Environmental Impact Assessment
Kusile 60-year Ash Disposal Facility

Specialist Assessment: Aquatic Ecosystems

[Wilge River, Nooitgedacht]

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INDEMNITY AND CONDITIONS RELATING TO THIS REPORT

The findings, results, observations, conclusions and recommendations given in this report are based on the author's best scientific and professional knowledge as well as available information. The report is based on survey and assessment techniques which are limited by time and budgetary constraints relevant to the type and level of investigation undertaken and Wetland Consulting Services (Pty.) Ltd. and its staff reserve the right to modify aspects of the report including the recommendations if and when new information may become available from ongoing research or further work in this field, or pertaining to this investigation.

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1. BACKGROUND INFORMATION

Wetland Consulting Services (Pty) Ltd was appointed by Zitholele (Pty) Ltd to undertake an aquatic ecosystem and alternatives assessment for the Kusile 60-year Ash Disposal Facility.

The baseline assessment of aquatic ecosystems was conducted in phases. Phase 1 comprised a regional assessment of aquatic ecosystems affected by the six alternative sites initially identified. These site alternatives are shown in Figure 1-1 and summarised below:

- A
- G
- F+G
- F+small a
- C
- B

Phase 2 comprised a comparative impact assessment of the six sites. Based on this, a preferred alternative was identified. The preferred alternative was identified as Site A (Figure 1-2). A full impact assessment was subsequently conducted for Site A, as well as site B (on request by the DWA).

The study area is located immediately to the south of the N4 freeway between Bronkhorstspruit and the Kusile Power Station.

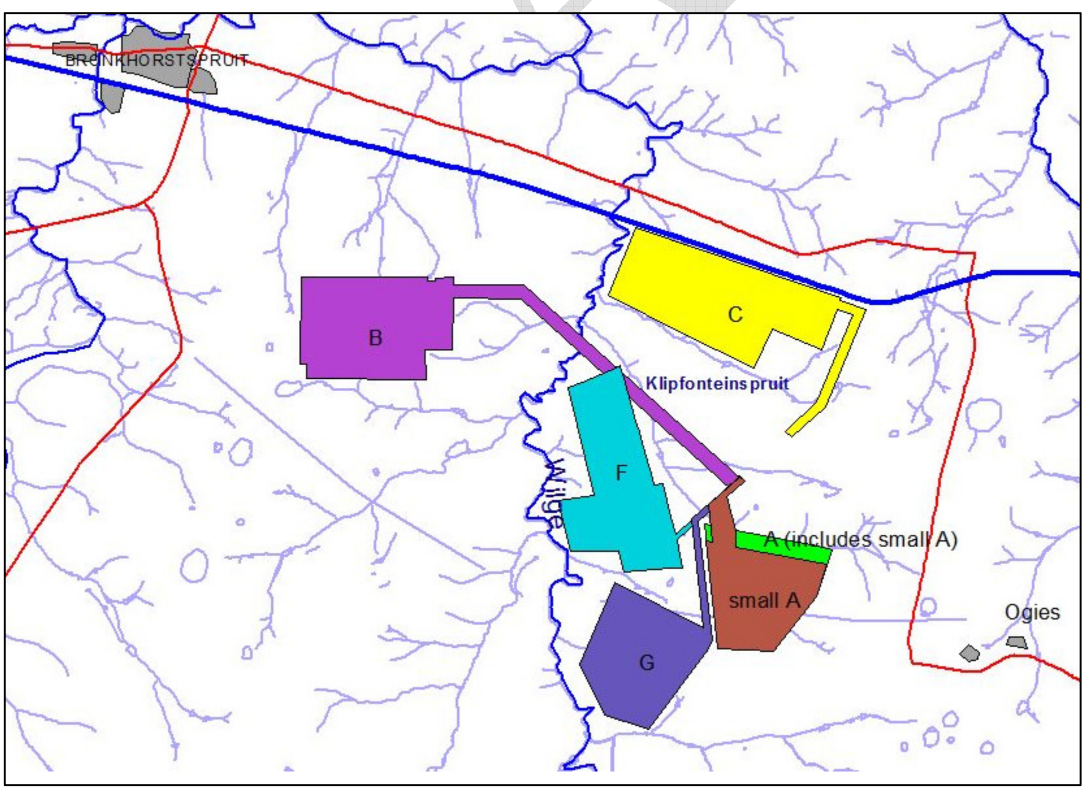

Figure 1-1. Location of the study area, site alternatives and potential conveyor routes.

2. TERMS OF REFERENCE

The terms of reference for this phase of the study included:

- Review of existing available data;
- Baseline ecological assessment of aquatic ecosystems associated with each alternative based on:
  - aquatic macroinvertebrates,
  - fish,
  - diatoms,
  - water quality,
  - habitat integrity;
- Present Ecological State (PES) using the DWAF scoring system (DWAF,1999);
- Identify sensitive areas;
- Ranking of alternative sites: a risk-based approach;
- Report compilation.

3. LIMITATIONS

- Reference conditions are not fully known due to the lack of studies pre-dating development. This limits the confidence with which the present ecological category is assigned;

- Aquatic ecosystems vary both temporally and spatially. Once-off surveys such as this are therefore likely to miss ecological information, thus limiting accuracy, detail and confidence. The results in this report therefore represent ecological conditions at the time of sampling.

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4. STUDY AREA

4.1 Catchments

The study area is located within the Highveld Ecoregion, Olifants River Catchment (Primary Catchment B) and within the upper reaches of quaternary catchments B20F, drained by the Wilge River, and B20F, drained by the Bronkhorstspruit. Site alternative B straddles the two catchments, with two unnamed tributaries draining eastwards into the Wilge River and two tributaries draining northwards into the Bronkhorstspruit. Tributaries associated with all other site alternatives drain westwards into the Wilge River. Most tributaries are unnamed, except for the Klipfonteinspruit which receives runoff from the Kusile Power Station, and the Holspruit, which drains Alternative A.

The Ezemvelo Nature Reserve is located along the Wilge River approximately 30 km downstream of site C. No river NFEPAs have been identified within the study Alternative And aquatic ecosystems are classified as Category C (Moderately Modified) according the DWAF database (2006).

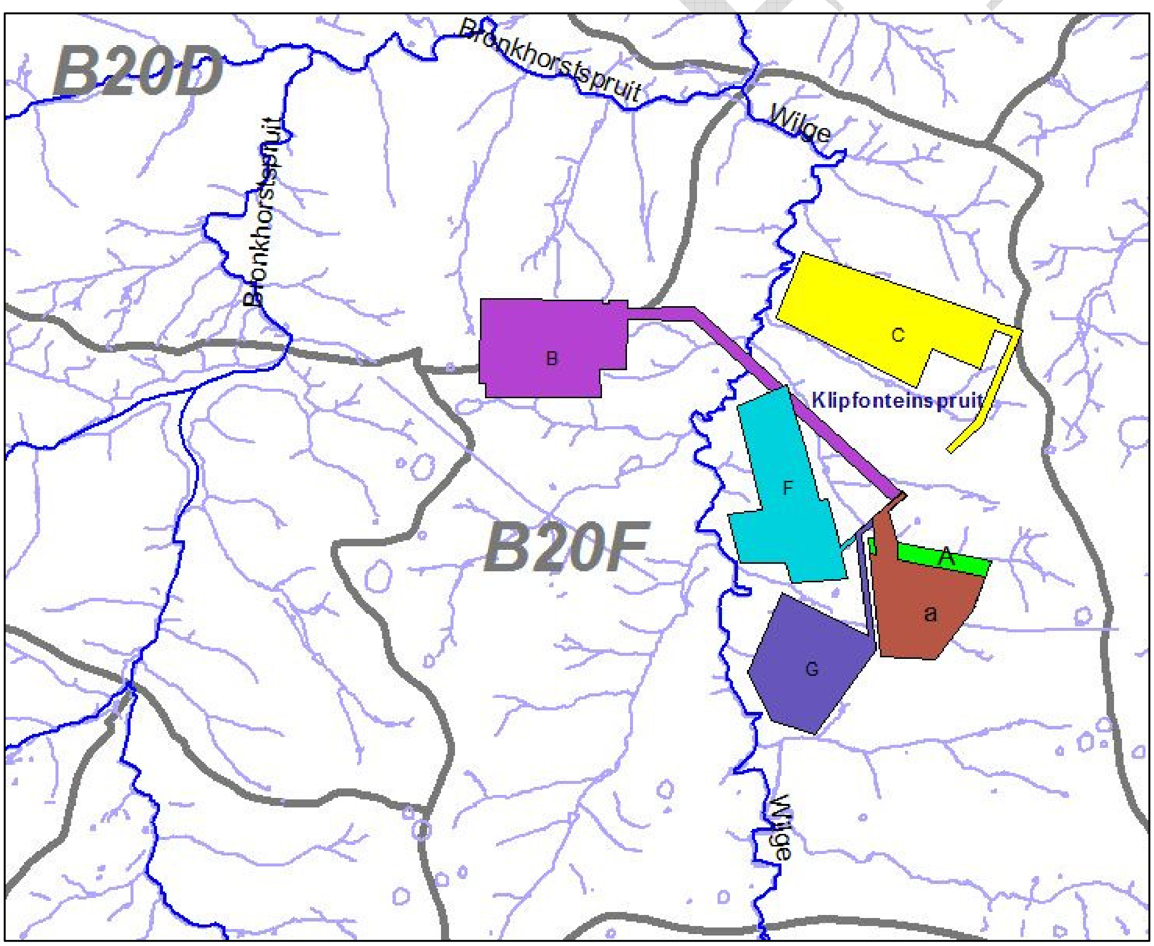

Figure 4-1. Map showing the site alternatives relative to watercourses and quaternary catchments.

4.2 Sampling sites for phase 1 of the baseline assessment

Sites were selected to be representative of all the surface water ecosystems associated with site alternatives, including conveyor corridors. These are outlined in Table 4-1, shown in Figure 4-2 and summarised below. Where possible, watercourses were sampled upstream and downstream of the activity so as to more accurately identify current impacts arising from the site and to provide a baseline against which future monitoring results can be compared.

The rationale for sampling sites is described below (All tributaries flow into the Wilge River,unless specified):

Alternative B:
Four unnamed non-perennial tributaries draining away from Alternative B were labelled B1, B2, B3, B4. B1 and B2 flow northwards into the Bronkhorstspruit, while B3 and B4 flow eastward into the Wilge River. In addition, a seasonal pan immediately south-west of Alternative B, was sampled (Pan2). The conveyor crossing points were also sampled along the Wilge River, the Wilge tributary at Site B4 and the Klipfonteinspruit (Sites KF2, KF3).

Alternative G:
Three Wilge River sites (W1, W2 and W3) were sampled upstream and downstream of Alternative G. In addition, two unnamed non-perennial tributaries draining Alternative G were sampled (T1 and T2). G2 will additionally impact upon the Holspruit (HS) and the Klipfonteinspruit (KF2). The conveyor route to Alternative G will cross the Klipfonteinspruit (KF2) and the Kusile tributary that flows into the Klipfonteinspruit (Kus).

Alternative A:
The Holspruit and Klipfonteinspruit drain Alternative A. One site was sampled along the Holspruit (HS1) and three sites were sampled along the Klipfonteinspruit, upstream and downstream of Alternative A (KFS 1 and KFS2). T2 is a non-perennial tributary of the Wilge River also likely to receive runoff from Alternative A. The conveyor route to Alternative A will cross the Klipfonteinspruit (KF2) and the Kusile tributary that flows into the Klipfonteinspruit (Kus). Alternative A may impact on the Wilge River via the Klipfonteinspruit so all sampling sites along the Wilge River also apply to Alternative A.

Alternative F+G and F+a:
The Wilge River was sampled upstream and downstream of Area F (W3 and W4 respectively) and the Klipfonteinspruit was sampled upstream and downstream of Area F (KFS2 and KFS3). The unnamed tributary that drains westward into the Klipfonteinspruit from the diversion within the Kusile Power Station, was also sampled (Kus). In addition, a seasonal pan within Area F was sampled and T2, to the south, was also considered to receive runoff from Area F.

Alternative C:
The unnamed non-perennial tributary that drains westward from Alternative C was sampled at site T4. In addition, three sites along the Wilge River were sampled upstream (W4), adjacent to (W5) and downstream (W6) of Alternative C. The conveyor route to are C will cross the tributary upstream of T4.

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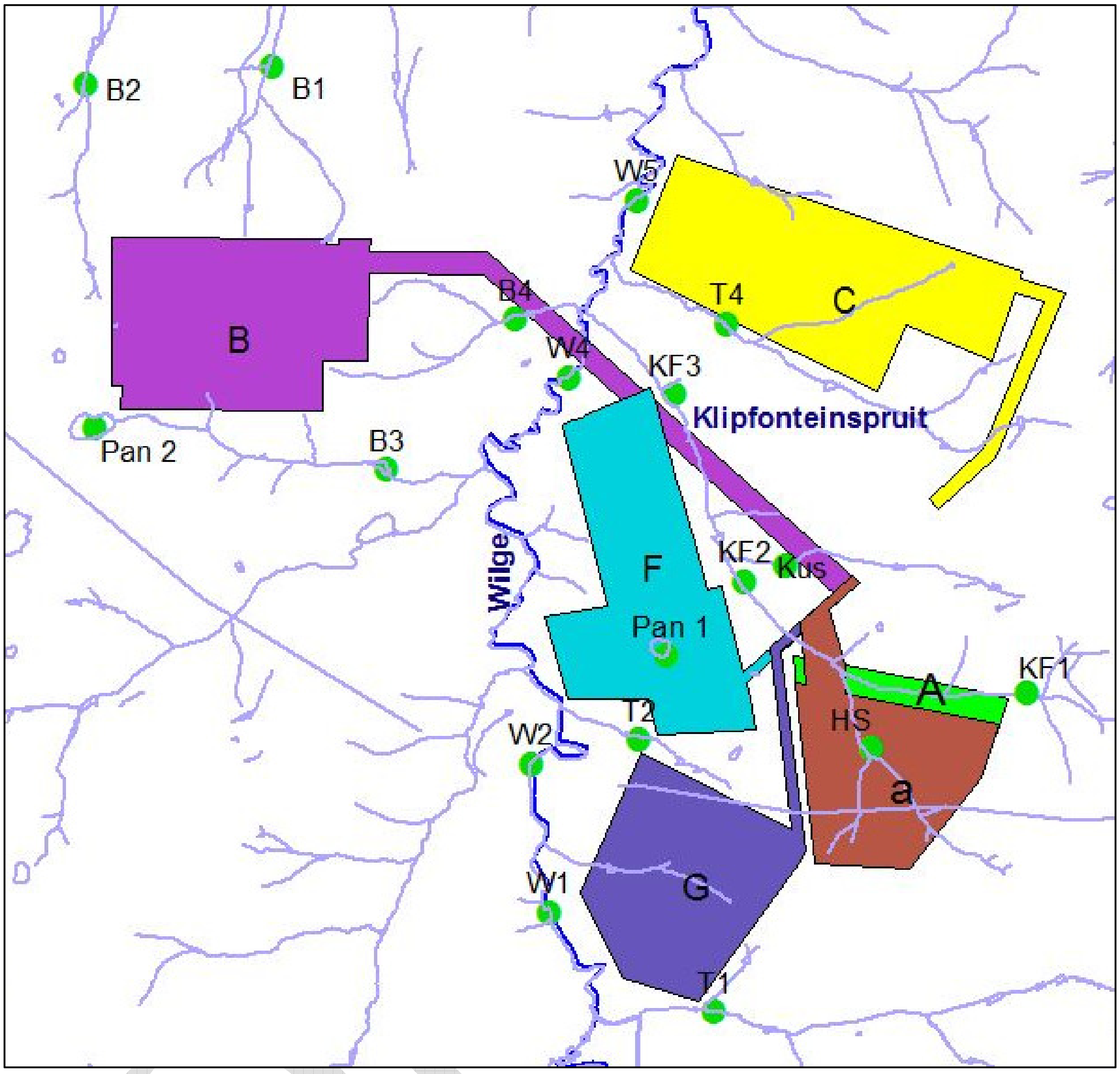

Figure 4-2. Aquatic sampling sites for the Kusile 60-year Ash Disposal Facility baseline survey.

Table 4-1: Aquatic sampling sites selected for the purpose of the baseline study.

Site Name	Coordinates		Associated Site Alternative(s)	Sampled for:
W1	-6.01420809	28.86850975	Upstream of Alternative G	SASS5, fish, on-site water quality
W2	-25.98508594	28.85431114	Adjacent to Alternative G	SASS5, diatoms, water quality
W3	-25.95996906	28.85113085	Downstream of Alternative G, Upstream of Area F	SASS5, fish, diatoms, water quality
W4	-25.88954362	28.86046222	Downstream of Area F, Upstream of Alternative C, conveyor crossing of the Wilge River for Alternative B	SASS5, fish, diatoms, water quality
W5	-25.86426796	28.86896241	Adjacent to Alternative C	SASS5, diatoms, water quality

Site Name	Coordinates		Associated Site Alternative(s)	Sampled for:
W6	-25.85176688	28.86974449	Downstream of Alternative C	SASS5, fish, on-site water quality
T1	-26.00193673	28.88225483	Non-perennial tributary draining Alternative G	SASS5, fish, diatoms, water quality
T2	-25.95573408	28.86944834	Non-perennial tributary draining Areas G, A and F	Limited surface water: diatoms, water quality
HS1	-25.95728430	28.90874311	Non-perennial tributary draining Alternative A	Fish, SASS5, diatoms, water quality
KFS1	-25.94819991	28.93606437	Non-perennial tributary upstream of Alternative A	Fish, SASS5, on-site water quality
KFS2	-25.93728542	28.89423269	Non-perennial tributary downstream of Alternative A and upstream of Area F. Potential conveyor crossing.	Fish, SASS5, diatoms, water quality
KFS3	-25.88751755	28.86615923	Non-perennial tributary downstream of Area F. Potential conveyor crossing for Alternative B.	Fish, SASS5, on-site water quality
Kus	-25.92540938	28.89078773	Tributary of the Klipfonteinspruit draining Kusile Power Station. Potential conveyor crossing.	Fish, SASS5, ons-site water quality
T4	-25.88918261	28.89037821	Non-perennial tributary draining Alternative C. Potential conveyor crossing.	Fish, SASS5, diatoms, water quality
B1	-25.84157813	28.80680753	Non-perennial tributary of the Bronkhorstspruit draining Alternative B	Fish, SASS5, water quality, diatoms
B2	-25.84449909	28.77562168	Non-perennial tributary of the Bronkhorstspruit draining Alternative B	Fish, SASS5, water quality, diatoms
B3	-25.90995492	28.82663763	Non-perennial tributary of the Wilge River draining Alternative B	Dry at time of sampling
B4	-25.88288045	28.85580285	Non-perennial tributary of the Wilge River draining Alternative B. Potential conveyor crossing for Alternative B.	Fish, SASS5, water quality, diatoms
Pan 1	-25.90283878	28.77706550	Seasonal Pan within Area F	SASS5, water quality
Pan 2	-25.94073281	28.87385125	Seasonal Pan adjacent to Alternative B	SASS5, water quality

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4.3 Sampling sites for phase 2 of the baseline assessment

Upon completion of phase 1 of the study, a comparative assessment was conducted which identified Site A as the preferred alternative. Alternatives A and B were selected for a more comprehensive assessment and impact assessment. Sampling sites associated with these alternatives are shown in the map below.

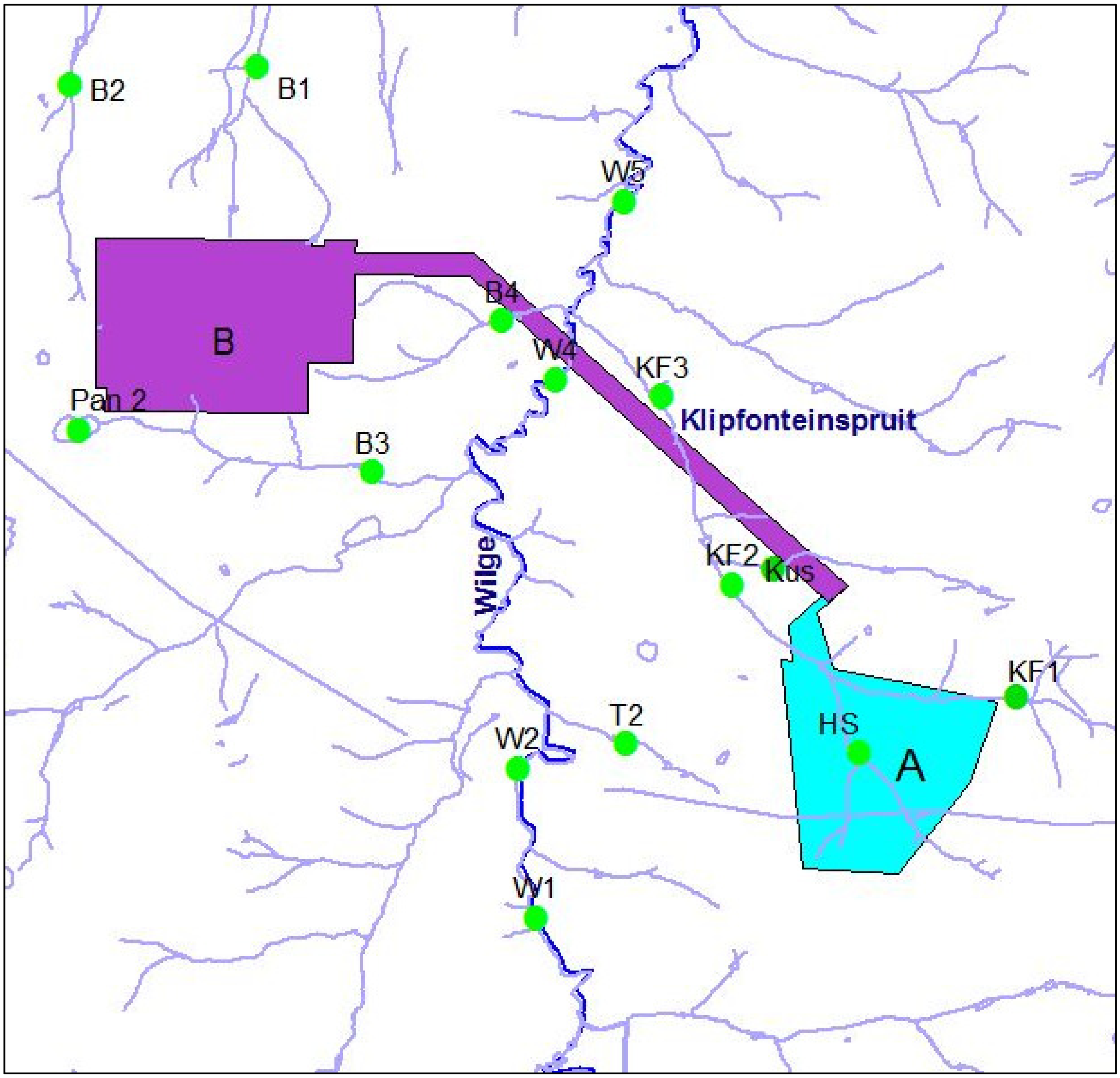

Figure 4-3. Aquatic sampling sites associated with alternatives A and B for the proposed Kusile Ash Disposal Facility.

5. APPROACH

5.1 Fish

Fish are used as indicators of river condition as they are relatively long-lived and mobile, and indicate long-term influences and general habitat conditions, integrate effects of lower trophic levels and are consumed by humans (Uys et al., 1996). Fish samples were collected using a battery operated electro-fishing device (Smith-Root LR24). This method relies on an immersed anode and cathode to temporarily stun fish in the water column; the stunned fish can then be scooped out of the water with a net for identification. The responses of fish to electricity are determined largely by the type of electrical current and its wave form. These responses include avoidance, electrotaxis (forced swimming), electrotetanus (muscle contraction), electronarcosis (muscle relaxation or stunning) and death (USGS, 2004). Electrofishing is regarded as the most effective single method for sampling fish communities in wadeable streams (Plafkin et al., 1989).

All fish were identified in the field using the guide Freshwater Fishes of Southern Africa (Skelton, 2001). Reference specimens were preserved for laboratory confirmation of field identifications and the remainder of the fish released at the point of capture.

