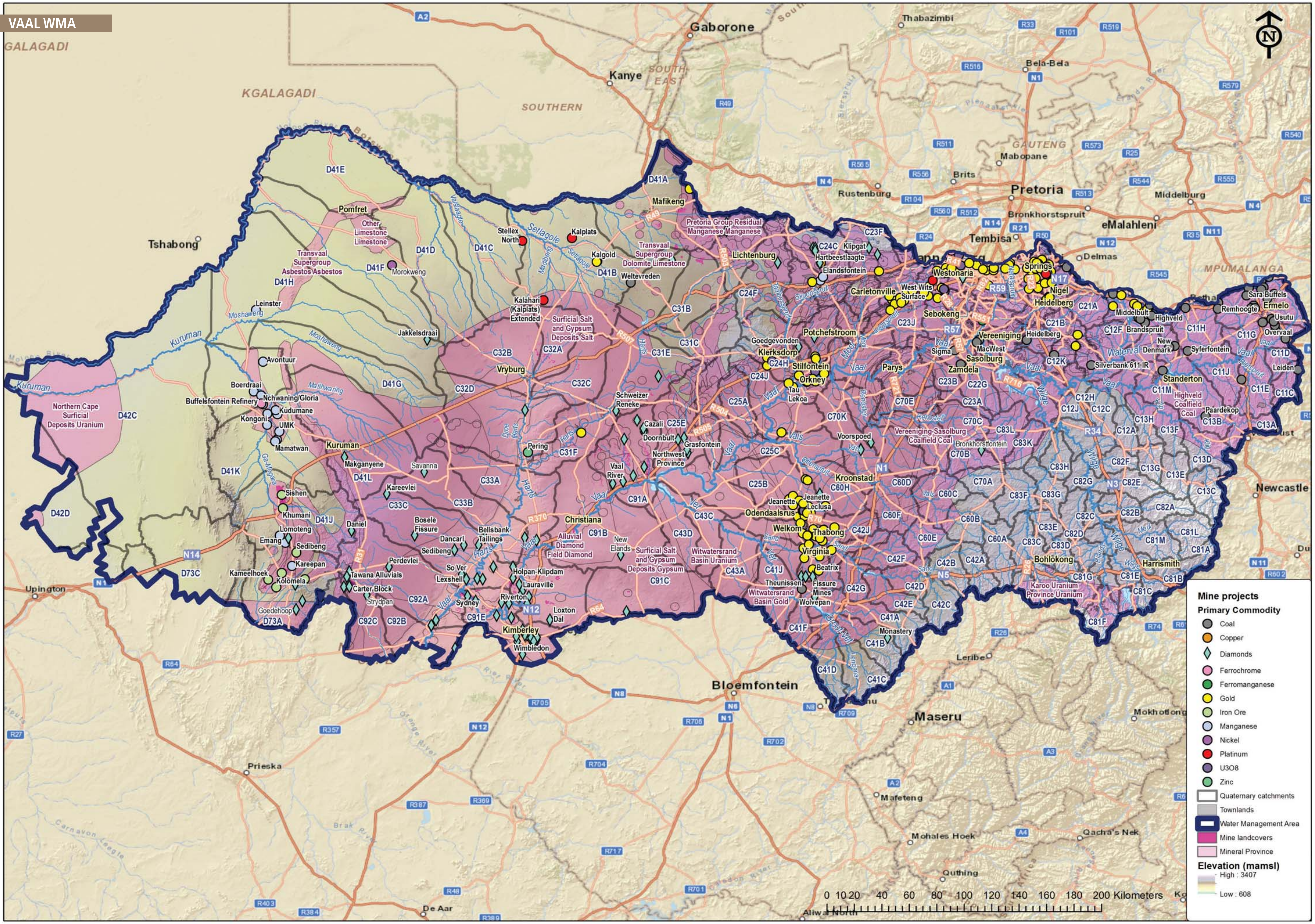
- Gauteng and Northwest Dolomite Water Area – vulnerability rating from 3.5 (high) to 4.0 (significant) due to high yields (>5 l/s), fresh water quality (<70 mS/m) and environmental sensitive wetlands and dolomitic springs;
- Ghaap Plateau Dolomite Water Area – vulnerability rating from 2.4 (moderate, low yields: 0.1 to 0.35 l/s) to 3.2 (high, fresh water systems); and
- Sishen-Postmasburg Dolomite/BIF Water Areas – vulnerability rating 2.4 (moderate, moderate yields at 0.5 to 2.0 l/s and brackish water quality)
- In combination with diabase/Karoo Dolerite dykes – vulnerability rating increases to >4.0 and maximum 4.4.

Key areas of concern:

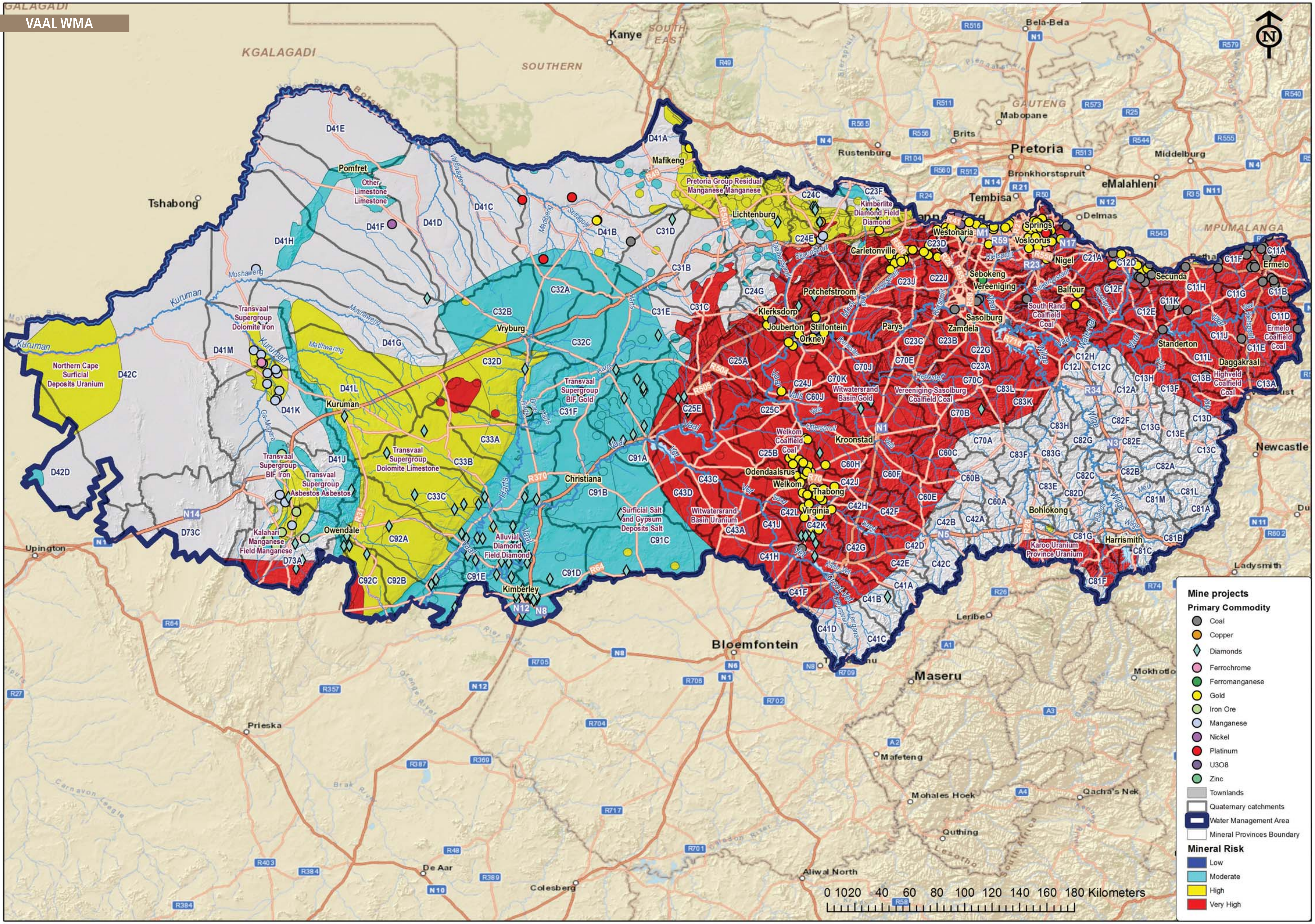
- Fresh water aquifers systems with water quality <70 mS/m mapped in most of the intergranular & fractured and fractured aquifer systems;
- Over abstractions from deep Kalahari Group aquifers for mine dewatering may enhance upward migration of hyper saline water from the deeper saline aquifers (i.e. a multi-layered aquifer system);
- Karst aquifer systems are vulnerable to local pollution due to the presence of preferential pathways from the ground surface to the aquifer system with shallow water table conditions (<10 m in many cases); and
- Karst aquifer systems drive large fresh water environments at dolomitic springs and mining activities in the upstream areas may cause pollutants to reach the springs.


Photo Credit: Golder

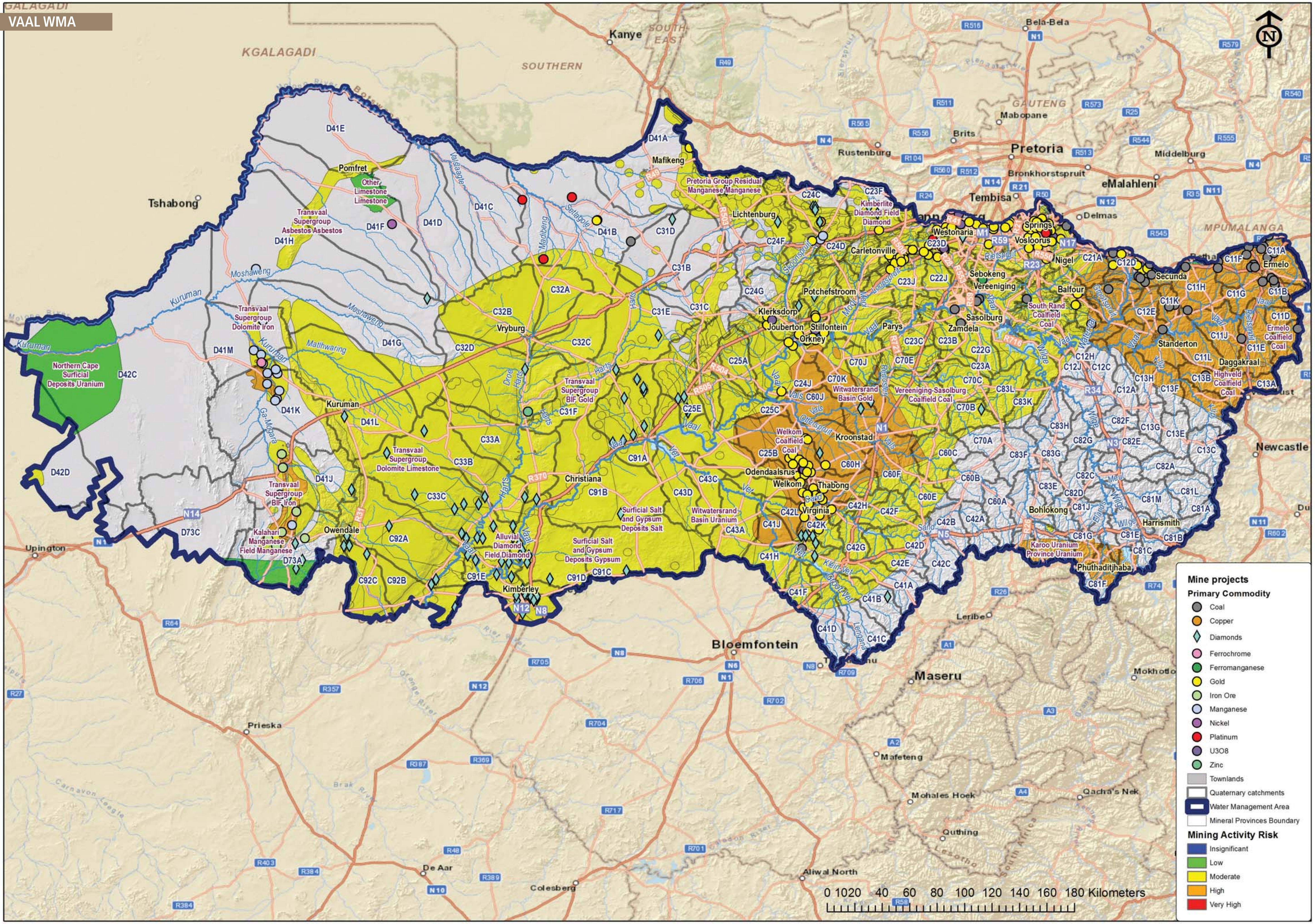
VAAL WMA


Mine projects
Primary Commodity
Coal
Copper
Diamonds
Ferrochrome
Ferromanganese
Gold
Iron Ore
Manganese
Nickel
Platinum
U3O8
Zinc
Quaternary catchments
Townlands
Water Management Area
Mine landcovers
Mineral Province
Elevation (mamsl)
High : 3407
Low : 608
0 10 20 40 60 80 100 120 140 160 180 200 Kilometers
Gaborone
Pretoria
Bloemfontein
Maseru
Kimberley
Vryburg
Kuruman
Mafikeng
Lichtenburg
Potchefstroom
Klerksdorp
Welkom
Kroonstad
Vereeniging
Sasolburg
Springs
Heidelberg
Standerton
Ermelo
Harrismith
Newcastle
Christiana
Upington
Prieska
De Aar

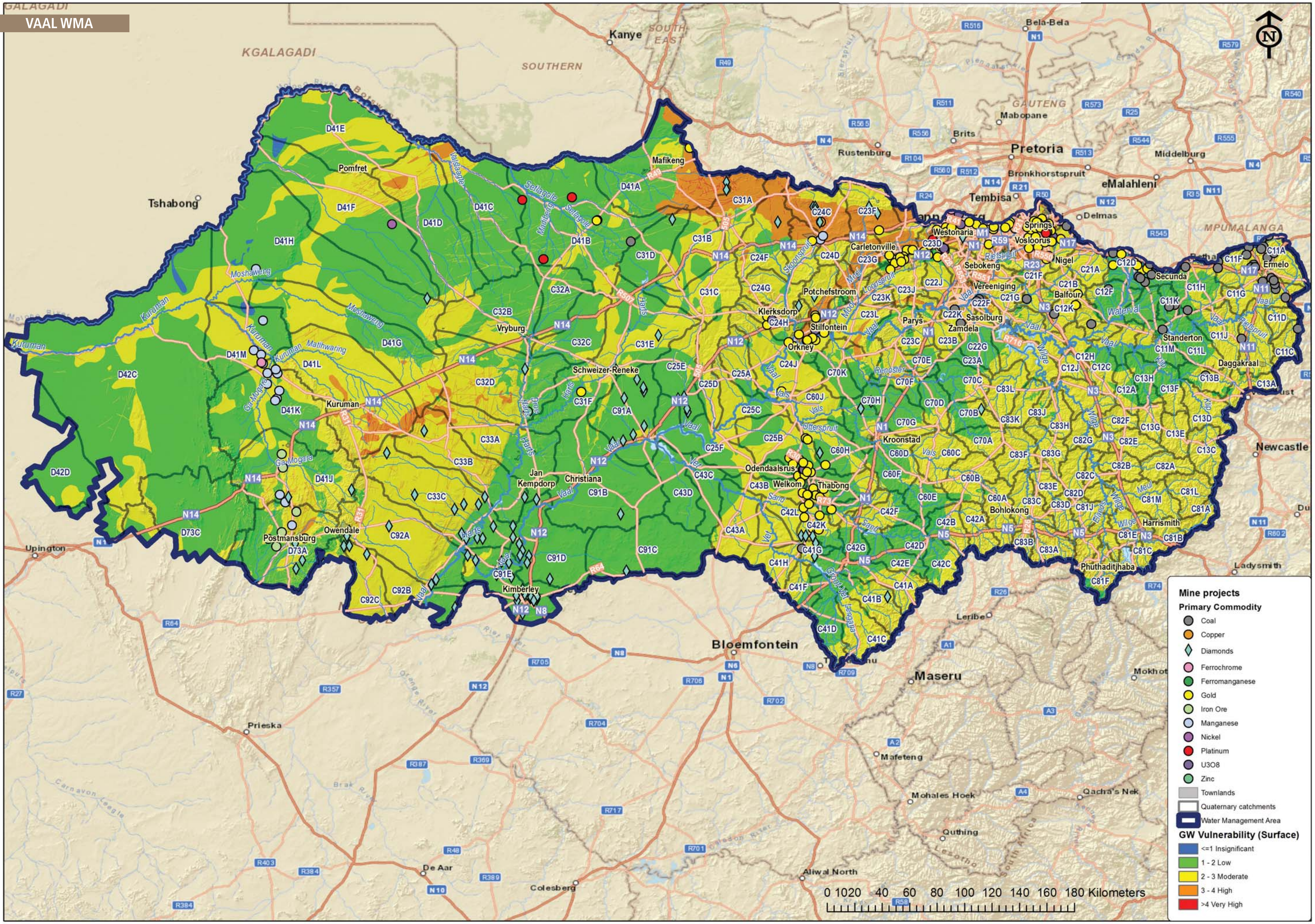
VAAL WMA


Pretoria Group Residual Manganese Manganese
Kimberlite Diamond Field Diamond
Transvaal Supergroup Dolomite Iron
Northern Cape Surficial Deposits Uranium
Other Limestone Limestone
Transvaal Supergroup BIF Gold
Transvaal Supergroup Dolomite Limestone
Transvaal Supergroup BIF Iron
Transvaal Supergroup Asbestos Asbestos
Kalahari Manganese Field Manganese
Alluvial Diamond Field Diamond
Surficial Salt and Gypsum Deposits Salt
Witwatersrand Basin Gold
Witwatersrand Basin Uranium
Welkom Coalfield Coal
Vereeniging-Sasolburg Coalfield Coal
South Rand Coalfield Coal
Highveld Coalfield Coal
Ermelo Coalfield Coal
Karoo Uranium Province Uranium
Mafikeng
Lichtenburg
Carletonville
Westonaria
Springs
Vosloorus
Nigel
Secunda
Ermelo
Potchefstroom
Klerksdorp
Stilfontein
Orkney
Parys
Sasolburg
Vereeniging
Sebokeng
Balfour
Standerton
Daggakraal
Vryburg
Kuruman
Christiana
Kimberley
Kroonstad
Odendaalsrus
Welkom
Virginia
Thabong
Bohlokong
Harrismith
Bloemfontein
Maseru
Mine projects
Primary Commodity
Coal
Copper
Diamonds
Ferrochrome
Ferromanganese
Gold
Iron Ore
Manganese
Nickel
Platinum
U3O8
Zinc
Townlands
Quaternary catchments
Water Management Area
Mineral Provinces Boundary
Mineral Risk
Low
Moderate
High
Very High
0 10 20 40 60 80 100 120 140 160 180 Kilometers

VAAL WMA


Mine projects
Primary Commodity
Coal
Copper
Diamonds
Ferrochrome
Ferromanganese
Gold
Iron Ore
Manganese
Nickel
Platinum
U3O8
Zinc
Townlands
Quaternary catchments
Water Management Area
Mineral Provinces Boundary
Mining Activity Risk
Insignificant
Low
Moderate
High
Very High
0 1020 40 60 80 100 120 140 160 180 Kilometers

VAAL WMA


Mine projects
Primary Commodity
Coal
Copper
Diamonds
Ferrochrome
Ferromanganese
Gold
Iron Ore
Manganese
Nickel
Platinum
U3O8
Zinc
Townlands
Quaternary catchments
Water Management Area
GW Vulnerability (Surface)
<=1 Insignificant
1 - 2 Low
2 - 3 Moderate
3 - 4 High
>4 Very High
0 10 20 40 60 80 100 120 140 160 180 Kilometers
N
Kanye
KGALAGADI
SOUTHERN
Tshabong
Mafikeng
Rustenburg
Brits
Pretoria
Mabopane
GAUTENG
Bronkhorstspruit
eMalahleni
Middelburg
Tembisa
Delmas
MPUMALANGA
Springs
Vosloorus
Nigel
Secunda
Ermelo
Westonaria
Carletonville
Sebokeng
Vereeniging
Potchefstroom
Klerksdorp
Stilfontein
Orkney
Parys
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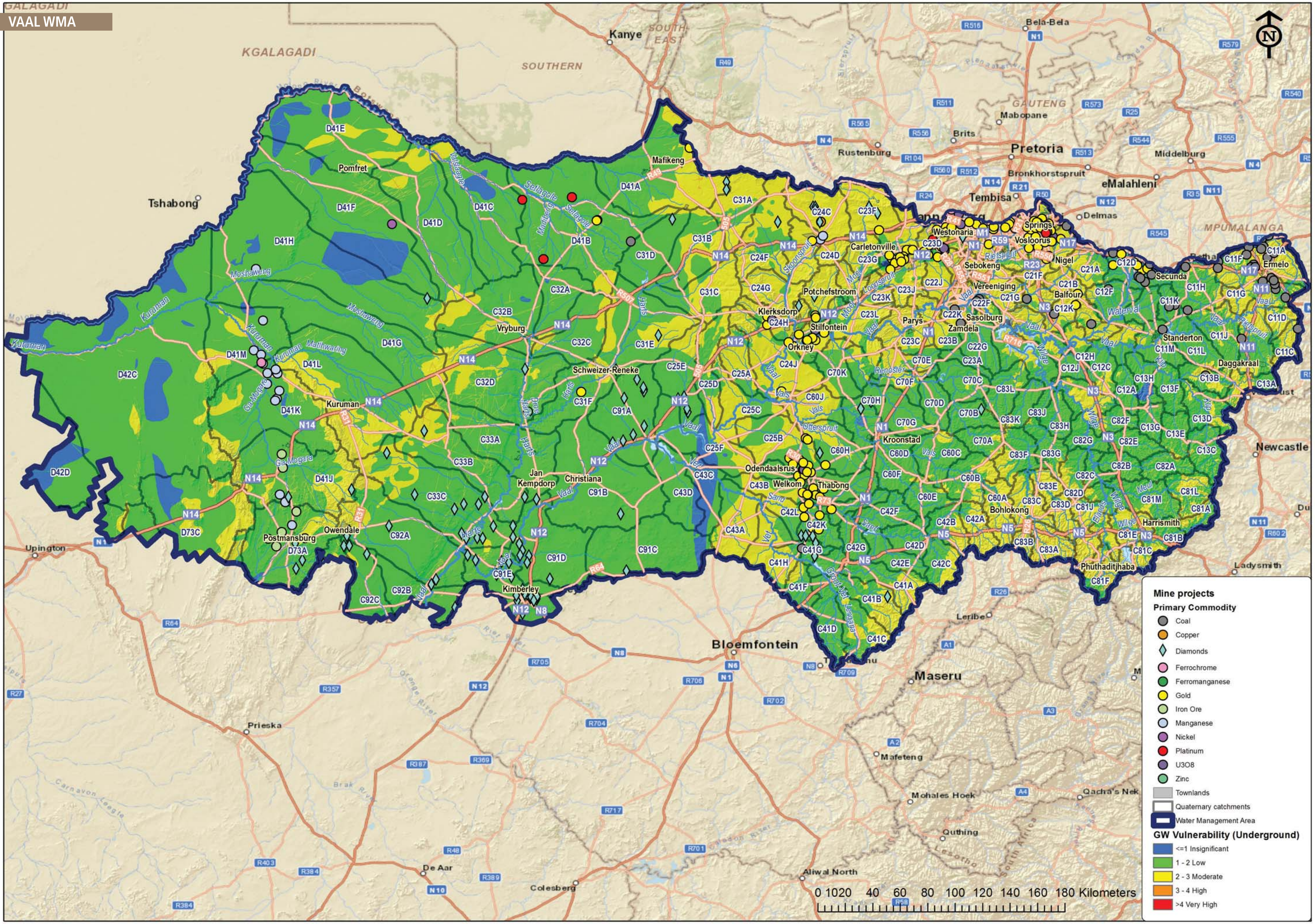
Zamdela
Standerton
Balfour
Daggakraal
Vryburg
Schweizer-Reneke
Pomfret
Kuruman
Postmansburg
Owendale
Jan Kempdorp
Christiana
Kimberley
Kroonstad
Odendaalsrus
Welkom
Thabong
Bohlokong
Phuthaditjhaba
Harrismith
Newcastle
Bloemfontein
Maseru
Leribe
Mafeteng
Mohales Hoek
Qacha's Nek
Quthing
Aliwal North
Prieska
De Aar
Colesberg
Upington
Ladysmith
Bela-Bela

GROUNDWATER VULNERABILITY - UNDERGROUND

VAAL WMA



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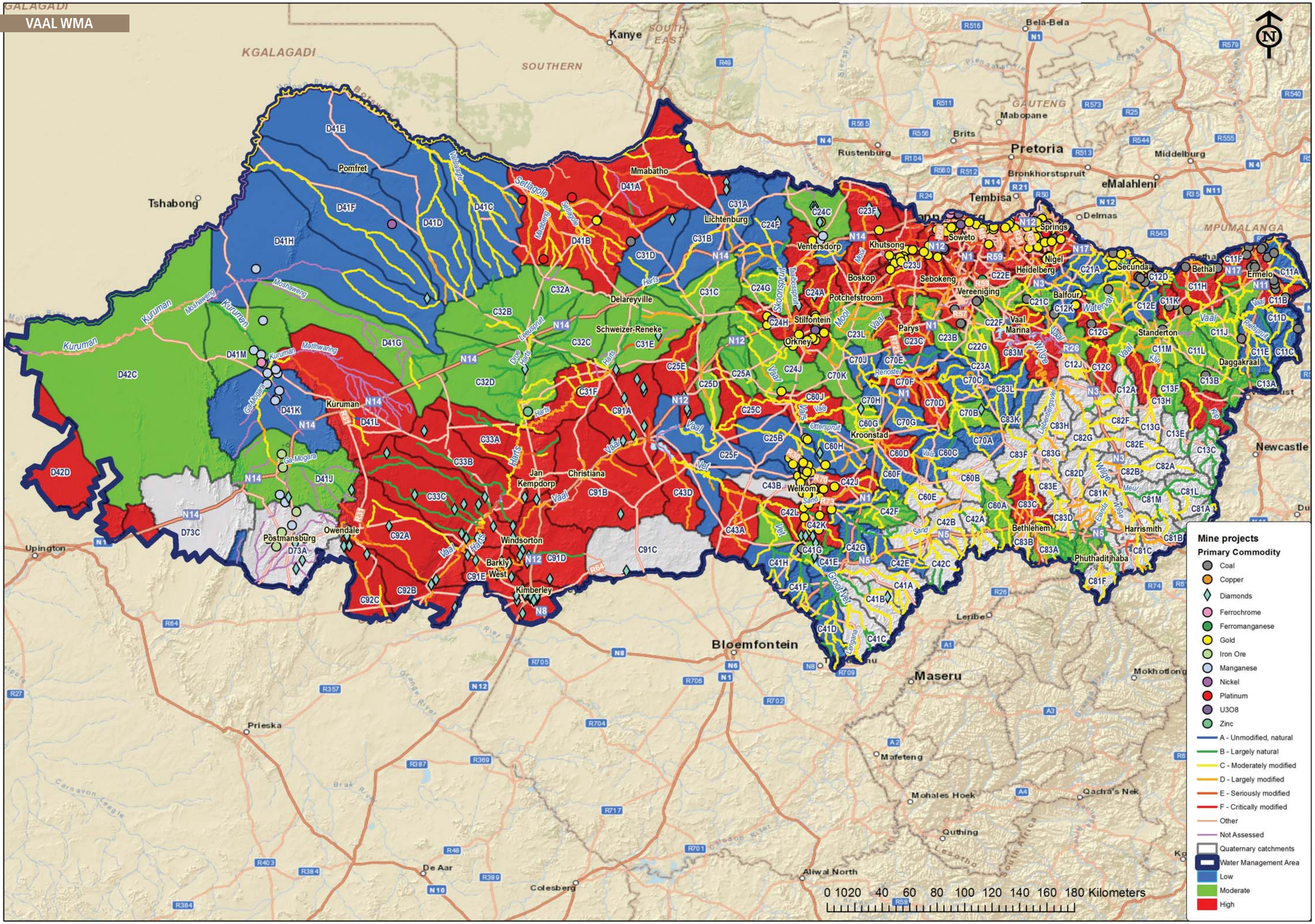
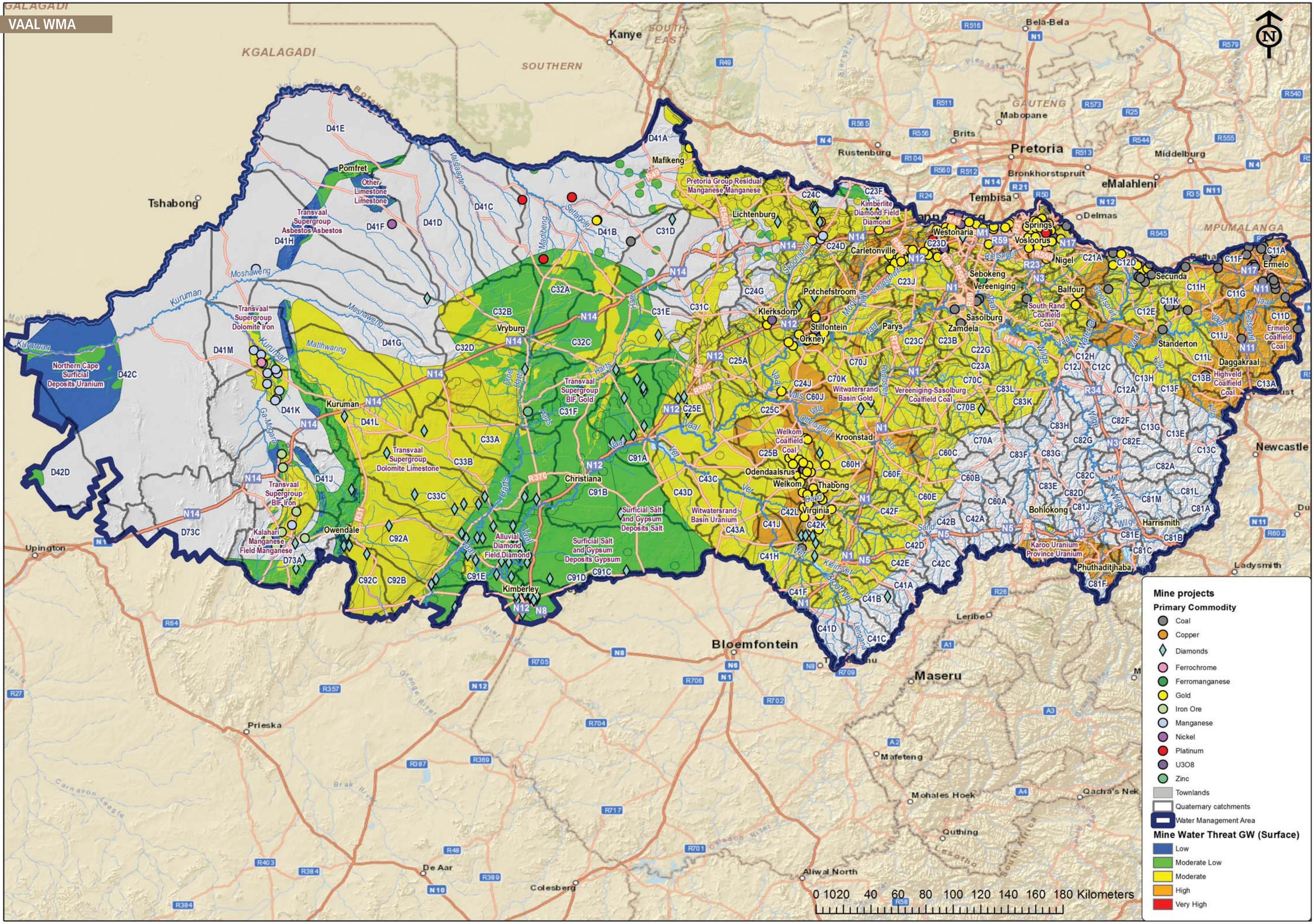
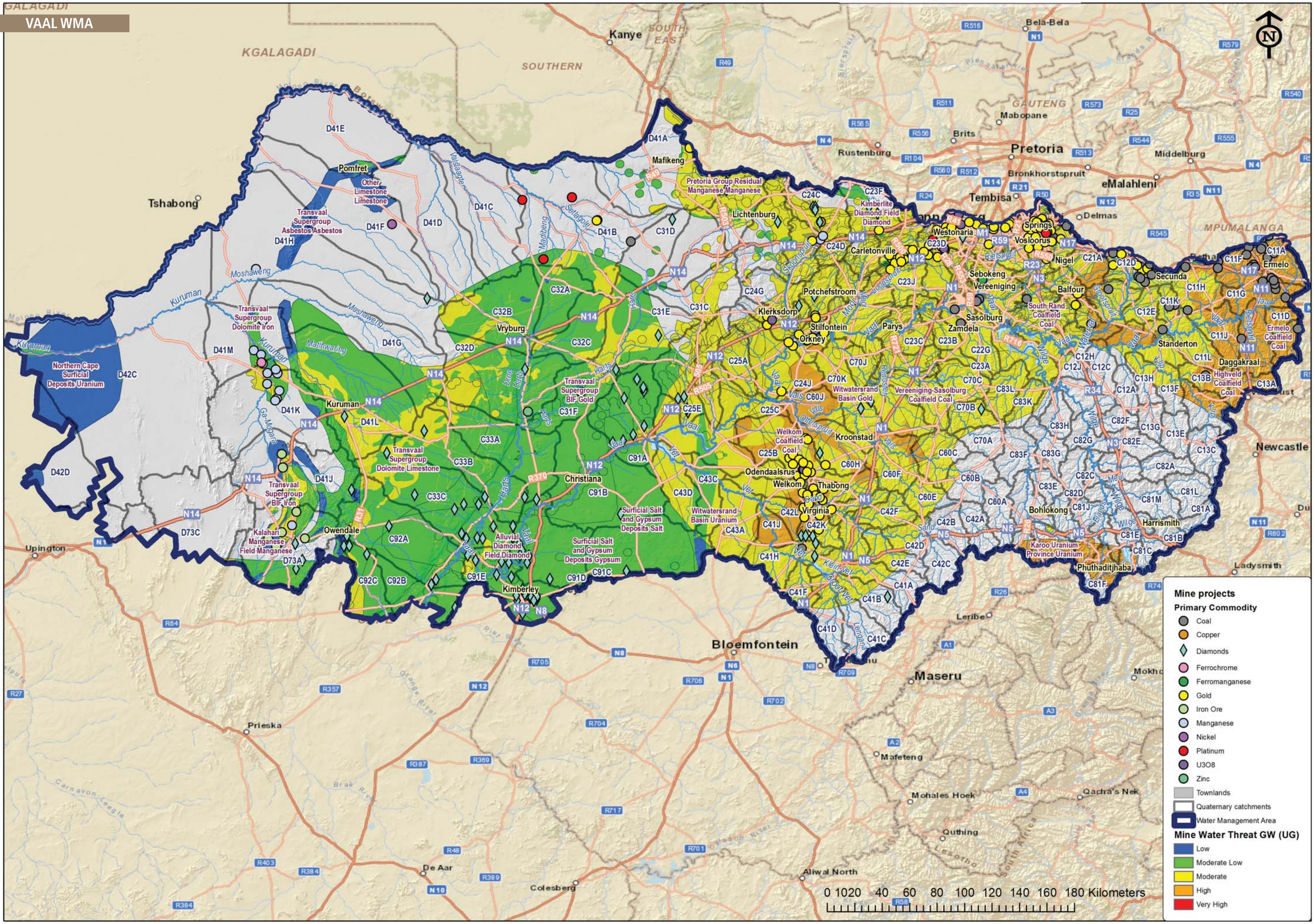

