EMP Consolidation for Thubelisha, Trichardtsfontein and Vaalkop

Aquatic Baseline & Impact Assessment Report

Project Number:

SAS3869

Prepared for:

Sasol Mining (Pty) Ltd

September 2017

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Project Name:	**EMP Consolidation for Thubelisha, Trichardtsfontein and Vaalkop**
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Name	Responsibility	Signature	Date
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Byron Bester	Technical Review		September 2017
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DECLARATION OF INDEPENDENCE

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I, Nathan Cook as duly authorised representative of Digby Wells and Associates (South Africa) (Pty) Ltd., hereby confirm my independence (as well as that of Digby Wells and Associates (South Africa) (Pty) Ltd.) and declare that neither I nor Digby Wells and Associates (South Africa) (Pty) Ltd. have any interest, be it business, financial, personal or other, in any proposed activity, application or appeal in respect of Sasol Mining (Pty) Ltd, other than fair remuneration for work performed, specifically in connection with the Environmental Management Plan (EMP) consolidation of the Sasol Twistdraai Colliery: Thubelisha Shaft (TCTS), and well as the Trichardtsfontein and Vaalkop Mining Right areas ("the Project"), located between the town of Trichardt and Bethal,Mpumalanga.

Full Name:	Nathan Gerard Cook
Title/ Position:	Aquatic Ecologist
Qualification(s):	BSc Environmental Science
Experience (Years):	1

EXECUTIVE SUMMARY

Sasol Mining (Pty) Ltd (hereinafter Sasol) appointed Digby Wells Environmental (hereinafter Digby Wells) to provide specialist studies in support of the legislative authorisation process for the consolidation of their Twistdraai Colliery: Thubelisha Shaft (TCTS), as well as Trichardtsfontein and Vaalkop Mining Right areas ("the Project"). The proposed consolidation of the Mining Right areas will be completed in terms of Section 102 of the Minerals and Petroleum Resources Development Act, 2002 (Act No. 28 of 2002) (MPRDA).

The aim of the study was to determine the baseline ecological status of the rivers associated with the Project. In order to do so, the following river reaches within the B11C and B11D quaternary catchments were assessed during two seasonal surveys (i.e. high-flow and low-flow conditions):

- Trichardtspruit;
- Debeerspruit;
- Piekespruit; and
- Steenkoolspruit.

It is important to note that a number of tributaries of the above mentioned reaches were also assessed. For the purpose of the study these tributaries included:

- Debeerspruit Tributary;
- Piekespruit Tributary; and
- Steenkoolspruit Tributary.

Through the application of standardised River Ecosystem Monitoring Programme techniques, the Present Ecological Status (PES) of the above mentioned river reaches were determined. The results of the assessment varied with the ecostatus for the assessed reaches ranging from largely modified (category D) to moderately modified (category C). This was largely attributed to the existing impacts within the catchment area which comprised mainly of cultivation and livestock as well as other mining operations in the B11D quaternary catchment. These activities were believed to facilitate elevated pH and conductivity values within the assessed systems, which have possibly led to the loss of a number of fish and macroinvertebrate taxa.

In light of the aforementioned ecological conditions, an impact assessment was conducted to identify any potential impacts associated with the Project that are likely to affect the associated watercourses. Based on this assessment, several key impacts were identified as indicated in Table 1-1 below:

A summary of the impact assessment is provided in the table below (Table 1-1).

Table 1-1: Summary of Potential Impacts

Interaction	Impact	Severity after mitigation
Phase: Construction		
Site clearance within river catchment and construction of surface infrastructure (ventilation shafts)	Increased runoff resulting in erosion and sedimentation of downstream habitats. Increased runoff from manmade structures resulting in the erosion and sedimentation of downstream river reaches	Negligible
Waste generation and disposal	Runoff containing pollutants and solid waste resulting in water and habitat quality degradation in downstream river reaches	Negligible
Phase: Operational		
Underground blasting and mining of high to definite risks subsidence areas	Undermining of wetlands and rivers leading to hydrological and geomorphic changes to the functioning of the ecosystem; particularly related to groundwater impacts	Major
Underground blasting and mining of low risk subsidence areas	Undermining of wetlands and rivers leading to hydrological and geomorphic changes to the functioning of the ecosystem; particularly related to groundwater impacts	Minor
The emergency stockpiling of coal	Runoff water which may come into contact with the carboniferous material will contain various pollutants that may contaminate downstream river reaches	Negligible
Waste generation/disposal and working with hazardous products	Runoff containing hazardous substances and solid waste resulting in water and habitat quality degradation in downstream river reaches	Negligible
Phase: Closure and Rehabilitation		

Interaction	Impact	Severity after mitigation
Removal of infrastructure and surface rehabilitation	Similarly to the construction phase, the removal of the infrastructure will lead to potential negative impacts on the habitat integrity of the associated aquatic ecosystems	Negligible
Underground mine closure and rehabilitation	Post-mining decant of groundwater will have negative impacts on the downstream water quality	Minor

Considering these potential impacts, should the mining operation go ahead provision should be made to mitigate against the any notable changes to the hydrology of the systems, water quality impairment, and/or potential subsidence of surrounding areas.

Key monitoring conditions have been recommended within this report along with various mitigation actions, including:

- Buffer zone establishment: 100 m from delineated wetland boundaries and river areas as stipulated in the Wetlands report by Digby Wells (2017);
- Effective storm water management, so as to limit (or prevent) potential contamination from 'dirty' water runoff originating from the ventilation shafts;
- Exposed topsoils and soil stockpiles must be revegetated to reduce erosion and subsequent sedimentation;
- Correct storage and management of hazardous products must be implemented;
- Although a basic geotechnical study has been completed for TCTS, it is recommended that a comprehensive geotechnical study must be conducted for the entire project area to assess the risk of subsidence in areas associated with river systems. Mitigation actions to increase stability should then be used in high risk areas. These mitigation actions include limiting mining underneath the river systems and the use of thicker support pillars. However, detailed mitigation actions should be defined in the comprehensive geotechnical study. Subsidence is expected to result at all shallow mining areas (100 m or less) as illustrated in Figure 10-2. Therefore mitigation measures for these areas are not feasible due to the shallow depth of mining.

This report should not be considered in isolation and other specialist reports, such as surface water, groundwater and wetland studies should be reviewed to ensure a holistic understanding of the study area.

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1 Introduction

Standard water quality monitoring techniques fail to record the dynamic fluctuations of water chemistry within river systems (Wepener, 2005). Aquatic biota, which are permanently exposed to the dynamic conditions, have been used extensively as a means to obtain information pertaining to the fluctuations of contaminants in river systems (Moore and Murphy, 2015).

Sasol Mining (Pty) Ltd (hereinafter Sasol) appointed Digby Wells Environmental (hereinafter Digby Wells) as the independent environmental practitioner to undertake a Section 102 process in accordance with the Mineral and Petroleum Resources Development Act, 2002 (Act No. 28 of 2002) (MPRDA).This report serves to detail the findings of a specialist Aquatic Impact Assessment for the Project.

1.1 Project Overview

Sasol Mining (Pty) Ltd (Sasol Mining) holds mining rights for the Twistdraai Colliery: Thubelisha Shaft (TCTS) and the Vaalkop mining area, which were both incorporated into the regional Sasol Mining Right (Ref: MP30/5/1/2/2/138MR). It must be noted that no EMPr was compile for the Vaalkop mining right area even though a mining right was approved. Further to this, the mining right for the Trichardtsfontein Mine (Ref: MP30/5/1/2/2/10056MR) was ceded from Glencore Operations South Africa (Pty) Ltd in accordance with Section 11 of the Mineral and Petroleum Resources Development Act, 2002 (Act No. 28 of 2002) (MPRDA) to Sasol Mining. Sasol Mining is proposing that the Trichardtsfontein mining right area be incorporated into the regional Sasol Mining Right (Ref: MP30/5/1/2/2/138MR). Therefore all three mining right areas will operate under a single mining right (Sasol Mining Right).

It is therefore required that the Environmental Management Programme Reports (EMPrs) for the above mentioned mining right areas be compiled (Vaalkop), consolidated and updated to reflect changes in the mining plans and methodologies and consider additional infrastructure requirements. Digby Wells is therefore proposing a submission in terms of the provisions of Section 102 of the MPRDA and Regulation 31 of the National Environmental Management Act, 1998 (Act No. 107 of 1998) (NEMA) to obtain the required authorisation for both the amendment and consolidation process of the EMPrs (referred to in general as the Environmental Authorisation (EA) Amendment process). A basic assessment process will also be undertaken to obtain environmental authorisation for the construction and operation of the ventilation shafts. This will be undertaken as a consolidated process in accordance with the one environmental system.

The mining method proposed for the extraction of coal at the Trichardtsfontein Mine included the conventional bord-and-pillar method. Sasol now propose to include high extraction mining methodologies across all three aforementioned MR areas between an approximate depth of 30-215 m below surface. To this effect, Sasol must consider the potential impacts that may result from this amendment, specifically the increased risk of surface subsidence. In addition, all waste rock and Run of Mine (RoM) coal will be conveyed directly from the mine workings to the TCTS, located adjacent to the Trichardtsfontein Mine. Additionally, two ventilation shafts have been proposed, which will assist in providing sufficient ventilation to the underground mining area.

The Vaalkop mining area is approximately 8 600 hectares (ha) in extent. The initial mining activities in this area will be conducted as green field operations as no existing infrastructure for coal mining exists in the area. No infrastructure will be constructed on the Vaalkop mining area as all required infrastructure will be located at the TCTS site.

1.2 Terms of Reference

Sasol appointed Digby Wells Environmental (hereinafter Digby Wells) to provide specialist studies in support of the legislative authorisation process for the consolidation of their Twistdraai Colliery: Thubelisha Shaft (TCTS), Trichardtsfontein and Vaalkop Mining Right areas ("the Project"). The proposed consolidation of the Mining Right areas will be completed in terms of Section 102 of the Minerals and Petroleum Resources Development Act, 2002 (Act No. 28 of 2002) (MPRDA).

2 Details of the Specialist

Nathan Cook has completed the aquatic ecology study for this project. He holds a BSc in environmental sciences and is an accredited SASS5 practitioner in terms of the Department of Water & Sanitation's (previously Department of Water Affairs and Forestry) River Ecostatus Monitoring Programme (previously the River Health Programme) with. Nathan has completed numerous aquatic ecology assessments in South Africa and has surveyed systems within Senegal in West Africa, as well as within the Zambezi and Chobe rivers in Botswana, Zambia and Namibia. He has a good technical understanding on the variable conditions within South African rivers as well as their biological compositions, especially in the Highveld Lower ecoregion.

3 Aims and Objectives

The aim of this study was to determine the aquatic ecosystem baseline conditions for the river systems associated with the proposed mining operations, as indicated in the Study Area section, prior to commencement of the proposed mining and mining related development. This was achieved by means of a detailed infield assessment along the associated watercourses and the determination of their Present Ecological Status (PES).

In addition, potential impacts on the aquatic ecosystems as a result of the proposed mining related development were identified, evaluated and mitigation measures were recommended to avoid, prevent, limit and/or minimize the potential impacts associated with the proposed development.

Lastly, based on the findings of the baseline and impact assessments, a monitoring programme was compiled to monitor various recommended aquatic ecosystem parameters on a long-term basis to identify any changes and/or impact in an effort to ensure compliance with local, provincial and national legislation, including the stipulated Resource Water Quality Objectives (RWQO) and the National Water Act, 1998 (Act No. 36 of 1998) (NWA).

4 Methodology

4.1 Literature Review and Desktop Assessment

Studies related to aquatic ecosystems of the region were reviewed to gain an understanding of the nature of the aquatic ecosystem of the surrounding environment. Desktop information consulted was based primarily on the most up to date version of the Desktop Assessment for the PES, Ecological Importance (EI) and Ecological Sensitivity (ES) per Sub Quaternary Reaches (SQR) of Secondary Catchments in South Africa (Department of Water and Sanitation, 2016).

4.2 Fieldwork and Seasonal Influence

To identify temporal ecological trends within the associated river systems, a survey was conducted in the high flow season (8th-10th March 2017) and within the low flow season (28th – 30th June 2017).

4.3 Water Quality

Water quality was measured using a calibrated Extech DO 700 multimeter. Constituents considered included temperature, pH, Dissolved Oxygen (DO) (mg/l) and conductivity (µS/cm). The results of the Digby Wells Surface Water Assessment (Digby Wells, 2017a), in which the chemical analysis of water was completed, was used to supplement these results. Water quality guidelines used in this report are for Aquatic Ecosystems (DWAF, 1996).

4.4 Habitat Quality

The availability and diversity of aquatic habitat is important to consider in assessments due to the reliance and adaptations of aquatic biota to specific habitats types (Barbour *et. al*., 1996). Habitat quality and availability assessments are usually conducted alongside biological assessments that utilise fish and macroinvertebrates. Aquatic habitat (habitat) was assessed through visual observations on each river system considered.

4.4.1 Intermediate Habitat Integrity Assessment

To define a general habitat, for baseline purposes, the instream and riparian habitat was assessed and characterised according to “Procedure for Rapid Determination of Resource Directed Measures for River Ecosystems (Section D).

The Intermediate Habitat Integrity Assessment (IHIA) model was used to assess the integrity of the habitats from a riparian and instream perspective. The habitat integrity of a river refers to the maintenance of a balanced composition of physico-chemical and habitat characteristics on a temporal and spatial scale that are comparable to the characteristics of natural habitats of the region (Kleynhans, 1996). The criteria utilised in the assessment of habitat integrity in the current study are presented in Table 4-1.

Table 4-1: Criteria in the Assessment of Habitat Integrity

Criterion	Relevance
Water abstraction	Direct impact on habitat type, abundance and size. Also implicated in flow, bed, channel and water quality characteristics. Riparian vegetation may be influenced by a decrease in the supply of water.
Flow modification	Consequence of abstraction or regulation by impoundments. Changes in temporal and spatial characteristics of flow can have an impact on habitat attributes such as an increase in duration of low flow season, resulting in low availability of certain habitat types or water at the start of the breeding, flowering or growing season.
Bed modification	Regarded as the result of increased input of sediment from the catchment or a decrease in the ability of the river to transport sediment (Gordon *et. al*., 1993). Indirect indications of sedimentation are stream bank and catchment erosion. Purposeful alteration of the stream bed, e.g. the removal of rapids for navigation (Hilden & Rapport, 1993) is also included.
Channel modification	May be the result of a change in flow, which may alter channel characteristics causing a change in marginal instream and riparian habitat. Purposeful channel modification to improve drainage is also included.
Water quality modification	Originates from point and diffuse point sources. Measured directly or alternatively agricultural activities, human settlements and industrial activities may indicate the likelihood of modification. Aggravated by a decrease in the volume of water during low or no flow conditions.
Inundation	Destruction of riffle, rapid and riparian zone habitat. Obstruction to the movement of aquatic fauna and influences water quality and the movement of sediments (Gordon *et. al*., 1992).
Exotic macrophytes	Alteration of habitat by obstruction of flow and may influence water quality. Dependent upon the species involved and scale of infestation.
Exotic aquatic fauna	The disturbance of the stream bottom during feeding may influence the water quality and increase turbidity. Dependent upon the species involved and their abundance.
Solid waste disposal	A direct anthropogenic impact which may alter habitat structurally. Also a general indication of the misuse and mismanagement of the river.
Indigenous vegetation removal	Impairment of the buffer the vegetation forms to the movement of sediment and other catchment runoff products into the river (Gordon *et. al*., 1992). Refers to physical removal for farming, firewood and overgrazing.
Exotic vegetation encroachment	Excludes natural vegetation due to vigorous growth, causing bank instability and decreasing the buffering function of the riparian zone. Allochtonous organic matter input will also be changed. Riparian zone habitat diversity is also reduced.

Criterion	Relevance
Bank erosion	Decrease in bank stability will cause sedimentation and possible collapse of the river bank resulting in a loss or modification of both instream and riparian habitats. Increased erosion can be the result of natural vegetation removal, overgrazing or exotic vegetation encroachment.

The relevant criteria is then weighted and scored according to Kleynhans (1996), as seen in the tables below (Table 4-2 and

Table 4-3).

Table 4-2: Descriptive Classes for the Assessment of Modifications to Habitat Integrity

Impact Category	Description	Score
None	No discernible impact or the modification is located in such a way that it has no impact on habitat quality, diversity, size and variability.	0
Small	The modification is limited to very few localities and the impact on habitat quality, diversity, size and variability are also very small.	1-5
Moderate	The modifications are present at a small number of localities and the impact on habitat quality, diversity, size and variability are also limited.	6-10
Large	The modification is generally present with a clearly detrimental impact on habitat quality, diversity, size and variability. Large areas are, however, not influenced.	11-15
Serious	The modification is frequently present and the habitat quality, diversity, size and variability in almost the whole of the defined area are affected. Only small areas are not influenced.	16-20
Critical	The modification is present overall with a high intensity. The habitat quality, diversity, size and variability in almost the whole of the defined section are influenced detrimentally.	21-25

Table 4-3: Criteria and Weights used for the Assessment of Habitat Integrity

Instream Criteria	Weight	Riparian Zone Criteria	Weight
Water abstraction	14	Indigenous vegetation removal	13
Flow modification	13	Exotic vegetation encroachment	12
Bed modification	13	Bank erosion	14
Channel modification	13	Channel modification	12
Water quality	14	Water abstraction	13
Inundation	10	Inundation	11

Instream Criteria	Weight	Riparian Zone Criteria	Weight
Exotic macrophytes	9	Flow modification	12
Exotic fauna	8	Water quality	13
Solid waste disposal	6		
TOTAL	**100**	**TOTAL**	**100**

Scores are calculated based on ratings received from the assessment. The estimated impacts of the criteria are summed and expressed as a percentage to arrive at a provisional habitat integrity assessment. The scores are placed into the IHIA categories (Kleynhans, 1996) as seen in Table 4-4.

It should be noted that the IHIA was based on regions assessed in the current studies and therefore may only constitute the assessment of conditions within the considered Sub Quaternary Reach (SQR) length.

Table 4-4: Intermediate Habitat Integrity Categories (Kleynhans, 1996)

Category	Description	Score
A	Unmodified, natural.	90-100
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.	80-90
C	Moderately modified. A loss and change of natural habitat and biota have occurred but the basic ecosystem functions are still predominantly unchanged.	60-79
D	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions has occurred.	40-59
E	The loss of natural habitat, biota and basic ecosystem functions is extensive.	20-39
F	Modifications have reached a critical level and the lotic 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.	0-19

4.5 Macroinvertebrates

Macroinvertebrate assemblages are good indicators of localised conditions because many benthic macroinvertebrates have limited migration patterns or a sessile mode of life. They are particularly well-suited for assessing site-specific impacts (upstream and downstream)

(Barbour *et. al*., 1999). Benthic macroinvertebrate assemblages are made up of species that constitute a broad range of trophic levels and pollution tolerances, thus providing strong information for interpreting cumulative effects (Barbour *et. al*., 1999). The assessment and monitoring of benthic macroinvertebrate communities forms an integral part of the monitoring of the health of an aquatic ecosystem.