Expected fish species list based on a desktop review of available literature and expected species list was compiled for the Kusile ash dump project (Kleynhans et al., 2007). Based on this assessment, a total of 10 indigenous fish species are expected to occur within the area (7 to 10 indigenous species per site), although some of the smaller "AD" sites may only expect to have a total of 4 indigenous fish species occurring (Table 5-1). In addition the introduced species *Cyprinus carpio* (Carp), *Gambusia affinis* (Mosquito fish) and *Micropterus salmoides* (Largemouth Bass) are also expected to occur in the area (Table 5-1).

Table 5-1. Fish species expected to occur in the Kusile project area (IUCN, 2011 and Kleynhans, 1999).

Species	Common Name	IUCN Status	Intolerance Rating
Barbus anoplus	Chubbyhead barb	Least Concern	2.6
Barbus paludinosus	Straightfin barb	Least Concern	1.8
Barbus trimaculatus	Threespot barb	Least Concern	2.2
**Cyprinus carpio*	Carp (Exotic)	Vulnerable	1.4
Chiloglanis pretoriae	Shortspine Suckermouth	Least Concern	4.6
Clarias gariepinus	Sharptooth catfish	Unlisted	1.2
**Gambusia affinis*	Mosquito fish (Exotic)	Unlisted	2.0
Labeo cylindricus	Redeye labeo	Least Concern	3.1
Labeobarbus marequensis	Lowveld Largescale yellow	Least Concern	2.6
Labeobarbus polylepis	Bushveld Smallscale yellowfish	Least Concern	3.1
**Micropterus salmoides*	Largemouth Bass (Exotic)	Unlisted	2.2
Pseudocrenilabrus philander	Southern mouthbrooder	Unlisted	1.3
Tilapia sparrmanii	Banded tilapia	Least Concern	1.3

**Red highlighted species are those that are classed as exotic in South Africa.*

In order to assess the Red Data Book status of the expected fish assemblage, the IUCN Red List of Threatened Species was consulted (IUCN, 2012). The result of the IUCN Red List assessment is presented in Table 5-1. Of the 13 fish species expected to occur in the sampling area:

- Four are currently unlisted on the IUCN Red List of which two of them are exotic in South Africa;
- Eight are currently listed as Least Concern (LC) on the IUCN Red List. Species in this category are considered to be widespread and abundant (IUCN, 2012); and
- One is Vulnerable (V) on the IUCN Red List although *Cyprinus carpio* is classed as an exotic species in South Africa.

Based on the IUCN Red List no rare threatened or endangered fish species are expected to occur in the project area.

5.1.1 Fish Assemblage Integrity Index (FAII)

The Fish Assemblage Integrity Index (FAII) was applied to sites associated with the Kusile ash dump alternatives. The FAII index uses the diversity and composition of fish populations, their relative tolerance/intolerance to disturbance, frequency of occurrence and health, to assess biotic integrity. This index measures the current integrity of the fish community relative to what is derived to have been present under natural/unimpaired conditions. The integrity of the fish assemblages is considered to provide a perspective on the broad biological integrity status of a river/stream.

Procedures used in the application of the FAII are described below:

Species Intolerance Ratings

Intolerance refers to the degree to which an indigenous species is unable to withstand changes in the environmental conditions at which it occurs (Kleynhans, 1999). Four components were considered in estimating the intolerance of fish species, i.e. habitat preferences and specialization (HS), food preferences and specialisation (TS), requirement for flowing water during different life stages (FW) and association with habitats with unmodified water quality (WQ). Each of these aspects was scored for a species according to low requirements/specialization (rating = 1), moderate requirement/specialization (rating = 3) and high requirement/specialization (rating = 5) (Table 5-2). The total intolerance (IT) of fish species is estimated as follows:

$$IT = (HS + TS + FW + WQ)/4$$

Table 5-2. Species intolerance ratings

Score	Class
1 - 1.9	Tolerant
>2 - 2.9	Moderately Tolerant
>3 - 3.9	Moderately Intolerant
>4 - 5.0	Intolerant

The expected fish species were ranked into classes based on their intolerance rating (Table 5-2). Based on that assessment, one intolerant species, *Chiloglanis pretoriae* may potentially occur

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within the area (Table 5-1). The presence of the *Chiloglanis pretoriae* in the Wilge River is of significance as it is an indicator of good water quality and habitat integrity. It is thought that the *C. pretoriae* fish population in the Wilge River represents one of the few remaining populations in the upper Olifants River catchment.

5.1.2 Fish Health Assessment

The assessment is conducted in such a way as to derive numeric values, which reflect the status of fish health. The percentage of fish with externally evident disease or other anomalies was used in the scoring of this metric (Kleynhans, 1999; Kilian et al., 1997). The following procedures were followed to score the health of individual species at site:

- Frequency of affected fish >5%. Score = 1;
- Frequency of affected fish 2 – 5%. Score = 3; and
- Frequency of affected fish < 2%. Score = 5.

This approach is based in the principle that even under unimpaired conditions a small percentage of individuals can be expected to exhibit some anomalies (Kleynhans, 1999).

5.1.3 Calculation of FAII Score:

The FAII consists of the calculation of an expected value, which serves as the baseline or reference, the calculation of an observed value and the comparison of the expected and observed scores that provide a relative FAII score. The expected FAII rating for a fish habitat segment is calculated as follows (Kleynhans, 1999):

FAII value (Exp) = SIT x ((F + H)/2)

Where:

- Exp = expected for a fish segment;
- IT = Intolerance rating for individual species expected to be present in a fish habitat segment and in habitats that were sampled; and
- H = Expected health rating for a species expected to be present.

The observed observation is calculated on a similar basis, but is based on information collected during the
survey:

FAII value (Obs) = SIT x ((F + H)/2)

Where:

Obs: = observed for a fish habitat segment

The relative FAII score is calculated by:

Relative FAII score = FAII value (Obs)/FAII value (exp) x 100

Interpretation of the relative FAII values is based on the habitat integrity classes of Kleynhans (1996) (Table 5-3).

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Table 5-3: Descriptive categories used to describe the present ecological status (PES) of biotic components (adapted from Kleynhans, 1999).

CATEGORY	BIOTIC INTEGRITY	DESCRIPTION OF GENERALLY EXPECTED CONDITIONS
A	Excellent	Unmodified, or approximates natural conditions closely. The biotic assemblages compares to that expected under natural, unperturbed conditions.
B	Good	Largely natural with few modifications. A change in community characteristics may have taken place but species richness and presence of intolerant species indicate little modifications. Most aspects of the biotic assemblage as expected under natural unperturbed conditions.
C	Fair	Moderately modified. A lower than expected species richness and presence of most intolerant species. Most of the characteristics of the biotic assemblages have been moderately modified from its naturally expected condition. Some impairment of health may be evident at the lower end of this class.
D	Poor	Largely modified. A clearly lower than expected species richness and absence or much lowered presence of intolerant and moderately intolerant species. Most characteristics of the biotic assemblages have been largely modified from its naturally expected condition. Impairment of health may become evident at the lower end of this class.
E	Very Poor	Seriously modified. A strikingly lower than expected species richness and general absence of intolerant and moderately tolerant species. Most of the characteristics of the biotic assemblages have been seriously modified from its naturally expected condition. Impairment of health may become very evident.
F	Critical	Critically modified. Extremely lowered species richness and an absence of intolerant and moderately tolerant species. Only intolerant species may be present with complete loss of species at the lower end of the class. Most of the characteristics of the biotic assemblages have been critically modified from its naturally expected conditions. Impairment of health generally very evident.

It must be emphasised that the A→F scale represents a continuum, and that the boundaries between categories are notional, artificially-defined points along the continuum (as presented below). This situation falls within the concept of a fuzzy boundary, where a particular entity may

potentially have membership of both classes (Robertson *et al*. 2004). These boundary categories are denoted as B/C, C/D, etc.

5.2 Aquatic Macroinvertebrates

Aquatic macroinvertebrates were assessed using the SASS 5 (South African Scoring System) methodology. SASS5 is based on the presence or absence of sensitive aquatic macroinvertebrates collected and analysed according to the methods outlined in Dickens and Graham (2002). A high relative abundance and diversity of sensitive taxa present indicates a relatively healthy system with good water quality. Disturbance to water quality and habitat results in the loss of sensitive taxa. As this method was developed specifically for rivers, the methods of collection and analysis were modified for wetlands and pans, where relevant.

Two methods were used to classify the PES of sites based on aquatic macroinvertebrates. Sites that were considered to be channelized wetlands, therefore having few stone biotopes, were classified according to the guidelines given in Dallas (2007), which is based on modelled data from the ecoregion.

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The PES of the Wilge River sites was additionally assessed using MIRAI (Macroinvertebrate Response Assessment Index) which classifies the PES of a site according to a comparison between expected and observed taxa, as obtained from the SASS5 results, and takes into account habitat diversity, suitability and/or availability, flow conditions as well as water quality.

Table 5-3 summarises the categories used to classify sites according to both aquatic macroinvertebrates and fish.

5.3 Water Quality

- *Water quality*: Analysis of major anions and cations, conductivity, TDS, pH and temperature. These were interpreted in terms of ecological responses only. ICP-OES scans for metals were also completed to provide baseline levels against future monitoring can be compared.

- *Diatoms*: Diatoms provide a rapid response to specific physico-chemical conditions in aquatic ecosystems and are often the first indication of change. The presence or absence of indicator taxa can be used to detect specific changes in environmental conditions such as eutrophication, organic enrichment, salinisation and changes in pH. Diatom slides were prepared by acid oxidation using hydrochloric acid and potassium permanganate. Clean diatom frustules were mounted onto a glass slide ready for analysis. Taxa were identified mainly according to standard floras (Krammer & Lange- Bertalot, 2000). The aim of the data analysis was to identify and count diatom valves (400 counts) to produce semi-quantitative data from which ecological conclusions can be drawn.

5.4 Habitat Integrity

The Index of Habitat Integrity (IHI) was used to determine habitat condition. This approach is based on the assessment of physical habitat disturbance (Kleynhans, 1997) and classifies the present ecological state of instream and riparian habitat integrity according to the categories given in Table 5-3, ranging from pristine/undisturbed to critically modified. The following disturbances were considered:

- Water abstraction,
- Flow modification,
- Bed modification,
- Channel modification,
- Inundation,
- Exotic macrophytes,
- Solid waste disposal,
- Indigenous vegetation removal,
- Exotic vegetation encroachment and
- Bank erosion.

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6. AQUATIC ECOSYSTEM ASSESSMENT

6.1 Water Quality

Water quality results were interpreted in terms of ecosystem requirements only. A full water quality assessment is given in the surface water report. The pH and temperature measured at all sites fell within guideline limits and were not considered limiting to the biota. The water quality results are summarised in Table 6-1 and discussed below.

Water draining Alternative B was of a good quality. Artesian springs flow into the headwaters of the four streams flowing away from the site. Landowners report that these springs flow perennially. Salinity was exceptionally low within these streams and the water is extensively utilised for agricultural activities (irrigation, livestock watering, poultry production) further downstream. The streams drain into the Bronkhorstspruit and Wilge Rivers.

The Wilge River had elevated salinity levels, particularly within the upper reaches (W2 and W3). In addition to calcium, sodium and chloride ions, indicative of agricultural return flows and/or mining activities, relatively high concentrations of sulphate ions, were recorded. Where sulphate concentrations greatly exceed chloride concentrations, contamination is usually indicated, including contamination from mining activities. Sulphate levels were far lower further downstream at sites W4 and W5.

Salinity and sulphate levels were also relatively high within the Klipfonteinspruit at site KF2, while high concentrations of elemental Sulphur were also recorded. Elevated levels of boron and calcium were also recorded. Subsequent monitoring at site KF2 yielded an acidic pH of 3.25, strongly suggesting periodical contamination from acid mine drainage.

Oxidised sulphides produce sulphates and sulphuric acid, which in turn may increase the solubility of metals and other substances (under acidic conditions). Under anaerobic conditions sulphate ions are reduced by bacteria to hydrogen sulphide, which is highly toxic (Dallas and Day 1993). The upper limit for sulphate levels stipulated by the DWAF guidelines for domestic use (DWAF 1996) is 300mg/l. No guidelines are available in South Africa for aquatic ecosystems.

The pH and temperature measured at all sites fell within guideline limits for aquatic ecosystems (DWAF 1996) and were not considered limiting to the biota.

The effects of increased salinities are difficult to predict but usually involve a change in community patterns as sensitive species are lost and tolerant species increase. An increase in salinity tends to improve the clarity of water, with consequent implications for increased algal production (associated with lower dissolved oxygen concentrations during the day) and algal species composition. Salinity levels exceeding 250mg/ℓ can change the algal species composition (Chutter and Walmsley 1994). Freshwater invertebrates are generally tolerant of elevated salinities of up to about 1000 mg/ℓ, providing the changes are not sudden (Chutter and Walmsley 1994). Likewise, fish are generally tolerant of salinities of up to 750mg/ℓ, although juveniles and eggs are significantly more sensitive (Chutter and Walmsley 1994).

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The DWAF Water Quality Guidelines for Aquatic Ecosystems (1996) states that the site-specific TDS concentrations should not vary by more than 15% of the normal (undisturbed) cycle to avoid disruption of osmotic/physiological processes, or of ecosystem processes and structures. Therefore, although salinities are elevated at certain sites, they remained within guideline limits (DWAF 1996). However, they do suggest impacts due to human activities within the upper Wilge River and the lower reaches of the Klipfonteinspruit.

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Table 6-1. Water quality measurements at Kusile sampling sites. Cells highlighted in orange indicate elevated levels relative to the other sites. (Variables with concentrations below detection limits are not shown and no comparisons were made with guideline limits.) A full surface water quality analysis is given in the surface water report.

	Wilge River Sites				Wilge River Tributaries							Bronkhorstspruit Tributaries		Seasonal Pans	
	W2	W3	W4	W5	T1	T2	HS	KF2	KF3	T4	B4	B1	B2	Pan F	Pan B
pH – Value at 25°C	7.7	7.7	7.8	7.9	7.7	7.3	7.4	7.5	7.7	7.6	7.3	7.2	6.5	8.2	9.2
Electrical Conductivity in mS/m at 25°C	35.2	35.9	19.2	30.1	18.4	14	7.1	25.6	16.4	11.9	12	8.9	6.5	159	32.2
Total Dissolved Solids	200	211	102	173	107	85	49	160	84	65	61	45	33	974	176
Total Alkalinity as $CaCO_3$	100	112	84	124	84	68	44	56	80	48	60	24	24	656	108
Chloride as Cl	15	15	7	12	10	6	<5	5	<5	<5	<5	8	6	140	39
Sulphate as SO_4	58	59	11	31	13	11	7	69	6	12	<5	6	<5	61	<5
Fluoride as F	0.5	0.5	0.3	0.4	0.4	0.2	0.3	0.3	0.3	0.3	<0.2	<0.2	<0.2	3.5	0.8
Nitrate as N	0.6	0.6	<0.2	0.2	<0.2	<0.2	<0.2	1.6	<0.2	0.7	<0.2	<0.2	<0.2	1.2	<0.2
Nitrite as N	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Free & Saline Ammonia as N	<0.2	<0.2	<0.2	0.2	<0.2	<0.2	<0.2	<0.2	0.2	<0.2	0.2	0.2	0.2	<0.2	0.2

	W2	W3	W4	W5	T1	T2	HS	KF2	KF3	T4	B4	B1	B2	Pan F	Pan B
Al	<0.100	0.100	0.105	0.110	<0.100	0.205	0.598	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	1.77	<0.100
B	0.027	0.027	<0.025	<0.025	<0.025	<0.025	<0.025	0.038	0.026	<0.025	<0.025	<0.025	<0.025	0.057	<0.025
Ba	0.055	0.063	0.039	0.053	0.040	0.054	0.036	0.044	0.047	0.042	0.037	0.026	0.031	0.079	0.042
Ca	21	21	13	19	11	8	4	25	15	8	13	6	4	10	13
Fe	0.073	0.055	0.168	0.073	0.062	0.801	0.642	0.045	0.034	0.099	0.037	0.304	1.01	3.94	0.683
K	4.6	4.7	3.1	3.7	3.6	2.5	<1.0	2.1	2.1	1.7	1.5	<1.0	3.2	22	14.4
Mg	14	16	11	14	7	7	2	7	6	4	7	3	4	4	8
Mn	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0.045	<0.025
Na	25	25	6	18	11	7	6	10	7	8	13	2	5	336	33
P	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	1.03	<0.025
S	22	25	4.05	11	6.25	4.94	3.12	28	5.4	3.19	<0.1	0.244	3.06	17	1.35
Si	2.6	3.1	3.6	4.2	2.1	2.9	2.1	4.0	2.8	4.3	2.5	3.2	2.2	7.4	0.5
Sn	<0.025	<0.025	<0.025	<0.025	0.057	0.040	0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0.046	<0.025
Sr	0.192	0.141	0.086	0.117	0.065	0.047	0.037	0.142	0.071	0.045	0.083	<0.025	0.025	0.076	0.083

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6.2 Diatoms

Appendix A displays a list of diatom species and abundances recorded for each of the Kusile sites. There were insufficient cell counts at site KF3 and therefore any conclusions on water quality based on diatom communities could not be formulated for this site. Presence of any valves at site KF3 were identified and included in Appendix A.

6.2.1 Flowing systems

Diatoms were sampled within moderate flowing waters at these sites, hence the use of the diatom software package, OMNIDIA to infer water quality conditions. Index values were calculated in OMNIDIA for epiphytic diatom data (i.e. diatoms attached to submerged vegetation) and epilithon data (attached to rocks) (Lecointe et al. 1993). In general, each diatom species used in the calculation of the index is assigned two values; the first value reflects the tolerance or affinity of the particular diatom species to a certain water quality (good or bad) while the second value indicates how strong (or weak) the relationship is. These values are then weighted by the abundance of the particular diatom species in the sample. The general water quality indices (integrating impacts from organic material, electrolytes, pH and nutrients), used in the assessment, are:

- the Specific Pollution sensitivity Index (SPI), one of the most extensively tested indices in Europe; and
- the percentage of (organic) pollution tolerant valves (%PTV)

The interpretation of the SPI scores applied in this study is displayed in Table 6-2 and the SPI scores and classification for each site are shown in Table 6-3. A list of the dominant species occurring at each site, expressed as a percentage of the total sample is shown in Table 6-4.

Table 6-2. Class limit boundaries for the Specific Pollution sensitivity Index (SPI) (Koekemoer and Taylor, 2011).

SPI Score	Class	Ecological Category
>17.3	High quality	A
16.8-17.2		A/B
13.3-16.7	Good quality	B
12.9-13.2		B/C
9.2-12.8	Moderate quality	C
8.9-9.1		C/D
5.3-8.8	Poor quality	D
4.8-5.2		D/E
<4.8	Bad quality	E

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Table 6-3. Specific Pollution sensitivity Index (SPI) score classification for Kusile sites with flowing water in January 2013.

Site	Specific Pollution Sensitivity Index (SPI)	Pollution Tolerant Valves (%PTV)	Class	Ecological Category
W2	12.5	18.3	Moderate Quality	C
W3	11	22	Moderate Quality	C
W4	12.1	14	Moderate Quality	C
W5	12.4	18.5	Moderate Quality	C
T1	13.7	18.8	Good Quality	B
KF2	5.7	52.5	Poor Quality	D
KF1	13.5	7.5	Good Quality	B
Kus	8.8	26	Poor Quality	D
B4	13.6	22.3	Good Quality	B

- The ecological water quality for all Wilge River sites are of a **category C (Moderate quality)** with a reasonably low %PTV (range, 14-22%, Table 6-3) implying that these sites have a small amount of organic content. Species found at these sites such as *Gomphonema minutum, Diploneis elliptica* and *Encyonema minutum* occur in waters with moderate electrolyte content and are not tolerant to more than moderate levels of pollution.

- Recorded at sites W2, W4 and W5 is taxon *Cocconeis placentula* (significantly more at site W4) indicative of nutrient enrichment which may be a result of agricultural inputs from fertilisers or runoff from livestock feedlots. W4 lies adjacent to Toppigs piggery.

- Tributaries T1, B4 and the upper reaches of the Klipfonteinspruit at KF1 fall into a **category B (Good quality)**. This is reflected by the high abundance of taxon *Achnanthes minutissima* (Table 6-4) which is generally found in well oxygenated, clean, freshwaters (Slàdecek, 1986; Leclercq and Maquet, 1987; Prygiel and Coste, 2000). [It should be noted that there are certain discrepancies surrounding the ecology of these taxa (Deniseger et al., 1986; Genter et al., 1987; Medley and Clements, 1998; Ivorra et al., 1999, Gold et al., 2002, 2003, Cattaneo et al., 2004, Ferreira da Silva et al., 2009). However, surrounding landuse points to unpolluted systems.]

- Other species present at site KF1 such as species of the *Eunotia* genus and *Navicula heimansioides*, generally found in weakly acidic to circumneutral, oligotrophic, electrolyte poor waters may imply that the water quality is in fact in good condition.

- Sites KF2 (Klipfonteinspruit downstream of the Kusile Road) and Kus (the Kusile power station tributary) are of an ecological **category D (Poor quality).** This is largely a result of dominant taxon *Nitzschia palea*, (significantly more at site KF2), a species often associated with elevated nutrients and electrolytes as a result of fertiliser runoff impacting the system. However at site Kus is sub-dominant taxon *Gomphonema parvulum* which is also contributing towards a low SPI score of 8.8. This species is associated with organic inputs.

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Table 6-4. List of dominant diatom species occurring at the Kusile sites, expressed as a percentage of the total sample.

Taxa	% of total sample													
	W2	W3	W4	W5	T1	T2	KF1	KF2	T4	HS	Kus	B2	B1	B4
ACHNANTHIDIUM F.T. Kützing	7	6												
Achnanthidium biasolettianum Lange-Bertalot	19													
Achnanthidium eutrophilum Lange-Bertalot	7													
Achnanthidium macrocephalum(Hust.)Round & Bukhtiyaro.														5
Achnanthes minutissima Kützing v.minutissima					46	11	69	7	81	24	14.5		6	19.5
Achnanthidium saprophilum (Kobayasi et Mayama)								8			24			
AULACOSEIRA G.H.K. Thwaites						5								
Brachysira neoexilis Lange-Bertalot										5				
Cocconeis placentula Ehrenberg var. placentula	21		139	21										
Cymbella turgidula Grunow 1875 in A.Schmidt				4.5										
Cymbopleura naviculiformis (Auerswald) Krammer										6.5				
Eolimna minima(Grunow) Lange-Bertalot													6	
Encyonema minutum (Hilse in Rabh.) D.G. Mann		4.75			4.75						6.5			
Eunotia bilunaris (Ehr.) Mills var. bilunaris												12		
Eunotia minor (Kützing) Grunow in Van Heurck										9		8		
Gomphonema angustatum (Kützing) Rabenhorst						4.5								
Gomphonema exilissimum(Lange-Bertalot & Reichardt						6							10	
Gomphonema lagenula Kützing										10				
Gomphonema minutum(Ag.)Agardh f. minutum	12	8	11	16	19								5	
Gomphonema parvulum (Kützing) Kützing				12	15						5.5		6.5	
Gomphonema parvulius Lange-Bertalot & Reichardt						5.25							27.5	
Navicula capitatoradiata Germain		5.5		5.75										
Navicula heimansioides Lange-Bertalot										10.5		10		
Navicula symmetrica Patrick											5			
Navicula vandamii Schoeman & Archibald var. vandamii														10.5
Nitzschia dissipata(Kützing)Grunow var.dissipata														5
Nitzschia liebetruthii Rabenhorst var.liebetruthii								6						
Nitzschia linearis(Agardh) W.M.Smith var.subtilis(Grunow)														9
Nitzschia palea (Kützing) W.Smith	5					4.75		33.5			14			6
Planothidium frequentissimum(Lange-Bertalot)													5.5	
Reimeria uniseriata Sala Guerrero & Ferrario				4.5										
Sellaphora pupula (Kützing) Mereschkowksy						6								

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6.2.2 Standing water and slow-flowing streams

The diatom software programme OMNIDIA is a tool to assess the health of moderate flowing waters and is not applicable to slow flowing waters as was found at sites T2, HS, B1, B2 and T4. Analyses of diatoms were therefore based on measures of relative abundance and species composition (i.e. assemblage patterns) to infer baseline water quality conditions at these sites.

To further determine water quality based on diatom composition at these sites, diatoms assemblages collected from 259 sites throughout the Highveld were included in a cluster analysis to provide a more reliable inference of water quality.

