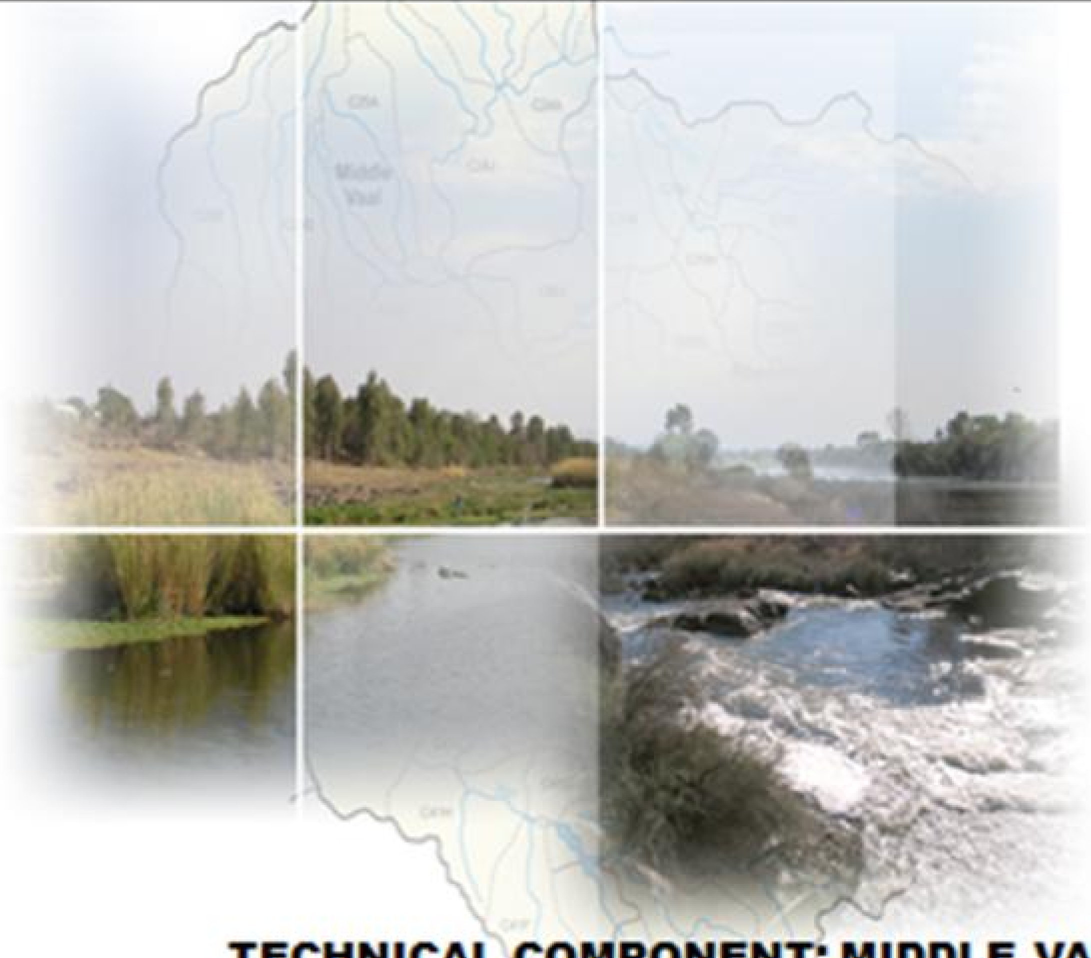
COMPREHENSIVE RESERVE DETERMINATION

INTEGRATED VAAL RIVER SYSTEM

SURFACE WATER

MAIN INTEGRATED REPORT



TECHNICAL COMPONENT: MIDDLE VAAL

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DOCUMENT INDEX

Reports as part of this project:

Bold type indicates this report.

Report INDEX	REPORT NUMBER	Report title
1.1	RDM/ WMA09C000/01/CON/0107	Middle Vaal Comprehensive Reserve determination: Surface Water Inception report
1.2	RDM/ WMA09C000/01/CON/ 0207	Middle Vaal Comprehensive Reserve determination: Surface Water Desktop EcoClassification report
1.3	RDM/ WMA09C000/ 01/CON/ 0108	Middle Vaal Comprehensive Reserve determination: Surface Water Basic Human Needs Reserve report
1.4	RDM/ WMA09C000/ 01/CON/ 0109	Middle Vaal Comprehensive Reserve determination: Surface Water Resource Units report
1.5	RDM/ WMA09/10C000/ 01/CON/ 0209	Middle Vaal Comprehensive Reserve determination: Surface Water Wetland/Pans Assessment report
1.6	RDM/ WMA09C000/ 01/CON/ 0110	Middle Vaal Comprehensive Reserve determination: Surface Water EcoClassification report
1.7	RDM/ WMA09C000/ 01/CON/ 0210	Middle Vaal Comprehensive Reserve determination: Surface Water Ecological Water Requirements report
1.8	RDM/ WMA09C000/ 01/CON/ 0310	Middle Vaal Comprehensive Reserve determination: Surface Water Operational scenarios and ecological consequences report
1.9	RDM/ WMA09/10C000/01/CON/ 0410	Middle Vaal Comprehensive Reserve determination: Surface Water Socio Economic Present State Evaluation Report
1.10	RDM/ WMA09C000/ 01/CON/ 0510	Middle Vaal Comprehensive Reserve determination: Surface Water Ecospecs and monitoring report
1.11	**RDM/ WMA09C000/ 01/CON/ 0610**	**Middle Vaal Comprehensive Reserve determination: Surface Water Main Integration Report**
1.12	RDM/ WMA09C000/ 01/CON/ 0710	Middle Vaal Comprehensive Reserve determination: Surface Water Electronic information
1.13	RDM/ WMA09C000/ 01/CON/ 0112	Middle Vaal Comprehensive Reserve Determination study for selected water Resources in the Middle Vaal Water Management Area. Environmental Water Requirements: Re-assessment of the EWR Scenarios.