Mine projects
Primary Commodity
Coal
Copper
Diamonds
Ferrochrome
Ferromanganese
Gold
Iron Ore
Manganese
Nickel
Platinum
U3O8
Zinc
A - Unmodified, natural
B - Largely natural
C - Moderately modified
D - Largely modified
E - Seriously modified
F - Critically modified
Other
Not Assessed
Quaternary catchments
Water Management Area
Low
Moderate
High
0 10 20 40 60 80 100 120 140 160 180 Kilometers
Pretoria
Tembisa
Soweto
Springs
Vereeniging
Potchefstroom
Klerksdorp
Welkom
Kroonstad
Bethlehem
Harrismith
Standerton
Secunda
Kimberley
Bloemfontein
Maseru
Mmabatho
Lichtenburg
Schweizer-Reneke
Christiana
Jan Kempdorp
Barkly West
Postmansburg
Tshabong
Upington
Prieska
De Aar
Colesberg
Newcastle
Ermelo
eMalahleni
Middelburg
Rustenburg
Kanye

MINE WATER THREAT GROUNDWATER - OPEN CAST

VAAL WMA

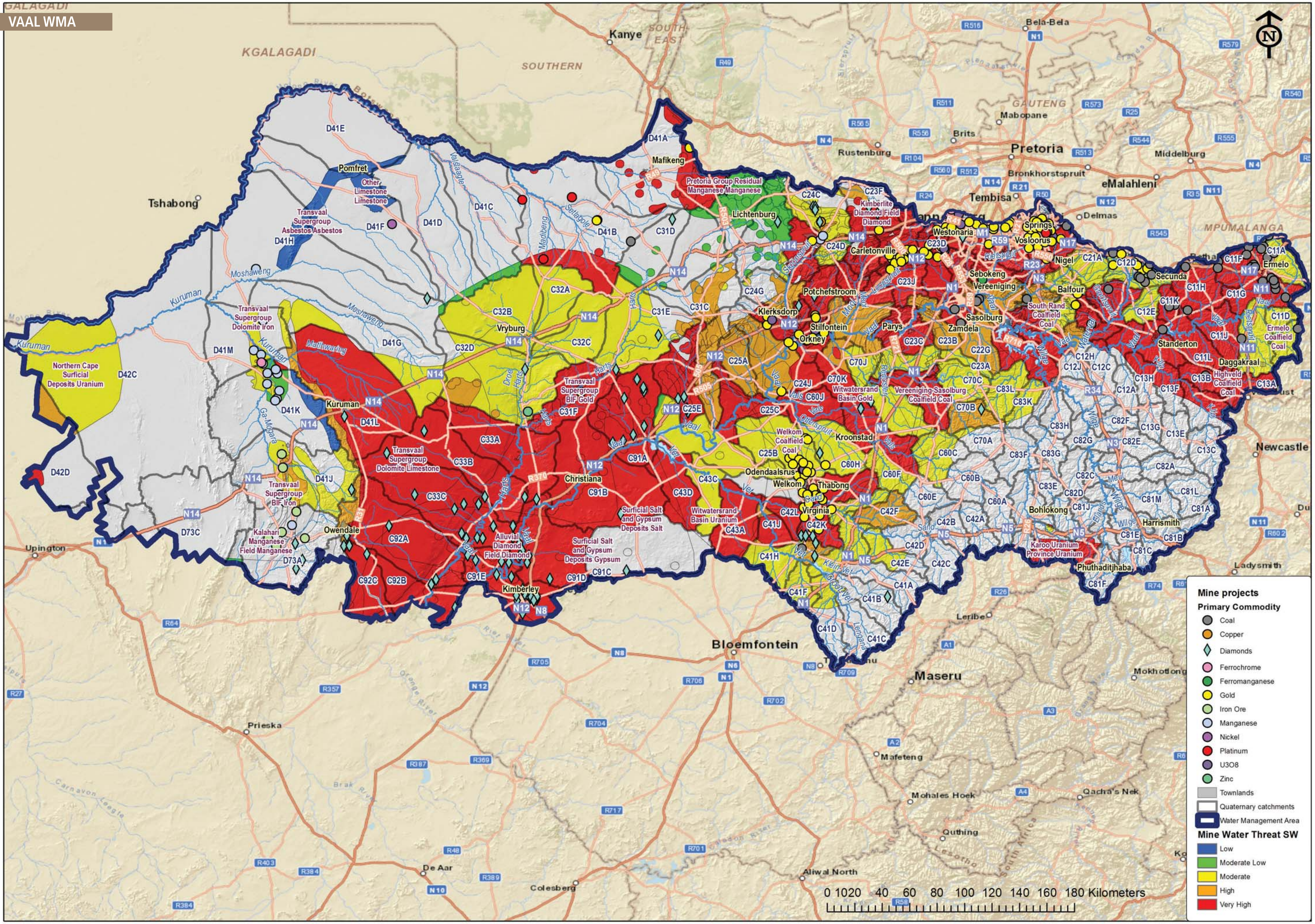


VAAL WMA


Mine projects
Primary Commodity
Coal
Copper
Diamonds
Ferrochrome
Ferromanganese
Gold
Iron Ore
Manganese
Nickel
Platinum
U3O8
Zinc
Townlands
Quaternary catchments
Water Management Area
Mine Water Threat GW (UG)
Low
Moderate Low
Moderate
High
Very High
0 10 20 40 60 80 100 120 140 160 180 Kilometers
Pretoria
Bloemfontein
Maseru
Kimberley
Mafikeng
Welkom
Potchefstroom
Klerksdorp
Vryburg
Kuruman
Christiana
Secunda
Standerton
Ermelo
Harrismith
Newcastle
Kanye
Tshabong
Prieska
De Aar
Colesberg
Aliwal North
KGALAGADI
SOUTHERN
GAUTENG
MPUMALANGA

MINE WATER THREAT SURFACE WATER

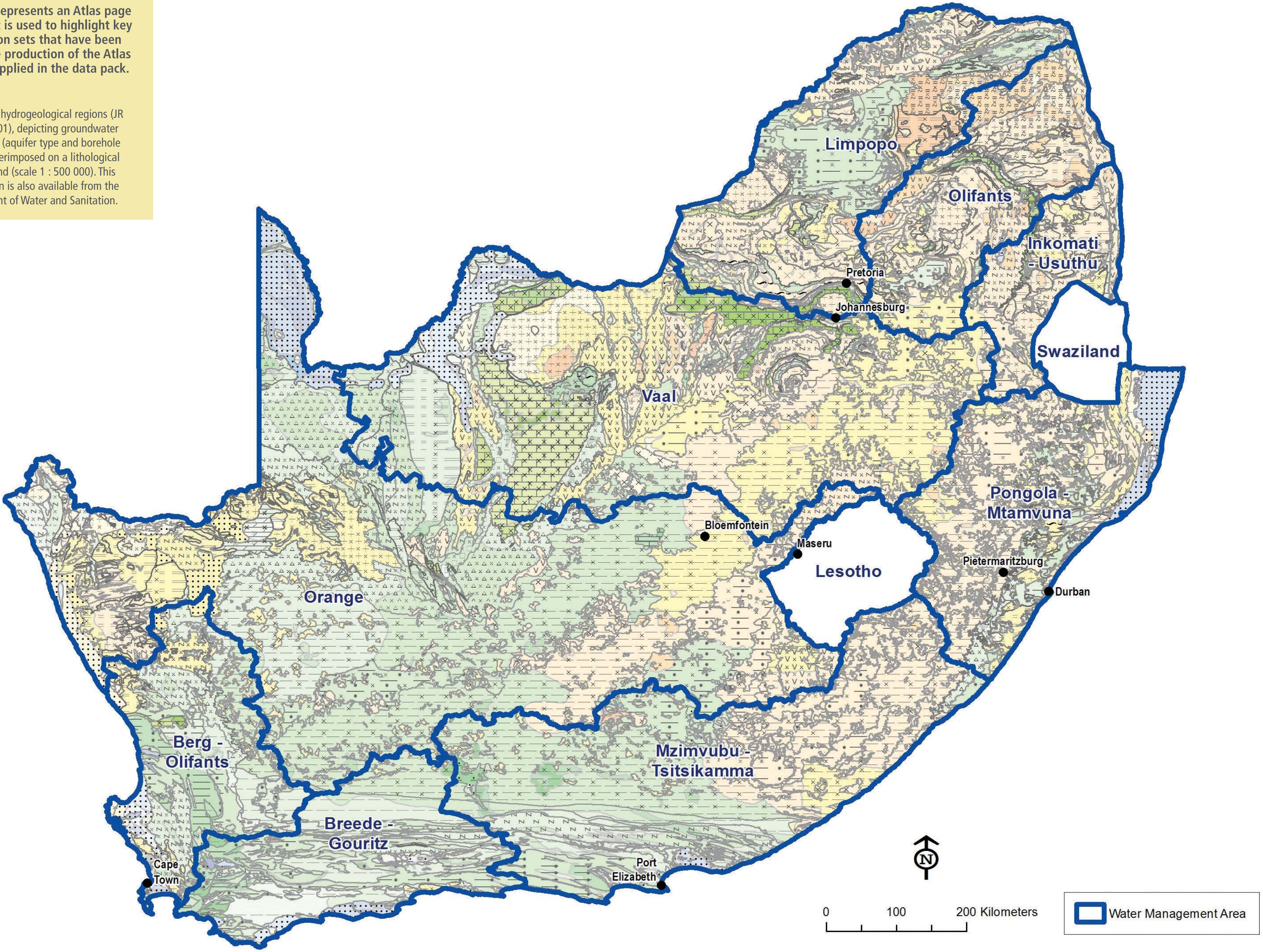
VAAL WMA



HYDRO-GEOLOGICAL MAP OF SOUTH AFRICA

This page represents an Atlas page holder that is used to highlight key foundation sets that have been used in the production of the Atlas and are supplied in the data pack.

The map of hydrogeological regions (JR Vegter, 2001), depicting groundwater occurrence (aquifer type and borehole yields) superimposed on a lithological background (scale 1 : 500 000). This information is also available from the Department of Water and Sanitation.



4.6 PONGOLA MTAMVUNA WMA

WMA OVERVIEW

The Pongola Mtamvuna WMA comprises the Mhlatuze, Pongola, Mkuze, Mfolozi, Thukela, Mngeni, Mvoti, Mkomazi, Mtamvuna and Mzimkulu systems. These systems vary in size from medium to very large catchment areas with all rivers flowing directly into the sea, apart from the Pongola River which confluences with the Maputo River in Mozambique. There are some water transfers across catchments, the most important being the transfer of water from the Thukela system to the Vaal system, with additional water being reserved for long term requirements. The current critical issue facing the WMA is the additional water supply needed to meet the growing requirements of the KwaZulu-Natal Coastal Metropolitan Area (Durban-Pietermaritzburg, KwaDukuza in the north to Amanzimtoti in the south). Water requirements are still increasing, with systems already in deficit. Currently, the Thukela pipeline project, the raising of Hazelmere Dam and the building of Spring Grove Dam are under way as interventions to address water shortages. Further options being investigated are dams on the Mkomazi and Mvoti rivers as well as desalination and re-use of wastewater plus seawater desalination.

Mhlathuze, Mfolozi, Mkuze and the Pongola catchment areas include industrial, agricultural and transportation as the key economic sectors. Land use in the catchment area, from a water resources perspective, is dominated by irrigation and afforestation. A large portion of the catchment is tribal land which is typically used for stock farming. There are old mining areas in the vicinity of Vryheid. The Richards Bay area is a fast growing industrial hub with a number of industrial complexes within the Mhlatuze catchment. The majority of the population in the catchment live in rural areas. The Pongola System includes the massive Pongolapoort Dam which supports the Pongola Irrigation Scheme and the Bivane Dam upstream which provides irrigation water to sugar cane farmers. The Mkuze and Mfolozi catchments are large unregulated catchments, supporting primarily forestry and irrigation water use. The catchment includes the world famous heritage site, Lake St Lucia. Upstream water use, poor catchment management and erosion in the catchment have impacted on the ecological condition of the St Lucia estuary. There is potential for water resource development within this wider catchment area.

The Thukela River is the largest river within the WMA, and includes Little Thukela, Klip, Bloukrans, Bushmans, Sundays, Mooi and Buffalo rivers as its major tributaries. The resources of the Thukela River are used to support requirements for water in other parts of the country, with large transfers of water to neighbouring catchments. The river is relied upon for transfers into the Vaal System, and to the Mhlatuze catchment to its north and Mooi-Mgeni system to the south. Eight major dams within the catchment include Woodstock, Spioenkop, Zaaihoek, Driel Barrage, Kilburn, Ntshingwayo, Craigie Burn and Wagendrift Dams. The catchment includes the major towns of Newcastle, Dundee, Ladysmith and Escourt. Most people in the catchment are dependent on agriculture for their livelihood. Subsistence farming is practised on communal land, which covers much of the catchment area. The catchment also includes a paper mill at Mandini.

The Mngeni, Mvoti, Mdloti, Mzimkulu and Mtamvuna systems form the southern portion of the WMA. The Mzimkulu and Mkomazi comprise the two larger river systems, the Mngeni and Mvoti the two medium-sized and the Mzumbe, Mdloti, Tongaat, Ifafa, Lovu and Mtamvuna as several smaller river systems. The Mvoti, Mdloti and Mngeni catchment areas are stressed with water requirements exceeding the available water supply. The catchment area makes the fourth largest contribution to the GDP of the national economy. The predominant land uses is dominated by major urban settlements along the Durban- Pietermaritzburg axis. The Durban metropolitan area is one of the major urban areas in South Africa. Several small urban settlements are located in the hinterland and support the surrounding agricultural sector. Outside of the urban areas there are large tracts of commercial and subsistence agricultural land. Timber, sugar cane, pastures and cash crops are the dominant land uses in the commercial agricultural areas. There is substantial industrial development in the urban areas of Durban, Stanger and Pietermaritzburg. There are no significant mining concerns or power stations situated in the catchment.

MINING WITHIN WMA: OVERVIEW

The main product of the mining industry in the Mhlatuze catchment is coal. Iscor Hillendale Mine mines zircon. Although the many collieries are assumed inactive, water discharge from these collieries impacts on the quality of the water resources in the area. The catchment also includes Richards Bay Minerals, heavy mineral sands producing titanium and zirconium

Coal mining is also predominant in the Thukela catchment. The main mining area is the Buffalo River catchment. A number of other commodities such as sand and dolerite are also mined. Although many of the collieries in WMA are inactive, they impact on the quality of the water resources in the area. The economy of the Newcastle area is heavily dependent on mining activity. The natural drainage from geological formations but especially from coal mine workings also contains appreciable amounts of nitrates and phosphate.

SURFACE WATER PROFILE

Water Quality

The salinity status of the water resources within the WMA reflects a good to fair condition, with a number of sites within the ideal to acceptable range. The status of the smaller river systems, viz. Umbilo River, Wasbank River and Nseleni Rivers are in the unacceptable range for salinity. Additional and more extensive water quality monitoring is required within the WMA to understand the water quality status.

Ecological Condition

The larger part of the WMA is in a good ecological condition, with the majority of river reaches in a largely natural to a moderately modified state (B and C present ecological state). A smaller portion of the river systems specifically in the vicinity of the urbanised developed areas are largely modified (D present ecological state), due to the impacts from land use and associated activities. The lower reaches of the Mgeni River, Mhlali, Mfolozi, Mhlatuze and Msunduzi are degraded and are in a seriously modified state (E category).

Threat to the Surface Water Resources

Within the Pongola Mtamvuna WMA, of the 65% of the quaternary catchments assessed (with data available) 13% (5 rating red) of the catchment area includes stressed surface water resources that are under threat, 1% (5 rating green) that require the precautionary approach to management to maintain good condition, and 85%,(rated 1 or 3) where the surface water resources do have capacity available to accept degrees of impact. Refer to the map on page 72.

MINERALOGY PROFILE

There are three major mineral provinces in the WMA:

- The Karoo coalfields have significant risk of ARD, resulting in a high mineralogical risk where there is low neutralisation capacity (Klip River and Vryheid Coalfields) and medium risk where there is more neutralisation capacity (Nongoma, Somkele and Utrecht Coalfields).
- The Natal Metamorphic Belt produces iron, lead and andalusite with a generally low mineralogical risk, except for the lead deposits which have a high risk rating due to ARD and potentially toxic trace elements, notably lead.
- The sedimentary-hosted deposits are of various ages, including Karoo iron and phosphates and Quaternary bauxites, gypsum and heavy mineral sands – all are largely chemically inert and have low mineralogical risk ratings.

The remaining mineral deposits in the WMA include lead deposits, which have a high mineralogical risk rating due to ARD and potentially toxic trace elements and kimberlites with medium risk ratings.

GROUNDWATER VULNERABILITY PROFILE

General aquifer profile (Lithology aquifer type): there are three major aquifer systems in the WMA:

- Intergranular and fractured aquifers with borehole yields between 0.5 and 2.0 l/s and water quality ranges <70 mS/m and 70 - 300 mS/m;
- Fractured aquifers with borehole yields between 0.5 and 2.0 l/s and water quality ranges <70 mS/m; and
- Intergranular/alluvial (T-Qm coastal and inland deposits) with borehole yields between 0.5 and 2.0 l/s, but multi-layered aquifer systems may occur in the coastal belts (fresh, underlain by saline).

Aquifer vulnerability rating:

The overall vulnerability rating in the WMA varies from ~1.5 (insignificant, less than 2% of the WMA) to (>3.00 (high, ~5% of the WMA area) with the remaining part ranging from low to moderate (1.9 to 2.5).

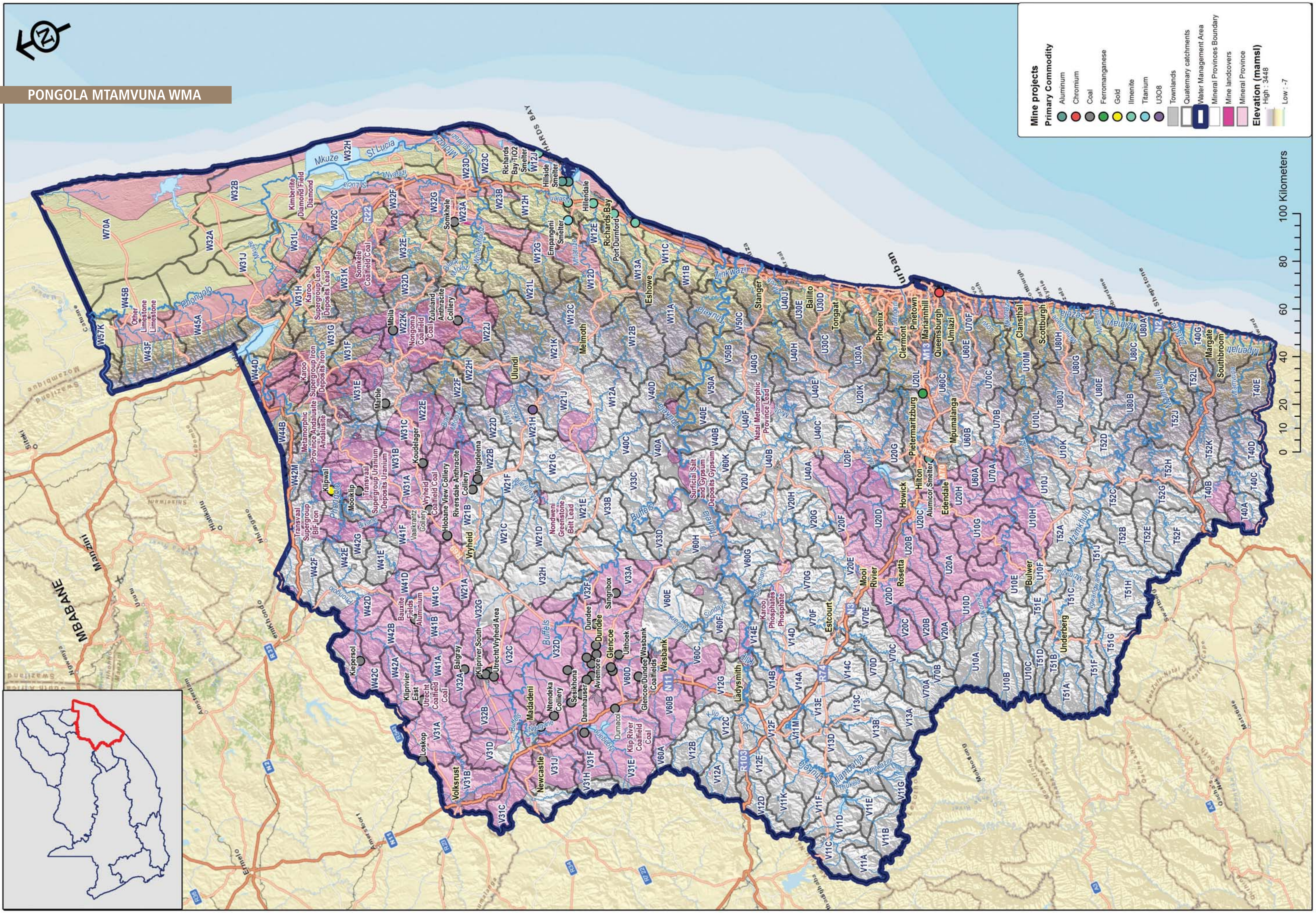
Intergranular (alluvial)

- Unconsolidated/semi-consolidated coastal and inland deposits (T-Qm) – vulnerability rating 3.0;
- Intergranular and fractured aquifer systems:
- Drakensberg Group Letaba basalt and Jozini rhyolite – vulnerability rating 1.7 (low) and 2.1 (moderate) and high (>3.00) where dolerite dykes/sills occur;
- Karoo Supergroup aquifers: Adelaide/Escourt Subgroups, Normandien Formation (successive mudstone and arenite formations), Volksrust shales and Tarkastad mudstones/arenites – vulnerability ratings from 1.5 (Low) to 2.4 (moderate), but 3.4 (high) where Karoo Dolerite dykes occurs and
- Pongola Supergroup (quartzite/hornfels/shale), Tugela Group (amphibolite/gneiss/schists), Mambulu Complex (gabbro/norite/pyroxenite/anorthosite) and Mapumulo Metamorphoc Suite (gneiss/granulite) – vulnerability rating varies from 1.8 (low) to 2.4 (moderate);
- Cape Supergroup, Natal Group mudrock/sandstone/arenite/conglomerate – vulnerability rating 2.3 (moderate).

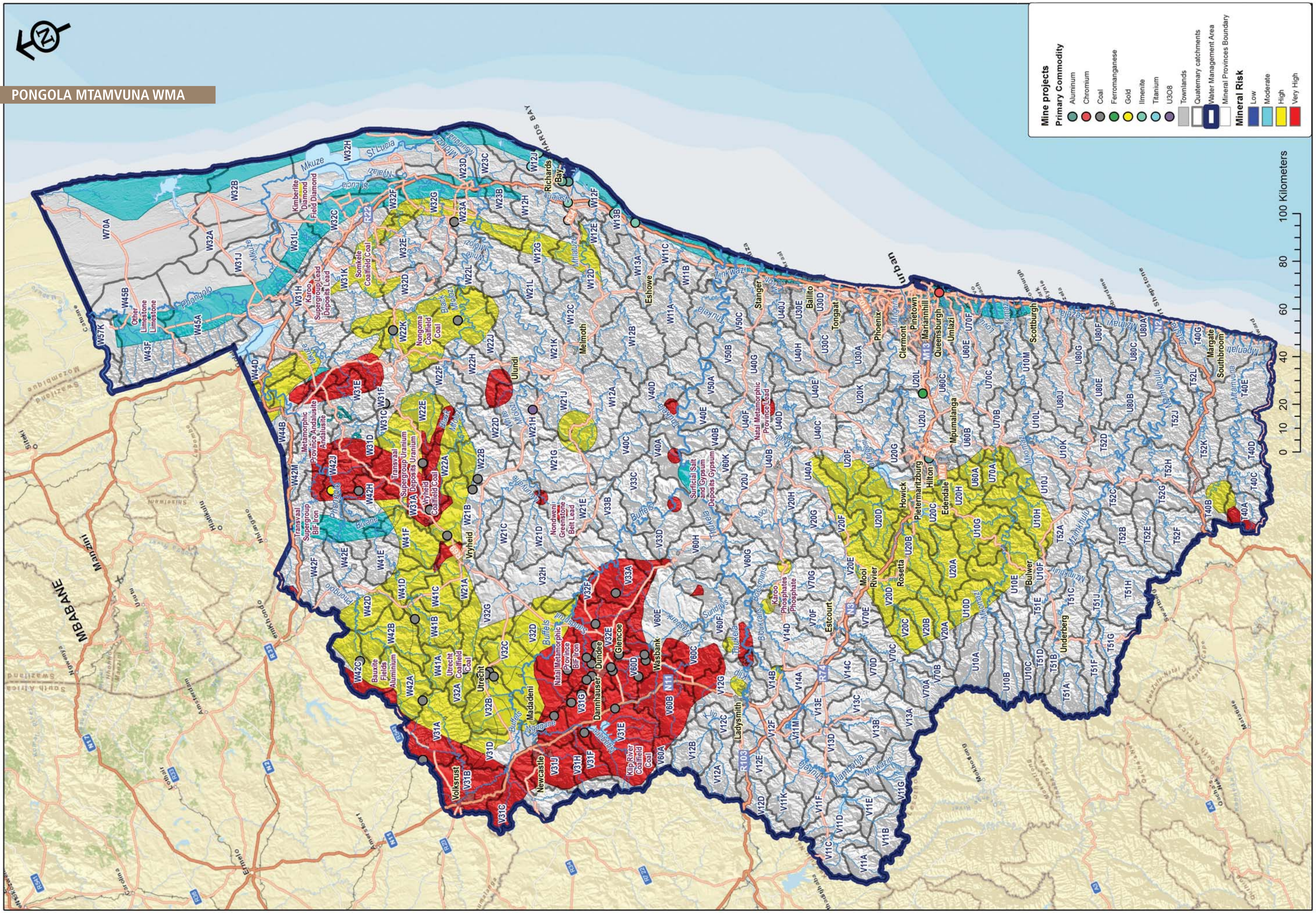
Key areas of concern:

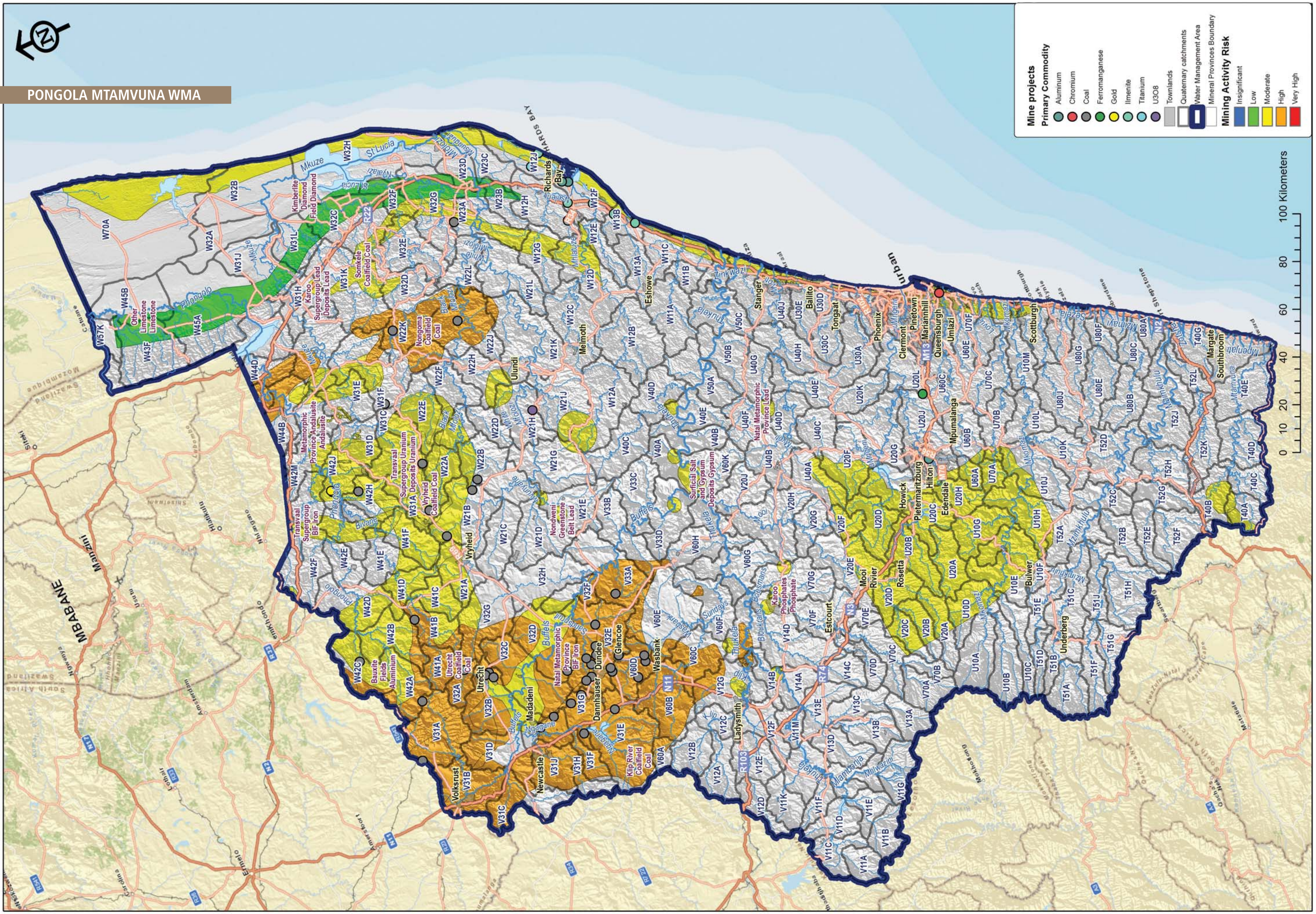
- Fresh water aquifers: aquifer systems with water quality <70 mS/m mapped in most of the intergranular and fractured, and fractured aquifer systems;
- Coastal aquifers may be underlain by brackish to saline water which will migrate upowards to the fresh water aquifer during mining/bulk water abstractions; and
- Abundant occurrences of Karoo Dolerite dykes in the Karoo Supergroup rocks resulting in a vulnerability rating of >3.00 (high) where these dykes are present.

PONGOLA MTAMVUNA WMA

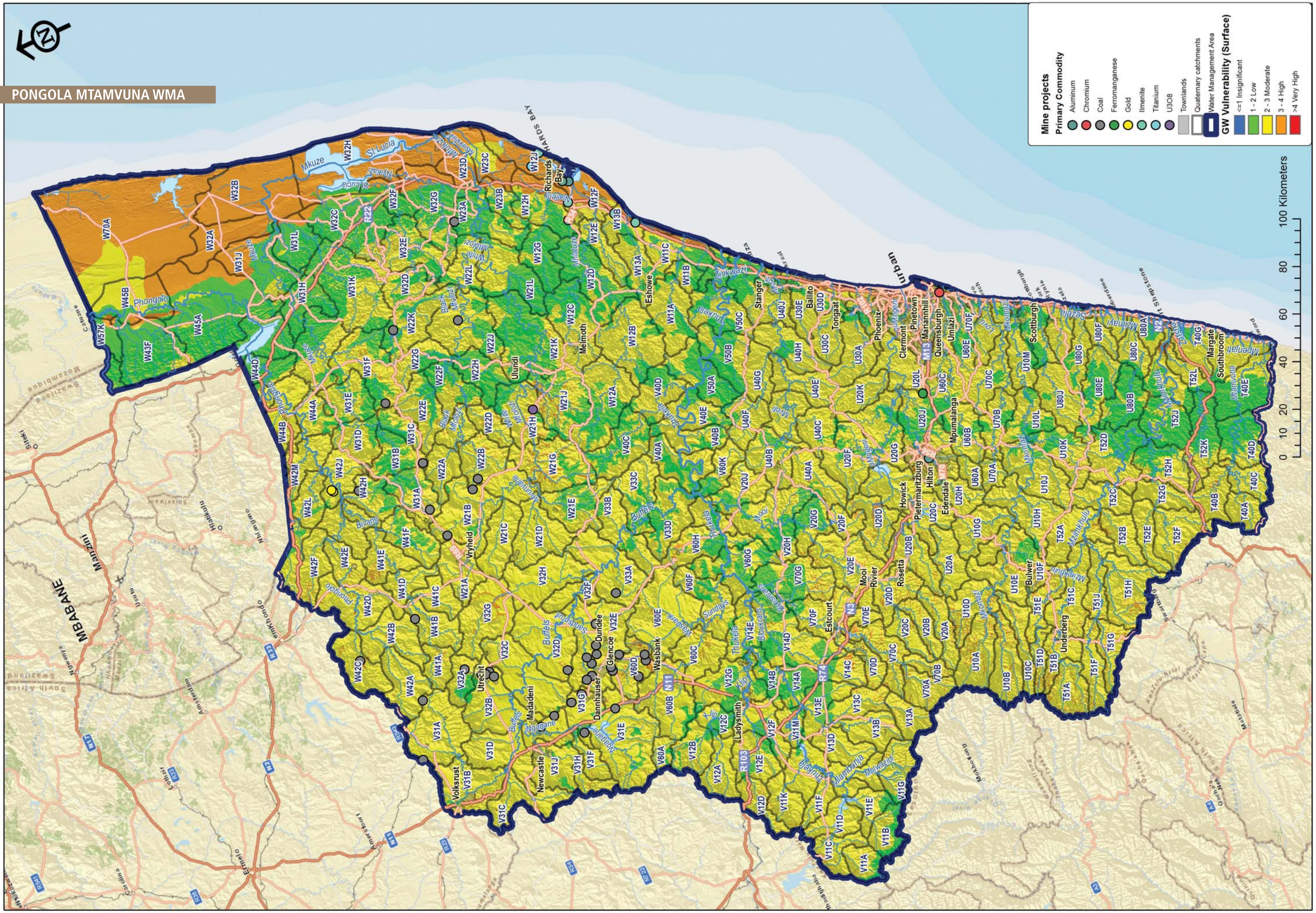


PONGOLA MTAMVUNA WMA




PONGOLA MTAMVUNA WMA
Mine projects
Primary Commodity
Aluminum
Chromium
Coal
Ferromanganese
Gold
Ilmenite
Titanium
U3O8
Townlands
Quaternary catchments
Water Management Area
Mineral Provinces Boundary
Mining Activity Risk
Insignificant
Low
Moderate
High
Very High
0 10 20 40 60 80 100 Kilometers
MBABANE
Durban
Pietermaritzburg
Newcastle
Ladysmith
Richards Bay

PONGOLA MTAMVUNA WMA



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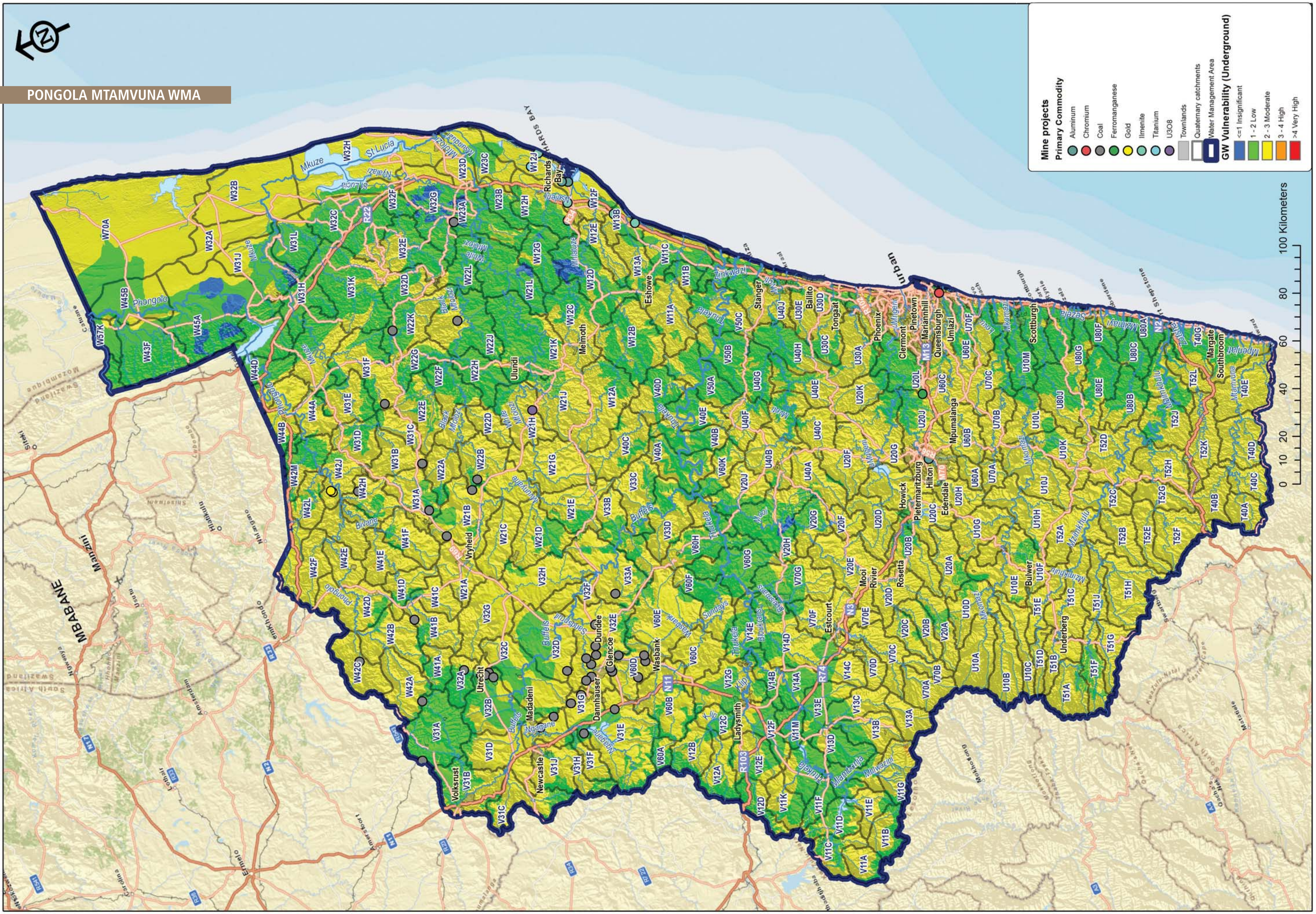