Diatom assemblage patterns at these sites suggest that these sites had relatively good water quality. The following observations were made:

- Overall, the diatom assemblages for sites T2, HS, B1, B2 and T4 suggest relatively good water quality as reflected by dominant taxon *Achnanthes minutissima* (significantly more at site T4). [It should be noted that there are certain discrepancies surrounding the ecology of these taxa (Deniseger et al., 1986; Genter et al., 1987; Medley and Clements, 1998; Ivorra et al., 1999, Gold et al., 2002, 2003, Cattaneo et al., 2004, Ferreira da Silva et al., 2009). However, surrounding landuse points to unpolluted systems.]

- Other species recorded at sites T2, B1 and HS such as *Gomphonema exilissimum*, *Nitzschia fonticola* and *Gomphonema parvulius* are often associated with clean, electrolyte-poor waters which may signify that the water quality is in good condition at these sites and can be categorised as a **category B (Good quality).**

- At site T2 and B1 the presence of *Nitzschia palea* may point to slight nutrient and electrolyte enrichment from agricultural activities.

- Site B3 is dominated by taxon *Navicula heimansioides* and species of the *Eunotia* group, taxa generally found in good quality, mildly acidic, electrolyte-poor, slow flowing waters. For this reason the water quality at this site can be assigned an ecological **category B (Good quality).**

- Cluster analysis of sites T2, HS and T4 along with 259 sites across the Highveld revealed the following:
  - Site T2 was closely related to a fairly fresh, seasonal pan with moderate electrolyte content and generally good water quality.
  - Site HS and T4 was closely grouped with a clean, freshwater, slow flowing channel in generally good condition.

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6.3 Habitat Integrity

6.3.1 Wilge River

The instream and riparian habitat integrity of the Wilge River was considered Moderately to Largely Modified (PES C/D) (Table 6-5, Figure 6-1). Most impacts related to agricultural activities higher up in the catchment and included changes in flow regime and bank erosion (stemming from irrigation, impoundments, road crossings and abstraction) and decline in water quality (resulting from agricultural return-flows and nutrient-enriched runoff). Alien trees, such as *Populus* spp, *Acacia mearnsii, Melia azedarach and Salix babylonica,* have resulted in moderate to serious modifications of riparian habitats.

6.3.1 Wilge River tributaries

The tributaries draining westward into the Wilge River were, for the most part, highly modified in terms of riparian habitats (Table 6-5, Figure 6-2). This was mostly as a result of erosion downstream of farm dams and road crossings. In addition, high volumes and velocities of water enters the Klipfonteinspruit from the Kusile Power Station, causing massive erosion of the channel and seriously compromising water quality (i.e. high turbidity and suspended solids) and habitat integrity (erosion of banks, substrate modification and absence of marginal vegetation). The upper reaches of the Klipfonteinspruit (KF1) were still relatively intact (PES C) but reaches downstream of the Kusile Road deteriorate steadily down to a PES category of E (Seriously Modified) as the stream approaches the Wilge River.

6.3.1 Klipfonteinspruit tributaries

The Holspruit was considered largely intact in terms of aquatic habitat integrity, with a PES of Largely Natural to Moderately Modified (B/C) (Table 6-5, Figure 6.3). However, the tributary that drains eastwards from the Power Station into the Klipfonteinspruit is so badly eroded that it essentially functions as a canal. Marginal habitats have been critically compromised and the water is highly turbid with high sediment loads. High turbidity affects visual predators, such as fish and dragonflies. This tributary was considered to have a PES category of E (Seriously Modified).

6.3.1 Alternative B tributaries

The tributaries draining away from Alternative B were all considered to be Moderately Modified (PES C) in terms of habitats (Table 6-5, Figure 6-4). The main impacts were due to the construction of farms dams which altered flows (decreased volumes but increased velocities) and caused erosion of beds and banks.

6.3.1 Seasonal Pans

The habitat integrity of the seasonal pans (Figure 6-5) was assessed as part of the Wetland Assessment Report.

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Figure 6-1. Wilge River aquatic sampling sites. Rows 1: W1 and W2, Row 2: W3 and W4, Row 3: W5

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Figure 6-2. Aquatic sampling sites along Wilge River tributaries. Row 1: Sites T1 and T2, Row 2: Row 3: KF1 and KF2, Row 4: KF3 and T4

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Figure 6-3. Sampling sites along the Klipfonteinspruit tributaries: Holspruit (site HS) (top row) and the Kusile tributary (site KUS) which drains away from the Kusile Power Station (bottom row).

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Figure 6-4. Aquatic sampling sites within tributaries draining away from Alternative B: Sites B1 and B2 (top row) and sites B3 and B4 (bottom row)

Figure 6-5. Seasonal Pans within Alternative F and adjacent to Alternative B.

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Table 6-5. Index of Habitat Integrity Assessment for the Kusile Ash Disposal Facility project.

Scoring:	NONE	SMALL	MODERATE	LARGE	SERIOUS	CRITICAL										
	(0)	(1-5)	(6-10)	(11-15)	(16-20)	(21-25)										
INSTREAM HABITAT INTEGRITY	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**T1**	**KF1**	**KF2**	**KF3**	**T4**	**B4**	**HS**	**Kus**	**B1**	**B2**
WATER ABSTRACTION	12	12	14	14	14	13	11	5	6	12	8	13	5	0	8	10
FLOW MODIFICATION	7	12	8	10	9	8	14	9	16	21	12	15	11	21	15	11
BED MODIFICATION	8	8	12	5	5	4	8	5	12	13	9	9	8	20	11	9
CHANNEL MODIFICATION	8	9	9	9	4	7	13	9	13	20	11	19	12	21	14	11
WATER QUALITY	13	12	11	11	7	7	4	3	5	1	5	2	1	7	2	4
INUNDATION	2	4	2	0	3	0	0	0	0	0	0	0	0	0	0	0
EXOTIC MACROPHYTES	6	7	8	8	9	7	1	14	3	2	2	3	2	2	2	2
EXOTIC FAUNA	5	5	5	5	3	3	0	0	0	0	0	2	0	0	2	0
RUBBISH DUMPING	2	1	2	1	1	1	0	0	2	0	0	1	0	0	0	1
INSTREAM HABITAT INTEGRITY SCORE	62	56	56	62	70	71	64	79	59	44	69	55	73	41	64	69
INSTREAM INTEGRITY CLASS	C	D	D	C	C	C	C	C	D	D	C	D	C	D/E	C	C
RIPARIAN HABITAT INTEGRITY	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**T1**	**KF1**	**KF2**	**KF3**	**T4**	**B4**	**HS**	**Kus**	**B1**	**B2**
VEGETATION REMOVAL	3	7	5	9	7	5	3	2	2	2	1	0	0	2	5	0
EXOTIC VEGETATION	5	7	12	12	11	9	5	15	4	4	3	5	2	3	7	6
BANK EROSION	8	12	11	9	9	8	19	11	11	16	8	7	8	22	9	4
CHANNEL MODIFICATION	7	12	8	8	7	6	17	11	12	14	7	8	7	21	9	10
WATER ABSTRACTION	5	4	6	6	9	8	8	3	3	2	5	6	5	0	5	5
INUNDATION	2	9	0	0	5	0	0	0	0	0	0	0	0	0	0	0
FLOW MODIFICATION	2	8	5	8	7	5	9	7	15	21	8	5	5	19	9	2
WATER QUALITY	1	2	2	2	2	2	2	1	1	1	3	1	1	7	1	1
RIPARIAN ZONE HABITAT INTEGRITY SCORE	83	55	59	66	65	78	43	51	51	34	82	84	86	22	77	86
RIPARIAN INTEGRITY CLASS	B	D	D	C	C	C	D	D	D	E	B	B	B	E	C	B
	W1	**W2**	**W3**	**W4**	**W5**	**W6**	**T1**	**KF1**	**KF2**	**KF3**	**T4**	**B4**	**HS**	**Kus**	**B1**	**B2**
AVERAGE PES SCORE	73	55	58	64	67	75	54	65	55	39	76	69	80	31	70	78
OVERALL INTEGRITY CLASS	C	D	D	C	C	C	D	C	D	E	C	C	B/C	E	C	C

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6.4 Fish

6.4.1 Observed Fish Species List

Six of the 10 expected indigenous fish species were recorded in the project area during the December 2012 survey (0 to 4 species per site) (Table 6-6). In addition, three exotic species namely *Cyprinus carpio* (Carp), *Gambusia affinis* (Mosquito fish) and *Micropterus salmoides* (Largemouth Bass) were recorded at sites KF2, W1, W3, W4 and B1 (Table 6-6). The highest combined fish abundance (n = 41) was recorded at the Holspruit site (HS), of which more than half of the fish recorded were *Barbus anoplus* (Chubbyhead Barb). No fish were recorded at sites KUS and B4. This may be attributed to high turbidity, limited habitat availability and limited flow conditions at these sites. At site B2, four adult *B. anoplus* were recorded, coupled with a large quantity (155) of juvenile fish believed to be *B. anoplus* but too small to positively identify. Overall, *B. anoplus* was the most abundant species throughout the project area, with 85 individuals being sampled (Table 6-6). *B. trimaculatus* (Threespot barb), *Clarias gariepinus* (Sharptooth catfish), *Labeo cylindricus* (Redeye labeo) and *Labeobarbus polylepis* (Bushveld smallscale yellowfish) were not recorded during the December 2012 survey (Table 6-6). *Chiloglanis pretoriae* was recorded at sites KUS13, KUS16 and KUS18, with 24 individuals recorded at site KUS18 (Table 6-6). *C. pretoriae* is considered to be a useful indicator species in studies on river conservation (Skelton, 2001).

Table 6-6. Fish species observed in the Kusile Project Area - December 2012. (Site B3 was not sampled for fish as it was dry at the time of sampling.)

SITE	*Barbus anoplus*	*Barbus paludinosus*	*Barbus trimaculatus*	*Cyprinus carpio*	*Chiloglanis pretoriae*	*Clarias gariepinus*	*Gambusia affinis*	*Labeo cylindricus*	*Labeobarbus marequensis*	*Labeobarbus polylepis*	*Micropterus salmoides*	*Pseudocrenilabrus philander*	*Tilapia sparrmanii*	*Diversity*	*Abundance*
B1											2			1	3
B2	4													1	5
B3														Not sampled	
B4														0	0
T1	13											4		2	19
KF1	5													1	6
KF2	7													1	8
KF3		2					1							2	5
T4	8	19											2	3	32
HS	24											17		2	43
Kus														0	0
W1	20			1								16		3	40
W3	4			1	1							1		4	11
W4				1	24				4				3	4	36
W6		5			5				6					3	19
Total	**85**	**26**		**3**	**30**		**1**		**10**		**2**	**38**	**5**		

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6.4.2 Presence of Red Data Species

No red data species were recorded during the December 2012 survey.

6.4.3 Fish Health Assessment

The majority of the individuals sampled at sites T1 and W3, showed signs of abnormalities and heavy parasite loads during the December 212 survey (Figure 6-6).

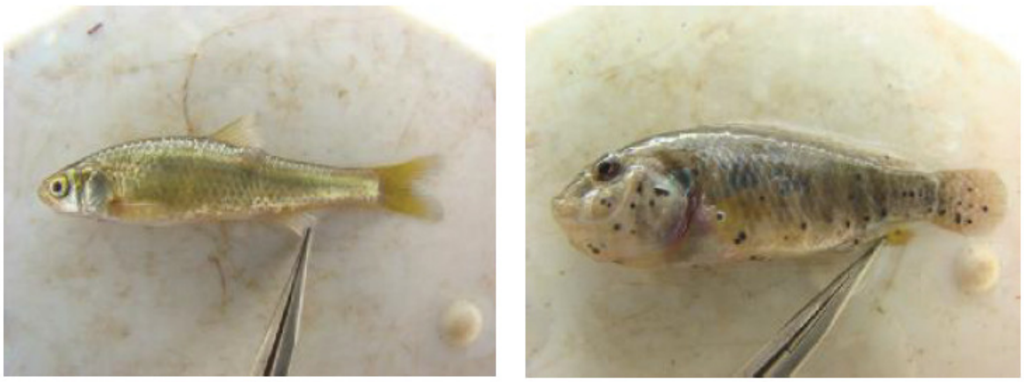

Figure 6-6: Signs of abnormalities on *B. anoplus* at T1(left) and *P. philander* at W3 (right).

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6.4.4 Fish Assemblage Integrity Index (FAII)

The interpretation of the FAII scores follows a descriptive procedure into which the FAII scores are allocated into particular classes (Table 6-7). The Present Ecological State (PES) classes for each of the sites are presented in Table 6-7.

Table 6-7. Present Ecological State (PES) Classes recorded during the December 2012 survey

SITE	Relative FAII Score	PES Class	Description
B1	0	F	Critically Modified
B2	10	F	Critically Modified
B4	0	F	Critically Modified
T1	19	F	Critically Modified
KF1	22	E	Seriously Modified
KF2	22	E	Seriously Modified
KF3	26	E	Seriously Modified
T4	33	E	Seriously Modified
HS	33	E	Seriously Modified
Kus	0	F	Critically Modified
W1	16	F	Critically Modified
W3	32	E	Seriously Modified
W4	34	E	Seriously Modified
W6	41	D	Largely Modified

Based on the FAII results, biotic integrity throughout the entire project area ranged from largely to critically modified (Table 6-7). The lowest FAII score was recorded at sites B4 and KUS where no fish were sampled, while at Site B1, only exotic species (*M. salmoides*) were recorded during the December 2012 survey (Table 6-6).

Based on the FAII results biotic integrity in the Wilge River increased in a downstream direction, with the highest FAII score (Class D) recorded at site W6 (Table 6-7). The lowest scores were recorded at the upstream site on the Wilge River (sites W1). W3 and W4 were classified as PES E (Seriously Modified for fish).

The reduced biotic integrity of the surrounding tributaries, particularly those that drain Alternative B, may be attributed to limited habitat availability and low flow conditions.

6.4.5 Historical FAII results

Between March 2011 and December 2012 the biotic integrity of the fish communities within the Wilge River and surrounding tributaries fluctuated from moderately to critically modified (Table 6-8). The greatest decline in biotic integrity was evident within the Kusile tributary (Kus) and within the upper reaches of the Wilge River (W1). Fish integrity does not seem to have recovered at either of these sites. W4 also showed a marked decline since 2011 but is showing signs of recovery in the current season.

Table 6-8: Historical FAII results. Shading progresses from lighter to darker to indicate PES gradient from Moderately Modified (PES C) to Critically Modified (PES F). No historical data exists for tributaries B1-4.

	Mar-11	Jun-11	Sep-11	Nov-11	Aug-12	Dec-12
T1	E	E	F	E	E	F
KF1	C	E	F	E	DRY	E
KF2	D	E	F	E	E	E
KF3	E	E	F	E	E	E
T4	C	E	E	E	E	E
HS	DRY	D	E	E	DRY	E
Kus	E	E	F	E	F	F
W1	E	F	F	F	F	F
W3	D	D	E	D	F	E
W4	F	C	C	C	F	E
W6	D	D	C	D	D	D

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6.5 Aquatic Macroinvertebrates

Summarised SASS5 data is shown in Table 6-9, with the full taxon list given in Appendix B. Interpretation of SASS5 results was based on modelled data for the Highveld Ecoregion as given in Dallas (2007). However, the reaches sampled fell either within the lower limits of the upper zone or the upper limits of the lower zone. For this reason the percentiles given for the combined data were considered to be most appropriate to categorise the PES (Present Ecological State) of sites, based on aquatic macroinvertebrates. Categories used were thus:

SASS5 Score	ASPT	Description	PES category
≥230	≥6.7	Pristine, unmodified	A
170 - 229	6.1 – 6.6	Largely Natural	B
131 - 169	5.5 – 6.0	Moderately Modified	C
82 - 130	4.8 – 5.4	Largely Modified	D
<82	<4.8	Seriously - Critically Modified	E - F

According to these guidelines, the Wilge River was considered Largely Natural to Moderately Modified for aquatic macroinvertebrates (PES B-C).

MIRAI was additionally used to classify the PES of Wilge River sites, based on aquatic macroinvertebrates. According to this method, the PES of all Wilge River sites fell within Category C, Moderately Modified. The highest scores were obtained at sites 1, 3 and 6, (72.5, 71.5 and 75.39) reflecting the good flow conditions and a range of suitable habitats available at these sites. Site 2 had a slightly lower score (70.8) due to apparent water quality impacts (fewer sensitive taxa than expected), while aquatic macroinvertebrate assemblages at site 5 reflected the altered flow conditions caused by a road crossing (score: 70.22).

The highest proportion of sensitive taxa was recorded from sites W1, W3 and W5, with ASPT exceeding 6.0 at W1 and W3. The greatest diversity of aquatic macroinvertebrates was recorded from sites W4 and W6. The following taxa that are sensitive to changes in water quality or habitat modifications were recorded:

- Atyidae (Freshwater Shrimps) – require moderate water quality and vegetation biotopes
- Baetidae (Mayflies) > 2 sp – require good water quality
- Heptageniidae (Flatheaded Mayflies) – require good water quality, moderately fast flow conditions and cobble substrates
- Tricorythidae (Stout Crawlers) – require very fast flow conditions, good water quality and cobble substrates
- Leptophlebiidae (Prongills) – require moderate water quality and cobble substrates
- Elmidae (Riffle Beetles) - require moderate water quality, very fast flow conditions and cobble substrates

The Holspruit (HS, draining Alternative A), tributary B4 (draining Alternative B) and tributary T4 (Alternative C) had ASPT of over 5.0 and were also considered Largely Natural to Moderately Modified (PES B – C). Sensitive taxa were particularly prevalent at Sites T4 and B4, these including Baetidae > 2 sp, Heptageniidae, Tricorythidae, Leptophlebiidae and Elmidae. Also

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present were dixid midges which have a preference for slow flow conditions and moderate water quality.

Tributary 1 (Alternative G) and the upper reaches of the Klipfonteinspruit (KF1) were considered to be Moderately to Largely Modified (PES C/D), with a lower ASPT, suggesting possible mining-related water quality impacts. However, KF1 was situated downstream of a black wattle grove and a farm dam, while T1 was situated downstream of a dam and the Kusile Road. These impacts may have impacted upon habitats at these sites, further reducing diversity. Sensitive tricorythid mayflies and dixid midges were present at T1, while ecnomid caddisflies and aeshnid dragonflies were present at KF1.

The Klipfonteinspruit downstream of the Kusile Road (KF2 and KF3), together with its tributary that drains away from Kusile Power Station, were considered to be Seriously Modified (PES E). The large volumes and velocities of highly turbid water carried by the Kusile stream are thought to have caused excessive erosion of the channel, thus seriously compromising the availability of suitable benthic and marginal habitats available to aquatic biota. The high sediment loads are also likely to have displaced sensitive taxa, in particular visual predators such as dragonflies and damselflies. Atyid shrimps and >2 species of mayfly were the only sensitive taxa recorded from Sites KF3 and KF 2 respectively. The Kusile stream has an extremely low diversity with a complete absence of sensitive taxa and was considered Critically Modified (PES F).

The two tributaries flowing northwards from Alternative B, into the Bronkhorstspruit, also had a low diversity with a low prevalence of sensitive taxa. However, as these sites occurred high up in the catchment with wetland features predominating, low flow conditions are expected and a low diversity does not necessarily reflect disturbance. Nevertheless, agricultural dams have impacted on habitats (as a result of erosion and accelerated flows downstream of the dam) and flow rates within both of these channels are expected to have had a minor effect on aquatic macroinvertebrates. A PES category of C – Moderately Modified for aquatic macroinvertebrates is probably most accurate.

6.5.1 Seasonal Pans

The SASS5 methodology is designed for flowing waters and was not applicable to aquatic invertebrates sampled from the two seasonal pans. Both pans are naturally saline and a large number of crustaceans that are specifically adapted to these highly variable saline conditions, as well as a seasonal hydrological regime, were sampled. These included ostracods, cladocerans and copepods. Seasonal pans also tend to have a high biomass of planktonic organisms and algae which, together with the aforementioned crustaceans, provide an important food source for water birds, including flamingos which were recorded at both pans (with lesser flamingos being present at Pan 1, Alternative F). The birds, in turn, contribute to the nutrient cycling that supports the aquatic biota.

Considering the uniqueness of these habitats and the high level of specialisation required to survive within this complex ecosystem, it is likely that unique or rare species are present. However, identification of crustaceans and plankton was beyond the scope of this project.

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Table 6-9. Summary of aquatic macroinvertebrates sampled for the Kusile Ash Disposal Facility project, using the SASS5 methodology. Site B3 was not sampled as it was dry at the time of sampling.

		Wilge River Sites						Tributaries of the Wilge River						Klipfonteinspruit Tributaries		Bronkhorstspruit Tributaries	
SITE		W1	W2	W3	W4	W5	W6	T1	KF1	KF2	KF3	T4	B4	HS	Kus	B1	B2
	Temp (℃):	25.7	22.6	23.7	22	24.9	23.5	26.2	21	23.3	24.2	27.6	23.1	27	24.2	29.3	17.5
	pH:	8.34	8.03	7.97	7.8	8.02	7.8	8.3	7.6	7.72	7.72	7.37	7.14	7.52	7.51	7.43	7.5
	Cond (mS/m):	39.7	35.1	37.1	20	31.6	32	18.1	5.3	30.6	16.4	12.5	13	6.4	11.6	12.8	12.3
Biotopes sampled	Stones in current	4	4	3	4	3	3	3	3	2	2	4	3	2	1	2	3
	Stones out of current	2	2	2	3	3	2	4	2	3	3	3	2	3	3	4	2
	Vegetation	3	3	3	3	2	3	3	4	4	4	4	4	3	2	3	3
	Gravel, sand, mud	2	3	1	2	3	1	3	3	2	3	3	3	2	4	3	3
TOTAL No.TAXA		18	20	20	25	19	24	18	19	12	11	18	19	8	5	19	14
SASS Score		112	110	122	139	111	135	84	92	55	51	96	112	44	21	79	61
Average Score per Taxon		6.2	5.5	6.1	5.6	5.8	5.6	4.7	4.8	4.6	4.6	5.3	5.9	5.5	4.2	4.2	4.4
PES		B	C	B	C	B/C	C	C/D	C/D	E	E	C	B/C	C	F	C	C

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7. SUMMARY OF BASELINE ENVIRONMENT

The Wilge River was considered most sensitive in terms of aquatic ecosystems. Sites sampled within the Wilge River had a high diversity of aquatic macroinvertebrates and a high prevalence of sensitive biota, including the shortfin suckermouth, *Chiloglanis pretoriae*, which is sensitive to changes in water quality, substrate modifications and flow regime. The population *C. pretoriae* in the Wilge River represents one of the few remaining populations in the upper Olifants River catchment. Site alternatives bordering on the Wilge River, or requiring a conveyor crossing of the river, were thus considered most sensitive.

A number of Wilge River tributaries had good water quality, notably sampling sites T1 and T2 (adjacent to Alternatives A and G), the Holspruit (Alternative A) and all the tributaries draining Alternative B (B1, B2, B4). It should be noted that Alternative B is located on the catchment divide between two quaternary catchments and thus stands to impact on both the Wilge River and Bronkhorstpruit via the four spring-fed headwater streams draining the site. Water quality was assessed in greater detail in a surface water report.

The Klipfonteinspruit was identified as being the most severely impacted by upstream activities. In particular, high volumes and velocities of water entering the Klipfonteinspruit from upstream developments, including the Kusile Power Station, has caused severe erosion of the channel, thus seriously compromising habitats available to aquatic biota, as well as water quality. The tributary that enters the Klipfonteinspruit from the Kusile construction site had a critically low diversity of aquatic macroinvertebrates and a complete absence of fish as a result of erosion and turbidity.

Finally, the two seasonal pans (associated with Alternatives F and B) were considered important and sensitive in terms of potential biodiversity support.

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8. COMPARISON OF ALTERNATIVES

The risk ratings are given in Table 8-1. The comparison of alternatives hinged on protecting the sensitive Wilge River from water quality impacts. For this reason, Alternative B was considered highly unfavourable as it would require a conveyor crossing, not only of the Wilge River, but also of the Klipfonteinspruit as well as a Wilge River tributary on the western bank. In addition, Alternative B will impact upon the headwaters of 4 spring-fed tributaries within two quaternary catchments – two tributaries flowing into the Bronkhorstspruit and two flowing into the Wilge River. The quality of the water within these tributaries is particularly good. Alternative B will also impact on the water quality and habitats within the adjacent seasonal pan.