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EXECUTIVE SUMMARY

Background

Chapter 3 of the National Water Act (NWA) (Act No. 36, 1998) provides for the protection of water resources of the country through the implementation of Resource Directed Measures (RDM), based on the guiding principles of sustainability and equity. In terms of the Act, before any authorization to utilise a particular water resource can be granted, it is necessary to determine the Reserve for the relevant ecological component of the resource that will be impacted by the proposed water use. The Reserve can be defined as, 'the quantity, quality and reliability of water needed to sustain both basic human needs and aquatic ecosystems.

The Chief Directorate: Resource Directed Measures (CD: RDM) is tasked with the responsibility of ensuring that the Reserve requirements, which have priority over other uses in terms of the Act, are determined before any new water uses are authorised. The Reserve requirements must be met, before the requirements for economic development or water uses are satisfied so as to ensure that the long-term integrity of ecosystems are not comprised or severely impacted upon'. As the Department of Water Affairs (DWA) is the custodian of the nation's water resources, it is their responsibility to ensure the adequate protection and effective management of these resources.

The CD: RDM initiated a Comprehensive Reserve Determination Study for the water resources of the Middle Vaal Water Management Area (WMA) that forms part of the overall comprehensive Reserve determination of the integrated Vaal River System. The purpose of this Reserve Determination Study is to determine the ecological and basic human needs water quantity and quality Reserve for the Middle Vaal at a comprehensive level of detail.

The Middle Vaal WMA forms part of the integrated Vaal River System, and falls within the C drainage region of South Africa. The Middle Vaal WMA is one of the three cascading WMAs in the Vaal River System catchment, which includes the drainage area of the Vaal River from its headwaters to the confluence of the Vaal and Orange Rivers. The Middle Vaal WMA covers a catchment area of 52 563 km^2, and includes parts of the Free State and North-West Provinces. It is situated in the north-western part of the country and forms part of the Orange River watercourse. The Middle Vaal River flows in a westerly direction to the Lower Vaal WMA. The WMA consists of the C24, C25, C41, C42, C43, C60 and C70 tertiary catchments.

The surface flow of the Middle Vaal River, most of which originates in the Upper Vaal WMA, represents the bulk of the surface water in the Middle Vaal WMA. The Vaal River is fed by a number of tributaries of which the most significant are the Renoster, Schoonspruit, Vals and Vet Rivers. Vlei areas occur along the lower Vet River and in the upper Schoonspruit catchment. The surface water flows that originate within the WMA are highly seasonal and intermittent.

Specialist surveys for the macroinvertebrate, fish, riparian vegetation, water quality and hydraulics were undertaken during 2007 and 2008.

Selected Ecological Water Requirement (EWR) sites are indicated in Table A.

Table A: Selected EWR sites for the Middle Vaal catchment

EWR Site number	EWR site name	River	National RHP site	Coordinates	Ecoregion (Level II)	Geomorphic zone	Altitude (m)	RU	Quaternary catchment
EWR12	Vaal River: Vermaasdrift	Vaal	C2-Vaal Orkne	S26.93615 E26.85025	11.01	E: Lower Foothills	1348	MRU Vaal F	C24A
EWR13	Vaal River: Regina bridge	Vaal	C2-Vaal Orkne	S27.10413 E26.52185	11.08	E: Lower Foothills	1285	MRU Vaal G	C24J
EWR14	Vals River: Proklameersdrift	Vals	C6Vals-Prokl	S27.48685 E26.81320	11.07	E: Lower Foothills	1400	MRU Vals B	C60J/C60G
EWR15	Vet River: Fisantkraal	Vet	C4-Vet-Hoops C4-Vet-Erfen	S27.93482 E26.12569	11.08	E: Lower Foothills	1247	MRU Vet C	C43A
RE-EWR3	Klein-Vet, just downstream of Winburg	Klein Vet	C4GVet-V4	S28.564708 E26.943946	11.03	E: Lower Foothills	1367 From Google	MRU Vet A	C41A

Figure A summarises the Present Ecological Status (PES), Ecological Importance and Sensitivity (EIS) and Recommended Ecological Category (REC) for each EWR site in the Middle Vaal.