4.5.1 Integrated Habitat Assessment System

The Integrated Habitat Assessment System (IHAS) was specifically designed to be used in conjunction with the South African Scoring System version 5 (SASS5), benthic macroinvertebrate assessment. The IHAS assesses the availability of the biotopes at each site and expresses the availability and suitability of habitat for macroinvertebrates, this is determined as a percentage, where 100% represents "ideal" habitat availability. A description based of the IHAS percentage scores is presented in Table 4-5.

Table 4-5: Description of IHAS Scores with the Respective Percentage Category

IHAS Score (%)	Description
>75	Very Good
65–74	Good
55–64	Fair/Adequate
<55	Poor

4.5.2 South African Scoring System (Version 5)

The South African Scoring System (SASS5) is the current biological index being used to assess the status of riverine macroinvertebrates in South Africa. According to Dickens and Graham (2002), the index is based on the presence of aquatic invertebrate families and the perceived sensitivity to water quality changes of these families. Different families exhibit different sensitivities to pollution, these sensitivities range from highly tolerant families (e.g. Muscidae and Psychodidae) to highly sensitive families (e.g. Oligoneuridae). SASS5 results are expressed both as an index score (SASS5 score) and the Average Score Per recorded Taxon (ASPT value).

Sampled invertebrates were identified using the "Aquatic Invertebrates of South African Rivers" (Gerber and Gabriel, 2002). Identification of organisms was made to family level (Thirion *et. al*., 1995; Dickens & Graham, 2002; Gerber & Gabriel, 2002).

All SASS5 and ASPT scores are compared with the SASS5 Data Interpretation Guidelines (Dallas, 2007) for the Highveld lower ecoregion. This method seeks to develop biological bands depicting the various ecological states and is derived from data contained within the Rivers Database and supplemented with other data not yet in the database. The table and figure below illustrate the biological banding and classification (Figure 4-1).

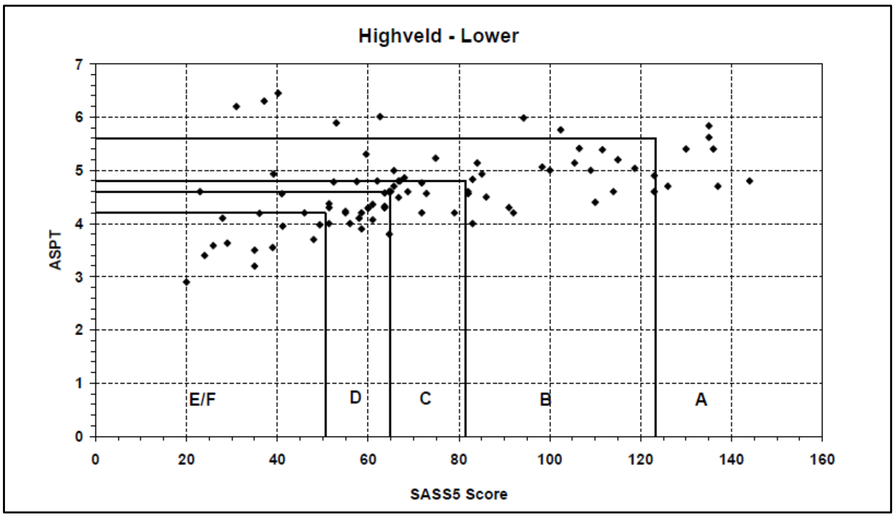

Figure 4-1: Guidelines used for the Interpretation and Classification of the SASS5 Scores (Dallas, 2007)

The SASS5 biotope ratings will also be used to obtain a score representing the diversity of macroinvertebrate habitat sampled.

4.5.3 Macroinvertebrate Response Assessment Index

The Macroinvertebrate Response Assessment Index (MIRAI) was used to provide a habitat-based cause-and-effect foundation to interpret the deviation of the aquatic invertebrate community from the calculated reference conditions for the Highveld Lower. This does not preclude the calculation of SASS5 scores if required (Thirion, 2007). The four major components of a stream system that determine productivity for aquatic macroinvertebrates are as follows:

- Flow regime;
- Physical habitat structure;
- Water quality; and
- Energy inputs from the watershed riparian vegetation assessment.

The results of the MIRAI will provide an indication of the current ecological category of the macroinvertebrate community established within each system at the time of the assessments and therefore assist in the determination of the PES.

4.6 Fish Response Assessment Index

Due the depths of water observed at the sites, fish were captured by means electroshocking. All fish were captured, identified and counted in the field and released alive at the point of capture. Fish species were identified using the “Complete Guide to the Freshwater Fishes of Southern Africa” (Skelton, 2001). The identified fish species were compared to those expected to be present for the B11C and B11D quaternary catchments. The expected fish species list was developed from a literature survey and included sources such as (Kleynhans *et. al*., 2007) and Skelton (2001).

The information gained using the Fish Response Assessment Index (FRAI) provides an indication of the PES of the river based on the fish assemblage structures observed. It must be noted that a reach based FRAI assessment was completed. For this assessment it is assumed that habitat is evenly distributed. Frequency of Occurrence (FROC) ratings were adjusted according to the habitat available at each site.

4.7 Present Ecological Status

The PES of the associated aquatic ecosystems was determined using the River Eco-status Monitoring Programme (REMP) Ecological Classification Manuals (Kleynhans and Louw, 2007). The PES was derived through the characterisation of the various biophysical attributes for the considered river systems as presented in the sections below.

5 Assumptions and Limitations

The methods outlined in this study assume that aquatic ecology within the associated river courses is evenly distributed. Access to several sites was not permissible due to land owners' refusal to allow aquatic specialists onsite during the surveys. These sites included several points on the lower reaches of the Trichardtspruit as well as several points on the upper reaches of the Piekespruit.

6 Study Area

The project is located between the town of Trichardt and Bethal in the province of Mpumalanga as illustrated in the local setting map (Figure 6-1) and falls within the Olifants Water Management Area (WMA). The MR areas are located within the B11C and B11D quaternary catchments (Figure 6-2). The primary drainage of these catchments is the Dwars-in-die-wegspruit (B11D-01424) in the B11D quaternary catchment and the Piekespruit (B11C-01472) and Steenkoolspruit (B11C-01449) in the B11C quaternary catchment. All of the SQRs of concern report to the larger Steenkoolspruit (B11D-01366).

The specific SQRs that will potentially be affected by the Project are the Trichardtspruit (B11D-01481), the Debeerspruit (B11C-01503), the Piekespruit (B11C-01542 and the B11C-01527 reporting to the larger Piekespruit) and the Steenkoolspruit (B11C-01449) as illustrated in (Figure 6-2).

6.1 Sampling Points

A total of nine sites were selected for the aquatic study as illustrated in Figure 6-3. Descriptions of the sites per SQR of concern are provided in Table 6-1 below.

Table 6-1: Site Locations and Descriptions

SQR	Site Name	Location Description	GPS coordinates

SQR	Site Name	Location Description	GPS coordinates
Trichardtspruit (B11D-01481)	T1	Situated directly below the Trichardtspruit Dam consisting of high flows and large amounts of instream cobbles.	26° 29' 38.12" S 29° 14' 18.90" E
Debeerspruit (B11C-01503)	D1	Situated at a secondary road crossing point approximately in the middle of the SQR. Farming activities can be clearly visible around the site as well as signs of severe erosion.	26° 24' 19.10" S 29° 18' 04.94" E
	D2	Situated along an unnamed tributary running adjacent to the Debeerspruit. For the purpose of the study the tributary is referred to as the Debeerspruit Tributary, however both report to the larger Piekespruit.	26° 24' 36.56" S 29° 18' 58.98" E
Piekespruit	P1	Situated in the upper reaches of the Piekespruit in an unnamed tributary (B11C-01527) at a secondary road crossing point.	26° 26' 01.05" S 29° 24' 09.43" E
	P2	Situated in the upper reaches of the Piekespruit in an unnamed tributary (B11C-01527) at a secondary road crossing point downstream of P1, just before the upper Piekespruit merges with this tributary into the larger Piekespruit (B11C-01501)	26° 24' 05.31" S 29° 21' 09.52" E
	P3	Situated in the upper reaches of the B11C - 01542 SQR approximately in the middle of the SQR.	26° 26' 34.66" S 29° 21' 09.52" E
	P4	This site was selected as the downstream/end-point site for the study in the B11C-01472 SQR. Impacts from the Debeerspruit and from all of the listed Piekespruit reaches are expected to be visible at this site.	26° 21' 03.96" S 29° 17' 55.23" E
Steenkoolspruit (B11C-01449)	S1	This site is situated approximately in the middle of the upper reaches of the Steenkoolspruit.	26° 20' 41.96" S 29° 24' 06.32" E
	S2	This site is situated along an unnamed tributary flowing into the Upper Steenkoolsruit below S1.	26° 22' 27.61" S 29° 22' 41.61" E

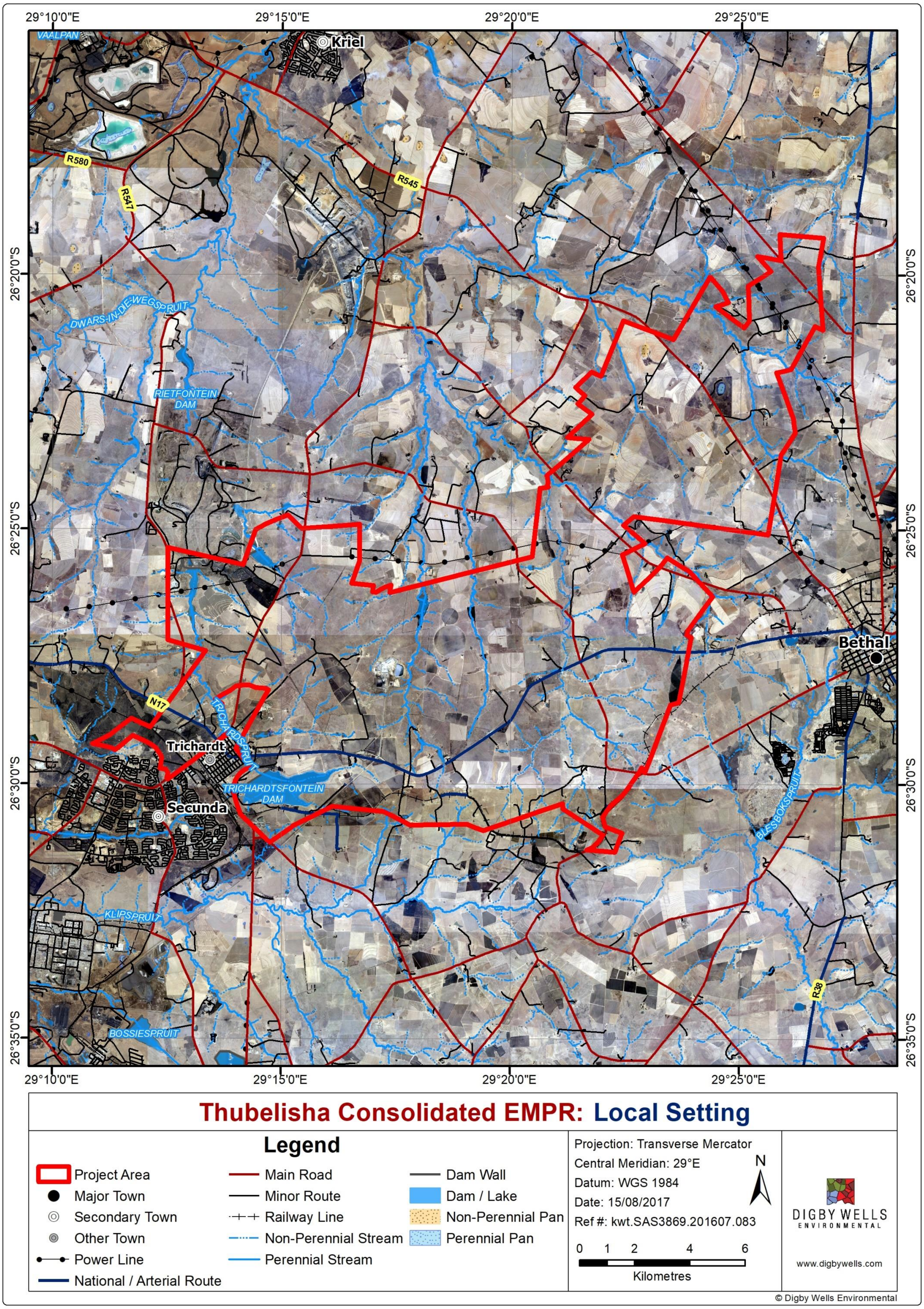

Figure 6-1: Local Setting of the Proposed Project

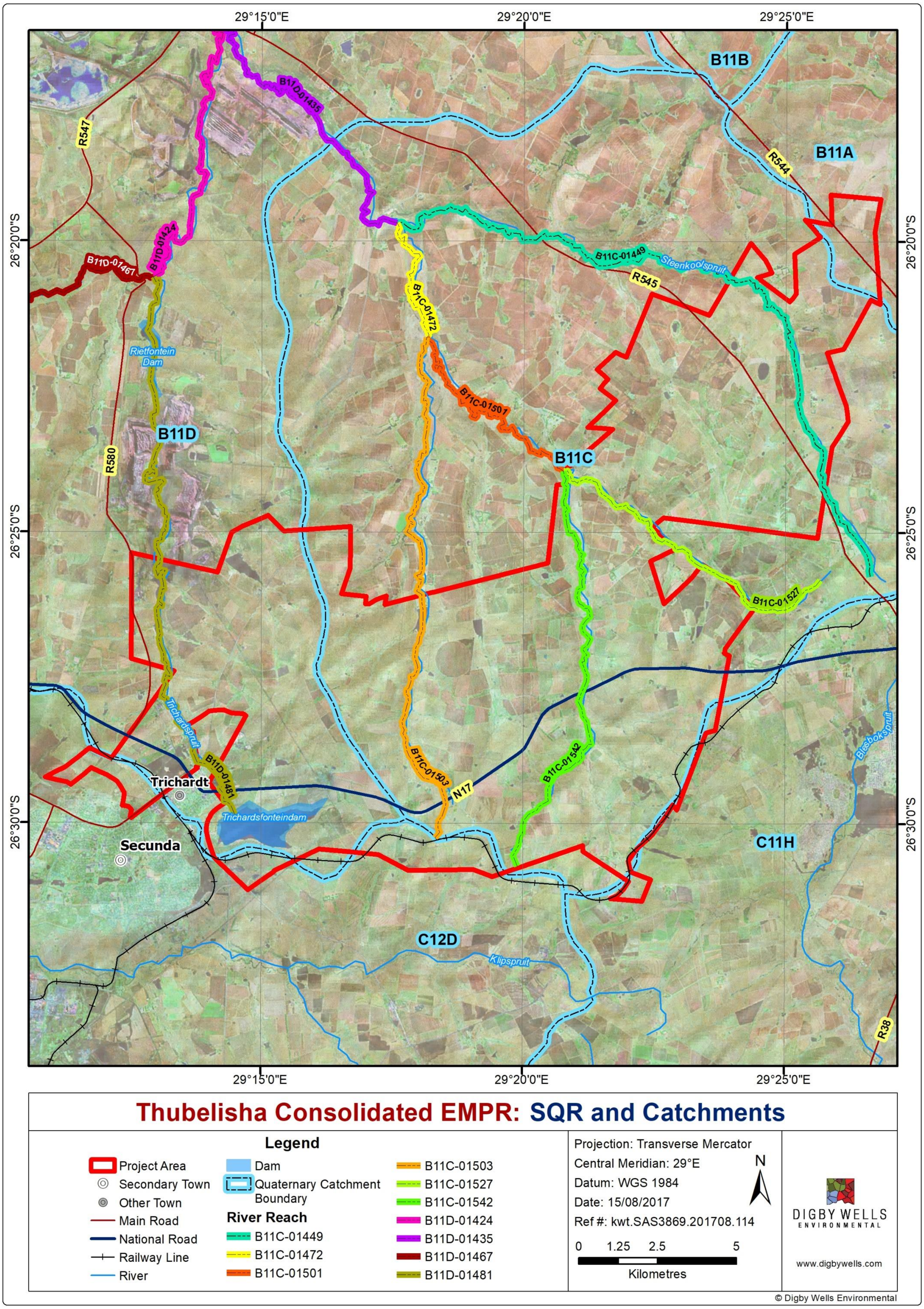

Figure 6-2: Location of the Proposed Mining Right Areas with regards to Quaternary Catchments and SQR's

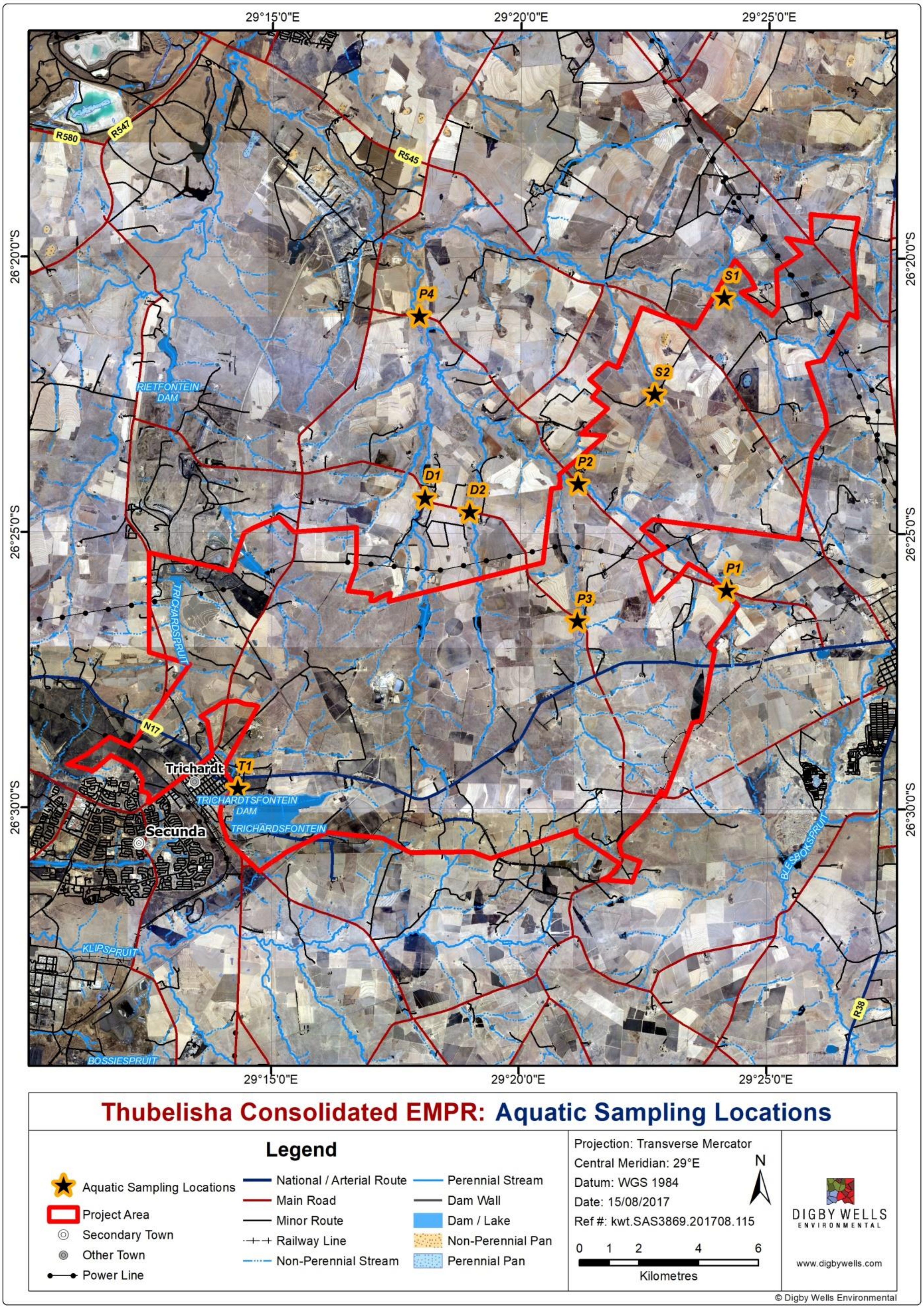

Figure 6-3: Aquatic Sampling Locations

7 Desktop Assessment

As explained above, the project area reports to three main SQRs, namely the Trichardtspruit (B11D-01481), the Piekespruit (B11C-01472) and the Steenkoolspruit (B11C-01449). A desktop study was conducted for each of the above listed SQRs and is provided below.