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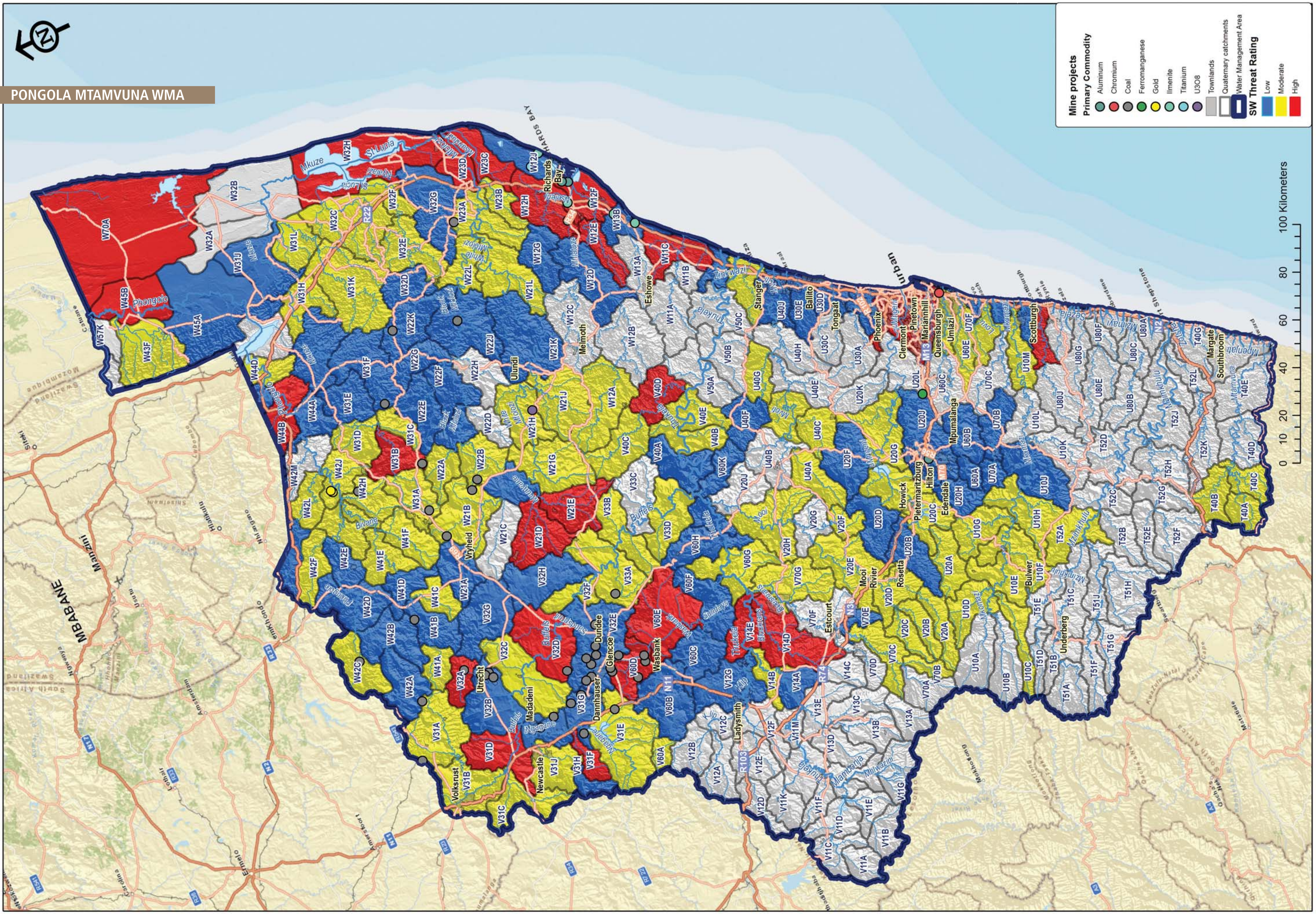
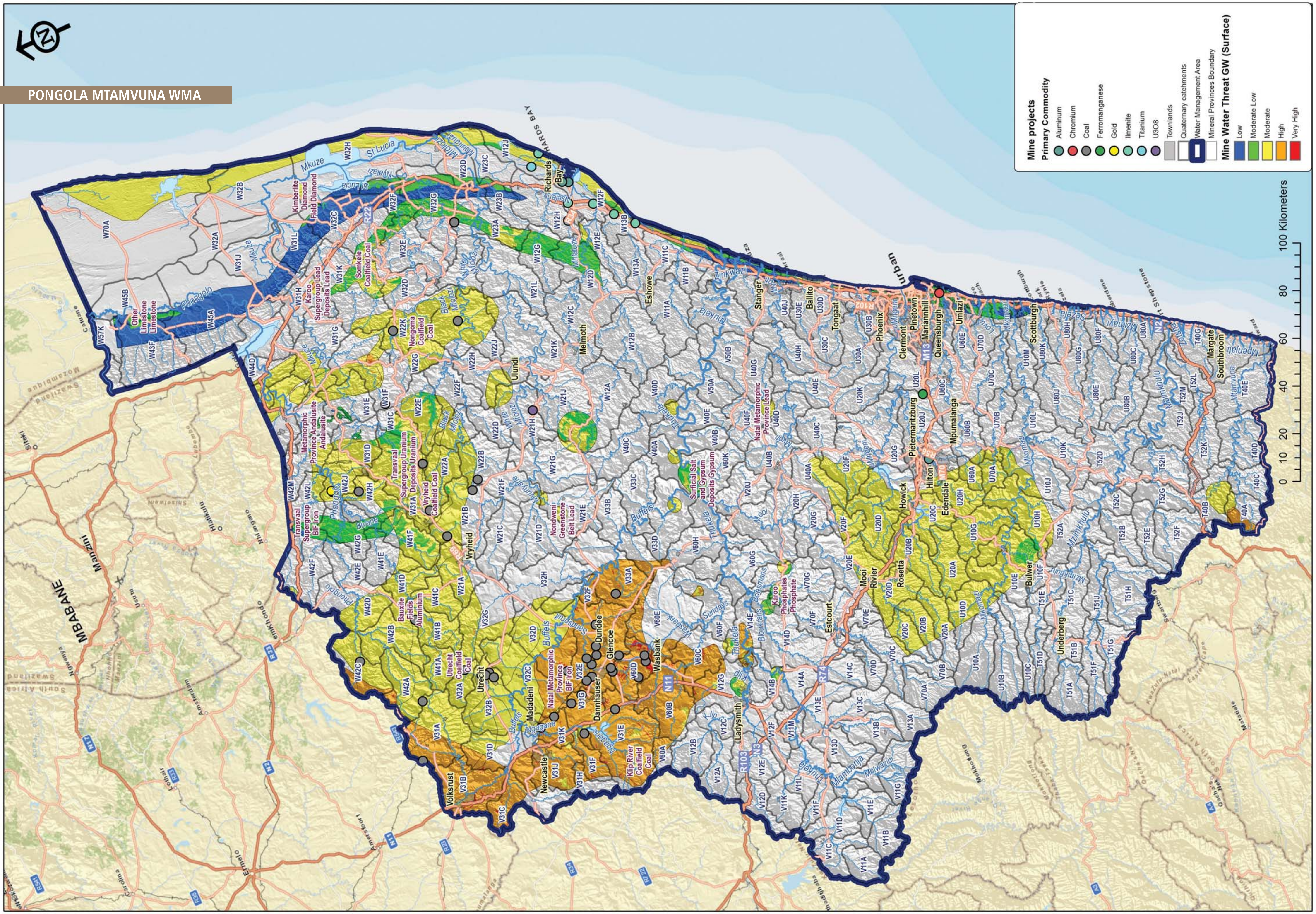


PONGOLA MTAMVUNA WMA



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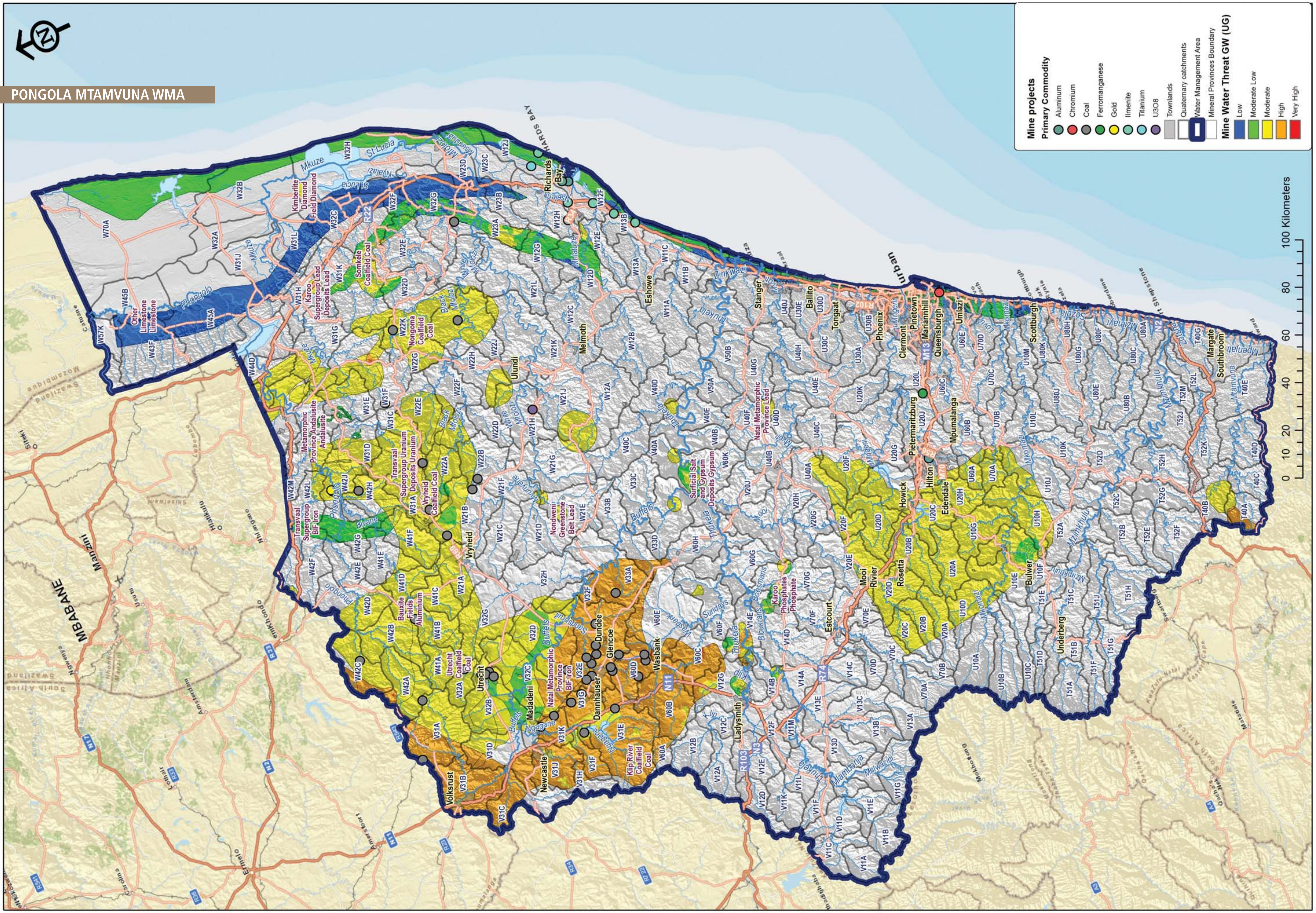

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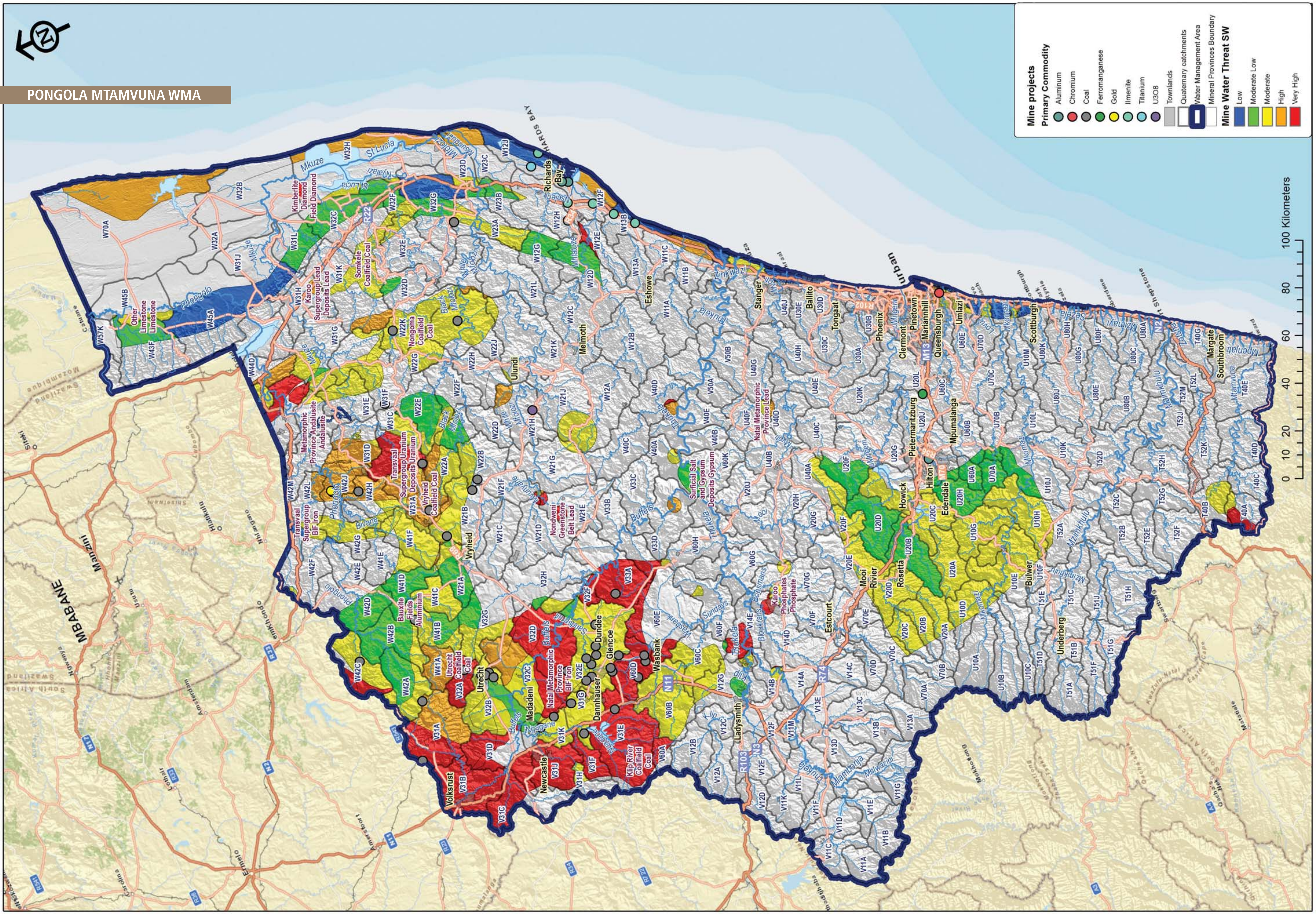


4.7 ORANGE WMA

WMA OVERVIEW

The Orange Water Management Area comprises the Upper Orange and Lower Orange catchment. The Orange River is of critical importance to South Africa. The Vaal River System is augmented from the upper Orange (Senqu) by the Lesotho Highlands Water Project, and supplies the economic heartland of South Africa. It also supplies thermal power stations on the Highveld, irrigation schemes covering large areas along the Vaal, middle and lower Orange Rivers. Some 15 million people are dependent on secure water supplies from this basin.

The Orange River rises in the Drakensberg mountains in Lesotho and flows westward through South Africa to the Atlantic Ocean at Alexander Bay and is the longest river in South Africa (2 200 km) with a basin area of about 973 000 km^2. Major tributaries in the catchment include the Vaal, Modder, Riet, Kraai and Caledon. The main storage dams in the Orange River are Gariep and Vanderkloof, Welbedacht Dam in the Caledon River, Rustfontein, Mockes, and Krugersdrift Dams in the Modder River with the Tierpoort and Kalkfontein Dams in the Riet River.

The Upper Orange River within the WMA stretches from the origin of the Senqu River in Lesotho to its confluence with the Vaal River at Douglas. Land use in the Upper Orange area of the WMA is mainly under natural vegetation with livestock farming as main economic activity. Extensive areas under dry land cultivation, mostly for the production of grains, are found in the north-eastern parts of the Upper Orange. The Modder Riet catchment is dominated by agricultural activities, with limited mining, and a few urban centres. Ficksburg is famous for the cherry orchards in the region. Large areas under irrigation for the growing of grain and fodder crops have been developed along the main rivers, mostly downstream of irrigation dams. Mangaung (Bloemfontein), Botshabelo and Thaba 'Nchu represent the main urban and industrial developments in the catchment. Two large hydropower stations were constructed at Gariep and Vanderkloof Dams. Mining activities have significantly declined and currently mainly relate to salt works and small diamond mining operations.

The Lower Orange includes the stretch of Orange River between the Orange-Vaal confluence and Alexander Bay. The Orange River, which forms a green strip in an otherwise arid but beautiful landscape, also forms the border between South Africa and Namibia. Other tributaries are the Ongers and Hartebeest rivers from the south, and the Molopo River and Fish River (Namibia) from the north. There are a number of highly intermittent water courses along the coast which drain directly to the ocean. The Lower Orange catchment is the largest, but also the driest and most sparsely populated catchment in South Africa.

Minerals and water from the Orange River are the key elements for economic development in the region, and still remain so. Irrigation is by far the dominant water use sector in the Lower Orange, representing 94% of the total requirements for water. The importance of the agriculture sector is attributable to the climate which is particularly suitable for the growing of some high value crops, together with the availability of water along the Orange River.

Both the flow regime and water quality in the Orange River have been severely impacted upon by extensive upstream developments. Salinity in the Orange River has increased due to the transfer of good quality water away from the Orange River (in Lesotho and the Upper Orange WMA) and as a result of saline irrigation return flows along the Orange River and its main tributaries. Poor quality water from the Vaal River, which contains a high proportion of irrigation return flows, mining drainage as well as treated urban effluent, also periodically enters the Orange River.

Present water demands on the Orange System are broadly in balance with supply. Any further demand will have to be met either by increasing the supply (by building more storage) or improving the management of existing uses.

MINING WITHIN WMA: OVERVIEW

In the Upper Orange catchment the main products of mining operations are diamonds and salt. The most significant mine is De Beers Koffiefontein. Discharges from mines are not significant in this WMA. The economy of the Upper Orange WMA is not influenced by the mining sector (<1.0 % of GDP), but urban centres such as Koffiefontein rely on the presence of mines for their existence (DWA, 2004i). Approximately 5% of the GDP of South Africa originates from the Upper Orange WMA (DWAF, 2003).

Mining operations in the Lower Orange include underground and surface mines as well as quarries. Products of the mining industry in the Lower Orange are predominantly alluvial diamonds, copper and salt. Base metals are also mined. There are a few quarries providing stone aggregate and gravel. O'Kiep Copper Mines, Black Mountain Mines (lead, zinc and copper), Allexkor Mine (alluvial diamonds), Kleinzee Diamond Mine and Hondeklipbaai Mine (alluvial diamonds) are the major mines in the catchment that contribute to the significantly on the economy. Wastewater from the mines is evaporated through evaporation ponds and is not returned directly into the river systems. As the mines are not dewatered the groundwater movement that produces pollution plumes in the dry river beds need to be investigated further.

SURFACE WATER PROFILE

Water Quality

Water quality monitoring in the WMA is limited to the main stem Orange River. The monitoring frequency is intermittent. The salinity status of the Upper Orange River is good, particularly water which flows from the Highlands of Lesotho in the Senqu River. The middle to lower Orange River is in a tolerable state with respect to salinity, with the reaches in vicinity of Onseepkans and Pella Mission being in the unacceptable range. The Modder and Riet Rivers are in a tolerable to unacceptable state in terms of salinity, primarily due to the impact of irrigation return flows and urbanisation. The salinity status at Douglas Barrage on the Vaal River is in the unacceptable range just upstream of the confluence with the Orange River, largely due to the impact of the upstream irrigation activities including from the Modder Riet catchment.

Ecological Condition

The present ecological state of the Upper Orange River is moderately to largely modified (C and D ecological categories), with an improvement to moderately modified to a largely natural state (C and B category) from Augrabies to the Orange River Mouth. The present ecological condition of many of the smaller tributaries are in a moderately modified state (category C) and largely modified state (D category) with a small percentage of smaller tributaries in less developed areas in the catchment in largely natural state (B present ecological condition).

Threat to the Surface Water Resources

Within the Orange WMA, of the 43% of the quaternary catchments assessed (with data available) 24% (5 rating red) of the catchment area includes stressed surface water resources that are under threat, 2% (5 rating green) that require the precautionary approach to management to maintain good condition, and 74% (rated 1 or 3) where the surface water resources do have capacity available to accept degrees of impact.

MINERALOGY PROFILE

There are four significant mineral provinces in the WMA:

- The TSG is a widespread mineral province from which iron, gold, asbestos and dolomite are produced. Generally the province has medium mineralogical risk, mainly due to potentially toxic trace elements, notably lead and zinc, which occur in minor/trace minerals within the dolomites. The iron and asbestos deposits (which overlie the dolomites) have low mineralogical risk.
- Quaternary sedimentary-hosted deposits are mainly diamonds, gypsum and heavy mineral sands – all are largely chemically inert and have low mineralogical risk ratings.
- The Karoo uranium province is a widespread , largely unexploited province with high mineralogical risk due to ARD and radionuclides.
- The Northern Cape base metal deposits are massive sulphide deposits of copper, lead and zinc, with high mineralogical risk due to their substantial ARD potential and numerous potentially toxic trace elements.

The remaining mineral deposits in the WMA include kimberlites with medium risk ratings and a variety of metamorphic belt-hosted deposits with low risk ratings.

GROUNDWATER VULNERABILITY PROFILE

General aquifer profile (Lithology aquifer type): there are three major aquifer systems in the WMA:

- Intergranular Coastal (undifferentiated coastal deposits) with borehole yields between <0.1 l/s – water quality >1000 mS/m.
- Intergranular alluvial river deposits with borehole yields <0.5 l/s, but poor water quality (EC >1000 mS/m).
- Intergranular Palaeo-alluvial deposits (Kalahari Group sediments) with boreholes <2.0 l/s and water quality from fresh (<70 mS/m) to hyper saline (>10 000 mS/m)
- Intergranular and fractured aquifers with borehole yields between <0.5 l/s and water quality ranges 70 to 300 mS/m and >1000 mS/m;
- Fractured aquifers with borehole yields between 0.1 and 2.0 l/s and water quality ranges <70 mS/m, 70-300 mS/m and >300-1000 mS/m;
- Secondary aquifer systems (Karoo Dolerite Dykes and large fault systems) in fractured aquifer systems with moderate to high yields (0.5 to 2.0 l/s).

Aquifer vulnerability rating:

The overall vulnerability rating in the WMA varies from ~1.0 to 1.4 (insignificant to low, in ~40% of the WMA due to low yielding, intergranular and fractured rock aquifer types with brackish to saline water quality). The remaining 60% of the WMA have fractured aquifer systems (50%) with vulnerability ratings between 1.5 (low) and 2.2 . Karoo Dolerite dykes in the Karoo Supergroup, Beaufort and Ecca Groups increase the vulnerability rating to 3.00 (moderate). The Kalahari Group aquifers have a vulnerability rating of ~2.5 depending on the local water quality status (i.e. fresh to saline).

Intergranular – Inland river alluvium and coastal alluvium deposits:

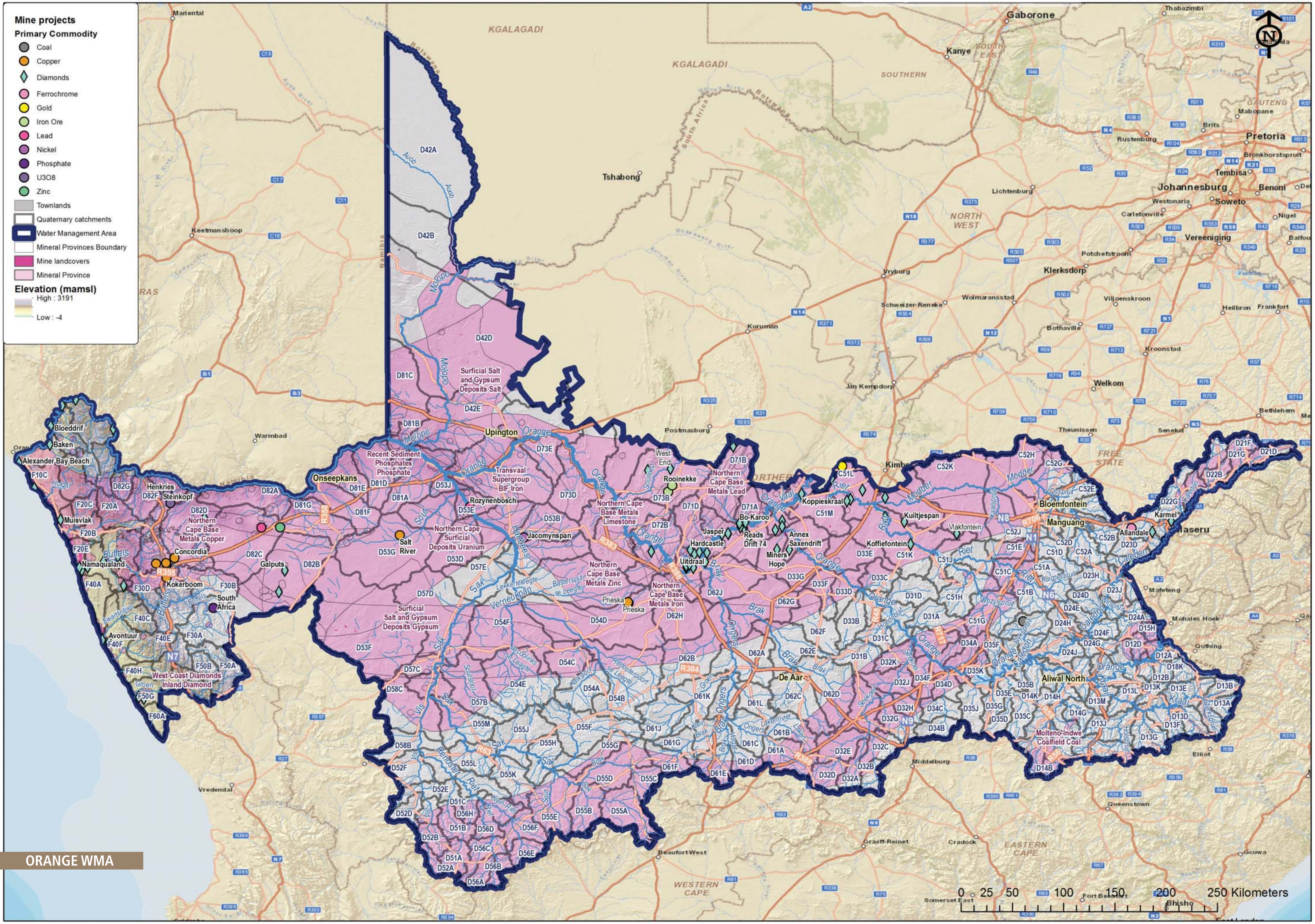
- Unconsolidated/semi-consolidated buried inland river alluvial deposits (T-Qk) – vulnerability rating from 2.1 (low with water quality 300 to 1000 mS/m) to 2.8 (low with water quality <300 mS/m); and
- Intergranular (coastal region) – vulnerability ratings ~2.5.
- Intergranular and fractured aquifer systems:
- Namaqua-Natal Metamorphic Belt Granite-Gneiss rocks (Mokolian various groups of acid/intermediate/alkaline intrusive rocks, granulites,) – vulnerability ratings from 1.2 (low) to 2.1 (moderate) due to variations in water qualities from saline (>300 mS/m) to brackish (70-300 mS/m);
- Namaqua-Natal Metamorphic Belt rocks – meta-arenaceous formations with vulnerability ratings of 1.0 to 1.7 (low) due to low yields (<0.5 l/s) and brackish to saline water (300 to 1000 mS/m) and meta-calcareous formation with vulnerability ratings of ~2.0 (moderate) due to fresh to brackish water quality (70 to 300 mS/m).

Fractured aquifer systems:

- Karoo Supergroup aquifers – Vulnerability ratings Beaufort Group Adelaide/Escourt Subgroups (argillaceous rocks) at 1.7 (low) to 2.1 (moderate) , Ecca Group Volksrust (shale) at 1.7 (low) and the underlying Dwyka Group (shale) at 1.3 (low);
- Karoo dolerite dykes (abundant) in the upper Beaufort Group – vulnerability ratings from 2.1 (moderate) to 3.0 (moderate).

Key areas of concern:

- Fresh water aquifers: aquifer systems with water quality <70 mS/m mapped in most of the intergranular & fractured and fractured aquifer systems;
- Local freshwater springs due to the occurrence of Karoo Dolerite dykes and sills; and
- Coastal aquifers may be underlain by brackish to saline water which will migrate upwards to the fresh water aquifer during mining/bulk water abstractions.


Mine projects
Primary Commodity
Coal
Copper
Diamonds
Ferrochrome
Gold
Iron Ore
Lead
Nickel
Phosphate
U3O8
Zinc
Townlands
Quaternary catchments
Water Management Area
Mineral Provinces Boundary
Mine landcovers
Mineral Province
Elevation (mamsl)
High : 3191
Low : -4
0 25 50 100 150 200 250 Kilometers
KGALAGADI
NORTH WEST
FREE STATE
EASTERN CAPE
WESTERN CAPE
Gaborone
Pretoria
Johannesburg
Soweto
Upington
Bloemfontein
Aliwal North
De Aar
Kimberley
Surficial Salt and Gypsum Deposits Salt
Recent Sediment Phosphates Phosphate
Transvaal Supergroup BIF Iron
Northern Cape Base Metals Limestone
Northern Cape Base Metals Lead
Northern Cape Base Metals Copper
Northern Cape Surficial Deposits Uranium
Northern Cape Base Metals Zinc
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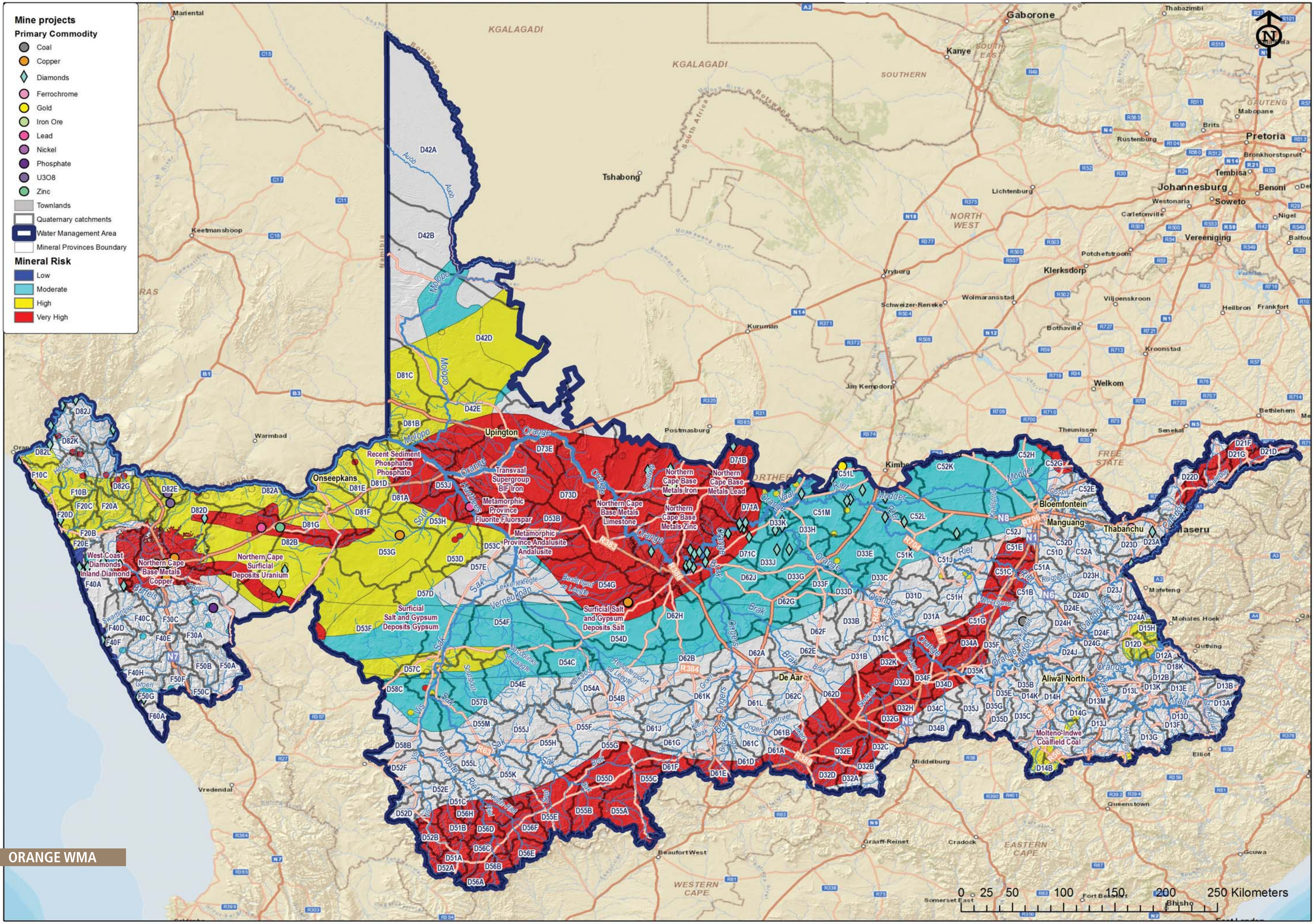
Surficial Salt and Gypsum Deposits Gypsum
West Coast Diamonds Inland Diamond
Molteno-Indwe Coalfield Coal

