PROPOSED RIEMVASMAAK HYDRO ELECTRIC POWER (RVMHEP) DEVELOPMENT, ORANGE RIVER, AUGRABIES, NORTHERN CAPE.

AQUATIC BASELINE ECOLOGICAL INTEGRITY & POTENTIAL IMPACT SURVEYS.

Prepared for:

RVM1 Hydro Electric Project (Pty) Ltd.

Report authors: Mathew Ross (*Pr Sci Nat,* MSc), Tahla Ross (PhD)
EnviRoss CC Report Ref: ENV_RVM_Baseline Aquatic_201503
Date: March 2015
Version: Draft v1.0

EnviRoss *CC*
CK 2007/051532/23
VAT: 4810234999
PO Box 369, Wendywood, 2144.
Tel/fax: 011 706 9753
Cell: 082 293 5752
Email: admin@enviross.co.za

DECLARATION

This report has been prepared according to the requirements of the Environmental Impact Assessments Regulations (GN R.543) in Government Gazette 33306 of 18 June 2010, as well as the Department of Water Affairs (DWA, 2005) *Guidelines for Delineating Wetland and Riparian Zones* and Department of Water Affairs (DWA, 2007) *River EcoClassification: Manual for EcoStatus Determination (vers 2)*. We (the undersigned) declare the findings of this report free from influence or prejudice.

Report Authors:

Mathew Ross *Pr Sci Nat* (Ecological Sciences) 400061/09

MSc (Aquatic Health) (RAU)
Currently completing PhD (Aquatic Health), (University of Johannesburg).

Field of expertise:

Fish ecology, fishway evaluations, biomonitoring and wetland evaluations, aquatic ecology, aquatic & terrestrial fauna and flora.

____________________ Date: 31 March 2015

Mathew Ross

Dr Tahla Ross

PhD (Zoology) (RAU)

Field of expertise:

Biomonitoring and wetland evaluations, aquatic ecology, aquatic & terrestrial fauna and flora.

____________________ Date: 31 March 2015

Dr Tahla Ross

EXECUTIVE SUMMARY

Introduction and Background.

Riemvasmaak Hydro Electric Power (Pty) Ltd has proposed the development of the Riemvasmaak Hydro Electric Power Scheme about 11km downstream of Augrabies on the Orange River. EnviRoss CC was requested to undertake an aquatic ecological and water quality survey for the construction and operations phases of the proposed development activities. This report details the findings of the initial baseline survey that has allowed for the benchmark to be set for analysis of future ecological trends.

The aim of the survey was to ascertain the present ecological state of the surface water resources that could potentially be impacted by the proposed development and thereafter to determine the significance of the potential impacts emanating from a development of this nature during routine monitoring. Two field survey were undertaken during September 2013 and march 2015.

Materials and Methods.

The standard South African Department of Water Affairs (DWA) River EcoClassification and EcoStatus Models were utilised to determine the Present Ecological State (PES) the EcoStatus category and the Ecological Importance and Sensitivity (EIS) (DWA, 2007 & 2008). Three aquatic survey sites were chosen that would best allow for determining any deleterious impacts emanating from the proposed development activities, namely upstream of the impact, at the impact and downstream of the impact.

The following methodologies were applied during the survey:

- General riparian and habitat assessments:
  - Walk-about surveys at all survey sites;
- Aquatic habitat assessments:
  - *In situ* water quality (pH, oxygen content, dissolved oxygen, electrical conductivity (EC), total dissolved solids (TDS) and temperature);
  - Laboratory analysis of water samples taken at each survey site;
  - River IHI (Index of Habitat Integrity);
  - MIRAI (Macro-invertebrate Response Assessment Index);
  - FRAI (Fish Response Assessment System);
  - VEGRAI (Vegetation Response Assessment Index).

Results and Discussions.

The EcoStatus models all indicated that the river segment within the survey area has suffered various forms of degradation. The EcoStatus models ultimately place the system within a C category (*Moderately modified*). The Ecological Importance and Sensitivity of the system remains within a *High* category, however.

Water quality results indicated that the river segment has retained relatively good water quality and that water quality is not regarded as a limiting factor to supporting aquatic biodiversity. Agrochemicals are thought to have an impact on aquatic invertebrates within the system, but these compounds were not tested for.

Impact significance ratings:

The magnitude of the significance of an impact emanating from a particular activity is dependent on various factors such as the spatial extent (S), the duration (D), the intensity (I), the effects on important ecosystems (E), the overall reversibility of the impact (R), and the probability of likelihood of the impact (P). That is to say, if a localised impact occurs for a few days a year, with a low impact and no effect on important ecosystems (aquatic/wetland habitat or habitat identified to be important to biodiversity conservation), and that impact can be easily rehabilitated, then the impact significance would be rated as Low. An impact spanning over a large area, is continuous with a high intensity and will impact on important ecosystems, with little success of rehabilitation, then that impact is considered to be High. The perceivable impacts emanating from the preconstruction and the construction phases, and those perceived to occur during the management and operations phases, are rated in **Error! Reference source not found.** and Table 2, respectively below. These are rated for both before and after the implementation of recommended mitigation measures. It can be seen that some impacts are inevitable due to the very nature of the proposed development. Other impacts are shown to be readily mitigated for, with greatly reduced magnitudes of significance.

Table 1: The significance ratings for the construction phase for both before and after implementation of mitigation measures of the main potential ecological impacts perceived to be associated to the proposed development activities.

<table>
<tr><th rowspan="2">Potential environ impact</th><th rowspan="2">Project activity or issue</th><th colspan="8">Environmental significance <u>before</u> mitigation**</th><th colspan="8">Environmental significance <u>after</u> mitigation**</th></tr>
<tr><th>S</th><th>D</th><th>I</th><th>E</th><th>R</th><th>P</th><th>Conf*</th><th>SP</th><th>S</th><th>D</th><th>I</th><th>E</th><th>R</th><th>P</th><th>Conf</th><th>SP</th></tr>
<tr><td colspan="18">PRECONSTRUCTION & CONSTRUCTION PHASES</td></tr>
<tr><td rowspan="8">Aquatic habitat features</td><td>Destruction of aquatic habitat to accommodate weir construction</td><td>1</td><td>4</td><td>3</td><td>4</td><td>1</td><td>3</td><td>High</td><td>33</td><td>1</td><td>1</td><td>1</td><td>2</td><td>2</td><td>2</td><td>High</td><td>6</td></tr>
<tr><td colspan="17"><u>Comment:</u>
The construction of this infrastructure will induce significant disturbance, but, upon completion the overall significance of this impact is considered to be localized and temporary. With proper site reinstatement the significance of the impacts will not carry over into the operations phase (see operations phase analysis for further details pertaining to this infrastructure development).
<u>Main mitigation points:</u>
The construction within an ecologically sensitive habitat feature needs to be considered and so the construction impacting footprint needs to remain as small as possible.
Indiscriminate habitat destruction must be avoided.
Consideration should be given to including a fish migratory bypass (fishway) into the weir design.
Proper site and habitat reinstatement must be implemented during site rehabilitation following the completion of the construction phase. Any loose rocks or cobbles that are to be removed to accommodate the infrastructure should be stored in order to make use of the same substrates during reinstatement of the habitats that have been disturbed.</td></tr>
<tr><td>Destruction of local watercourses and side tributaries to accommodate the construction of the canal/pipeline.</td><td>1</td><td>4</td><td>3</td><td>2</td><td>1</td><td>3</td><td>High</td><td>27</td><td>1</td><td>1</td><td>1</td><td>2</td><td>2</td><td>2</td><td>High</td><td>6</td></tr>
<tr><td colspan="17"><u>Comment:</u>
The region is considered arid and the orange River represents one of the very few perennial watercourses. Steep and undulating topography means that there are many surface water drainage lines that convey water during rainfall events. The degree of establishment of habitat is a function of the size of the local catchment area of the watercourse. This means that the watercourses are subject to greater or lesser volumes of surface water drainage and therefore are subject to greater or lesser potential for erosion to take place. Loose and unstructured soils are common, being either aeolian or alluvial in origin, and therefore are vulnerable to the effects of erosion. Further disturbances will merely aggravate the effects of erosion.
<u>Main mitigation points:</u>
The proposed canal/pipeline is an excavated and covered concrete-lined canal that inevitably has to cross through numerous watercourses of varying scales (no watercourses represent aquatic habitat as no surface water is retained for any significant period). Therefore mitigation is limited to erosion control and allowing the free-flow and natural course of the surface water drainage.
Again, indiscriminate habitat destruction must be avoided and vegetation disturbance minimized.</td></tr>
<tr><td>Reduction of water volume flowing over the Augrabies Falls to accommodate the hydropower scheme.</td><td>2</td><td>4</td><td>1</td><td>1</td><td>1</td><td>4</td><td>High</td><td>28</td><td>2</td><td>1</td><td>1</td><td>1</td><td>4</td><td>1</td><td>High</td><td>4</td></tr>
<tr><td colspan="17"><u>Comment:</u>
In order for the hydropower scheme to function, a portion of the water will be diverted from the main channel (that flows over the falls) through the canal to the turbines. This will deprive the aquatic habitat of that portion of water for approximately 10 km.
It is noted that the river flow rates below 30 m^3/s will see no diversion of water through the scheme, ensuring that the river flow never falls below this set volume as a result of project-related diversions during low flow periods. This is sufficient to ensure ecological functionality of the watercourse. Downstream of the falls sees the watercourse constrict to a narrow gorge, which requires relatively less water volume for maintenance as what the braided channel above the falls requires. Therefore this impact, from an ecological perspective, is not thought to be of major significance. The diverted water is returned to the main channel downstream and therefore the impact of the diversion is thought to be minimal to downstream users of the system. It is noted that a hydropower scheme is a non-consumptive use of the water resource.
<u>Main mitigation points:</u>
Active management of the scheme is required to ensure that flow volume to the main channel is never reduced below 30 m^3/s as a consequence of the scheme. It is acknowledged that flow rates lower than this could occur due to management of upstream impoundments, or natural low season flows.</td></tr>
<tr><td>Contamination of surface water features leading to loss of sensitive biota.</td><td>3</td><td>4</td><td>3</td><td>4</td><td>1</td><td>3</td><td>High</td><td>39</td><td>2</td><td>1</td><td>1</td><td>2</td><td>2</td><td>2</td><td>High</td><td>8</td></tr>
<tr><td colspan="17"><u>Comment/Mitigation points:</u> Fuel storage should be done within designated areas only, which are properly bunded to contain any potential fuel leaks. Construction vehicles should be properly serviced in order to avoid fluid leaks. Proper sewerage management should be implemented in order to avoid contamination of the surface waters through untreated sewerage.</td></tr>
</table>

Potential environ impact	Project activity or issue	Environmental significance *before* mitigation**								Environmental significance *after* mitigation**							
		S	D	I	E	R	P	Conf*	SP	S	D	I	E	R	P	Conf	SP
Riparian Vegetation Impacts	Impacts on riparian vegetation leading to decrease in runoff filtration.	2	4	3	3	2	4	High	**40**	1	1	1	2	2	3	High	**9**
	Comment/Mitigation points: *This is not thought to be a significant impact as the development activities will only include a small area of riparian vegetation. Indiscriminate destruction of riparian habitat should be avoided.*																
	Biodiversity impacts due to riparian vegetation loss.	2	4	3	3	2	4	High	**40**	1	1	1	2	2	2	High	**6**
	Comment/Mitigation points: *This is not thought to be a significant impact as the development activities will only include a small area of riparian vegetation. Indiscriminate destruction of riparian habitat should be avoided.*																
	Decreased flood attenuation capacity from removal of riparian vegetation.	2	4	3	3	2	4	High	**40**	1	1	1	2	2	2	High	**6**
	Comment/Mitigation points: *This is not thought to be a significant impact as the development activities will only include a small area of riparian vegetation. Indiscriminate destruction of riparian habitat should be avoided.*																
Soils	Soil stripping, soil compaction and vegetation removal will increase rates of erosion and entry of sediment into the general aquatic ecosystem.	2	4	3	4	1	4	High	**48**	1	1	1	2	2	2	High	**6**
	Comment/Mitigation points: *Erosion must be strictly controlled through the utilization of silt traps, silt fencing, Gabions, etc. This is especially pertinent within areas of steeper gradients.*																
	Erosion of stockpiled topsoil & disturbance of soils due to vegetation stripping leading to erosion and habitat inundation.	2	4	3	4	1	4	High	**48**	1	1	1	2	2	2	High	**6**
	Comment/Mitigation points: *Topsoil stockpiles should be protected from erosion through the utilization of silt traps, silt fencing, Gabions, etc.*																

*****See Appendix B for calculations & methodologies.** SP ratings: 0-33 (Low), 34-74 (Medium), 75-100 (High)*

Table 2: The significance ratings for the management phase for both before and after implementation of mitigation measures of the main potential ecological impacts perceived to be associated to the proposed development activities.