7.1 Trichardtspruit (B11D-01481)

The considered SQR forms part of the upper reaches or source zone of the Steenkoolspruit catchment which reports to the Olifants River. Considering this, topography is typical of the Highveld lower ecoregion, with gentle slopes and limited high gradient valley systems. However, due to the release of water from the Trichardtsfontein Dam, situated in the upper reaches of the system, the flow of the river was observed to be extremely high during both the low and high flow surveys. As a result, large amounts of erosion were visible along the reach in the form of deep undercut banks and subsequent sedimentation was observed.

The available desktop information on the considered SQR is presented below (Table 7-1).

Table 7-1: Desktop Information for the B11D-01481SQR (DWA, 2016)

Component	Rating
Reach Length (km)	22.00
Stream Order	1
PES	E
EI	Moderate
ES	High
Recommended Ecological Category	B

Considering the above findings the PES of the considered SQR is category E or seriously modified. This category has been derived based on the following criterion ratings:

- **Small Impacts:** Agricultural lands; bed stabilisation; large dams; roads; runoff/effluent from irrigation and sedimentation;
- **Moderate Impacts:** Inundation, erosion, exotic vegetation, runoff/effluent from urban areas and urbanisation;
- **Large Impacts:** Small dams;
- **Serious Impacts:** Abstraction, increased flows, canalisation and vegetation removal; and
- **Critical Impacts:** Mining and runoff/effluent from mining.

The ecological importance and sensitivity of the considered SQR was found to be rated as moderate. This moderate rating was derived based on the presence of some endangered vegetation grassland units with wetland and riparian habitats. According to DWA (2016) there are one protected and three endemic wetland species likely found in the considered SQR.

The ecological sensitivity was found to be high due to the presence of numerous flow dependent taxa (incl. fish and aquatic macroinvertebrates), as well as selected macroinvertebrate families that are highly sensitive to physio-chemical changes in the reach. However, due to the high flows in the reach, water quality modifications are expected to have less of an effect.

A total 39 aquatic macroinvertebrates and six indigenous fish species are expected in the SQR. The expected fish species list is presented in Table 7-2. The expected fish community appears to be composed of predominantly tolerant taxa. The translocated fish species, *Labeo umbratus*, was not included in the DWA (2016) expected species list for the SQR. However, this species is expected in the system according to the distribution of the species as stipulated by Skelton (2001). Thus, the species has been included in the expected list below.

Table 7-2: Expected Fish Species in the B11D-01481 SQR

Fish	Conservation Status
Enteromius anoplus	Least concern
Enteromius paludinosus	Least concern
Clarias gariepinus	Least concern
Labeobarbus polylepis	Least concern
Pseudocrenilabrus philander	Least concern
Tilapia sparmanni	Least concern
Translocated species	
Labeo umbratus	Least concern

7.2 Piekespruit (B11C-01472)

The considered SQR is comprised of four first order tributaries which reports to the downstream larger Piekespruit and then the Steenkoolspruit (B11D-01435) and eventually to the Olifants River. The following table (Table 7-3) provides the desktop information for the tributaries of the B11C-01472 SQR expected to be affected by the project according to the DWA (2016). It is important to note that the adjacent tributary flowing parallel to the Debeerspruit has not been categorised by the DWA and is referred to as the Debeerspruit Tributary in this study. Therefore, a combination of the desktop information obtained for the upper Piekespruit reaches will be used as a reference for the Debeerspruit Tributary (site D2).

Table 7-3: Desktop Information for the Piekespruit and the relevant tributaries (DWA, 2016)

Component	B11C-01503 (Debeerspruit)	B11C-01542 (Upper Piekespruit)	B11C-01527 (Piekespruit Tributary)	B11C-01472 (Lower Piekespruit)
Reach Length (km)	19.00	16.00	11.00	5.00
Stream Order	1	1	1	2
PES	C	B	B	B
EI	Moderate	High	Moderate	Moderate
ES	High	High	High	High
Recommended Ecological Category	B	B	B	B

Considering the above findings the PES of the considered downstream SQR (B11C-01472) is category B or minimally modified. This category has been derived based on the following criterion ratings:

- **Small Impacts:** Agricultural lands; bed stabilisation; mining; roads; abstraction; crossings; exotic vegetation; erosion; runoff/effluent from irrigation and mining; and sedimentation;
- **Moderate Impacts:** Trampling;
- **Large Impacts:** None;
- **Serious Impacts:** None; and
- **Critical Impacts:** None.

The upper reaches of the Piekespruit appear to have similar impacts as explained above (DWA, 2016). However, the Debeerspruit SQR has been categorised as moderately modified (category C) according to the desktop information obtained from the DWA (2016). This has been derived based on similar criterions to the above listed impacts but large impacts such as abstraction, small dams and trampling has been listed and most likely resulted in the modified categorisation of the SQR.

The ecological importance for the SQRs has been categorised as moderate to high. This appears to be due to the presence of important riparian vegetation along the upper (B11C-01542) and lower (B11C-01472) Piekespruit (DWA, 2016).

The ecological sensitivity was found to be high in all of the reaches due to the presence of numerous flow dependent taxa (fish and macroinvertebrates) as well as macroinvertebrates highly sensitive to physio-chemical changes in the reach. According to the DWA (2016) a total of 40 macroinvertebrate families are expected to be present in the Lower Piekespruit SQR (B11C-01472). A total of 39 families are expected in the Debeerspruit SQR (B11C-01503) (DWA, 2016). The expected macroinvertebrate lists according to the DWA (2016) were used as an indicator list when sampling and used to generate individual family lists for the MIRAIs run in the study.

The expected fish species list for the reaches is provided in Table 7-4. It is important to note that the tributary flowing parallel to the Debeerspruit, where site D2 is located, has been included in the Debeerspruit SQR's expected species list. The Piekespruit Tributary (B11C-01542) has been included in the Piekespruit expected species list.

Table 7-4: Expected Fish Species for the Debeerspruit and Piekespruit reaches of concern

Fish	Conservation Status
Enteromius anoplus	Least concern
Enteromius neefi	Least concern
Enteromius paludinosus	Least concern
Clarias gariepinus	Least concern
Labeobarbus polylepis	Least concern
Pseudocrenilabrus philander	Least concern
Tilapia sparmanni	Least concern
Translocated species	
Labeo umbratus	Least concern

7.3 Steenkoolspruit (B11C-01449)

This SQR forms one of the upper tributaries for the Lower Steenkoolspruit of concern (B11D-01366) which receives water from the above listed reaches (Trichardtspruit, Debeerspruit and Piekespruit). The B11C-01449 SQR flows directly into the B11D-01435 (Steenkoolspruit) SQR which merges with the reaches from Trichardtspruit and Piekespruit to form the Lower Steenkoolspruit. Table 7-5 provides the desktop information for the Steenkoolspruit reach of concern as categorised by DWA (2016).

Table 7-5: Desktop Information for the B11C-01449 SQR (DWA, 2016)

Component	Rating
Reach Length (km)	26.00
Stream Order	1
PES	C
EI	Moderate
ES	High

Component	Rating
Recommended Ecological Category	B

Considering the above findings the PES of the considered SQR (B11C-01449) is category C or moderately modified. This modified category has been derived based on the following criterion ratings:

- **Small Impacts:** Bed stabilisation; mining; roads; abstraction; crossings; exotic vegetation; roads; mining; runoff/effluent from mining; sedimentation; and urbanisation;
- **Moderate Impacts:** runoff/effluent from urban areas and erosion;
- **Large Impacts:** Abstraction; small farm dams; agricultural lands and trampling;
- **Serious Impacts:** None; and
- **Critical Impacts:** None.

The Ecological Importance for the reach has been categorised as moderate. This appears to be due to the presence of predominately common fish species but receives a slightly higher importance rating due to the likely presence of two protected and three endemic wetland and riparian vegetation species.

The Ecological Sensitivity for the reach has been classified as high. This appears to be due to the presence of a number of taxa intolerant to flow changes (*Enteromius neefi*) as well taxa sensitive to physio-chemical changes (*Enteromius neefi* and a Baetidae community comprising of more than two species).

A total of 41 macroinvertebrate families with six fish species are expected to be present in the SQR. The expected fish species list is provided in the Table 7-6 below.

Table 7-6: Expected Fish Species in the B11C-01449 SQR

Fish	Conservation Status
Enteromius anoplus	Least concern
Enteromius paludinosus	Least concern
Enteromius neefi	Least concern
Clarias gariepinus	Least concern
Pseudocrenilabrus philander	Least concern
Tilapia sparmanni	Least concern
Translocated species	
Labeo umbratus	Least concern

There is also a tributary of the Steenkoolspruit SQR of concern located in the project area. For the purpose of the study this tributary is referred to as the Steenkoolspruit Tributary and has not been categorised by the DWA. Desktop information obtained for the Steenkoolspruit will be used to supplement the data for the Steenkoolspruit Tributary.

8 Baseline Environment

8.1 Water Quality

The results of the *in situ* water quality analysis are presented in Table 8-1 for the high flow survey (March 2017) and in Table 8-2 for the low flow survey (June 2017).

Table 8-1: *In Situ* Water Quality Results for the March 2017 Survey

Constituent	Temperature (ºC)	pH	Conductivity (µS/cm)	Dissolved oxygen (mg/l)
Guidelines	**5-30**	**6-9**	**<700**	**>5**
T1	18	8.5	206	7.0
D1	25	9.0	382	7.3
D2	24	8.6	301	6.1
P1	25	8.4	750	6.2
P2	26	8.4	460	6.1
P3	22	8.5	370	6.8
P4	24	8.4	360	7.6
S1	28	8.5	380	6.3
S2	17	8.0	330	6.5
*Red shading indicates water quality constituents exceeding the guideline values (DWAF, 1996)				

The *in situ* water quality analysis during the high flow survey shows that temperature ranged from 17 ºC to 28 ºC. The pH values were shown to range from 8.0 at S2 to 9.0 at D1. Conductivity values ranged from 206 µS/cm at T1 to 750 µS/cm at P1. Dissolved oxygen concentrations were shown to range from 6.1 mg/l at D2 and P2 to 7.6 mg/l at P4.

Table 8-2: *In Situ* Water Quality Results for the June 2017 Survey

Constituent	Temperature (ºC)	pH	Conductivity (µS/cm)	Dissolved oxygen (mg/l)
Guidelines	**5-30**	**6-9**	**<700**	**>5**
T1	13	8.1	184	6.1
D1	14	8.5	530	8.6

Constituent	Temperature (ºC)	pH	Conductivity (µS/cm)	Dissolved oxygen (mg/l)
Guidelines	**5-30**	**6-9**	**<700**	**>5**
D2	17	7.9	440	6.3
P1	14	8.3	784	6.9
P2	15	8.8	637	7.4
P3	7.1	8.5	833	6.5
P4	10	7.9	608	6.1
S1	14	8.7	731	7.7
S2	12	8.5	716	6.2
*Red shading indicates water quality constituents exceeding the guideline values (DWAF, 1996)				

The *in situ* water quality analysis during the low flow survey shows that temperature ranged from 7.1 ºC to 17 ºC. The pH values were shown to range from 7.9 at D2 and P4 to 8.8 at P2. Conductivity values ranged from 206 µS/cm at T1 to 833 µS/cm at P3. Dissolved oxygen concentrations were shown to range from 6.1 mg/l at D2 and P2 to 8.6 mg/l at D1.

All the tested water quality constituents recorded during the high flow survey (March 2017) were below the threshold effect values as stipulated by the Department of Water Affairs and Forestry (DWAF,1996) with the exception of the conductivity value recorded at P1. It appears that farming activities (livestock and runoff) compounded by the stagnant nature of this site are most likely resulting in the high conductivity. It is also important to note that the pH at the majority of the sites were close to 9. This relatively high pH, the overall high dissolved oxygen values and the presence of large amounts of algae recorded at the sites are indicative of eutrophic conditions.

The conductivity at P1 remained above the threshold effect value of 700 µS/cm during the low flow survey with the conductivity at P3, S1 and S2 also exceeding this value. A large amount of algae was visible at these sites. This is most likely caused by the large abundance of livestock observed throughout the study at a majority of sites as illustrated in the figure below (Figure 8-1) compounded by the impacts of possible agricultural runoff entering the aquatic systems. Agricultural runoff was physically observed adjacent to the Piekespruit reach near P1 as illustrated in Figure 8-2.

The land use in upper reaches of the Piekespruit and Steenkoolspruit consisted mainly of agricultural activities comprised of cultivation and livestock. Thus, knowing this and observing the runoff during the study, it is most likely that these agricultural activities are resulting in the higher than normal conductivity and pH values recorded. It is also possible that the geology of the Project area may be playing a role in these high values but further investigation into this is required to make any concise conclusions.

Figure 8-1: Livestock present along the Piekespruit SQR

Figure 8-2: Farm effluent observed during the low flow survey (June 2017)

The Trichardtspruit monitoring site (T1) appears to be mainly impacted by the Trichardtspruit Dam situated directly above the site. Farming activities are taking place above the dam and are also most likely impacting the upper reaches of the SQR. However, all the water quality constituents recorded at this site were below the threshold effect values (DWAF, 1996) during both surveys. This site also had the lowest conductivity during both surveys which is most likely due to the discharge of water from the Trichardtsfontein Dam. According to the water quality recorded during the Surface Water Assessment conducted by Digby Wells (2017a), the upper tributaries above the dam appear to be in a fairly clean state with the exception of the most northern site (R14402W). The pH recorded at this site, despite it being within the recommended guidelines, was a high of 8.29 and the conductivity exceeded the threshold effect value of 700 µS/cm. It appears that the farming activities around this site are resulting in these elevated values. However, this poor water quality does not impact the downstream site (T1) which is most likely due to the Trichardtspruit Dam acting as barrier concentrating/trapping dissolved solids.

8.2 The Intermediate Habitat Integrity Assessment (IHIA)

The IHIA was completed for the SQR's in the project area categorised by DWA (2016), namely Trichardtspruit (B11D-01481), Debeerspruit (B11C-01503), Piekespruit Tributary (B11C-01542), Piekespruit (B11C-01527) and Steenkoolspruit (B11C-01449). The IHIA was also completed for the two uncategorised tributaries (DWA, 2016) in the project area, namely the Debeerspruit Tributary and the Steenkoolspruit Tributary. The results for each IHIA are provided below.

8.2.1 Trichardtspruit (B11D-01481)

The IHIA for this reach was conducted from the northern most tributary above the dam to approximately 10km downstream.

Table 8-3: Intermediate Habitat Integrity Assessment for Instream Habitat

Instream	Average Score	Score
Water abstraction	17.50	9.80
Flow modification	24.00	12.48
Bed modification	15.00	7.80
Channel modification	20.00	10.40
Water quality	11.00	6.16
Inundation	20.00	8.00
Exotic macrophytes	8.00	2.88
Exotic fauna	6.50	2.08
Solid waste disposal	8.00	1.92
Total Instream	**38.48**	

Category	E

Table 8-4: Intermediate Habitat Integrity Assessment for Riparian Habitat

Riparian	Average Score	Score
Indigenous vegetation removal	17.50	9.10
Exotic vegetation encroachment	8.00	3.84
Bank erosion	11.50	6.44
Channel modification	20.00	9.60
Water abstraction	17.50	9.10
Inundation	20.00	8.80
Flow modification	22.50	10.80
Water quality	11.00	5.72
Total Riparian	**36.60**	
Category		**E**

The IHIA results of the instream and riparian habitats within the SQR are classified as category E or seriously modified. Major impacts appear to be related to flow modification, caused by the release of water from the Trichardtsfontein Dam and mining activities (including a river diversion) taking place approximately 8km downstream from the Trichardtsfontein Dam. As a result the flow modification has almost been completely modified, with exception in the upper reaches. Therefore, a modification score of 24 was allocated to the flow modification metric. Ultimately the change in flow has led to a number of related impacts such as channel modification, bed modification and bank erosion. Lastly, farming and mining relating impacts along the SQR have led to the subsequent loss of natural/indigenous vegetation as was as most likely affecting the water quality. Water quality at the upper monitoring site, T1, appeared to be in a fairly clean state. However, it is assumed the water quality worsens further downstream towards the mining activities. Therefore, a moderate rating was assumed for the water quality modification downstream.

A minor non-perennial tributary, which is supposed to be flowing into the Trichardtspruit, is also located in the project area (26° 25' 58.31" S 29° 15' 03.72" E). This tributary appears to be completely inundated due to the downstream mining activities taking place. As a result the instream habitat appears to be seriously modified (category E). The upper riparian zones appear to be in a fairly healthy state with the exception of farming activities taking place in the southern tributary. However, the upper streams only flow for approximately 3km before reaching the impounded area of the tributary. Therefore, no IHIA has been conducted for this tributary but is assumed to be in a seriously modified state.

8.2.2 Debeerspruit (B11C-01503)

The IHIA for this SQR was conducted from the upper most part of the reach to approximately 19km downstream, past the monitoring site D1.