Based on the premise that the Klipfonteinspruit will be effectively managed and rehabilitated as part of an off-site mitigation plan, and that on-site mitigation can minimise and prevent further impacts to the Klipfonteinspruit, alternative A is considered the most suitable site in terms of aquatic ecosystems. Alternative A requires no conveyor crossing of the Wilge River, only one crossing of the Klipfonteinspruit and its greater distance from the Wilge River (relative to other alternatives) poses the lowest risk of contamination of the Wilge River via groundwater.

Should A not be deemed feasible, Alternative C could be considered, with the strong recommendation that the footprint be moved back from the Wilge River.

Alterative G is considered less favourable because of the extent of its river frontage, while alternatives F and G are considered least favourable due to impacts along the extensive river frontage.

The potential impacts to seasonal pans also render alternatives F and B unfavourable.

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Table 8-1. Summary of the comparison of alternatives. The risk rating used was as follows: 5 Very High Importance/risk; 4 High importance/risk; 3 Moderate importance/risk; 2 Low importance/risk; 1 Very Low importance/risk; 0 No Importance/risk.

Alternative	Associated Sites	Habitats	Water Quality	Aquatic Macroinvertebrates	Fish	Conveyor Crossings	Total Risk Rating	Rank
A	KF2, KF3, W5, HS, W6	**3.** Largely Natural Riparian habitats within the HS will be destroyed but habitats have been seriously compromised further downstream within the Klipfonteinspruit.	**3.** Water quality has been compromised downstream of A within the Klipfonteinspruit.	**3.** Sensitive taxa present within the Holspruit but fewer sensitive taxa within the Klipfonteinspruit	**3.** Klipfonteinspruit provides a buffer against impacts to sensitive *C. pretoriae* within the Wilge River.	**2.** Conveyor to impact upon the already impacted Klipfonteinspruit and Kusile Tributary. The main risk will be continued erosion of the Klipfonteinspruit, this reducing any water quality improvement functions provided by the affected wetland. Mitigation possible.	**14**	1
B	B1, B2, B4, W5, W6	**3.** A seasonal pan adjacent to B will be impacted upon	**4.** Streams leaving Alternative B have not been impacted on by mining. Only moderate agricultural impacts were evident.	**2.** Diversity was low within these streams, largely due to low flow conditions so high up in the catchment.	**2.** Diversity was low within these streams, largely due to low flow conditions so high up in the catchment. This limited the availability of habitats.	**5.** The conveyor will cross three river systems at four crossings, including the Klipfonteinspruit, Wilge River and Wilge tributary. The conveyor is likely to impact upon diversity and the prevalence of sensitive taxa within the Wilge River. The magnitude of these impacts cannot be accurately assessed but potentially severe with mitigation difficult.	**16**	3
C	T4, W5, W6	**3.** Habitat integrity within T4 is currently largely intact. Wilge River at risk from possible sedimentation and erosion.	**4.** T4 has a moderately good water quality but with low volumes of runoff. However the proximity of alternative C to the Wilge River poses substantial risk of pollution.	**3.** The Wilge River at Site 5 has a high diversity with several sensitive taxa.	**3.** Sensitive *C. pretoriae* will be impacted along the Wilge River frontage.	**2.** The conveyor crossing will pose a limited risk to an already-impacted watercourse draining away from Kusile Power Station.	**14**	1

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Alternative	Associated Sites	Habitats	Water Quality	Aquatic Macroinvertebrates	Fish	Conveyor Crossings	Total Risk Rating	Rank
F	W3, W4, W5, W6, KF2, KF3, T2	**4.** A seasonal Pan falls within Area F. This pan supports a number of pan-adapted crustaceans and plankton, which in turn provide food for birds (e.g. flamingos).	**4.** Area F has a large area facing onto the Wilge River, thus posing a large threat to water quality.	**4.** A high diversity and prevalence of sensitive taxa were recorded within the Wilge River at sites W3 and W4. There is a high risk that taxa will be lost due to water quality impacts.	**5.** Extensive Wilge River frontage poses a threat to the sensitive *C. pretoriae* .	**2.** Conveyor to impact upon the already impacted Klipfonteinspruit and Kusile Tributary. The main risk will be continued erosion of the Klipfonteinspruit, this reducing any water quality improvement functions provided by the affected wetland.	**19**	4
G	W3, W4, W5, W6, T2, HS, KF2, KF3	**3.** Habitats along T1 severely compromised. However, habitats along the Holspruit are largely intact and are therefore at risk. Wilge River at risk from possible sedimentation and erosion.	**3.** Water Quality within the Wilge River is of moderate quality, while T1 and T2 were considered to be of good quality. The main impacts are agricultural, although high sulphate concentrations within W1 and W2 suggest existing mining impacts.	**3.** High diversity and prevalence of sensitive taxa at risk within the Wilge River, as well as the Holspruit.	**4.** Sensitive C. pretoriae will be impacted along the Wilge River frontage.	**2.** Conveyor to impact upon the already impacted Klipfonteinspruit and Kusile Tributary. The main risk will be continued erosion of the Klipfonteinspruit, this reducing any water quality improvement functions provided by the affected wetland.	**15**	2
F+G	W2, W3, W4, W5, W6, KF3, KF2, T2, T1	**4.** A seasonal Pan falls within Area F. This pan supports a number of pan-adapted crustaceans and plankton, which in turn provide food for birds (e.g. flamingos).	**5.** Area F combined with G will have a large area facing onto the Wilge River, thus posing a significant risk of pollution.	**4.** A high diversity and prevalence of sensitive taxa were recorded within the Wilge River at sites W3 and W4. There is a high risk that taxa will be lost due to water quality impacts.	**5.** Extensive Wilge River frontage poses a threat to the sensitive *C. pretoriae* .	**2.** Conveyor to impact upon the already impacted Klipfonteinspruit and Kusile Tributary. The main risk will be continued erosion of the Klipfonteinspruit, this reducing any water quality improvement functions provided by the affected wetland.	**20**	5

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9. ANTICIPATED IMPACTS

It is understood that the Ash Disposal Facility will be suitably lined with an appropriate lining, with adequate stormwater management, energy dissipation and pollution control dams on site. The associated conveyors will have a servitude of approximately 100-130 metres and will be accompanied by stormwater trenches running alongside, with pollution control dams situated at regular intervals along the route. The conveyor will require infilling and, with the exception of the Wilge River, will be able to span wetland crossings. The Wilge River Crossing will require construction of embankments within riparian areas.

The major impacts of the Ash Disposal Facility are likely to include:

- Loss of aquatic habitats through direct wetland destruction
- Loss of habitats and wetland/riparian buffer zones through erosion
- Loss of habitats and buffer zones through sedimentation (altered substrates and vegetation)
- Contamination of surface water – contaminated surface runoff (containing sediments, contaminants), together with wind-blown contaminants and leaching via groundwater
- Turbidity – deterioration in water quality will affect aquatic species
- Overall decline in aquatic biodiversity because of all of the above

The major impacts at conveyor crossings are likely to include:

- Water quality impacts due to spills and leaks
- Erosion (and sedimentation) at wetland crossings as well as downstream of crossings
- Disturbance or loss of marginal and riparian habitats
- Disturbance of riparian migration corridors
- Altered flow regimes downstream of watercourse crossings

10. COMPARATIVE IMPACT ASSESSMENT

All six alternatives were assessed in terms of the impacts anticipated for each site. The impacts rating system is outlined in Section 12.1. The summarised results are displayed in Appendix C

The significance of anticipated impacts were lowest for Sites A and C but highest for Site F+G. Impacts due to the conveyor crossing of the Wilge River en route to Alternative B are also likely to be high.

11. PREFERRED ALTERNATIVE

Alternative A was considered to be the preferred alternative because of its greater relative distance from the Wilge River and no requirements for a conveyor crossing of the Wilge River. On-site mitigation is possible to address potential impacts to water quality and quantity on site, while additional opportunities for off-site mitigation within the Klipfonteinspruit also exist.

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12. ENVIRONMENTAL IMPACT ASSESSMENT

12.1 IMPACT ASSESSMENT METHODOLOGY

Impacts were assessed separately for the construction, operational, closure, and post-closure phases of the project; Impacts were described according to the Status Quo, Project Impact, Cumulative Impact, Mitigation Measures and Residual Impact as follows:

- The Status Quo assesses the existing impact on the receiving environment. The existing impact may be from a similar activity, e.g. an existing ash dump, or other activities e.g. mining or agriculture.
- The project impact assesses the potential impact of the proposed development on an environmental element;
- The cumulative impact on an environmental element is the description of the project impact combined with the initial status quo impacts that occur;
- Mitigation measures that could reduce the impact risk are then prescribed; and
- The residual impact describes the cumulative impact after the implementation of mitigation measures.

Impacts were rated against a predetermined set of criteria including (magnitude, duration, spatial scale, probability, and direction of impact); A rating matrix is provided for each environmental element per project phase summarising all the aforementioned in a single table.

More detailed description of each of the assessment criteria and any abbreviations used in the rating matrix is given in the following sections.

12.1.1 Magnitude / Significance Assessment

Significance rating (importance) of the associated impacts embraces the notion of extent and magnitude, but does not always clearly define these since their importance in the rating scale is very relative. For example, the magnitude (i.e. the size) of Alternative Affected by atmospheric pollution may be extremely large (1000 km2) but the significance of this effect is dependent on the concentration or level of pollution. If the concentration is great, the significance of the impact would be HIGH or VERY HIGH, but if it is diluted it would be VERY LOW or LOW. Similarly, if 60 ha of a grassland type are destroyed the impact would be VERY HIGH if only 100 ha of that grassland type were known. The impact would be VERY LOW if the grassland type was common. A more detailed description of the impact significance rating scale is given in Table 4-1Table 12-1.

Table 12-1: Description of the significance rating scale.

Rating			Description
Score	Code	Category	
7	SEV	SEVERE	Impact most substantive, no mitigation possible
6	VHIGH	VERY HIGH	Impact substantive, mitigation difficult/expensive
5	HIGH	HIGH	Impact substantive, mitigation possible and easier to implement
4	MODH	MODERATE-HIGH	Impact real, mitigation difficult/expensive
3	MODL	MODERATE-LOW	Impact real, mitigation easy, cost-effective and/or quick to implement

2	LOW	LOW	Impact negligible, with mitigation
1	VLOW	VERY LOW	Impact negligible, no mitigation required
0	NO	NO IMPACT	There is no impact at all - not even a very low impact on a party or system.

12.1.2 Spatial Scale

The spatial scale refers to the extent of the impact i.e. will the impact be felt at the local, regional, or global scale. The spatial assessment scale is described in more detail in Table 12-2

Table 12-2: Description of the spatial rating scale.

Rating			Description
Score	Code	Category	
7	NAT	*National*	The maximum extent of any impact.
6	PRO	*Provincial*	The spatial scale is moderate within the bounds of impacts possible, and will be felt at a provincial scale
5	DIS	*District*	The spatial scale is moderate within the bounds of impacts possible, and will be felt at a district scale
4	LOC	*Local*	The impact will affect an area up to 5 km from the proposed route corridor.
3	ADJ	*Adjacent*	The impact will affect the development footprint and 500 m buffer around development footprint
2	DEV	*Development footprint*	Impact occurring within the development footprint
1	ISO	*Isolated Sites*	The impact will affect an area no bigger than the servitude.

12.1.3 Duration / Temporal Scale

In order to accurately describe the impact it is necessary to understand the duration and persistence of an impact in the environment. The temporal scale is rated according to criteria set out in Table **12-3**.

Table 12-3: Description of the temporal rating scale.

Rating			Description
Score	Code	Category	
5	PERM	Permanent	The environmental impact will be permanent.
4	LONG	Long term	The environmental impact identified will operate beyond the life of operation.
3	MED	Medium term	The environmental impact identified will operate for the duration of life of the line.
2	SHORT	Short-term	The environmental impact identified will operate for the duration of the construction phase or a period of less than 5 years, whichever is the greater.
1	INCID	Incidental	The impact will be limited to isolated incidences that are expected to occur very sporadically.

12.1.4 Degree of Probability

The probability or likelihood of an impact occurring will be described as shown in Table 12-4 below.

Table 12-4: Description of the degree of probability of an impact accruing

Score	Code	Category
5	OCCUR	*It's going to happen / has occurred*
4	VLIKE	*Very Likely*
3	LIKE	*Could happen*
2	UNLIKE	*Unlikely*
1	IMPOS	*Practically impossible*

12.1.5 Degree of Certainty

As with all studies it is not possible to be 100% certain of all facts, and for this reason a standard "degree of certainty" scale is used as discussed in Table 12-5 below. The level of detail for specialist studies is determined according to the degree of certainty required for decision-making. The impacts are discussed in terms of affected parties or environmental components.

Table 12-5: Description of the degree of certainty rating scale

Rating	Description
Definite	More than 90% sure of a particular fact.
Probable	Between 70 and 90% sure of a particular fact, or of the likelihood of that impact occurring.
Possible	Between 40 and 70% sure of a particular fact or of the likelihood of an impact occurring.
Unsure	Less than 40% sure of a particular fact or the likelihood of an impact occurring.
Can't know	The consultant believes an assessment is not possible even with additional research.

12.1.6 Impact Risk Calculation

To allow for impacts to be described in a quantitative manner in addition to the qualitative description, a rating scale of between 1 and 5 was used for each of the assessment criteria. Thus the total value of the impact is described as the function of significance, spatial and temporal scale as described below:

$$Impact\ Risk = \frac{\text{Significance} + \text{Spatial} + \text{Temporal}}{2.714} \times \frac{\text{Probability}}{5}$$

An example of how this rating scale is applied is shown below in Table 12-6:

Table 12-6: Example of rating scale

Impact	Magnitude	Spatial scale	Temporal scale	Probability	Rating
Greenhouse gas emissions	2	*3*	3	3	1.8
	LOW	*Local*	Medium Term	*Could Happen*	**LOW**

***Note**: The significance, spatial and temporal scales are added to give a total of 8, that is divided by 2.714 to give a criteria rating of 2,95. The probability (3) is divided by 5 to give a probability rating of 0,6. The criteria rating of 2,95 is then multiplied by the probability rating (0,6) to give the final rating of 1,8, which is rounded to the first decimal.*

The impact risk is classified according to 5 classes as described in Table 12-7 below.

Table 12-7: Impact Risk Classes

Rating	Impact class	Description
6.1 - 7.0	**7**	**SEVERE**
5.1 - 6.0	**6**	**VERY HIGH**
4.1 - 5.0	**5**	**HIGH**
3.1 - 4.0	**4**	**MODERATE-HIGH**
2.1 - 3.0	**3**	**MODERATE-LOW**
1.1 - 2.0	**2**	**LOW**
0.1 - 1.0	**1**	**VERY LOW**

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13. ENVIRONMENTAL IMPACT STATEMENT: ALTERNATIVE A

Figure 13-1 shows Alternative A located south of the Kusile Power Station. Alternative A is located furthest away from the Wilge River. The Ash Disposal Facility will impact upon the Klipfonteinspruit and Holspruit which will be diverted around the development. The conveyor route will have a single wetland crossing and this will be over the diverted Klipfonteinspruit.

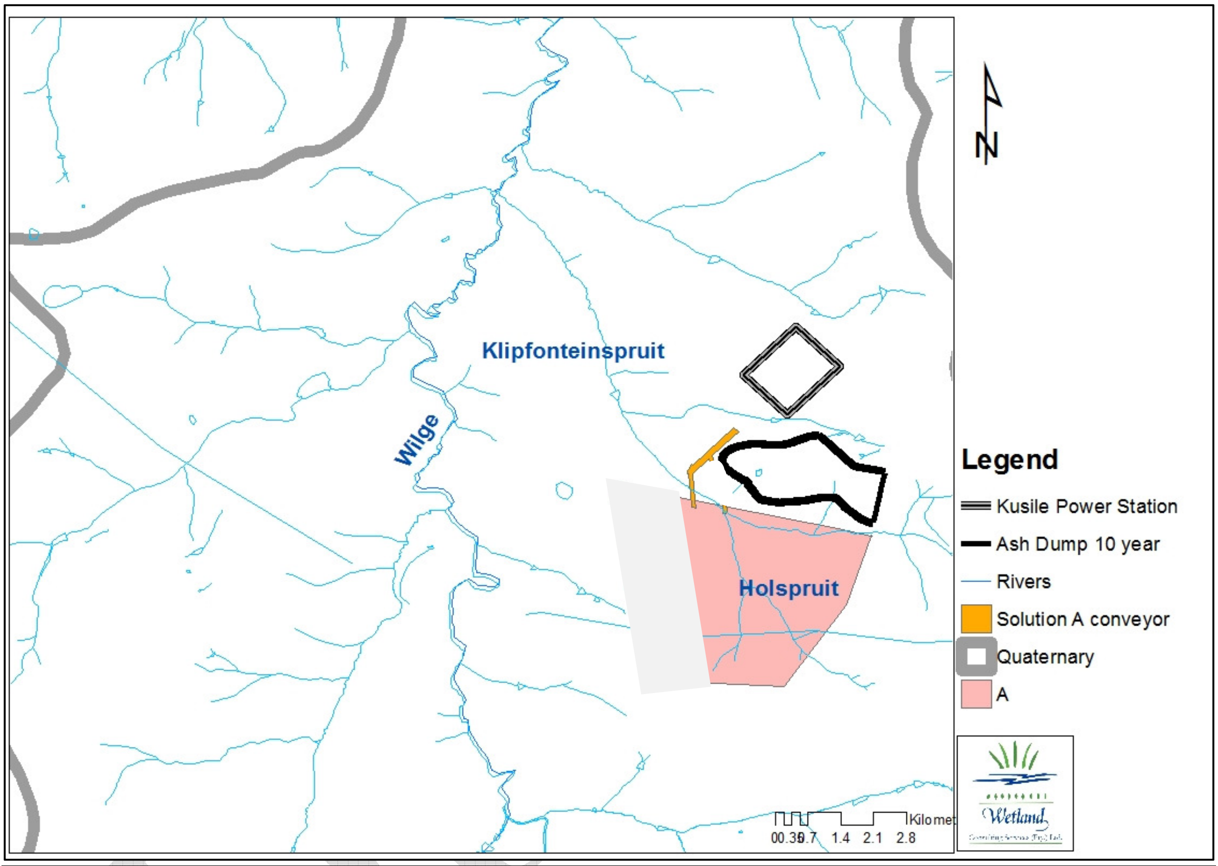

Figure 13-1. Map showing position and approximate extent of site alternative A, together with the approximate conveyor route (shown in orange), relative to watercourses and catchments.

The following details were provided for the diversion at the time of reporting:

- Steps have been included in the original design to counter the steepness of the slope. These steps will reduce the slope to 1:150 over a distance of 10m. Velocities will be below 2.0m/s over the 1:200 slope section, below 3.0m/s over the 1:100 slope section and below 4.0m/s over the short steep section (1:25) that will lead into the stilling basins. Crushed rock will be used in the basin of the diversion over the steep section to reduce the risk of erosion and ensure a higher roughness co-efficient.

- The diversion has been designed for a 1:2 year return interval within a concentrated flow channel and a 1:50 year return interval for the adjacent floodplain respectively. This will allow for more frequent wetting of the floodplain to encourage growth of wetland vegetation.

- The concentrated flow channel will have a sinuosity created by longitudinal gabion walls, which will also protect the side slopes from scour.

- Two consecutive stilling basins will be provided for the storm water collection canal on the downstream side of the facility. Both stilling basins will have an approximate volume of 50 000m^3. Access to the stilling basin for desliting will be provided in the design plans.

- A series of crushed rock weirs will slow flows and create pools to encourage colonisation by wetland and aquatic species.

- A bund wall on the downstream side of the diversion will prevent any drainage from entering the diversion.

13.1 STATUS QUO

The main current impacts to surface water include agriculture (primarily livestock grazing with crop production prevailing to the west of the Wilge River) and construction activities related to the Kusile Power Station. Mining-related water quality impacts were evident within the Klipfonteinspruit.

13.2 PROJECT IMPACTS (UNMITIGATED)

The major impacts associated with this site will be water quality as well as design and management of diversions and stormwater infrastructure. Impacts due to the conveyor are likely to be relatively minor, restricted to two wetland crossings, and mainly confined to the operational phase. At a catchment level, only quaternary catchment (B20F) and one watercourse will be impacted upon, making it easier to mitigate impacts on site and contain spills.

The anticipated impacts are likely to be as follows:

13.2.1 Construction Phase

Sections of the Holspruit and the Klipfonteinspruit will fall within the development footprint. Water that usually flows through these systems will have to be diverted around the dump site. The diversion, no matter how carefully constructed, is unlikely to mimic the original wetland conditions and aquatic biodiversity 100%. However, it is understood that the diversion will be designed to mimic natural flow rates and to create a diversity of natural habitats that encourage colonisation by a diverse range of wetland and aquatic biota (This is discussed more fully under ‘mitigation’). If correctly designed, it could have a slightly positive impact in terms of biodiversity and wetland function, when compared with the present highly eroded state of the affected reach.

The removal of vegetation and the laying of the impermeable membrane will decrease infiltration of rainwater and will result in greater volumes and velocities of storm water leaving the site. This will place additional pressure on the already-incised Klipfonteinspruit. Erosion of the Klipfonteinspruit, especially downstream of its confluence with the tributary draining the Kusile construction site, has become deeply incised due to scouring by storm water, resulting in the near-absence of marginal vegetation habitats for aquatic biota. Erosion will be exacerbated by further developments in the catchment. Erosion nick points are also likely to occur at conveyor crossings.

Sediments may be eroded from soil stockpiles, storm water channels and from the construction site itself. These will be transported into receiving watercourses where they will settle out in pools or under low flow conditions. This may impact on aquatic habitats by reducing the availability of deep pool habitats (preferred by certain fish) and altering the marginal habitats as silted up areas may be colonised by dense stands of *Typha.* In addition, visual predators (e.g. fish, dragonflies and damselflies) may be affected by the turbid conditions that result from high sediment loads. Should any sediments be carried into the Wilge River, cobble biotopes may become 'clogged' with sediment, thus affecting a range of fish (including *Chiloglanis pretoriae)* and aquatic macroinvertebrates that have a preference for clean, cobbled substrates.

During the construction phase, there may be water quality impacts due to accidental spills, for example of hydrocarbons (diesel, grease or oil), cement or sewage. In addition, leaks from faulty machinery or from ineffective toilet facilities, may create additional contamination. Solid waste, including hazardous waste items such as PVC and tyres, could also result in a decline in water quality. A decline in water quality and habitats may result in the displacement of certain taxa sensitive to changes in water quality.

Continued erosion of the Klipfonteinspruit will cause a progressive decline in any wetland functions it currently offers and impacts may be transferred further downstream to the Wilge River. The Klipfonteinspruit currently provides some water quality improvement, sediment trapping and flood attenuation functions. If flows are increased beyond its natural capacity to perform these functions, all impacts discussed above may be transferred to the Wilge River.

The combined weighted project impact to aquatic ecosystems (prior to mitigation) during the construction phase will **Probably** be of a VERY HIGH negative significance, at the *local* scale. The impact will act in the <u>long term</u> and will <u>*definitely*</u> occur. The impact risk class is thus **Very High.**

Mitigation will involve careful design of diversions and stormwater infrastructure according to ecological principles so that water quality and flow-related impacts are mitigated on-site. With mitigation, the impacts are likely to be reduced to MODERATELY LOW, *Local*, <u>Medium-term</u>, with a risk class of **Moderately High.**

13.2.2 Operational Phase

The main impacts during the Operational Phase are likely to be related to a decline in water quality. Surface runoff that comes into contact with ash is likely to become contaminated, these contaminants then being carried into downstream ecosystems. Wind-blown ash or conveyor spills as well as subsurface seepage are likely to cause additional contamination. Overflowing or structurally ineffective pollution control dams pose the greatest risk. The major water quality impacts are likely to be due to salts (sulphates in particular), acidity and heavy metals. A decline in water quality is likely to cause a loss of taxa that are sensitive to changes in water quality. This may affect animals higher up in the food chain (e.g. otters and water mongooses) that may rely on these taxa for food (e.g. crabs, fish).

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Impacts to habitats due to erosion, turbidity and sedimentation, as mentioned for the construction phase, will be ongoing during the operational phase, resulting in further declines in diversity as the availability of suitable habitats declines. If the Klipfonteinspruit continues to erode, its capacity to buffer against impacts to the Wilge River will decline and it is possible that there may be a loss or displacement of sensitive taxa from the Wilge River.

Major pollution incidents (e.g. dam failures) may result in regional water quality impacts, possibly extending as far as Mozambique.