Potential environ impact	Project activity or issue	Environmental significance *before* mitigation**								Environmental significance *after* mitigation**							
		S	D	I	E	R	P	Conf*	SP	S	D	I	E	R	P	Conf	SP
MANAGEMENT/ OPERATIONS PHASE																	
Aquatic habitat features	The diversion weir will act as an impounding structure that will reduce the flow velocity of water through the watercourse, leading to transformation of the aquatic habitat leading to transformation of the aquatic species community structures.	2	4	2	3	1	2	High	**20**	2	4	2	3	1	2	High	**20**
	Comment: *The diversion weir is not designed to be an impounding structure, but rather an offtake weir, meaning that impounding of the water will be minimal, creating an insignificant inundation upstream of the site.* ***Main mitigation points:*** *Active management of the scheme is required to ensure that flow volume to the main channel is never reduced below 30 m^3/s as a consequence of the scheme. It is acknowledged that flow rates lower than this could occur due to management of upstream impoundments, or natural low season flows.*																
	The diversion weir will act as a migratory barrier that will impede freedom of movement of migrating aquatic biota	2	4	1	3	1	2	High	**18**	2	1	1	1	4	1	High	**1**

Potential environ impact	Project activity or issue	Environmental significance *before* mitigation**								Environmental significance *after* mitigation**							
		S	D	I	E	R	P	Conf*	SP	S	D	I	E	R	P	Conf	SP
	Comment: *Migratory freedom is required to allow for aquatic biota to exploit available habitat for various reasons. Blocking migratory freedom deprives various species of resources, habitat and dispersal.* *This diversion weir, if found to block migrating aquatic biota, will delimit only a small section of the river before the natural and absolute barrier of the Augrabies Falls is encountered. The significance of this is therefore thought to be minimal.* ***Main mitigation points:*** *Analysis of the weir design, drown-out potential, and extent that it will pose as a migratory barrier should be explored and the provision for a fishway should be considered if it is found that one is required.*																
	Discharge of water into an otherwise seasonally dry watercourse will create artificial habitat and potentially disorientate migrating organisms	2	4	1	3	1	2	High	**18**	2	4	1	3	1	2	High	**18**
	Comment: *The transferring canal/headrace will discharge into a balancing dam (forebay/head pond), which then flows through the powerhouse/turbines. The outfall from the turbines is into a seasonally dry section of the river, therefore it will create artificial conditions that may disorientate migrating biota within the localized area. Fish would utilise this area for spawning purposes if they encounter an impassable migratory barrier and cannot locate an alternative (i.e. swim further upstream to locate more suitable breeding habitat). This is thought to be of limited significance as, for the vast majority of the time, the greater proportion of flow will be through the main channel, which will mean that fish will orientate themselves to follow the stronger current. The Augrabies Falls already poses an impassable barrier close to the site, meaning that fish have had to historically accommodate this feature. Flow into this side channel may also be a positive impacting feature as it will expand the available habitat within the local river reach.* ***Main mitigation points:*** *This feature is not something that can readily be mitigated once construction has taken place;* *Active management of the scheme is required to ensure that flow volume to the main channel is never reduced below 30 m^3/s as a consequence of the operations of the hydro power scheme.*																
	Contamination of surface water features leading to loss of sensitive biota.	2	4	5	4	2	4	High	**52**	1	1	1	2	3	2	High	**4**
	Comment/Mitigation points: *Containment of effluents and further accidental discharges to ensure that contaminants do not reach the surface waters will greatly reduce this impact. Strict management procedures will ensure correct operational procedures, which will, in turn, protect the surface water resources from contamination.*																
	Erosion of the watercourse at outfall sites (tailrace)	2	4	5	4	2	4	High	**52**	1	1	1	2	3	2	High	**4**
	Comment/Mitigation points: *Poor outfall design could lead to perpetual erosion. Careful planning and design should be implemented to abate the scouring effects of the release of high velocity water. This is thought to be minimal as the outfall region is dominated by granite bedrock.*																
Water quality impacts	Contamination of surface waters through accidental spillages leading to loss of aquatic biodiversity.	2	4	1	4	1	3	High	**30**	1	1	1	2	2	2	High	**6**
	Comment/Mitigation points: *Containment of accidental discharges/spillages to ensure that contaminants do not reach the surface waters will greatly reduce this impact. Strict management procedures will ensure correct operational procedures, which will, in turn, protect the surface water resources from contamination.*																
Biodiversity impacts	Exotic vegetation encroachment following soil disturbances.	2	4	1	2	2	4	High	**28**	1	1	1	1	4	2	High	**0**
	Comment/Mitigation points: *This is to require careful attention and active management considering that the proposed development is to take place within an area that is currently managed by SANParks.*																
Soil erosion	Resulting from poorly designed watercourse crossings of the transfer canal/pipeline leading to habitat transformation and ultimate siltation of the aquatic habitat.	2	4	3	4	1	4	High	**48**	1	1	1	2	2	2	High	**6**
	Comment/Mitigation points: *Stormwater engineering needs to take into consideration the deposition of silts transported after rainfall events into the surface water resources. This will lead to smothering of the aquatic habitat, ultimately displacing aquatic species.*																

*****See Appendix B for calculations & methodologies.*** *SP ratings: 0-33 (Low), 34-74 (Medium), 75-100 (High)*

Conclusions and Recommendations.

Recommendations and general mitigation measures are outlined below:

- The river reach has suffered a change from reference conditions in terms of biological integrity (fish, macro-invertebrates and riparian vegetation) as well as instream and riparian habitat, mostly as a result of transformed hydraulic conditions brought about by release management of upstream impoundments, and water quality impacts emanating from formal agriculture (mostly) within the region. The resultant Ecological Category is an overall C class. Even though there are transforming and degrading features present within the river reach, the overall Ecological Importance and Sensitivity (EIS) remains *High*. Mitigation measures should be in place to ensure that these ecological categories are not degraded;
- The surface water quality throughout the survey area is considered good, with the aquatic system supporting a diversity of sensitive aquatic macro-invertebrate taxa. It is therefore imperative that the contamination of the surface waters through deleterious effluents and runoff water be avoided;
- The proposed development is to take place within close proximity to an existing natural migratory barrier within the system (Augrabies Falls) and therefore any impacts to migratory species emanating from the construction of the weir is thought to be minimal. It does, however, fall within an area of the river considered to be relatively productive, which offers good habitat type. It is therefore recommended that a fishway be considered for this structure;
- The diversion of water from the main channel of the watercourse will adhere to a strict minimum flow policy, meaning that flow to the main channel (and therefore over the Augrabies Falls) will never fall below an agreed 30 m^3/s due to the operations of the hydro power scheme. This is considered sufficient to maintain the section of the river that will otherwise be deprived of a portion of the flow volume;
- Emergency procedures must be in place to timeously mitigate any accidental spillages of polluting materials (such as hydrocarbons or cement) and to isolate the impacting features as far as possible;
- Regular monitoring of water quality to enable early identification of contamination is recommended. The source of any contamination identified though the monitoring should be identified and managed according to best practice guidelines;
- Soil erosion emanating from disturbances within the riparian zones and other areas of steep gradients is thought to be a pertinent impacting feature to potentially impact the overall ecological integrity of the aquatic system. Disturbed soils and stockpiled soils should be protected from erosional impacts;

- The footprint of the actual development as well as the supporting structures and services during the construction phase should be retained as small as possible by, for instnace, construction vehicles being limited to designated roadways only. Destruction of the riparian habitat through the unnecessary clearing of vegetation should be avoided;
- Dumping of any excess rubble, building material or refuse must be prohibited within riparian and wetland habitat and a 50 m no dumping regulation should be observed from any watercourse, wetland or riparian zone. Dumping of materials should only take place at designated and properly managed areas;
- Adequate toilet facilities must be provided for all construction crews to negate informal ablutions taking place within watercourses or riparian zones;
- Fires within the riparian zones should be prohibited;
- Exotic vegetation that may establish following the disturbance of the soils should be actively managed;
- Provided that erosion management, together with the implementation of mitigation measures to abate the negative ecological impacts of the features mentioned above, the overall ecological impact of the proposed development activities can be limited.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION & TERMS OF REFERENCE

1.1. Background

RVM 1 Hydro Electric Power (Pty) Ltd (Riemvasmaak) intends to construct a run-of-river hydroelectric power station on the Orange River on the farm Riemvasmaak (Remainder of Farm no. 497) and on farm Waterval (Portion 1 of Farm no. 498), north of the Augrabies Falls, approximately 40 km north-west of Kakamas in the Northern Cape Province of South Africa. The power station will have an installed generating capacity of up to 40 megawatts (MW), and the annual energy output from the facility is anticipated to be approximately 235 gigawatt-hours (GWh). The locality of the proposed development site is presented in Figure 1.

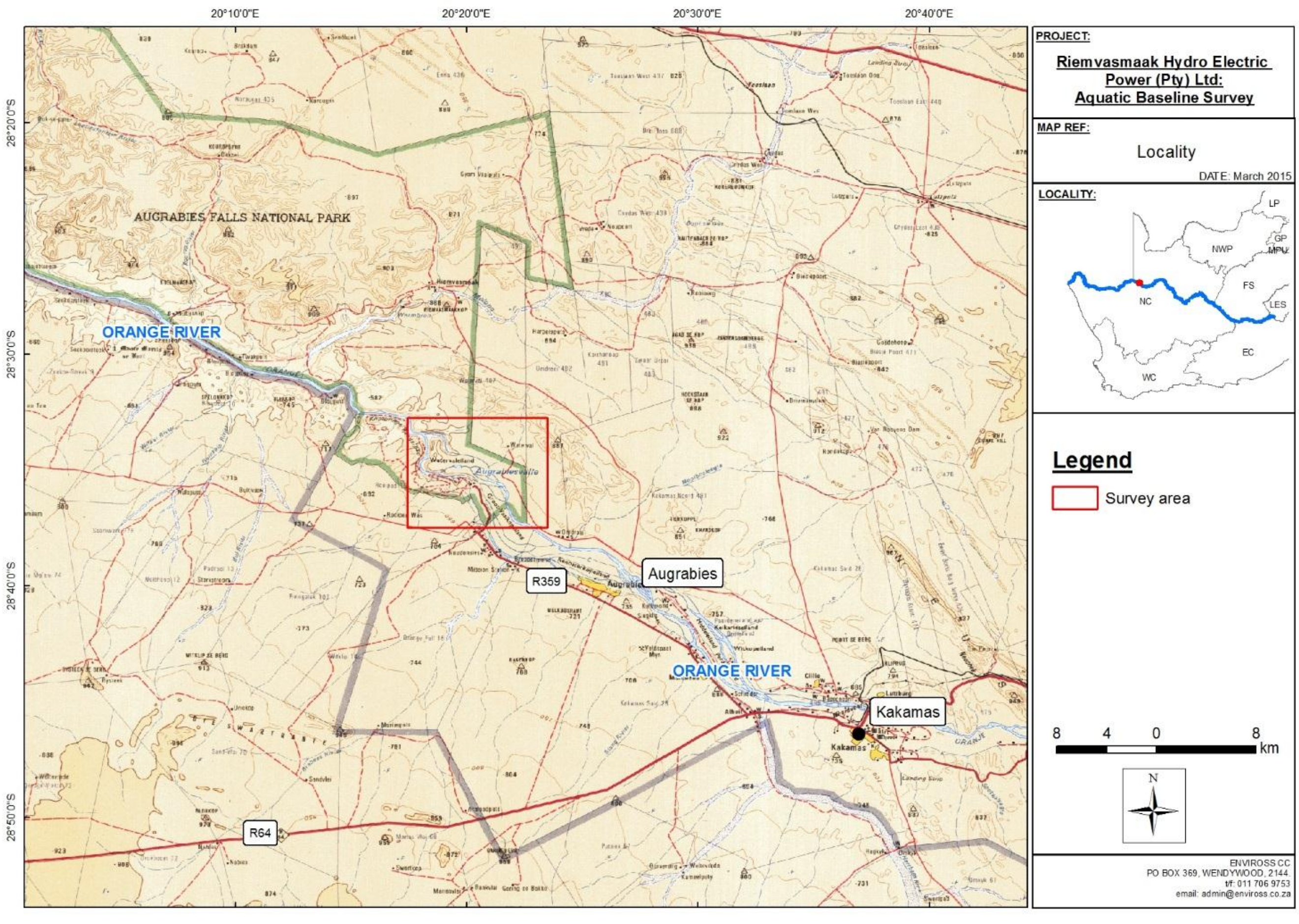

Figure 1: Locality of the proposed development site.

1.2. Hydroelectric power generation

Hydroelectricity is generated by the use of the gravitational force of flowing water to rotate a turbine, which in turn rotates a generator that converts the mechanical, rotational energy into electrical energy. The power that can be generated is proportional to the height through which the water falls to the turbine (the head), the volume of water flowing through the turbine per unit of time (the flow rate), and the efficiency of the turbine / generator combination at converting rotational energy into electrical energy.

1.2.1. Dammed hydroelectric power projects

Most large hydroelectric power projects (HPPs) create the head necessary to drive the turbine / generator sets by constructing a dam across a river, which stores water and releases it into the power house, and then back into the river downstream of the dam wall. This type of project has a significant effect on the flow regime of the river, especially in rivers where the flow rate varies between wet and dry seasons: natural low flows are increased by the need to generate electricity continuously, while natural high flows are reduced because of the need to store water in the dam for use during dry periods. The HPPs at the Gariep Dam (installed capacity 360 MW) and Vanderkloof Dam (installed capacity 120 MW), both on the Orange River upstream of the Augrabies Falls, are examples of projects of this type of HPP. In addition to generating electricity, both dams regulate the flow in the Orange River to provide water for the many irrigation schemes along the river. The dams also provide a measure of security for downstream areas against the destructive effects of all but the largest floods in the rivers.

Dammed HPPs do not directly consume water – they are non-consumptive water users - because the water used to generate electricity is returned to the river a short distance downstream of the dam, but large impounding reservoirs in hot climates do lose considerable volumes of water by evaporation from the open water surface of the reservoir. Associated impacts include loss and/or transformation of biodiversity and habitat from inundation of the area upstream of the impounding structure, hydrological changes of the river, and migratory barrier formation (if unmitigated). The decay of woody biomass not cleared from the flooded basin before inundation can also result in the release of methane from the water surface and flows over the spillways.

1.2.2. Run-of-river hydroelectric power projects

The proposed RVM HPP will be a run-of-river project. This type of project uses the natural drop in elevation along the course of a river to create the driving head, and usually has a much smaller storage capacity than a dammed scheme, or no storage at all. Where storage is required it is usually created by a low weir across the river, which diverts a portion of the natural flow of the river to the power house, and then back into the river a short distance downstream of the diversion weir. Since it is necessary to construct some form of open or closed conduit (a canal or pipeline) to convey the water from the diversion weir to the power house, a site with a short, steep drop in elevation - a natural geological feature such as a waterfall - is preferred in order to limit the length and cost of the conduit, which is referred to as the headrace.