Table 8-5: Intermediate Habitat Integrity Assessment for Instream Habitat

Instream	Average Score	Score
Water abstraction	9.00	5.04
Flow modification	10.00	5.20
Bed modification	8.00	4.16
Channel modification	10.00	5.20
Water quality	9.00	5.04
Inundation	13.00	5.20
Exotic macrophytes	6.00	2.16
Exotic fauna	15.00	4.80
Solid waste disposal	4.00	0.96
Total Instream	**62.24**	
Category		**C**

Table 8-6: Intermediate Habitat Integrity Assessment for Riparian Habitat

Riparian	Average score	Score
Indigenous vegetation removal	7.50	3.90
Exotic vegetation encroachment	8.00	3.84
Bank erosion	10.50	5.88
Channel modification	11.00	5.28
Water abstraction	10.00	5.20
Inundation	10.50	4.62
Flow modification	12.50	6.00
Water quality	8.00	4.16
Total Riparian	**61.12**	
Category		**C**

The IHIA results of the instream and riparian habitats within the SQR are classified as category C or moderately modified.

The upper reaches of the SQR appear to be in a fairly healthy state. However, farm dams, including an extremely large dam located approximately in the middle of the reach, has further inundated this non-perennial system. This has also led to flow, bed and channel modification along the reach. As a result the modification criterions categorised the instream and riparian habitat as moderately modified (category C).

8.2.3 Debeerspruit Tributary (site D2)

Table 8-7: Intermediate Habitat Integrity Assessment for Instream Habitat

Instream	Average Score	Score
Water abstraction	8.00	4.48
Flow modification	8.50	4.42
Bed modification	7.50	3.90
Channel modification	9.00	4.68
Water quality	9.00	5.04
Inundation	11.00	4.40
Exotic macrophytes	5.50	1.98
Exotic fauna	15.00	4.80
Solid waste disposal	3.00	0.72
Total Instream	**65.58**	
Category		**C**

Table 8-8: Intermediate Habitat Integrity Assessment for Riparian Habitat

Riparian	Average Score	Score
Indigenous vegetation removal	9.50	4.94
Exotic vegetation encroachment	7.50	3.60
Bank erosion	9.00	5.04
Channel modification	14.00	6.72
Water abstraction	9.50	4.94
Inundation	10.50	4.62
Flow modification	12.00	5.76
Water quality	8.00	4.16
Total Riparian	**60.22**	
Category		**C**

Similar findings were observed for this tributary as observed along the Debeerspruit SQR. The IHIA results also categorised the instream and riparian habitat for the Debeerspruit Tributary as category C or moderately modified.

The main cause behind the determined modified state appears to be a result of the number of impoundments existing along the tributary. These impoundments have further led to channel, bed and flow modification in the tributary. The impacts also have been compounded by the presence of livestock along the tributary which has possibly resulting in the large amount of algae observed at the Debeerspruit sites.

It is important to note that the riparian habitat for the Debeerspruit reaches of concern appear to be fairly intact. However, the scores for the IHIA appear to be too modified to classify the habitats as minimally modified (category B).

8.2.4 Piekespruit Tributary (B11C-01542)

The IHIA was conducted from the upper most part of the reach downstream until the merge with the Piekespruit (B11C-01527).

Table 8-9: Intermediate Habitat Integrity Assessment for Instream Habitat

Instream	Average Score	Score
Water abstraction	5.50	3.08
Flow modification	9.00	4.68
Bed modification	7.50	3.90
Channel modification	6.00	3.12
Water quality	6.00	3.36
Inundation	4.50	1.80
Exotic macrophytes	4.00	1.44
Exotic fauna	10.00	3.20
Solid waste disposal	1.00	0.24
Total Instream	**75.18**	
Category		**C**

Table 8-10: Intermediate Habitat Integrity Assessment for Riparian Habitat

Riparian	Average Score	Score
Indigenous vegetation removal	6.00	3.12
Exotic vegetation encroachment	3.50	1.68
Bank erosion	10.50	5.88
Channel modification	5.00	2.40

Riparian	Average Score	Score
Water abstraction	5.00	2.60
Inundation	3.00	1.32
Flow modification	3.50	1.68
Water quality	8.00	4.16
Total Riparian	**77.16**	
Category		**C**

The IHIA results classify the instream and riparian habitat as category C (moderately modified).

It appears that only one small farm dam has been built in the upper reaches of the SQR and as a result flow, bed and channel modifications have not been as severe as observed along the other SQR's in the project area. The river system also appears to be naturally slow flowing and as a result a low modification score was allocated to the inundation metric. The largest modification appears to be as a result of livestock along the reach which has possibly compounded the effects of bank erosion. Lastly, physical vegetation removal can be observed along the reach, especially noted in the lower section of the SQR, due to farming encroachment into the riparian zones of the river.

8.2.5 Upper Piekespruit (B11C-01527)

The IHIA for the Piekespruit was conducted from the upper most section of the system in the project area to where the Piekespruit and the Piekespruit Tributary meet.

Table 8-11: Intermediate Habitat Integrity Assessment for Instream Habitat

Instream	Average Score	Score
Water abstraction	7.00	3.92
Flow modification	6.00	3.12
Bed modification	6.00	3.12
Channel modification	8.50	4.42
Water quality	9.50	5.32
Inundation	8.00	3.20
Exotic macrophytes	5.00	1.80
Exotic fauna	15.00	4.80
Solid waste disposal	2.00	0.48
Total Instream	**69.82**	
Category		**C**

Table 8-12: Intermediate Habitat Integrity Assessment for Riparian Habitat

Riparian	Average score	Score
Indigenous vegetation removal	5.50	2.86
Exotic vegetation encroachment	4.00	1.92
Bank erosion	11.00	6.16
Channel modification	9.00	4.32
Water abstraction	7.00	3.64
Inundation	10.00	4.40
Flow modification	8.50	4.08
Water quality	10.00	5.20
Total Riparian	**67.42**	
Category		**C**

The IHIA results of the instream and riparian habitats within the SQR are classified as category C or moderately modified.

Modifications along this reach consist mainly of impoundments built in the upper sections resulting in modifications to the SQR's flow, channel and bank stability. The riparian habitat appears to be in a fairly intact state with the exception of farming activities affecting sections. Large amounts of algae was also observed at both of the monitoring points (P1 and P2) during the surveys which is most likely a result of the presence of livestock along the SQR.

8.2.6 Steenkoolspruit (B11C-01449)

The IHIA for the Steenkoolspruit was conducted from the upper most section outside of the project area near the town of Bethal up to where the Steenkoolspruit Tributary merges (approximately 15km).

Table 8-13: Intermediate Habitat Integrity Assessment for Instream Habitat

Instream	Average Score	Score
Water abstraction	7.00	3.92
Flow modification	6.00	3.12
Bed modification	7.00	3.64
Channel modification	9.00	4.68
Water quality	10.00	5.60
Inundation	8.00	3.20

Exotic macrophytes	5.00	1.80
Exotic fauna	10.00	3.20
Solid waste disposal	2.00	0.48
Total Instream	**70.36**	
Category		**C**

Table 8-14: Intermediate Habitat Integrity Assessment for Riparian Habitat

Riparian	Average Score	Score
Indigenous vegetation removal	5.50	2.86
Exotic vegetation encroachment	8.00	3.84
Bank erosion	10.00	5.60
Channel modification	10.00	4.80
Water abstraction	6.00	3.12
Inundation	7.50	3.30
Flow modification	7.50	3.60
Water quality	10.00	5.20
Total Riparian	**67.68**	
Category		**C**

The IHIA results of the instream and riparian habitats within the SQR are classified as category C or moderately modified.

Major impacts appear to be related to a few farm dams situated in the upper reaches of the SQR as well as large amounts of erosion observed throughout the SQR. Water quality at the monitoring site (S1) was also fairly poor, especially during the low flow survey. Large amounts of algae was also observed at the site which is possibly a result of livestock being present along the SQR as illustrated in Figure 8-3 below which also compound the effects of erosion on the system.

Figure 8-3: Livestock presence near the Steenkoolspruit SQR of concern

8.2.7 Steenkoolspruit Tributary

The IHIA for this river reach was conducted from the upper most section approximately 8km downstream to where the tributary merges with the Steenkoolspruit (B11C-01449). The results for the assessment are provided in the tables below.

Table 8-15: Intermediate Habitat Integrity Assessment for Instream Habitat

Instream	Average score	Score
Water abstraction	9.00	5.04
Flow modification	10.00	5.20
Bed modification	8.00	4.16
Channel modification	8.00	4.16
Water quality	8.50	4.76
Inundation	12.50	5.00
Exotic macrophytes	5.00	1.80
Exotic fauna	20.00	6.40
Solid waste disposal	2.00	0.48
Total Instream	**63.00**	
Category		**C**

Table 8-16: Intermediate Habitat Integrity Assessment for Riparian Habitat

Riparian	Average score	Score
Indigenous vegetation removal	7.00	3.64
Exotic vegetation encroachment	2.50	1.20
Bank erosion	10.00	5.60
Channel modification	8.00	3.84
Water abstraction	8.00	4.16
Inundation	12.50	5.50
Flow modification	7.50	3.60
Water quality	8.50	4.42
Total Riparian	**68.04**	
Category		**C**

The IHIA results of the instream and riparian habitats within the SQR are classified as category C or largely modified.

The presence of the large impoundment, located approximately in the middle of the tributary, appears to have a larger impact due to the tributary's short length (approximately 8km). Thus, a fairly high modification score was allocated to the flow modification metric. Large numbers of livestock were also observed at the monitoring site, S2, during the high flow survey as illustrated (Figure 8-4) further contributing to the modified IHIA categorisation.

Figure 8-4: Livestock present at S2 during the high flow survey (March 2017)

8.3 Macroinvertebrates

Water levels were sufficient at all of the selected sites, with the exception of S2, during both the low and high flow surveys for macroinvertebrate sampling. The macroinvertebrate indices for the study are provided in the sections below.

8.3.1 Integrated Habitat Assessment System and Biotope Assessment

The results of the Integrated Habitat Assessment System (IHAS) completed during the surveys are presented in the table below (Table 8-17).

Table 8-17: Integrated Habitat Assessment System results for the 2017 surveys

Site	Score	Suitability
T1	71	Good
D1	46	Poor
D2	58	Fair
P1	36	Poor
P2	44	Poor
P3	50	Poor
P4	60	Fair

Site	Score	Suitability
S1	55	Fair
S2	N/A	N/A

The IHAS results indicate that the majority of the sampled macroinvertebrate habitat ranged from fair to good with the sampled habitat at site T1 being classified as good due to the abundance of stones sampled in current.

The results of the biotope diversity assessments are presented in Table 8-18.

Table 8-18: Invertebrate Biotope Diversity (2017)

Biotope	T1	D1	D2	P1	P2	P3	P4	S1
High Flow								
Stones in current	3.5	0	1.5	0	0	0	2	1
Stones out of current	0	1.5	2	1	0	2	1	2
Bedrock	0	2	2	0	0	2.5	2	2
Aquatic Vegetation	1.5	2.5	1	2	2.5	0	0	0
Marginal Vegetation In Current	3	2	1.5	0	1	2	3	1
Marginal Vegetation Out Of Current	1.5	3	3	3	2	3.5	3	3
Gravel	3	0	2	0	1	1	0	1
Sand	0	0	2	0	2	2	3.5	3
Mud	0	0	0	2	3	2	1	1.5
Biotope Score	**12.5**	**11**	**15**	**9**	**11.5**	**15**	**15.5**	**14.5**
Low Flow								
Stones in current	3.5	0	3	0	0	0	3	0
Stones out of current	0	1.5	1	2	0	2	0	2
Bedrock	1.5	0	1	0	0	1.5	1.5	0

Biotope	T1	D1	D2	P1	P2	P3	P4	S1
Aquatic Vegetation	1	1	0	2.5	3	0.5	0	2
Marginal Vegetation In Current	3	2	1.5	0	0	1.5	1.5	0
Marginal Vegetation Out Of Current	2	2	2	3.5	1	3	1.5	2.5
Gravel	3	1.5	0	0	1.5	0	1	1
Sand	0	2	0	0	1.5	0	3	1
Mud	0	2	1	1	2	1	1	2.5
Biotope Score	**14**	**12**	**9.5**	**9**	**9**	**9.5**	**12.5**	**11**
Biotope Score (%)	**30**	**26**	**27**	**20**	**23**	**27**	**31**	**28**
Biotope suitability	**Fair**	**Fair**	**Fair**	**Poor**	**Poor**	**Fair**	**Fair**	**Fair**

The majority of the biotopes sampled at the sites were rated as fair with the exception of sites P1 and P2 being rated as poor.

8.3.2 South African Scoring System

The results of the SASS5 assessments completed for the study are presented in Table 8-19 and Table 8-20.

Table 8-19: SASS5 Results of the High Flow Survey (March 2017)

Site	T1	D1	D2	P1	P2	P3	P4	S1
SASS5	72	87	81	92	83	99	106	76
Taxa	15	18	19	19	18	21	22	17
ASPT	4.8	4.8	4.3	4.8	4.6	4.7	4.8	4.5
Category	C/B	B	C	B	B	B	B	C

The SASS5 scores obtained during the high flow survey ranged from 72 at T1 to 106 at P4. The taxa diversity at the sites ranged from 15 at T1 to 22 at P4. The ASPT values derived from the SASS5 scores ranged from 4.3 at D2 to 4.8 at T1, D1, P1 and P4.

Table 8-20: SASS5 Results of the Low Flow Survey (June 2017)

Site	T1	D1	D2	P1	P2	P3	P4	S1
SASS5	66	54	61	94	55	75	72	98
Taxa	13	14	14	22	13	17	17	21
ASPT	5.1	3.9	4.4	4.3	4.2	4.4	4.2	4.7
Category	B	D	D	B	D	C	C	B

The SASS5 scores obtained during the low flow survey ranged from 54 at D1 to 98 at S1. The taxa diversity at the sites ranged from 13 at T1 and P2 to 22 at P1. The ASPT values derived from the SASS5 scores ranged from 3.9 at D1 to 5.1 at T1.

The results of the SASS5 assessment indicate fairly healthy macroinvertebrate assemblages, especially during the high flow survey. The lowest categorisations (category C) during the high flow survey were recorded at D2 and S1 with the macroinvertebrate assemblage at T1 falling on the borderline between category C and B.

The overall results during the low flow survey decreased. This is normally expected due to the lower water levels generally occurring during the low flow season. The more sensitive macroinvertebrates usually are absent due to these conditions and as a result lower SASS5 scores are expected. However, the score recorded at S1 increased during the low flow survey. The cause of this increase was attributed to the presence of three previously absent families of Odonata (Dragonflies and Damselflies). These families were sampled in a section of aquatic vegetation that was not available for sampling during the high flow survey.

Typical SASS5 scores in the rivers show the presence of largely tolerant taxa adapted to marginal and instream vegetation and slow flowing water. Taxa specifically adapted to stones in current or flowing conditions were absent from the sites assessed, with the exception of the macroinvertebrate assemblages observed at T1. The MIRAI will provide further insight into the conditions in the assessed river system.

8.3.3 Macroinvertebrate Assessment Index

The MIRAI was conducted for the SQRs of concern as well as for the Debeerspruit Tributary. The results are explained below. It is important to note that the MIRAI results for the study have been calculated based on macroinvertebrate findings at only one site per SQR, with the exception of the upper Piekespruit having two sites. Thus, as explained in the Assumptions and Limitations section of the report, it is assumed that the aquatic ecology is evenly distributed throughout the river reaches.

8.3.3.1 Trichardtspruit (B11D-01481)

Table 8-21: MIRAI scores for the 2017 surveys

Invertebrate Metric Group	Score Calculated
Flow modification	43.1
Habitat	49.0
Water Quality	49.1
Ecological Score	**47.0**
Invertebrate Category	**D**

According to the MIRAI, the macroinvertebrate assemblage for the Trichardtspruit is in a largely modified state (category D). Despite the fairly high SASS5 scores recorded at T1 during both the low and high flow surveys, the MIRAI has indicated that a number of taxa intolerant to high flows are missing from the reach. This has resulted in high ASPT scores, due to the presence of less taxa with high sensitivity scores (usually associated to higher flows). However, the ecological category is low, according to the MIRAI, due to the subsequent loss of taxa intolerant to high flows resulting in a largely modified ecosystem.

8.3.3.2 Debeerspruit (B11C-01503)

Table 8-22: MIRAI scores for the 2017 surveys

Invertebrate Metric Group	Score Calculated
Flow modification	59.5
Habitat	59.8
Water Quality	54.9
Ecological Score	**58.1**
Invertebrate Category	**C/D**

According to the MIRAI, the macroinvertebrate assemblage for the Debeerspruit is in a moderately to largely modified state (category C/D). The major contributing factor to this modified categorisation appears to be due to poor water quality observed at site D1. As a result, sensitive taxa, intolerant to physio-chemical changes in water, have been lost from the system leading to the modified score.

8.3.3.3 Debeerspruit Tributary (Site D2)

Table 8-23: MIRAI scores for the 2017 surveys

Invertebrate Metric Group	Score Calculated
Flow modification	59.7

Invertebrate Metric Group	**Score Calculated**
Habitat	58.6
Water Quality	58.2
Ecological Score	**58.9**
Invertebrate Category	**C/D**

According to the MIRAI, the macroinvertebrate assemblage for the Debeerspruit is in a moderately to largely modified state (category C/D). Almost identical modifications as outlined by the MIRAI or the Debeerspruit were observed. However, less water quality modification was indicated by the score, which was most likely due to the mining activities taking place upstream of the Debeerspruit site.

8.3.3.4 Piekespruit Tributary (B11C-01542)

Table 8-24: MIRAI scores for the 2017 surveys

Invertebrate Metric Group	**Score Calculated**
Flow modification	61.1
Habitat	57.3
Water Quality	60.7
Ecological Score	**59.7**
Invertebrate Category	**C/D**

According to the MIRAI, the macroinvertebrate assemblage for the Piekespruit Tributary is in a moderately to largely modified state (category C/D). According to the MIRAI, habitat is the major factor causing the modified categorisation of the macroinvertebrates ecological score. Better scores may have been recorded if other sampling sites were selected along the reach due to the fairly healthy habitat ecological category determined by the IHIA.

8.3.3.5 Upper Piekespruit (B11C-01527)

Table 8-25: MIRAI scores for the 2017 surveys

Invertebrate Metric Group	**Score Calculated**
Flow modification	56.7
Habitat	59.4
Water Quality	52.8
Ecological Score	**56.4**
Invertebrate Category	**D**

According to the MIRAI, the macroinvertebrate assemblage for the Upper Piekespruit SQR is in a largely modified state (category D). Despite the fair habitat scores determined by the MIRAI, the water quality modifications appear to be in a largely modified state.