Additional impacts associated with the operational phase include leaks and spills (e.g. from machinery, inappropriate storage or disposal of potential contaminants (grease, fuel, oil, paints or other chemicals) and waste (e.g. PVC, used oils, tyres).

It is understood that rehabilitation will be ongoing during the operational phase. Impacts may include erosion of rehabilitated areas, causing sedimentation of drainage systems. Invasion by alien vegetation will be a further consideration.

The combined weighted project impact to aquatic ecosystems (prior to mitigation) during the operational phase will **Probably** be of a VERY HIGH negative significance, affecting the *Province.* The impact will act in the long term and will *definitely* occur. The impact risk class is thus **Very High.**

With mitigation, the impact can be reduced to HIGH, affecting the *District,* but the significance is likely to remain **High to Very High.**

13.2.3 Closure and Post-Closure Phases

All impacts associated with the operational phase will continue to be relevant during the decommissioning and closure phases. In addition, the dismantling of infrastructure will create solid waste and will increase the potential for spills.

The combined weighted project impact to aquatic ecosystems (prior to mitigation) during the Closure and Post-Closure phases will **Probably** be of a VERY HIGH negative significance, at the *Provincial* scale. The impact will act in the permanent and will *definitely* occur. The impact risk class is thus **Very High.**

With mitigation, the impact is likely to be reduced in terms of magnitude, extent and probability to a **Moderately High** risk class.

13.3 CUMULATIVE IMPACTS

The development of Alternative A will place additional stress on the Klipfonteinspruit, in terms of water quality and habitat integrity. This decline in water quality, however, is unlikely to significantly impact on the already depauperate aquatic biota within the Klipfonteinspruit. However, where water of poor quality reaches the Wilge River there are likely to be significant impacts, including the potential loss of sensitive fish and aquatic macroinvertebrate species. The Wilge River is currently relatively unimpacted by mining activities (which includes coal-fired power stations). As such, any impacts to the river will set a precedent that may facilitate the approval of future mining applications within the catchment. The Wilge River is also a tributary of the seriously impacted Olifants River. Impacts to the Wilge River will thus exacerbate impacts to the Olifants River system, potentially pushing these impacts beyond a critical level. Major pollution events (e.g. major spills or structural collapses) could potentially be carried as far as Mozambique, with international implications.

The baseline impacts are considered to be substantial, and additional project impact (if no mitigation measures are implement) will increase the significance of the existing baseline impacts, the cumulative unmitigated impact will **probably** be of a VERY HIGH negative significance, at the *Provincial to National Scale*. The impact *is going to happen* and will be permanent. The impact risk class is thus **Very High**.

13.4 MITIGATION

On-site mitigation measures for the Ash Disposal Facility would include, for example, sediment trapping, effective stormwater management, appropriate lining with an impermeable membrane, careful design and maintenance of pollution control dams and dust suppression. These measures are discussed in greater detail in 14.4.1-3. below.

It is further recommended that diversions and stormwater management structures be designed in consultation with a wetland specialist and hydrologist to ensure creation of habitats, migration corridors and flow rates that mimic the natural hydrology of the systems. Additional off-site mitigation could be further considered to rehabilitate eroded sections of the Klipfonteinspruit.

Recommended mitigation measures are discussed more fully below.

13.4.1 General Mitigation (All Phases)

13.4.1.1 Seepage Prevention

It is essential that the Ash Disposal Facility site, together with stormwater drains and pollution control dams, be appropriately lined (according to the relevant waste classification), so that no contaminants reach the groundwater.

13.4.1.2 Access Management

Wetland areas, together with their buffers, should be cordoned off and considered no-go areas as far as possible. In particular, vehicular traffic should be prohibited from entering wetland areas. Soil stockpiles and toilet facilities should be placed outside of wetland areas. All construction staff should be informed on the sensitivity of the wetlands.

It should be noted that all activities within wetland areas and its buffers (including rehabilitation) will require a Water Use Licence.

13.4.1.3 Footprint Minimisation

It is essential that the development footprint be optimised and minimised so as to minimise the loss of wetland areas. In particular, the need to divert the Klipfonteinspruit around the Ash Disposal Facility footprint should be avoided if possible. The feasibility of stacking the ash to greater heights,

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thus reducing the footprint, should be considered. If possible, deposition of ash should start from the south and progress downslope in a northerly direction. In this way, should an alternative means of disposal be found in future (e.g. co-disposal), the need to divert the Klipfonteinspruit may be obviated.

13.4.1.4 Ecological Design of Stream Diversions

The Klipfonteinspruit and Holfonteinspruit will have to be diverted around the development footprint, to avoid contamination of clean water. These diversions should be designed well in advance and should consider the following:

- Diverted flows should be engineered to mimic the natural flows as far as possible by using uneven surfaces, flow retardant structures and sinuous flow patterns. Substrates should consist of crushed rock, reno mattresses or wetland vegetation. The use of concrete should be strictly avoided.
- Design and management of diversions should aim to retard flows and to facilitate lateral connectivity (with marginal and riparian habitats) as well as longitudinal connectivity.
- The design of the diversion should aim to maintain wetland functions, specifically flow attenuation and water quality improvement.
- Habitat continuity - maintenance of habitat and migration corridors for fish, frogs and aquatic macroinvertebrates (e.g. fish ladders, fringing vegetation, pool habitats); A series of crushed rock weirs will facilitate this.
- Maintenance of riparian corridors for fauna (including, for example, frogs, otters, mongooses, water birds and duiker).
- Optimal habitat heterogeneity (including suitable and adequate marginal and instream habitats).
- The side slopes should be seeded with indigenous grasses. The slope of the side slopes should be gradual to minimise erosion and encourage colonisation by indigenous grasses.
- Alien vegetation (e.g. black wattle), which is likely to colonise the side slopes, will need to be controlled.
- Erosion protection and flow retardation measures should be applied at the diversion outlet to prevent erosion in downstream reaches.

13.4.1.5 Stream Crossings

The position and design of stream crossings should include the following factors

- Follow existing roads as far as possible.
- Crossings should ideally be perpendicular to streams to minimise the footprint.
- Conveyors and pedicels should span the wetland and its buffer zone and should be clear of major flood levels (at least 1:100 year events) so as to prevent contamination of water during floods.
- The conveyor should be enclosed at wetland crossings, including buffer zones, and should have adequate capacity to contain major spills.
- Transfers should be located outside of wetland areas.
- Dirty stormwater dams and trenches at conveyor crossings should be designed to prevent spills or leaks of contaminated water and no dirty water should be discharged directly into wetland areas.
- Ensure easy access for maintenance or clean ups.

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- The time period during which flow is modified due to construction should be kept as short as possible.
- All wetland/riparian areas disturbed during construction should be rehabilitated immediately upon completion of construction.

13.4.1.6 Stormwater Management

The design of the stormwater management system should take into account:
- Quality of water leaving the site (separation of clean and dirty water)
- Retention/treatment of dirty water
- Volumes and velocities of water leaving the site

Stormwater berms and trenches should be located so that all ‘clean’ water derived from the catchment upslope of the Ash Disposal Facility and soil stockpiles is diverted around it and into the downslope wetland areas. Sediments should be trapped before discharge into the Klipfonteinspruit (see section 12.6.1.8). Ensure adequate flow attenuation within stormwater trenches and at pond outlets. There should be a vegetated buffer between stormwater outlets and downstream wetlands.

Stormwater management should be applied at a catchment scale and should take into account impacts to the Klipfonteinspruit and Wilge River.

Stormwater management, including pollution control dams and stormwater trenches, should be designed according to DWAF Best Practice Guidelines (2006, 2007a, b, 2008). Infrastructure associated with dirty water (stormwater trenches and dams) should be lined with an appropriate impermeable layer (based on the waste classification) and should cater for the >1:50 year storm events.

13.4.1.7 Erosion and Sediment Management

Ideally, construction should take place in the dry season to avoid erosion from exposed soils and stockpiles. Areas to be cleared should be kept to a minimum at any one time.

No vegetation clearing or topsoil removal may take place within the 32m buffer surrounding wetlands. Vegetation clearing and topsoil removal should be restricted to as small an Alternative As possible and should be phased, i.e. avoid clearing the entire footprint at once.

Install sediment traps and stormwater berms as soon as possible during the construction process. These berms would serve to intercept flows containing suspended sediments and create a depositional environment. They should be located outside the wetland boundaries and should be created prior to construction and vegetation clearing on the stockpile footprint commencing. All surface runoff should be directed to a sediment trap. Silt traps should be regularly inspected and cleaned to ensure optimal functionality. Energy dissipaters and erosion protection measures should be incorporated at points of discharge which should be located outside of wetland areas. The 32m vegetated buffer will facilitate in trapping sediment. Stormwater berms should be appropriately sloped and stabilised (e.g. revegetated) to prevent collapses.

Locate all topsoil stockpiles outside the delineated wetland and 32m buffer zone. Install sediment barriers along the lower edge of the soil stockpile. Limit the height of the topsoil stockpile and minimise the slope of the side slopes so as to avoid collapses.

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13.4.1.8 Prevention of Spills and/or Leaks (See DWAF guidelines, 2007)

- Toilet facilities should be located outside of wetland areas.
- Ensure separation of clean and dirty water and allow clean water to enter natural water bodies after effective attenuation and sediment trapping.
- To prevent spillages, vehicles should be well maintained.
- Diesel and oil/grease should be stored in bunded areas that will allow any spillages to be easily and quickly isolated and prevent contamination of any soils or water.
- Spills should be cleaned up with approved absorbent material such as “Drizit” or “Spillsorb”. These should be kept in sufficient quantities on site to deal with small spills. Absorbent material and contaminated soil should be disposed of at a registered hazardous waste site.
- An emergency preparedness plan should be compiled and all construction staff aware of procedures in event of a spill.
- Hazardous waste (e.g. oil, diesel, grease, PVC, tyres), should be stored in bunded/impermeable areas and disposed of appropriately at a registered landfill site. Potential spills or seepage of hazardous waste must be anticipated and prevented.
- Should cement be used on site, the following mitigation measures apply:
    - Carefully control all on-site operations that involve the use of cement and concrete (this applies to areas other than the batching plant).
    - Limit cement and concrete mixing to single sites where possible.
    - Use plastic trays or liners when mixing cement and concrete: Do not mix cement and concrete directly on the ground.
    - Dispose of cement in the approved manner (solid waste concrete may be treated as inert construction rubble, but wet cement and liquid slurry, as well as cement powder must be treated as hazardous waste).
- Implement an aquatic biomonitoring and water quality programme. Where target endpoints are not met, recommendations should translate directly into follow-up action that is recorded and auditable.

13.4.1.9 Dust Suppression

Dust suppression should aim to minimise dustfall into wetland areas.

13.4.1.10 Monitoring

A monitoring, including biomonitoring, should be compiled and implemented. Recommendations for monitoring are given in 12.6.3 below. Monitoring/biomonitoring data must be compared with baseline levels given in this report. Where target endpoints are not met, recommendations should translate directly into follow-up actions that are documented and audited.

13.4.1.11 Off-Site Mitigation: Active Management of the Klipfonteinspruit

As an additional measure to ensure that no impacts to aquatic ecosystems are transferred to downstream reaches, the Klipfonteinspruit, which is seriously degraded, should be actively managed and rehabilitated, in consultation with a wetland specialist. Management of the Klipfonteinspruit should aim to restore and maintain wetland functions, specifically flow attenuation and water quality improvement. It is envisaged that major structural interventions such as weirs, dams and artificial wetlands will, in the long term, be required to manage all runoff from Kusile-related developments (including the power plant itself, which is already generating high volumes

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and velocities of runoff). Management of the Klipfonteinspruit should take into consideration the increased runoff (decreased infiltration) from the Ash Disposal Facility, as well as the possible accelerated flows caused by stream diversions and stormwater outlets.

It is additionally recommended that flow-gauging structures be incorporated into the design of the Klipfonteinspruit management plan, so that volumes and velocities can be more effectively managed. V-notch weirs would be useful to measure (and regulate) stormwater volumes being discharged from the Ash Disposal Facility site itself.

13.4.2 Operational and Closure/Post-Closure Phases

All general mitigation given above should apply to all phases of the development equally. The following additional mitigation measures apply to the Operational, Closure and Post-Closure phases:

13.4.2.1 Prevent Water Quality Declines

The following measures should be applied to prevent and minimise impacts to water quality due to the Ash Disposal Facility and its conveyors during operational and closure phases:

- Pollution Control dams should be designed according to strict safety requirements and should be regularly inspected for leaks, damage or maintenance requirements. Where irregularities are detected, they should be speedily remedied to avoid the risk of structural failure.
- Conveyor and road crossings of wetlands should be regularly inspected for erosion, mechanical problems, leaks or spillages. These should be timeously repaired.
- Should larger spillages occur due to malfunctioning of the conveyor or for any other reason, clean-up of the spillages should be undertaken as soon as possible following the incident. In this regard regular inspection of the entire conveyor route should be undertaken.
- An emergency response plan should be compiled to address structural failures and major accidental spillages.

13.4.2.2 Dust Suppression

It is understood that the Ash Disposal Facility will be irrigated to reduce dust. Dampness should be monitored to ensure a balance is maintained between dust suppression and slumping/collapses due to excessive wetting. Stormwater should be used for dust suppression to avoid the need for abstraction from natural water resources.

13.4.2.1 Ongoing Management of the Klipfonteinspruit

It is recommended that the catchment-level approach be adopted to manage the Klipfonteinspruit and Wilge River throughout the operational and closure phases. Regular monitoring, with timeous management interventions, should ensure that wetland functions are maintained and that impacts are not being transferred to the Wilge River.

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13.4.2.1 Rehabilitation of the Ash Disposal Facility

It is understood that rehabilitation will be ongoing, involving the revegetation of completed areas. It is essential that placement of topsoil is uniformly applied so as to prevent pooling of water. Revegetated areas should be regularly inspected for erosion rills and these should be timeously managed so as to prevent structural collapses.

An alien vegetation management plan should be compiled and implemented as part of the rehabilitation process and should aim to avoid invasion of wetland and riparian areas and the water-borne dispersal of propagules/seeds to downstream areas (i.e. the Klipfonteinspruit and Wilge River).

13.4.2.2 Waste Management

Deconstruction activities should be confined to a minimum area, which should be clearly demarcated. Delineated wetlands should be considered no-go areas during decommissioning and closure. Sediment trapping mechanisms should prevent soils from being washed into wetlands. Movement of machinery and vehicles during the infrastructure removal process must be strictly controlled to prevent disturbance to wetland areas.

13.4.3 Recommendations for Monitoring

A comprehensive monitoring (including biomonitoring) programme should be compiled. Monitoring should target discharge points as well as impacts to downstream watercourses. Results should be compared with baseline levels given in this report (and any other pre-development data).

The discharges points that should be included within the monitoring plan include all of the stormwater discharge points, discharges from the sediment traps, the sediment traps themselves and wetland crossings. Visual inspections with photographic records should be conducted regularly (e.g. weekly - monthly). Discharge points should be inspected for signs of erosion and sediment deposition, and corrective measures implemented should any erosion damage be observed. Where sediment build up occurs at the discharge points or sediment smothers vegetation downstream of the discharge points, the source of the sediment should be identified and corrective measures implemented to prevent further sedimentation. The sediment traps should be inspected and cleaned on a regular basis to ensure efficient operation of the sediment trap. Monitoring and maintenance guidelines as detailed in the surface water hydrology report (which includes the design of the sediment trap) should be applied.

Biomonitoring should include:

- Water quality (including major anions and cations, pH, ICP scans for metals, TSS, turbidity)
- Habitat Integrity
- SASS5 and fish
- Wetland Rehabilitation and/or erosion (e.g. of the Klipfonteinspruit)

Sampling sites should include sites KS1, KS2, KS3, W5, W6 and TS2, with additional sites where relevant.

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It is recommended that water quality monitoring be conducted every four months, with pH, Electrical conductivity, suspended solids and turbidity monitored weekly during the construction phase. Biomonitoring should be conducted every 4-6 months.

It is essential that recommendations given in monitoring and biomonitoring reports be translated into follow-up action that is documented and audited. Failure to do so renders the biomonitoring process useless.

13.5 RESIDUAL IMPACT

The residual impact of the development is likely to include loss of wetland areas and declines in water quality and habitat suitability and/or availability. These impacts are likely to be, for the most part, restricted to the local scale. However, it is anticipated that water quality in the Wilge River will decline, even with mitigation. In addition, there is a significant risk that large-scale spills will impact on water quality further afield within the Olifants River system, potentially extending as far as Mozambique.

After mitigation the impacts to aquatic ecosystems will probably be of a MODERATELY LOW negative significance, affecting the *district* area in extent. The impact is going to happen and will be *permanent*. The impact risk class is thus **Moderately High**.

13.6 IMPACT MATRIX

The impacts identified and discussed above have been rated according to the impact assessment methodology described in section 13.1 above. These ratings are provided in the matrix presented in the Tables (13-8) below.

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Table 13-1. Impact Ratings for Construction, Operational, Closure and Post-Closure Phases for Alternative A.

				Site A				
IMPACT DESCRIPTION		Direction of Impact	Degree of Certainty	Magnatude	Spatial	Temporal	Probability	**Impact Risk**
Code	*Phase*							
	CONSTRUCTION							
Habitat loss due to sedimentation. Eroded sediments and dust will end up in watercourses and wetlands, smothering benthic habitats, increasing turbidity and resulting in the colonisation oif marginal habitats by monospecific stands of Typha. Changes in habitats may be followed by a loss of species and overall biodiversity.		Negative	Probable	5	4	3	5	**-4.4**
				HIGH	LOC	MED	OCCUR	**HIGH**
Habitat loss/decline due to Erosion. Runoff is likely to increase as a result of vegetation clearing and replacing it with an impermeable lining. Release of concentrated flows into downstream watercourses will cause erosion which, in turn, will cause a deterioration in the availability and suitability of marginal and riparian habitats. This may lead to a loss of habitat specilists and an overall decline in biodiversity.		Negative	Probable	7	3	4	5	**-5.2**
				SEV	ADJ	LONG	OCCUR	**VHIGH**
Decline in water quality due to spills and leaks as well as turbidity due to erosion and sediment transport		Negative	Definite	5	4	3	5	**-4.4**
				HIGH	LOC	MED	OCCUR	**HIGH**
Destruction of wetlands that fall within the development footprint.		Negative	Definite	6	2	5	5	**-4.8**
				VHIGH	DEV	PERM	OCCUR	**HIGH**
Loss of sensitive species and biodiversity due to declines in water quality and habitats		Negative	Possible	4	4	5	3	**-2.9**
				MODH	LOC	PERM	LIKE	**MODL**
Impacts to overall integrity of ecologically sensitive and important downstream ecosystems (e.g. Wilge River)		Negative	Probable	3	5	5	5	**-4.8**
				MODL	DIS	PERM	OCCUR	**HIGH**
Impacts to habitats and biodiversity due to conveyor crossings of the Klipfonteinspruit and its tributary. Impacts include removal of marginal vegetation, disturbance of banks and beds, flow alterations, increased erosion, turbidity and sedimentation		Negative	Definite	4	4	3	5	**-4.1**
				MODH	LOC	MED	OCCUR	**HIGH**
Impacts to downstream reaches due to diversion of the Klipfonteinspruit		Negative	Probable	4	4	2	4	**-2.9**
				MODH	LOC	SHORT	VLIKE	**MODL**
Impacts due to conveyor crossings of the Klipfonteinspruit to downstream ecosystems and biota		Negative	Definite	3	4	2	4	**-2.7**
				MODL	LOC	SHORT	VLIKE	**MODL**
CUMULATIVE IMPACT	INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, **BEFORE MITIGATION**			6	4	4	5	**5.2**
				VHIGH	LOC	LONG	OCCUR	**VHIGH**
RESIDUAL IMPACT	INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, **AFTER MITIGATION**			3	4	3	5	**3.7**
				MODL	LOC	MED	OCCUR	**MODH**

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IMPACT DESCRIPTION		Direction of Impact	Degree of Certainty	Site A: Magnatude	Site A: Spatial	Site A: Temporal	Site A: Probability	Site A: **Impact Risk**
Code	*Phase*							
	Operational							
Habitat loss due to sedimentation. Eroded sediments and dust will end up in watercourses and wetlands, thus causing: smothering of benthic habitats, decrease in pool depths, increased turbidity and the colonisation of marginal habitats by monospecific stands of Typha. Changes in habitats may be followed by a loss of species and overall biodiversity. Erosion is likely to occur from soil stockpiles, rehabilitated areas and wetland crossings.		Negative	Probable	4 MODH	4 LOC	3 MED	4 VLIKE	**-3.2 MODH**
Habitat loss/decline due to Erosion. Where storm water is diverted around the Ash Disposal Facility or is concentrated at conveyor/road crossings, flow velocities will increase, causing erosion. This, in turn, will cause a deterioration in the availability and suitability of marginal and riparian habitats. This may lead to a loss of habitat specialists and an overall decline in biodiversity.		Negative	Probable	5 HIGH	3 ADJ	4 LONG	5 OCCUR	**-4.4 HIGH**
Decline in water quality due to ash dust blown into aquatic ecosystems - from the ash dump		Negative	Definite	5 HIGH	5 DIS	4 LONG	5 OCCUR	**-5.2 VHIGH**
Decline in water quality due to ash spills, seepage and contaminated stormwater (e.g. overflowing pollution control dams, leaking pipelines).		Negative	Definite	6 VHIGH	7 NAT	4 LONG	4 VLIKE	**-5 HIGH**
Decline in water quality due to spills, leaks (hydrocarbons) and solid waste		Negative	Possible	3 MODL	3 ADJ	2 SHORT	4 VLIKE	**-2.4 MODL**
Loss of sensitive species and biodiversity due to declines in water quality and habitats		Negative	Probable	5 HIGH	4 LOC	5 PERM	3 LIKE	**-3.1 MODH**
Impacts to water quality and habitats due to the Klipfonteinspruit diversion		Negative	Possible	3 MODL	4 LOC	4 LONG	4 VLIKE	**-3.2 MODH**
Impacts to overall integrity and biodiversity within the Klipfonteinspruit diversion		Positive	Possible	2 LOW	2 DEV	4 LONG	3 LIKE	**-1.8 LOW**
Impacts to water quality and habitats due to the conveyor(s). Impacts may include dust, spills, erosion and sedimentation.		Negative	Probable	5 HIGH	4 LOC	4 LONG	5 OCCUR	**-4.8 HIGH**
Impacts to overall integrity of ecologically sensitive downstream Ecosystems (Wilge River)		Negative	Possible	4 MODH	5 DIS	4 LONG	5 OCCUR	**-4.8 HIGH**
Impacts to water quality and habitats due to the conveyor(s). Impacts may include dust, spills, erosion and sedimentation.		Negative	Probable	6 VHIGH	6 PRO	4 LONG	4 VLIKE	**-4.7 HIGH**
Impacts to water quality as a result of major conveyor malfunctions		Negative	Possible	4 MODH	5 DIS	4 LONG	5 OCCUR	**-4.8 HIGH**
Loss of species and biodiversity and decline in overall integrity of downstream Ecosystems (Wilge River)		Negative	Possible	6 VHIGH	7 NAT	5 PERM	3 LIKE	**-4 MODH**
CUMULATIVE IMPACT	INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, **BEFORE MITIGATION**	Negative	Probable	6 VHIGH	6 PRO	4 LONG	5 OCCUR	**-5.9 VHIGH**
RESIDUAL IMPACT	INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, **AFTER MITIGATION**	Negative	Probable	5 HIGH	5 DIS	4 LONG	5 OCCUR	**-5.2 VHIGH**