Run-of-river projects do not affect the flow regime of the river as much as dammed schemes. The diversion capacity is generally not sufficient to materially affect seasonal high flows in the river, and provisions are usually made in the project operating rules to minimise the effects of the diversion at seasonal low flow rates.

Run-of-river HPPs are also non-consumptive water users, and the evaporative losses from the very much smaller open water surfaces of the weir impoundment, offtake, open (canal) headrace and head pond, are also much reduced compared to a dammed scheme.

1.3. General Project Description

1.3.1. Infrastructure

In broad terms, the project will entail the construction of infrastructure comprising:

1. A low diversion weir across the Orange River upstream of the Augrabies Falls.
2. An off-take structure at the weir to facilitate diversion of water from the river.
3. A conduit – the headrace - to convey water from the intake structure to the penstock head pond.
4. A head pond and power station intake structure – forebay/headpond.
5. Vertical (or very steep) penstocks – pipes - to transfer the water from the head pond to the power chamber.
6. An underground power chamber containing up to four Francis turbines.

7. An underground tailrace and outlet works to convey water from the power chamber back to the river channel.
8. A haulage way and / or haul roads to facilitate access for construction and the removal of excavated material off site for disposal or re-use.
9. A high voltage (HV) power line to evacuate the power from the power station to the national grid partly underground for approximately 8 km and partly above ground for approximately a further 8 km.
10. A transformer yard and mini substation located at the headpond and a new substation.
11. Fencing as required for public safety.

.

In addition, a previously existing pedestrian bridge across the river channel a short distance upstream of the Augrabies Falls, which was washed away by a recent flood event, might be rebuilt as part of the hydropower project.

1.3.2. Weir design and features

The weir will be designed in such a way that there will be no physical barrier preventing water flowing to the falls. The assumption is that 30m³/s will be adopted as the minimum flow. This equates to roughly the minimum flow the river experiences.

Figure 2: Conceptual diagram showing the proposed diversion weir and intake structure (*from* HydroSA (Pty) Ltd).

Normally a weir crest of this type would be uniform in level across the full length. The RVM weir will have "slots" in the crest that govern how much water is allowed to pass the weir and how much is diverted into the hydroelectric project. The general arrangement of the weir (as viewed from upstream) is shown in Figure 3.

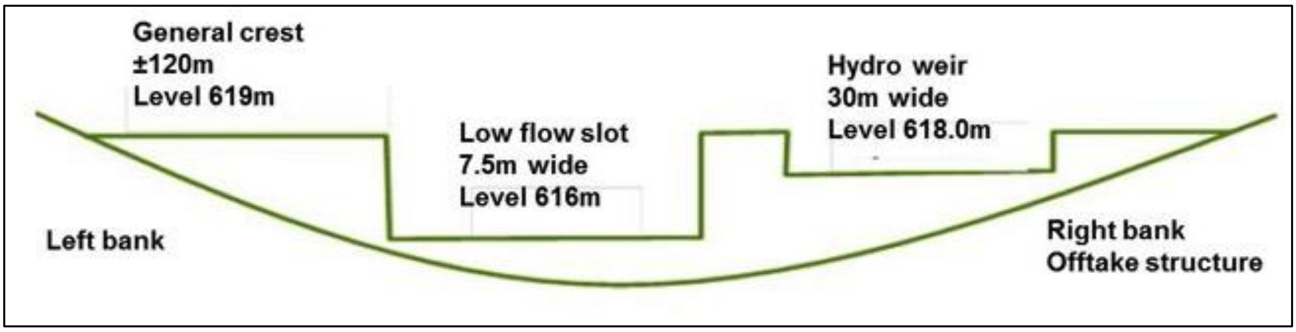

Figure 3: Design concept of the diversion weir as viewed from upstream.

The illustration indicates how, the "low slot" will allow water to pass the weir before water can flow over the "hydro slot" and be diverted into the pipeline for the hydroelectric project. The level at which the "hydro slot" is set will be determined by the agreed minimum flow and will coincide with the level at which water will pass through the "low slot" at the agreed minimum flow rate (i.e. 30 m^3/s).

Basic hydraulics states that flow is proportional to area. As the depth of water increases in both the "low slot" and the "hydro slot", so too does the flow through those slots. The implication of this is that although flow is increasing through the "hydro slot", so too will it be increasing through the "low slot". At a total river flow of 30 m^3/s, the flow in the "low slot" is 30 m^3/s and there is zero flow through the "hydro slot". The maximum flow into the hydroelectric project is 38m^3/s. When this flow is achieved, the total river flow is approximately 90 m^3/s, meaning the flow through the "low slot" is 52 m^3/s, which then flows over the falls. When total river flow exceeds approximately 90 m^3/s, water spills over the full length of the weir crest but the flow into the hydroelectric project is capped at 37.6 m^3/s by the operation of gates on the offtake structure. To operate optimally the maximum proportion of the flow taken by the hydroelectric project is 40% at a flow rate of 90 m^3/s and hence the hydroelectric project can never take all the water away from the falls.

To quantify the impact of the weir, flow duration curves have been developed, which compare the flow over the falls before and after implementation of the proposed RVM Hydro Electric Project. These curves are presented in Figure 4. The curves show that:

- For ±20% of the time no flow will be diverted into the tailrace:
  - For ±15% of the time (55 days) the river flows at or less than 30m³/s, so no flow will be diverted into the headrace and the HPP will not operate.
  - For ±5% of the time (18 days) the river flows at or more than 800m³/s. At this flow rate it is anticipated that the sediment loads in the river will begin to increase to such an extent that sediment could be drawn into the headrace, and could result in damage to the turbines. No flow will be diverted into the headrace, power generation will be shut down to prevent damage to the turbines.
- For ±45% of the time (165 days, or 5.4 months) river flows are between 30m³/s and 90m³/s, diverted flow will progressively increase from zero to 37.6m³/s, and the power station will operate at less than its installed generating capacity.
- For ±35% of the time (128 days, or 4.2 months river flows exceed 90m³/s but are less than 80090m³/s, diverted flow will be at a maximum of 37.6m³/s, and the power station will operate at its full design capacity

Construction of the proposed weir will not cause the water to stop flowing over the falls. It will only divert a portion of the total river flow (in the opinion of the authors), which, in the opinion of the authors, would not impact on the overall aesthetic appeal of the falls to most casual observers.

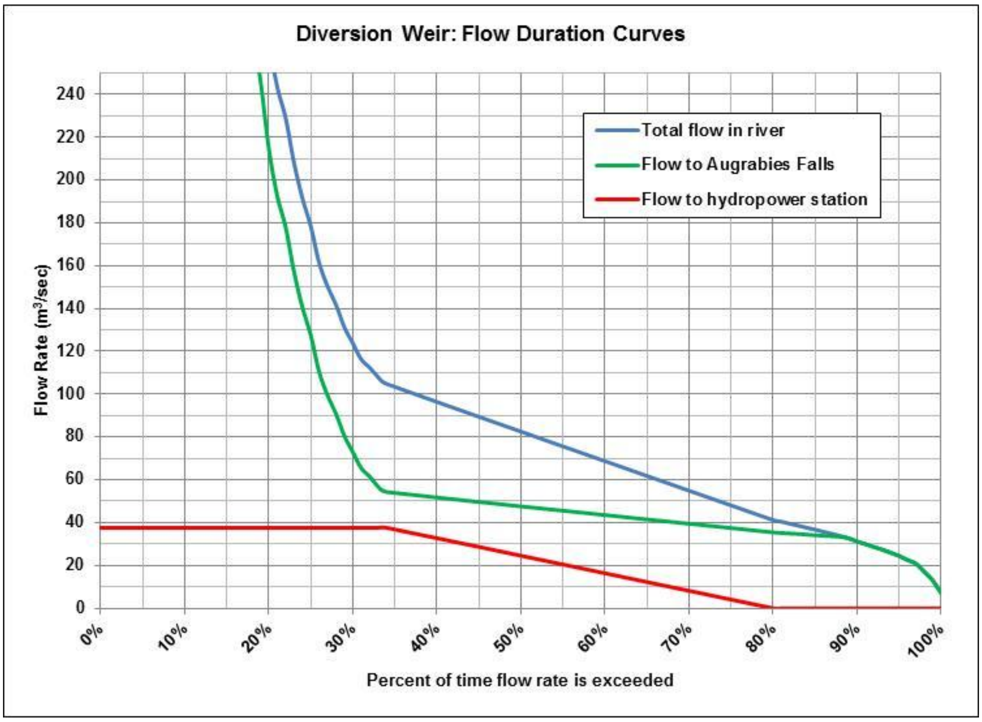

Figure 4. Comparison of Flow Duration Curves

1.4. Scope of Work

The Scope of Work included an ecological survey for the riverine habitat to establish baseline data for the river reach that would be impacted by the development activities. These baseline data would then allow for impact evaluations (from both predictions as well as routine future monitoring) in order to evaluate the potential impacts on the system. Water samples were also to be taken at the time of the sampling for comprehensive elemental analysis of all components. A general impact assessment for the surface water resources was to be developed, which would allow for mitigation measures to be proposed in order abate or manage overall negative ecological impacts.

1.5. Aims & Objectives

The objective of this report is to provide the relevant biological information pertaining to the surface water resources and the implications of the potential to the planning, management and construction teams of the proposed development activities, so as to manage and minimise the ecological impacts. It is also to provide baseline data that would serve as the benchmark data that would allow for trend analysis of future data.

This report details the findings of two field surveys that were undertaken during October 2013 and March 2015.

1.6. Assumptions & Limitations

The conclusions to the PES and the overall perceived potential impacts alluded to within this report represents the results of a single survey. Certain assumptions have been made regarding the future trends and the influence of seasonality that have been based on professional judgement and experience gained by the field ecologists whilst surveying within similar areas. The confidence of the trend analysis will increase when more surveys have been undertaken.

2. STUDY AREA & CATCHMENT CHARACTERISTICS

The survey area included the segment of the Orange River associated with the Augrabies Falls (upstream and downstream), that is located approximately 35 km downstream of Kakamas in the Northern Cape Province. The locality of the survey area is presented in Figure 5. Flow gauging of the Orange River is undertaken by DWA upstream at the Neusberg Gauging Weir and downstream at Blouputs Gauging Weir (located approximately 22 km downstream of Augrabies Falls).

The survey area falls within the Orange River (D) Primary Catchment, and within the DWA Lower Orange River Water Management Area (WMA14). It falls within the D81A Quaternary Catchment. The dominant land use within the immediate area is open, with the area forming part of a formally conserved national park. Within the survey area the southern bank of the Orange River forms part of the Augrabies Falls National Park, which is managed by South African National Parks (SANParks). The area on the northern banks of the river within the conserved areas is owned by the local community, but managed by SANPARKS. Further afield formal agriculture dominates the greenbelt area associated with the river that is serviced by a formal irrigation scheme. The Orange River represents one of the very few perennial river systems within an otherwise arid region, with the vast majority of the rivers and streams being seasonal in nature. The predominant surrounding vegetation type is Lower Gariep Alluvial Vegetation, Lower Gariep Broken Veld and Bushmanland Arid Grassland. Lower Gariep Alluvial Vegetation is regarded as an *Endangered* vegetation type due to large scale transformation through formal agriculture within the riparian zones of the Orange River within the region. The remaining vegetation units are regarded as *Least Threatened* (Mucina & Rutherford, 2006).

The Orange River at the proposed development site, within the segment above the Augrabies Falls, is a highly braided channel. There is a main channel, which is regarded as the active channel during low flow periods, feeds the Augrabies Falls where the water is constricted through a narrow granitic gorge, plunging approximately 60 m. Side channels become increasingly inundated as the flow rate in the river increases, with a proportion of the main water volume bypassing the main waterfall through these side channels located to the north of the main active channel. These side channels also forms waterfalls when flowing, and join the main watercourse approximately 4 to 6 km downstream of the falls.

The riparian zones of the river form a distinctive greenbelt within an otherwise arid region, which supports an alluvial vegetation (azonal) type, known as Lower Gariep Alluvial Vegetation. It is regarded as an *Endangered* vegetation unit due to the lack of substantive areas incorporated into formal conservation areas, the limited extent of the vegetation unit, and the high transformation rate that has taken place to accommodate formal agriculture. Dominant and characteristic floral species include *Salix mucronata, Ziziphus mucronata, Searsia pendulina, Euclea pseudebenus, Acacia karroo* and *Tamarix usneoides*. Unstructured alluvial and aeolian sands are common along the banks of the means that pioneering grass species dominate, with the most common species being *Cynodon dactylon*.