EWR 12			
Components	**PES**	**EIS**	**REC[1]**
Hydrology	D	MODERATE	D
Physico-chemical	D/E		D/E
Geomorphology	C/D		C/D
Fish	C/D		C/D
Invertebrates	D		D
INSTREAM	C/D		C/D
Riparian vegetation	D		D
ECOSTATUS	D		D

EWR 13			
Components	**PES**	**EIS**	**REC**
Hydrology	C	MODERATE	C
Physico-chemical	D		D
Geomorphology	C		C
Fish	C/D		C/D
Invertebrates	C		C
INSTREAM	C		C
Riparian vegetation	C/D		C/D
ECOSTATUS	C/D		C/D

EWR 14			
Components	**PES**	**EIS**	**REC**
Hydrology	D	MODERATE	D
Physico-chemical	C/D		C/D
Geomorphology	B/C		B/C
Fish	D		C/D
Invertebrates	C		C/D
INSTREAM	C/D		C/D
Riparian vegetation	D		D
ECOSTATUS	C/D		C/D

EWR 15			
Components	**PES**	**EIS**	**REC**
Hydrology	C	MODERATE	C
Physico-chemical	C		C
Geomorphology	C		C
Fish	C		C
Invertebrates	D		D
INSTREAM	C/D		C/D
Riparian vegetation	C/D		C/D
ECOSTATUS	C/D		C/D

Figure A: Summary of PES, EIS and REC for the EWR sites in the Middle Vaal

The EcoStatus and EIS for the Middle Vaal vary considerably and are mainly due to water quality and flow changes.

In order to improve the in-stream status of the main stem of the Middle Vaal River the flow regime and water quality needs to be changed back to a more natural condition (pre the formation of Johannesburg). Couple to this is the current operational procedure of the Vaal River as a water supply scheme for irrigation, dilution of salts and drinking water supply. The current operation is not suitable for ecological sustainability and the PES is moderately to highly impacted at all sites.

The hydrology of the Middle Vaal WMA is impacted in the main stem of the Vaal by the Vaal Dam and Vaal Barrage (completed in 1919). The flow regime in the main stem of the Vaal is impacted by the following:

- Vaal Dam storage
- Releases from Vaal Dam to dilute salts to 600 mg/L TDS (mainly in winter)
- Releases from Vaal Dam and Vaal River Barrage to supply the Vaal Hartz irrigation scheme (completed 1938)
- Interbasin transfers into the Vaal from Lesotho and Grootdraai Dam

This altered flow regime has resulted in increased winter base flows in the Middle Vaal River and smaller floods being reduced in summer.

Due to this regulation having being implemented in varying degrees for 90 years the aquatic organisms have adapted with both fish and macroinvertebrates having adapted to a C/D or D ecological category and the river banks are stable.

In the tributaries, the Vals and Vet rivers, the hydrology has changed due to increased irrigation usage, upstream dams and urban requirements. These rivers have less flow in winter as well as summer due to these anthropogenic changes.

The impacts on the riparian vegetation are mainly from encroachment of alien invasive species and are therefore non-flow related. Unless management intervention to remove these plants forms part of a strategy for the Middle Vaal, the riparian vegetation will continue to deteriorate and ultimately also impacts on the habitat and biota of the system.

The other major driver of change in the Middle Vaal WMA is water quality. The water quality in the main stem of the Vaal River (EWR sites 12 and 13) is impacted by gold mine return flows in the Upper Vaal (Witwatersrand), Mooi River and Wonderfonteinspruit (Middle Vaal) and the KOSH area (Schoonspruit and Koekermoerspruit). The mine related water quality impacts are associated with high salts, acidity, elevated metals (iron, aluminium and manganese) and radioactivity. The other major impactor of water quality is associated with high nutrient values originating from waste water treatment works not meeting discharge standards. These elevated nutrient levels have resulted in prolific algal growth (filamentous, water hyacinth and blooms of blue green and green algae) which has resulted in a reduction in available habitat for both fish and macroinvertebrates.

The water quality in the Val and Vet rivers are impacted by diffuse return flows from agriculture (salts and nutrients) as well as high nutrient values originating from waste water treatment works.

In order to recommend the magnitude, duration and timing of specific flows and flow patterns that are considered to be the most important for maintaining the abiotic (e.g. geomorphology) and biotic components (plants and animals) of each Resource Unit in a particular condition, or Ecological Category, data analysis focused on the relationships between discharge and habitat availability and key ecosystem processes. This process did not consider whether these flows could be supplied or managed, and impacts on users were not considered.

EWR DETERMINATION: LOW FLOWS

The Habitat Flow Stressor Response method and a modification of the Building Block Methodology (BBM) was used to determine the low (base) flow EWRs. This method is an accepted DWA method for determining EWRs.

High flows were not reassessed and the original high flows determined during the Ecological Reserve process were accepted.

The results are summarised in the table below for the different EWR sites as a percentage of the Mean Annual Runoff of Present Day and Virgin flows.