IMPACT DESCRIPTION		Direction of Impact	Degree of Certainty	Site B: Magnatude	Site B: Spatial	Site B: Temporal	Site B: Probability	Site B: Impact Risk
Code	*Phase*							
	Post-Closure							
Habitat loss due to sedimentation. Eroded sediments and dust from rehabilitated areas will end up in watercourses and wetlands, smothering benthic habitats, increasing turbidity and resulting in the colonisation of marginal habitats by monospecific stands of Typha. Changes in habitats may be followed by a loss of species and overall biodiversity.		Negative	Probable	2	3	3	4	**-2.4**
				LOW	ADJ	MED	VLIKE	**MODL**
Decline in water quality due to ash dust blown into aquatic ecosystems		Negative	Probable	3	4	4	4	**-3.2**
				MODL	LOC	LONG	VLIKE	**MODH**
Decline in water quality due to slumping of Ash Disposal Facility walls, seepage and stormwater containing ash contaminants (e.g. overflowing pollution control dams, leaking pipelines).		Negative	Definite	5	4	4	4	**-3.8**
				HIGH	LOC	LONG	VLIKE	**MODH**
Loss of sensitive species and biodiversity due to declines in water quality and habitats		Negative	Definite	3	3	5	4	**-3.2**
				MODL	ADJ	PERM	VLIKE	**MODH**
Impacts to overall integrity of ecologically sensitive downstream Ecosystems (Wilge River)		Negative	Possible	4	5	4	3	**-2.9**
				MODH	DIS	LONG	LIKE	**MODL**
CUMULATIVE IMPACT	INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, **BEFORE MITIGATION**	Negative	Probable	5	5	4	4	**-4.1**
				HIGH	DIS	LONG	VLIKE	**HIGH**
RESIDUAL IMPACT	INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, **AFTER MITIGATION**	Negative	Probable	4	4	4	4	**-3.5**
				MODH	LOC	LONG	VLIKE	**MODH**
Impacts to overall integrity of ecologically sensitive downstream Ecosystems (Wilge River)		Negative	Possible	4	5	4	4	**-3.8**
				MODH	DIS	LONG	VLIKE	**MODH**
Impacts due to the conveyor crossings of the Klipfonteinspruit and its tributary (e.g. erosion, sedimentation, increased turbidity and sedimentation)		Negative	Probable	4	5	4	4	**-3.8**
				MODH	DIS	LONG	VLIKE	**MODH**
Impacts to water quality and habitat integrity by solid waste including hazardous waste		Negative	Possible	3	3	4	4	**-2.9**
				MODL	ADJ	LONG	VLIKE	**MODL**
CUMULATIVE IMPACT	INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, **BEFORE MITIGATION**	Negative	Probable	5	5	4	5	**-5.2**
				HIGH	DIS	LONG	OCCUR	**VHIGH**
RESIDUAL IMPACT	INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, **AFTER MITIGATION**	Negative	Probable	4	5	4	4	**-3.8**
				MODH	DIS	LONG	VLIKE	**MODH**

IMPACT DESCRIPTION		Direction of Impact	Degree of Certainty	Site A				
				Magnitude	Spatial	Temporal	Probability	**Impact Risk**
Code	*Phase*							
	Post-Closure							
Habitat loss due to sedimentation. Eroded sediments and dust from rehabilitated areas will end up in watercourses and wetlands, smothering benthic habitats, increasing turbidity and resulting in the colonisation of marginal habitats by monospecific stands of Typha. Changes in habitats may be followed by a loss of species and overall biodiversity.		Negative	Probable	3	3	3	4	**-2.7**
				MODL	ADJ	MED	VLIKE	**MODL**
Decline in water quality due to ash dust blown into aquatic ecosystems		Negative	Probable	3	4	4	3	**-2.4**
				MODL	LOC	LONG	LIKE	**MODL**
Decline in water quality due to slumping of Ash Disposal Facility walls, seepage and stormwater containing ash contaminants (e.g. overflowing pollution control dams, leaking pipelines).		Negative	Definite	4	5	4	4	**-3.8**
				MODH	DIS	LONG	VLIKE	**MODH**
Loss of sensitive species and biodiversity due to declines in water quality and habitats		Negative	Definite	3	3	5	4	**-3.2**
				MODL	ADJ	PERM	VLIKE	**MODH**
Impacts to overall integrity of ecologically sensitive downstream Ecosystems (Wilge River)		Negative	Possible	4	4	5	4	**-3.8**
				MODH	LOC	PERM	VLIKE	**MODH**
CUMULATIVE IMPACT	INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, **BEFORE MITIGATION**	Negative	Probable	6	6	4	5	**-5.9**
				VHIGH	PRO	LONG	OCCUR	**VHIGH**
RESIDUAL IMPACT	INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, **AFTER MITIGATION**	Negative	Probable	3	5	5	4	**-3.8**
				MODL	DIS	PERM	VLIKE	**MODH**

14. ENVIRONMENTAL IMPACT STATEMENT: ALTERNATIVE B

Figure 14-1 shows Alternative B located on the catchment divide between B20F and B20D. As such, it will impact on the headwaters of four tributaries, two draining into the Bronkhorstspruit and two draining into the Wilge River. These tributaries are spring-fed and have a particularly good water quality. The conveyor route will run alongside the Klipfonteinspruit, crossing it and its two tributaries in three places, with additional crossings of the Wilge River as well as a tributary of the Wilge River on the western bank. Relevant aquatic sampling sites include B1-4, Pan B, KF3, Kus and W4.

Limitations and assumptions:
It should be noted that no detailed plans were available for this site, nor for the conveyor crossings. As such impacts were generically assessed.

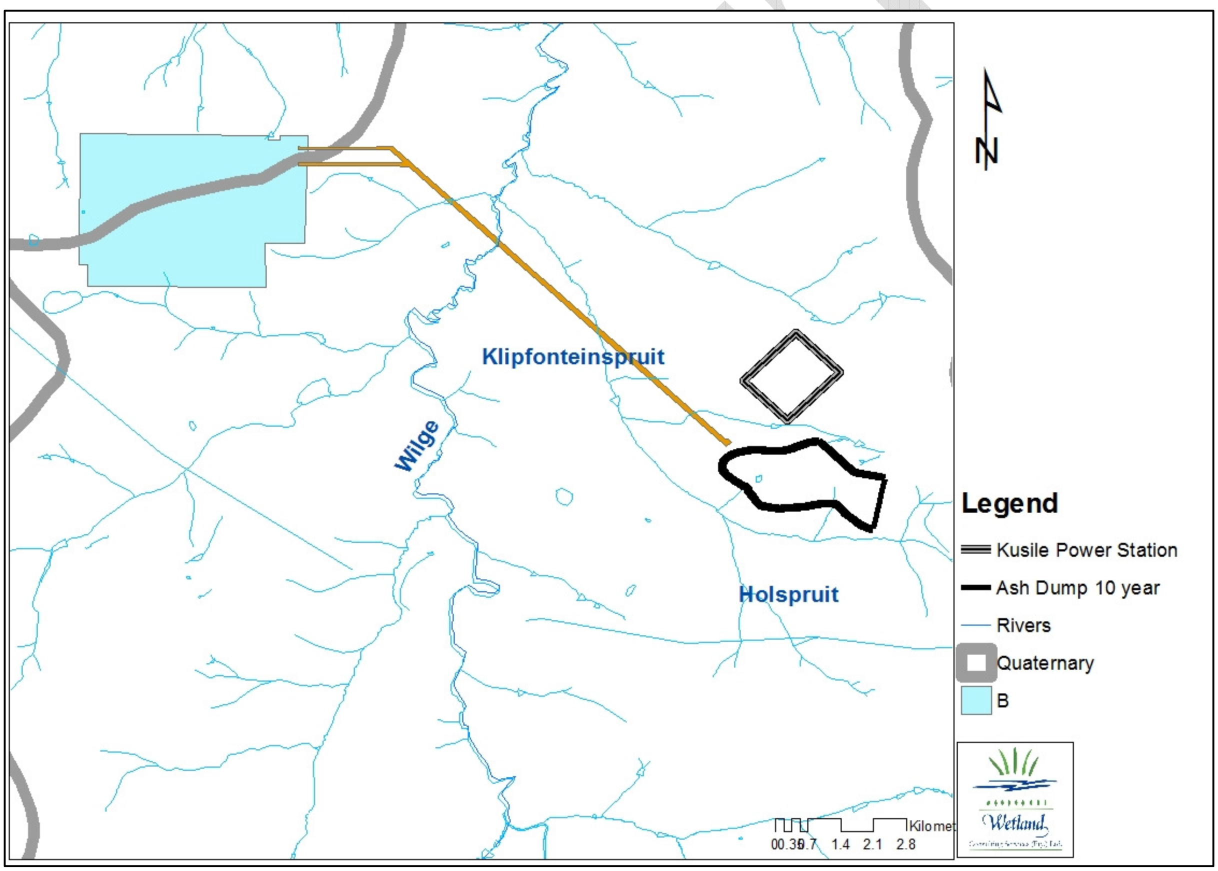

Figure 14-1. Figure showing the location and approximate extent of Alternative B, together with its conveyor route, relative to watercourses and catchments.

14.1 STATUS QUO

The main current impacts to surface water are related to agriculture. The Ash Disposal Facility footprint covers an area that is commercially cultivated and irrigated. Construction activities related to the Kusile Power Station, as well as mining-related water quality impacts were evident within the Klipfonteinspruit.

14.2 PROJECT IMPACTS (UNMITIGATED)

Impacts associated with Alternative B will be widespread, stretching across two quaternary catchments (B20F and B20D) and will affect six watercourses (including the Klipfonteinspruit and Wilge River) and one seasonal pan. As such, mitigation will be difficult, especially with regard to spill containment, and a catchment level approach will be essential.

The major impacts associated with Alternative B are likely to be due to the extensive conveyor route which will run alongside the Klipfonteinspruit and cross four watercourses, including the Wilge River. Impacts associated with potential spills at conveyor crossings cannot be accurately predicted and mitigation of such events will be difficult. As such, the worst case scenario was assumed. This impact could be far-reaching but would be mostly evident in the operational phase.

The Ash Disposal Facility itself will impact upon the headwater streams draining into two quaternary catchments (the Bronkhorstspruit system and the Wilge River). Water quality is currently good within these systems and water quality impacts are likely to be highly significant.

The impacts are discussed more fully below.

14.2.1 Construction Phase

The major impacts during construction will be due to mobilisation of sediments. Conveyor crossings, in particular, will result in significant disturbance to riparian and marginal habitats as well as to flow regimes. Existing impacts to the Klipfonteinspruit due to erosion and turbidity will be exacerbated. Continued erosion of the Klipfonteinspruit will cause a progressive decline in any wetland functions it currently offers and current water quality impacts may be transferred further downstream to the Wilge River.

Erosion at the crossings of the Wilge River, its western tributary and the Klipfonteinspruit will result in significantly increased sediment loads being carried into the Wilge River. This will result in water quality impacts (e.g. turbidity) and, where sediments settle out, there will be a decline in the availability and suitability of clean, cobbled habitats favoured by sensitive species, including *Chiloglanis pretoriae.* There may thus be a loss of sensitive fish and aquatic macroinvertebrates from downstream reaches and an overall decline in biodiversity, potentially at a provincial scale.

Within the Ash Disposal Facility footprint, the removal of vegetation and the laying of the impermeable membrane will decrease infiltration of rainwater and will result in greater volumes and velocities of storm water leaving the site via the four tributary systems draining into the Wilge River and Bronkhorstspruit. Increased flow volumes and velocities will cause erosion, with eroded sediments being deposited further downstream where they will cause an alteration in instream or marginal habitats, followed by changes in species composition and assemblage patterns.

Sediments and dust may be washed or blown from soil stockpiles, storm water berms and from the construction site itself. These will be transported into receiving watercourses where they will settle

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out in pools under low flow conditions. This may impact on aquatic habitats by reducing the availability of deep pool habitats (preferred by certain fish) and altering the marginal habitats as silted up areas may be colonised by dense stands of *Typha.* In addition, visual predators (e.g. fish, dragonflies and damselflies) may be affected by the turbid conditions that result from high sediment loads. Should any sediments be carried into the Wilge River, cobble biotopes may become ‘clogged’ with sediment, thus affecting a range of fish (including *Chiloglanis pretoriae)* and aquatic macroinvertebrates that have a preference for clean, cobbled substrates.

During the construction phase, there may be water quality impacts due to accidental spills, for example of hydrocarbons (diesel, grease or oil), cement or sewage. In addition, leaks from faulty machinery or from ineffective toilet facilities, may create additional contamination. Solid waste, including hazardous waste items such as PVC and tyres, could also result in a decline in water quality. A decline in water quality and habitats may result in the displacement of certain taxa sensitive to changes in water quality.

The combined weighted project impact to aquatic ecosystems (prior to mitigation) during the construction phase will **Probably** be of a VERY HIGH negative significance, at the *provincial* scale. The impact will act in the long term and will *definitely* occur. The impact risk class is thus **Very High.**

With mitigation, impacts can be reduced in magnitude, extent and likelihood to a risk factor of **High.**

14.2.2 Operational Phase

The main impacts during the Operational Phase are likely to be related to a decline in water quality. Surface runoff that comes into contact with ash is likely to become contaminated, these contaminants then being carried into downstream ecosystems. Wind-blown ash or conveyor spills as well as subsurface seepage are likely to cause additional contamination. Overflowing or inadequate pollution control dams, dam failures or conveyor malfunctions pose the greatest risk to water quality. Conveyor malfunctions or major spills at stream crossings, especially the Wilge River crossing, will have severe consequences in terms of water quality and loss of biota, these impacts potentially being carried downstream as far as The Kruger National Park and Mozambique. Such an impact could potentially have national consequences for rare species such as *Chiloglanis pretoriae.*

The major water quality impacts are likely to be due to salts (sulphates in particular), acidity and heavy metals. A decline in water quality is likely to cause a loss of taxa that are sensitive to changes in water quality which may, in turn, affect animals higher up in the food chain (e.g. otters and water mongooses). There will also be significant impacts to commercial agriculture through the loss of good quality and quantities of water (although assessment of this impact is beyond the scope of this report).

Impacts to habitats due to erosion, turbidity and sedimentation, as mentioned for the construction phase, will be ongoing during the operational phase, resulting in further declines in diversity as the availability of suitable habitats declines. As the Klipfonteinspruit continues to erode, its wetland

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functions (e.g. flow attenuation, water quality improvement) will be compromised so that impacts are more likely to be transferred further downstream as far as the Wilge River.

There will almost certainly be a loss or displacement of sensitive taxa from the Wilge River due to both habitat changes and water quality impacts associated with the conveyor crossings as well as storm water and groundwater impacts from the Ash Disposal Facility.

Additional impacts associated with the operational phase include leaks and spills (e.g. from machinery, inappropriate storage or disposal of potential contaminants (grease, fuel, oil, paints or other chemicals) and waste (e.g. PVC, used oils, tyres).

It is understood that rehabilitation will be ongoing during the operational phase. Impacts may include erosion of rehabilitated areas, causing sedimentation of drainage systems. Invasion by alien vegetation will be a further consideration.

The combined weighted project impact to aquatic ecosystems (**prior to mitigation**) during the operational phase will depend on the occurrence of major spills, especially at conveyor crossings. Thus the impact will Probably be of a VERY HIGH to SEVERE negative significance, at a Provincial to National scale. The impact will be permanent and will *definitely* occur. The impact risk class is thus **Very High to Severe.**

Impacts due to the conveyor crossings, particularly of the Wilge River, will be difficult to reliably mitigate during the operational phase. However, **with mitigation,** the scale of the impact can be reduced to *District*, although the risk class will remain **Very High to Severe**.

14.2.3 Closure and Post-Closure Phases

With regard to the Ash Disposal Facility, all impacts associated with the operational phase will continue to be relevant during the decommissioning and closure phases. Water quality impacts due to seepage or ineffective storm water and pollution control handling will continue to be a risk.

With regard to the conveyor, the dismantling of infrastructure will create solid waste and will increase the potential for spills as well as for erosion of exposed banks. However, impacts due to accidental spills of ash at the conveyor crossings of watercourses will no longer be a major risk during closure and post-closure. However, catchment-scale impacts to the Wilge and Bronkhorstspruit systems, sustained during the operational phase of the project, may already have caused severe and permanent impacts (e.g. local extinction of species and permanent loss of habitats) that would render rehabilitation or restoration of these systems difficult or impossible.

The combined weighted project impact to aquatic ecosystems (prior to mitigation) during the Closure and Post-Closure phases will **Probably** be of a HIGH negative significance, at the *Provincial* scale. The impact will act in the long-term and will *very likely* occur. The impact risk class is thus **High.**

With effective mitigation, the extent of the impact can be limited to the district scale while the risk class remains **HIGH**.

14.3 CUMULATIVE IMPACTS

Developing a 60-year Ash Disposal Facility at Alternative B will cause water quality and quantity issues within the headwaters of four tributaries currently considered to have good water quality, with only agricultural impacts to habitats and water quality evident. These impacts will be spread out over two quaternary catchments. The Bronkhorstpruit catchment currently has very few mining-related impacts and impacts to these headwater streams will set the stage for future developments within this quaternary catchment.

The selection of Alternative And its associated conveyor route is likely to spread the impacts of the Kusile Power Station and associated Ash Disposal Facility over two catchments and six watercourses, including the Wilge River, the Klipfonteinspruit, four tributaries draining Alternative B and two additional Klipfonteinspruit tributaries. The spread of these impacts will make mitigation extremely difficult, particularly in terms of containing accidental spills. The Wilge River is most at risk. Considering the health of this river in terms of habitats and aquatic macroinvertebrates and the presence of sensitive fish species, as well as the existence of conservation areas downstream (e.g. Ezemvelo Nature Reserve), cumulative impacts to the river could potentially be highly significant.

The development of the conveyor to Alternative B will also add to the already-impacted erosion and channelization of the Klipfonteinspruit.

The Wilge River is a tributary of the seriously impacted Olifants River. Impacts to the Wilge River will thus exacerbate impacts to the Olifants River system, potentially pushing these impacts beyond a critical level. Major pollution events (e.g. major spills or structural collapses) could potentially be carried as far as Mozambique, with international implications.

The baseline impacts are considered to be substantial, and additional project impact (if no mitigation measures are implement) will increase the significance of the existing baseline impacts, the cumulative unmitigated impact will **probably** be of a VERY HIGH negative significance, at the *Provincial to National Scale*. The impact *is going to happen* and will be permanent. The impact risk class is thus **Very High**.

14.4 MITIGATION

Mitigation measures for the Ash Disposal Facility can be implemented with relative ease and would include, for example, sediment trapping, effective stormwater management, appropriate lining with an impermeable membrane, careful design and maintenance of pollution control dams and dust suppression. These measures are discussed in greater detail in 14.4.1-3. below.

Impacts due to the conveyor will be more difficult to mitigate. However the following measures could be applied:

- Appropriate housing, especially at river crossings to prevent contamination due to dust and spills.
- Conveyors and conveyor pedicels should span the watercourse and its floodlines (at least >1:100 year floodlines) so as not to modify flows or to risk flooding during large storm events.
- Conscientious monitoring and maintenance of the conveyor to prevent malfunctions.

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- Conscientious monitoring and maintenance of stormwater trenches and pollution control dams to prevent leaks, spills or seepage.
- An emergency preparedness plan should aim to contain spills and, in particular, prevent contamination of downstream reaches of the Wilge River.
- Sediments should be contained at sources and prevented from entering watercourses.
- Active management and rehabilitation of the Klipfonteinspruit would be required to curtail continued erosion.

Even with effective mitigation, however, impacts to the Wilge River are likely to be unavoidable.

14.4.1 General Mitigation (All Phases)

14.4.1.1 Seepage Prevention

It is essential that the Ash Disposal Facility site, together with stormwater drains and pollution control dams, be appropriately lined (according to the relevant waste classification), so that no contaminants reach the groundwater.

14.4.1.2 Erosion prevention and management along the conveyor route

To mitigate impacts to the Klipfonteinspruit due to the conveyor, the Klipfonteinspruit, which is already seriously eroded, will need to be actively managed and, where necessary, rehabilitated, in consultation with a wetland specialist. Management of the Klipfonteinspruit should aim to restore and maintain wetland functions, specifically flow attenuation, habitat continuity and water quality improvement, so that impacts are not transferred downstream to the Wilge River.

It is additionally recommended that flow-gauging structures be incorporated into the design of the Klipfonteinspruit management plan, so that volumes and velocities can be more effectively managed. V-notch weirs would be useful to measure (and regulate) stormwater volumes being discharged from upstream developments.

14.4.1.3 Access Management

Wetland areas, together with their buffers, should be cordoned off and considered no-go areas as far as possible. In particular, vehicular traffic should be prohibited from entering wetland areas. Soil stockpiles and toilet facilities should be placed outside of wetland areas. All construction staff should be informed on the sensitivity of the wetlands.

It should be noted that all activities within wetland areas and their buffers (including rehabilitation) will require a Water Use Licence.

14.4.1.4 Stream/River Crossings

The position and design of stream crossings should include the following factors

- Follow existing roads as far as possible.
- Disturbance of riparian areas along the Klipfonteinspruit should be minimised. Adjacent riparian areas should be cordoned off and considered no-go-areas.
- The conveyor crossings should maintain migration corridors and habitat continuity for riparian vertebrates (e.g. otter, duiker, water mongooses and frogs).
- Crossings should ideally be perpendicular to streams to minimise the footprint.

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- The conveyor should be enclosed at stream crossings, including buffer zones, and should have adequate capacity to contain major spills.
- Transfers should be located outside of wetland areas.
- Dirty stormwater dams and trenches at conveyor crossings should be designed to prevent spills or leaks of contaminated water and no dirty water should be discharged directly into wetland areas.
- Ensure easy access for maintenance or clean ups.
- The time period during which flow is modified due to construction should be kept as short as possible.
- All wetland/riparian areas disturbed during construction should be rehabilitated immediately upon completion of construction.
- Conveyors and conveyor pedicels should span the watercourse and its floodlines (at least >1:100 year floodlines) so as not to modify flows or to risk flooding during large storm events.
- Sediments should be contained at sources and prevented from entering watercourses.

14.4.1.5 Stormwater Management

The design of the stormwater management system should take into account:

- Quality of water leaving the site (separation of clean and dirty water)
- Retention/treatment of dirty water
- Volumes and velocities of water leaving the site

Stormwater berms and trenches should be located so that all ‘clean’ water derived from the catchment upslope of the Ash Disposal Facility and soil stockpiles is diverted around it and into the downslope wetland areas. Sediments should be trapped before discharge into wetlands or watercourses. Ensure adequate flow attenuation within stormwater trenches and at pond outlets. There should be a vegetated buffer between stormwater outlets and downstream wetlands.

Stormwater management should be applied at a catchment scale and should take into account impacts to the Klipfonteinspruit, Wilge River and Bronkhorstspruit.

Stormwater management, including pollution control dams and stormwater trenches, should be designed according to DWAF Best Practice Guidelines (2006, 2007a, b, 2008). Infrastructure associated with dirty water (stormwater trenches and dams) should be lined with an appropriate impermeable layer (based on the waste classification) and should cater for the >1:50 year storm events.

14.4.1.6 Erosion and Sediment Management

Construction should take place in the dry season to avoid the need for major stream diversions or coffer dams and prevent erosion from exposed soils and stockpiles. Areas to be cleared should be kept to a minimum at any one time.

No vegetation clearing or topsoil removal may take place within the 32m buffer surrounding watercourses/wetlands. Vegetation clearing and topsoil removal should be restricted to as small an Alternative As possible and should be phased, i.e. avoid clearing the entire footprint at once.

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Install sediment traps and stormwater berms as soon as possible during the construction process. These berms would serve to intercept flows containing suspended sediments and create a depositional environment. They should be located outside the wetland boundaries and should be created prior to construction and vegetation clearing on the stockpile footprint commencing. All surface runoff should be directed to a sediment trap. Silt traps should be regularly inspected and cleaned to ensure optimal functionality. Energy dissipaters and erosion protection measures should be incorporated at points of discharge which should be located outside of wetland areas. The 32m vegetated buffer will facilitate in trapping sediment. Stormwater berms should be appropriately sloped and stabilised (e.g. revegetated) to prevent collapses.

Locate all topsoil stockpiles outside the delineated wetland and 32m buffer zone. Install sediment barriers along the lower edge of the soil stockpile. Limit the height of the topsoil stockpile and minimise the slope of the side slopes so as to avoid collapses.

14.4.1.7 Prevention of Spills and/or Leaks (See DWAF guidelines, 2007)

- Toilet facilities should be located outside of wetland areas.
- Ensure separation of clean and dirty water and allow clean water to enter natural water bodies after effective attenuation and sediment trapping.
- To prevent spillages, vehicles should be well maintained.
- Diesel and oil/grease should be stored in bunded areas that will allow any spillages to be easily and quickly isolated and prevent contamination of any soils or water.
- Spills should be cleaned up with approved absorbent material such as “Drizit” or “Spillsorb”. These should be kept in sufficient quantities on site to deal with small spills. Absorbent material and contaminated soil should be disposed of at a registered hazardous waste site.
- An emergency preparedness plan should be compiled and all construction staff aware of procedures in event of a spill.
- Hazardous waste (e.g. oil, diesel, grease, PVC, tyres), should be stored in bunded/impermeable areas and disposed of appropriately at a registered landfill site. Potential spills or seepage of hazardous waste must be anticipated and prevented.
- Should cement be used on site, the following mitigation measures apply:
    - Carefully control all on-site operations that involve the use of cement and concrete (this applies to areas other than the batching plant).
    - Limit cement and concrete mixing to single sites where possible.
    - Use plastic trays or liners when mixing cement and concrete: Do not mix cement and concrete directly on the ground.
    - Dispose of cement in the approved manner (solid waste concrete may be treated as inert construction rubble, but wet cement and liquid slurry, as well as cement powder must be treated as hazardous waste).
- Implement an aquatic biomonitoring and water quality programme. Where target endpoints are not met, recommendations should translate directly into follow-up action that is recorded and auditable.