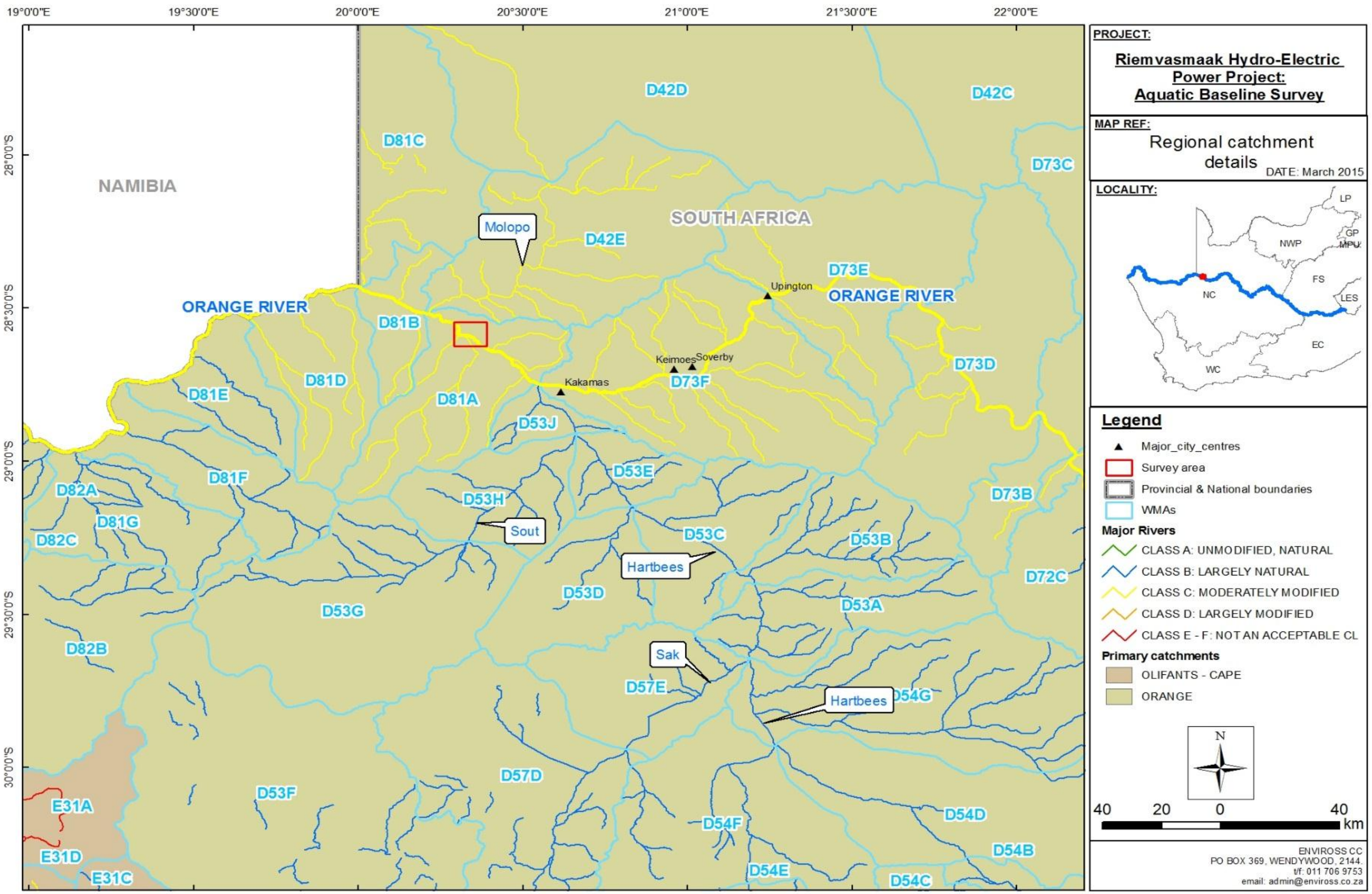

Figure 5: Regional catchment details of the area associated with the proposed development site.

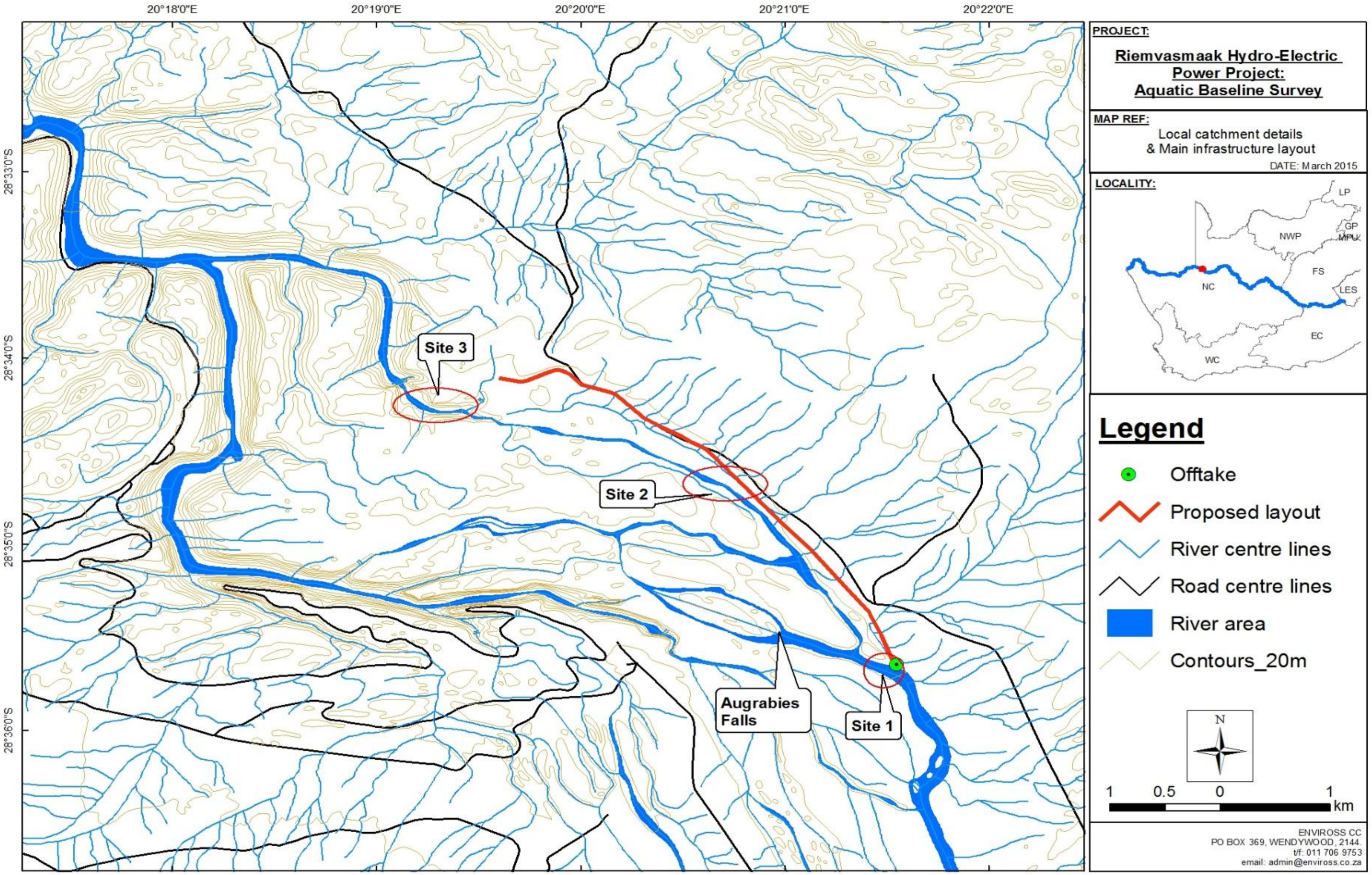

Figure 6: Proposed infrastructure layout of the RVM HEPS showing the localities of the survey sites/areas.

3. SITE DESCRIPTIONS

The flow rate in the river was considered relatively low at the time of the survey (approximately 30 m^3/s from DWA D8H014 gauging weir located downstream of the site at Blouputs), and therefore the flow was mainly confined to the main watercourse rather than being dispersed within side channels.

3.1. Site 1: Diversion weir site.

The proposed diversion weir site is located upstream of the Augrabies Falls within a section of the river that has a highly braided channel. Increasing river volume increases the diversity of habitat within this area as the increasing volume inundates side channels. These side channels offer varying levels of available aquatic habitat as persistence of surface waters vary between channels. There is, however, a main watercourse, which was the focus of the study within this river segment as flow within the river was mainly confined to this main channel.

Substrate at the site is dominated by bedrock within the main channel, with deposition of gravel and sand where hydraulic features induce deposition (sheltered back eddies, etc). Flow-depth classes within the main channel includes fast deep, fast shallow, slow deep and slow shallow areas. Outside of the main channel are sheltered backwater areas that offer slow shallow and slow deep areas, where gravel deposition is common, together with cobbles and stones. The vegetation biotope included emergent marginal vegetation, predominantly reeds and roots. Aquatic vegetation was limited to an isolated occurrence of *Elodea* sp. that occurred out of current within a backwater area. Isolated patches of algae occurred as well. The gradient of the channel at the site was relatively low, so cascading flow and associated rapids and riffle habitat was uncommon. Flowing habitat was predominantly glides where constrictions in the channel occur, such as between boulders, etc, but flow was predominantly flat.

Flowing water habitat units were mostly associated with bedrock substrates, making for the assumption that the habitat at the site is not highly productive and therefore not conducive to supporting a high diversity of aquatic macro-invertebrates. The site does, however, offer a diversity of habitat types/biotopes for supporting a variety of fish species and therefore a relatively good diversity and abundance is expected to occur within this section of the river.

Riparian vegetation and riparian zones are considered near-natural to natural due to the area being managed as a conservation area. Encroachment to within the watercourse was evident, however, due to the lack of regular flooding events. The almost total lack of utilisation of the northern banks for tourism also means that this area remains in a good ecological state, albeit that historical utilisation for inhabitation and livestock is shown by a small degree of transformation of the vegetation, and by remaining infrastructure. A low density of wildlife within the area utilise the riparian zones and therefore tracks occur, but this is regarded as a natural use of the riparian zones and is therefore not considered a driver of ecological change. Reedbeds occur along the banks as well as colonising sandbars. Colonising sandbars traps further sediments and gravel, offering opportunity for encroachment to within the watercourse. This occurs in the absence of large flood events and is something that the upper sections of the river (above the falls) is impacted by.

Figure 7: Various views of typical habitat features of the site at the proposed diversion weir.

3.2. Site 2: Seasonal side channel.

This section of the river represents a seasonal side tributary of the main watercourse. This channel was chosen as a study site as it was shown to offer persistent surface water that provided habitat for a diversity of aquatic organisms. It was observed that the channel was supplied with a minimal amount of flow that ensured that persistent pools remained full, with some flowing-type habitat between pools. This was true for the upper section of the channel. The water within the channel did tend to dissipate further along the channel, making for the assumption that the water percolated into the gravel beds. The flow rate in the mainstem river channel was approximately 30 m^3/s at the time of the survey, and this side channel was still receiving some water. It is assumed that flow rates lower than this would see a lack of surface water, but that the channel would still be fed to a degree by seepage. Releases from upstream impoundments means that flow rates less than 25 to 30 m^3/s are temporary within the system and therefore this side channel offers almost permanent habitat to aquatic organisms.

The substrate within this watercourse included a high prominence of sand and gravel, cobbles, bedrock and large boulders. Aquatic vegetation included algae (largely due to limited flow, and high nutrient loads), with marginal vegetation being dominated by emergent reedbeds (*Phragmites australis*) and roots of riparian vegetation. Flow-depth classes were dominated by slow shallow and slow deep habitat. Habitat diversity was considered high, but productivity of the channel is regarded as being limited by the general lack of flow. An increase in flow would see this channel support a high abundance and diversity of aquatic macro-invertebrates and fish.

Figure 8: Various views of typical habitat features of the side channel.

3.3. Site 3: Main channel downstream of discharge.

The main channel downstream of the proposed discharge (outfall) point. The channel at this point falls within the Orange River Gorge, and is characterised by a constricted, bedrock-dominated, steep-sided channel. The water is generally deep and fast-flowing. There is a distinct lack of riparian vegetation, as well as instream and aquatic vegetation, which is largely due to the flooding regimes of the site. Because of the narrowing of the channel, the effect of flood events are more significant within this section of the river. The scouring effect of the floodwaters reduces the chances of vegetation being able to anchor sufficiently, which is a feature of the main watercourse of the Orange River Gorge. Sandbar and gravel bar deposition does occur where the river bends and hydraulic conditions induce deposition, but these are dynamic and are continually changing with the varying hydraulic conditions of the watercourse. Due to dangerous conditions and flow-depth classes, this section of the river is difficult to sample. The habitat types (biotopes) that are available makes for the assumption that productivity is low and that limited diversity and abundance of aquatic macro-invertebrates would inhabit this section of the river. A diversity of fish species does occur within this section of the river as they are able to exploit the varying hydraulic conditions to their advantage.

4. ECOCLASSIFICATION

4.1. Concepts and principles

EcoClassification is the term used for the Ecological Classification process and refers to the determination and categorisation of the Present Ecological State (PES i.e. the health of integrity) of various biophysical attributes of rivers relative to the natural or close to the natural reference condition. The purpose of EcoClassification is to gain insight and understanding into the causes and sources of the deviation of the PES of biophysical attributes from the reference condition. This provides the information needed to derive desirable and attainable future ecological objectives for the river. The EcoClassification and EcoStatus determination are undertaken according to DWA guidelines (Kleynhans & Louw, 2007, Module A).

The steps followed in EcoClassification are as follows:

- Determine reference conditions for each component.
- Determine the PES for each component, as well as for the integrated EcoStatus.
- Determine the trend for each component, as well as for the EcoStatus.

- Determine the reasons for the PES and whether these are flow or non-flow related.
- Determine the Ecological Importance and Sensitivity (EIS) for the biota and habitats.
- Considering the PES and the EIS, suggest a realistic Recommended Ecological Category
- (REC) for each component, as well as for the EcoStatus.

4.1.1. EcoStatus

The EcoClassification process followed for this survey is based on a combination of the Desktop EcoStatus level and an EcoStatus Level I determination and involved the use of the following indices:

- Determination of the PES for each component using the various EcoStatus models:
  - Index of Habitat integrity (IHI): Kleynhans *et al*. (2009a).
  - Physico-chemical Assessment Index (PAI): Kleynhans *et al*. (2005b).
  - Fish Response Assessment Index (FRAI): Kleynhans (2007a).
  - Macroinvertebrate Assessment Index (MIRAI): Thirion (2007).
  - Riparian Vegetation Assessment index (VEGRAI): Kleynhans *et al*. (2007d).
- Determine the EcoStatus which involves integration of the individual Ecological Category (EC) values of the abovementioned components to obtain an overall EcoStatus category (as outlined below).
- Determination of the trend for the various driver and response PES and integrated EcoStatus.

The Present Ecological State (PES) of the river is expressed in terms of biophysical components:

- Drivers (physico-chemical, geomorphology, hydrology), which provide a particular habitat template; and
- Biological responses (fish, aquatic macro-invertebrates and riparian vegetation).