Table B: EWR flows for the different EWR sites as a percentage of the Mean Annual Runoff of Present Day and Virgin flows

EWR site	EC	NMAR (MCM)	PMAR (MCM)	Maintenance low flows (%NMAR)	Drought low flows (%NMAR)	High flows (%NMAR)	Long term mean (%NMAR)	Maintenance low flows (%PMAR)	Drought low flows (%PMAR)	High flows (%PMAR)	Long term mean (%PMAR)
EWR 12	C/D Instream PES, REC	2546.39	1574.64	22.89	9.15	9.81	32.71	37.01	14.8	15.88	52.89
EWR 13	C/D PES, REC	2654.26	1638.37	22.1	8.72	10.3	32.4	35.8	14.13	16.68	52.48
EWR 14	C/D PES, REC	145.79	118.04	5.41	0.09	11.64	17.04	6.68	0.12	14.25	21.05
EWR 15	C/D PES, REC	253.15	413.04	3.33	1.45	7.82	11.16	5.44	2.37	12.76	18.2

The confidence in the flow requirements set at the different EWR sites within the Vaal Catchment were generally Low. This was mainly due to an array of problems encountered during the EWR assessment and a summary of these various problems are provided below.

Hydrology

For the application of the Desktop Reserve Model (DRM) the Present Day (PD) hydrology was used as reference hydrology because PD hydrology was higher than natural during the dry season. Therefore the EWRs were set higher than natural and the DRM cannot accommodate this situation as the program will keep on decreasing the flows down to natural. As all flows that were set were less than PD, PD could therefore be used as the reference. This also meant that PD hydrology would guide the seasonal distribution of the EWRs which was acceptable as the objectives for these sites were to set a realistic flow regime considering the present conditions. This matched the overall objective of maintaining the PES which is a function of the PD hydrology at these sites.

Riparian vegetation

The riparian vegetation component was not surveyed along the hydraulic profile during the 2007-2008 Reserve determination study. In the absence of surveyed vegetation data assumptions had to be made regarding the presence of important vegetation indicators as well as inundation levels in order to check the low flow requirements, set by the in-stream biotic components, to ensure that the flows catered for any riparian vegetation (specifically marginal) requirements.

Hydraulic data

The cross-sections at EWR 13 was placed through a pool. This is a problem 13 because the zero flow did not equate to zero depth. Therefore the lookup tables did not provide information for low flows below the depth of the pools. These depths are required to set low and drought flows in the fast flowing areas such as riffles. Furthermore, the biological surveys were undertaken at a multi-channel area with riffles further downstream. The biota found at the site and the habitats they require and utilize were not representative of the conditions in the pool. The cross-section and hydraulic data could not be used to set EWRs. It was however noted that the PD flows were very similar to EWR 12 and that the same indicator taxa and habitats as present at EWR 12 occurred in the reach represented by EWR 13. It was therefore decided to extrapolate the EWRs set at EWR 12 to EWR 13. The changes were made proportionately to the changes in the modelled PD flows between EWR 12 and 13.

Water quality

The water quality of the Vaal River in the Middle Vaal WMA was generally poor due to high dissolved salts and high nutrients, e.g. the Vaal River at Orkney (C2H007) was characterised by unacceptable high EC (90 mS/m; ~630 mg TDS/ℓ), P concentration (0.224 mg/ℓ) and pH (9.11).

The water quality in the Renoster River (C7H006) and Sandspruit (C2H067) was fair in terms of salts (331 & 373 mg/ℓ), but poor in terms of nutrients, 0.080 and 0.118 mg PO4-P/ℓ respectively.

Koekemoerspruit (C2H139) and Skoonspruit (C2H073) are hotspot areas with unacceptable high salts concentrations, 1 760 and 987 mg/ℓ respectively. The salt load evidently originates from the mining activities and the high nutrients draining from the KOSH urban area.

Another problem area is the Sand River at Bloudrift (C4H016) with unacceptable high salts (2 415 mg/ℓ) from the Welkom-Virginia gold mines and very high nutrients (nitrate, 1.05; P, 0.50 mg/ℓ), evidently from poorly treated sewage effluent.

The water quality in the Vals River at Kroonstad (C6H007) was fair with ideal ammonia, sulphate and nitrate concentrations, acceptable pH (8.39), and salts (316 mg/ℓ), but with unacceptable high phosphate concentration (0.080 mg/ℓ). However, the Vals River at Bothaville (C6H002) was in a poor state with high salts concentration (837 mg/ℓ), probably originating mainly from seepage water and return flows from irrigation, unacceptable high pH (8.69) and phosphate concentration (0.90 mg/ℓ).

The water quality in Erfenis Dam (C4R002) was generally good except for the very high phosphate concentrations (0.126 mg/ℓ) that indicate a serious potential for algal productivity. However, the water quality in the lower section of the Vet River (C4H004) was poor with high salts (666 mg/ℓ) and high nutrients concentrations (phosphate, 0.088 mg/ℓ).

All the parameters in Heuningspruit at Dankbaar Mispah (C7H003) were ideal, except for the unacceptable P concentrations (0.194 mg/ℓ) that results in a poor quality.