8.3.3.6 Steenkoolspruit (B11C-01449)

Table 8-26: MIRAI scores for the 2017 surveys

Invertebrate Metric Group	Score Calculated
Flow modification	61.0
Habitat	61.9
Water Quality	54.7
Ecological Score	**59.3**
Invertebrate Category	**C/D**

According to the MIRAI, the macroinvertebrate assemblage for the Steenkoolspruit is in a moderately to largely modified state (category C/D). The major contributing factor to this modified state appears to be poor water quality. This has resulted in the loss of a number of sensitive taxa and most likely the drop in categorisation from category C.

8.4 Fish Response Assessment Index

The presence/absence of the expected fish species recorded during the surveys is presented in Table 8-27 below.

Table 8-27: Fish species presence/absence

Species	T1	D1	D2	P1	P2	P3	P4	S1
High Flow Survey (March 2017)								
Enteromius anoplus	•	✓	✓	✓	✓	✓	✓	✓
Enteromius neefi	N/A	•	•	•	•	•	•	•
Enteromius paludinosus	•	✓	✓	•	✓	✓	✓	✓
Clarias gariepinus	•	•	✓	•	•	✓	•	•
Labeo umbratus	•	•	✓	•	•	✓	•	•
Labeobarbus polylepis	•	•	•	•	•	•	•	N/A
Pseudocrenilabrus philander	•	✓	✓	•	✓	•	✓	✓
Tilapia sparmani	•	✓	•	•	•	✓	✓	✓
Total number of species	0	4	5	1	3	5	4	4
Low Flow Survey (June 2017)								

Species	**T1**	**D1**	**D2**	**P1**	**P2**	**P3**	**P4**	**S1**
Enteromius anoplus	•	✓	✓	✓	✓	✓	✓	✓
Enteromius neefi	N/A	•	•	•	•	•	•	•
Enteromius paludinosus	•	✓	•	•	•	✓	✓	•
Clarias gariepinus	•	•	•	•	•	•	•	•
Labeo umbratus	•	•	✓	•	•	✓	•	•
Labeobarbus polylepis	•	•	•	•	•	•	•	N/A
Pseudocrenilabrus philander	•	✓	•	•	•	•	✓	✓
Tilapia sparmani	•	✓	•	•	•	✓	✓	✓
Total number of species	0	4	2	1	1	4	4	3
*N/A depicts fish species which are not expected at the relevant site								

No fish species were sampled at site T1, but are expected to be present in the system further downstream (Nepid Consultants, 2008). The fish species varied throughout the remaining sites with the dominant species being *Enteromius anoplus*, which was sampled at all of the sites (except T1) during both the low and high flow surveys.

8.4.1 Trichardtspruit Fish Ecological Category

Fish sampling was conducted at site T1 during both surveys. No fish species were sampled during either survey. However, it is assumed that there are fish in the reach especially due to the discharge of water from the Trichardtsfontein Dam. The study conducted by Nepid Consultants (2008) indicated large numbers of fish downstream of the monitoring site (T1) used in this study. Thus, the FRAI was not determined for the reach. Instead the data recorded by Nepid Consultants was used in the PES determination with a low confidence rating incorporated into the calculation. According to Nepid Consultants the fish assemblage for the Trichardtspruit was in a seriously modified state (category E) which does reflect the sampling effort observed at T1 during both surveys (March and June 2017).

The FRAI was calculated for the reaches where fish sampling was successful. This included the Debeerspruit sites, all sites along the Piekespruit, as well as the Steenkoolspruit. The FRAI results for the relevant reaches are provided in the tables below.

Table 8-28: FRAI results for the Debeerspruit SQR (B11C-01503)

Automated FRAI Score (%)	54.5
Adjusted FRAI Score (%)	62.7
Ecostatus	C

According to the FRAI, the fish assemblage for the Debeerspruit appears to be in a moderately modified state (category C). The most likely cause of this modified state appears to be flow modification leading to the loss of the two species sensitive to no flow, *Enteromius neefi* and *Labeobarbus polylepis*, which also happen to be fairly sensitive to poor water quality and a lack of substrate.

Table 8-29: FRAI results for the Debeerspruit Tributary

Automated FRAI Score (%)	49.6
Adjusted FRAI Score (%)	62.3
Ecostatus	C

According to the FRAI, the fish assemblage for the Debeerspruit Tributary appears to be in a moderately modified state (category C). This can be primarily attributed to the absence of *Tilapia sparrmanii* which has a high preference for overhanging vegetation as well as the absence of *Enteromius neefi* and *Labeobarbus polylepis* which are intolerant to no flow conditions and lack of substrate. Continued sampling may have led to the capture of *Tilapia sparrmanii* as vegetation was sufficient for its presence, thus increasing the score. However, *Enteromius neefi* and *Labeobarbus polylepis* appear to be absent from the system as they were not sampled at any of the monitoring sites along the whole of the Piekespruit system of concern (as observed in the Piekespruit FRAI below).

Table 8-30: FRAI results for the Upper Piekespruit SQR (B11C-01527)

Automated FRAI Score (%)	38.8
Adjusted FRAI Score (%)	50.9
Ecostatus	D

According to the FRAI, the fish assemblage for the Upper Piekespruit appears to be in a largely modified state (category D). A number of species were missing during the study and, unlike the other reaches; two sites were sampled in this SQR. This largely modified categorisation appears to be a result of physio-chemical and flow modification that have taken place resulting in the subsequent loss of a number of species.

Table 8-31: FRAI results for the Piekespruit Tributary (B11C-01542)

Automated FRAI Score (%)	54.5
Adjusted FRAI Score (%)	65.6
Ecostatus	C

According to the FRAI, the fish assemblage for the Piekespruit Tributary appears to be in a moderately modified state (category C). This can be attributed to the absence of the sensitive *Enteromius neefi* as well as other species. However, the constant presence of the three species (*Enteromius anoplus, Pseudocrenilabrus philander* and *Tilapia sparrmanii*) sampled during the study has resulted in a less modified categorisation than expected.

Table 8-32: FRAI results for the Piekespruit Tributary (B11C-01542)

Automated FRAI Score (%)	51.7
Adjusted FRAI Score (%)	63.1
Ecostatus	C

According to the FRAI, the fish assemblage for the Steenkoolspruit is in a moderately modified state (category C). Similarly to the findings in the Piekespruit Tributary, this modified categorisation can be attributed to the absence of the sensitive *Enteromius neefi* as well as other species mentioned in the sampling list (Table 8-27). However, *Labeobarbus polylepis* was not expected in this tributary and thus not included in the FRAI. Therefore, a less modified categorisation has resulted due to the exclusion of the species from the scores.

8.5 Present Ecological Status

The results of the ecological classification and PES for the river reaches considered are provided in the tables below.

8.5.1 Trichardtspruit

The PES for the considered SQR was determined based on FRAI scores determined at site T1 and at a downstream site (T2) by Nepid Consultants (2008) as well as ecological categories determined during this study (2017). Due to the fact that the FRAI results were obtained in 2008, a low confidence rating was allocated to them when calculating the overall PES.

Table 8-33: The Present Ecological Status of the river reach in this study

Category	Score	Ecological category
Riparian Habitat Ecological Category	36.6	**E**
Fish Ecological Category (T1)	N/A	**E**
Fish Ecological Category (T2)	N/A	**D**
Macroinvertebrate Ecological Category	47.0	**D**
Ecostatus		**D/E**

Considering the determined ecological categories and the categories obtained from the study conducted by Nepid Consultants (2008), the ecostatus for the SQR is category D/E or largely to seriously modified. It is important to note that this categorisation speaks mainly to the upper reaches of the SQR. Macroinvertebrates with fairly high sensitivity scores (Hydropsychidae) were collected at the monitoring site T1. However, it appears that they were present in the system due to the high flow from the Trichardtsfontein Dam and not due to good ecosystem functioning, as indicated by the modified MIRAI categorisation (category D). The riparian ecological category indicates far more degraded conditions. This is especially noted downstream

8.5.2 Debeerspruit

Table 8-34: The Present Ecological Status of the river reach in this study

Category	Score	Ecological category
Riparian Habitat Ecological Category	61.1	**C**
Fish Ecological Category	62.7	**C**
Macroinvertebrate Ecological Category	59.7	**C/D**
Ecostatus		**C**

The overall PES for the Debeerspruit was determined to be in a moderately modified state (category C). This modified state appears to be a result of the combination of the modified ecological indicators observed in the river. The fish and macroinvertebrate assemblages appear to be degraded due to the compounded effect of fairly poor water quality and habitat modification.

8.5.3 Debeerspruit Tributary

Table 8-35: The Present Ecological Status of the river reach in this study

Category	Score	Ecological category
Riparian Habitat Ecological Category	60.2	**C**
Fish Ecological Category	62.3	**C**
Macroinvertebrate Ecological Category	58.9	**C/D**
Ecostatus		**C**

The overall PES for the Debeerspruit was determined to be in a moderately modified state (category C). Impacts observed in the Debeerspruit were similar to those observed in the Debeerspruit Tributary. The higher scores recorded for the riparian habitat and fish ecological categories were able to categorise the overall PES as category C (moderately modified) instead of C/D (moderately to seriously modified) as determined for the macroinvertebrates.

8.5.4 Piekespruit Tributary

Table 8-36: The Present Ecological Status of the river reach in this study

Category	Score	Ecological category
Riparian Habitat Ecological Category	**80.4**	**B**
Fish Ecological Category	**65.6**	**C**
Macroinvertebrate Ecological Category	**59.7**	**C/D**
Ecostatus		**C**

The PES for the Piekespruit Tributary was determined to be category C or moderately modified. This modified state is a result of the modified fish and macroinvertebrate assemblages recorded at site P3.

8.5.5 Piekespruit

Table 8-37: The Present Ecological Status of the river reach in this study

Category	Score	Ecological category
Riparian Habitat Ecological Category	67.4	**C**
Fish Ecological Category	50.9	**D**
Macroinvertebrate Ecological Category	56.4	**D**
Ecostatus		**C/D**

The PES for the Piekespruit was determined to be category C/D or moderately to largely modified. This modified state is a result of the modified fish and macroinvertebrate assemblages recorded at sites P1 and P2 which is most likely due to habitat and water quality impacts relating to the associated farming activities.

8.5.6 Steenkoolspruit Tributary

Table 8-38: The Present Ecological Status of the river reach in this study

Category	Score	Ecological category
Riparian Habitat Ecological Category	68.0	**C**
Fish Ecological Category	N/A	**N/A**

Category	Score	Ecological category
Macroinvertebrate Ecological Category	N/A	**N/A**
Ecostatus		**C**

The PES determined for the Steenkoolspruit Tributary was based solely on the IHIA. Macroinvertebrate and fish sampling were not possible due to the low conditions of the monitoring site (S2). Therefore, it is assumed that the ecostatus of the Steenkoolspruit Tributary is category C or in a moderately modified state. Modifications appear to be directly associated with agricultural activities taking place in proximity to the tributary. This was especially noted with the number of livestock present, even at the monitoring site during sampling (Figure 8-4).

8.5.7 Steenkoolspruit

Table 8-39: The Present Ecological Status of the river reach in this study

Category	Score	Ecological category
Riparian Habitat Ecological Category	67.7	**C**
Fish Ecological Category	63.1	**C**
Macroinvertebrate Ecological Category	59.3	**C/D**
Ecostatus		**C**

The PES for the Steenkoolspruit was calculated as category C or moderately modified. This modified status can be attributed to impacted habitat (instream and riparian) which appears to be due to farming activities taking place in proximity to the SQR. The modified habitat and overall poor water quality has resulted in modified macroinvertebrate and fish assemblages, as observed at site S1, which has further resulted in the modified PES categorisation.

9 Sensitivity Analysis and No-Go Areas

Sensitive areas in respect to aquatic ecology include any areas associated with riverine or wetland habitats. Due to the fairly diverse macroinvertebrate assemblages within the assessed river systems and further modification to habitat associated with the aquatic ecosystem could result in the decline PES. Considering this, a buffer zone of 100 m between surface infrastructure (ventilation shafts) and waterbodies (wetlands and rivers) (as delineated in the wetland assessment conducted by Digby Wells (2017b) are considered sensitive areas. These areas are illustrated in the figure below (Figure 9-1).

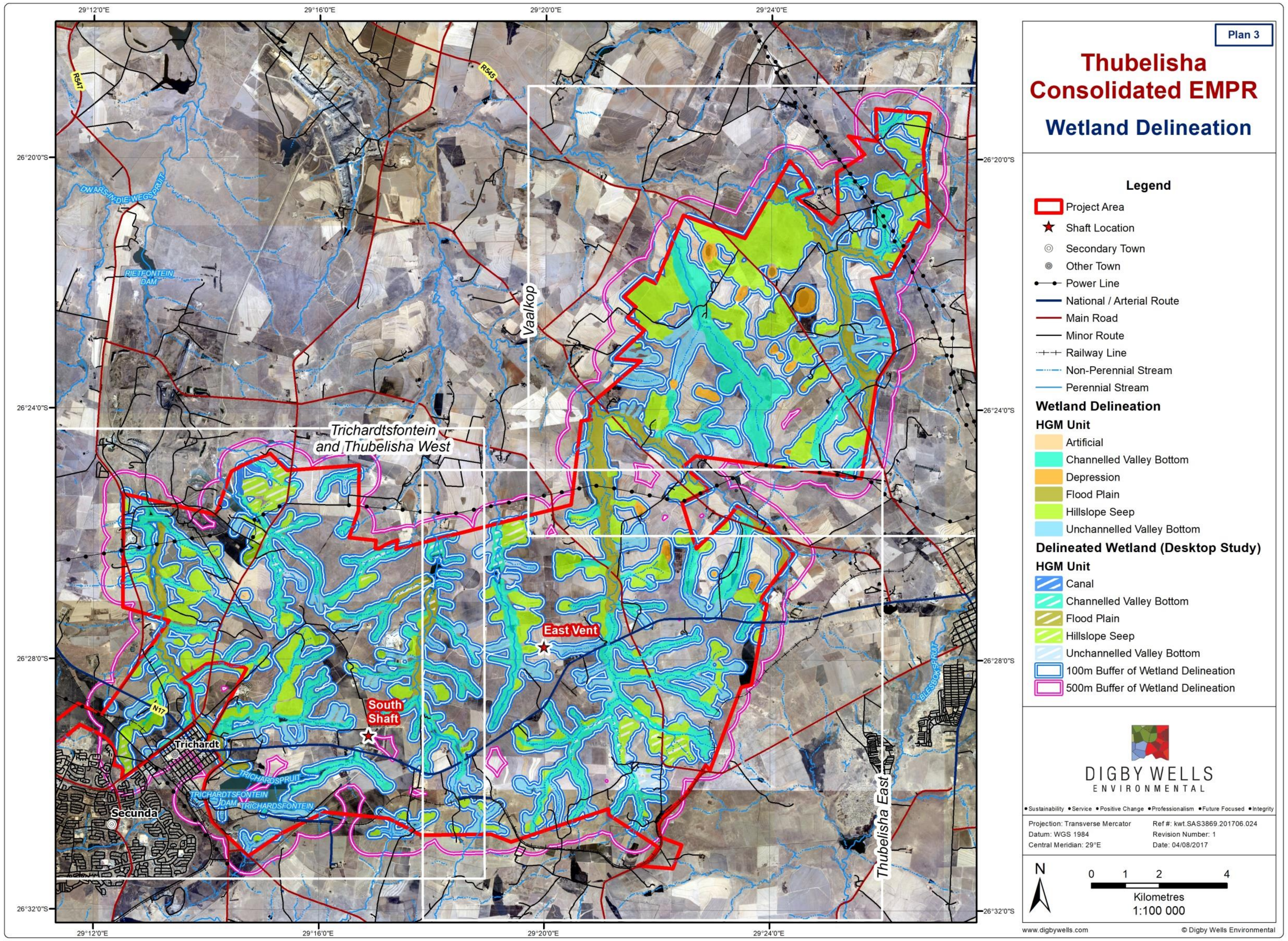

Figure 9-1: Sensitivity Area in relation to Aquatic Ecology

10 Aquatic Impact Assessment

10.1 Methodology used in Determining and Ranking the Nature, Significance, Consequence, Extent, Duration and Probability of Potential Environmental Impacts and Risks

Details of the impact assessment methodology used to determine the significance of physical, bio-physical and socio-economic impacts are provided below.

The significance rating process follows the established impact/risk assessment formula:

Significance = Consequence x Probability x Nature

Where

Consequence = Intensity + Extent + Duration

And

Probability = Likelihood of an impact occurring

And

Nature = Positive (+1) or negative (-1) impact

Note: In the formula for calculating consequence, the type of impact is multiplied by +1 for positive impacts and -1 for negative impacts.

The matrix calculates the rating out of 147, whereby Intensity, Extent, Duration and Probability are each rated out of seven as indicated in Table 10-3. The weight assigned to the various parameters is then multiplied by +1 for positive and -1 for negative impacts.

Impacts are rated prior to mitigation and again after consideration of the mitigation measure proposed in this report. The significance of an impact is then determined and categorised into one of eight categories, as indicated in Table 10-2, which is extracted from Table 10-1. The description of the significance ratings is discussed in Table 10-3.

It is important to note that the pre-mitigation rating takes into consideration the activity as proposed, i.e. there may already be certain types of mitigation measures included in the design (for example due to legal requirements). If the potential impact is still considered too high, additional mitigation measures are proposed.

Table 10-1: Impact Assessment Parameter Ratings

Rating	Intensity/Replacability		Extent	Duration/Reversibility	Probability
	Negative Impacts (Nature = -1)	Positive Impacts (Nature = +1)			
7	Irreplaceable loss or damage to biological or physical resources or highly sensitive environments. Irreplaceable damage to highly sensitive cultural/social resources.	Noticeable, on-going natural and / or social benefits which have improved the overall conditions of the baseline.	International The effect will occur across international borders.	Permanent: The impact is irreversible, even with management, and will remain after the life of the project.	Definite: There are sound scientific reasons to expect that the impact will definitely occur. >80% probability.
6	Irreplaceable loss or damage to biological or physical resources or moderate to highly sensitive environments. Irreplaceable damage to cultural/social resources of moderate to highly sensitivity.	Great improvement to the overall conditions of a large percentage of the baseline.	National Will affect the entire country.	Beyond project life: The impact will remain for some time after the life of the project and is potentially irreversible even with management.	Almost certain / Highly probable: It is most likely that the impact will occur. <80% probability.