ORANGE WMA


Mine projects
Primary Commodity
Coal
Copper
Diamonds
Ferrochrome
Gold
Iron Ore
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Nickel
Phosphate
U3O8
Zinc
Townlands
Quaternary catchments
Water Management Area
Mineral Provinces Boundary
Mineral Risk
Low
Moderate
High
Very High
Recent Sediment Phosphates Phosphate
Transvaal Supergroup BIF Iron
Metamorphic Province Fluorite Fluorspar
Metamorphic Province Andalusite Andalusite
Northern Cape Base Metals Iron
Northern Cape Base Metals Lead
Northern Cape Base Metals Limestone
Northern Cape Base Metals Zinc
West Coast Diamonds Inland Diamond
Northern Cape Base Metals Copper
Northern Cape Surficial Deposits Uranium
Surficial Salt and Gypsum Deposits Gypsum
Surficial Salt and Gypsum Deposits Salt
Molteno-Indwe Coalfield Coal
Upington
Onseepkans
Bloemfontein
Manguang
Thabanchu
Maseru
De Aar
Aliwal North
Gaborone
Kanye
Tshabong
Pretoria
Johannesburg
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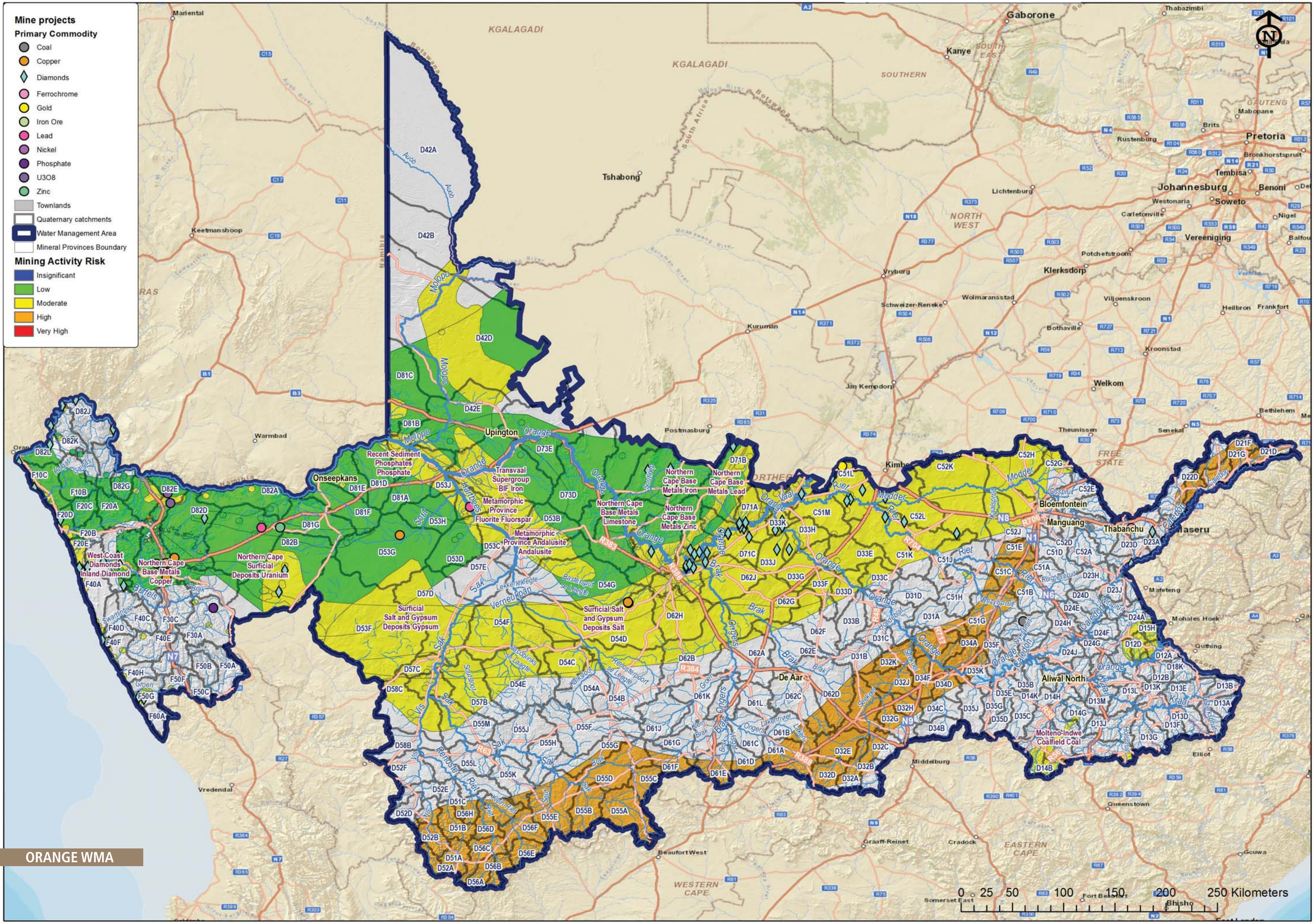
Vereeniging
Klerksdorp
Welkom
Kimberley
Middelburg
Queenstown
Cradock
Graaff-Reinet
Beaufort West
Vredendal
Warmbad
Keetmanshoop
Mariental
KGALAGADI
SOUTHERN
NORTH WEST
FREE STATE
EASTERN CAPE
WESTERN CAPE
GAUTENG
0 25 50 100 150 200 250 Kilometers

ORANGE WMA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Townlands
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Water Management Area
Mineral Provinces Boundary
Mining Activity Risk
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Transvaal Supergroup BIF Iron
Metamorphic Province Fluorite Fluorspar
Metamorphic Province Andalusite Andalusite
Northern Cape Base Metals Iron
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Molteno-Indwe Coalfield Coal
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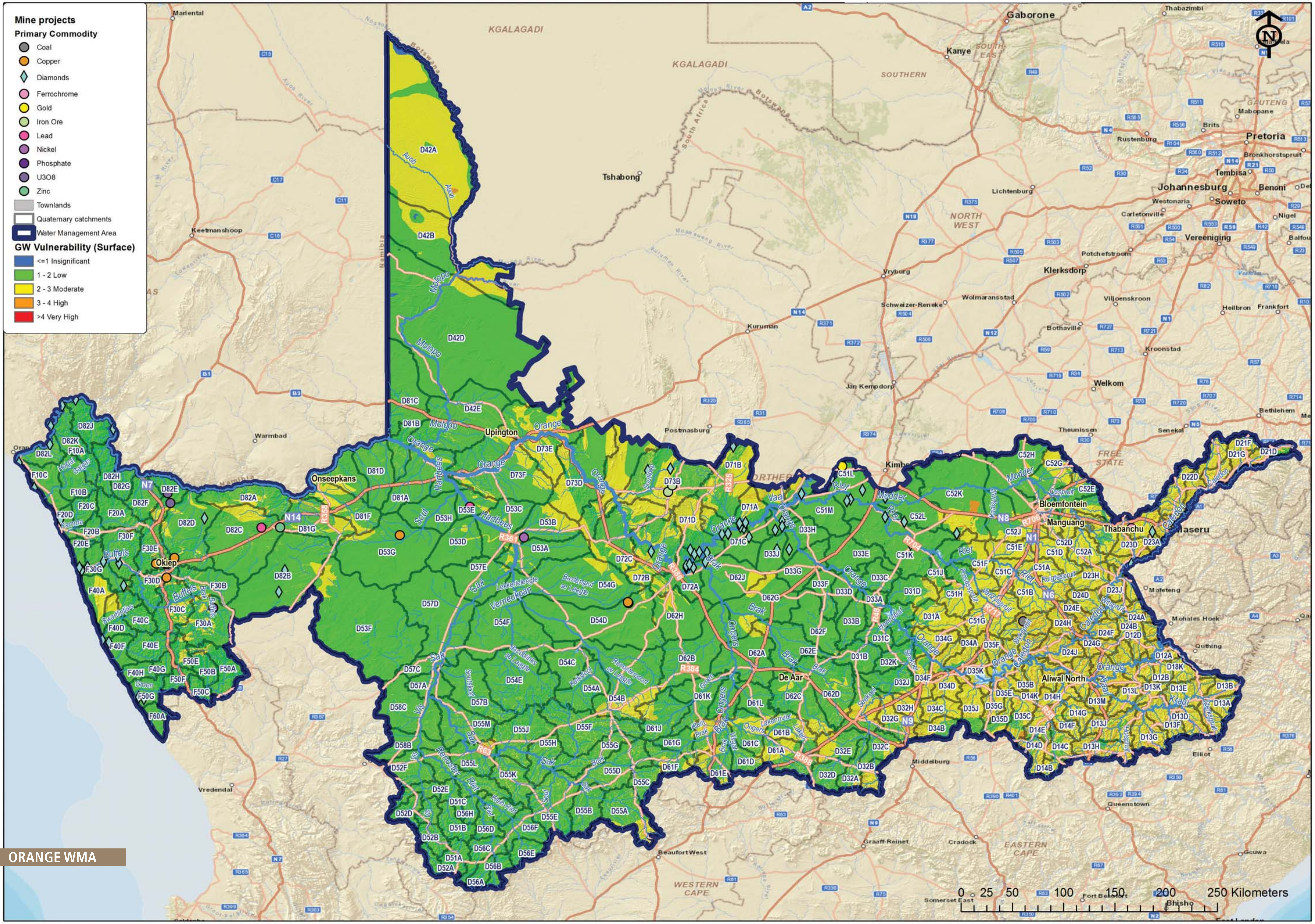
ORANGE WMA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Lead
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Phosphate
U3O8
Zinc
Townlands
Quaternary catchments
Water Management Area
GW Vulnerability (Surface)
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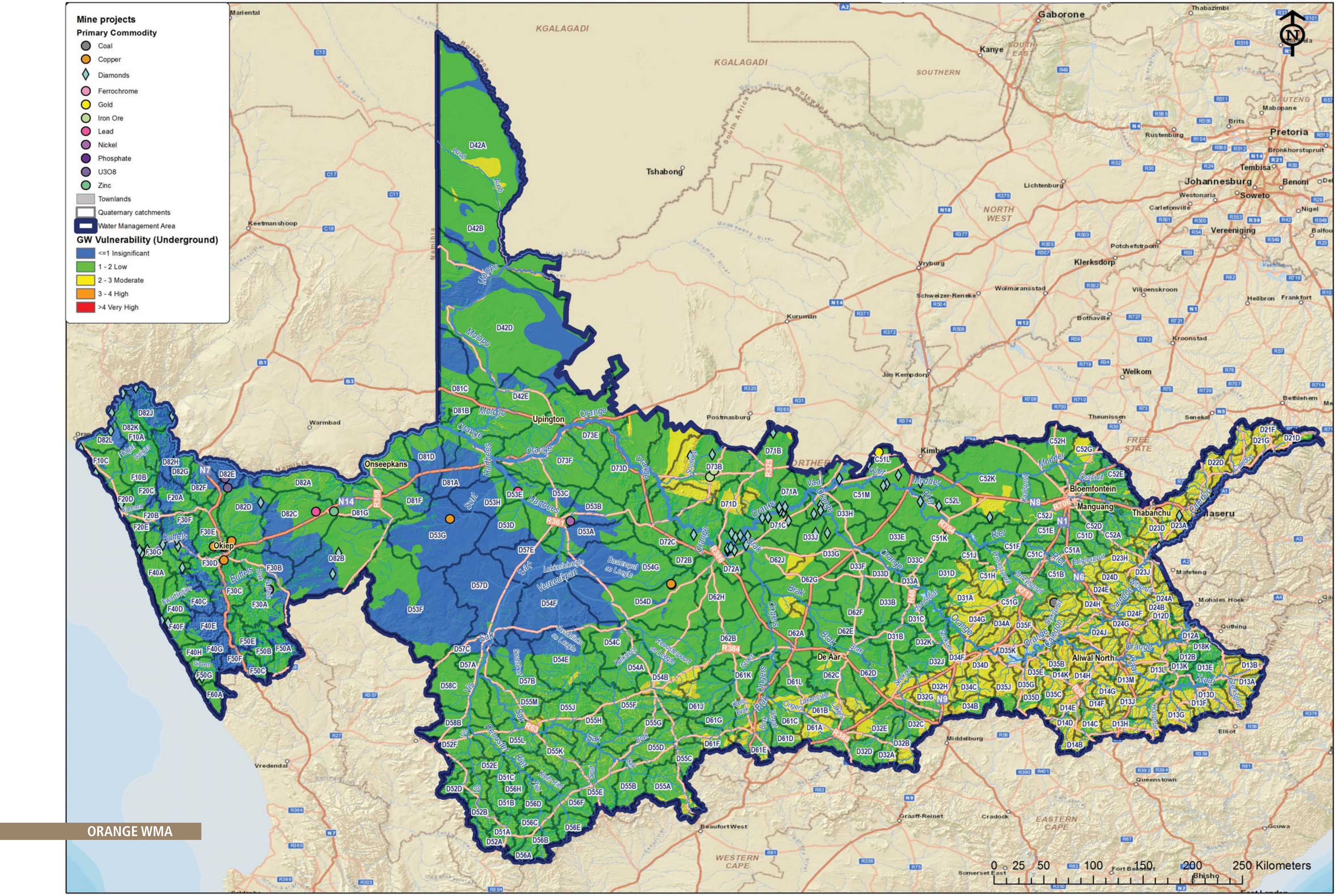
1 - 2 Low
2 - 3 Moderate
3 - 4 High
>4 Very High
0 25 50 100 150 200 250 Kilometers

ORANGE WMA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Iron Ore
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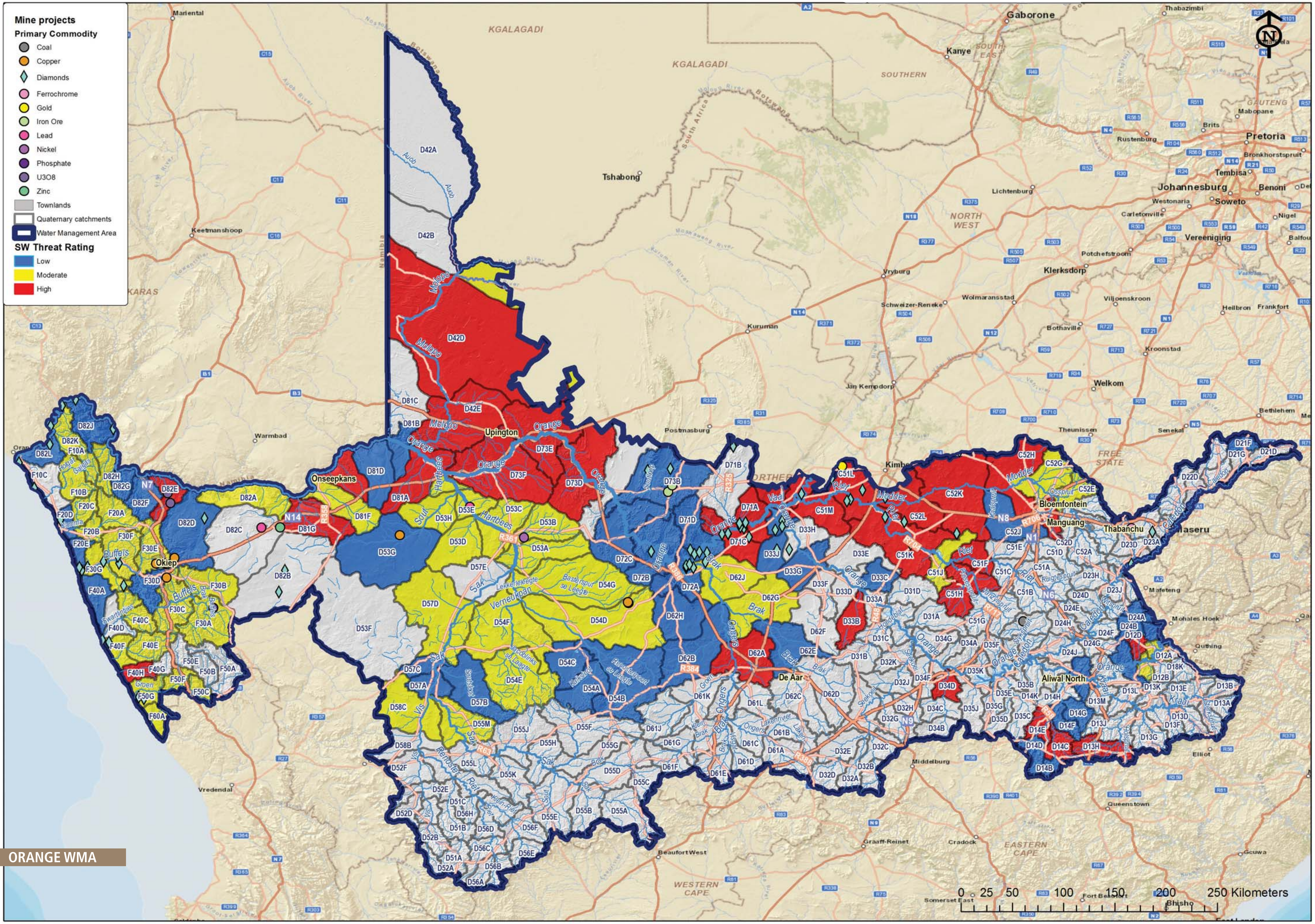
Phosphate
U3O8
Zinc
Townlands
Quaternary catchments
Water Management Area
GW Vulnerability (Underground)
<=1 Insignificant
1 - 2 Low
2 - 3 Moderate
3 - 4 High
>4 Very High
ORANGE WMA
0 25 50 100 150 200 250 Kilometers
KGALAGADI
Gaborone
Pretoria
Johannesburg
Bloemfontein
Upington
Maseru
Aliwal North
De Aar
Okiep
Onseepkans
Welkom
Kimberley
NORTH WEST
FREE STATE
EASTERN CAPE
WESTERN CAPE
Orange


Mine projects
Primary Commodity
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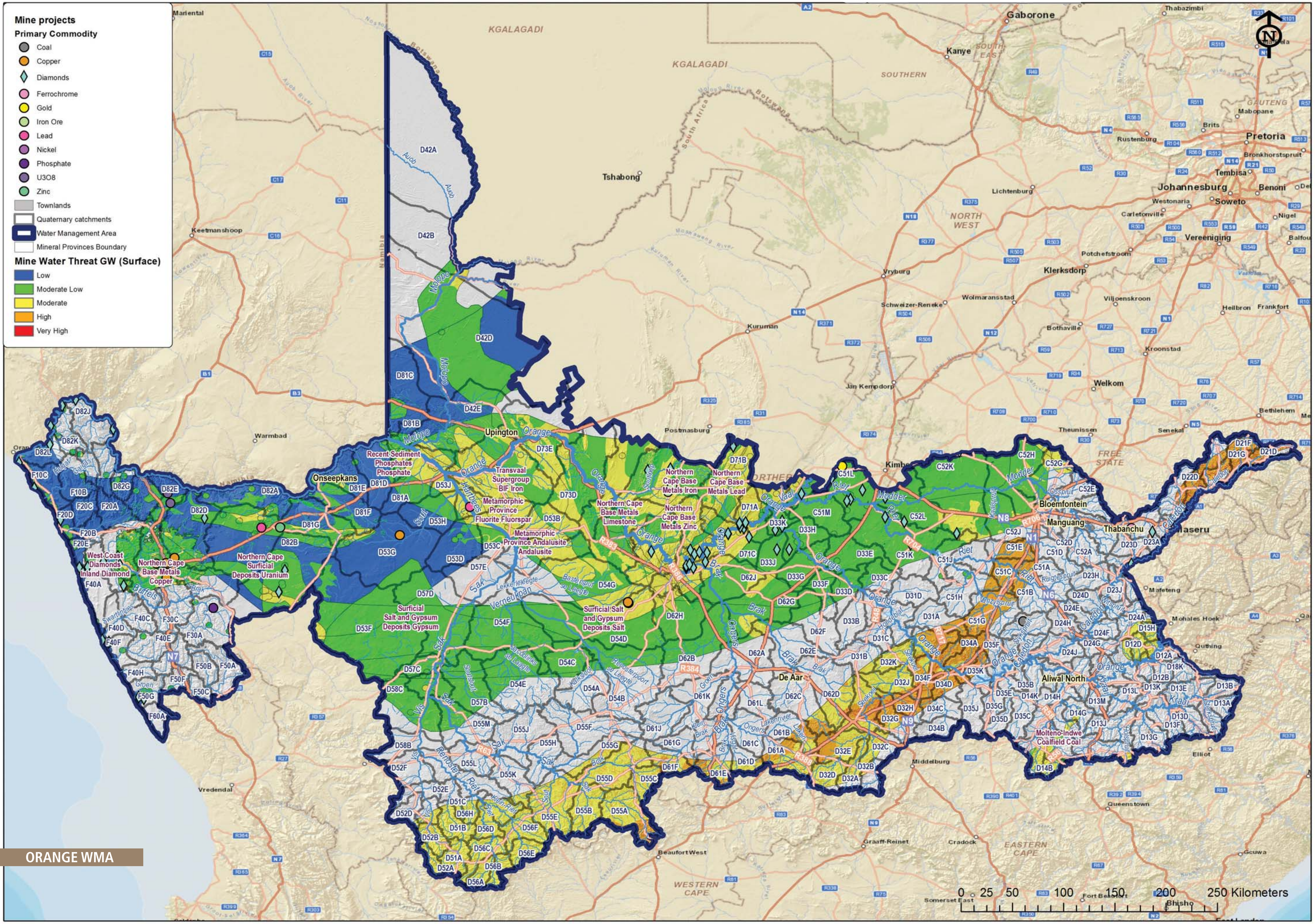
Phosphate
U3O8
Zinc
Townlands
Quaternary catchments
Water Management Area
SW Threat Rating
Low
Moderate
High
0 25 50 100 150 200 250 Kilometers
KGALAGADI
Gaborone
Kanye
SOUTHERN
Tshabong
Mariental
Keetmanshoop
KARAS
Warmbad
Pretoria
Johannesburg
Soweto
Vereeniging
Klerksdorp
Potchefstroom
Rustenburg
Lichtenburg
NORTH WEST
Vryburg
Kuruman
Welkom
FREE STATE
Bloemfontein
Thabanchu
Maseru
Upington
Onseepkans
Okiep
De Aar
Aliwal North
Postmasburg
Middelburg
Beaufort West
WESTERN CAPE
EASTERN CAPE
Queenstown
Cradock
Graaff-Reinet
Vredendal
Orange
Molopo
Vaal
Riet
Modder
Caledon
Sak
Brak
Hartbees
Buffels


Mine projects
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Diamonds
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Iron Ore
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Nickel
Phosphate
U3O8
Zinc
Townlands
Quaternary catchments
Water Management Area
Mineral Provinces Boundary
Mine Water Threat GW (Surface)
Low
Moderate Low
Moderate
High
Very High
Recent Sediment Phosphates Phosphate
Transvaal Supergroup BIF Iron
Metamorphic Province Fluorite Fluorspar
Metamorphic Province Andalusite Andalusite
Northern Cape Base Metals Iron
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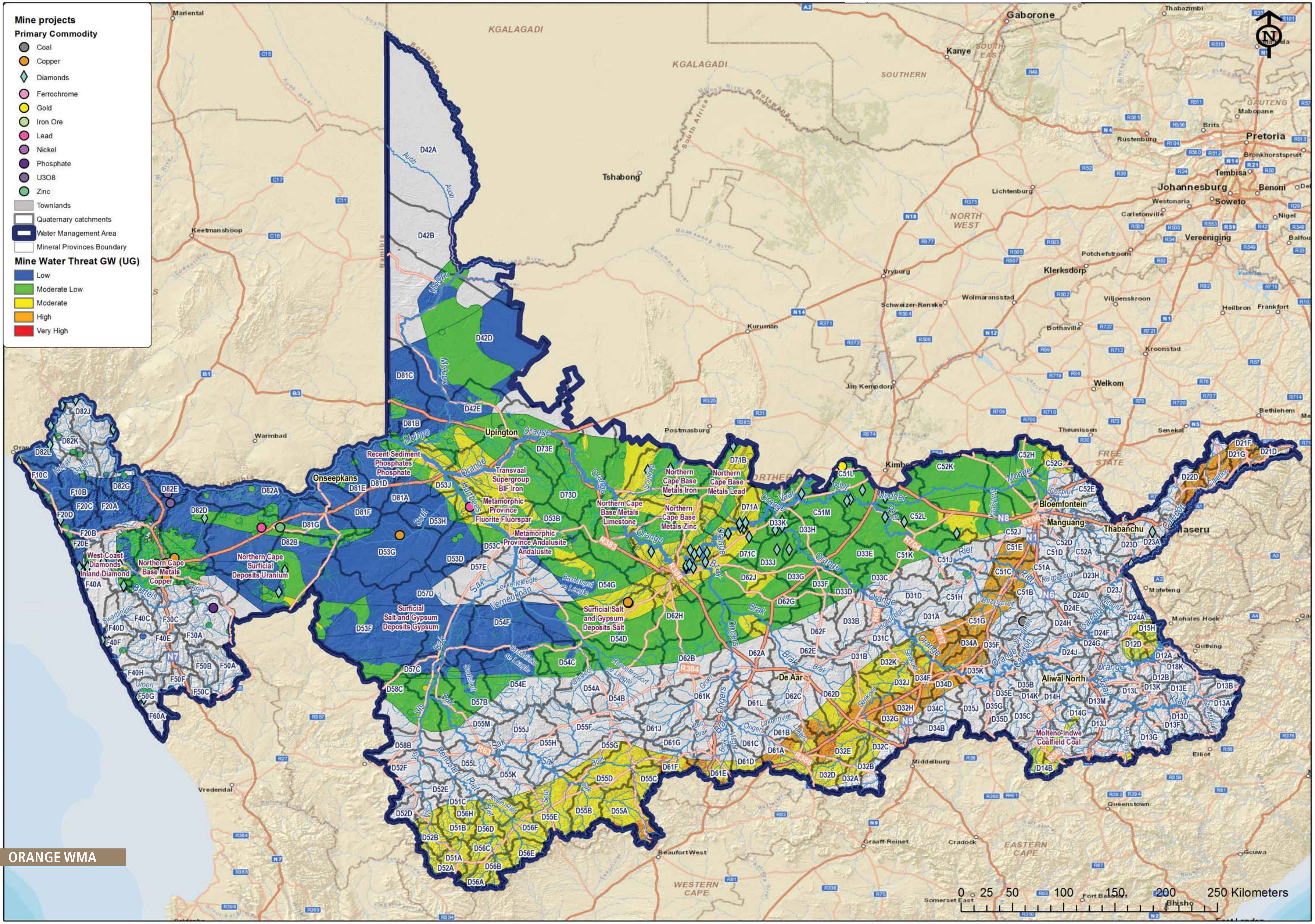
Surficial Salt and Gypsum Deposits Salt
Molteno-Indwe Coalfield Coal
Upington
Bloemfontein
De Aar
Aliwal North
Maseru
0 25 50 100 150 200 250 Kilometers

ORANGE WMA


Mine projects
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Diamonds
Ferrochrome
Gold
Iron Ore
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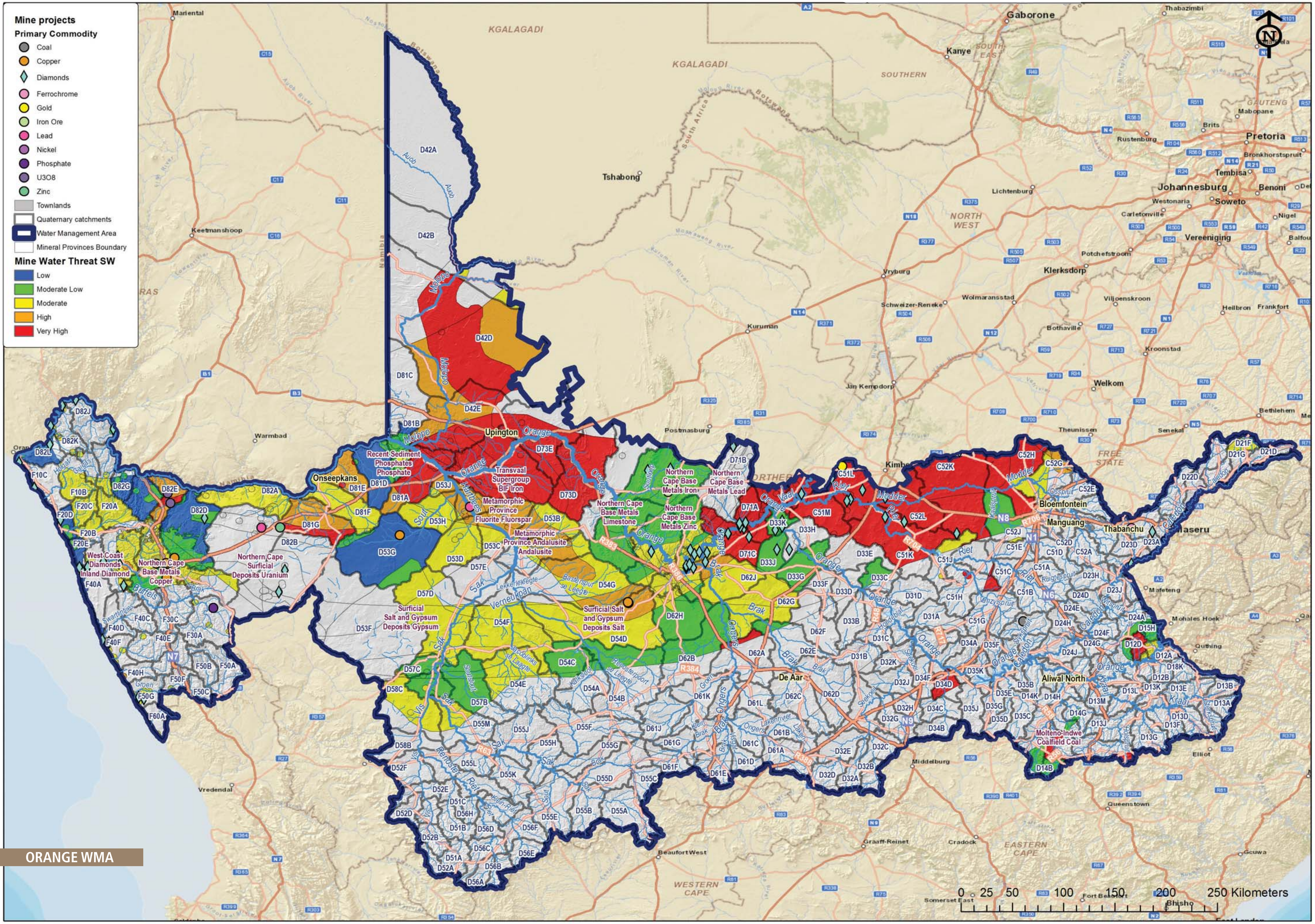
Nickel
Phosphate
U3O8
Zinc
Townlands
Quaternary catchments
Water Management Area
Mineral Provinces Boundary
Mine Water Threat GW (UG)
Low
Moderate Low
Moderate
High
Very High
Upington
Bloemfontein
Kimberley
Johannesburg
Pretoria
Maseru
De Aar
Aliwal North
0 25 50 100 150 200 250 Kilometers

ORANGE WMA


Mine projects
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Diamonds
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Iron Ore
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Phosphate
U3O8
Zinc
Townlands
Quaternary catchments
Water Management Area
Mineral Provinces Boundary
Mine Water Threat SW
Low
Moderate Low
Moderate
High
Very High
0 25 50 100 150 200 250 Kilometers

ORANGE WMA

MZIMVUBU TSITSIKAMMA WMA

WMA OVERVIEW

The Mzimvubu-Tsitsikamma WMA comprises almost the entire Eastern Cape Province. It includes a number of very large and vastly different catchments, from the arid Karoo in the west to the sub-tropical in the north east. The WMA comprises the Mzimbuvu, Mtata, Mbashe, Groot Kei, Nahoon, Buffalo, Keiskamma, Boesmans River, Great Fish, Sundays, Kowie, Kromme, Groot, Gamtoos and Tsitsikamma catchment areas. All these rivers drain to the Indian Ocean.

The Mzimvubu River (the largest undeveloped river in South Africa) flows through deep gorges across the coastal plain before discharging into the Indian Ocean at Port St Johns. The Amatola coastal catchments feature the main rivers of the Buffalo, Keiskamma and Nahoon that drain in a south-easterly direction into the Indian Ocean near East London. The Great Kei catchment drains the northern slopes of the Amatola mountain range and the southern slopes of the Stormberg / Drakensberg range with the Great Kei River exiting into the Indian Ocean at Kei Mouth north of East London. The catchments of the Great Fish and Sundays Rivers extend from the watershed of the Orange River system to the shoreline of the east coast of South Africa. The Fish and Sundays catchments are very dry. The Krom River drains a narrow valley between the Sundays Mountains to the interior and the Tsitsikamma Mountains towards the coast. The Gamtoos River catchment includes the Groot River and Kouga River as major tributaries. The Groot River catchment lies in the Karoo and the Kouga River rises in the Baviaanskloof Valley. These rivers join to form the Gamtoos River which drains the western slopes of the Elandsberg mountain range to the Indian Ocean.

The climate and temperature variations are closely related to elevation and proximity to the coast. The area experiences a mild, temperate climate along the coast to more extreme conditions inland with most rainfall occurring during the summer months.

Urban areas include Nelson Mandela Bay (Port Elizabeth, Uitenhage and Despatch) and Buffalo City and the towns of Grahamstown, Craddockand Queenstown.

A large percentage of the population of the WMA is situated in rural areas where their incomes are directly linked to the agricultural sector, which is mainly subsistence. Extensive irrigation agriculture has developed alongside the Fish and Sundays Rivers. Other main economic activities include tourism and commercial forestry activities, as well as manufacturing - vehicle manufacturing being the dominant industry in the Buffalo City Municipal Area. The only area expected to experience significant growth in the future are the Buffalo City Municipal and the Nelson Mandela Bay Municipal areas where employment opportunities will attract people from the smaller urban centres and rural areas.

The Mzimvubu to Keiskamma area is a water rich area in which the water resources have not been fully developed. Small hydro-electric developments exist in the area, and inter-basin water transfer occurs between the Kei and the Mbashe catchments. The water requirements of the area are much less than the potential yield and this situation is likely to continue. There are few areas where water requirements exceed the yield of the local water resources and interventions are needed. Feasibility studies are underway for future dams. These areas include additional water supply for Queenstown (possibly from Xonxa Dam), for Buffalo City Municipality, Albany Coast and towns in the Bushman's River catchment. Future water resource development and interventions are also required in the Nelson Mandela Metropolitan Municipality to support growth in water requirements. The water requirements of the Great Fish and Sundays catchments are being met with water transferred from the Orange River. Groundwater development and improved management is required to meet the water requirements and support water services in many areas in the WMA.

MINING WITHIN WMA: OVERVIEW

Mining activity in the WMA is very limited with the Molteno-Indwe Coalfield and isolated deposits of phosphate, nickel, lead, titanium and zirconium.

SURFACE WATER PROFILE

Water Quality

The water quality in the WMA is not well monitored. Monitoring is limited to the middle reaches of the Mzimvubu catchment, upper tributary catchments of the Kei River catchment (S20 and S50) and selected coastal quaternary catchments in the Fish and Sundays River catchment areas. Based on the available data, the water quality present state as related to salinity related water quality variables varies within the WMA. Within the Mzimvubu catchment the salinity status of the upper tributaries is good, as is that of the smaller tributaries within the S20 and S50 catchments. The salinity status of the coastal areas of the Fish to Sundays river catchments are in the unacceptable range. This is influenced by the naturally saline nature of these rivers due to the geology of the area, but also due to intensive irrigation return flow which impacts the river systems. Improved monitoring is required to fully understand the water quality state of the WMA.

Ecological Condition

The present ecological condition of the rivers in the Mzimbuvu catchment area is good with the area predominantly in a natural to moderately modified state (B and C present ecological state). The rivers in the Groot Kei and Amatole Regions are in a moderately modified to largely modified state (C and D category) with a small percentage of smaller tributaries in less developed areas in the catchment in a natural to largely natural (B present ecological condition). Within the Fish to Tsitsikamma catchments, the present ecological condition of the rivers is predominantly in a largely natural to moderately modified state (B and C present ecological state). However rivers in the vicinity of Craddock, Port Elizabeth, Uitenhage and other smaller town have a D present ecological state.

Threat to the Surface Water Resources

Within the Mzimvubu Tsitsikamma WMA, of the 21% of the quaternary catchments assessed (with data available) 35% (5 rating red) of the catchment area includes stressed surface water resources that are under threat, and 65%,(rated 1 or 3) where the surface water resources do have capacity available to accept degrees of impact. Refer to the map on page 92.

MINERALOGY PROFILE

There are two significant mineral provinces in the WMA:

- The Karoo coalfields with significant risk of ARD, resulting in a medium risk where there is more neutralisation capacity (Molteno-Indwe Coalfield).
- Quaternary sedimentary-hosted deposits are mainly phosphate, gypsum and heavy mineral sands – all are largely chemically inert and have low mineralogical risk ratings.