14.4.1.8 Dust Suppression

Dust suppression should aim to minimise dustfall into wetland areas.

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14.4.1.9 Monitoring

A monitoring, including biomonitoring, should be compiled and implemented. Recommendations for monitoring are given in 14.4.3 below. Monitoring/biomonitoring data must be compared with baseline levels given in this report. Where target endpoints are not met, recommendations should translate directly into follow-up actions that are documented and audited.

14.4.2 Operational and Closure/Post-Closure Phases

All general mitigation given above should apply to all phases of the development equally. The following additional mitigation measures apply to the Operational, Closure and Post-Closure phases:

14.4.2.1 Prevent Water Quality Declines

The following measures should be applied to prevent and minimise impacts to water quality due to the Ash Disposal Facility and its conveyors during operational and closure phases:

- Pollution Control dams should be designed according to strict safety requirements and should be regularly inspected for leaks, damage or maintenance requirements. Where irregularities are detected, they should be speedily remedied to avoid the risk of structural failure.
- Conveyor and road crossings of wetlands should be regularly inspected for erosion, mechanical problems, leaks or spillages. These should be timeously repaired.
- Should larger spillages occur due to malfunctioning of the conveyor or for any other reason, clean-up of the spillages should be undertaken as soon as possible following the incident. In this regard regular inspection of the entire conveyor route should be undertaken.
- An emergency response plan should be compiled to address structural failures and major accidental spillages. This should address the containment of spills as well as the post-spill rehabilitation.

14.4.2.2 Dust Suppression

It is understood that the Ash Disposal Facility will be irrigated to reduce dust. Dampness should be monitored to ensure a balance is maintained between dust suppression and slumping/collapses due to excessive wetting. Stormwater should be used for dust suppression to avoid the need for abstraction from natural water resources.

14.4.2.3 Ongoing Management of watercourses impacted by the conveyor

It is essential that the catchment-level management of the Klipfonteinspruit and Wilge River continue throughout the operational and closure phases. Regular monitoring, with timeous management interventions, should ensure that wetland functions are maintained and that impacts are not being transferred downstream into the Wilge River.

14.4.2.4 Rehabilitation

It is understood that rehabilitation will be ongoing, involving the revegetation of completed areas. It is essential that placement of topsoil is uniformly applied so as to prevent pooling of water.

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Revegetated areas should be regularly inspected for erosion rills and these should be timeously managed so as to prevent structural collapses.

An alien vegetation management plan should be compiled and implemented as part of the rehabilitation process and should aim to avoid invasion of wetland and riparian areas and the water-borne dispersal of propagules/seeds to downstream areas.

14.4.2.5 Waste Management

Deconstruction activities should be confined to a minimum area, which should be clearly demarcated. Delineated wetlands and riparian areas should be considered no-go areas during decommissioning and closure. Sediment trapping mechanisms should prevent soils from being washed into watercourses. Movement of machinery and vehicles during the infrastructure removal process must be strictly controlled to prevent disturbance to wetland and riparian areas.

14.4.3 Recommendations for Monitoring

A comprehensive monitoring (including biomonitoring) programme should be compiled. Monitoring should target discharge points as well as impacts to downstream watercourses. Results should be compared with baseline levels given in this report (and any other pre-development data).

The discharges points that should be included within the monitoring plan include all of the stormwater discharge points, discharges from the sediment traps, the sediment traps themselves and wetland crossings. Visual inspections with photographic records should be conducted regularly (e.g. weekly - monthly). Discharge points should be inspected for signs of erosion and sediment deposition, and corrective measures implemented should any erosion damage be observed. Where sediment build up occurs at the discharge points or sediment smothers vegetation downstream of the discharge points, the source of the sediment should be identified and corrective measures implemented to prevent further sedimentation. The sediment traps should be inspected and cleaned on a regular basis to ensure efficient operation of the sediment trap. Monitoring and maintenance guidelines as detailed in the surface water hydrology report (which includes the design of the sediment trap) should be applied.

Biomonitoring should include:

- Water quality (including major anions and cations, pH, ICP scans for metals, TSS, turbidity)
- Toxicity testing downstream of pollution control dams
- Habitat Integrity
- SASS5 and fish
- Wetland Rehabilitation and/or erosion (e.g. of the Klipfonteinspruit)

Sampling sites should include sites, KS2, KS3, W3, W4, W5, W6, B1, B2, B3, B4, B Pan, with additional sites where relevant.

It is recommended that water quality monitoring be conducted every four months, with pH, Electrical conductivity, suspended solids and turbidity monitored weekly during the construction phase. Biomonitoring should be conducted every 4-6 months.

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It is essential that recommendations given in monitoring and biomonitoring reports be translated into follow-up action that is documented and audited. Failure to do so renders the biomonitoring process useless.

14.5 RESIDUAL IMPACT

The residual impact of the development is likely to include significant declines in water quality and habitat suitability and/or availability. These impacts are likely to be spread across two quaternary catchments (drained by the Wilge River and the Bronkhorstspruit) and six watercourses, as well as a seasonal pan. It is anticipated that water quality in the Wilge River will decline, even with mitigation, and the loss of sensitive species will almost definitely occur. Should there be major spills at the conveyor crossing, this impact will be severe and will potentially extend downstream as far as Mozambique.

After mitigation the impacts to aquatic ecosystems will probably be of a MODERATELY HIGH negative significance, affecting the *province* in extent. The impact is going to happen and will be *permanent*. The impact risk class is thus **Moderately High**.

14.6 IMPACT MATRIX

The impacts identified and discussed above have been rated according to the impact assessment methodology described in section 12.1. These ratings are provided in the matrix presented in the Tables (14-1) below.

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Table 14-1. Impact Ratings for Construction, Operational, Closure and Post-Closure Phases for alternative B.

Code	IMPACT DESCRIPTION	Direction of Impact	Degree of Certainty	Magnatude	Spatial	Temporal	Probability	Impact Risk
Code	*Phase*							
	CONSTRUCTION							
	Habitat loss due to sedimentation. Eroded sediments and dust will end up in watercourses and wetlands, smothering benthic habitats, increasing turbidity and resulting in the colonisation oif marginal habitats by monospecific stands of Typha. Changes in habitats may be followed by a loss of species and overall biodiversity.	Negative	Probable	4	3	4	5	**-4.1**
				#N/A	ADJ	LONG	OCCUR	**HIGH**
	Habitat loss/decline due to Erosion. Runoff is likely to increase as a result of vegetation clearing and replacing it with an impermeable lining. Release of concentrated flows into downstream watercourses will cause erosion which, in turn, will cause a deterioration in the availability and suitability of marginal and riparian habitats. This may lead to a loss of habitat specialists and an overall decline in biodiversity.	Negative	Probable	5	3	4	5	**-4.4**
				HIGH	ADJ	LONG	OCCUR	**HIGH**
	Decline in water quality due to spills and leaks as well as turbidity due to erosion and sediment transport	Negative	Definite	4	4	2	5	**-3.7**
				MODH	LOC	SHORT	OCCUR	**MODH**
	Destruction of wetlands that fall within the development footprint.	Negative	Definite	5	2	5	5	**-4.4**
				HIGH	DEV	PERM	OCCUR	**HIGH**
	Loss of sensitive species and biodiversity due to declines in water quality and habitats	Negative	Possible	4	4	5	3	**-2.9**
				MODH	LOC	PERM	LIKE	**MODL**
	Impacts to overall integrity of ecologically sensitive and important downstream ecosystems (e.g. Wilge River)	Negative	Probable	4	5	5	4	**-4.1**
				MODH	DIS	PERM	VLIKE	**HIGH**
	Impacts to habitats and biodiversity due to conveyor crossings of the Wilge River, Klipfonteinspruit and Wilge Tributary. Impacts include removal of riparian and marginal vegetation, disturbance of banks and beds, flow alterations, increased erosion, turbidity and sedimentation	Negative	Definite	5	4	5	5	**-5.2**
				HIGH	LOC	PERM	OCCUR	**VHIGH**
	Impacts due to conveyor crossings of the Wilge River, Klipfonteinspruit and Wilge Tributary to downstream ecosystems and biota	Negative	Definite	4	6	5	4	**-4.4**
				MODH	PRO	PERM	VLIKE	**HIGH**
CUMULATIVE IMPACT	INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, **BEFORE MITIGATION**			6	6	4	5	**5.9**
				VHIGH	PRO	LONG	OCCUR	**VHIGH**
RESIDUAL IMPACT	INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, **AFTER MITIGATION**			5	5	4	4	**4.1**
				HIGH	DIS	LONG	VLIKE	**HIGH**

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Code	IMPACT DESCRIPTION	Direction of Impact	Degree of Certainty	Site B: Magnatude	Site B: Spatial	Site B: Temporal	Site B: Probability	Site B: **Impact Risk**
Code	*Phase*							
	Operational							
	Habitat loss due to sedimentation. Eroded sediments and dust will end up in watercourses and wetlands, thus causing: smothering of benthic habitats, decrease in pool depths, increased turbidity and the colonisation of marginal habitats by monospecific stands of Typha. Changes in habitats may be followed by a loss of species and overall biodiversity. Erosion is likely to occur from soil stockpiles, rehabilitated areas and wetland crossings.	Negative	Probable	4 MODH	4 LOC	3 MED	4 VLIKE	**-3.2** **MODH**
	Habitat loss/decline due to Erosion. Where storm water is diverted around the Ash Disposal Facility or is concentrated at conveyor/road crossings, flow velocities will increase, causing erosion. This, in turn, will cause a deterioration in the availability and suitability of marginal and riparian habitats. This may lead to a loss of habitat specialists and an overall decline in biodiversity.	Negative	Probable	5 HIGH	3 ADJ	4 LONG	5 OCCUR	**-4.4** **HIGH**
	Decline in water quality due to ash dust blown into aquatic ecosystems - from the ash dump	Negative	Definite	5 HIGH	6 PRO	4 LONG	5 OCCUR	**-5.5** **VHIGH**
	Decline in water quality due to ash spills, seepage and contaminated stormwater (e.g. overflowing pollution control dams, leaking pipelines).	Negative	Definite	7 SEV	7 NAT	4 LONG	4 VLIKE	**-5.3** **VHIGH**
	Decline in water quality due to spills, leaks (hydrocarbons) and solid waste	Negative	Possible	3 MODL	3 ADJ	2 SHORT	4 VLIKE	**-2.4** **MODL**
	Loss of sensitive species and biodiversity due to declines in water quality and habitats	Negative	Probable	6 VHIGH	4 LOC	5 PERM	4 VLIKE	**-4.4** **HIGH**
	Impacts to water quality and habitats due to the conveyor(s). Impacts may include dust, spills, erosion and sedimentation.	Negative	Probable	7 SEV	6 PRO	4 LONG	5 OCCUR	**-6.3** **SEV**
	Impacts to water quality as a result of major conveyor malfunctions	Negative	Possible	7 SEV	7 NAT	5 PERM	3 LIKE	**-4.2** **HIGH**
	Loss of species and biodiversity and decline in overall integrity of downstream Ecosystems (Wilge River)	Negative	Possible	7 SEV	7 NAT	5 PERM	4 VLIKE	**-5.6** **VHIGH**
CUMULATIVE IMPACT	INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, **BEFORE MITIGATION**	Negative	Probable	7 SEV	7 NAT	5 PERM	5 OCCUR	**-7** **SEV**
RESIDUAL IMPACT	INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, **AFTER MITIGATION**	Negative	Probable	7 SEV	6 PRO	5 PERM	5 OCCUR	**-6.6** **SEV**

IMPACT DESCRIPTION		Site B						
		Direction of Impact	Degree of Certainty	Magnatude	Spatial	Temporal	Probability	**Impact Risk**
Code	*Phase*							
	Closure							
Habitat loss due to sedimentation. Eroded sediments/dust from stockpiles and rehabilitated areas will end up in watercourses and wetlands, smothering benthic habitats, increasing turbidity and resulting in the colonisation of marginal habitats by monospecific stands of Typha. Changes in habitats may be followed by a loss of species and overall biodiversity. Dismantling of infrastructure and conveyors may result in the mobilisation of sediments that are washed into downstream watercourses.		Negative	Probable	3	4	3	4	**-2.9**
				MODL	LOC	MED	VLIKE	**MODL**
Habitat loss/decline due to Erosion. Where storm water is diverted around the Ash Disposal Facility or is concentrated at conveyor/road crossings, flow velocities will increase, causing erosion. This, in turn, will cause a deterioration in the availability and suitability of marginal and riparian habitats and a decline in water quality. This may lead to a loss of habitat specialists and an overall decline in biodiversity.		Negative	Probable	4	3	4	3	**-2.4**
				MODH	ADJ	LONG	LIKE	**MODL**
Decline in water quality due to ash dust blown into aquatic ecosystems		Negative	Definite	4	4	4	4	**-3.5**
				MODH	LOC	LONG	VLIKE	**MODH**
Decline in water quality due to slumping of Ash Disposal Facility walls, seepage and stormwater containing ash contaminants (e.g. overflowing pollution control dams, leaking pipelines).		Negative	Definite	5	4	4	4	**-3.8**
				HIGH	LOC	LONG	VLIKE	**MODH**
Decline in water quality due to spills and leaks		Negative	Possible	3	3	2	4	**-2.4**
				MODL	ADJ	SHORT	VLIKE	**MODL**
Loss of sensitive species and biodiversity due to declines in water quality and habitats		Negative	Probable	6	4	5	3	**-3.3**
				VHIGH	LOC	PERM	LIKE	**MODH**
Impacts to overall integrity of ecologically sensitive downstream Ecosystems (Wilge River)		Negative	Possible	5	6	4	4	**-4.4**
				HIGH	PRO	LONG	VLIKE	**HIGH**
Impacts due to the conveyor crossings of the Wilge River, Klipfonteinspruit and Wilge Tributary (including erosion, sedimentation, increased turbidity and sedimentation		Negative	Probable	5	6	3	5	**-5.2**
				HIGH	PRO	MED	OCCUR	**VHIGH**
Impacts to water quality and habitat integrity by solid waste including hazardous waste		Negative	Possible	3	3	4	4	**-2.9**
				MODL	ADJ	LONG	VLIKE	**MODL**
CUMULATIVE IMPACT	INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, **BEFORE MITIGATION**	Negative	Probable	5	6	4	4	**-4.4**
				HIGH	PRO	LONG	VLIKE	**HIGH**
RESIDUAL IMPACT	INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, **AFTER MITIGATION**	Negative	Probable	5	5	4	4	**-4.1**
				HIGH	DIS	LONG	VLIKE	**HIGH**

IMPACT DESCRIPTION		Site B						
		Direction of Impact	Degree of Certainty	Magnatude	Spatial	Temporal	Probability	**Impact Risk**
Code	*Phase*							
	Post-Closure							
Habitat loss due to sedimentation. Eroded sediments and dust from rehabilitated areas will end up in watercourses and wetlands, smothering benthic habitats, increasing turbidity and resulting in the colonisation of marginal habitats by monospecific stands of Typha. Changes in habitats may be followed by a loss of species and overall biodiversity.		Negative	Probable	2 LOW	3 ADJ	3 MED	4 VLIKE	**-2.4** **MODL**
Decline in water quality due to ash dust blown into aquatic ecosystems		Negative	Probable	3 MODL	4 LOC	4 LONG	4 VLIKE	**-3.2** **MODH**
Decline in water quality due to slumping of Ash Disposal Facility walls, seepage and stormwater containing ash contaminants (e.g. overflowing pollution control dams, leaking pipelines).		Negative	Definite	5 HIGH	4 LOC	4 LONG	4 VLIKE	**-3.8** **MODH**
Loss of sensitive species and biodiversity due to declines in water quality and habitats		Negative	Definite	3 MODL	3 ADJ	5 PERM	4 VLIKE	**-3.2** **MODH**
Impacts to overall integrity of ecologically sensitive downstream Ecosystems (Wilge River)		Negative	Possible	4 MODH	5 DIS	4 LONG	3 LIKE	**-2.9** **MODL**
CUMULATIVE IMPACT	INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, **BEFORE MITIGATION**	Negative	Probable	5 HIGH	5 DIS	4 LONG	4 VLIKE	**-4.1** **HIGH**
RESIDUAL IMPACT	INITIAL IMPACTS TO ENVIRONMENT + ADDITIONAL IMPACTS FROM PROJECT, **AFTER MITIGATION**	Negative	Probable	4 MODH	4 LOC	4 LONG	4 VLIKE	**-3.5** **MODH**

15. CONCLUSION

The Kusile 60-year Ash Disposal Facility is likely to have significant impacts to aquatic ecosystems in terms of water quality and habitat integrity. Impacts of particular concern include erosion, and the increased turbidity and sedimentation that will follow, and water quality impacts, which will include salinization and acidification of receiving watercourses due to contamination from coal ash discharged in stormwater, groundwater seepage and dust. In addition, the risk of contamination of water resources, notably the Wilge River, from spills at conveyor crossings is potentially highly significant.

Six alternative sites were initially investigated. Once sensitivities and risks were compared for these sites, a shortlist of two sites were identified: Alternatives A and B. Both alternatives will impact on the Wilge River which was considered to be sensitive in terms of its aquatic biodiversity, relatively good water quality and presence of sensitive species, including *Chiloglanis pretoriae* which is intolerant to changes to water quality, flow and the availability of clear cobbled substrates. It is thought that the *C. pretoriae* fish population in the Wilge River represents one of the few remaining populations in the upper Olifants River catchment.

As such, alternatives were assessed in terms of potential impacts to the Wilge River. Alternative A was considered the favoured site and was thus assessed fully in terms of impacts. The DWA requested that Alternative B additionally be assessed in full. The findings are summarised below:

- Alternative A is located furthest away from the Wilge River. It falls within quaternary catchment B20F and will affect the Holspruit and Klipfonteinspruit. The major impacts associated with this site will be water quality and continued erosion of the Klipfonteinspruit. These impacts can, however, be mitigated on-site with effective stormwater management and careful design of diversions according to ecological principles, including creation of habitats and mimicking natural hydrological patterns. Impacts due to the conveyor are likely to be relatively minor, restricted to two wetland crossings, and mainly limited to the operational phase. At a catchment level, only one quaternary catchment and two watercourses will be impacted upon, making it easier to mitigate impacts on site and contain spills, thus preventing impacts to the Wilge River. A number of additional off-site mitigation and rehabilitation measures should also be considered for Alternative A so as to manage impacts to water resources at a catchment level. Effective implementation of all mitigation should reduce the overall project impact to a moderate level at a district level, with an overall residual risk of 'Moderately High'.

- Alternative B will require a lengthy conveyor route which will include a crossing of the Wilge River. The impacts due to accidental spills at this crossing are difficult to predict but are potentially severe and far-reaching. Alternative B, together with its conveyor, will spread the impact across two quaternary catchments (drained by the Wilge River and Bronkhorstspruit respectively) and will impact upon five Wilge River tributaries, the Wilge River itself and a seasonal pan adjacent to the site. The conveyor will run adjacent to the eroded Klipfonteinspruit and will cross four watercourses, including the Wilge River. While impacts due to the Ash Disposal Facility will be relatively easy to implement, impacts due to the conveyor will be difficult to impossible to mitigate, in particular in the case of major spills. With mitigation, the impact risk class is likely to remain 'very high to severe' during the operational phase. Post closure impacts are likely to revert to a Moderately High Risk.

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17. APPENDIX A: LIST OF DIATOMS SAMPLED

List of diatom species and associated abundances per site in January 2013.

	Sites											
Taxa	W1	W2	W4	W5	T1A	T3B	T2	T3A	T3C	T4	KF1	KF3
Achnanthidium affine (Grun) Czarnecki	0	2	0	0	0	0	0	0	-	2	0	0
ACHNANTHIDIUM F.T. Kützing	28	22	2	6	0	2	2	0	-	5	0	2
ACHNANTHES J.B.M. Bory de St. Vincent	2	0	0	0	0	0	0	1	-	0	0	0
Amphora copulata (Kütz) Schoeman & Archibald	0	1	2	0	0	0	0	0	-	0	0	0
Achnanthidium biasolettianum Lange-Bertalot	76	0	6	1	0	0	0	0	-	1	0	0
Achnanthidium eutrophilum (Lange-Bertalot)	28	0	0	0	0	0	0	0	X	0	0	0
Achnanthidium saprophilum (Kobayasi et Mayama)	0	0	0	0	0	32	0	0	-	0	0	96
Achnanthidium macrocephalum(Hust.)Round &	0	0	0	0	0	0	0	0	-	6	10	0
Amphora inariensis Krammer	0	2	0	0	0	0	0	0	-	0	0	0
Achnanthes minutissima Kützing v.minutissima	14	0	2	0	185	28	43	275	-	322	96	58
Amphora montana Krasske	0	1	0	0	2	0	0	0	-	0	0	0
Anomoeoneis serians (Breb.)Cleve var.apiculata Boyer	0	0	0	0	6	0	0	0	-	0	0	0
Aulacoseira granulata (Ehr.) Simonsen var.angustissima	0	2	3	7	3	0	0	0	-	0	0	0
Aulacoseira granulata (Ehr.) Simonsen	0	0	2	11	0	0	0	0	-	0	0	0
AULACOSEIRA G.H.K. Thwaites	0	11	0	2	0	0	18	0	-	0	0	0
Brachysira neoexilis Lange-Bertalot	0	0	0	0	0	0	0	0	-	16	20	8
Caloneis bacillum (Grunow) Cleve	0	0	0	3	0	4	0	1	-	0	0	0
Cymbopleura naviculiformis (Auerswald) Krammer	0	0	0	2	0	0	5	1	-	0	26	0
Cymbella cymbiformis Agardh	0	1	0	0	0	0	0	0	-	0	0	0
Cyclotella meneghiniana Kützing	0	0	2	1	0	0	0	0	-	0	0	0
Caloneis molaris (Grunow) Krammer	0	0	0	2	0	0	0	0	-	0	0	0
Cocconeis pediculus Ehrenberg	0	2	2	3	0	0	0	0	-	0	0	0
Cocconeis placentula Ehrenberg var. placentula	21	5	139	21	0	0	0	0	-	0	0	0
CRATICULA A. Grunow	1	0	0	0	0	0	0	0	-	0	0	0
Craticula vixnegligenda Lange-Bertalot	0	0	0	0	0	0	0	0	0	0	6	0
Cymbella turgidula Grunow 1875 in A.Schmidt	1	0	0	18	0	6	0	2	-	0	0	4
Cymbella tumida (Brebisson)Van Heurck	0	3	1	11	0	0	0	0	-	0	0	0
CYCLOTELLA F.T. Kützing ex A de Brébisson	2	13	1	3	0	0	0	0	-	0	0	0
CYMBELLA C.Agardh	0	1	0	0	0	0	0	0	-	0	0	0
Diploneis elliptica (Kützing) Cleve	0	13	5	9	0	0	0	0	-	0	0	0
DIPLONEIS C.G. Ehrenberg ex P.T. Cleve	3	0	0	0	0	0	0	0	-	0	0	0
Diatoma vulgaris Bory	0	1	0	0	0	0	0	0	-	0	0	0
Eunotia bilunaris (Ehr.) Mills var. bilunaris	0	0	0	0	0	0	5	0	-	1	0	0
Encyonopsis cesatii (Rabenhorst) Krammer	0	0	0	0	0	0	0	0	-	1	0	0
Encyonopsis krammeri Reichardt	0	1	2	0	0	0	0	0	-	0	0	0
Eunotia formica Ehrenberg	1	0	0	0	0	0	0	0	-	0	0	0
Eunotia flexuosa(Brebisson)Kützing	0	0	0	0	0	0	0	0	0	0	2	0