Rating	Intensity/Replacability		Extent	Duration/Reversibility	Probability
	Negative Impacts (Nature = -1)	**Positive Impacts (Nature = +1)**			
5	Serious loss and/or damage to physical or biological resources or highly sensitive environments, limiting ecosystem function. Very serious widespread social impacts. Irreparable damage to highly valued items.	On-going and widespread benefits to local communities and natural features of the landscape.	Province/ Region Will affect the entire province or region.	Project Life (>15 years): The impact will cease after the operational life span of the project and can be reversed with sufficient management.	Likely: The impact may occur. <65% probability.
4	Serious loss and/or damage to physical or biological resources or moderately sensitive environments, limiting ecosystem function. On-going serious social issues. Significant damage to structures / items of cultural significance.	Average to intense natural and / or social benefits to some elements of the baseline.	Municipal Area Will affect the whole municipal area.	Long term: 6-15 years and impact can be reversed with management.	Probable: Has occurred here or elsewhere and could therefore occur. <50% probability.

Rating	Intensity/Replacability		Extent	Duration/Reversibility	Probability
	Negative Impacts (Nature = -1)	**Positive Impacts (Nature = +1)**			
3	Moderate loss and/or damage to biological or physical resources of low to moderately sensitive environments and, limiting ecosystem function. On-going social issues. Damage to items of cultural significance.	Average, on-going positive benefits, not widespread but felt by some elements of the baseline.	Local Local extending only as far as the development site area.	Medium term: 1-5 years and impact can be reversed with minimal management.	Unlikely: Has not happened yet but could happen once in the lifetime of the project, therefore there is a possibility that the impact will occur. <25% probability.
2	Minor loss and/or effects to biological or physical resources or low sensitive environments, not affecting ecosystem functioning. Minor medium-term social impacts on local population. Mostly repairable. Cultural functions and processes not affected.	Low positive impacts experience by a small percentage of the baseline.	Limited Limited to the site and its immediate surroundings.	Short term: Less than 1 year and is reversible.	Rare / improbable: Conceivable, but only in extreme circumstances. The possibility of the impact materialising is very low as a result of design, historic experience or implementation of adequate mitigation measures. <10% probability.

Rating	Intensity/Replacability		Extent	Duration/Reversibility	Probability
	Negative Impacts (Nature = -1)	**Positive Impacts (Nature = +1)**			
1	Minimal to no loss and/or effect to biological or physical resources, not affecting ecosystem functioning. Minimal social impacts, low-level repairable damage to commonplace structures.	Some low-level natural and / or social benefits felt by a very small percentage of the baseline.	Very limited/Isolated Limited to specific isolated parts of the site.	Immediate: Less than 1 month and is completely reversible without management.	Highly unlikely / None: Expected never to happen. <1% probability.

Table 10-2: Probability/Consequence Matrix

Probability	Significance																																					
7	-147	-140	-133	-126	-119	-112	-105	-98	-91	-84	-77	-70	-63	-56	-49	-42	-35	-28	-21	21	28	35	42	49	56	63	70	77	84	91	98	105	112	119	126	133	140	147
6	-126	-120	-114	-108	-102	-96	-90	-84	-78	-72	-66	-60	-54	-48	-42	-36	-30	-24	-18	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120	126
5	-105	-100	-95	-90	-85	-80	-75	-70	-65	-60	-55	-50	-45	-40	-35	-30	-25	-20	-15	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105
4	-84	-80	-76	-72	-68	-64	-60	-56	-52	-48	-44	-40	-36	-32	-28	-24	-20	-16	-12	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80	84
3	-63	-60	-57	-54	-51	-48	-45	-42	-39	-36	-33	-30	-27	-24	-21	-18	-15	-12	-9	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60	63
2	-42	-40	-38	-36	-34	-32	-30	-28	-26	-24	-22	-20	-18	-16	-14	-12	-10	-8	-6	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42
1	-21	-20	-19	-18	-17	-16	-15	-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	-21	-20	-19	-18	-17	-16	-15	-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	Consequence																																					

Table 10-3: Significance Rating Description

Score	Description	Rating
109 to 147	A very beneficial impact that may be sufficient by itself to justify implementation of the project. The impact may result in permanent positive change	Major (positive) (+)
73 to 108	A beneficial impact which may help to justify the implementation of the project. These impacts would be considered by society as constituting a major and usually a long-term positive change to the (natural and / or social) environment	Moderate (positive) (+)
36 to 72	A positive impact. These impacts will usually result in positive medium to long-term effect on the natural and / or social environment	Minor (positive) (+)
3 to 35	A small positive impact. The impact will result in medium to short term effects on the natural and / or social environment	Negligible (positive) (+)
-3 to -35	An acceptable negative impact for which mitigation is desirable. The impact by itself is insufficient even in combination with other low impacts to prevent the development being approved. These impacts will result in negative medium to short term effects on the natural and / or social environment	Negligible (negative) (-)
-36 to -72	A minor negative impact requires mitigation. The impact is insufficient by itself to prevent the implementation of the project but which in conjunction with other impacts may prevent its implementation. These impacts will usually result in negative medium to long-term effect on the natural and / or social environment	Minor (negative) (-)
-73 to -108	A moderate negative impact may prevent the implementation of the project. These impacts would be considered as constituting a major and usually a long-term change to the (natural and / or social) environment and result in severe changes.	Moderate (negative) (-)
-109 to -147	A major negative impact may be sufficient by itself to prevent implementation of the project. The impact may result in permanent change. Very often these impacts are immitigable and usually result in very severe effects. The impacts are likely to be irreversible and/or irreplaceable.	Major (negative) (-)

10.2 Impact Assessment

Refer to the project description for more information on the mining method. A brief summary is provided below: A brief summary of the project description is provided below:

- A high extraction method of mining using bord-and-pillar mining at a depth between 30-215 m. Stooping will occur outside of the 1:100 flood lines and developed areas;
- Two ventilation shafts (ventilation downcast shaft (0.25 ha) and ventilation upcast shaft (1.5 ha)) will be constructed at Trichardtsfontein and TCTS; and
- No surface infrastructure is proposed to be constructed at the Vaalkop Project area.

The major risk associated with underground mining is subsidence of unconsolidated sediments. Figure 10-1 represents the Life of Mine (LoM) plan in relation to the rivers in the project area, the wetland delineation and recommended buffers. Figure 10-2 indicates the subsidence risk. Areas of 30-50 m mining depth will have a definite risk of subsidence, 50-100 m mining depth has a high risk of subsidence and 100 or more has a low risk of subsidence. This is also based on the expected mining method for that area. •There are over 100 ha of wetland that will have a definite risk of subsidence. High risk areas include 608.4 ha of wetlands and low risk areas include 561.3 ha of wetlands (excluding the 100m buffer areas).

10.2.1 Summary of Proposed Project Interactions with Rivers and Wetlands

The Project construction is limited to the construction of the two proposed ventilation shafts as illustrated in Figure 10-3. As observed in the figure, the proposed location of the East Vent Shaft is within the 500m wetland buffer zones but not within the 100 m buffer zones. The South Vent Shaft does not fall within the 100 m or 500m wetland buffer zones. However, it is important to note that the underground mining activities interact with the rivers and wetlands, as well as their ecological buffer zones (100 m and 500m) as observed in Figure 10-1. The following outcomes must result from a comprehensive geotechnical investigation to reduce the overall impact:

- Provide appropriate design parameters for pillar and overburden stability, in line with the actual geotechnical rockmass properties;
- Indicate any areas (undermining of the wetlands) that may fall outside of these design parameters; and
- Following the geotechnical investigation, where required a provision must be made for the rehabilitation of these areas in the event of a possible risk of subsidence / intersection collapse.

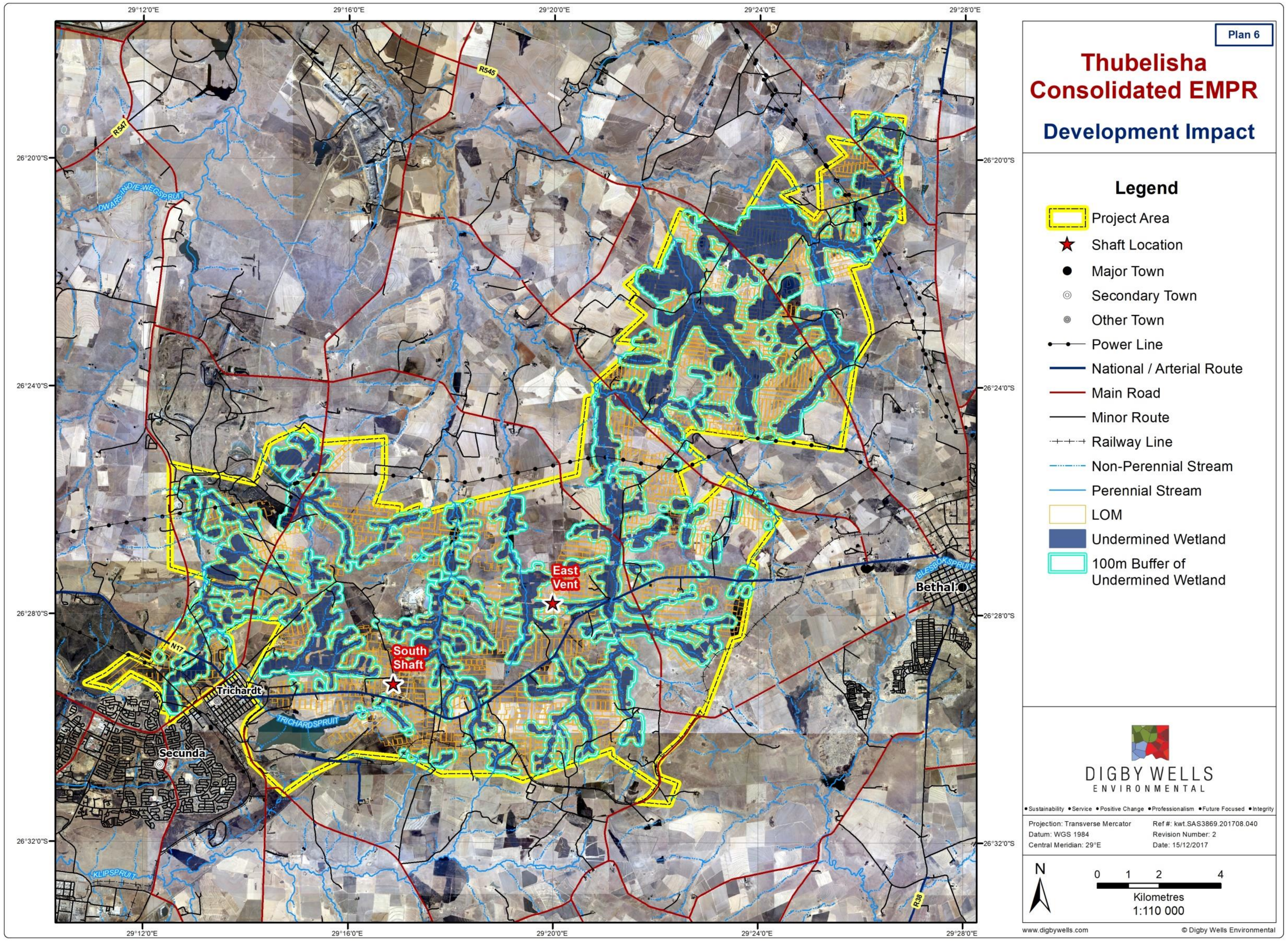

Figure 10-1: Underground Mine Layout in relation to rivers and delineated wetlands

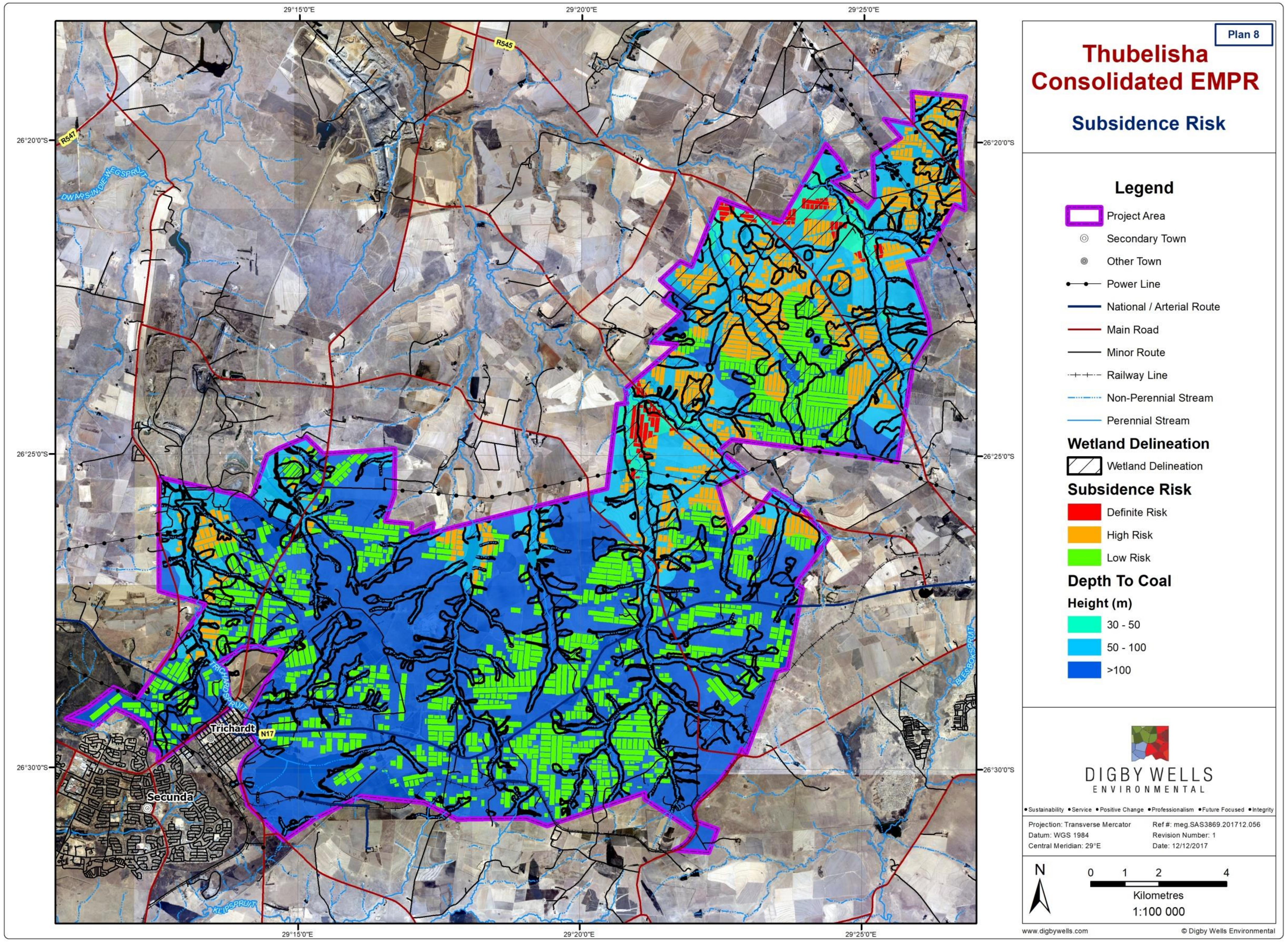

Figure 10-2: Subsidence Risk

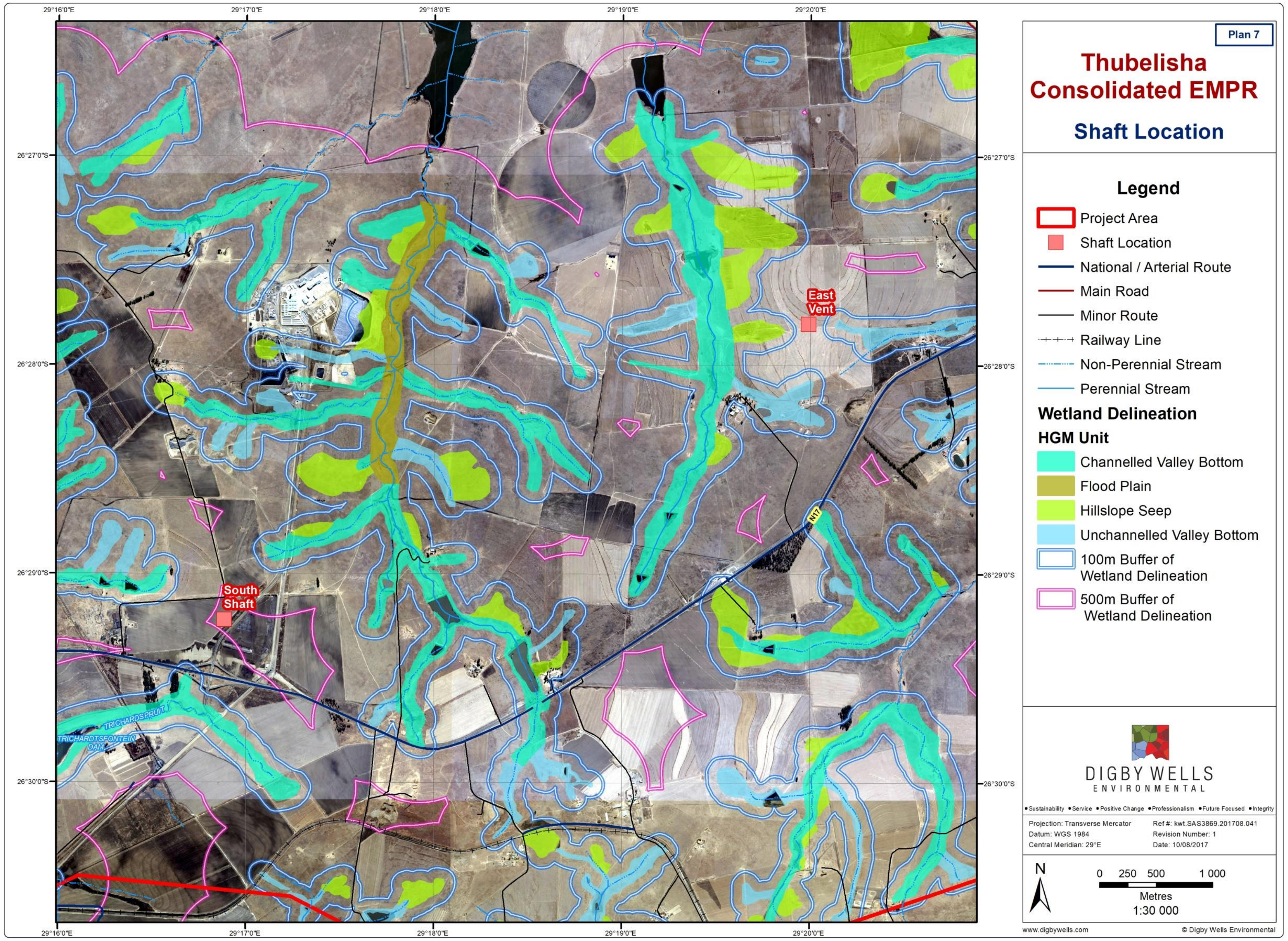

Figure 10-3: Vent Shaft Locations

10.2.2 Construction Phase Impact Assessment: Aquatic Ecology

The only surface infrastructure required is the construction of two ventilation shafts as mentioned above. It is proposed that access to the underground mining areas will be from TCTS thus no new surface entry is required. The construction of the ventilation shafts is outside of the 100 m wetland buffer. However, the following impacts (Table 10-4) were identified with regards to the construction phase activities and the impacts to aquatic ecology.