Different processes (indices) are followed to assign a category (A → F; A = Natural, and F = critically modified) to each component. Ecological categories are assigned the A to F categories within a continuum, with no clearly-defined boundaries. This concept is illustrated in Figure 9.

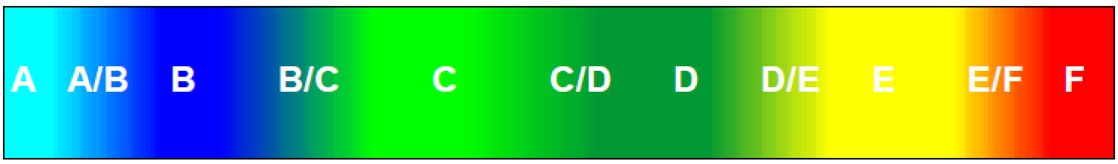

Figure 9: Illustration of the distribution of Ecological Categories on a continuum (from DWA, 2007).

Ecological evaluation in terms of expected reference conditions, followed by integration of these components, represents the Ecological Status or EcoStatus of a river. Thus, the EcoStatus can be defined as the totality of the features and characteristics of the river and its riparian areas that bear upon its ability to support an appropriate natural flora and fauna (*modified from* Iversen *et al*., 2000). This ability relates directly to the capacity of the system to provide a variety of goods and services.

Table 3: Generic interpretation of the EcoStatus categories (*from* Kleynhans & Louw, 2007).

Ecological Category	Description
A (90-100%)	Unmodified, natural.
B (80-89%)	Largely natural with few modifications. A small change in natural habitats and biota may have taken place, but the ecosystem functions are essentially unchanged.
C (60-79%)	Moderately modified. Loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged.
D (40-59%)	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions has occurred.
E (20-39%)	Seriously modified. The loss of natural habitat, biota and basic ecosystem functions is extensive.
F (0-19%)	Critically /Extremely modified. Modifications have reached a critical level and the system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.

4.1.2. Ecological importance and Sensitivity (EIS)

The ecological importance of a river is an expression of its importance to the maintenance of biological diversity and ecological functioning on local and wider scales. Ecological sensitivity (or fragility) refers to the system's ability to resist disturbance and its capability to recover from disturbance once it has occurred (resilience). Both abiotic and biotic components of the system are taken into consideration in the assessment of ecological importance and sensitivity (Kleynhans & Louw, 2007).

4.2. Present Ecological State

4.2.1. Reference Conditions

The EcoStatus model would ordinarily call for a theoretical reference state to be determined for the river reach under question, as the Present Ecological State (PES) is discerned through determining by how much the present state differs from the reference state (under natural conditions). A background survey was undertaken for the site to gain a theoretical reference state model so that the EcoStatus models could be effectively applied. It should be noted, however, that this survey will be regarded as the reference state and any trending changes brought about by the proposed development activities will be benchmarked against these data in future. The theoretical reference conditions for the various components for the river reach under study are presented in Table 4.

Table 4: Theoretical reference conditions applicable to the river reach under study.

Component	Reference conditions	Conf
Physico-chemical characteristics	A comprehensive water quality assessment has been undertaken as part of the survey. Baseline data will serve as the reference data for future monitoring comparisons.	-
Riparian vegetation	*Inner marginal zones:* A steep and well-defined gradient is expected between the outer edges of the marginal zones and the inner zones where permanent moisture would occur. Reedbeds (predominantly *Phragmites australis*) would occur within these inner marginal zones and form dominant stands. *Outer marginal zones:* The outer marginal zones would see a greater inclusion of woody elements, including *Salix mucronata, Ziziphus mucronata, Searsia pendulina* and *Acacia karroo*. Outer marginal zones would see species representative of arid conditions, with *Tamarix usneoides* being dominant. Loose and unstructured soils would mean that soil dispersal by wind action would be common. It is therefore thought that some open areas (especially within areas of high gradients) would occur. Below the Augrabies Falls, within the gorge habitat unit, limited riparian vegetation occurs due to the predominance of bedrock and the regular occurrence of floods. The geomorphology of the river reach within this area (steep-sloping riparian zones with narrow channels) means that flood events affect these habitat zones more profoundly than within the areas upstream of the falls, where the macro-channel is significantly wider and the riparian zones and geomorphological features of the river reach have a significantly greater attenuating capacity for flooding events of similar magnitude. The regularity of flood events within the gorge areas means that riparian vegetation is sparse as limited opportunity is given for vegetation to anchor sufficiently to withstand these flooding events.	4
Fish	The DWA provides a reference list of fish species that would be expected to occur at the site (FROC data, Kleynhans, 2008). No actual reference site is provided for the Orange River Gorge ecoregion and therefore reference data remains at the discretion of the aquatic specialist. Nearest reference sites are at Neusberg Weir (upstream), Blouputs and Onseepkans (both located downstream of the gorge habitat unit). These three sites are taken collectively and utilised to provide a reference list of expected species. It should also be noted that the Augrabies Falls remains an absolute migratory barrier to the fish species within the river reach, and also acts as a delimiter to *Barbus hospes* (Namaqua barb) from occurring anywhere other than downstream of the falls. The falls also acts as a delimiter to the local distribution of *Mesobola brevianalis* (River sardine). This species only occurs downstream of the falls within this system, although it occurs within other systems as well. Therefore reference conditions for fish community structures will be different for above and below the falls. **<u>Above the falls:</u>** There are 11 indigenous species that occur within the river reach above the falls (applicable to the diversion weir site and side channels upstream of any significant waterfalls), namely *Austroglanis sclateri, Barbus anoplus, Labeobarbus aeneus, Labeobarbus kimberleyensis, Barbus paludinosus, Barbus trimaculatus*, *Clarias gariepinus*, *Labeo capensis*, *Labeo umbratus*, *Pseudocrenilabrus philander* and *Tilapia sparrmanii.*	4

Component	Reference conditions	Conf
	<u>Below the falls:</u> There are 12 indigenous species that are expected to occur within the river reach below the falls, namely *Austroglanis sclateri, Labeobarbus aeneus, Labeobarbus kimberleyensis, Barbus paludinosus, Barbus trimaculatus*, *Barbus hospes, Mesobola brevianalis, Clarias gariepinus*, *Labeo capensis*, *Labeo umbratus*, *Pseudocrenilabrus philander* and *Tilapia sparrmanii.* The diversity of available habitat is taken into consideration when discerning the overall probability of all of these species occurring within the applicable river reach.	
Aquatic macroinvertebrates	SASS5 interpretation guidelines are provided by Dallas, 2005, wherein the expected macro-invertebrate scores are provided for various PES categories as follows. Two aquatic ecoregions are applicable to the survey area, namely Nama Karoo and Orange River Gorge. Reference (natural) conditions with adequate habitat would therefore refer to an "A" category for both ecoregions. **<u>Nama Karoo (applicable to the diversion weir site):</u>** Category SASS Score ASPT A >109 >6.0 B 101-109 5.6-6.0 C 71-100 5.3-5.5 D 35-70 4.7-5.2 E/F 0.34 0-4.6 **<u>Orange River Gorge*:</u>** Category SASS Score ASPT A >115 >5.8 B 90-115 5.5-5.7 C 65-89 4.9-5.4 D 40-64 4.8-4.9 E/F 0-39 0-4.8 **** Limited data available for statistical analysis so reference data may need further interpretation.*** Again, the diversity of available habitat is taken into consideration when discerning the overall probability of all of these taxa occurring within the applicable river reach/survey sites. Of concern is the abundance of blackfly (*Simulium chutteri*) that has been induced due to various impacting features experienced by the river. Impounding the river to the expected level of the proposed hydropower scheme is not thought to significantly increase the abundance of this species and create any further shift from reference conditions. This is rather applicable to large-scale impoundments and not necessarily to the scale that the RVM HPS is proposing.	4

4.2.2. Present Ecological State

Various indices were utilised to assign the river reach in question a baseline PES rating, which included the River Index of Habitat Integrity (River-IHI), MIRAI (Macro-invertebrate Response Assessment Index), FRAI (Fish Response Assessment Index) and VEGRAI (Vegetation Response Assessment Index). The results from these various components are summarised in Table 5, where the overall EC (Ecological Category) is also provided.

Table 5: Summary of the EcoStatus models for the river segment pertaining to the proposed development area.

Component	EC (%)	Ecological Category
Index of Habitat Integrity		
Instream IHI	73.2%	C
Riparian IHI	62.4%	C
Fish Response Assessment Index	72.8%	C
Macro-invertebrate Response Assessment Index	62.9%	C
Vegetation Response Assessment Index	80.0%	B/C
	ECOSTATUS	**C (Confidence: 4)**

4.2.3. Drivers of ecological change

4.2.3.1. Instream IHI

The instream IHI rates the survey system within a C category. The largest driver of ecological change is the change in hydrological characteristics of the system due to upstream impoundments and flow release management strategies that induce an artificial seasonality within the system. There are therefore changes in base flows as well as the natural occurrence and extent of flooding events. Historically the Orange River was considered a seasonal system, with occurrences of the river ceasing to flow during exceptional drought periods. Since the construction of the Gariep and Van der Kloof dams and the subsequent releases to satisfy irrigation demand as well as hydropower generation demand, flow within the river does not cease and only major flooding events affect the seasonality of the system. The upstream impoundments are generally able to attenuate (absorb by reducing the peak flows and extending the duration of) minor flooding and freshets (natural short-lived high flows following normal rainfall periods) flows that would otherwise function to maintain the watercourse by regularly flushing sediments that had settled during the low flow periods. The riparian IHI also places the system within a C category for similar reasoning. The encroachment of riparian vegetation is managed through large flood events. Channel maintenance therefore does not occur to the extent that it would under reference conditions, which sees a transformation of the riparian vegetation, sand bar deposition that loses dynamism and tend to become permanent features of the watercourse, especially when colonised by reedbeds.

4.2.3.2. Fish

The FRAI rates the fish species community structure within a C category. This is largely due to a portion of the expected species not being sampled during the survey. Habitat integrity proved to be relatively good, and water quality was also not found to be a limiting factor. The overall poor results are therefore thought to be attributed to the efficiency of the collection techniques employed during the survey. Limitations to fish collection techniques include the inability to sample deep water effectively and the practical limitations to sampling fast-flowing water, as well as the safety factors imposed on the efficiency of the operators. It is assumed that, with routine monitoring, that the fish collection data will improve. There was a good diversity of fish sampled during the survey, and it was the relevant abundances that differed from reference conditions that tended to lower the ratings. Fish community structures are dynamic within the various river reaches and therefore only long-term data that is able to determine trends will enable greater accuracy. This would also tend to improve the accuracy of expected reference state conditions.

4.2.3.3. Aquatic macroinvertebrates

The results of the MIRAI placed the system within a C category. Water quality tends to limit the occurrence of sensitive species, which emanates from agricultural activities upstream of the river section. Agrochemicals and an increase in nutrient loading of the system are the greatest drivers of ecological change in terms of water quality, which impacts the aquatic species community structures. Actual instream habitat quality and availability was also considered a limiting factor during the time of sampling as it was noted that flowing water (which is regarded as the most productive condition) was largely limited to bedrock areas, a substrate that is not considered to be highly productive).

The SASS5 scores ranged from 99 (ASPT: 5.0, number of taxa: 20) to 53 (ASPT 4.1, number of taxa: 13) throughout the survey area.

4.3. Ecological Importance and Sensitivity (EIS)

The use of biotic data in the assessment of the EIS considers the presence of rare and endangered species, unique species and species (including various life-history stages) with a particular sensitivity to flow (and flow-related water quality aspects) in combination with other ecological information on the study area. The

EIS of a river is an expression of its importance to the maintenance of ecological diversity and functioning on local and wider scales. Ecological Sensitivity refers to the ability of the system ability to tolerate disturbance and its resilience once an impact has taken place (Kleynhans, 1999b). The EIS of the system is regarded as being *High*. The most important and relevant points are summaries in Table 6.

Table 6: Summary of the relevant points of the EIS determination.

Determinant	Score	Conf	Reason
PRIMARY DETERMINANTS			
Rare and endangered species	4	4	*Labeobarbus kimberleyensis; Austroglanis sclateri*
Populations of unique/isolated species	3	4	*Aridity of the surrounding region means that the riparian zones and river habitat would be utilised by many unique and isolated species.*
Species / taxon richness	3	4	*Moderate/High* – 7/11 of the expected fish species sampled. Rich diversity of birds and Herpetofauna and mammalian species
Diversity of habitat types or features	3	4	*Moderate/High* - instream biotopes diverse through interlinking channels, islands.
Migration/breeding and foraging site for wetland/riparian species	2	4	The riparian zones form a greenbelt through an arid area that is readily utilised for agriculture. It is therefore important to maintain this for maintenance of migrations and connectivity.
Sensitivity to changes in natural hydrological regime	3	4	Many fish species sampled are regarded as being flow dependent, with flow being a primary trigger for stimulating migratory movements.
Sensitivity to water quality changes	3	3	Some sensitive biodiversity noted within the aquatic habitat that would be impacted by deterioration of water quality.
Flood storage and energy dissipation	2	2	The Orange River has a large catchment area. There is limited capacity for flood attenuation due to limited flood plain interaction.
Base-flow augmentation and dilution	3	2	Large catchment with significant mean annual runoff, with the Orange River representing the main watercourse for the region.
MODIFYING DETERMINANTS			
Protected status	4	4	Aquatic and riparian habitats are statutorily protected and the survey area falls within a formally conserved area.
Ecological importance (rarity of size/type/condition)	2	3	The Orange River represents the main watercourse for the region and one of the very few perennial systems within an arid environment.
TOTAL	***32***		
MEDIAN	**3**	**3**	
		EIS	**High**

5. WATER QUALITY

The *in situ* water quality of all of the aquatic biomonitoring sites were taken using a *Hanna model 9828* multi-parameter water quality meter. These data are important to the interpretation of the biological data that are gathered during the sampling at the various sites. The parameters that were recorded were: Dissolved oxygen (%), Oxygen content (mg/ℓ), pH, Total dissolved solids (Tds) (ppm), Electro-conductivity (EC) (µS/cm) and Temperature (°C).