The remaining mineral deposits in the WMA include various lead and nickel deposits, all of which have a high mineralogical risk rating due to ARD potential and potentially toxic trace elements

GROUNDWATER VULNERABILITY PROFILE

General aquifer profile (Lithology aquifer type): there are three major aquifer systems in the WMA:

- Intergranular and fractured aquifers with borehole yields between 0.5 and 2.0 l/s and water quality ranges <70 mS/m;
- Fractured aquifers with borehole yields between 0.1 and 2.0 l/s and water quality ranges <70 mS/m, 70-300 mS/m and >300-1000 mS/m;
- Intergranular Coastal (T-Qa undifferentiated coastal deposits) with borehole yields between 2.0 and 5.0 l/s – water quality 70-300 mS/m and >300. Multi-layered aquifer systems may occur in the coastal belts (fresh, underlain by saline groundwater); and
- Intergranular Alluvial river deposits with borehole yields >5 l/s, but with poor water quality (EC >1000 mS/m).
- Intergranular and Fractured aquifer systems (Karoo Dolerite dykes and sills) with moderate to high yields (0.5 to 2.0 l/s).

Aquifer vulnerability rating:

The overall vulnerability rating in the WMA varies from ~1.0 to 1.9 (insignificant to low, less than 20% of the WMA due to low yielding, fractured rock aquifer types) to (>3 high, ~15% of the WMA area due to Karoo Dolerite sills/dykes and inland alluvial/coastal aquifer systems) with the remaining part falling in the moderate vulnerability rating slot (1.9 to 2.6 for intergranular and fractured and fractured aquifer systems).

Intergranular (alluvial)

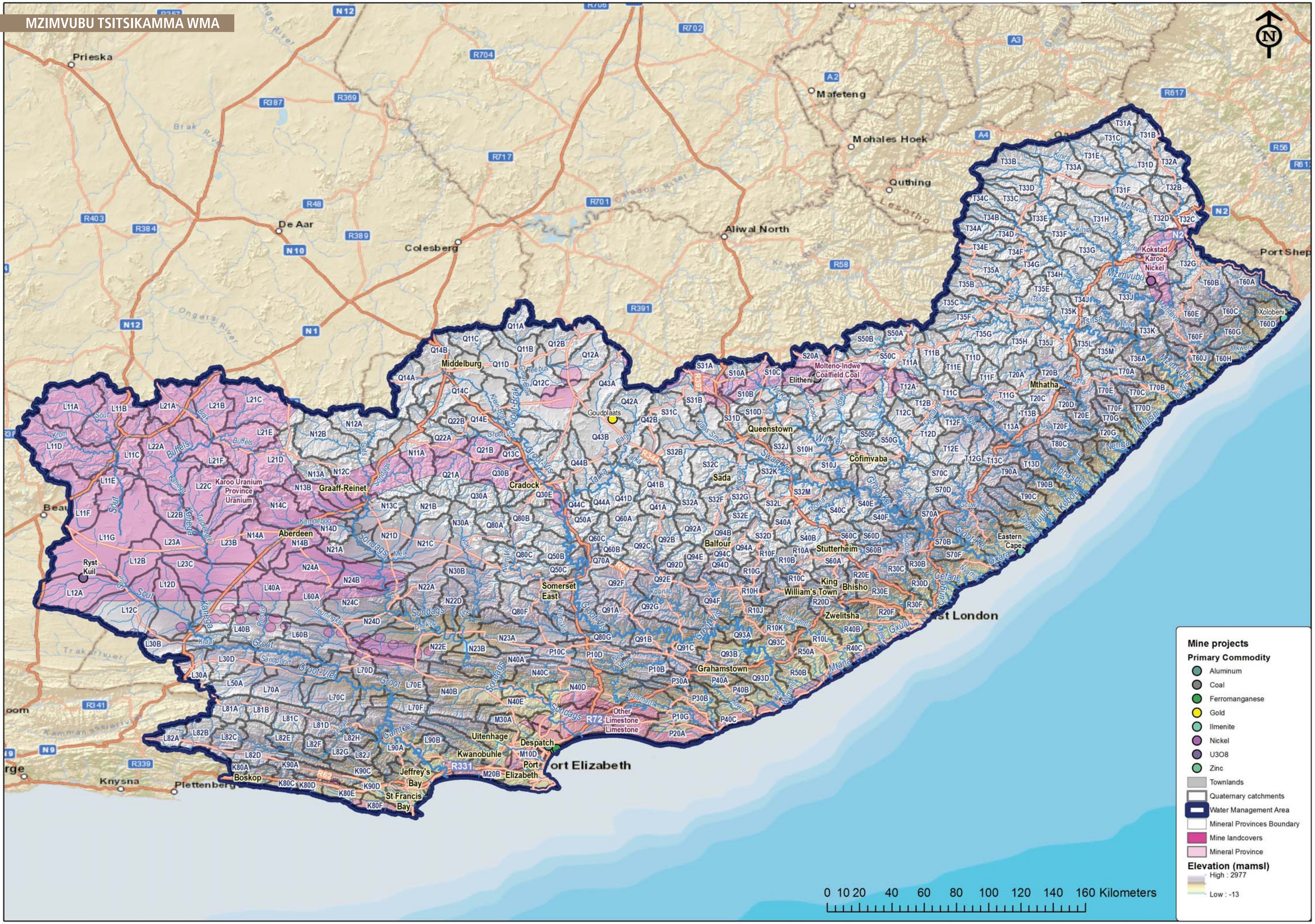
- Unconsolidated/semi-consolidated coastal and inland river alluvial deposits (T-Qm) – vulnerability rating of ~2.6 (moderate);
- Intergranular and fractured aquifer systems:
- Karoo Supergroup aquifers in the Cape Folded Belt region: Beaufort Group Adeliade and Escourt mudstone and arenite – vulnerability ratings at 1.6 ± 0.1 (low). Cape Fold Belt region vulnerability rating to just below 2.0 (moderate);

Fractured:

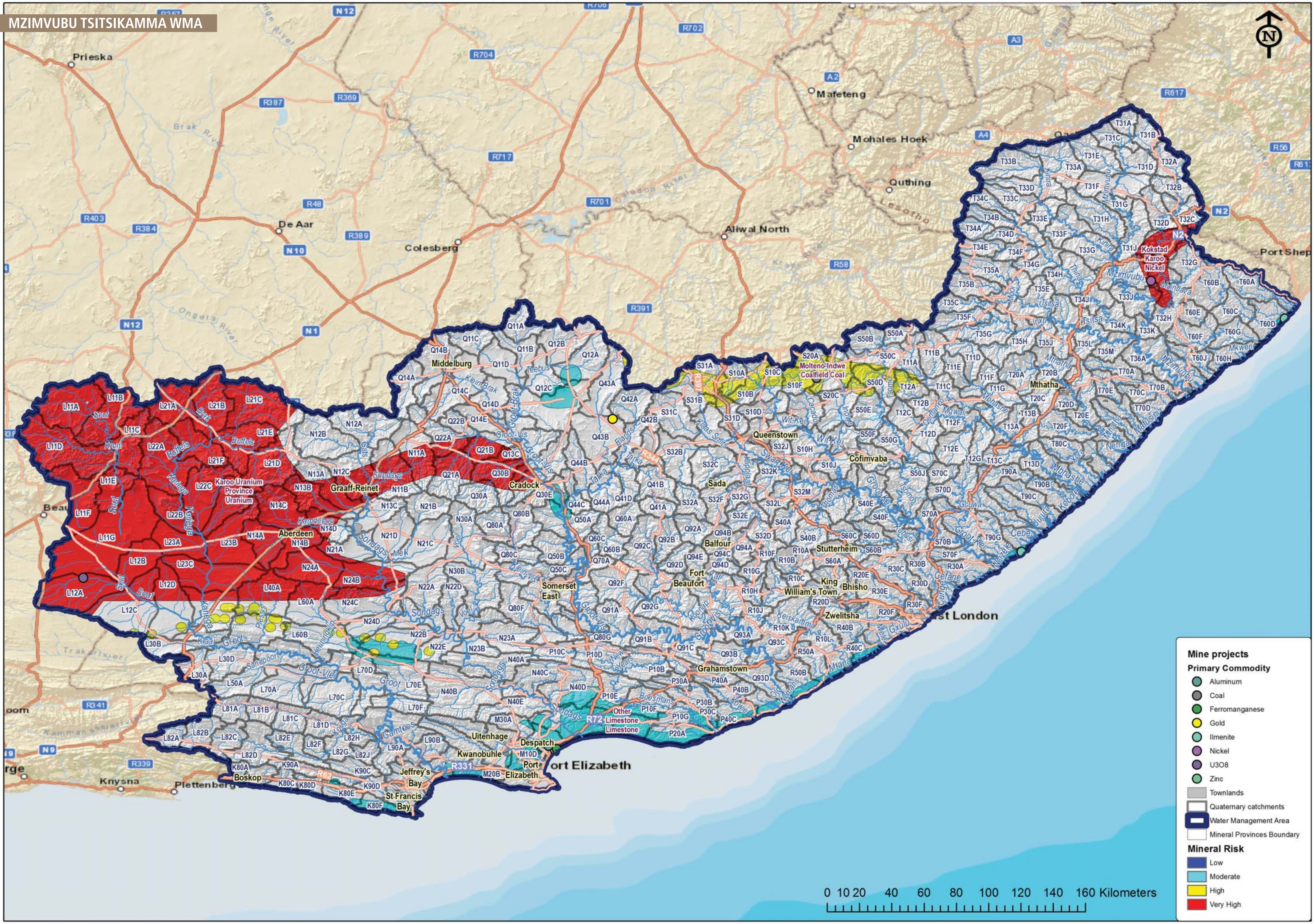
- Karoo Supergroup aquifers: Adelaide/Escourt (mudstones and arenite), Katberg Formation (sandstone and mudrock) and the underlying Dwyka/Ecca Group (shales) – vulnerability ratings from 1.9 (low) to 2.3 (low - moderate), higher vulnerability ratings for Karoo Dolerite dykes (2.5) and Karoo Dolerite Sills (2.7) where these features occurs; and
- Cape Supergroup aquifers: Witteberg Group (shale/sandstone/quartzite – vulnerability rating of 1.0 to 1.6 (low) due to low yields (0.1 to 0.5 l/s) and brackish to saline water;
- Cape Supergroup aquifer/aquiclude: Bokkeveld Group (shale/siltstone/arenites) – vulnerability rating of 1.0 to 1.1 (low) due to poor water quality (>300 mS/m) and low yields (<0.5 l/s);
- Cape Supergroup: Table Mountain Group (sandstone, arkose, quartzite) – vulnerability rating of 2.3.

Key areas of concern:

- Fresh water aquifers: aquifer systems with water quality <70 mS/m mapped in most of the intergranular and fractured and fractured aquifer systems;
- Local freshwater springs due to the occurrence of Karoo Dolerite dykes and sills;
- Coastal aquifers may be underlain by brackish to saline water which will migrate upwards to the fresh water aquifer during mining/bulk water abstractions; and
- Abundant occurrences of Karoo Dolerite dykes and sills in the Karoo Supergroup rocks resulting in a vulnerability rating of 2.7 (moderate-high) to 3.3 (high).


MZIMVUBU TSITSIKAMMA WMA
Prieska
De Aar
Colesberg
Mafeteng
Mohales Hoek
Quthing
Aliwal North
Lesotho
Middelburg
Goudplaats
Queenstown
Elliot
Molteno-Indwe Coalfield Coal
Mthatha
Kokstad
Karoo Nickel
Xolobeni
Port Shepstone
Cofimvaba
Sada
Cradock
Graaff-Reinet
Karoo Uranium Province Uranium
Aberdeen
Ryst Kuil
Beaufort West
Somerset East
Balfour
Stutterheim
King William's Town
Bhisho
Zwelitsha
East London
Eastern Cape
Grahamstown
Other Limestone
Limestone
Uitenhage
Despatch
Kwanobuhle
Port Elizabeth
Jeffrey's Bay
St Francis Bay
Boskop
Knysna
Plettenberg Bay
George
Mine projects
Primary Commodity
Aluminum
Coal
Ferromanganese
Gold
Ilmenite
Nickel
U3O8
Zinc
Townlands
Quaternary catchments
Water Management Area
Mineral Provinces Boundary
Mine landcovers
Mineral Province
Elevation (mamsl)
High : 2977
Low : -13
0 10 20 40 60 80 100 120 140 160 Kilometers

MZIMVUBU TSITSIKAMMA WMA



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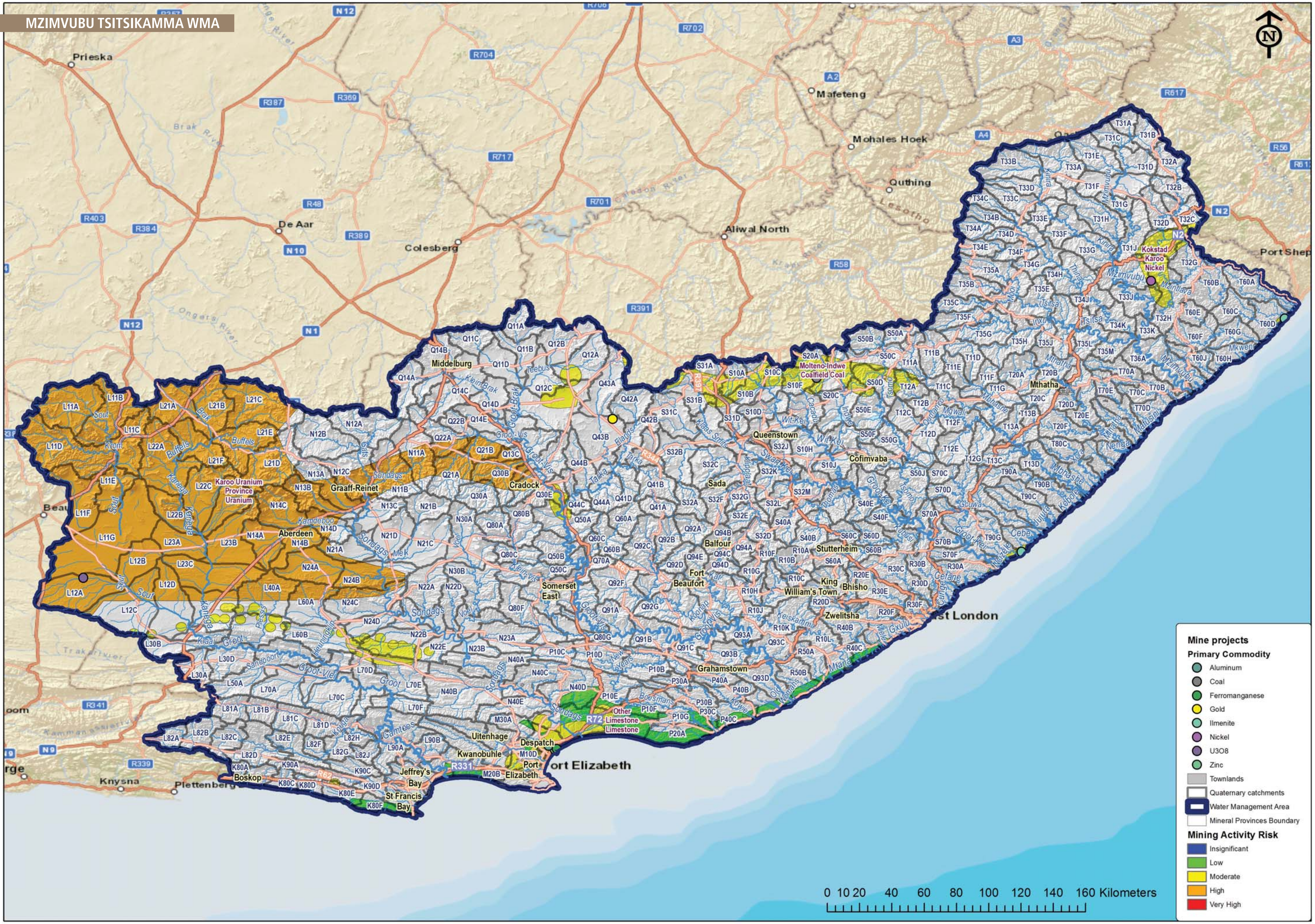

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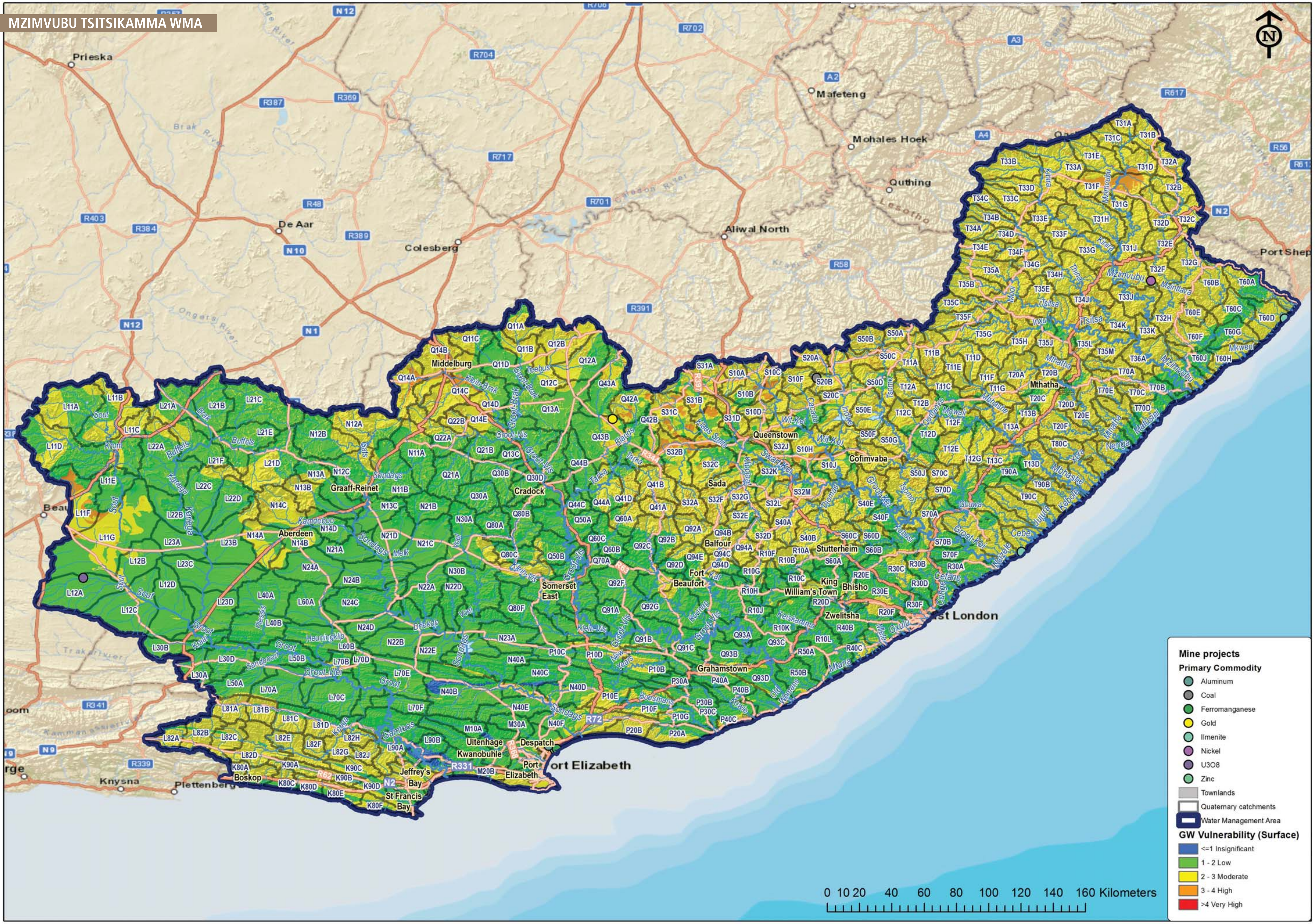

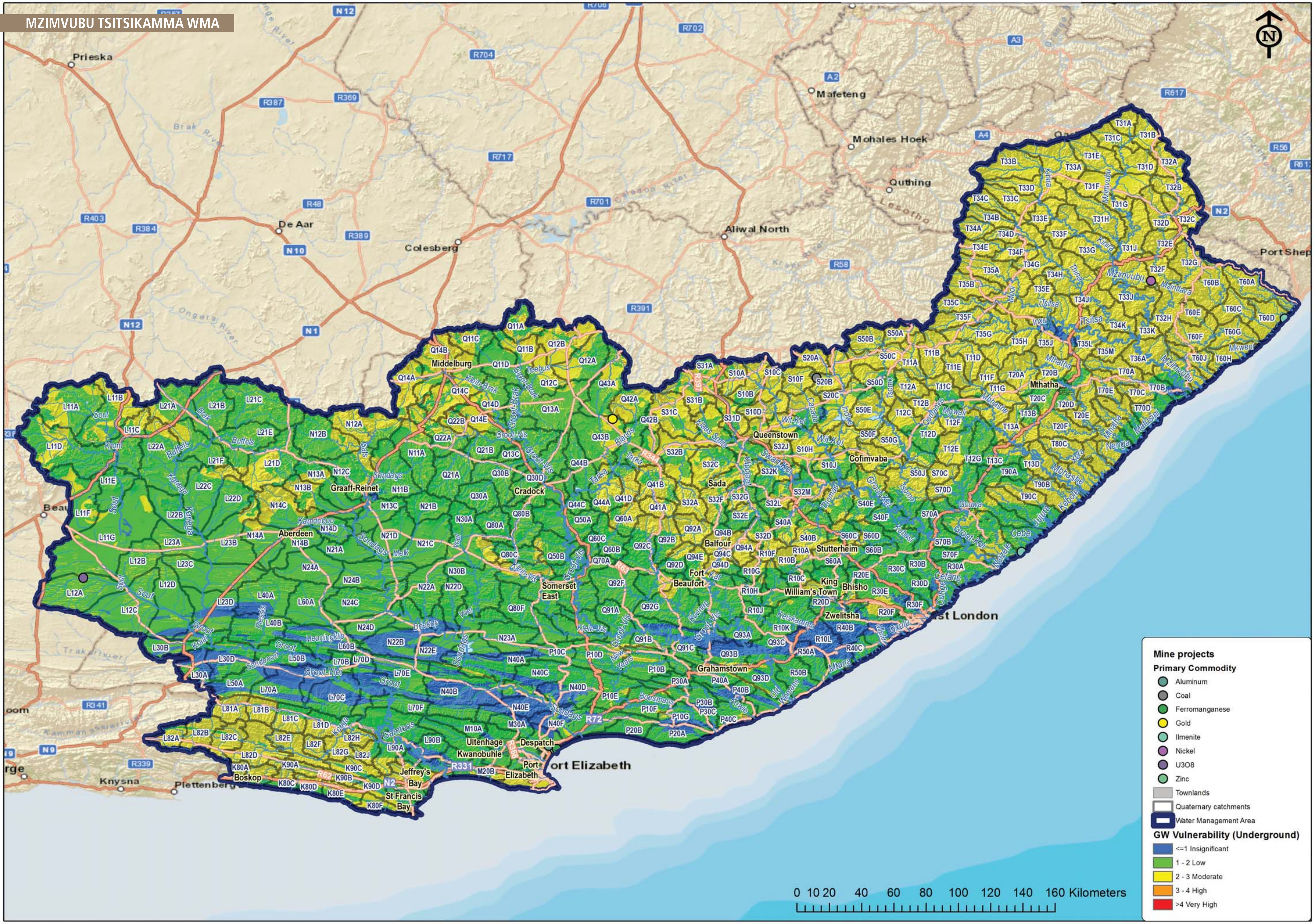
MZIMVUBU TSITSIKAMMA WMA
Prieska
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Colesberg
Mafeteng
Mohales Hoek
Quthing
Aliwal North
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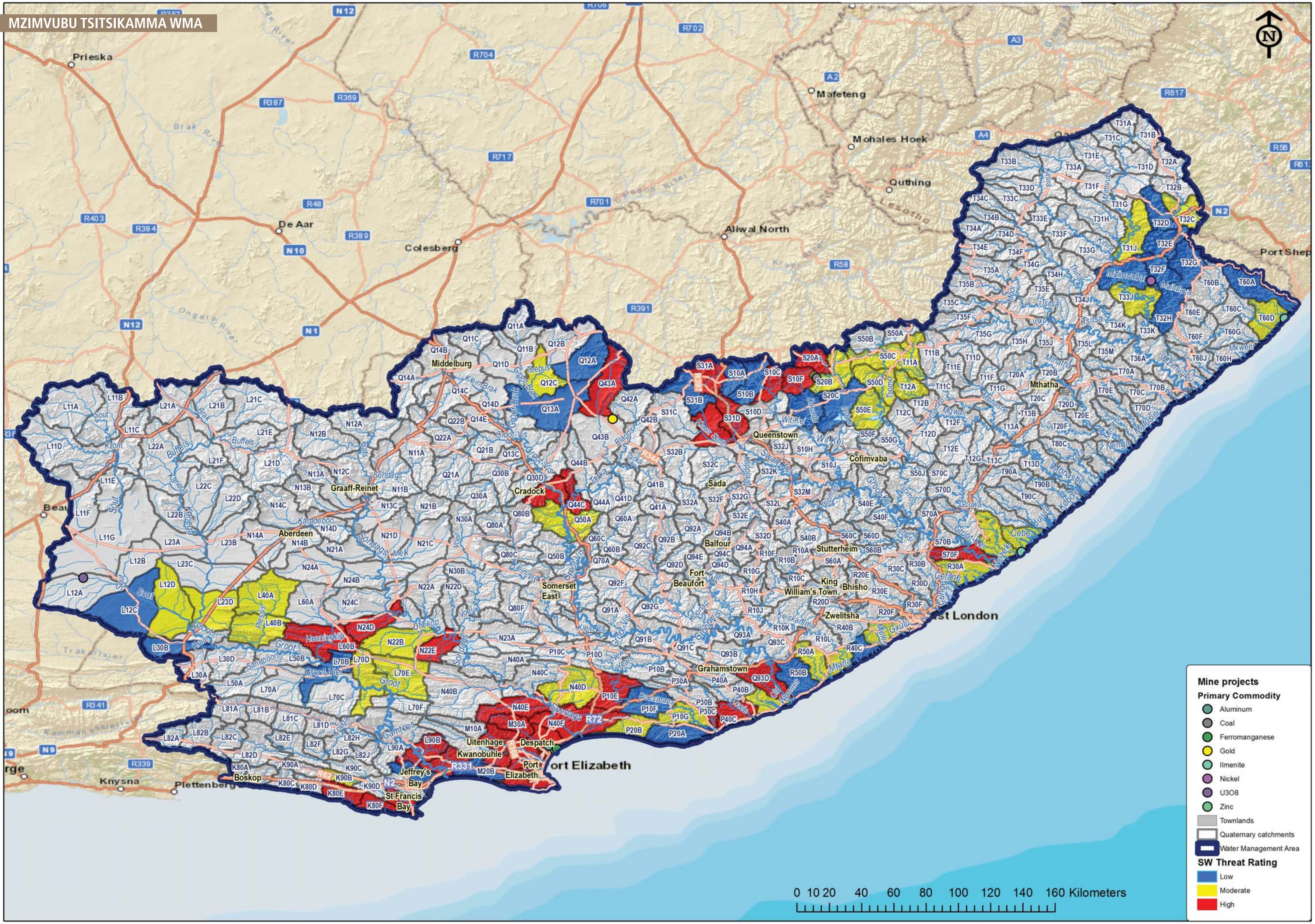
Graaff-Reinet
Cradock
Aberdeen
Queenstown
Cofimvaba
Mthatha
Sada
Balfour
Stutterheim
Fort Beaufort
Somerset East
King William's Town
Bhisho
Zwelitsha
Grahamstown
Uitenhage
Kwanobuhle
Despatch
Port Elizabeth
Jeffrey's Bay
St Francis Bay
Boskop
Knysna
Plettenberg
Mine projects
Primary Commodity
Aluminum
Coal
Ferromanganese
Gold
Ilmenite
Nickel
U3O8
Zinc
Townlands
Quaternary catchments
Water Management Area
GW Vulnerability (Underground)
<=1 Insignificant
1 - 2 Low
2 - 3 Moderate
3 - 4 High
>4 Very High
0 10 20 40 60 80 100 120 140 160 Kilometers

MZIMVUBU TSITSIKAMMA WMA



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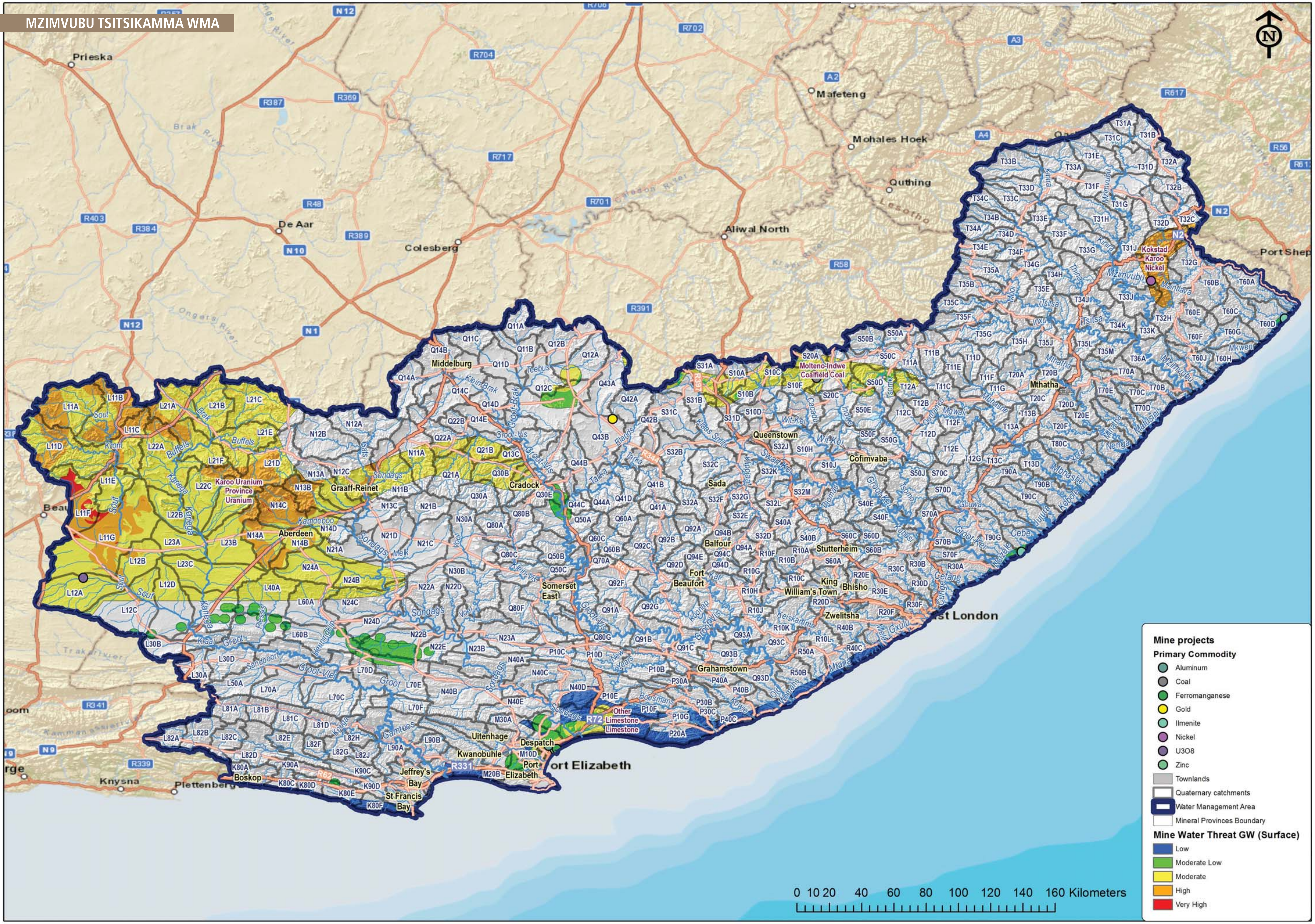

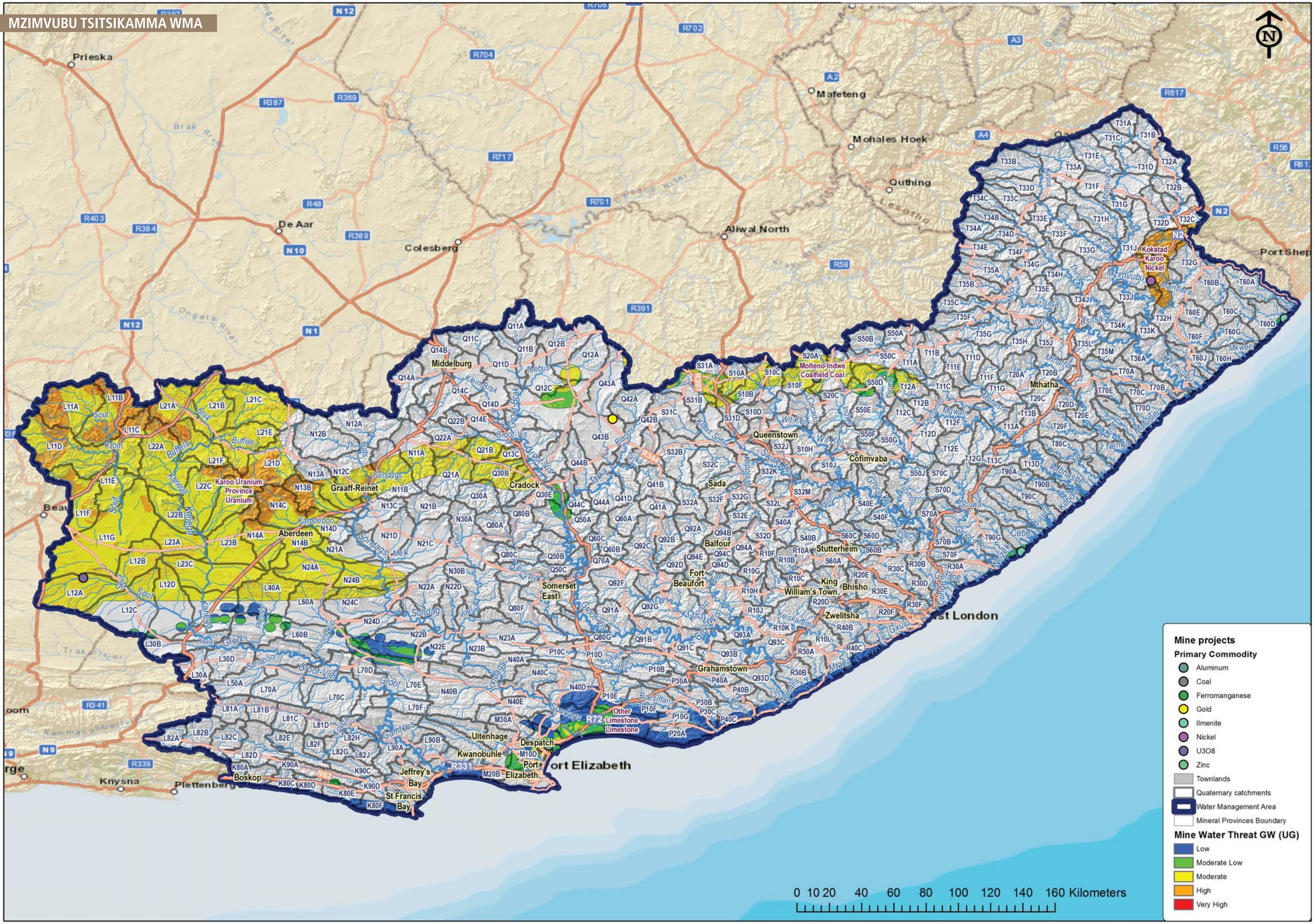
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U3O8
Zinc
Townlands
Quaternary catchments
Water Management Area
Mineral Provinces Boundary
Mine Water Threat GW (UG)
Low
Moderate Low
Moderate
High
Very High
0 10 20 40 60 80 100 120 140 160 Kilometers
Prieska
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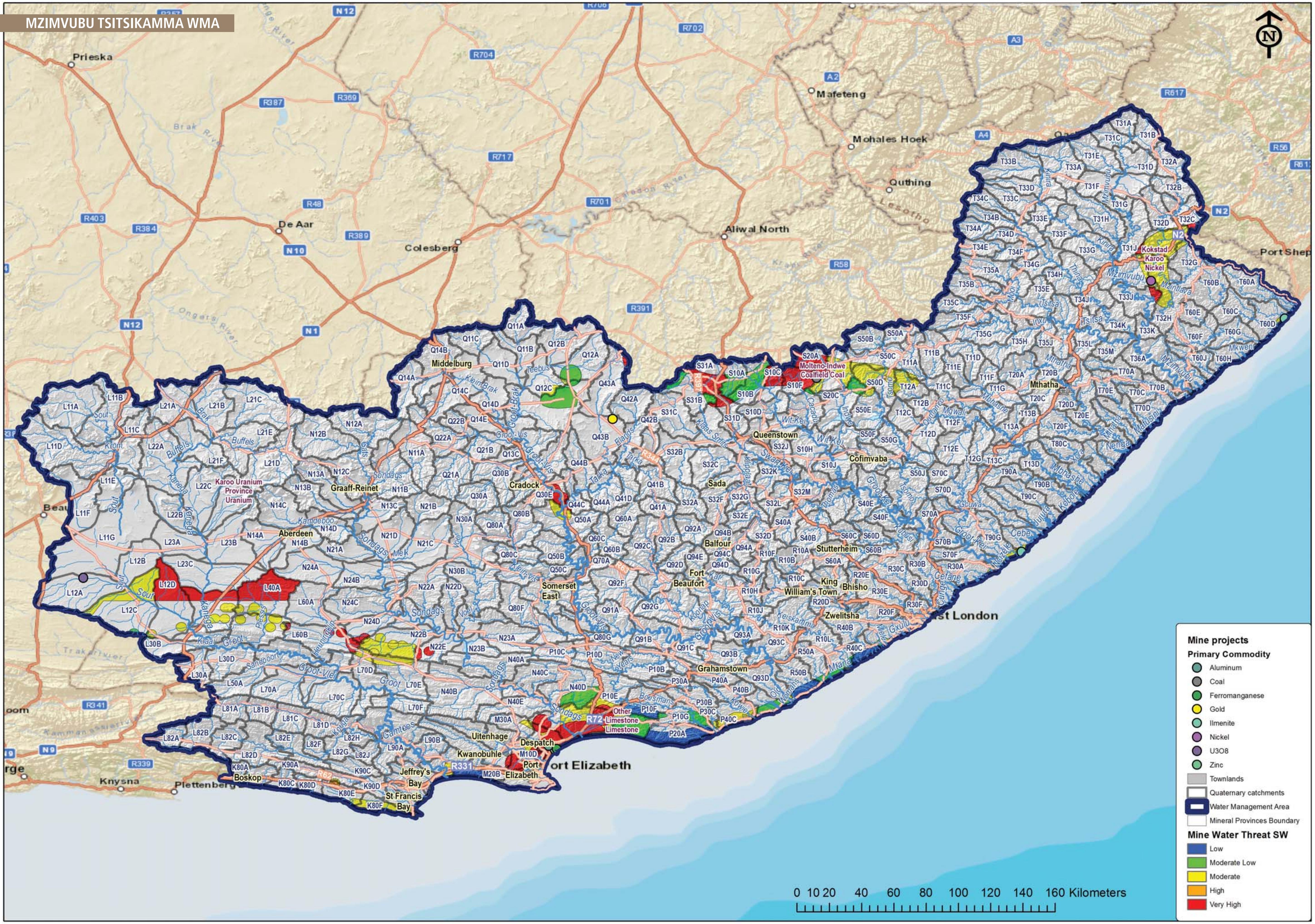
Colesberg
Mafeteng
Mohales Hoek
Quthing
Aliwal North
Middelburg
Graaff-Reinet
Cradock
Aberdeen
Queenstown
Cofimvaba
Mthatha
Kokstad
Karoo Nickel
Molteno-Indwe Coalfield Coal
Karoo Uranium Province Uranium
Sada
Balfour
Stutterheim
Fort Beaufort
Somerset East
King William's Town
Bhisho
Zwelitsha
Grahamstown
Other Limestone
Limestone
Uitenhage
Despatch
Kwanobuhle
Port Elizabeth
Jeffrey's Bay
St Francis Bay
Boskop
Knysna
Plettenberg

MZIMVUBU TSITSIKAMMA WMA



4.9 BERG OLIFANTS WMA

WMA OVERVIEW

The WMA includes the Berg and Olifants catchment areas, and the major rivers, Berg, Diep, Steenbras, Olifants, Doorn, Krom, Sand and Sout. The WMA lies within the Western Cape and Northern Cape Provinces and includes Cape Town, the second most populous metropolitan area in South Africa. There are several large towns in the WMA, with economies based in tourism, education, agriculture and industry. Natural vegetation comprises large areas of Cape Fynbos, which represents one of the unique floral kingdoms of the world and is a recognised World Heritage Site. A number of conservation and heritage sites are found in the WMA. Large spatial variations in rainfall, water availability, level and nature of economic development, population density as well as potential for development for growth exists in the WMA.