Table 10-4: Interactions and impacts to aquatic ecology for the construction phase

Interaction	Impact
Site clearance within river catchment and construction of surface infrastructure (ventilation shafts)	Increased runoff from cleared land and man-made structures (vent shafts, vehicle routes to and from construction and paved areas) resulting in erosion and sedimentation of downstream habitats
Waste generation/disposal and working with hazardous products	Runoff containing hazardous substances and solid waste resulting in water and habitat quality degradation in downstream river reaches

10.2.2.1 Impact Description: Water and Habitat Quality Deterioration

The activities and interactions listed above (Table 10-4) have the potential to degrade water and habitat quality within the nearby river systems. Water quality impacts may include increased dissolved/suspended solids, as well as potential persistent pollutants within the water column and sediments of the associated watercourse. In addition, general water chemistry modification may occur as a result of changed salt balances. Habitat quality impacts may include sedimentation, bed, channel and flow modification, as well as the general loss of aquatic habitat through direct modification during the construction of watercourse crossings.

Although the PES (baseline) of the river reaches assessed was derived to be modified from reference conditions, further deterioration is possible and thus a potential decline in the PES could be observed. In addition, erosion and sedimentation of the rivers is currently widespread in the current catchment area and additional habitat loss will result in the overall lowering of the PES.

10.2.2.2 Management Objectives

The objective for management is to preserve the PES and prevent further degradation of local aquatic environments. This objective can be achieved through the management of potential water and habitat quality impacts as listed in the section below.

10.2.2.3 Management Actions

General mitigation actions provided in the surface water, wetlands and groundwater studies conducted by Digby Wells (2017a,2017b,2017c) should be used to guide the effective management of aquatic resources potentially affected by the project. However, important management actions are briefly listed below.

The establishment of a clearly marked buffer zone, which is defined as a region of natural vegetation between the rivers/wetlands and the proposed activity, is the primary management action that should take place. Literature suggests that a buffer zone can reduce aquatic habitat and water quality impacts of large developments, making this management action of particular importance (WRC, 2014). According to Water Research Commission (2014) the efficacy of a buffer is related to the distance between the river system and the zone of disturbance. Therefore, by increasing the length of a buffer, the potential aquatic modification related to the proposed activity is reduced. Considering this, it is recommended that, a buffer zone of 100 m is placed between infrastructure and riparian zones or the 1:100 floodline (whichever is largest). The designated buffer zones should then be demarcated using signage.

The removal of vegetative cover and exposure of bare soil has been recognised as being responsible for increased runoff, sedimentation and subsequent water and habitat quality degradation in downstream portions of river systems (WRC, 2014). As such the careful management of vegetation removal and sedimentation control should take place. This can be achieved through:

- Minimise the removal of vegetation in the infrastructure footprint area;
- Revegetation of the construction footprint as soon as possible;
- Construction should take place during the dry season (if possible) to reduce runoff and possibly erosion
- Storm water must be diverted from construction activities and managed in such a manner to disperse runoff and prevent the concentration of storm water flow;
- Sequential removal of the vegetation (not all vegetation immediately); and
- The vegetation of bare surfaces.

During the various phases of the project, waste generated and the working with hazardous products can result in the runoff and seepage of contaminated water from the proposed ventilation shafts which can cause degradation of the aquatic ecosystems. In order to prevent this, the use of effective storm water management through diversions and containment strategies is of importance. This can be achieved through effective groundwater and surface water management as per the surface and groundwater studies (Digby Wells, 2017a, 2017c); however management actions are briefly listed below:

- Storm water must be diverted from construction activities and managed in such a manner to disperse runoff and prevent the concentration of storm water flow that may carry contaminants from the sites into the associated aquatic system;
- Ensure correct waste management; and
- Ensure correct storage systems are used for the storage of hazardous products when constructing.

10.2.2.4 Impact Ratings

Table 10-5: Potential Impacts of the Construction Phase

<table>
<tr><th>Dimension</th><th>Rating</th><th>Motivation</th><th>Significance</th></tr>
<tr><td colspan="4">Activity and Interaction: Site clearance and construction of manmade structures within associated wetland habitats and river catchment</td></tr>
<tr><td colspan="4">Impact Description: Increased runoff and erosion within the rivers nearby to the ventilation shafts</td></tr>
<tr><td colspan="4">Prior to Mitigation/Management</td></tr>
<tr><td>Duration</td><td>Long Term (4)</td><td>Once vegetation is cleared, no re-vegetation will occur until the closure phase of the project unless natural regrowth around the impacted areas occurs</td><td rowspan="5">Negligible (negative) – 18</td></tr>
<tr><td>Extent</td><td>Limited (2)</td><td>The extent of the impact will likely be limited to the immediate river sections impacted by the runoff</td></tr>
<tr><td>Intensity x type of impact</td><td>Moderate - Negative (-3)</td><td>Due to the scale of the proposed site clearance, the intensity to aquatic ecology appears to be moderate.</td></tr>
<tr><td>Probability</td><td>Unlikely (3)</td><td>It is unlikely that the impact will occur of any significance due to the small footprint and distance from the associated river systems</td></tr>
<tr><td>Nature</td><td colspan="2">Negative</td></tr>
<tr><td colspan="4">Mitigation/Management Actions</td></tr>
<tr><td colspan="4">▪ Minimise and keep the footprint as small as possible;
▪ Buffer zones (100 m wetlands and 100 m riparian);
▪ Revegetation of the construction footprint as soon as possible;
▪ Storm water should be diverted from construction activities and managed in such a manner to disperse runoff and prevent the concentration of storm water flow;
▪ Construction should take place during the dry season to minimise runoff; and
▪ Sequential removal of the vegetation (not all vegetation immediately).</td></tr>
</table>

Dimension	Rating	Motivation	Significance
Post-Mitigation			
Duration	Long Term (4)	Once vegetation is cleared, no re-vegetation will occur until the closure phase of the project. Although revegetation will mitigate	Negligible (negative) – 14
Extent	Limited (2)	Runoff will still most likely only impact the immediate river sections associated with the ventilation shafts	
Intensity x type of impact	Very Low - Negative (-1)	Intensity will decrease if the bare land around the ventilation shafts are revegetated but slight runoff will most likely occur from the shafts until decommissioning	
Probability	Improbable (2)	The likelihood of the impact occurring is reduced by the mitigation	
Nature	Negative		

Dimension	Rating	Motivation	Significance
Activity and Interaction: Waste generation/disposal and the use of hazardous products			
Impact Description: Water and habitat quality deterioration			
Prior to Mitigation/Management			
Duration	Long Term (4)	If hazardous products enter the river systems, aquatic ecology will be affected for a long period, however will not last for the duration of the Project	Negligible (negative) – 33
Extent	Limited (2)	The extent of the impact will likely affect the downstream regions but most likely limited due to limited flow observed in the rivers associated with the proposed ventilation shaft areas	
Intensity x type of impact	High - Negative (-5)	Aquatic ecosystems are sensitive to disturbance and thus any contaminants entering the system will have a severe impact on the aquatic ecology	

Dimension	Rating	Motivation	Significance
Probability	Unlikely (3)	It is unlikely that the impact will occur of any significance due to the small footprint and distance from the 100 m buffer zones of the proposed ventilation shafts	
Nature	Negative		
Mitigation/Management Actions			
▪ Storm water must be diverted from construction activities and managed in such a manner to disperse runoff and prevent the concentration of storm water flow that may carry contaminants from the sites into the associated aquatic systems ; ▪ Ensure correct waste management; and ▪ Ensure correct storage systems are used for the storage of hazardous products when constructing.			
Post-Mitigation			
Duration	Medium Term (3)	The aquatic ecology will already have been affected by the impact but will most likely recover quicker after mitigation	Negligible (negative) – 16
Extent	Limited (2)	The extent of the impact will likely have already the immediate river sections associated with the ventilation shafts	
Intensity x type of impact	High - Negative (-3)	The intensity of the impact will decrease severely if mitigation measures are in place, limiting hazardous substances from entering the aquatic systems	
Probability	Improbable (2)	The likelihood of the impact occurring is reduced by the mitigation	
Nature	Negative		

10.2.3 Operational Phase

High extraction mining will take place during the operational phase of the Project. Therefore, the probability of subsidence occurring is high and will have serious effects on aquatic ecology. As observed in Figure 10-2, the risk of subsidence has been categorised into three classes (namely definite risk, high risk and low risk). As a result, two separate impact ratings were developed for the proposed high to definite risk subsidence areas and for the proposed low risk subsidence areas.

It is important to note that at the time of the impact ratings, no detailed geotechnical data of the underground workings was available. The assumption was made that detailed geotechnical investigations would be conducted and that the required safety factor will be sufficient to prevent any subsidence where high extraction is proposed and associated surface cracks of the undermined areas to prevent any negative impacts with regards to subsidence (i.e. decant) within the undermined wetland / aquatic areas. The main impacts associated with the operational phase are summarised in Table 10-6 below.

Table 10-6: Interactions and impacts to aquatic ecology for the operation phase

Interaction	Impact
Underground mining	Undermining of wetlands and rivers leading to hydrological and geomorphic changes to the functioning of the ecosystem; particularly related to groundwater impacts
The emergency stockpiling of coal	Runoff water which may come into contact with the carboniferous material will contain various pollutants that may contaminate downstream river reaches
Waste generation/disposal and working with hazardous products	Runoff containing hazardous substances and solid waste resulting in water and habitat quality degradation in downstream river reaches

10.2.3.1 Impact Description: Water and Habitat Quality Impacts

The activities and interactions listed above (Table 10-6) have the potential to degrade water and habitat quality within all of the undermined river systems. The major anticipated impacts would result from subsidence of areas associated with the wetland and riverine areas. The subsidence of land can alter the hydrology of the river catchment resulting in major effects to local aquatic biota. The possible runoff from the emergency stockpile is also of concern and poses a threat to water and habitat quality.

10.2.3.2 Management Objectives

The objective for management is to preserve the PES and prevent further degradation of local aquatic environments. This objective can be achieved through the management of potential water and habitat quality impacts as listed in the section below.

10.2.3.3 Management Actions

A comprehensive geotechnical study should be conducted detailing the degree of risk associated with the subsidence of areas located under wetlands/rivers. Based on the results of the study the mine plan should be adapted to support or avoid high risk subsidence areas and/or ensure a sufficient safety factor and sufficient pillar support to prevent subsidence and associated cracks forming in the undermined wetland areas to protect wetlands and aquatic ecosystems. No mitigation measure will be able to reduce the impact on aquatic ecology if mining commences in the high to definite risk subsidence areas where subsidence will most likely occur if mining in these areas commences.

Important management actions are briefly listed below:

- The highest safety factor possible (at least 2) must be used;
- Underground dykes and sills must be carefully managed/avoided as this can lead to dewatering of aquatic/wetland areas if undesired aquifers are punctured;
- Ensure sufficient pillar support and safety factors to prevent subsidence of undermined wetland/aquatic areas;
- Mining should not occur above 100 m below aquatic/wetland areas (confirm with geotechnical study if areas can been mined shallower than 100 m without the risk of subsidence);
- No high extraction should take place under rivers within the 100 m buffer zones; and
- Monitoring should take place for excessive inflow into the underground workings.

During the operational phase of the proposed project, the storage and handling of carboniferous material can result in the degradation of downstream aquatic ecosystems.

To prevent this, the use of diversion and containment management is of importance. This can be achieved through effective groundwater and surface water management as per the surface and groundwater studies (Digby Wells, 2017a, 2017b; however important management actions are briefly listed below:

- Clean and dirty storm water management: Clean water should be managed in a manner according to the Department of Water and Sanitation Best Practice Guidelines;
- Barrier systems, including synthetic, clay and geological/natural or other approved mitigation methods to minimise contaminated seepage and runoff from entering the local aquatic systems;
- Storm water management plan should be implemented where storm water should be diverted away from the surface operations and dirty water stored in the existing Pollution Control Dam (PCD);
- The emergency stockpile should be managed to minimise infiltration of contaminants to the groundwater. Mitigation methods that should be considered include:
  - Management of the stockpile shape to control the ease with which water can run off from the facility.
  - The vegetation of the stockpile and covering them with soil to minimise rainfall infiltration and mobilisation of dissolved metals.
  - Implementation of a lime cover on overburden stockpiles to neutralise acidity.

10.2.3.4 Impact Ratings

Table 10-7: Impact Ratings for the Operational Phase

Dimension	Rating	Motivation	Significance
Activity and Interaction: Underground mining high to definite risk subsidence areas			
Impact Description: Subsidence of land within the river catchment and subsidence of land underneath river channels resulting in poor ecosystem functioning			
Prior to Mitigation/Management			
Duration	Permanent (7)	The undermining of a river course and resulting subsidence will be a permanent impact	Major (negative) – 119
Extent	Municipal (4)	The impact would likely impact on the water balance of the associated river systems and thus beyond a local extent	
Intensity x type of impact	Irreplaceable Loss (-6)	The loss of the headwaters of a river system will be permanent and will seriously affect the functioning and connectivity of the downstream river reaches	
Probability	Almost certain (7)	Should mining occur, there is a very high likelihood of the impact occurring especially in the areas where high extraction is proposed	
Nature	Negative		
Mitigation/Management Actions			
▪ No mitigation measures will be able to prevent subsidence where the depth of mining is shallower than 100 m.			
Post-Mitigation			
Duration	Permanent (7)	The impact, should it occur, would still be a permanent feature	Major (negative) – 119
Extent	Municipal (4)	Should subsidence occur, the impact to the associated river systems, specifically the water balance, is likely to extend beyond the project site (municipal extent)	
Intensity x type of impact	Irreplaceable Loss (-6)	The impact would have already resulted in a loss of headwater of the associated river systems and cannot be replaced	

Dimension	Rating	Motivation	Significance
Probability	Probable (7)	Should such a shallow depth of mining occur, there is a very high likelihood of the impact occurring where mitigation will not be possible.	
Nature	Negative		

Dimension	Rating	Motivation	Significance
Activity and Interaction: Underground mining low risk subsidence areas			
Impact Description: Subsidence of land within the river catchment and subsidence of land underneath river channels resulting in poor ecosystem functioning			
Prior to Mitigation/Management			
Duration	Permanent (7)	The undermining of a river course and resulting subsidence will be a permanent impact	Moderate (negative) – 102
Extent	Municipal (4)	The impact would likely impact on the water balance of the associated river systems and thus beyond a local extent	
Intensity x type of impact	Irreplaceable Loss (-6)	The loss of the headwaters of a river system will be permanent and will seriously affect the functioning and connectivity of the downstream river reaches	
Probability	Almost certain (6)	Should mining occur, there is a very high likelihood of the impact occurring especially in the areas where high extraction is proposed	
Nature	Negative		
Mitigation/Management Actions			

Dimension	Rating	Motivation	Significance
▪ Complete a geotechnical study to identify high risk subsidence areas and avoid or mitigate to support them; ▪ Ensure sufficient pillar support and safety factors to prevent subsidence of undermined wetland/aquatic areas; ▪ The highest safety factor possible (at least 2) must be used for areas of shallow mining (confirm with geotechnical study); ▪ Underground mining should avoid aquifers especially due to the proposed high extraction near aquatic and wetland systems. Punctured aquifers could lead to the dewatering of aquatic/wetland systems; ▪ Mining should not occur above 100 m below aquatic/wetland areas or within the 100 m wetland buffer zones (confirm with geotechnical study if areas can be mined shallower than 100 m without the risk of subsidence); and ▪ Monitoring should take place for excessive inflow into the underground workings.			
Post-Mitigation			
Duration	Permanent (7)	The impact, should it occur, would still be a permanent feature	Minor (negative) – 68
Extent	Municipal (4)	Should subsidence occur, the impact to the associated river systems, specifically the water balance, is likely to extend beyond the project site (municipal extent)	
Intensity x type of impact	Irreplaceable Loss (-6)	The impact would have already resulted in a loss of headwater of the associated river systems and cannot be replaced	
Probability	Probable (4)	Should the mitigation measures be implemented, the likelihood of subsidence is reduced and therefore reduced probability	
Nature	Negative		

Dimension	Rating	Motivation	Significance
Activity and Interaction: Emergency coal stockpiling			
Impact Description: Runoff from the emergency coal stockpile into local aquatic systems will result in the degradation of the water and habitat quality of the polluted system			
Prior to Mitigation/Management			
Duration	Project life (5)	Runoff from the emergency stockpile will continue to occur for the life of the Project	Minor (negative) – 65

Dimension	Rating	Motivation	Significance
Extent	Local (3)	The impact would likely affect downstream reaches from where the stockpile runoff enters a water system	
Intensity x type of impact	High - Negative (-5)	Aquatic ecosystems are sensitive to disturbance and thus any impact is regarded as serious	
Probability	Likely (5)	Should mining occur, there is a high likelihood of the impact occurring	
Nature	Negative		
Mitigation/Management Actions			
▪ Clean and dirty water storm water management: Clean water should be managed in a manner according to the Department of Water and Sanitation Best Practice Guidelines; ▪ Barrier systems, including synthetic, clay and geological/natural or other approved mitigation methods to minimise contaminated seepage and runoff from entering the local aquatic systems; ▪ Storm water management plan should be implemented where storm water should be diverted away from the surface operations and dirty water stored in the existing PCD; and ▪ The emergency stockpile should be managed to minimise infiltration of contaminants to the groundwater. Mitigation methods that should be considered include: ▪ Management of the stockpile shape to control the ease with which water can run off from the facility. ▪ The vegetation of the soil/overburden stockpile and covering them with soil to minimise rainfall infiltration and mobilisation of dissolved metals. ▪ Implementation of a lime cover on overburden stockpiles to neutralise acidity.			
Post-Mitigation			
Duration	Project life (5)	Runoff from the emergency stockpile will continue to occur for the life of the Project	Negligible (negative) – 33
Extent	Local (3)	The impact would likely affect downstream reaches from where the stockpile runoff enters a water system	
Intensity x type of impact	High - Negative (-3)	Aquatic ecosystems are sensitive to disturbance and thus any impact is regarded as serious. However, the intensity will decrease mitigation measures are properly installed/managed	

Dimension	Rating	Motivation	Significance
Probability	Unlikely (3)	The likelihood of the impact will decrease if the emergency stockpile is managed correctly	
Nature	Negative		

Dimension	Rating	Motivation	Significance
Activity and Interaction: Storage/disposal of generated waste and the working with hazardous products			
Impact Description: Runoff from operational site containing contaminants will degrade habitat and water quality of polluted aquatic systems			
Prior to Mitigation/Management			
Duration	Project life (5)	The use of hazardous products/waste generation will continue for the life of the Project	Minor (negative) – 52
Extent	Local (3)	Pollutants will affect downstream reaches	
Intensity x type of impact	High - Negative (-5)	Aquatic ecosystems are sensitive to disturbance and thus any impact is regarded as serious	
Probability	Probable (4)	Should mining occur, there is a high likelihood of the impact occurring	
Nature	Negative		
Mitigation/Management Actions			
▪ Storm water must be diverted from operational sites and managed in such a manner to disperse runoff to prevent the concentration of storm water flow that may carry contaminants from the site to aquatic systems; ▪ Ensure correct waste management; and ▪ Ensure correct storage systems are used for the storage of hazardous products throughout the project life.			
Post-Mitigation			
Duration	Project Life (5)	The impact, should it occur, would still be a permanent feature	Negligible (negative) – 26
Extent	Local (3)	Should subsidence occur, the impact to the associated river systems, specifically the water balance, is likely to extend beyond the project site (local extent)	

Dimension	Rating	Motivation	Significance
Intensity x type of impact	High - Negative (-5)	Aquatic ecosystems are sensitive to disturbance and thus any impact is regarded as serious	
Probability	Improbable (2)	If managed correctly the chances of contaminants entering local water systems will decrease	
Nature	Negative		

10.2.4 Closure and Rehabilitation Phase

The major aquatic related impact foreseen during the closure and rehabilitation phase is the possible risk of decant of dirty water from the mine workings into the associated aquatic systems. The following interactions between the closure and rehabilitation phase activities and the impacts to aquatic ecology are summarised below (Table 10-8).