Water samples were taken and analysed for general parameters and full metal screening. Samples from all biomonitoring sites were taken during the high flow survey, whilst it was only possible to take water samples from selected sites during the low flow survey due to the seasonal nature of many of the streams. Sediment samples were taken at all the sites and analysed for metal content.

The water quality evaluation formed an integral part in determining the potential impact of the proposed development activities on the conservation of the surface water resources. The proposed development falls within a sensitive and important aquatic resource, with the water resource being supplied to rural and formal sectors. This means that the maintenance of the quality of the water resource within acceptable limits should be a management priority.

5.1. *In situ* water quality results

In situ water quality parameters were taken at various points throughout the survey area to best gain average water quality parameter values for the surface waters at the time of the biological sampling. Samples from all of the biological survey sites were taken, which were done in triplicate, using a hand-held *Hanna Multi-parameter water quality meter: Model 9828*. . The water quality parameters reported on are therefore the average values at each site. This was done to improve the accuracy of the data.

Water quality determination forms an integral part of enabling accurate interpretations of the biological data as the final ecological class allocation, and associated interpretations of the results, is a combination between the habitat quality, water quality and biological integrity. The parameters tested for and the results from each site sample are presented in Table 7. The South African Water Quality Guidelines for Aquatic Ecosystems (DWA SAWQG's, 1996) are used to evaluate the results.

Table 7: *In situ* water quality results for each site taken during the high flow survey.

Site	DO mg/ℓ	DO %	pH	Temp °C	mbar	EC µS/cm	TDS ppm	Salinity	ORP
Diversion weir	8.95	119.6	8.44	26.22	941.7	310	155	0.15	41.0
Side channel	6.23	86.4	8.39	26.84	942.0	314	158	0.15	35.4
Below discharge	8.88	117.2	8.46	26.48	946.4	312	157	0.15	44.0
Guideline Values (DWA, 1996)	>5 mg/ℓ	>60%	Between 6 and 8, and should not exceed 0.5 pH units or 5% of the natural pH range for a given system at any given time	Should not fluctuate by more than 2 °C or 10% of the normal daily cycle	-	TDS of <1000 ppm or not fluctuate by more than 15% of the normal range of a system within a 24hr cycle.			-

The DWA (1996) guidelines for aquatic ecosystems provides parameters and guideline values that are considered for maintaining ecosystem health. These parameters are provided as a degree of deviation from the normal seasonal variations that a system would naturally experience. To analyse the degree of deviation from normal conditions, some background knowledge of the baseline water quality of the system is required. The authors have gained such knowledge from extensive monitoring along the Orange River over the last number of years.

5.1.1. Water temperature

Water temperature plays an integral role in biochemical processes and therefore governs the rate of associated metabolic processes of poikilothermic ("cold-blooded") aquatic organisms. The metabolic rate of aquatic organisms is governed by temperature and therefore the rate of development and growth as well as repair of damaged tissue and the functionality of associated stress-coping mechanisms of aquatic organisms is also all governed by the water temperature. The South African Water Quality Guidelines (SAWQG's) (1996) stipulate that water temperature should not fluctuate by more than 2°C or 10% of the normal daily temperature cycle of a system for the season associated with the sampling. Different river systems and even different reaches of the same river system have differing temperature regimes due to the origin of the water source or the habitat through which the watercourse passes. Underground water fed streams display typically colder water temperatures than that of the mid waters of a wide river that has been exposed to radiant temperature for a longer period of time. Water temperature also varies according to local conditions, position within the water column (deeper water tends to be colder than shallower water), movement (mixing) of water (temperature stratification occurs outside of the mixing zones, whereas temperature stratification (thermoclines) develop in deeper, still-standing water). Aquatic organisms have evolved to survive within an optimal range of water temperatures for a given reach of a river and are able to move position to exploit areas of optimal temperatures if allowed the migratory freedom to do so. Any sudden fluctuations that are artificially induced adversely affect the survival rates and is regarded as a limitation to supporting of aquatic biota.

The water temperatures recorded at the time of sampling ranged between 26.2 and 26.8 °C (Table 7). The water temperature recorded at all of the sites is what could be expected for the characteristics of the watercourses, climatic zones and the season and are therefore not expected to be a limiting factor on the survival of the aquatic organisms.

5.1.2. pH

The pH of the natural waters of a river system is influenced by both geological and atmospheric factors as well as, to a lesser extent, biological processes that take place within the water. Most natural waters are relatively well buffered to pH fluctuations due to the presence of bicarbonates and other buffering chemicals (SAWQG's, 1996) and therefore aquatic organisms have evolved to function optimally within a generally very narrow pH range. An undue fluctuation in pH of a system therefore has adverse effects on the survival of aquatic organisms.

According to the SAWQG's (1996), pH of a river system should not fall outside of the range of 6 to 8 pH units. The fluctuation of pH during one 24-hr cycle should also not exceed 0.5 pH units or 5% of the natural pH range for a given system at any given time.

The pH recorded throughout the survey area was regarded as being within optimal ranges for supporting aquatic organisms, being recorded as between 8.4 and 8.5 (Table 7). The pH of the system is therefore not thought to be a limiting factor to supporting a diversity of aquatic biota.

5.1.3. Dissolved oxygen and oxygen content

The maintenance of adequate dissolved oxygen (DO) concentrations is critical for the survival and functioning of the aquatic biota because it is required for the respiration of all aerobic organisms. Therefore, the DO concentration provides a useful measure of the health of an aquatic ecosystem (SAWQG's, 1996). This can be measured as oxygen saturation expressed as a percentage (saturation points differ for water with different temperatures and chemical constituents), or as dissolved oxygen concentration, expressed in mg/ℓ (an absolute value). The general guideline value of oxygen content for supporting aquatic life is >5 mg/ℓ. Oxygen saturation of the water varies and is dependent on the temperature of the water. In general, the cooler the water, the higher the saturation (100%) point. As the water approaches freezing temperature, its saturation point for oxygen content is at its greatest, explaining the reason why ice floats on the surface of water.

Many factors influence the oxygen content of water. The most influential oxygen depleting mechanism applicable to (but not limited to) urban systems is nutrient and hydrocarbon contamination. High nutrient contamination has a consequential high biological oxygen demand (BOD), which, in turn, depletes the water of oxygen to be utilised in biochemical processes to metabolise the nutrients. These nutrients are typically in the form of sewerage (both raw as well as processed) and fertilisers from lawns (golf courses, gardens, etc.) and therefore are not limited to urban systems as agro-chemicals are also well-known to deplete oxygen concentrations within natural waters. Hydrocarbon contaminations from spilled fuels and motor oils on roadways that enter the water course through runoff storm waters have a high chemical oxygen demand (COD). The chemical interactions of hydrocarbons (and other chemicals) with water upon entering the watercourse also then deplete the system of oxygen available for sustaining aquatic life. Many aquatic organisms are specifically adapted to life under low oxygen conditions, and an abundance of these organisms is often an indication of low oxygen content within the system. Oxygen content can be increased in a system first and foremost by photosynthesis of aquatic plants and algae, as well as by mechanical means as a result of turbulence that exposes more of the water surface for oxygen exchange with the atmosphere, such as flowing over weirs, etc. Shallow waters also tend to have a greater oxygen content than comparatively deeper water.

The system was characterised by slow to medium-flowing water, with gravel or sand substrates within the watercourses. Cascading flows were relatively rare. The general oxygen content was therefore expected to be within the average to lower bracket for aquatic ecosystems. Oxygen saturation levels ranged between 119.6% and 86.4%. The oxygen content of the surface waters throughout the survey area was not viewed as being a limiting factor to supporting aquatic diversity.

5.1.4. Total dissolved solids/Electrical conductivity

The measure of total dissolved solids (TDS) is coupled to the measure of the salinity (the amount of dissolved salts) of the water. This is, in turn, coupled to the electrical conductivity (EC) of the water as lasts carry an electrical charge when in solution. Aquatic organisms are dependent on salts within the system for normal metabolic functionality as well as to maintain osmoregulation (salt balance) within their bodies. Too high salinity values (>1,000 ppm) are considered, however, to be a limiting factor especially to many aquatic macro-invertebrates (SAWQG's, 1996). The EC values throughout the survey area ranged between 310 and 314 µS/cm. The TDS of a system should not range by more than 15% for the "normal range" for any given system (DWA, 1996). This, however, requires more extensive surveys to gain cyclic data in order to interpret accurately. The TDS values recorded at the time of biological sampling were between 155 and 158 ppm (Table 7). Both the EC and TDS values are not considered limiting factors to supporting aquatic biota.

5.2. Laboratory analyses: Water quality results

A full complement of water samples from each biological sampling site from was sent to a laboratory for analysis. The results are presented in Table 8. These values are compared to the South African Target Water Quality Guidelines (1996) values for aquatic ecosystems (DWA, 1996). It was found that no parameters tested for fall outside of these target ranges.

Table 8: Results of the laboratory water quality analyses (general water parameters).

Analyses in mg/ℓ (Unless specified otherwise)	Method Identification	Sample Identification
		RVM-Weir
Sample Number		22267
pH – Value at 25°C	WLAB001	8.1
Electrical Conductivity in mS/m at 25°C	WLAB002	51.6
Total Dissolved Solids at 180°C *	WLAB003	314
Suspended Solids at 105°C *	WLAB004	8.0
Turbidity in N.T.U	WLAB005	5.3
Total Alkalinity as $CaCO_3$	WLAB007	168
Chloride as Cl	WLAB046	46
Sulphate as SO_4	WLAB046	48
Fluoride as F	WLAB014	0.4
Nitrate as N	WLAB046	0.2
Total Coliform Bacteria / 100 mℓ *	WLAB021	6
E. Coli / 100 mℓ *	WLAB021	1
Free & Saline Ammonia as N	WLAB046	<0.2
ICP-MS Scan (Dissolved) [s]	---	SeeTable 9
% Balancing	---	99.0

Table 9 presents the results of the element scan of the constituents of the water. Of concern is a slight occurrence of arsenic (As). The target amount of As within an aquatic ecosystem (SA Water Quality Guidelines 1996) is 0.01 mg/ℓ, making this value within the guideline value, but chronic effects are seen from 0.02 mg/ℓ and acute effects from 0.13 mg/ℓ. Although the tested value falls within the guideline values, it is an element that is highly toxic and therefore should be regarded as one of the target elements during routine monitoring surveys. This is an element used in pesticides and therefore it can be assumed that it has its source from agrochemical usage upstream within the catchment area. Chromium (Cr) levels are also considered high, measuring 0.141 mg/ℓ. Target guideline levels indicate less than 0.012 mg/ℓ, with chronic effects noted from 0.024 mg/ℓ. Acute effects occur at values exceeding 0.340 mg/ℓ. It is assumed then that therefore aquatic organisms within the system suffer limitations due to the effects of Chromium. Again, this is an element that should be the focus of routine monitoring in the future. This element is a by-product of the steel industry and its derivatives (such as electro-plating, for instance), and may also be released into the environment through mining. The most probable source of chromium in the water is through industrial effluent discharged upstream of the site.

Table 9: Elemental scan results of the laboratory water quality analyses.

Element	Units	Detection limits	RVM Weir site	Possible source	Element	Units	Detection limits	RVM Weir site	Possible source
Ag	mg/ℓ	<0.01	<0.01		Na	mg/ℓ	<0.01	45.4	Agrochemical
Al	mg/ℓ	<0.01	<0.01		Nb	mg/ℓ	<0.01	<0.01	
As	mg/ℓ	<0.01	0.003	Slightly high. Source: Agrochemical pesticide	Nd	mg/ℓ	<0.01	<0.01	
Au	mg/ℓ	<0.01	<0.01		Ni	mg/ℓ	<0.01	<0.01	
B	mg/ℓ	<0.01	0.061	Natural geology	Os	mg/ℓ	<0.01	<0.01	
Ba	mg/ℓ	<0.01	0.060	Natural geology	P	mg/ℓ	<0.80	<0.80	
Be	mg/ℓ	<0.01	<0.01		Pb	mg/ℓ	<0.01	<0.01	
Bi	mg/ℓ	<0.01	<0.01		Pd	mg/ℓ	<0.01	<0.01	
Ca	mg/ℓ	<0.01	34.4	Natural geology	Pr	mg/ℓ	<0.01	<0.01	
Cd	mg/ℓ	<0.01	<0.01		Pt	mg/ℓ	<0.01	<0.01	
Ce	mg/ℓ	<0.01	<0.01		Rb	mg/ℓ	<0.01	<0.01	
Co	mg/ℓ	<0.01	<0.01		Re	mg/ℓ	<0.01	<0.01	
Cr	mg/ℓ	<0.01	0.141	Slightly high. Source: Mining or industry.	Ru	mg/ℓ	<0.01	<0.01	
Cs	mg/ℓ	<0.01	<0.01		Sb	mg/ℓ	<0.01	<0.01	
Cu	mg/ℓ	<0.01	<0.01		Sc	mg/ℓ	<0.01	<0.01	
Dy	mg/ℓ	<0.01	<0.01		Se	mg/ℓ	<0.01	<0.01	
Er	mg/ℓ	<0.01	<0.01		Si	mg/ℓ	<0.01	2.15	Natural geology
Eu	mg/ℓ	<0.01	<0.01		Sm	mg/ℓ	<0.01	<0.01	
Fe	mg/ℓ	<0.01	0.025	Natural geology	Sn	mg/ℓ	<0.01	<0.01	
Ga	mg/ℓ	<0.01	<0.01		Sr	mg/ℓ	<0.01	0.242	Natural geology
Gd	mg/ℓ	<0.01	<0.01		Ta	mg/ℓ	<0.01	<0.01	
Ge	mg/ℓ	<0.01	<0.01		Tb	mg/ℓ	<0.01	<0.01	
Hf	mg/ℓ	<0.01	<0.01		Te	mg/ℓ	<0.01	<0.01	
Hg	mg/ℓ	<0.01	<0.01		Th	mg/ℓ	<0.01	<0.01	
Ho	mg/ℓ	<0.01	<0.01		Ti	mg/ℓ	<0.01	0.014	Natural geology
Ir	mg/ℓ	<0.01	<0.01		Tl	mg/ℓ	<0.01	<0.01	
K	mg/ℓ	<0.01	2.34	Natural geology, but may be increased through fertilisers	Tm	mg/ℓ	<0.01	<0.01	
La	mg/ℓ	<0.01	<0.01		U	mg/ℓ	<0.01	<0.01	
Li	mg/ℓ	<0.01	<0.01		V	mg/ℓ	<0.01	<0.01	
Lu	mg/ℓ	<0.01	<0.01		W	mg/ℓ	<0.01	<0.01	
Mg	mg/ℓ	<0.01	22.2	Natural geology	Y	mg/ℓ	<0.01	<0.01	
Mn	mg/ℓ	<0.01	<0.01		Yb	mg/ℓ	<0.01	<0.01	
Mo	mg/ℓ	<0.01	<0.01		Zn	mg/ℓ	<0.01	<0.01	
					Zr	mg/ℓ	<0.01	<0.01	

6. SIGNIFICANCE RATINGS OF PERCEIVED ENVIRONMENTAL IMPACTS

Impacting features of the proposed development are separated into the construction phase and the operations phase as the characteristics of associated impacts for these phases are different in terms of longevity, severity and scale.