The Berg River catchment comprises the Upper Berg area which includes the Berg River catchment down to Misverstand Weir; the Lower Berg area, which includes the downstream reaches of the Berg River together with the endoreic areas along the west coast including the Diep River catchment and the Greater Cape Town area, the southern portion of the WMA with a number of smaller river catchments.

The Olifants and Doring River catchment comprises the well-watered valleys of the Olifants River catchment, the arid Doring River catchment and the highly developed Sandveld area forming the western coastal boundary.

The diversified economy of the Berg River catchment is dominated by industrial and other activities in the Cape Town Metropolitan area. Other significant economic sectors include irrigated agriculture, namely wine production, table grapes and deciduous fruit exports, and tourism. The Olifants area is dominated by extensive commercial agriculture (irrigated citrus, deciduous fruits, grapes and potatoes), but also includes tourism, livestock farming, some industries related to food processing and packaging, and limited forestry.

The water resources of the WMA are fully developed and investigations are underway to assess options to augment water supply, including water conservation and demand management, infrastructure development, re-use of water, groundwater exploitation and desalination. .

MINING WITHIN WMA: OVERVIEW

Mining activity in the WMA is very limited. The only major mine is the Namakwa Sands heavy minerals mine located to the north-west of the WMA. There are also several granite quarrying operations in the vicinities of Vrendendal and Vanrhysdorp and the Vredendal gossanous iron deposit. Dredging for marine diamonds occurs offshore.

SURFACE WATER PROFILE

Water Quality

Limited water quality monitoring data is available spatially for the WMA to assess salinity present state. In terms of the limited data available, the Kruis River in the Olifants catchment and the Lower reaches of the Olifants salinity status are in the unacceptable range. The salinity status of the Doring River is good. The state of the Berg River catchment is within the ideal to acceptable ranges in the upper reaches and tributary catchments but deteriorates to unacceptable ranges downstream. This could be attributed to impact of agricultural activities and anthropogenic impacts.

Ecological Condition

The present ecological condition of the rivers in the Berg River catchment are predominantly in a moderately modified state (category C) and largely modified state (D category) to the southern and western portions of the WMA. Much of the river reaches in the Olifants catchment (north to eastern parts of the WMA) are in natural to largely natural state (A and B present ecological condition). A small percentage of river reaches in the vicinity of the urban centres and agricultural areas have been severely degraded and are in a seriously modified state (E category). The modified river condition that is largely present in the WMA is due to impacts agricultural activities and urban development.

Threat to the Surface Water Resources

Within the Berg Olifants WMA, of the 48% of the quaternary catchments assessed (with data available) 45% (5 rating red) of the catchment area includes stressed surface water resources that are under threat, 14% (5 rating green) that require the precautionary approach to management to maintain good condition, and 41%,(rated 1 or 3) where the surface water resources do have capacity available to accept degrees of impact. Refer to the map on page 102.

MINERALOGY PROFILE

There are four significant mineral provinces in the WMA:

- Quaternary sedimentary-hosted deposits are mainly diamonds, gypsum and heavy mineral sands – all are largely chemically inert and have low mineralogical risk ratings.
- The Karoo uranium province is a widespread, largely unexploited province with high mineralogical risk due to ARD and radionuclides.
- The Northern Cape surficial uranium deposits have a medium mineralogical risk, and unlike the Karoo uranium deposits they have low risk of ARD due to absence of sulphide minerals.
- The Northern Cape base metal deposits are massive sulphide deposits of copper, lead and zinc, with high mineralogical risk due to their substantial ARD potential and numerous potentially toxic trace elements.

The remaining mineral deposits in the WMA include kimberlites with medium risk ratings.

GROUNDWATER VULNERABILITY PROFILE

General aquifer profile (Lithology aquifer type): there are three major aquifer systems in the WMA:

- Fractured aquifers with borehole yields between <0.1 and 2.0 l/s and water quality ranges <70 mS/m, 70-300 mS/m and >300-1000 mS/m;
- Intergranular and fractured: Inland Quaternary deposits (Qz) with borehole yields 0.1 to 0.5 l/s and water quality ranges 300 – 1000 mS/m;
- Intergranular Coastal (T-Qs undifferentiated coastal deposits) with borehole yields between 2.0 and 5.0 l/s – water quality <70, 70-300 mS/m and >300. Multi-layered aquifer systems may occur in the coastal belts (fresh, underlain by saline groundwater); and
- Intergranular Inland: Berg River alluvium with borehole yields of 0.1 to 0.5 l/s (interconnected with underlying fractured hard rock aquifers).

Aquifer vulnerability rating:

The overall vulnerability rating in the WMA is clustered in the Cape Supergroup formations (insignificant at 0.8 for the Bokkeveld) to moderate at 2.3 (Table Mountain Group) which covers about 45% of the WMA. The Karoo Supergroup formations with low vulnerability ratings at 1.5 - 1.7 (Ecca and Beaufort Groups). Older rock formations, such as the Vanrhynsdorp Group have a vulnerability rating at 1.4 (low).
Intergranular aquifer systems (coastal and inland alluvial deposits) have vulnerability ratings between 1.8 (low) and 2.8 (moderate-high).Lange coastal, fresh water wetlands regions on the West Coast have vulnerability ratings from 2.5 (moderate) to 3.6 (high).

Intergranular (alluvial)

- Unconsolidated/semi-consolidated coastal – Saldanha area with vulnerability rating at 1.7, Cape Flats with vulnerability rating at 2.6, and Witzand areas with vulnerability rating at 3.2;
- Unconsolidated/semi-consolidated inland river alluvium – Olifants-Doorn at 3.6 (high) and the Berg River at 3.0 (high); and
- Inland wetland areas: Jakkalsvlei (Lamberts Bay area) with vulnerability ratings from 2.5 to 2.9 (low), Verlorenvlei (Elands Bay area) with vulnerability ratings 3.6 (high).

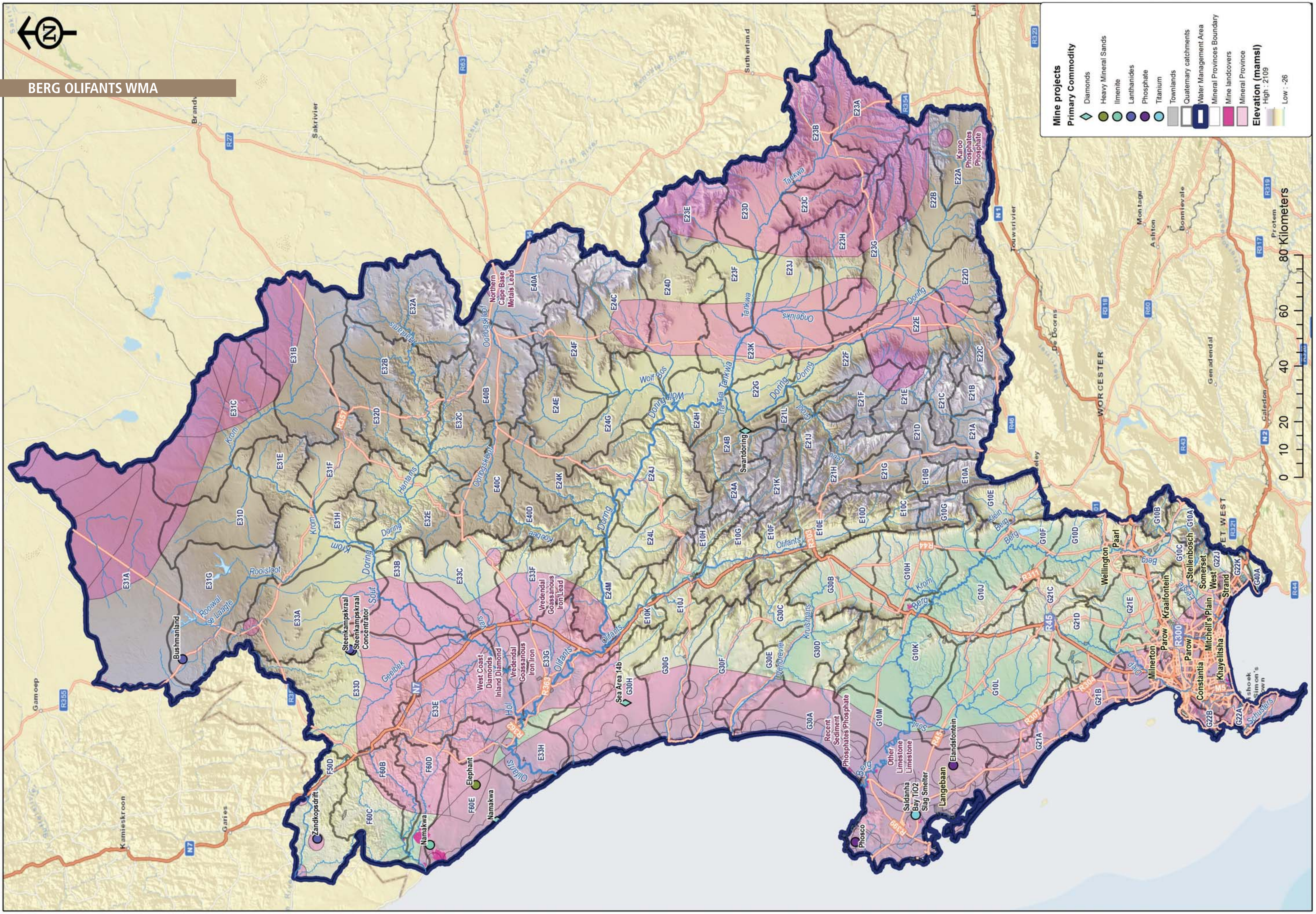
Fractured:

- Karoo Supergroup aquifers: Ecca Group Volksrust shales – vulnerability ratings at 1.6 ±0.1 (low), Ecca Group Tierberg shake/siltstone – vulnerability ratings at 1.7 (low) and higher vulnerability ratings for Karoo Dolerite dykes (2.5);
- Karoo Supergroup aquifers: Beaufort Group Adeliade and Escourt mudstone and arenite – vulnerability ratings at 1.6±0.1 (low). Significant folding due to Cape Fold Belt increases vulnerability rating to just below 2.0 (moderate);
- Cape Supergroup aquifers: Table Mountain Group sandstone/arkose/quartzite – vulnerability rating at 2.4±0.1 (moderate) due to moderate yields (0.5 to 2.0 l/s) and fresh water (<70 mS/m);
- Cape Supergroup aquifers/aquiclude: Bokkeveld Group shale – vulnerability rating at <0.8 (insignificant) to 1.7 (low) due to low yields (0.1 to 0.5 l/s) and saline water (>1000 mS/m); and
- Vanrhynsdorp Group aquifers: (shale/siltstone/sandstone/limestone) – vulnerability rating of 1.4 (low) due to poor water quality (>300 mS/m).

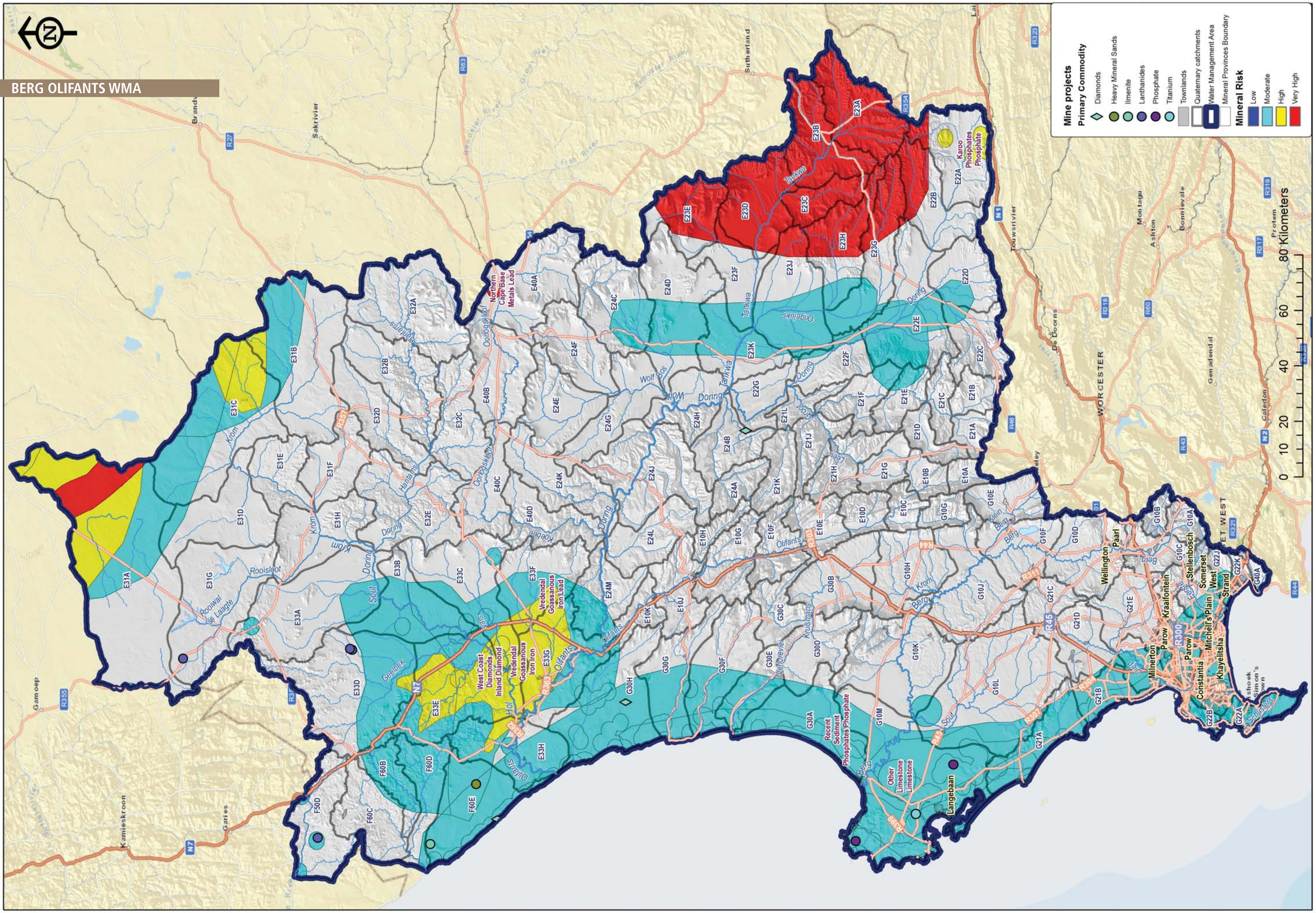
Key areas of concern:

- Large fresh water aquifers/wetlands along the West Coast: Aquifer systems with water quality <70 mS/m associated with high yielding Table Mountain Group aquifers systems;
- Coastal aquifers may be underlain by brackish to saline water which will migrate upwards to the fresh water aquifer during mining/bulk water abstractions; and
- Localised occurrences of Karoo Dolerite dykes and sills in the Karoo Supergroup rocks resulting in a vulnerability rating of 2.7 (moderate-high) to 3.3 (high).

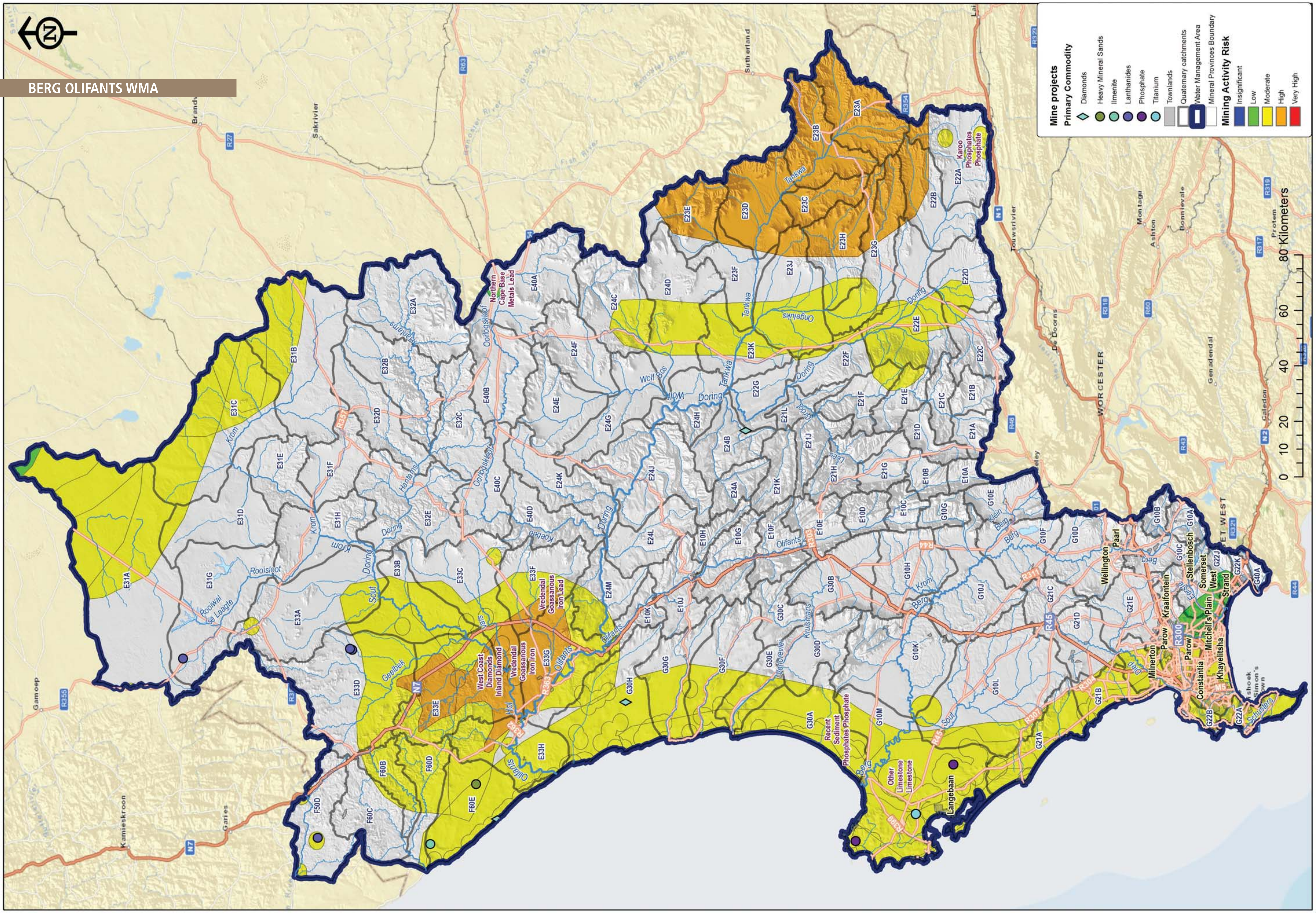
BERG OLIFANTS WMA

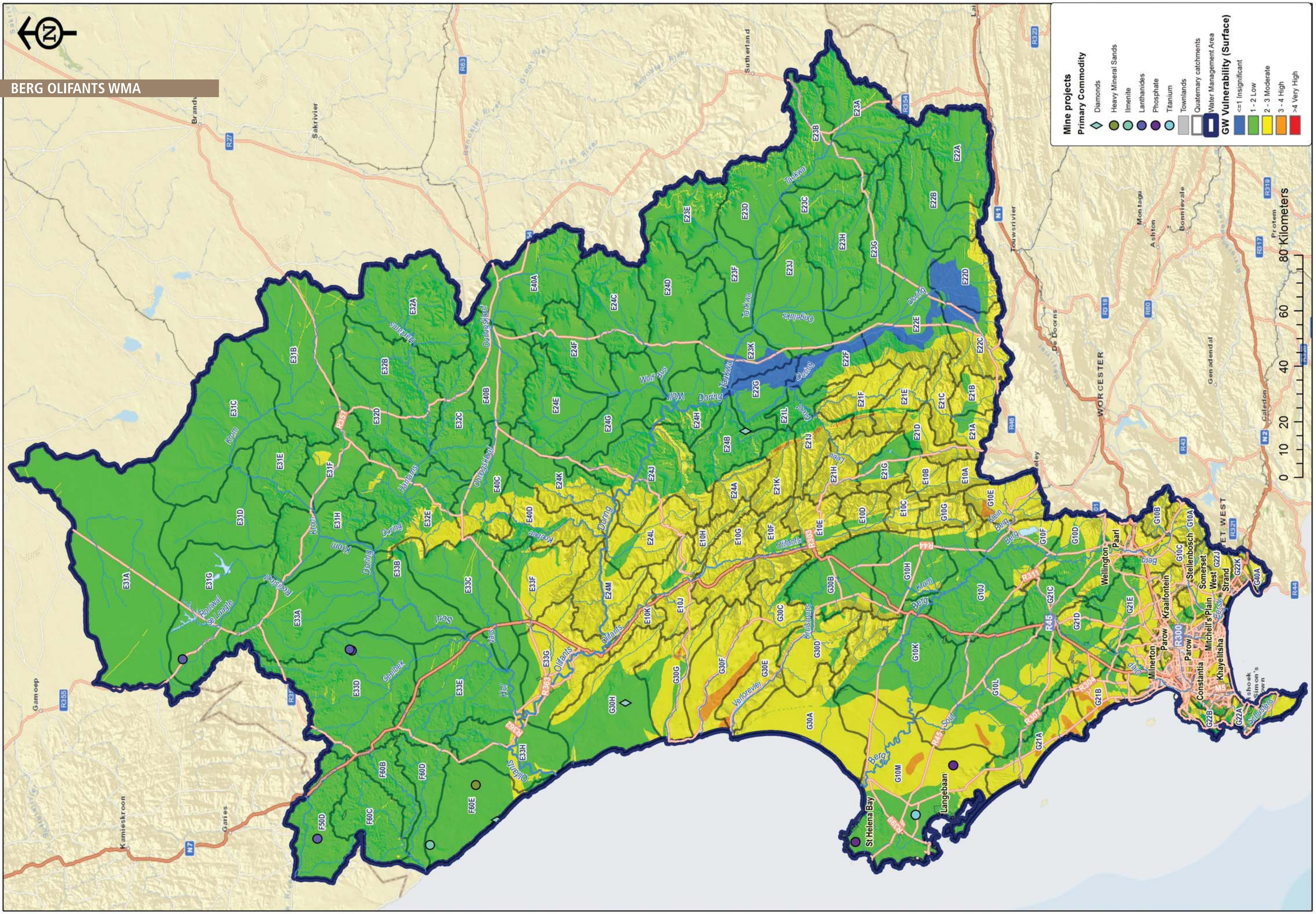


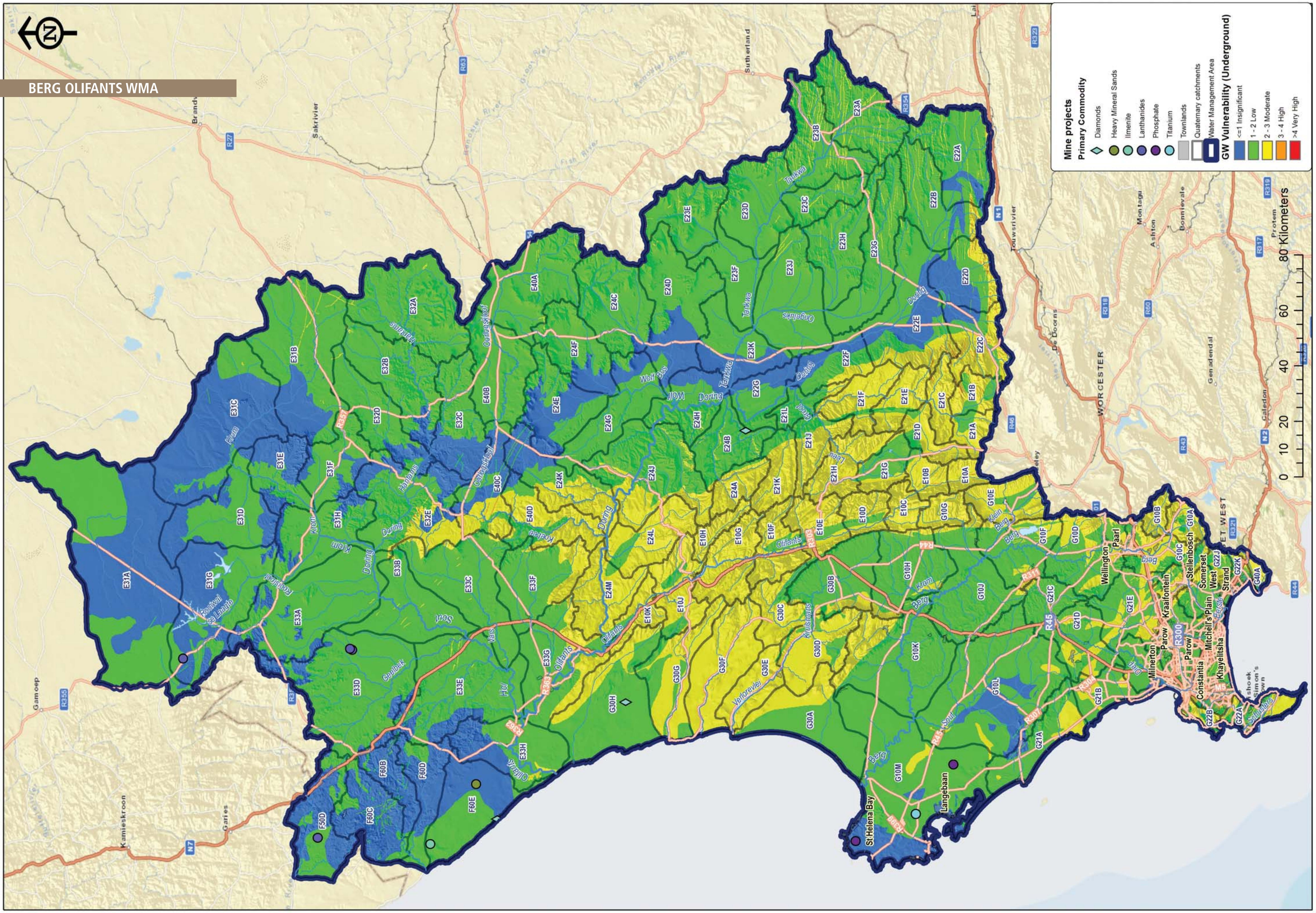
BERG OLIFANTS WMA



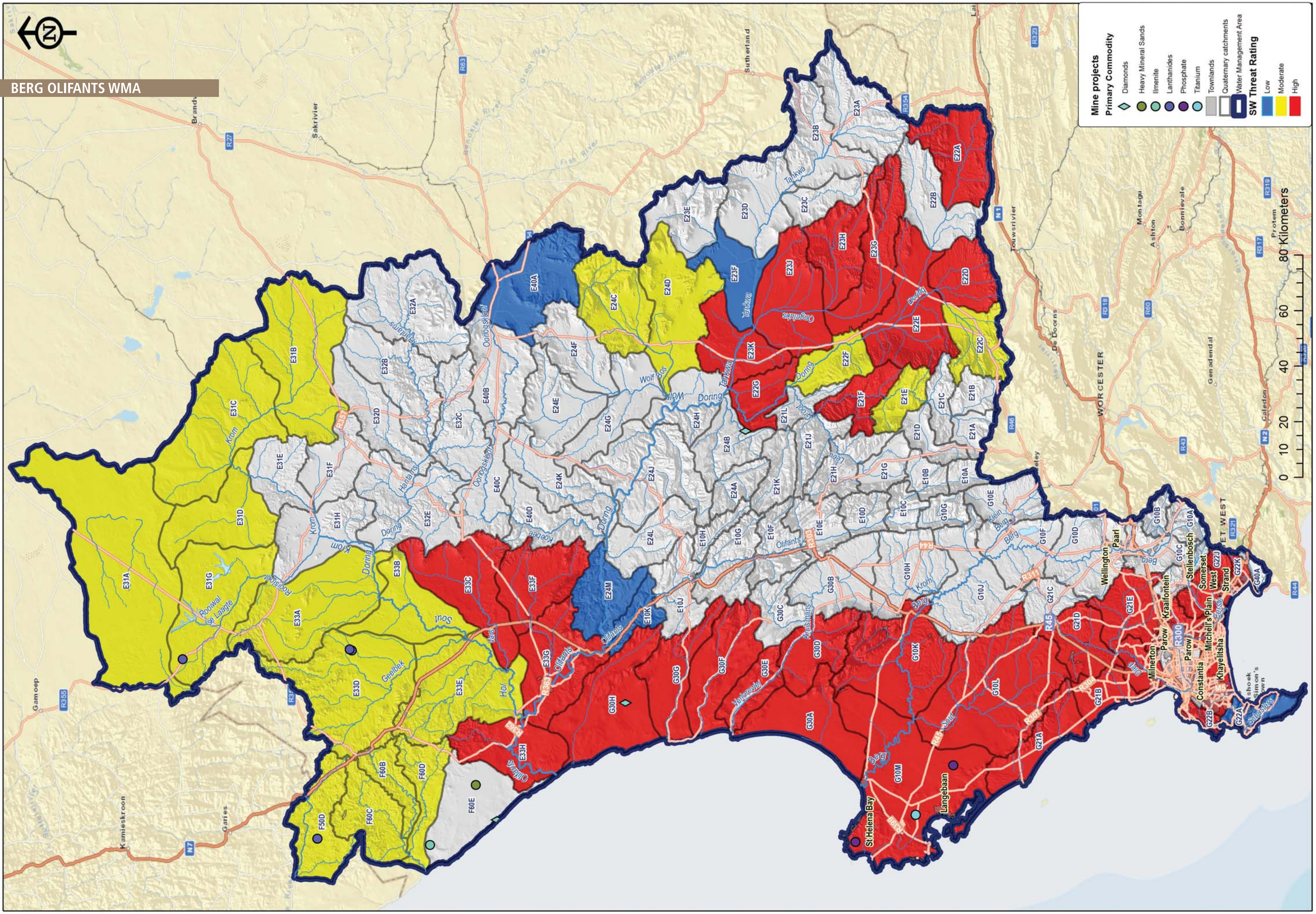
BERG OLIFANTS WMA

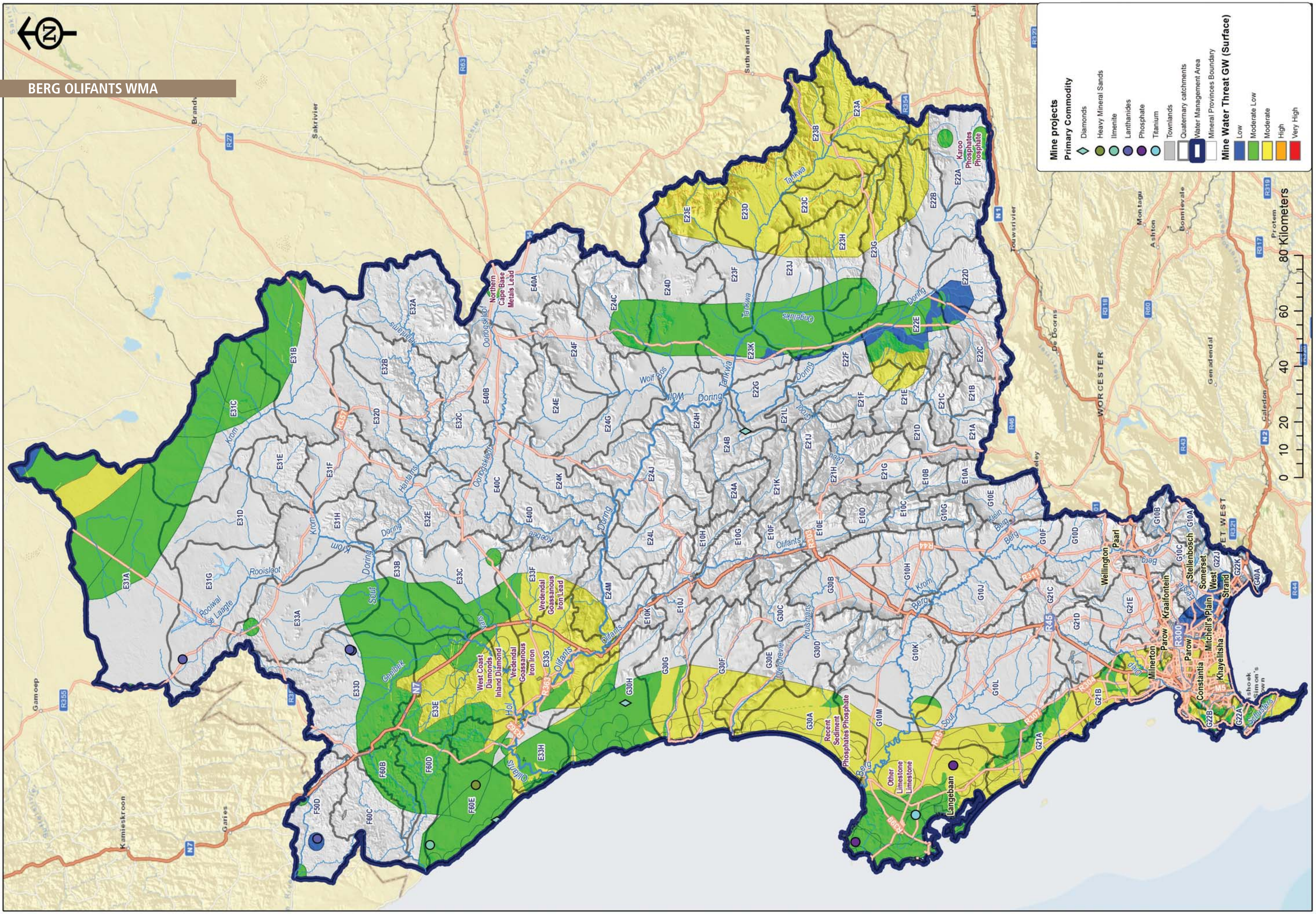



BERG OLIFANTS WMA
Mine projects
Primary Commodity
Diamonds
Heavy Mineral Sands
Ilmenite
Lanthanides
Phosphate
Titanium
Townlands
Quaternary catchments
Water Management Area
GW Vulnerability (Surface)
<=1 Insignificant
1 - 2 Low
2 - 3 Moderate
3 - 4 High
>4 Very High
0 10 20 40 60 80 Kilometers
St Helena Bay
Langebaan
Wellington
Paarl
Stellenbosch
Somerset West
Strand
Milnerton
Parow
Khayelitsha
Constantia
Kraaifontein
Worcester