Impacts of the mining activities and mine closure

The economy of the Middle Vaal WMA is dominated by the mining sector, with a contribution of 45.6 % to GGP, particularly gold mining. However, discharges from mines impact significantly on both the hydrology and water quality of the Middle Vaal system. The impacts from the gold mining activities on groundwater have been recognised as early as 1960 when localised dewatering became an issue at Stilfontein Gold Mine. Only more recently have the impacts on the quality of the groundwater and the interaction with the Vaal

River becomes a concern. The largest volumes are abstracted at Stilfontein Gold Mine's Margaret Shaft. Although Stilfontein's underground operations has ceased for more than ten years, pumping at Margaret shaft continues for the safety of the downstream mines. The volume of water abstracted daily is estimated at 32 Mℓ/d. The water is utilized by a number of users and any excess is discharged to the Koekemoer Spruit. Groundwater is also abstracted from other operating shafts in the KOSH mining area for safety and the water is utilized as process water Due to the large quantities of water present in the mined Witwatersrand rocks, a large quantity of water (120 -150 Mℓ/d) is pumped to the surface for accessibility each day. This groundwater however has average conductivities of 500 mS/m (~3 500 mg/ℓ) and cannot be used for drinking or irrigation purposes.

Water quality in the Vaal River is of serious concern because of high salinity and nutrient content, which mainly results from urban and industrial return flows as well as mining activities in the Upper Vaal WMA. The closure of mines may have further water quality impacts.

Management of wastewater treatment works discharges

A large proportion of the sewage emanating from SA urban areas is not treated properly prior to discharge, because the sewer systems are incomplete, or sewage treatment plants are overloaded. Matjhabeng Local Municipality (Welkom, Odendaalsrus, Virginia, Hennenman, Allanridge and Ventersburg) with 11 sewage purification plants and the Moqhaka municipality (Kroonstad, Maokeng, Steynsrus and Viljoenskroon) have failed to present information to DWA for the Green Drop certification and are classified with zero Green Drop scores. These local municipalities have been implicated for polluting the local rivers and lakes with poorly treated sewage and occasionally raw sewage spills.

Municipal wastewater treatment plants, not complying with effluent standards and informal, unsewered human settlements along the river banks or in the close vicinity of the Vaal River, pose a threat to regional water quality, especially eutrophication (nutrient enrichment) and human health. There is a general non-compliance to phosphate RWQO throughout the WMA.

Sewage wastewater, by its nature, is teeming with microbes. Therefore, from a social perspective, the discharge of sewage effluent into the natural environment can have negative impacts on human health, primarily from bacteriological and other forms of pathogens that survive the biological treatment process and inadequate disinfection of the effluent. However, Municipal wastewater effluent is also one of the impacts that are most easy to mitigate because they are easily identified, measured, and susceptible to control by policies and regulation.

Eutrophication

The Vaal River in the Middle Vaal WMA experience regular algal blooms and has been classified as hypertrophic (nutrient over-enriched), that cause several problems to man and the environment. Eutrophication effects and problems are profound in the Vaal River and have become a matter of major concern to all water users. The impacts of eutrophication are ecological, social and economical. Infestations of alien vegetation are also found along the Vaal River.

Erfenis, Koppies and Allemanskraal Dams are classified as oligotrophic, however, toxic cyanobacterial incidents have been recorded. Bloemhof Dam is eutrophic and experience cyanobacterial blooms usually dominated by Microcystis spp. and Oscillatoria sp.

Cyanobacterial blooms (frequency and intensity) in the Vaal River are increasing. As cyanobacterial blooms become more common, the likelihood grows that people will be exposed to increased doses of toxins and the risk of animal die-offs grows as well.

Urbanisation

Over 75% of the population in the WMA are classified as living in urban areas, and about 25% as rural. Most of the population are concentrated in the main urban and mining centres of Klerksdorp, Orkney and Stilfontein in the Middle Vaal sub-area; Welkom and Virginia in the Sand-Vet sub-area, as well as Kroonstad (which is not a mining town) in the Rhenoster-Vals sub-area. South Africa’s freshwater resources are under increasing stress from a growing population and an expanding economy.

Water Transfers and availability

Substantial transfers take place from the Upper Vaal to the Middle Vaal (790 Mm^3/a). However, there are no large control structures with respect to the regulation of flow in the Vaal River within the Middle Vaal WMA, and both the quantity and quality of water in the Vaal River are largely influenced by management practices in the Upper Vaal WMA. There are existing weirs on the Vaal River at Orkney and Balkfontein. Water from tributaries as well as from groundwater in the water management area is fully utilised, mainly for irrigation and for towns remote from the Vaal River.

Hydrology

The hydrology of the Middle Vaal WMA is impacted in the main stem of the Vaal by the Vaal Dam and Vaal Barrage (completed in 1919). The flow regime in the main stem of the Vaal is impacted by the following:

- Vaal Dam storage;
- Releases from Vaal Dam to dilute salts to 600 mg/L TDS (mainly in winter);
- Releases from Vaal Dam and Vaal River Barrage to supply the Vaal Hartz irrigation scheme (completed 1938);
- Interbasin transfers into the Vaal from Lesotho and Grootdraai Dam.

This altered flow regime has resulted in increased winter base flows in the Middle Vaal River and smaller floods being reduced in summer.

Due to this regulation having being implemented in varying degrees for 90 years the aquatic organisms have adapted and the river banks are stable.