6.1. Construction phase

Construction pertaining to the proposed development extends further than only the actual footprint of the permanent infrastructure. Service roads, haul roads, construction camps and storage yards, site offices, vehicular and equipment storage, fuel storage, soil and rock dumps, workshops and construction areas are all part of the service provision (construction support areas). These support areas do create negative ecological impacts, but the severity of the impact can be greatly reduced by correct siting of the infrastructure.

Construction associated with the actual infrastructure include the diversion weir, abstraction (offtake) infrastructure and the twin-culvert buried headrace that delivers the water to the forebay /headpond, the actual forebay / headpond, penstock, power house, and outlet infrastructure (tailrace). The construction phase of the infrastructure requires excavations, haulage of rock and aggregate and on-site concrete work. This requires the disturbance of soils, removal of vegetation and other disturbance features. The construction of the weir will have the greatest impact on the aquatic habitat, as it requires instream infrastructure, and diversion of flow during the construction phase. This will destroy aquatic habitat temporarily and will therefore displace aquatic organisms, destroy riparian vegetation and impact on instream habitat. Disturbance of soils may also induce soil erosion, especially where watercourses are to be crossed.

Table 10 presents the significance ratings of the potential ecological impacts for the pre-construction and construction phases of the proposed development activities. The ratings are calculated for the scenarios of both before and after the implementation of mitigation measures. This was done in order to show how the degree of impacts can be reduced by careful planning and the following of relatively simple mitigation measures.

Table 10: The significance ratings for the construction phase for both before and after implementation of mitigation measures of the main potential ecological impacts perceived to be associated to the proposed development activities.

Potential environ impact	Project activity or issue	Environmental significance ***before*** mitigation**								Environmental significance ***after*** mitigation**							
		S	D	I	E	R	P	Conf*	SP	S	D	I	E	R	P	Conf	SP
	PRECONSTRUCTION & CONSTRUCTION PHASES																
Aquatic habitat features	Destruction of aquatic habitat to accommodate weir construction	1	4	3	4	1	3	High	33	1	1	1	2	2	2	High	6
	Comment: *The construction of this infrastructure will induce significant disturbance, but, upon completion the overall significance of this impact is considered to be localized and temporary. With proper site reinstatement the significance of the impacts will not carry over into the operations phase (see operations phase analysis for further details pertaining to this infrastructure development).* ***Main mitigation points:*** *The construction within an ecologically sensitive habitat feature needs to be considered and so the construction impacting footprint needs to remain as small as possible.* *Indiscriminate habitat destruction must be avoided.* *Consideration should be given to including a fish migratory bypass (fishway) into the weir design.* *Proper site and habitat reinstatement must be implemented during site rehabilitation following the completion of the construction phase. Any loose rocks or cobbles that are to be removed to accommodate the infrastructure should be stored in order to make use of the same substrates during reinstatement of the habitats that have been disturbed.*																
	Destruction of local watercourses and side tributaries to accommodate the construction of the canal/pipeline.	1	4	3	2	1	3	High	27	1	1	1	2	2	2	High	6
	Comment: *The region is considered arid and the orange River represents one of the very few perennial watercourses. Steep and undulating topography means that there are many surface water drainage lines that convey water during rainfall events. The degree of establishment of habitat is a function of the size of the local catchment area of the watercourse. This means that the watercourses are subject to greater or lesser volumes of surface water drainage and therefore are subject to greater or lesser potential for erosion to take place. Loose and unstructured soils are common, being either aeolian or alluvial in origin, and therefore are vulnerable to the effects of erosion. Further disturbances will merely aggravate the effects of erosion.* ***Main mitigation points:*** *The proposed canal/pipeline is an excavated and covered concrete-lined canal that inevitably has to cross through numerous watercourses of varying scales (no watercourses represent aquatic habitat as no surface water is retained for any significant period). Therefore mitigation is limited to erosion control and allowing the free-flow and natural course of the surface water drainage.* *Again, indiscriminate habitat destruction must be avoided and vegetation disturbance minimized.*																
	Reduction of water volume flowing over the Augrabies Falls to accommodate the hydropower scheme.	2	4	1	1	1	4	High	28	2	1	1	1	4	1	High	4
	Comment: *In order for the hydropower scheme to function, a portion of the water will be diverted from the main channel (that flows over the falls) through the canal to the turbines. This will deprive the aquatic habitat of that portion of water for approximately 10 km.* *It is noted that the river flow rates below 30 m^3/s will see no diversion of water through the scheme, ensuring that the river flow never falls below this set volume as a result of project-related diversions during low flow periods. This is sufficient to ensure ecological functionality of the watercourse. Downstream of the falls sees the watercourse constrict to a narrow gorge, which requires relatively less water volume for maintenance as what the braided channel above the falls requires. Therefore this impact, from an ecological perspective, is not thought to be of major significance. The diverted water is returned to the main channel downstream and therefore the impact of the diversion is thought to be minimal to downstream users of the system. It is noted that a hydropower scheme is a non-consumptive use of the water resource.* ***Main mitigation points:*** *Active management of the scheme is required to ensure that flow volume to the main channel is never reduced below 30 m^3/s as a consequence of the scheme. It is acknowledged that flow rates lower than this could occur due to management of upstream impoundments, or natural low season flows.*																
	Contamination of surface water features leading to loss of sensitive biota.	3	4	3	4	1	3	High	39	2	1	1	2	2	2	High	8

Potential environ impact	Project activity or issue	Environmental significance *before* mitigation**								Environmental significance *after* mitigation**							
		S	D	I	E	R	P	Conf*	SP	S	D	I	E	R	P	Conf	SP
	Comment/Mitigation points: *Fuel storage should be done within designated areas only, which are properly bunded to contain any potential fuel leaks. Construction vehicles should be properly serviced in order to avoid fluid leaks. Proper sewerage management should be implemented in order to avoid contamination of the surface waters through untreated sewerage.*																
Riparian Vegetation Impacts	Impacts on riparian vegetation leading to decrease in runoff filtration.	2	4	3	3	2	4	High	**40**	1	1	1	2	2	3	High	**9**
	Comment/Mitigation points: *This is not thought to be a significant impact as the development activities will only include a small area of riparian vegetation. Indiscriminate destruction of riparian habitat should be avoided.*																
	Biodiversity impacts due to riparian vegetation loss.	2	4	3	3	2	4	High	**40**	1	1	1	2	2	2	High	**6**
	Comment/Mitigation points: *This is not thought to be a significant impact as the development activities will only include a small area of riparian vegetation. Indiscriminate destruction of riparian habitat should be avoided.*																
	Decreased flood attenuation capacity from removal of riparian vegetation.	2	4	3	3	2	4	High	**40**	1	1	1	2	2	2	High	**6**
	Comment/Mitigation points: *This is not thought to be a significant impact as the development activities will only include a small area of riparian vegetation. Indiscriminate destruction of riparian habitat should be avoided.*																
Soils	Soil stripping, soil compaction and vegetation removal will increase rates of erosion and entry of sediment into the general aquatic ecosystem.	2	4	3	4	1	4	High	**48**	1	1	1	2	2	2	High	**6**
	Comment/Mitigation points: *Erosion must be strictly controlled through the utilization of silt traps, silt fencing, Gabions, etc. This is especially pertinent within areas of steeper gradients.*																
	Erosion of stockpiled topsoil & disturbance of soils due to vegetation stripping leading to erosion and habitat inundation.	2	4	3	4	1	4	High	**48**	1	1	1	2	2	2	High	**6**
	Comment/Mitigation points: *Topsoil stockpiles should be protected from erosion through the utilization of silt traps, silt fencing, Gabions, etc.*																

*****See Appendix B for calculations & methodologies.** SP ratings: 0-33 (Low), 34-74 (Medium), 75-100 (High)*

6.2. Management (Operational) Phase

The management phase of the development should include follow-up surveys of the aquatic habitats to determine the extent of functionality of the mitigation measures provided for during the construction phases. Ongoing monitoring will also identify if any accidental discharges are having significant impacts on the system. Soil erosion management as well as management of exotic vegetation should be ongoing.

Pertinent to the management phase is the assurance that no less than 30 m^3/s flow volume remains within the main watercourse as a result of the management of the hydro power scheme. Management of upstream impoundments, or fluctuations in flow as a result of seasonality may see the overall flow rate fall below 30 m^3/s, however. This flow rate will ensure ecological maintenance and sustainability of the system.

Table 11: The significance ratings for the management phase for both before and after implementation of mitigation measures of the main potential ecological impacts perceived to be associated to the proposed development activities.

Potential environ impact	Project activity or issue	Environmental significance *before* mitigation**								Environmental significance *after* mitigation**							
		S	D	I	E	R	P	Conf*	SP	S	D	I	E	R	P	Conf	SP
MANAGEMENT/ OPERATIONS PHASE																	
Aquatic habitat features	The diversion weir will act as an impounding structure that will reduce the flow velocity of water through the watercourse, leading to transformation of the aquatic habitat leading to transformation of the aquatic species community structures.	2	4	2	3	1	2	High	20	2	4	2	3	1	2	High	20
	Comment: *The diversion weir is not designed to be an impounding structure, but rather an offtake weir, meaning that impounding of the water will be minimal, creating an insignificant inundation upstream of the site.* ***Main mitigation points:*** *Active management of the scheme is required to ensure that flow volume to the main channel is never reduced below 30 m^3/s as a consequence of the scheme. It is acknowledged that flow rates lower than this could occur due to management of upstream impoundments, or natural low season flows.*																
	The diversion weir will act as a migratory barrier that will impede freedom of movement of migrating aquatic biota	2	4	1	3	1	2	High	18	2	1	1	1	4	1	High	1
	Comment: *Migratory freedom is required to allow for aquatic biota to exploit available habitat for various reasons. Blocking migratory freedom deprives various species of resources, habitat and dispersal.* *This diversion weir, if found to block migrating aquatic biota, will delimit only a small section of the river before the natural and absolute barrier of the Augrabies Falls is encountered. The significance of this is therefore thought to be minimal.* ***Main mitigation points:*** *Analysis of the weir design, drown-out potential, and extent that it will pose as a migratory barrier should be explored and the provision for a fishway should be considered if it is found that one is required.*																
	Discharge of water into an otherwise seasonally dry watercourse will create artificial habitat and potentially disorientate migrating organisms	2	4	1	3	1	2	High	18	2	4	1	3	1	2	High	18
	Comment: *The transferring canal/headrace will discharge into a balancing dam (forebay/head pond), which then flows through the powerhouse/turbines. The outfall from the turbines is into a seasonally dry section of the river, therefore it will create artificial conditions that may disorientate migrating biota within the localized area. Fish would utilise this area for spawning purposes if they encounter an impassable migratory barrier and cannot locate an alternative (i.e. swim further upstream to locate more suitable breeding habitat). This is thought to be of limited significance as, for the vast majority of the time, the greater proportion of flow will be through the main channel, which will mean that fish will orientate themselves to follow the stronger current. The Augrabies Falls already poses an impassable barrier close to the site, meaning that fish have had to historically accommodate this feature. Flow into this side channel may also be a positive impacting feature as it will expand the available habitat within the local river reach.* ***Main mitigation points:*** *This feature is not something that can readily be mitigated once construction has taken place;* *Active management of the scheme is required to ensure that flow volume to the main channel is never reduced below 30 m^3/s as a consequence of the operations of the hydro power scheme.*																
	Contamination of surface water features leading to loss of sensitive biota.	2	4	5	4	2	4	High	52	1	1	1	2	3	2	High	4
	Comment/Mitigation points: *Containment of effluents and further accidental discharges to ensure that contaminants do not reach the surface waters will greatly reduce this impact. Strict management procedures will ensure correct operational procedures, which will, in turn, protect the surface water resources from contamination.*																
	Erosion of the watercourse at outfall sites (tailrace)	2	4	5	4	2	4	High	52	1	1	1	2	3	2	High	4
	Comment/Mitigation points: *Poor outfall design could lead to perpetual erosion. Careful planning and design should be implemented to abate the scouring effects of the release of high velocity water. This is thought to be minimal as the outfall region is dominated by granite bedrock.*																