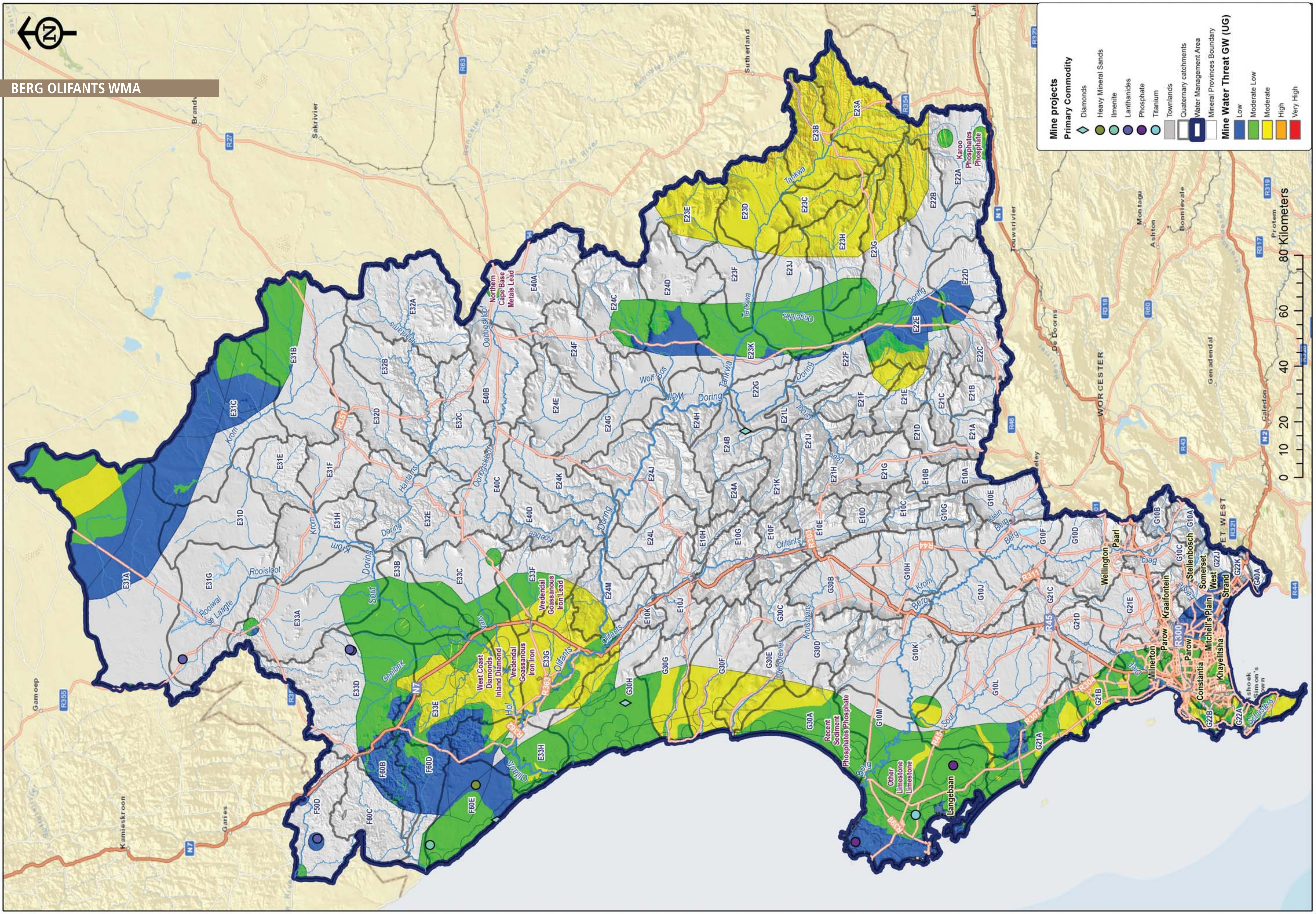

BERG OLIFANTS WMA
Mine projects
Primary Commodity
Diamonds
Heavy Mineral Sands
Ilmenite
Lanthanides
Phosphate
Titanium
Townlands
Quaternary catchments
Water Management Area
GW Vulnerability (Underground)
<=1 Insignificant
1 - 2 Low
2 - 3 Moderate
3 - 4 High
>4 Very High
0 10 20 40 60 80 Kilometers

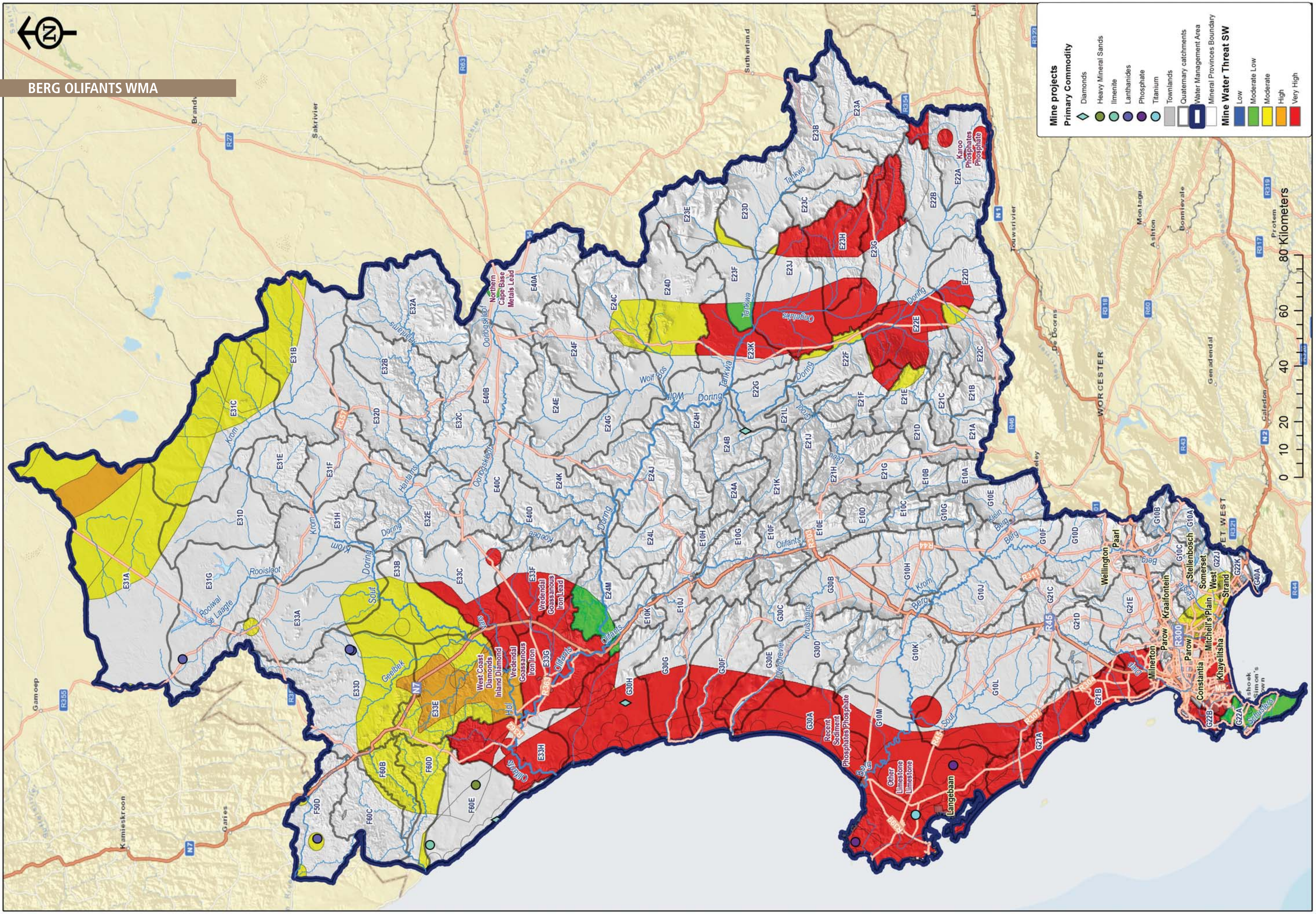
BERG OLIFANTS WMA




BERG OLIFANTS WMA
Mine projects
Primary Commodity
Diamonds
Heavy Mineral Sands
Ilmenite
Lanthanides
Phosphate
Titanium
Townlands
Quaternary catchments
Water Management Area
Mineral Provinces Boundary
Mine Water Threat GW (Surface)
Low
Moderate Low
Moderate
High
Very High
0 10 20 40 60 80 Kilometers

BERG OLIFANTS WMA




BERG OLIFANTS WMA
Mine projects
Primary Commodity
Diamonds
Heavy Mineral Sands
Ilmenite
Lanthanides
Phosphate
Titanium
Townlands
Quaternary catchments
Water Management Area
Mineral Provinces Boundary
Mine Water Threat SW
Low
Moderate Low
Moderate
High
Very High
0 10 20 40 60 80 Kilometers

4.10 BREEDE GOURITZ WMA

WMA OVERVIEW

The Breede Gouritz WMA comprises the Breede, Overberg, the Karoo and Klein Karoo and Outeniqua Coastal Area (Stilbaai to Plettenberg Bay) catchments. The WMA is located in south-western South Africa and lies predominantly within the Western Cape Province, with a small portion in the Eastern and Northern Cape Provinces. The major rivers include the Breede, Sonderend, Sout, Bot, Palmiet, Gouritz, Olifants, Kamanassie, Gamka, Buffels, Touws, Goukou and Duiwenhoks. Much of the WMA is rural in nature.

The Breede Overberg catchment is characterized by mountain ranges, the Breede River valley and the hills of the Overberg in the south. The Breede River is currently intensively utilised, with two large dams viz. the Brandvlei and Theewaterskloof dams. There are also numerous medium to small dams and a large number of farm dams. The area includes the major towns of Worcester and Ceres, and a number of smaller towns which include Grabouw, De Doorns, Robertson, Swellendam, Montagu, Caledon, Hermanus and Gansbaai. Groundwater use in the area is important to supply many towns and farms in the area. Intensive irrigation in the Breede catchment is causing increased salinisation of the rivers in the area, and impacting on water quality. The Palmiet River catchment is intensively farmed. The lower reaches of the Palmiet River is protected as part of the Kogelberg Biodiversity Reserve requiring the ecological condition to be maintained.

Within the Karoo to Klein Karoo catchment, the area is vast and dry. Some water does flow through the Swartberg mountain range. The area includes the Beaufort West, as the major town in the north west of the area, which is largely reliant on groundwater. Other smaller towns include Oudtshoorn and De Rust within the Gouritz catchment area, which also include the Dwyka, Groot, Gamka and Olifants tributaries. The Gouritz River is the main river, contributing a large proportion of the surface flow in the catchment area. The Gouritz catchment area has good arable land available however irrigation is limited due to the low and variable rainfall. Existing resources have been over allocated with no opportunity for further dam development. The Klein Karoo is water stressed, as there is no additional surface water development available to support the growing needs of Oudtshoorn, Dysseldorp and surrounding areas. Potential exists to exploit groundwater to augment water supply. Elevated salinity occurs naturally within the inland catchments of the Karoo and Klein Karoo due to the geology of the area. Impacts on water quality have been observed due to land based activities in the more populated areas.

The Outeniqua coastal catchment area (Stilbaai to Outeniqua) is ecologically sensitive, with many short steep rivers of high ecological importance. There are a number of National Parks and conservation areas in the catchment. This is a major growth area, popular as a retirement location and year-round tourist destination. The area includes small to medium sized dams (Wolwedans and Garden Route Dams). Surface water resources have been almost fully developed and alternative supplies are required.

The land use is dominated by commercial agriculture in the Breede and Overberg areas. Irrigated agriculture (wine and table grapes, dairy and deciduous fruit), livestock farming, dry land agriculture (wheat and canola) and associated activities (packaging and processing) and the primary economic activities in the area. The catchment area produces 70% of South Africa's table grapes, apples and fynbos for export. Tourism and residential development along the coast are also key economic drivers in the region. In the Karoo to Klein Karoo and Outeniqua coastal areas the agricultural sector provides the primary economic driver of the region (a large variety of crops, livestock and fruit). The fish and shellfish industry, tourism and the ostrich industry are also significant for the economy of the coastal region. Land use is dominated by irrigation and afforestation activities.

MINING WITHIN WMA: OVERVIEW

Mining activity in the WMA is very limited, with a few isolated deposits of phosphate, limestone and salt.

SURFACE WATER PROFILE

Water Quality

Very limited water quality data is available spatially for the WMA to assess salinity present state. In terms of the limited data available, isolated coastal catchment areas in the vicinity of Knysna, Grabouw and George indicated good status. For the remaining quaternary catchments scattered throughout the WMA, where some data is present, the salinity status is in the unacceptable range. This could be attributed to the natural saline geology of the area and to the impact of agricultural activities and anthropogenic impacts.

Ecological Condition

The present ecological condition of the rivers in the Breede to Gouritz WMA are predominantly in a moderately modified state (category C) and largely modified state (D category) to the southern and western portions of the WMA. Many of the smaller tributaries in the Karoo catchment area are in natural to largely natural state (A and B present ecological condition). These are in less developed and impacted areas of the catchment. A small percentage of river reaches in the vicinity of the towns and agricultural areas have been severely degraded and are in a seriously modified state (E category). The modified river condition that is largely present in the WMA is due to impacts of agricultural activities and urban development.

Threat to the Surface Water Resources

Within the Breede Gouritz WMA, of the 20% of the quaternary catchments assessed (with data available) 44% (5 rating red) of the catchment area includes stressed surface water resources that are under threat, 5% (5 rating green) that require the precautionary approach to management to maintain good condition, and 51%,(rated 1 or 3) where the surface water resources do have capacity available to accept degrees of impact. Refer to the map on page 112.

MINERALOGY PROFILE

The only mineral deposits in this WMA are sedimentary-hosted deposits, mainly phosphates, limestone, gypsum and salt – all are largely chemically inert and have low mineralogical risk ratings.

Groundwater Vulnerability Profile

General aquifer profile (Lithology aquifer type): there are three major aquifer systems in the WMA:

- Fractured aquifers with borehole yields between <0.1 and 2.0 l/s and water quality ranges <70 mS/m, 70-300 mS/m and >300-1000 mS/m; and
- Intergranular Coastal (T-Qs undifferentiated coastal deposits) with borehole yields between 2.0 and 5.0 l/s – water quality 70-300 mS/m and >300. Multi-layered aquifer systems may occur in the coastal belts (fresh, underlain by saline groundwater).
- Intergranular Inland: Berg River alluvium with borehole yields of 0.1 to 0.5 l/s (interconnected with underlying fractured hard rock aquifers), Breede River alluvium with borehole yields of >5.0 l/s, Gouritz River alluvium with borehole yields of 0.1 to 0.5 l/s

AQUIFER VULNERABILITY RATING:

The overall vulnerability rating in the WMA is clustered in the Cape Supergroup formations (insignificant at 0.8 for the Bokkeveld) to moderate at 2.3 (Table Mountain Group) which covers about 50% of the WMA. The Karoo Supergroup formations with low vulnerability ratings at 1.5 - 1.7 (Ecca group Tierberg Formation and Beaufort Group). Older rock formations present such as the Malmesbury Group at a vulnerability rating of 1.2 (low).

Intergranular aquifer systems (coastal and inland alluvial deposits) have vulnerability ratings between 1.8 (low) and 2.8 (moderate-high).

- Intergranular (alluvial)
- Unconsolidated/semi-consolidated coastal – Breede River coast at 2.8 and Goukou/Gouritz coast from 2.6 to 3.0; and
- Unconsolidated/semi-consolidated inland river alluvium – vulnerability rating for Upper Gouritz (Olifants) at 1.8 (low), Touws River at 1.0 – 2.94 (low to moderate), Breede River at 3.7 (High).

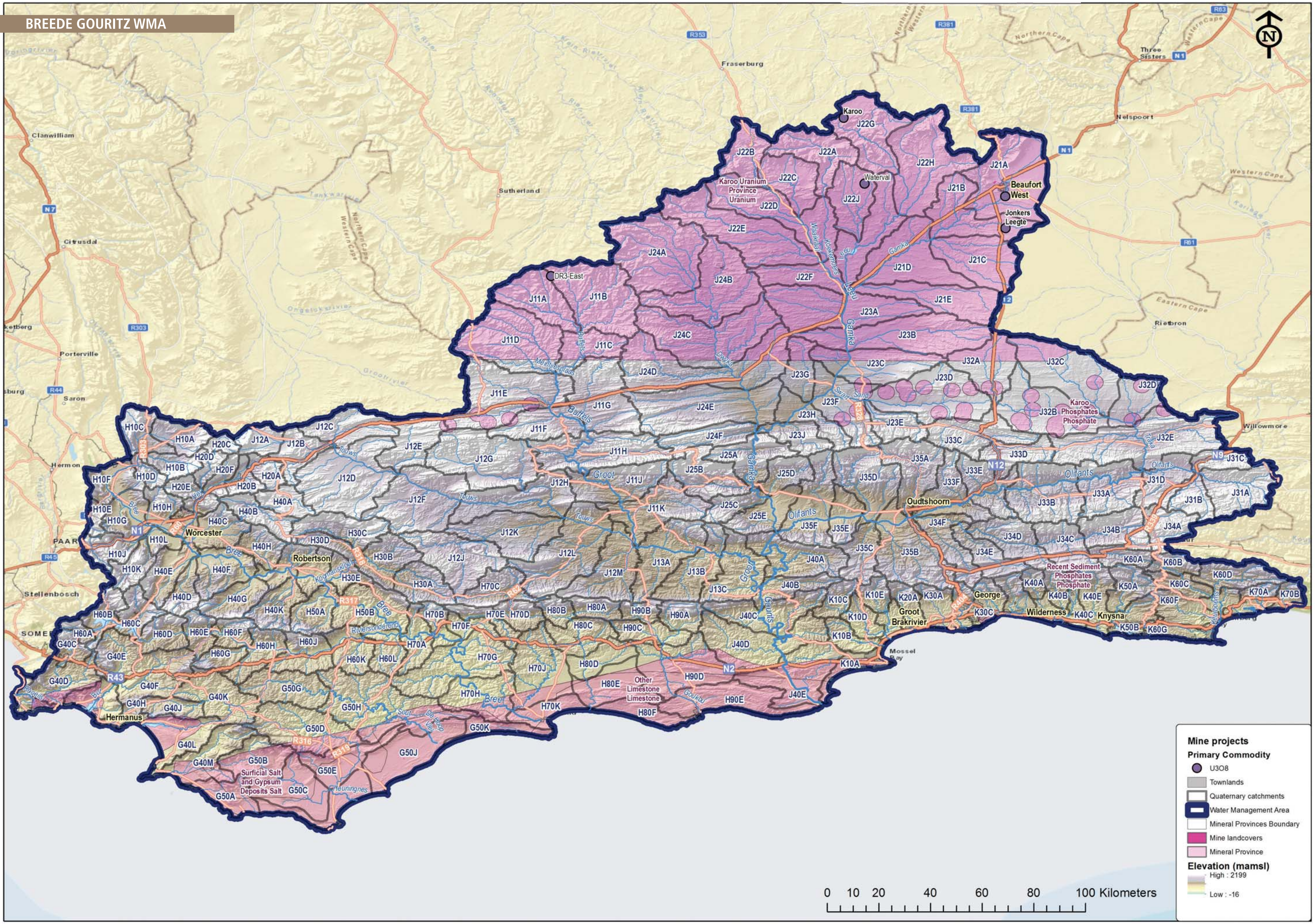
Fractured:

- Karoo Supergroup aquifers: Ecca Group Volksrust shales – vulnerability ratings at 1.6 (low), Ecca Group Tierberg shake/siltstone – vulnerability ratings at 1.7 (low) and higher vulnerability ratings for Karoo Dolerite dykes (2.5);
- Karoo Supergroup aquifers: Beaufort Group Adeliade and Escourt mudstone and arenite – vulnerability ratings at 1.6 (low). Significant folding due to the Cape Fold Belt increases vulnerability rating to just below 2.0 (moderate);
- Cape Supergroup aquifers: Table Mountain Group sandstone/arkose/quartzite – vulnerability rating at 2.4 (moderate) due to moderate yields (0.5 to 2.0 l/s) and fresh water (<70 mS/m);
- Cape Supergroup aquifers/aquiclude: Bokkeveld Group shale – vulnerability rating at <0.8 (insignificant) to 1.7 (low) due to low yields (0.1 to 0.5 l/s) and saline water (>1000 mS/m);
- Kango Group aquifers (shale/arenite/conglomerate/limestone) – vulnerability rating of 1.6 (low) due to presence of limestone formations.

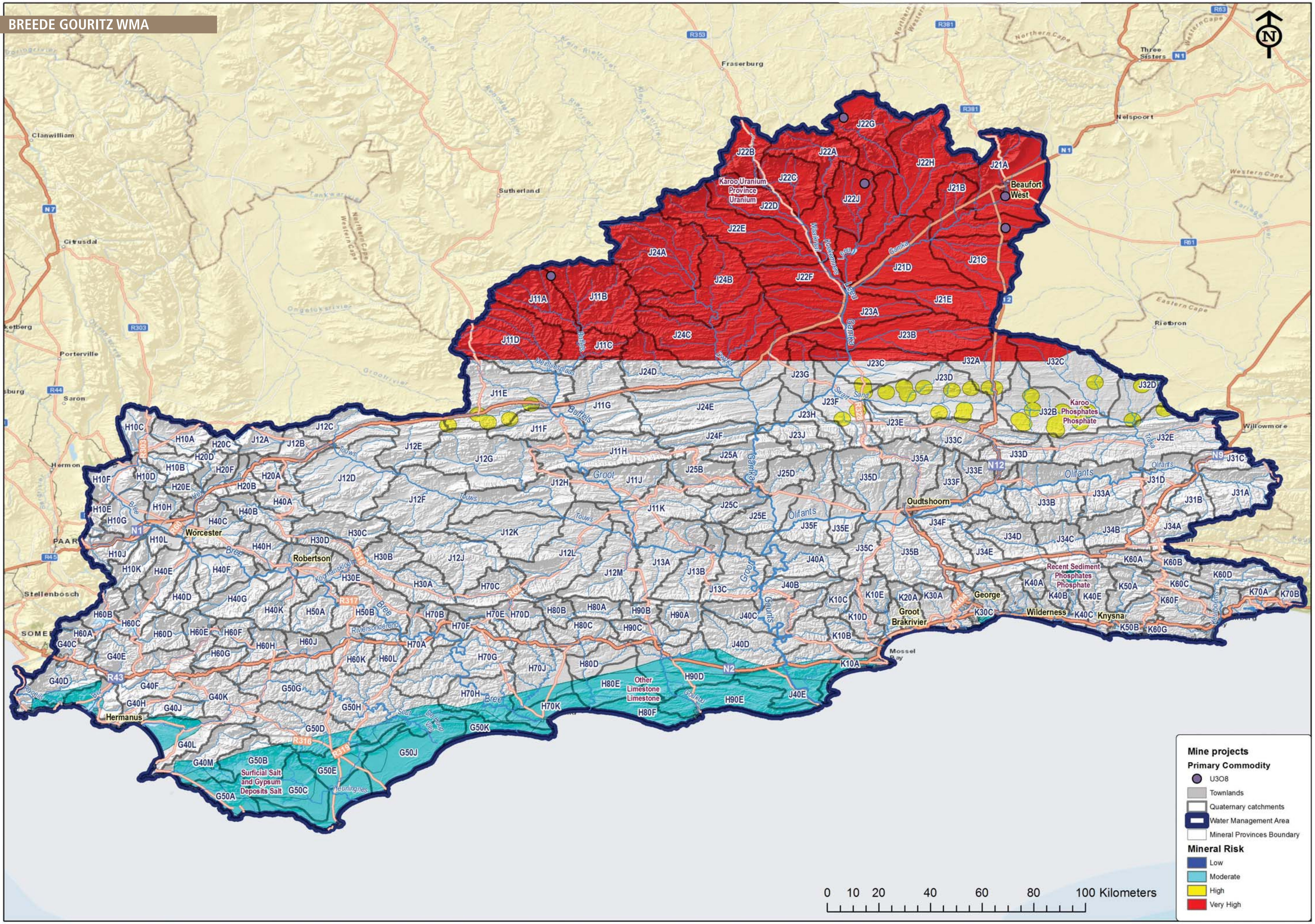
Key areas of concern:

Fresh water aquifers/springs/wetlands:

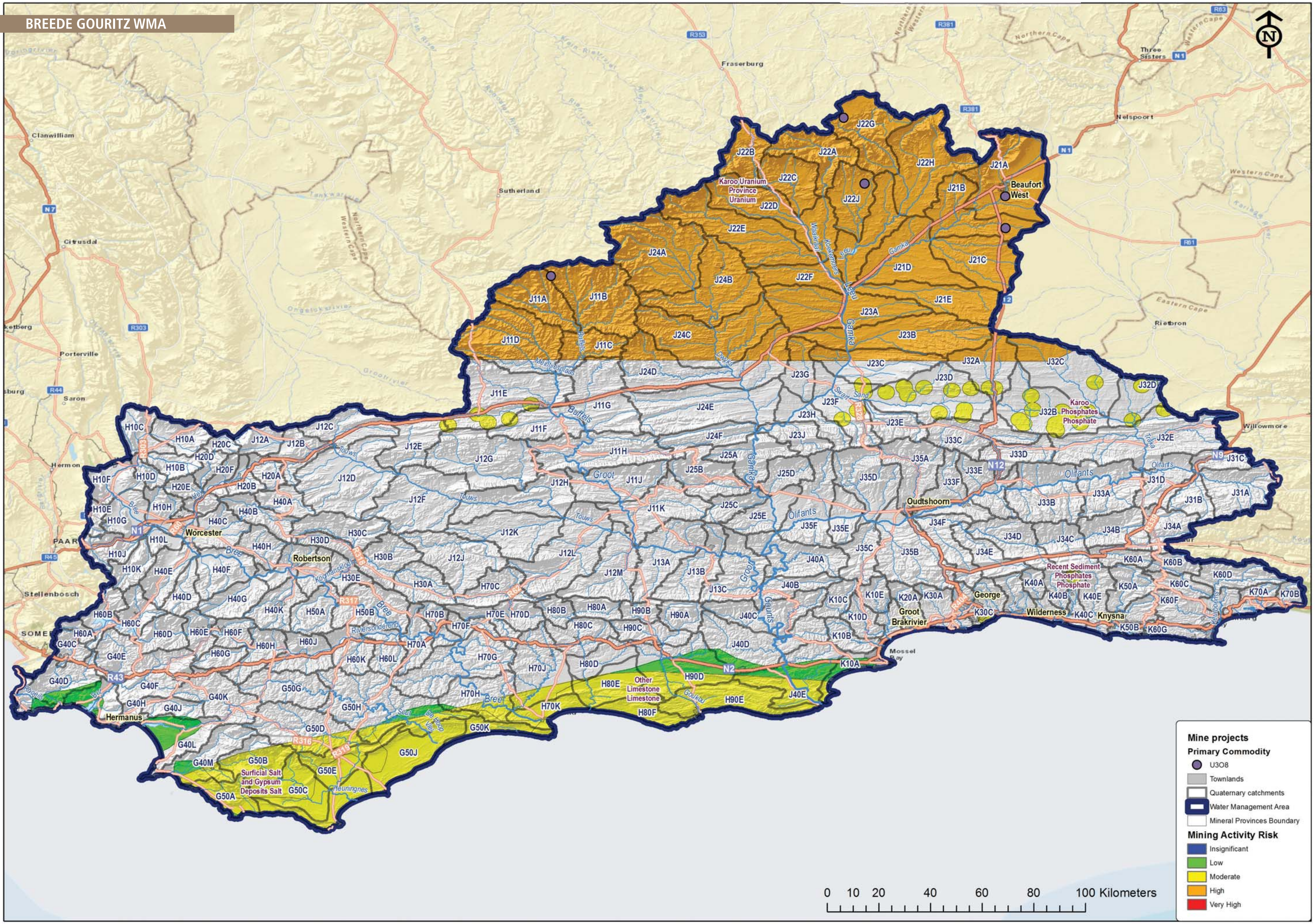
- Aquifer systems with water quality <70 mS/m mapped in Karoo Supergroup (in association with Karoo Dolerite dykes/sills) and Table Mountain Group environments;
- Coastal aquifers may be underlain by brackish to saline water which will migrate upwards to the fresh water aquifer during mining/bulk water abstractions; and
- Localised occurrences of Karoo Dolerite dykes and sills in the Karoo Supergroup rocks resulting in a vulnerability rating of 2.7 (moderate-high) to 3.3 (high).