In the Vals and Vet Rivers the hydrology has changed due to increase irrigation usage, upstream dams and urban requirements. These rivers have less flow in winter as well as summer due to these anthropogenic changes.

This report provides the results of the Ecological consequences of proposed operational flows in the rivers of the Middle Vaal catchment area. The Ecological Water Requirement (quantity) scenarios developed are as sets of possible flows to achieve different river states (or Ecological Categories) for each EWR. This process did not consider whether these flows could be supplied or managed. To provide decision makers with more comprehensive information, it is necessary to examine each of the scenarios and their full range of implications. Thereafter, a process was followed to devise an optimised scenario (if necessary) that would have the least overall impact on the users and the ecology. All these operational scenarios were tested to determine the resulting state of the river, and the water quality consequences of each flow scenario were supplied.

The objectives of this task were to develop a range of operational scenarios that result in different impacts on different users. The impacts of incorporating the EWR on the ecology, system yield, services and overall economic activities could then be assessed.

The purpose of this step (step 5) in the 8 step Reserve process is to predict the driver and biotic responses to each operational scenario, including natural and present day hydrology and derive the ecological categories for each EWR site. All information generated during steps 3 (ecoclassification) and step 4 (determination of Ecological Water Requirement) is used during this step.

The following steps were followed to determine the ecological consequences of the operational flow scenarios.

- The operational scenarios (DWA, 2010a) were modelled using the WRPM and a time series was provided for each scenario at each EWR site.

- The time series was converted to a flow duration table and both was provided to the physico chemical and geomorphology specialists.

- The impacts of these time series of the operational scenarios were analysed by the physico chemical and geomorphology specialists by completion of the Physico-chemical Assessment Index (PAI) and Geomorphology Assessment Index (GAI) models to predict the driver ecological category.

- The riparian vegetation specialist then assessed the response on the marginal and other riparian zones and supplied this information to the instream biotic specialists (macroinvertebrates and fish).

- Where required, the riparian vegetation specialist ran the Vegetation Response Assessment Index (VEGRAI) model to predict the ecological category for each operational scenario.

The following instream biotic assessment was then undertaken:

- Each time series was converted into a stress duration table and provided on a graph for the same months as evaluated during the EWR workshop.

- The requirements set for the low flow EWR scenarios for both fish and macroinvertebrates were copied onto these graphs.
- The operational scenarios were then compared to the EWRs set for the various ecological categories.
- If it was not obvious what the resulting category was, the stress and habitat implications for the operational scenario were investigated and the responses modelled in the Fish Response Assessment Index (FRAI) and Macro invertebrate response Assessment Index (MIRAI) to determine the ecological category.
- The VEGRAI, MIRAI and FRAI results were then used as input to the Ecostatus model to determine the resulting ecological category per operational scenario.

Table D provides a summary of the operational scenarios that were modelled using the WRPM.

Table D: Summary of the operational scenarios evaluated

Sc No	Dev Level	EWR Status	Scenario description	Reasoning
1	2008	Excluded	Base scenario representing the status quo.	This is a new PRESENT DAY. This scenario was not evaluated, but differences from the old PD were noted and reasoning was provided.
4	2008	Included	Based on Scenario 1. EWR Scenario: With exception of EWR 4 and EWR 5, all EWRs in Vaal and one EWR in Thukela downstream of Driel Barrage were included.	Although EWRs are provided as a demand, it was still evaluated. One EWR site (e.g. in the Lower Vaal), could drive the requirements and result in unacceptable situations at EWR sites in the Upper Vaal (too much flow e.g.). NB: The EWR was included as a priority demand and this has a knock on effect on other users, and the operation rules of dams. This is relevant for all scenarios where dams are included.
5	2020	Excluded	Sc 1 representing the future 2020 development conditions excluding the EWRs. Includes VRESSAP pipeline from Vaal Dam to Eastern Sub-system. Includes proposed Polihali Dam and conveyance infrastructure. Includes proposed re-use of mine water. Includes projected possible transfer to the Crocodile catchment.	Key scenarios. Includes most likely future developments and illustrates resulting flows at EWR sites. NO EWRs were included as a demand in the system. Basically, this is the WHAT IF scenarios, i.e., what if we manage the system in this manner without providing EWRs – will the EcoStatus change and if so, how much.
6	2020	Included	Based on Sc 5. EWR Scenario: With exception of EWR 4 and EWR 5, all EWRs in Vaal and one EWR in Thukela downstream of Driel Barrage were included.	Combination of Sc 5 and Sc 4.

Sc No	Dev Level	EWR Status	Scenario description	Reasoning
7	Full utilization (Future development scenario)	Excluded	Scenario representing the full utilization of available water. Based on current infrastructure. Includes VRESSAP pipeline from Vaal Dam to Eastern Sub-system.	This is also a future scenario, but brings in new developments apart from the VRESSAP pipeline. Full utilisation means that there is allocated water, or water available in dams, which have not been used yet.
8	Full utilization (Future development scenario)	Included	Based on Sc 7. EWR Scenario: With exception of EWR 4 and EWR 5, all EWRs in Vaal and one EWR in Thukela downstream of Driel Barrage were included.	Combination of Sc 7 and Sc 4.