Potential environ impact	Project activity or issue	Environmental significance *before* mitigation**								Environmental significance *after* mitigation**							
		S	D	I	E	R	P	Conf*	SP	S	D	I	E	R	P	Conf	SP
Water quality impacts	Contamination of surface waters through accidental spillages leading to loss of aquatic biodiversity.	2	4	1	4	1	3	High	30	1	1	1	2	2	2	High	6
	Comment/Mitigation points: *Containment of accidental discharges/spillages to ensure that contaminants do not reach the surface waters will greatly reduce this impact. Strict management procedures will ensure correct operational procedures, which will, in turn, protect the surface water resources from contamination.*																
Biodiversity impacts	Exotic vegetation encroachment following soil disturbances.	2	4	1	2	2	4	High	28	1	1	1	1	4	2	High	0
	Comment/Mitigation points: *This is to require careful attention and active management considering that the proposed development is to take place within an area that is currently managed by SANParks.*																
Soil erosion	Resulting from poorly designed watercourse crossings of the transfer canal/pipeline leading to habitat transformation and ultimate siltation of the aquatic habitat.	2	4	3	4	1	4	High	48	1	1	1	2	2	2	High	6
	Comment/Mitigation points: *Stormwater engineering needs to take into consideration the deposition of silts transported after rainfall events into the surface water resources. This will lead to smothering of the aquatic habitat, ultimately displacing aquatic species.*																

***See Appendix B for calculations & methodologies.** *SP ratings: 0-33 (Low), 34-74 (Medium), 75-100 (High)*

7. CONCLUSIONS & RECOMMENDATIONS

Two field surveys were undertaken during September 2013 and March 2015 to the proposed Riemvasmaak Hydro Electric Power Scheme Site at Augrabies on the Orange River to determine the ecological integrity of the river section and to assign a pre-construction baseline EcoStatus value to form a benchmark for trend analysis for future monitoring. Upon completion of the survey the following general conclusions were drawn and some mitigation measures proposed:

- The river reach suffers a change from reference conditions in terms of biological integrity (fish, macro-invertebrates and riparian vegetation) as well as instream and riparian habitat, mostly as a result of transformed hydraulic conditions brought about by release management of upstream impoundments, and water quality impacts emanating from formal agriculture (mostly) within the region. The resultant Ecological Category is an overall C class. Even though there are transforming and degrading features present within the river reach, the overall Ecological Importance and Sensitivity (EIS) remains *High*. Mitigation measures should be in place to ensure that these ecological categories are not degraded;
- The surface water quality throughout the survey area is considered good, with the aquatic system supporting a diversity of sensitive aquatic macro-invertebrate taxa. It is therefore imperative that the contamination of the surface waters through deleterious effluents and runoff water be avoided;

- The proposed development is to take place within close proximity to an existing natural migratory barrier within the system (Augrabies Falls) and therefore any impacts to migratory species emanating from the construction of the weir is thought to be minimal. It does, however, fall within an area of the river considered to be relatively productive, which offers good habitat type. It is therefore recommended that a fishway be considered for this structure;
- The diversion of water from the main channel of the watercourse will adhere to a strict minimum flow policy, meaning that flow to the main channel (and therefore over the Augrabies Falls) will never fall below an agreed 30 m^3/s due to the operations of the hydro power scheme. This is considered sufficient to maintain the section of the river that will otherwise be deprived of a portion of the flow volume;
- Emergency procedures must be in place to timeously mitigate any accidental spillages and to isolate the impacting features as far as possible;
- Regular monitoring of water quality to enable early identification of contamination is recommended. The source of any contamination identified though the monitoring should be identified and managed according to best practice guidelines;
- Soil erosion emanating from disturbances within the riparian zones and other areas of steep gradients is thought to be a pertinent impacting feature to potentially impact the overall ecological integrity of the aquatic system. Disturbed soils and stockpiled soils should be protected from erosional impacts;
- The footprint of the actual development as well as the supporting structure and services during the construction phase should be retained as small as possible by construction vehicles being limited to designated roadways only. Destruction of the riparian habitat through the unnecessary clearing of vegetation should be avoided;
- Dumping of any excess rubble, building material or refuse must be prohibited within riparian and wetland habitat and a 50 m no dumping regulation should be observed from any watercourse, wetland or riparian zone. Dumping of materials should only take place at designated and properly managed areas;
- Adequate toilet facilities must be provided for all construction crews to negate informal ablutions taking place within riparian zones;
- Fires within the riparian zones should be prohibited;
- Exotic vegetation should be actively managed that may establish following the disturbance of the soils;

- Provided that erosion management, together with the implementation of mitigation measures to abate the negative ecological impacts of the features mentioned above, the overall ecological impact of the proposed development activities can be limited.

8. REFERENCES

BOK, A., KOTZE, P., HEATH, R. and ROSSOUW, J. (2007). **Guidelines for the planning, design and operation of fishways in South Africa.** WRC Report no. TT287/07. Water Research Commission, Pretoria, South Africa.

BODO, BA (2001). **Annotations for monthly discharge data for world (excluding former Soviet Union) Rivers derived from submissions to UNESCO and other sources.** Version 1.3. Toronto, Canada.

CAVANAGH, et al (2010). **A framework for predicting and managing water quality impacts of mining on streams: a user's guide.** Landcare Research (contract report Lc0910/114), CRL Evergy (CRL report 10-41100), Universities of Cantebury and Otago.

CHUTTER, F. M. (1998) **Research on the Rapid Biological Assessment of Water Quality Impacts in Streams and Rivers.** *Water Research Commission.* WRC Report No. 422/1/98, Water Research Commission, Pretoria, South Africa.

DALLAS, H.F. and DAY, J.A. (2004). **The Effect of Water Quality Variables on Aquatic Ecosystems: A Review.** WRC Report No. TT 224/04.

DICKENS C and GRAHAM M (2002). The South African Scoring System (SASS) Version 5 Rapid Bioassessment Method for Rivers. *African Journal of Aquatic Science*. 27; 1-10.

D.W.A.F. (1996) **South African Water Quality Guidelines. Volume 7: Aquatic Ecosystems.** Department of Water Affairs and Forestry, Pretoria, South Africa.

D.W.A.F. (2005) **A practical field procedure for identification and delineation of wetlands and riparian areas (edition 1).** Department of Water Affairs and Forestry, Pretoria.

D.W.A.F. (2005) **River eco-classification: Manual for EcoStatus determination (version 1).** Document no. KV 168/05, Department of Water Affairs and Forestry, Pretoria.

D.W.A.F. (2007) River Health Programme: South African Scoring System (SASS) data interpretation guidelines. *Contract research undertaken by:* **Dallas, H.F**, Freshwater Consulting Group/Freshwater Research Unit, University of Cape Town.

GERBER, A. and GABRIEL, MJM. (2002). **Aquatic Invertebrates of South Africa: A Field Guide.** Institute of Water Quality Studies (IWQS), DWAF, Pretoria, South Africa.150pp.

GOOGLE EARTH® (2013) is thanked for the use of aerial imagery for the proposed development area.

KEMPSTER, PL., HATTINGH, WHJ., and VAN VLIET, HR. (1982). **Summarised water quality criteria. Technical report NR. Tr 108.** Department of Environmental Affairs and Forestry, Pretoria.

KLEYNHANS, CJ. (1996). **A qualitative procedure for the assessment of the habitat integrity status of the Luvuvhu River (Limpopo System, South Africa).** *Journal of Aquatic Ecosystem Health 5:41-54*.

KLEYNHANS, CJ. (1997). **An exploratory investigation of the Instream Biological Integrity of the Crocodile River, Mpumalanga, as based on the Assessment of Fish Communities.** Draft Report, Department of Water Affairs and Forestry, Institute for Water Quality Studies, Pretoria. 61 pp.

KLEYNHANS, CJ. LOUW, MD. (2007). **Module A: EcoClassification and EcoStatus determination in River EcoClassification: Manual for EcoStatus Determination (version 2).** Joint Water Research Commission and Department of Water Affairs and Forestry report. WRC Report No. TT329/08.

KLEYNHANS, CJ., LOUW, MD., MOOLMAN, J.(2007). **Reference frequency of occurrence of fish species in South Africa.** Report produced for the Department of Water Affairs and Forestry (Resource Quality Services) and the Water Research Commission

LISTON, P. & MAHER, W. (1997). **Water quality for maintenance of aquatic ecosystems: Appropriate indicators and analysis, Australia: State of the Environment Technical Paper Series (Inland Waters).** Department of the Environment, Sport and Territories, Canberra.

McMILLAN, PH. (1998). **An Integrated Habitat Assessment System (IHAS v2), for the Rapid Biological Assessment of Rivers and Streams.** A CSIR research project. Number ENV-P-I 98132 for the Water Resources Management Programme. CSIR. ii + 44 pp.

SKELTON PH. (2001). **A complete guide to freshwater fishes of southern Africa.** Struik Publishers (Pty) Ltd., Cape Town, South Africa. 395pp.

THIRION, CA., MOCKE, A. and WOEST, R. (1995). **Biological Monitoring of Streams and Rivers using SASS4: A User Manual. Final Report, No. N 000/00/REQ/1195.** Institute of Water Quality Studies, Department of Water Affairs and Forestry, Pretoria.

THIRION, C. (2007). **Module E: Macroinvertebrate Response Assessment Index in River EcoClassification: Manual for Eco Status Determination (version 2).** Joint Water Research Commission and Department of Water Affairs and Forestry report, Pretoria, South Africa.

USEPA (1986). **Quality criteria for water: 1986.** EPA document no 440/5-86-001. Office of Water Environmental Protection Regulations and Standards, Washington DC, 20460.

APPENDIX A - METHODOLOGIES APPLIED DURING THIS BIOMONITORING ASSESSMENT – AQUATIC MACRO-INVERTEBRATE COLLECTION – SASS5 METHODOLOGY.

Sample Collection.

A standard SASS invertebrate net (300 x 300 mm square with 1mm gauge mesh netting) was used for the collection of the organisms. The available biotopes at each site were identified and each of the biotopes was sampled by different methods explained under the relevant sections.

The biotopes were combined into three different groups, which were sampled and assessed separately:

a) Stone (S) Biotopes:

Stones in current (SIC) or any solid object: Movable stones of at least cobble size (3 cm diameter) to approximately 20 cm in diameter, within the fast and slow flowing sections of the river. Kick-sampling is used to collect organisms in this biotope. This is done by putting the net on the bottom of the river, just downstream of the stones to be kicked, in a position where the current will carry the dislodged organisms into the net. The stones are then kicked over and against each other to dislodge the invertebrates (kick-sampling) for ± 2 minutes.

Stones out of current (SOOC): Where the river is still, such as behind a sandbank or ridge of stones or in backwaters. Collection is again done by the method of kick-sampling, but in this case the net is swept across the area sampled to catch the dislodged biota. Approximately 1 m^2 is sampled in this way.

Bedrock or other solid substrate: Bedrock includes stones greater than 30cm, which are generally immovable, including large sheets of rock, waterfalls and chutes. The surfaces are scraped with a boot or hand and the dislodged organisms collected. Sampling effort is included under SIC and SOOC above.

b) Vegetation (Veg) Biotopes:

Marginal vegetation (MV): This is the overhanging grasses, bushes, twigs and reeds growing on the edge of the stream, often emergent, both in current (MvegIC) and out of current (MvegOOC). Sampling is done by holding the net perpendicular to the vegetation (half in and half out of the water) and sweeping back and forth in the vegetation (± 2m of vegetation).

Submerged vegetation (AQV): This vegetation is totally submerged and includes Filamentous algae and the roots of floating aquatics such as water hyacinth. It is sampled by pushing the net (under the water) against and amongst the vegetation in an area of approximately one square meter.

c) Gravel, Sand and Mud (GSM) biotopes:

Sand: This includes sandbanks within the river, small patches of sand in hollows at the side of the river or sand between the stones at the side of the river. This biotope is sampled by stirring the substrate by shuffling or scraping of the feet, which is done for half a minute, whilst the net is continuously swept over the disturbed area.

Gravel: Gravel typically consists of smaller stones (2-3 mm up to 3 cm). It is sample in a similar fashion to that of sand.

Mud: It consists of very fine particles, usually as dark-collared sediment. Mud usually settles to the bottom in still or slow flowing areas of the river. It is sample in a similar fashion to that of sand.

d) Hand picking and visual observation:

Before and after disturbing the site, approximately 1 minute of "hand-picking" for specimens that may have been missed by the sampling procedures was carried out.

APPENDIX B – IMPACT RATING SIGNIFICANCE METHODOLOGIES & CALCULATIONS.

The significance rating (SP) is calculated by the following formula:

SP = Consequence X Probability (P)

Where: Consequence = (S + D + I + E) – R

S= Spatial extent
D=Duration
I=Intensity
E=Effects on important ecosystems
R=Reversibility

Table 12: Rating scores for the various factors used for calculating the significance rating of a particular impact.

S		D		I		E		R		P	
Rating	**Score**	**Rating**	**Score**	**Rating**	**Score**	**Rating**	**Score**	**Rating**	**Score**	**Rating**	**Score**
Site specific	1	Short (0-15yrs)	1	Low	1	None	1	Irreversible	0	Improbable	1
Local	2	Medium (2-15yrs)	2	Medium	3	Negligible	2	Largely irreversible	1	Possible	2
Regional	3	Long (16-30yrs)	3	High	5	Insignificant	3	Somewhat reversible	2	More than likely	3
National	4	Discontinuous	4			Significant	4	Largely reversible	3	Highly probable	4
International	5	Permanent	5			Vast	5	Totally reversible	4	Definite	5

Confidence limits:

The impact ratings are all defined in terms of confidence limits. A High impact rating with a High degree of confidence is considered to have the greatest significance. A High impact rating with a Low confidence rating therefore has a limited significance. It should be noted that a Low degree of confidence could either be attributed to a lack of sufficient data that would allow for accurate measurement of the potential impact, or that the impact falls outside the scope of the survey. This is indicated where applicable.