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Taxa	W1	W2	W4	W5	T1A	T3B	T2	T3A	T3C	T4	KF1	KF3
Eunotia incisa Gregory var.incisa	0	0	0	0	0	0	0	0	0	0	6	0
Eunotia minor (Kützing) Grunow in Van Heurck	0	0	0	0	0	2	0	3	-	0	36	0
Eunotia pectinalis(Kütz.)Rabenhorst var.undulata (Ralfs)	0	0	0	0	0	0	0	0	0	0	2	0
Encyonopsis microcephala (Grunow) Krammer	8	5	1	1	0	0	0	0	-	0	0	0
Encyonopsis leei var. sinensis Metzeltin & Krammer	0	0	0	1	0	0	0	0	-	0	0	0
Encyonema minutum (Hilse in Rabh.) D.G. Mann	5	19	8	14	19	4	17	2	X	6	0	26
Eolimna minima(Grunow) Lange-Bertalot	2	2	0	0	0	2	2	0	-	0	0	2
Eolimna subminuscula Moser Lange-Bertalot & Metzeltin	4	0	2	1	0	0	0	0	-	0	0	0
Encyonopsis subminuta Krammer & Reichardt	0	0	0	0	0	0	0	0	-	2	0	0
Fragilaria biceps (Kützing) Lange-Bertalot	0	1	0	1	0	6	1	0	-	0	0	0
Fragilaria capucina Desmazieres var.capucina	0	0	0	0	0	0	0	0	-	2	0	0
Fragilaria capucina Desm. rumpens (Kütz.) Lange-Bert.	0	0	0	0	13	0	4	0	-	0	0	0
Frustulia crassinervia (Breb.) Lange-Bertalot et Krammer	0	0	0	0	0	0	6	1	-	0	0	0
Fragilaria capucina var.vaucheriae(Kützing)Lange-Bert	0	0	0	0	1	0	0	0	-	0	0	0
Fallacia monoculata (Hustedt) D.G. Mann	0	0	0	0	0	0	2	0	-	0	0	0
Fragilaria nanana Lange-Bertalot	0	0	0	0	0	0	0	0	-	0	2	0
Fragilaria parasitica (W.Sm.) var. subconstricta Grunow	0	0	0	0	0	0	4	1	-	0	0	0
FRAGILARIA H.C. Lyngbye	0	1	0	3	1	0	1	0	-	0	0	0
Frustulia saxonica Rabenhorst	0	0	0	0	0	2	0	3	-	0	2	0
Fragilaria tenera (W.Smith) Lange-Bertalot	0	1	2	0	0	0	2	0	-	0	0	0
Fallacia tenera (Hustedt) Mann in Round	0	1	1	0	0	0	0	0	-	0	0	0
Fragilaria ulna (Nitzsch.)Lange-Bertalot var.acus (Kütz.)	0	0	0	0	6	0	7	0	-	0	0	0
Fragilaria ulna (Nitzsch.) Lange-Bertalot var. ulna	0	0	0	3	0	2	0	0	-	0	0	0
Frustulia vulgaris (Thwaites) De Toni	0	0	0	0	0	0	5	0	-	0	4	0
Gomphonema angustatum (Kützing) Rabenhorst	0	0	0	9	0	0	18	0	-	0	0	0
Gomphonema auritum A.Braun ex Kützing	1	0	0	0	9	0	0	0	-	0	0	0
Gomphonema exilissimum(Lange-Bertalot & Reichardt	0	2	0	0	3	2	25	6	-	0	2	0
Gomphonema gracile Ehrenberg	1	0	1	1	0	0	1	0	-	16	0	0
Gomphonema hebridense Gregory	0	0	0	0	0	0	0	2	-	0	0	0
Gomphonema lagenula Kützing	0	1	0	0	3	8	11	13	-	2	40	18
Gomphonema minutum(Ag.)Agardh f. minutum	48	30	43	62	19	4	0	0	X	0	0	14
GOMPHONEMA C.G. Ehrenberg	1	12	1	4	6	0	18	4	-	2	0	0
Gomphonema parvulum (Kützing) Kützing	15	11	14	49	58	6	12	2	X	0	0	22
Gomphonema parvulum var.parv. f.saprophilum Lange	0	0	1	0	0	2	0	0	-	0	0	0
Gomphonema pseudoaugur Lange-Bertalot	0	0	0	0	0	4	3	0	-	0	0	0
Gomphonema parvulius Lange-Bertalot & Reichardt	0	0	0	0	1	2	21	1	-	0	6	0
Gomphonema truncatum Ehr.	0	0	0	0	0	0	0	3	-	0	0	0
Gyrosigma acuminatum (Kützing)Rabenhorst	0	0	0	0	0	0	3	1	-	0	0	0
Gyrosigma scalproides (Rabenhorst)Cleve	0	0	0	0	0	0	0	0	-	0	2	0
Hantzschia amphioxys (Ehr.) Grunow	0	0	0	0	0	0	0	0	-	0	2	0
Hippodonta capitata Lange-Bert.Metzeltin & Witkowski	0	6	1	0	0	2	0	3	-	0	0	0
Luticola mutica (Kützing) D.G. Mann	0	1	0	1	1	0	0	0	-	0	0	0

Taxa	W1	W2	W4	W5	T1A	T3B	T2	T3A	T3C	T4	KF1	KF3
Luticola undulata (Hilse)Stoermer & Kreis	0	1	0	0	0	0	0	0	-	0	0	0
Mayamaea atomus (Kützing) Lange-Bertalot	4	6	5	0	0	2	0	0	-	1	0	0
Mayamaea atomus var. permitis (Hustedt) Lange-Bert	3	0	2	0	0	0	0	0	-	0	0	0
Melosira varians Agardh	0	0	9	8	0	0	0	0	-	0	0	0
Nitzschia acidoclinata Lange-Bertalot	0	0	0	0	0	0	7	4	-	7	12	0
Nitzschia agnewii Cholnoky	4	0	0	0	0	0	0	1	-	0	0	0
Navicula arvensis Hustedt var.maior Manguin	0	0	1	0	3	0	0	0	-	0	0	0
NAVICULA J.B.M. Bory de St. Vincent	7	2	3	4	2	0	13	7	-	0	8	0
Nitzschia chasei Cholnoky	0	2	0	0	0	0	0	0	-	0	0	0
Nitzschia clausii Hantzsch	1	2	0	0	0	8	6	3	-	0	0	8
Navicula capitatoradiata Germain	4	22	5	23	0	0	0	0	-	0	0	4
Navicula cryptocephala Kützing	0	0	0	0	2	12	9	2	X	0	6	6
Navicula cryptotenella Lange-Bertalot	7	9	12	9	0	0	0	0	-	0	0	0
Nitzschia desertorum Hustedt	0	0	0	0	0	0	1	0	-	0	0	0
Nitzschia dissipata(Kützing)Grunow var.dissipata	0	9	10	1	5	0	0	0	-	0	0	0
Nitzschia dissipata(Kützing)Grunow var.media	0	0	4	3	0	0	0	0	-	0	0	0
Nitzschia elegantula Grunow	0	0	0	0	4	0	0	0	-	0	0	0
Neidium productum (W.M.Smith)Cleve	0	0	0	0	0	0	2	0	-	0	0	0
Navicula erifuga Lange-Bertalot	2	2	1	7	2	8	0	0	X	0	0	8
Nitzschia fonticola Grunow in Cleve et Möller	0	0	0	0	0	2	0	9	-	0	0	4
Navicula antonii Lange-Bertalot	0	0	0	0	0	4	0	0	-	0	0	0
Navicula gregaria Donkin	0	0	0	0	2	0	0	0	-	0	0	0
Navicula heimansioides Lange-Bertalot	0	0	0	4	0	2	0	2	-	0	42	0
Nitzschia archibaldii Lange-Bertalot	0	0	1	2	2	4	8	2	-	2	0	2
Nitzschia frustulum(Kützing)Grunow var.frustulum	0	0	0	0	0	0	3	0	-	0	0	0
Nitzschia gracilis Hantzsch	0	0	0	0	0	0	0	5	-	0	2	0
Nitzschia inconspicua Grunow	0	1	3	0	0	0	0	0	-	0	0	0
Nitzschia pura Hustedt	0	0	0	0	0	2	0	0	-	0	0	0
Nitzschia solita Hustedt	0	4	2	4	0	0	0	0	-	0	0	0
NITZSCHIA A.H. Hassall	5	10	5	3	9	4	31	9	-	1	14	6
Nitzschia liebetruthii Rabenhorst var.liebetruthii	6	3	0	0	0	24	0	0	-	0	0	2
Navicula libonensis Schoeman	0	2	1	3	0	0	0	0	-	0	0	0
Nitzschia linearis(Agardh) W.M.Smith var.linearis	1	4	4	5	0	2	2	0	-	0	0	0
Nitzschia linearis(Agardh) W.M.Smith var.subtilis	2	2	0	2	0	0	0	0	-	0	0	0
Navicula microcari Lange-Bertalot	6	5	6	0	0	0	0	0	-	0	0	0
Navicula menisculus Schumann var. menisculus	1	4	4	4	0	0	0	0	-	0	0	0
Nitzschia nana Grunow in Van Heurck	0	0	0	0	0	2	3	0	-	0	2	4
Nitzschia palea (Kützing) W.Smith	20	17	16	1	6	134	19	2	X	0	14	56
Navicula reichardtiana Lange-Bertalot var. reichardtiana	4	3	5	2	9	0	0	0	-	0	0	0
Navicula recens (Lange-Bertalot) Lange-Bertalot	0	11	0	0	0	0	0	0	-	0	0	0
Navicula rostellata Kützing	2	7	1	2	6	14	14	10	X	0	0	16
Navicula schroeteri Meister var. schroeteri	0	8	13	6	0	0	0	0	-	1	0	0

Taxa	W1	W2	W4	W5	T1A	T3B	T2	T3A	T3C	T4	KF1	KF3
Nitzschia sigma(Kützing)W.M.Smith	0	0	0	0	0	2	0	0	-	0	0	0
Nitzschia sinuata (Thwaites) Grunow var.tabellaria	0	4	1	1	1	0	0	0	-	0	0	0
Nitzschia valdecostata Lange-Bertalot et Simonsen	0	0	0	0	0	2	0	0	-	0	0	0
Navicula symmetrica Patrick	17	10	13	4	1	6	0	0	-	0	0	20
Navicula tenelloides Hustedt	8	4	3	1	0	0	1	1	-	0	0	0
Navicula tripunctata (O.F.Müller) Bory	0	3	0	4	0	0	0	0	-	0	0	0
Navicula trivialis Lange-Bertalot var. trivialis	3	1	1	0	3	0	1	0	-	0	0	4
Navicula vandamii Schoeman & Archibald var. vandamii	0	2	5	0	0	4	2	5	-	0	0	4
Navicula veneta Kützing	12	9	2	0	0	6	1	0	-	0	0	0
Navicula viridula (Kützing) Ehrenberg	0	0	0	0	0	2	0	0	-	0	0	0
Navicula zanoni Hustedt	0	4	0	0	0	0	5	1	-	1	0	0
Nitzschia supralitorea Lange-Bertalot	15	16	4	0	0	18	0	0	X	0	0	4
Pinnularia borealis Ehrenberg var. borealis	0	1	0	0	0	0	0	0	-	0	0	0
Placoneis dicephala (W.Smith) Mereschkowsky	0	0	0	1	0	0	3	2	-	0	0	0
Placoneis placentula (Ehr.) Heinzerling	0	0	0	0	0	0	0	0	-	0	6	0
Pinnularia interrupta W.M.Smith	0	0	0	0	0	0	1	0	-	0	0	0
PINNULARIA C.G. Ehrenberg	0	0	0	0	0	0	2	1	-	0	0	0
Planothidium frequentissimum(Lange-Bertalot)	2	0	0	0	0	0	0	0	-	0	0	0
Planothidium rostratum (Oestrup) Lange-Bertalot	0	0	1	0	0	0	0	0	-	0	0	0
Pinnularia subbrevistriata Krammer	0	0	0	0	0	0	1	0	-	0	0	0
Pinnularia subcapitata Gregory var. subcapitata	0	0	0	1	0	0	0	0	-	0	0	0
Pinnularia viridis (Nitzsch) Ehrenberg var.viridis	0	0	0	0	0	0	1	0	-	0	0	0
Rhoicosphenia abbreviata	0	4	5	5	0	0	0	0	-	3	0	0
Reimeria uniseriata Sala Guerrero & Ferrario	0	6	1	18	0	0	0	0	-	0	0	0
Surirella angusta Kützing	0	2	3	6	0	6	1	0	-	0	0	0
Seminavis strigosa (Hustedt) Danieledis & Economou	0	0	0	0	0	0	0	0	-	0	4	0
Staurosira construens Ehrenberg	0	0	0	1	0	0	0	0	-	0	0	0
Stenopterobia delicatissima (Lewis) Brebisson	0	0	0	0	0	0	0	0	-	0	8	2
Simonsenia delognei Lange-Bertalot	0	0	1	0	0	0	0	0	-	0	0	0
Sellaphora pupula (Kützing) Mereschkowksy	0	1	0	3	5	4	24	5	-	0	16	0
Sellaphora seminulum (Grunow) D.G. Mann	0	0	0	0	0	0	3	3	-	0	0	0
Tryblionella apiculata Gregory	0	1	0	0	0	0	0	0	-	0	0	0
Tryblionella debilis Arnott ex O'Meara	0	1	0	1	0	0	0	0	-	0	0	0
Tabellaria flocculosa(Roth)Kützing	0	0	0	0	0	0	0	1	-	0	2	0
Tryblionella hungarica (Grunow) D.G. Mann	2	16	2	10	2	0	0	0	-	0	0	0
Tryblionella levidensis Wm. Smith	0	5	1	1	0	0	0	0	X	0	0	0

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18. APPENDIX B. AQUATIC MACROINVERTEBRATES SAMPLED

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		Wilge River Sites						Tributaries of the Wilge River						Klipfonteinsp		Bronkhorsts	
SITE		W1	W2	W3	W4	W5	W6	T1	KF1	KF2	KF3	T4	B4	HS	Kus	B1	B2
Temp (°C):		25.7	22.6	23.7	22	24.9	23.5	26.2	21	23.3	24.2	27.6	23.1	27	24.2	29.3	17.5
pH:		8.34	8.03	7.97	7.8	8.02	7.8	8.3	7.6	7.72	7.72	7.37	7.14	7.52	7.51	7.43	7.5
Cond (mS/m):		39.7	35.1	37.1	20	31.6	32	18.1	5.3	30.6	16.4	12.5	13	6.4	11.6	12.8	12.3
Biotopes sampled Scored 1-5	Stones in current	4	4	3	4	3	3	3	3	2	2	4	3	2	1	2	3
	Stones out of current	2	2	2	3	3	2	4	2	3	3	3	2	3	3	4	2
	Vegetation	3	3	3	3	2	3	3	4	4	4	4	4	3	2	3	3
	Gravel, sand, mud	2	3	1	2	3	1	3	3	2	3	3	3	2	4	3	3
TOTAL No.TAXA		18	20	20	25	19	24	18	19	12	11	18	19	8	5	19	14
SASS Score		112	110	122	139	111	135	84	92	55	51	96	112	44	21	79	61
Average Score per Taxon		6.2	5.5	6.1	5.6	5.8	5.6	4.7	4.8	4.6	4.6	5.3	5.9	5.5	4.2	4.2	4.4
SASS5 Taxon	**SASS5 Sensitivity Score***																
Porifera	5																
Turbellaria	3		A		A		A	A	A	A		1					A
ANNELIDA																	
Oligochaeta (Earthworms)	1	1								1		1	A			A	1
Hirudinea (Leeches)	3													1			
CRUSTACEA																	
Potamonautidae* (Crabs)	3		A	A	A	A	A	A	Obs			1			A	remains	
Atyidae (Freshwater Shrimps)	8				A	A	A				A						
HYDRACARINA (Mites)	8							1						A		A	
EPHEMEROPTERA (Mayflies)																	
Baetidae 1sp	4										1					A	
Baetidae 2 sp	6							B	A						B		
Baetidae > 2 sp	12	A	A	A	B	A	A			B		A	B	A			B
Caenidae (Squaregills/Cainfles)	6	A	A		A		A		A			A	A			A	A
Heptageniidae	13	B		A	A		A					1					
Tricorythidae (Stout Crawlers)	9	A	A	A	A	A	A	A					A				
Leptophlebiidae (Prongills)	9	A	A	A	A	A	A					A					
ODONATA (Dragonflies & Damselflies)																	
Coenagrionidae (Sprites and blues)	4	A	A	?	A	A	A		A		A	A	A	A		A	A
Lestidae (Emerald Damselflies/Spreadwings)	8																
Aeshnidae (Hawkers & Emperors)	8	A	1	1		1			1				1				
Gomphidae (Clubtails)	6					1			1								
Libellulidae (Darters/Skimmers)	4								A								
HEMIPTERA (Bugs)																	
Belostomatidae* (Giant water bugs)	3		A	A	A	A	A	1				A				A	
Corixidae* (Water boatmen)	3	B	B	A	A		A	A	B	A		A	B	A	B	A	A
Gerridae* (Pond skaters/Water striders)	5		A	A		A		A		A		A	A			A	1
Hydrometridae* (Water measurers)	6																
Naucoridae* (Creeping water bugs)	7											1					
Nepidae* (Water scorpions)	3				A	1	1				1	A					
Notonectidae* (Backswimmers)	3		A		1	A		1		A	A	A	A			1	
Pleidae* (Pygmy backswimmers)	4				1		A	1	A					1		A	A
Veliidae/M...veliidae* (Ripple bugs)	5	A		A	1	A	A		A	B	B	A	A	A		A	A
TRICHOPTERA (Caddisflies)																	
Hydropsychidae 1 sp	4							A			1		1		A		
Hydropsychidae 2 sp	6	A	A	A	A	A	A			B							
Ecnomidae	8								1								
Philopotamidae	10																
Cased caddis:																	
Hydroptilidae	6																
Leptoceridae	6				A											1	
COLEOPTERA (Beetles)																	
Dytiscidae* (Diving beetles)	5	A	A		1	A	A		A	A	A		A				B
Noteridae*	5			1					1								
Gyrinidae* (Whirligig beetles)	5	A					A	A	A	A	A	A	A	A		1	A
Haliplidae* (Crawling water beetles)	5																
Elmidae	8	A	A	A	1	A	A						1				
Helodidae (Marsh beetles)	12												1				
Hydraenidae* (Minute moss beetles)	8																
Hydrophilidae	5					1		A	1		1		A				
Limnichidae (Marsh-Loving Beetles)	10																
DIPTERA (Flies)																	
Athericidae (Snipe flies)	10																
Ceratopogonidae (Biting midges)	5				1		A		A								
Chironomidae (Midges)	2	A	A	A	1		A	A	A	A			A			A	A
Culicidae* (Mosquitoes)	1																
Dixidae* (Dixid midge)	10							A				1	A				
Empididae (Dance flies)	6																
Ephydridae (Shore flies)	3																
Muscidae (House flies, Stable flies)	1											1					1
Psychodidae (Moth flies)	1																
Simuliidae (Blackflies)	5	A	A	A	A		A	A	A	A	A		B		A	A	A
Syrphidae* (Rat tailed maggots)	1																
Tabanidae (Horse flies)	5	1															
Tipulidae (Crane flies)	5		1	A				1									
GASTROPODA (Snails)																	
Ancylidae (Limpets)	6	A	1	A	A	A	A	1								1	
Sphaeridae	3																
Unionidae (mussels)	6																
Lymnaeidae* (Pond snails)	3															A	

19. APPENDIX C: SUMMARY OF COMPARATIVE IMPACT ASSESSMENT

	Site A					SITE B					SITE C					SITE A+F					SITEA+G					SITE F+G					NO-GO				
	Magnatude	Spatial	Temporal	Probability	Impact Risk	Magnatude	Spatial	Temporal	Probability	Impact Risk	Magnatude	Spatial	Temporal	Probability	Impact Risk	Magnatude	Spatial	Temporal	Probability	Impact Risk	Magnatude	Spatial	Temporal	Probability	Impact Risk	Magnatude	Spatial	Temporal	Probability	Impact Risk	Magnatude	Spatial	Temporal	Probability	Impact Risk
Construction																																			
RESIDUAL IMPACT	3	4	4	5	4.1	4	4	4	5	4.4	4	4	4	5	4.4	5	4	4	5	4.8	5	4	4	5	4.8	6	4	4	5	5.2	3	3	4	4	2.9
	MODL	LOC	LONG	OCCUR	HIGH	MODH	LOC	LONG	OCCUR	HIGH	MODH	LOC	LONG	OCCUR	HIGH	HIGH	LOC	LONG	OCCUR	HIGH	HIGH	LOC	LONG	OCCUR	HIGH	VHIGH	LOC	LONG	OCCUR	VHIGH	MODL	ADJ	LONG	VLIKE	MODL

	Site A					SITE B					SITE C					SITE A+F					SITEA+G					SITE F+G					NO-GO				
	Magnatude	Spatial	Temporal	Probability	Impact Risk	Magnatude	Spatial	Temporal	Probability	Impact Risk	Magnatude	Spatial	Temporal	Probability	Impact Risk	Magnatude	Spatial	Temporal	Probability	Impact Risk	Magnatude	Spatial	Temporal	Probability	Impact Risk	Magnatude	Spatial	Temporal	Probability	Impact Risk	Magnatude	Spatial	Temporal	Probability	Impact Risk
Code	*Phase*																																		
	Operational																																		
RESIDUAL IMPACT	5	5	4	5	5.2	7	5	4	5	5.9	5	6	4	5	5.5	7	6	3	4	4.7	5	6	4	5	5.5	6	6	4	5	5.9	3	4	4	5	4.1
	HIGH	DIS	LONG	OCCUR	VHIGH	SEV	DIS	LONG	OCCUR	VHIGH	HIGH	PRO	LONG	OCCUR	VHIGH	SEV	PRO	MED	VLIKE	HIGH	HIGH	PRO	LONG	OCCUR	VHIGH	VHIGH	PRO	LONG	OCCUR	VHIGH	MODL	LOC	LONG	OCCUR	HIGH

	Site A					SITE B					SITE C					SITE A+F					SITEA+G					SITE F+G					NO-GO				
	Magnatude	Spatial	Temporal	Probability	Impact Risk	Magnatude	Spatial	Temporal	Probability	Impact Risk	Magnatude	Spatial	Temporal	Probability	Impact Risk	Magnatude	Spatial	Temporal	Probability	Impact Risk	Magnatude	Spatial	Temporal	Probability	Impact Risk	Magnatude	Spatial	Temporal	Probability	Impact Risk	Magnatude	Spatial	Temporal	Probability	Impact Risk
Code																																			
Closure																																			
RESIDUAL IMPACT	4	5	4	4	3.8	4	5	4	4	3.8	5	6	4	4	4.4	6	6	4	4	4.7	5	6	4	4	4.4	6	6	4	4	4.7	0	4	4	4	2.4
	MODH	DIS	LONG	VLIKE	MODH	MODH	DIS	LONG	VLIKE	MODH	HIGH	PRO	LONG	VLIKE	HIGH	VHIGH	PRO	LONG	VLIKE	HIGH	HIGH	PRO	LONG	VLIKE	HIGH	VHIGH	PRO	LONG	VLIKE	HIGH	NO	LOC	LONG	VLIKE	MODL

	Site A					SITE B					SITE C					SITE A+F					SITEA+G					SITE F+G					NO-GO				
	Magnatude	Spatial	Temporal	Probability	Impact Risk	Magnatude	Spatial	Temporal	Probability	Impact Risk	Magnatude	Spatial	Temporal	Probability	Impact Risk	Magnatude	Spatial	Temporal	Probability	Impact Risk	Magnatude	Spatial	Temporal	Probability	Impact Risk	Magnatude	Spatial	Temporal	Probability	Impact Risk	Magnatude	Spatial	Temporal	Probability	Impact Risk
	Phase																																		
Post-Closure																																			
RESIDUAL IMPACT	4	5	5	4	4.1	4	5	5	4	4.1	4	5	5	5	5.2	5	6	5	5	5.9	5	5	5	5	5.5	6	6	5	5	6.3	0	5	5	4	2.9
	MODH	DIS	PERM	VLIKE	HIGH	MODH	DIS	PERM	VLIKE	HIGH	MODH	DIS	PERM	OCCUR	VHIGH	HIGH	PRO	PERM	OCCUR	VHIGH	HIGH	DIS	PERM	OCCUR	VHIGH	VHIGH	PRO	PERM	OCCUR	SEV	NO	DIS	PERM	VLIKE	MODL

DRAFT

DRAFT