Ecological and water quality consequences of the various operational scenarios were assessed and are described in the sections below. The ecological evaluation is based on an assessment of the impact on the status or ECs recommended for each component. Information on the water quality assessment as a key driver is provided below, followed by the overall assessment.

A summary of the scenario consequences are shown in **Table E**.

Table E: Scenario consequences

Main Stem	Sc 1 PD	Sc 4	Sc 5	Sc 6	Sc7	Sc 8
	REC					
12 Vermaasdrift	D	C	C/D	C/D	D	C
13 Regina	C/D	C	C	C	C	C
Tributaries						
14 Vals	C/D	C/D	D	C/D	C/D	C/D
15 Vet	C/D	D	D/E	D	D/E	D

Significant deviations between Scenario 7 and 8 were found for EWR R1 (Renoster), 14 (Vals), V1 and V2 (Vet). Negative economic impacts (in terms of GDP and employment) may occur as a consequence of applying the Ecological Reserve in the Renoster, Vals and Vet Rivers:

- Little impact on Ecosystem goods and services – negative impact at Vals River for Scenario 5
- Main stem of Vaal all scenario's meet PES and REC
- Tributaries Scenarios, 4, 7 and 8 meet PES and REC
- Water quality driver and management plans for nutrients and salts – aquatic ecosystem adapted
- Extra flows but main stem altered for many years

- Tributaries less water and water quality issues

A summary of ecological consequences per scenario are included for the main stem (Figure 2) and the tributaries (**Figure 3**), and an overview for the Lower Vaal EWR sites (Figure 4).

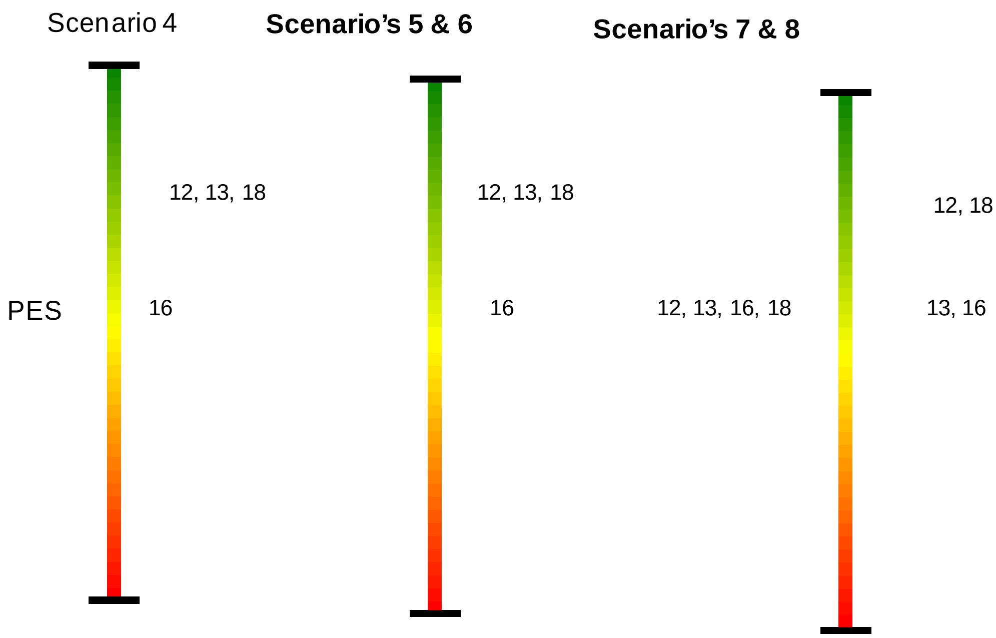


Figure 2: Summary of ecological consequences per scenario for the main stem of the Vaal EWR sites