Table 10-8: Rehabilitation and Closure Phase Interactions

Interaction	Impact
Removal of infrastructure and surface rehabilitation	Similarly to the construction phase, the removal of the infrastructure will lead to potential negative impacts on the habitat integrity of the associated aquatic ecosystems
Underground mine closure and rehabilitation	Post-mining decant of groundwater will have negative impacts on the associated rivers downstream water quality

10.2.4.1 Impact Description: Water and Habitat Quality Impacts

Similar to the construction phase the removal of infrastructure and rehabilitation activities will be a relatively small scale operation and thus has the potential, but limited, to affect the associated aquatic ecosystems. Attention needs to be paid to the ventilation shaft areas during this phase to limit the possibility of impacted the nearby river systems.

Typically, following the cessation of underground mining activities groundwater returns to the voids created by the mining process. This process results in the contamination of the groundwater resource. Following this influx of groundwater, seepage and decant at specific locations can result in the ingress of contaminated water in the downstream river systems, thus severely degrading the local PES. The groundwater study completed for this project will include modelled simulations that show possible effects after closure and the expected time frame of these effects.

10.2.4.2 Management Objectives

The objective for management is to preserve the PES and prevent further degradation of local aquatic environments. This objective can be achieved through the management of potential water and habitat quality impacts as listed in the section below.

10.2.4.3 Management Actions

To mitigate against the increase in runoff during closure limited activity should take place in natural/unimpeached areas as well as in the 100 m buffer zones.

To mitigate against the decant of contaminated water, the actions recommended in groundwater report of this project should be considered. However, water treatment and the discharge of clean water is an option available to reduce the possible ingress of contaminated water as well as the collection and storage of dirty water from the possible decant.

10.2.4.4 Impact Ratings

Table 10-9: Impact Ratings for the Closure and Rehabilitation Phase

Dimension	Rating	Motivation	Significance
Activity and Interaction: Removal of infrastructure and surface rehabilitation.			
Impact Description: Increased runoff and erosion			
Prior to Mitigation/Management			
Duration	Medium term (3)	The impact will only occur during the closure and rehabilitation phase	Negligible (negative) – 33
Extent	Local (3)	The extent of the impact will likely affect the downstream regions	
Intensity x type of impact	High - Negative (-5)	Aquatic ecosystems are sensitive to disturbance and thus any impact is regarded as serious	
Probability	Unlikely (3)	It is unlikely this impact will occur due to the ventilation shafts and TCTS infrastructure being situated outside the 100 m buffer zones	
Nature	Negative		
Mitigation/Management Actions			
▪ Avoid rehabilitation or unimpeached areas; ▪ Stay within already impacted areas and avoid activity within the 100 m buffer zones; and ▪ Commence the phase during the dry season to limit runoff.			
Post-Mitigation			

Dimension	Rating	Motivation	Significance
Duration	Medium term (3)	The impact will only occur during this phase	Negligible (negative) – 22
Extent	Local (3)	The extent of the impact will likely affect the downstream regions	
Intensity x type of impact	High - Negative (-5)	Aquatic ecosystems are sensitive to disturbance and thus any impact is regarded as serious	
Probability	Improbable (2)	The impact will most likely be reduced after mitigation	
Nature	Negative		

Dimension	Rating	Motivation	Significance
Activity and Interaction: Underground mine closure and rehabilitation			
Impact Description: Decant of severely contaminated water into local aquatic ecosystems			
Prior to Mitigation/Management			
Duration	Permanent (7)	Decant of contaminated water will likely be permanent	Moderate (negative) – 102
Extent	Municipal (4)	Decant is likely to affect downstream river systems, thus extending further than local systems	
Intensity x type of impact	Serious - negative (-6)	The change of water quality in the headwaters of the associated river systems will seriously affect the functioning of the downstream reaches and impact aquatic ecology severely	
Probability	Highly Probable (6)	Should mining occur, there is a very high likelihood of the impact occurring	
Nature	Negative		
Mitigation/Management Actions			
▪ Decant should not be allowed to discharge into the associated aquatic systems. The decant can be collected and stored in PCD's as a short term mitigation measure; and ▪ Investigation into long term solutions for decant management needs to be conducted.			
Post-Mitigation			
Duration	Permanent (7)	The decant of contaminated water will likely be permanent	Minor (negative) – 64

Dimension	Rating	Motivation	Significance
Extent	Municipal (4)	The discharge after mitigation is likely to affect downstream river systems, thus extending further than local systems	
Intensity x type of impact	Serious - negative (-5)	The change of water quality in the headwaters of the river systems will have seriously affected the functioning of the downstream river reaches, however mitigation measures should decrease the impact	
Probability	Unlikely (4)	If water treatment is completed, the probability of the impact will decrease	
Nature	Negative		

11 Cumulative Impacts

The following cumulative impacts have been identified, and can occur due to the proposed development:

- Cumulative deterioration of water quality within the associated river systems; and
- Cumulative deterioration of aquatic habitat within the associated river systems.

The PES of the river reaches associated with the project is currently modified as a result of habitat quality modification and the moderate water quality modification. The proposed project will likely not affect water quality of this reach until the closure phase, where-after potential decant poses a risk to the water quality impairment.

Dissolved solids (salinity) and the pH of the rivers within the project area have been increasing as a possible result of extensive farming practices. Therefore, it is probable that the proposed project will contribute toward these increasing water quality constituents and further degradation of water quality within the associated reaches. Considering this, if mitigation actions are not put in place, the effects thereof will be significant.

12 Unplanned Events and Low Risks

The planned activities will have known impacts as discussed above; however, unplanned events may happen on any project that may have potential impacts which will need mitigation and management. Table 12-1 is a summary of the findings from an aquatic ecology perspective. Please note not all potential unplanned events may be captured herein and this must therefore be managed throughout all phases.

Table 12-1: Unplanned Events, Low Risks and their Management Measures

Unplanned event	Potential impact	Mitigation/ Management/ Monitoring
Hydrocarbon spill into riverine habitat	Contamination of sediments and water resources associated with the spillage	A spill response kit must be available at all times. The incident must be reported on and if necessary an aquatic ecology specialist must investigate the extent of the impact and provide rehabilitation recommendations
Uncontrolled erosion	Sedimentation of downstream river reach	Erosion control measures must be put in place

13 Environmental Management Plan

The objective of an Environmental Management Plan (EMP) is to present mitigation (a) to manage undue or reasonably avoidable adverse impacts associated with the development of a project and (b) to enhance potential positives.

13.1 Project Activities with Potentially Significant Impacts

The following is a summary of the identified significant impacts to wetland and river systems that will require mitigation measures for the project to go ahead.

Table 13-1: Potentially significant project impacts

Activity	Impact
Construction Phase	
Site clearance within associated wetland habitats and river catchment and construction of surface infrastructure	Increased runoff resulting in erosion and sedimentation of downstream habitats. Increased runoff from manmade structures resulting in the erosion and sedimentation of downstream river reaches.
Operational Phase	
Existing mine operations (emergency coal stockpile) and underground mining	Undermining of wetlands and rivers leading to hydrological and geomorphic changes to the functioning of the ecosystem; particularly related to groundwater impacts.
Closure Phase	
Underground mine closure and rehabilitation	Post-mining decant of groundwater will have negative impacts on the downstream water quality.

13.2 Summary of Mitigation and Management

Table 13-2 provides a summary of the proposed project activities, environmental aspects and impacts on the receiving environment. Information on the frequency of mitigation, relevant legal requirements, recommended management plans, timing of implementation, and roles / responsibilities of persons implementing the EMP. All of the mitigation measures have been previously listed in the impact assessment tables as well.

Table 13-2: Mitigation and Management Plan

Activities	Potential Impact	Size and scale of disturbance	Aspects Affected	Phase	Mitigation Type/Measures	Compliance with standards/Standard to be achieved	Time period for Implementation
Site clearance within associated wetland habitats and river catchment and construction of surface infrastructure	Increased runoff resulting in erosion and sedimentation of downstream habitats. Increased runoff from manmade structures resulting in the erosion and sedimentation of downstream river reaches	Limited	Aquatic Ecology	Construction phase	▪ Minimise and keep the footprint as small as possible; ▪ Buffer zones (100 m wetlands and 100 m riparian), where these areas cannot be avoided a Wetland offset strategy should be implemented; ▪ Revegetation of the construction footprint as soon as possible; ▪ Storm water should be diverted from construction activities and managed in such a manner to disperse runoff and prevent the concentration of storm water flow; ▪ Construction should take place during the dry season to minimise runoff; and ▪ Sequential removal of the vegetation (not all vegetation immediately).	The National Water Act (NWA), 1998 (Act No. 36 of 1998)	Design and construction phase
Waste generation/disposal and working with hazardous products	Runoff containing pollutants and solid waste resulting in water and habitat quality degradation in downstream river reaches.	Limited			▪ Approved barrier systems to minimise contaminated seepage and runoff from entering the local aquatic systems; ▪ Storm water must be diverted from construction activities and managed in such a manner to disperse runoff and prevent the concentration of storm water flow through the sites of concern that may carry contaminants into the associated aquatic systems; ▪ Ensure correct waste management; and ▪ Ensure correct storage systems are used for the storage of hazardous products when constructing.		

Activities	Potential Impact	Size and scale of disturbance	Aspects Affected	Phase	Mitigation Type/Measures	Compliance with standards/Standard to be achieved	Time period for Implementation

The emergency stockpiling of coal	Runoff water which may come into contact with the carboniferous material will contain various pollutants that may contaminate downstream river reaches	Local		Operation phase	▪ Clean and dirty water management: Clean water should be managed in a manner according to the Department of Water and Sanitation Best Practice Guidelines;
					▪ Barrier systems, including synthetic, clay and geological/natural or other approved mitigation methods to minimise contaminated seepage and runoff from entering the local aquatic systems;
					▪ Storm water management plan should be implemented where storm water must be diverted away from the surface operations and dirty water stored in the existing PCD;
					▪ The emergency stockpile should be managed to minimise infiltration of contaminants to the groundwater. Mitigation methods that should be considered include:
					  ▪ Management of the stockpile shape to control the ease with which water can run off from the facility.
					  ▪ The vegetation of the soil/overburden stockpile and covering them with soil to minimise rainfall infiltration and mobilisation of dissolved metals.
					  ▪ Implementation of a lime cover on overburden stockpiles to neutralise acidity.
							Operation phase

Activities	Potential Impact	Size and scale of disturbance	Aspects Affected	Phase	Mitigation Type/Measures	Compliance with standards/Standard to be achieved	Time period for Implementation
Underground blasting and mining	Undermining of wetlands and rivers leading to hydrological and geomorphic changes to the functioning of the ecosystem; particularly related to groundwater impacts.	Municipality			▪ Complete a geotechnical study to identify high risk subsidence areas and avoid or mitigate to support them; ▪ Ensure sufficient pillar support and safety factors to prevent subsidence of undermined wetland/aquatic areas; ▪ The highest safety factor possible(at least 2) must be used for areas of shallow mining (confirm with geotechnical study); ▪ Underground mining should avoid aquifers especially due to the proposed high extraction near aquatic and wetland systems. Punctured aquifers could lead to the dewatering of aquatic/wetland systems; ▪ Mining should not occur above 100 m below aquatic/wetland areas; ▪ Monitoring should take place for excessive inflow into the underground workings; and ▪ Mining of areas shallower than 100m should be avoided as no mitigation measures will be able to stop subsidence.		Operation phase
Waste generation/disposal and working with hazardous products	Runoff containing hazardous substances and solid waste resulting in water and habitat quality degradation in downstream river reaches	Local			▪ Storm water must be diverted from operational sites and managed in such a manner to disperse runoff and prevent the concentration of storm water flow through the sites of concern that may carry contaminants from the sites into the associated aquatic systems; ▪ Ensure correct waste management; and ▪ Ensure correct storage systems are used for the storage of hazardous products when constructing.		

Activities	Potential Impact	Size and scale of disturbance	Aspects Affected	Phase	Mitigation Type/Measures	Compliance with standards/Standard to be achieved	Time period for Implementation
Removal of infrastructure and surface rehabilitation.	Similarly to the construction phase, the removal of the infrastructure will lead to potential negative impacts on the integrity of the associated aquatic ecosystems	Local		Rehabilitation and closure phase	▪ Established buffer zones: 100 m from wetland areas; and ▪ Commence the phase during the dry season to limit runoff.		Rehabilitation and closure phase
Underground mine closure and rehabilitation	Post-mining decant of groundwater will have negative impacts on the downstream water quality	Municipality			▪ Decant capture and storage.		

13.3 Monitoring Plan

An aquatic biomonitoring programme is an essential management tool. The monitoring programme should be designed to enable the detection of potential negative impacts brought about by the Project. Table 13-3 highlights some important aspects to monitor in reference to aquatic biota for the duration of the project. Monitoring should be conducted by a certified aquatic specialist. The parameters in the table below should be monitored at the monitoring points in this study (with the exception of toxicity testing). However, site S2 as illustrated in Figure 6-3 should be moved further downstream to an area where macroinvertebrate and fish sampling can be conducted.

Table 13-3: Aquatic Ecology Monitoring Programme

Parameters to be monitored	Monitoring objectives	Frequency of monitoring
In Situ water quality	Maintaining within the threshold effect values stipulated by DWAF (1996)	Bi-annual (dry and wet season)
IHAS and IHIA (Habitat Indicators)	Determine changes in habitat condition and maintain/improve determined category per reach in this study	Bi-annual for IHAS (dry and wet season) and annually for the IHIA
Macroinvertebrate assemblages using SASS5 and MIRAI	Determine changes in macroinvertebrate assemblages of the associated aquatic systems and maintain/improve determined category per reach in this study	Bi-annual sampling using SASS5 (dry and wet season) with the MIRAI being conducted annually
Fish assessment using FRAI	Determine changes in fish assemblages of the associated aquatic systems and maintain/improve determined category per reach in this study	Fish sampling conducted bi-annually (dry and wet season) with the FRAI being determined annually
Ecostatus determination using the ecostatus model (version 2.0)	Determine changes from the calculated ecostatus for the river reaches of concern in this study and maintain/improve determined category per reach	Ecostatus determination should be done annually
Toxicity Testing (screening)	Determine the toxicity of stored mine or decant water in any PCD associated with aquatic systems	Bi-annual (dry and wet season)

14 Conclusions and Recommendations

Standard River Ecosystem Monitoring Programme techniques were used to determine the PES of the following river reaches within the B11C and B11D quaternary catchments which were assessed during two seasonal surveys (i.e. high-flow and low-flow conditions):

- Trichardtspruit;
- Debeerspruit;
- Piekespruit; and
- Steenkoolspruit.

It is important to note that a number of unnamed tributaries of the above mentioned reaches were also assessed. For the purpose of the study these tributaries included:

- Debeerspruit Tributary;
- Piekespruit Tributary; and
- Steenkoolspruit Tributary.

The PES of the above mentioned river reaches varied. The categorisations for the assessed reaches ranged from largely modified (category D) to moderately modified (category C). This was largely attributed to the existing impacts within the catchment area, comprised mainly of cultivation and livestock as well as other mining operations in the B11D quaternary catchment. These activities were believed to facilitate elevated pH and conductivity values within the assessed systems, which have possibly led to the loss of a number of fish and macroinvertebrate taxa.

In light of the aforementioned ecological conditions, an impact assessment was conducted to identify any potential concerns likely to affect the associated watercourses. Based on this assessment, several key impacts were identified as indicated below:

- Increased runoff due to the construction of the proposed ventilation shafts and during the closure phase;
- Contaminants/hazardous products from the mining activities (emergency coal stockpile and ventilation shaft construction) entering into the aquatic systems;
- Undermining of wetlands and waterbodies; and
- Potential decant of Acid Mine Drainage during the closure and post-closure phases resulting in significant water quality modification in the associated river systems.

Considering these potential impacts, should the mining operation go ahead provision should be made to mitigate against the any notable changes to the hydrology of the systems, water quality impairment, and/or potential subsidence of surrounding areas. It is also highly recommended that high to definite risk subsidence areas within the 100 m wetland buffer zones (Figure 10-2) are not mined.

Monitoring conditions have been recommended within this report along with various mitigation actions, including:

- Buffer zone establishment: 100 m from delineated wetland and river areas as stipulated in the Wetlands report by Digby Wells (2017b);
- Effective storm water management, so as to limit (or prevent) potential contamination from 'dirty' water runoff originating from the ventilation shafts or emergency coal stockpile;
- Exposed topsoils and soil stockpiles must be revegetated to reduce erosion and subsequent sedimentation;
- Correct storage and management of hazardous products must be implemented;
- Although a basic geotechnical study has been completed for TCTS, it is recommended that a comprehensive geotechnical study must be conducted for the entire project area to assess the risk of subsidence in areas associated with river systems. Mitigation actions to increase stability should be used in delineated high risk areas. These mitigation actions include limiting mining underneath the river system and the use of thicker support pillars. However, detailed mitigation actions should be defined in the comprehensive geotechnical study.

This report should not be considered in isolation and other specialist reports, such as surface water, groundwater and wetland studies should be reviewed to ensure a holistic understanding of the study area.

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Appendix A: Site Photographs

Site	High Flow	Low Flow
Rivers		
T1		
D1		
D2		

Site	High Flow	Low Flow
P1		
P2		
P3		

Site	High Flow	Low Flow
P4		
S1		
S2