BREEDE GOURITZ WMA
Karoo
Waterval
Beaufort West
Jonkers Leegte
DR3-East
Karoo Uranium Province Uranium
Karoo Phosphates Phosphate
Recent Sediment Phosphates Phosphate
Other Limestone Limestone
Surficial Salt and Gypsum Deposits Salt
Fraserburg
Sutherland
Clanwilliam
Citrusdal
Porterville
Nelspoort
Three Sisters
Rietbron
Willowmore
Worcester
Robertson
Stellenbosch
Hermanus
Oudtshoorn
George
Groot Brakrivier
Mossel Bay
Wilderness
Knysna
Mine projects
Primary Commodity
U3O8
Townlands
Quaternary catchments
Water Management Area
Mineral Provinces Boundary
Mine landcovers
Mineral Province
Elevation (mamsl)
High : 2199
Low : -16
0 10 20 40 60 80 100 Kilometers

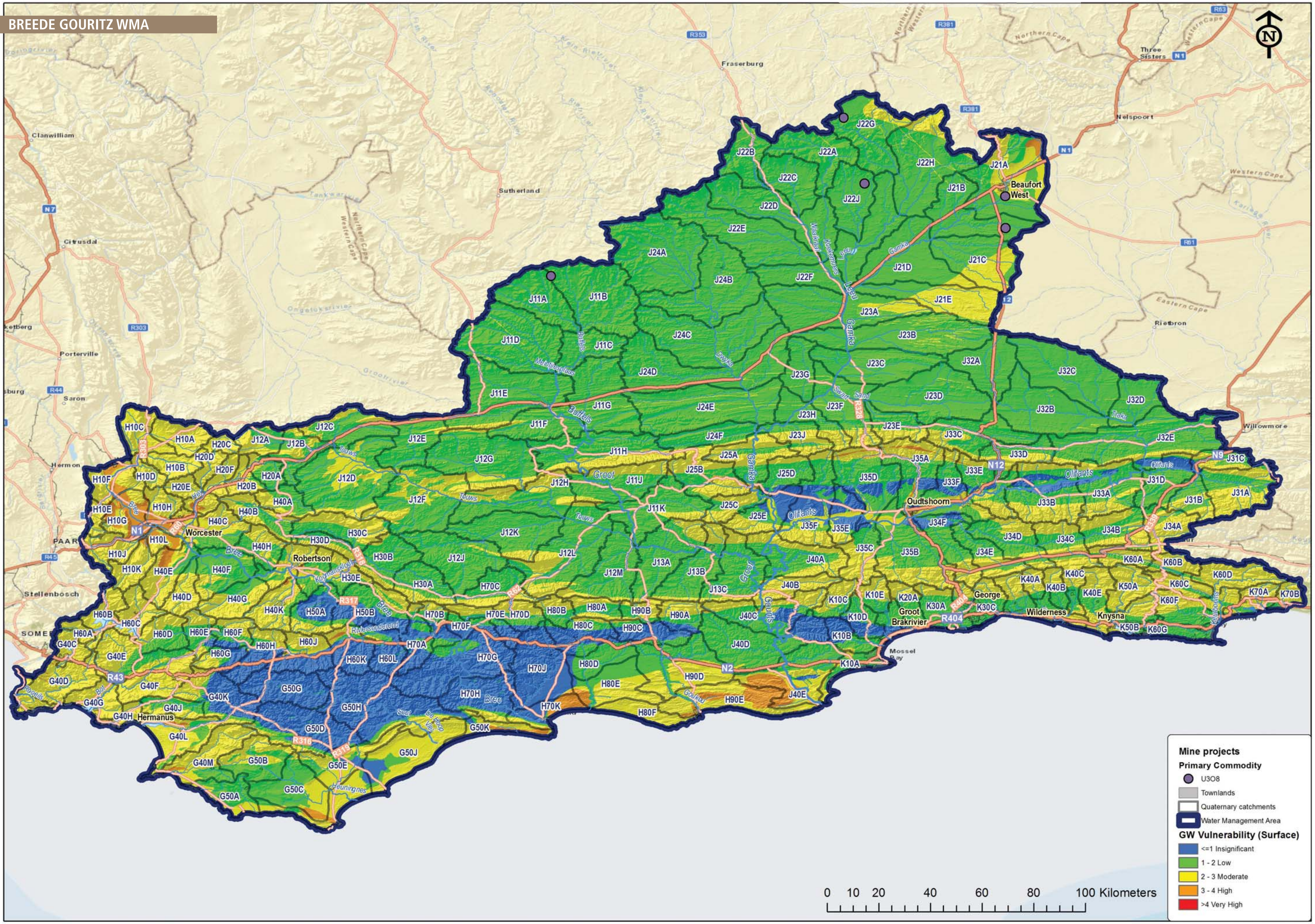
BREEDE GOURITZ WMA



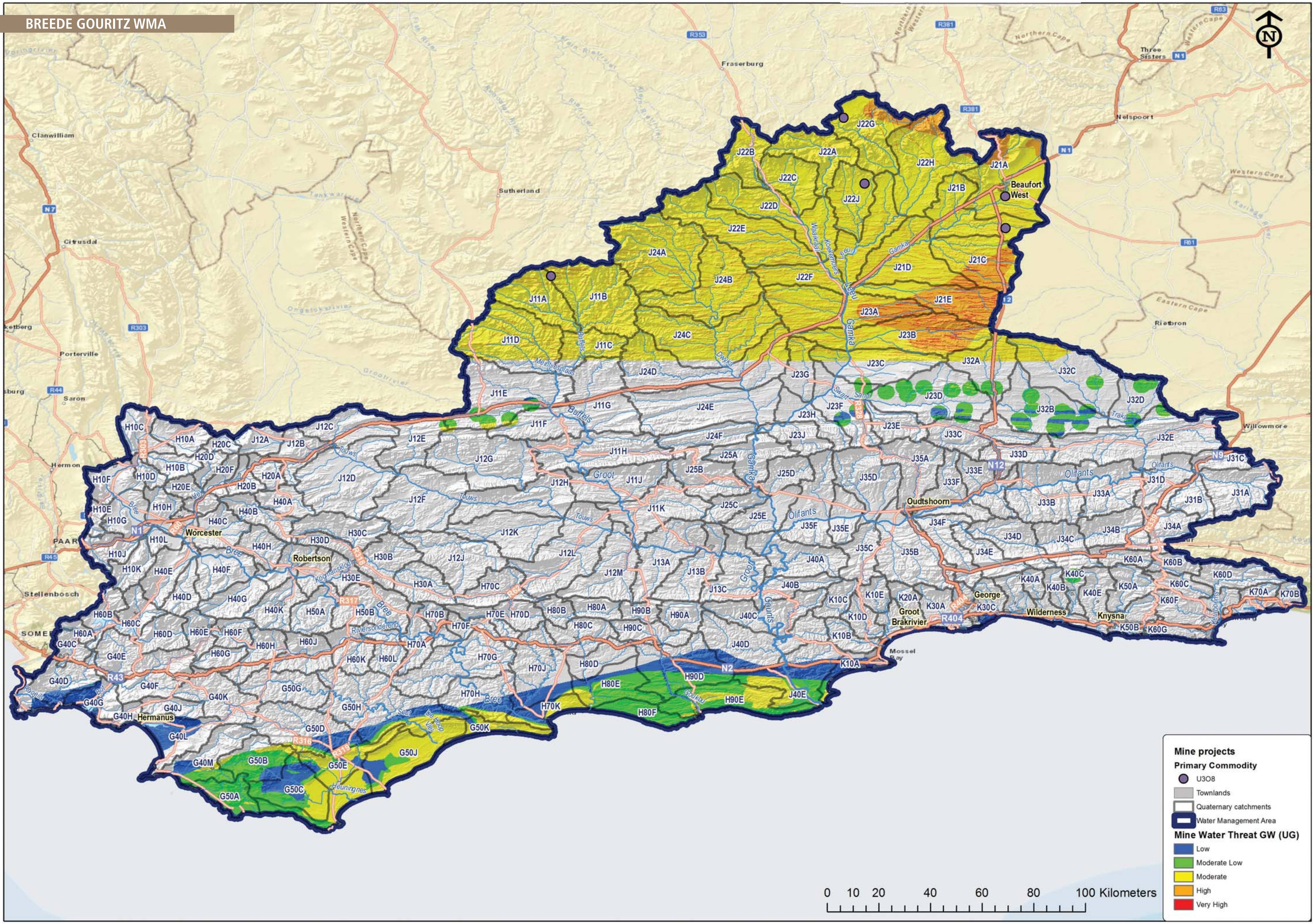
BREEDE GOURITZ WMA

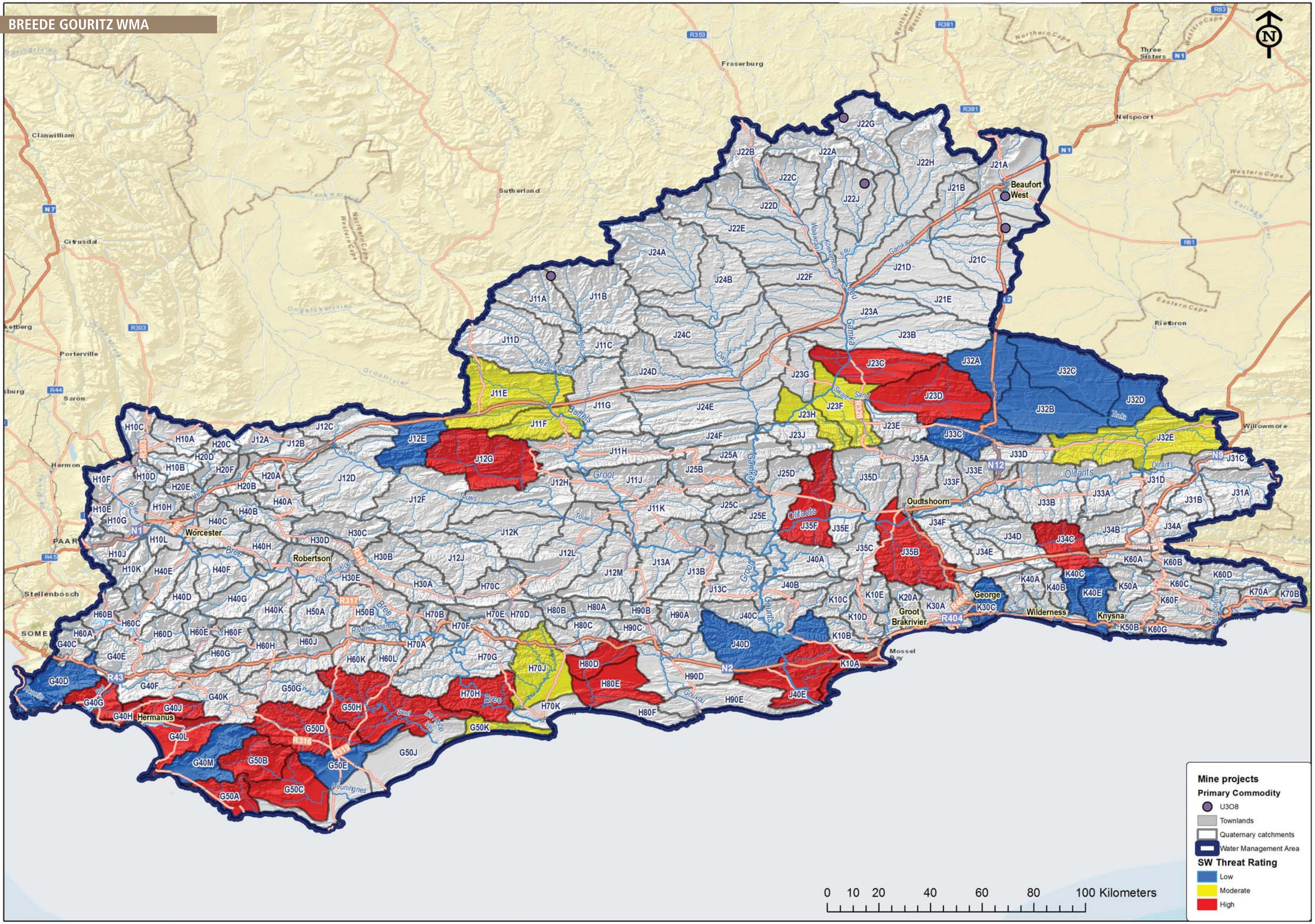


BREEDE GOURITZ WMA

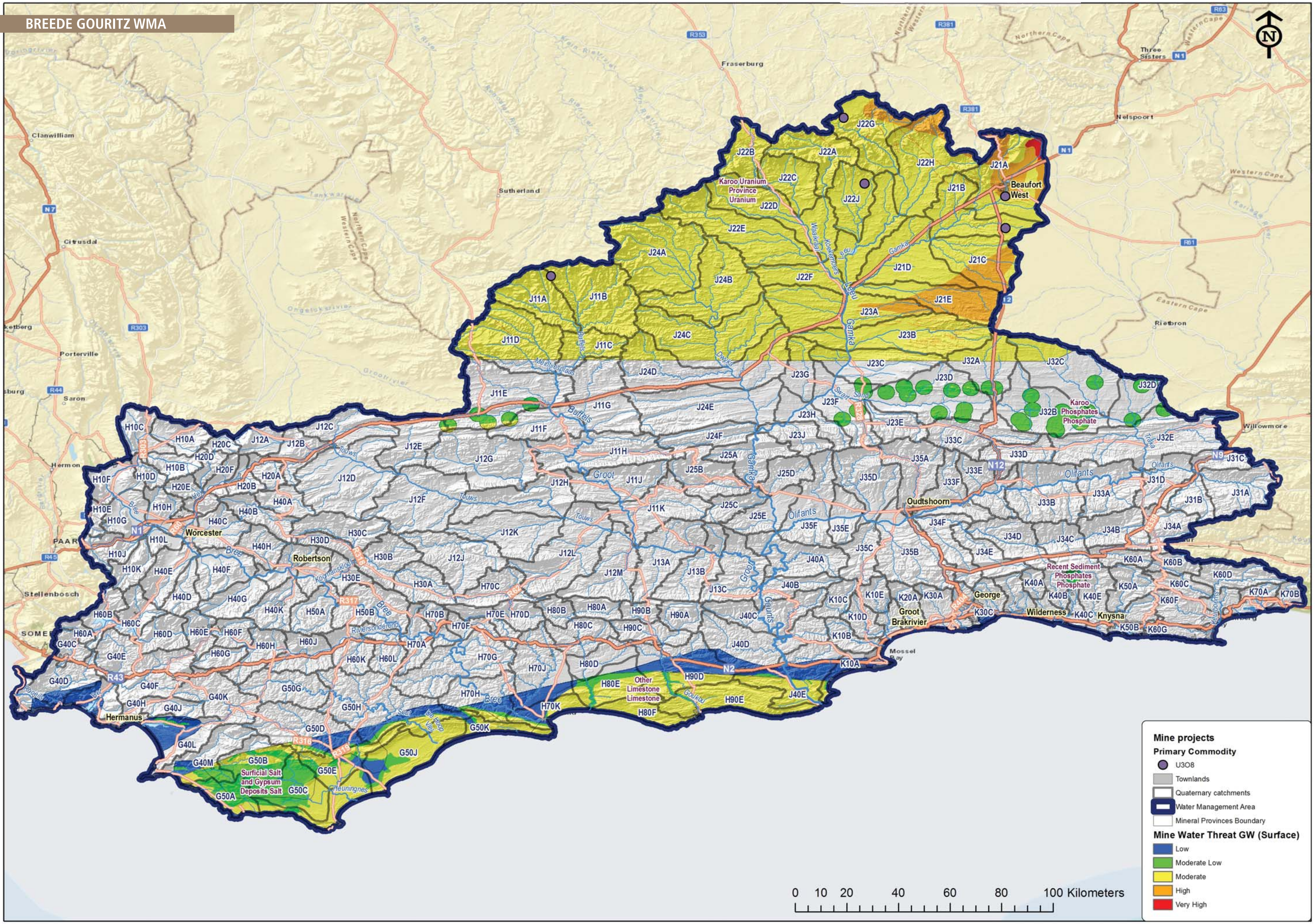


BREEDE GOURITZ WMA

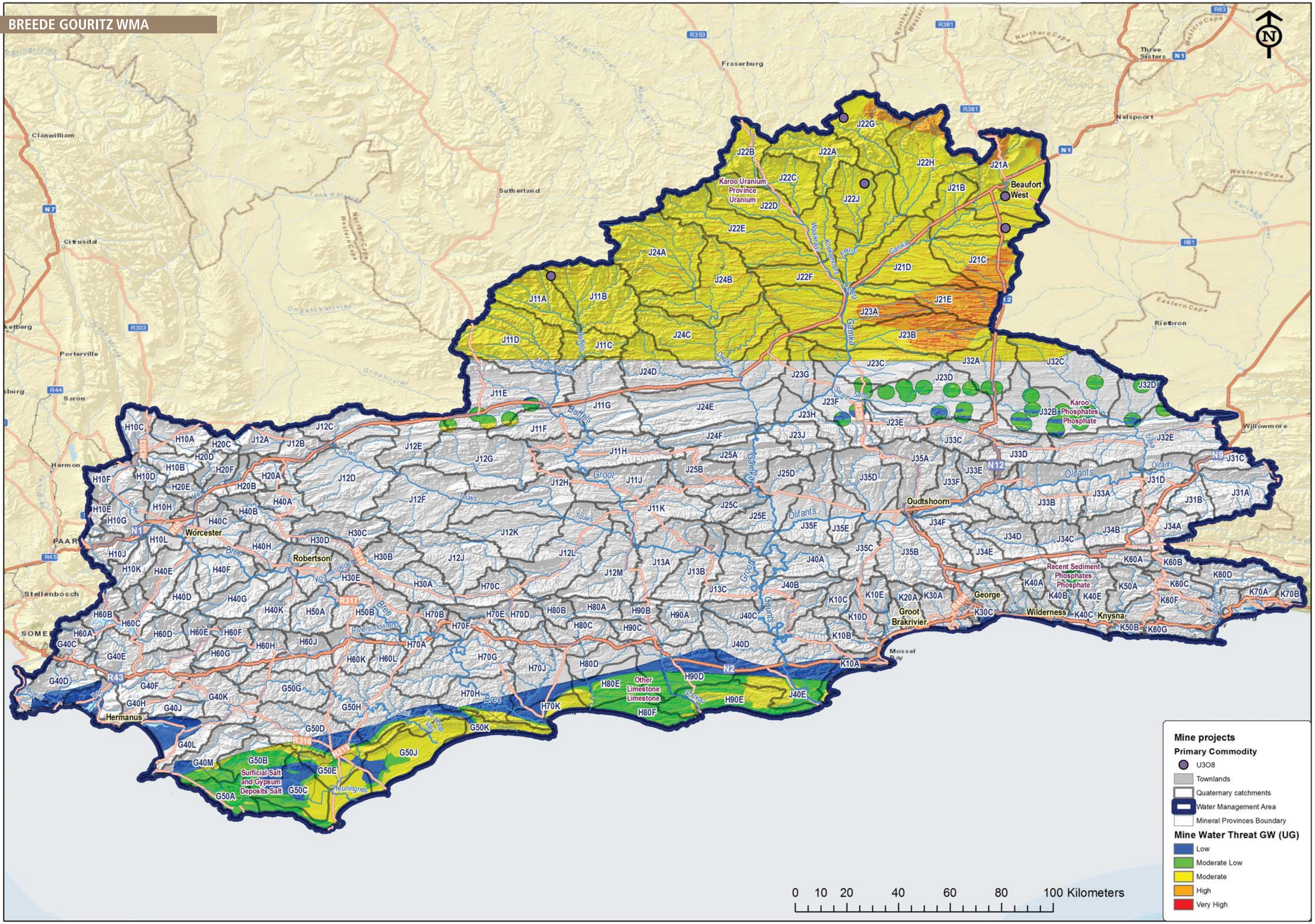



BREEDE GOURITZ WMA
Fraserburg
Sutherland
Clanwilliam
Citrusdal
Porterville
Saron
Hermon
Worcester
Robertson
Stellenbosch
Hermanus
Beaufort West
Nelspoort
Three Sisters
Rietbron
Willowmore
Oudtshoorn
George
Wilderness
Knysna
Groot Brakrivier
Mossel Bay
Mine projects
Primary Commodity
U3O8
Townlands
Quaternary catchments
Water Management Area
SW Threat Rating
Low
Moderate
High
0 10 20 40 60 80 100 Kilometers

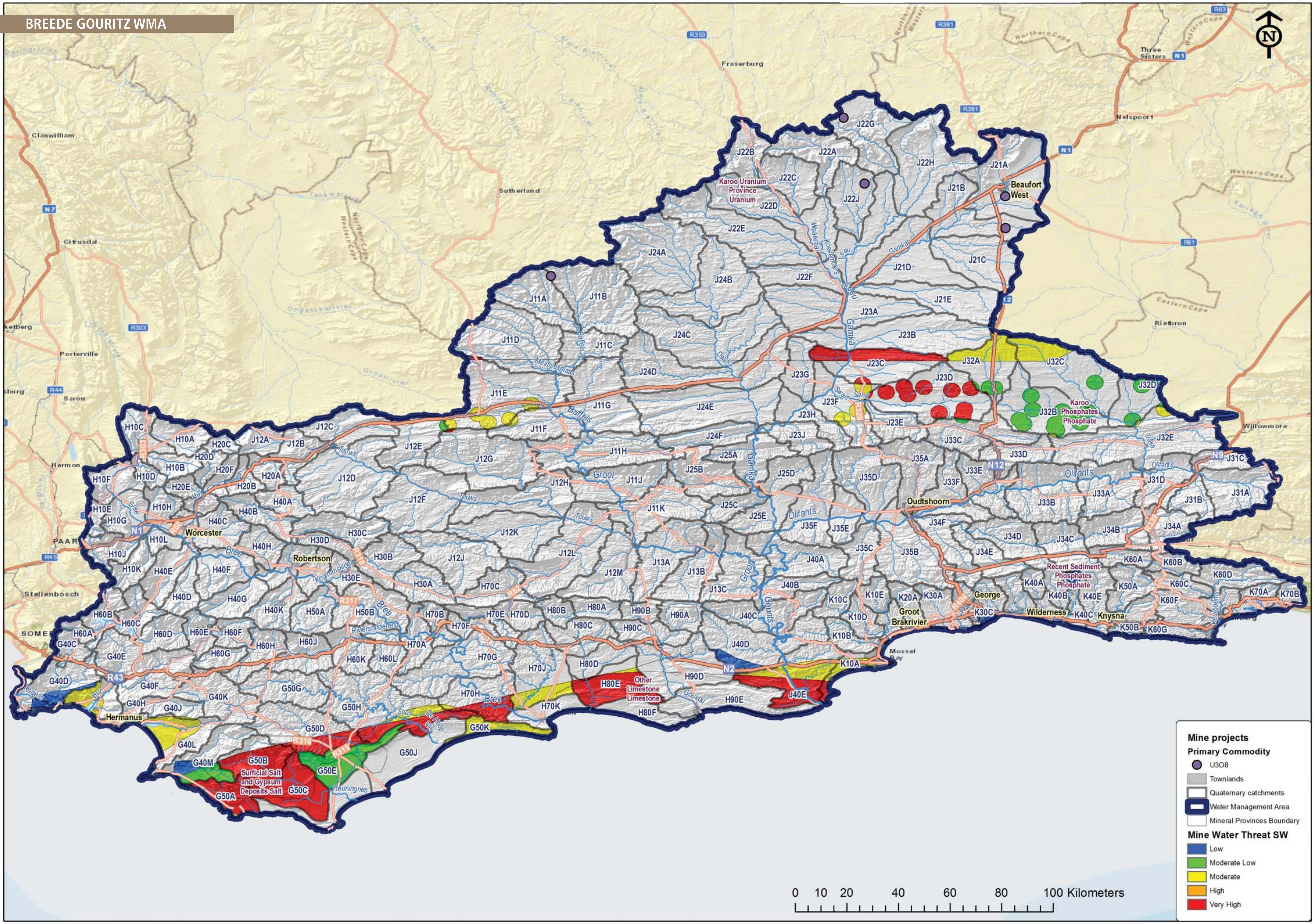
BREEDE GOURITZ WMA



BREEDE GOURITZ WMA



BREEDE GOURITZ WMA



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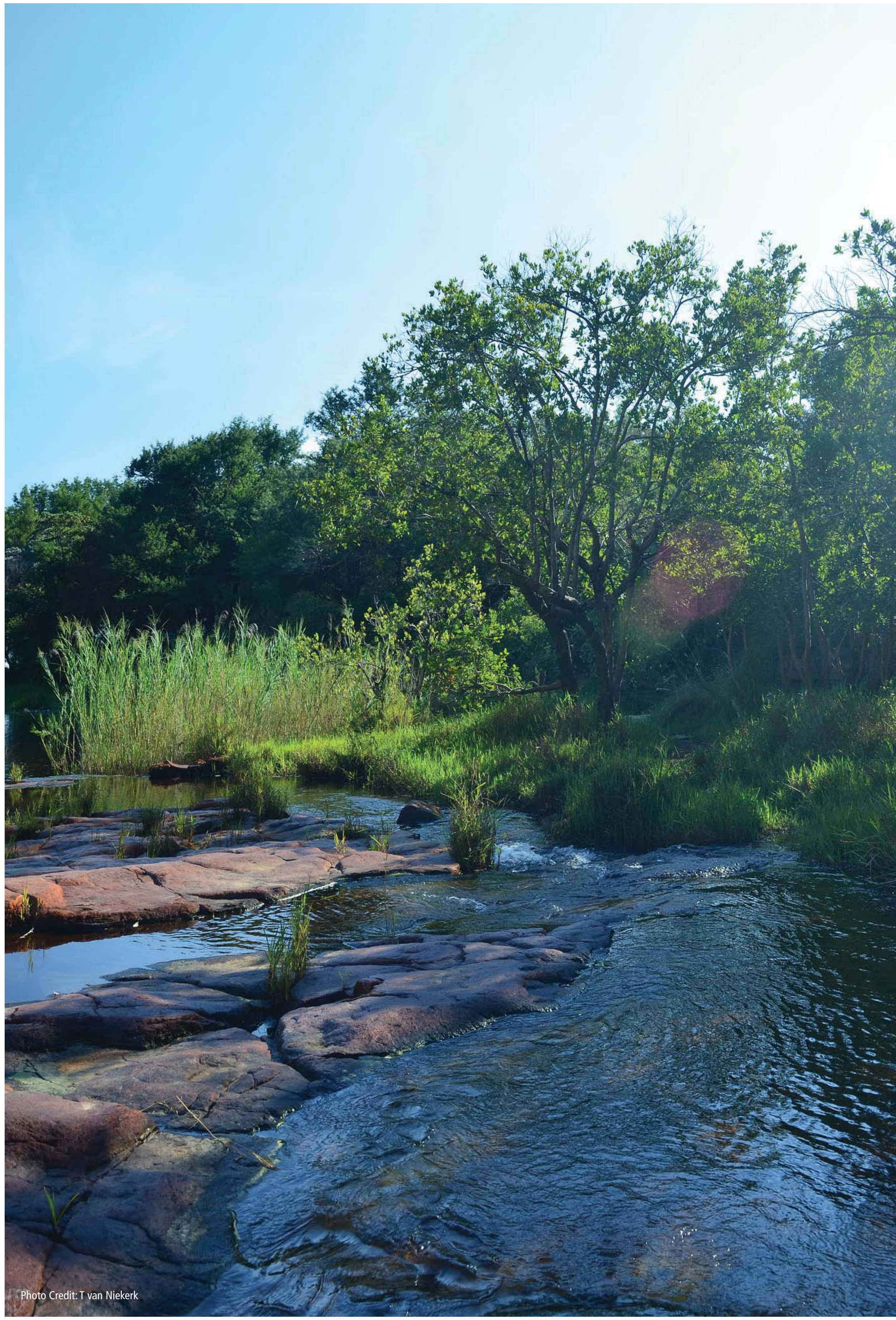
SPATIAL DATA SOURCES

Base datasets used in maps	Source	Currency
Water Management Areas	Dept. of Water & Sanitation (DWA)	2013
Rivers	DWA/NFEPA	2013
Roads	AfriGIS	2012
Quaternary Catchments	Dept. of Water & Sanitation	unknown
Mine Projects	SNL (www.snl.com)	2015
Dams	Dept. of Water & Sanitation	2012
Townlands	Stats SA (EA Mainplace)	2011
National Landcover	Dept. of Environmental Affairs (DEA)	2014
Present Ecological State	Dept. of Water & Sanitation	2013
Topography	SRTM gobal 90m DEM	N/A
Base Map service	ESRI	N/A
Primary datasets used in the production of derived datasets		
National 1:250 000 Geological map series vectors	Council for Geoscience	Unknown
Hydrogeological Map of South Africa	Dept. of Water & Sanitation	Unknown
Mineralogical Map of South Africa	Council for Geoscience	2010
Project datasets (dervied or generated)		
Mineral Province Boundaries	Council for Geoscience, Golder Associates	2015
National Groundwater Vulnerability (to surface mining)	Golder Associates / WRC	2015
National Groundwater Vulnerability (to underground mining)	Golder Associates / WRC	2015
Mineralogical Risk (per mineral province)	Golder Associates / WRC	2015
Mining Activity Risk (per mineral province)	Golder Associates / WRC	2015
Catchment Water Quality Rating (per quaternary catchment)	Golder Associates / WRC	2015
Catchment PES Rating (per quaternary catchment)	Golder Associates / WRC	2015
Surface Water Vulnerability (per quaternary catchment)	Golder Associates / WRC	2015
Mine Water Threat (to surface water)	Golder Associates / WRC	2015
Mine Water Threat (to groundwater from surface mining)	Golder Associates / WRC	2015
Mine Water Threat (togroundwater from underground mining)	Golder Associates / WRC	2015



SURFACE MINING RATING MATRIX

SURFACE MINING OPERATIONS

LITHOLOGY_AQTYPE	Hydrolithological description	Lith_Code	Rating
GIS Information Platform: Geohydrological Map Series (1: 500k)			
Based on the primary rock type (storage/storativity) with no secondary features. Contains the saturated fractured and weathered rock profile.			
Calcareous rocks	Limestone, dolomite, calcarenite	26, 44	3
Alluvium	Clay, sand, boulders	21	5
Unconsolidated to semi-consolidated sediments	Calcrete, conglomerate, aeonianite, clay	22	4
Arenaceous rocks	Sandstone, arkose, orthoquartzite	24, 42	2
Undifferentiated rocks & mixed lithologies:	Thinly bedded, Intensely folded		
	Phyllites, limestone & ironstones	40	2
	Limestone, dolomite & chert	58	4
Iron Formation	Banded ironstone	29, 47	2
Argillaceous/Arenaceous	Sandstone - mudrock (50-50)	25, 43	2
Meta-argillaceous rocks	Slate, phyllite, schist, amphibolite, ...	54	2
Meta-arenaceous rocks	Quartzite	37, 55	1
Mafic, intrusive rocks (sills only)	Dolerite, diabase, diorite, gabbro, dunite, ...	50	1
Mafic, intrusive rocks (dykes only)	Dolerite only	74, 75	2
Meta-calcareous rocks	Marble, cals-silicate	56	1
Rudaceous rocks	Conglomerate, grit, breccia	27, 45	2
Mafic/U-Mafic extrusive rocks	Basalt, andesite	34, 52	1
Argillaceous rocks, Diamictite (C-Pd),	Shale, claystone, mudstone, siltstone	23, 28, 41, 46 & 48.	1
Meta-arenaceous rocks	Gneiss, migmatite	37, 55	1
Pyroclastic rocks	Tuff, agglomerate, breccia, ignimbrite	49	1
Acid-Alkaline extrusive rocks	Rhyolite, felsite, quartsporphyry	53	1
Acid-Alkaline intrusive rocks	Various granitoids (basement granites)	51	1
Undifferentiated metamorphic rocks	Gneissoid rocks with xenoliths	57	1
	WEIGHTING FACTOR = 0.150		

Hydro-lithology Yield	Lith_Code	Rating
GIS Information Platform: GW_Occurences, Geohydrological Map Series (1:500k).		
Rating based on aquifer replenishment/sustainability and aquifer/aquiclude/aquitard transmissivity excluding any secondary features (fracturing, dykes, lineaments and folding).		
Intergranular	21, 22 (Link to AQ_TYPE)	3
Intergranular and Fractured (also fractured and weathered)	Link to AQ_TYPE	2
Fractured	Link to AQ_TYPE	1
Karst	26, 44, 56 (Link to aquifer type)	4
WEIGHTING FACTOR = 0.150		

Secondary structures: Regional (>5km^2)	Lith_Code/ Structures	Rating
GIS Information Platform: 1:250k Geological Maps Series (CGS)		
Folded formations, Joint development on bedding planes and regional fracturing. (These are regional features which may have jointing, fracturing and slipping development along primary bedding planes).		
No regional features	-	0
Over folding impl's Fractured rock	154, 193, 188 187, 155, 190.	4
Jointed (Formations with bedding planes)	40 & 58 29 & 47 25 & 43 32 & 50.	3
Anticlinal folding	143, 34, 138 36, 38, 142 33 & Structural dome (185)	2
Synclinal folding	142, 144 35, 35 139, 37 & Structural basin (186).	1
WEIGHTING FACTOR = 0.095		

Secondary structures: Local (<5km^2)	Lith_Code	Rating
GIS Information Platform: 1: 250k Geological Map Series (CGS).		
Lineaments, dolerite/diabase dykes, faults/fracture zones and shear zones.		
No local features	-	0
Dyke Swarms/Network: Dolerite, diabase (only <100m appart).	J-d; 74, 75; 76, V-di	5
Chromite layer	117	5
Dyke Swarms/ Network dolerite, diabase and aeromagnetic lineaments >100 - 750m appart	J-d; 22; 74, 75 76.	4
Single dykes (>750m appart): DOLERITE, DIABASE + Faults & fractures & all lineaments.	J-d, V-di, M1, 21, 23, 68, 74, 75, 76, 128, 135, 138,	3
Karoo Dolerite Sill	32	
Veins: breccia, quartz	3, 1 26	
Dykes: Basalt, basic dyke swarm and brecciated quartz-porhyry (<100m spacing)	Kzr1, Ngn, J5	5
Dykes: Quartz porphyry, quartz syenite	Kk2, Kk1,	2
Dykes: Kimberlite, Carbonitite, Pyroxenite, granite/granophyr	J1, C1, V19, R10 M36, Jts1 79	1
Lineament, undifferentiated	20	3
WEIGHTING FACTOR = 0.155		

76 = V-di: Diabase dyke
74 = J-d: Karoo dolerite dyke
75 = M-s: Syenite dyke
32 - J-d: Karoo dolerite sill

Borehole Yield Class	Bh Yields	Rating
GIS Information Platform: Yield polygons derived from the Borehole Yield Class (DWS)		
High	>5.0 l/s	5
Moderate	2.0-5.0 l/s	4
Minor	>0.5-<2.0 l/s	3
Low	0.1-0.5 l/s	2
Insignificant	<0.1 l/s	1
WEIGHTING FACTOR = 0.225		

General water quality criteria	Range	Rating
GIS Information Platform: Water quality based on the Geohydrological Map Series (1:500k).		
Fresh water (Class 0)	EC < 70 mS/m / TDS <455 mg/l	5
Brackish water (Class I-II)	EC . 70 - 300 mS/m / TDS = >455 - 1950 mg/l	3
Saline water (Class III-IV)	EC >300 mS/m / TDS >1950 mg/l	1
WEIGHTING FACTOR = 0.225		

UNDERGROUND MINING RATING MATRIX

UNDERGROUND MINING (>100m BELOW SURFACE)

LITHOLOGY_AQTYPE	Hydrolithological description	Lith_Code	Rating
GIS Information Platform: Geohydrological Map Series (1: 500k)			
Based on the primary rock type (storage/storativity) with no secondary features. Contains fully/partially the saturated fractured and weathered rock profile.			
Calcareous rocks	Limestone, dolomite, calcarenite	26, 44	3
Undifferentiated coastal and inland deposits	Unconsolidated sediments	T-Qm	0
		T-Qk	0
Arenaceous rocks	Sandstone, arkose, orthoquartzite	24, 42	3
Undifferentiated rocks & mixed lithologies: Kraaipan Grp	Thinly bedded, Intensely folded		
	Phyllites, limestone & ironstones	40	1
	Limestone, dolomite & chert	58	3
Iron Formation	Banded ironstone	29, 47	1
Argillaceous/Arenaceous	Sandstone - mudrock (50-50)	25, 43	2
Meta-argillaceous rocks	Slate, phyllite, schist, amphibolite, ...	54	1
Meta-arenaceous rocks	Quartzite	37, 55	1
Mafic, intrusive rocks (sills only)	Dolerite, diabase, diorite, gabbro, dunite, ...	32, 50	1
Mafic, intrusive rocks (dykes only)	Dolerite only	74, 75	1 (0)
Meta-calcareous rocks	Marble, cals-silicate	56	1
Rudaceous rocks	Conglomerate, grit, breccia	27, 45	2
Mafic/U-Mafic extrusive rocks	Basalt, andesite	34, 52	1
Argillaceous rocks, Diamictite (C-Pd),	Shale, claystone, mudstone, siltstone	23, 28, 41, 46 & 48.	1
Meta-arenaceous rocks	Gneiss, migmatite	37, 55	2
Pyroclastic rocks	Tuff, agglomerate, breccia, ignimbrite	49	1
Acid-Alkaline extrusive rocks	Rhyolite, felsite, quartsporphyry	53	1
Acid-Alkaline intrusive rocks	Various granitoids (basement granites)	51	1
Undifferentiated metamorphic rocks	Gneissoid rocks with xenoliths	57	1
WEIGHTING FACTOR = 0.125			

Hydro-lithology Yield	Aquifer type	Rating
GIS Information Platform: GW_Occurences, Geohydrological Map Series (1:500k).		
Rating based on aquifer replenishment/sustainability and aquifer/aquiclude/aquitard transmissivity excluding any secondary features (fracturing, dykes, lineaments and folding).		
Intergranular	21, 22 and (Link to AQ_TYPE)	0
Intergranular and Fractured (also fractured and weathered)	Link to AQ_TYPE	1
Fractured	Link to AQ_TYPE	2
Karst	26/44, 56 (Link to AQ_TYPE)	1
WEIGHTING FACTOR = 0.125		

Secondary structures: Regional (>5km^2)	Lith_Code/ Structures Code	Rating
GIS Information Platform: 1:250k Geological Maps Series (CGS)		
Folded formations, Joint development on bedding planes and regional fracturing. (These are regional features which may have jointing, fracturing and slipping development along primary bedding planes).		
No regional secondary features	Blank	0
Over folding impl's Fractured rock	154, 193, 188, 187, 155, 190.	4
Jointed (Formations with bedding planes): •Primary Calcareous rocks overlain by karst aquifers.	40/58, 29/47, 25/43, 32/50, •26/44, 56	5
Anticlinal folding	143, 34, 138, 36, 38, 142, 33 & Structural dome (185)	3
Synclinal folding	142, 144, 35, 35, 139, 37 & Structural basin (186).	3
WEIGHTING FACTOR = 0.225		

Secondary structures: Local (<5km^2)	Lith_Code	Rating
GIS Information Platform: 1: 250k Geological Map Series (CGS).		
Lineaments, dolerite/diabase dykes, faults/fracture zones and shear zones.		
No local secondary features	Blank	0
Dyke Swarms/Network: Dolerite, diabase (only <100m appart)	J-d, 74 = J-d 75 = M-s 76 = V-di	3
Chromite layer Merensky Reef	117 22	3
Dyke Swarms/ Network dolerite, diabase and aeromagnetic lineaments >100 - 750m appart	J-d; 22; 74, 75	2
Dolerite Sills (contact zones)	32	3
Single dykes: DOLERITE, DIABASE + Faults & fractures & all lineaments.	J-d, V-di, M1; 68, 74, 75, 21, 23, 24, 103, 115, 128, 135, 136, 138.	1
Veins: breccia, quartz	1, 3 26, 172	
Dykes: Basalt, basic dyke swarm and brecciated quartz-porhyry (<100m spacing)	Kzr1, Ngn, J5	2
Dykes: Quartz porphyry, quartz syenite	Kk2, Kk1,	1
Dykes: Kimberlite, Carbonitite, Pyroxenite, granite/granophyre	J1, C1, V19, R10, M36, Jts1, 20, 79	1
WEIGHTING FACTOR = 0.200		

Borehole Yield Class	Actual yield	Rating
GIS Information Platform: Yield polygons derived from the Borehole Yield Class (DWS)		
Yield polygons derived from the Borehole Yield Class		
High	>5.0 l/s	5
Moderate	2.0-5.0 l/s	3
Minor	0.5-<2.0 l/s	2
Low	0.1-<0.5 l/s	1
Insignificant	<0.1 l/s	0
WEIGHTING FACTOR = 0.100		

General water quality criteria	Range	Rating
GIS Information Platform: Water quality based on the Geohydrological Map Series (1:500k).		
Water quality of the main aquifer system as per Geohydrology Maps.		
Fresh water (Class 0)	EC < 70 mS/m / TDS <455 mg/l	5
Brackish water (Class II)	EC . 150 - 370 mS/m / TDS = >1000 - 2400 mg/l	3
Saline water (Class III)	EC >370 - 520 mS/m / TDS >2400-3400 mg/l	1
Highly saline water (Class IV)	EC >520 mS/m / TDS > 3400	
WEIGHTING FACTOR = 0.225		

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