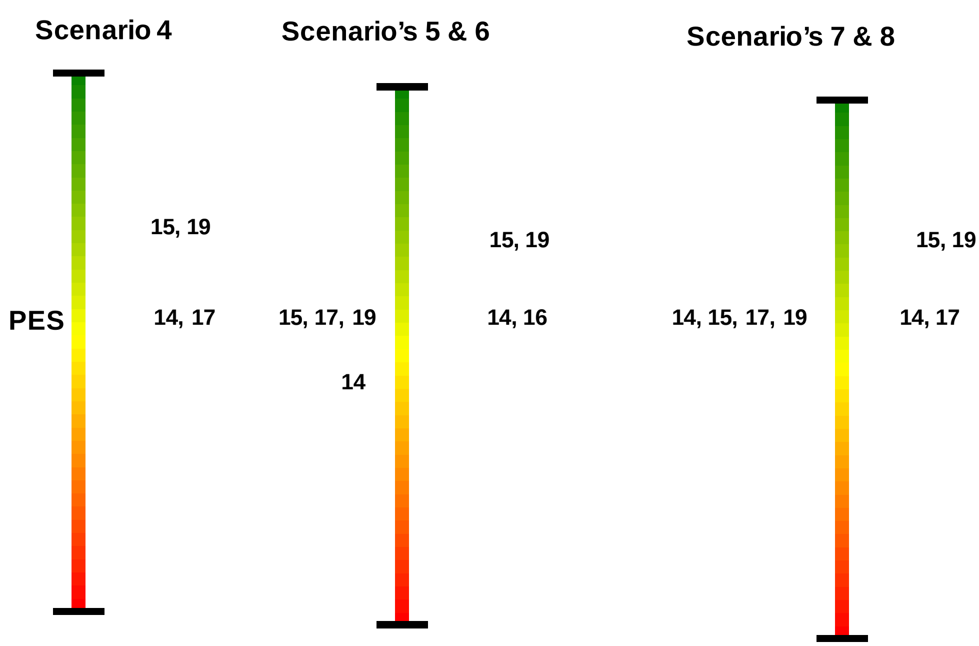


Figure 3: Summary of ecological consequences per scenario for the tributaries of the Vaal EWR sites

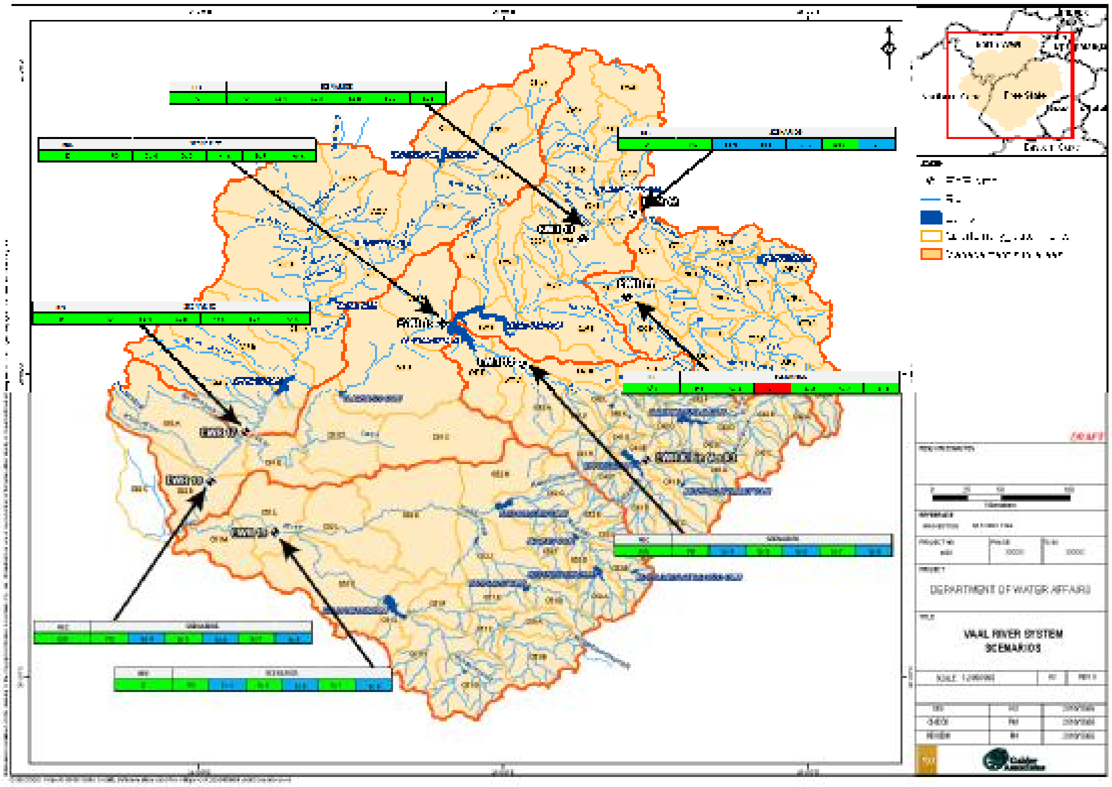


Figure 4: Summary of the Ecological Consequences for the Middle Vaal Catchment scenario's.

Based on a similar approach used for the socio-economic impact assessment for the Upper Vaal WMA (as undertaken by Connningarth), the Middle and Lower Vaal WMAs were partitioned into defined economic zones. Several EWR sites were identified and establish along the Vaal River in the Upper, Middle and Lower Vaal WMAs within these economic zones in order to measure present day water use and to make predictions on future water use. These EWR sites were evaluated and identified according to criteria which included hydraulics, land use, regulation and accessibility. Eight EWR sites were then identified within the Middle and Lower Vaal WMAs and present day water use for various water users estimated. From the relevant socio-economic data collected for irrigated agriculture, mining and manufacturing and population within each WMA baseline economic indicators such Gross Domestic Product (GDP), employment and household income were generated for each economic zone using Water Multipliers. These baseline results were then adapted to account for water use (demand) at each of the eight EWR sites.

Although all eight scenarios were analysed as part of the overall study, Scenario 8 (which included the EWR) was assessed relative to Scenario 7 specifically for the socio-economic component of the Project. The remaining scenarios were used to assess the impact of alternative options for the inclusion of the EWRs.

For the ecosystems services assessment, 5 water allocation Scenarios were assessed according to impacts on the following river resources:

- Fish;
- Riparian vegetation;
- Recreation; and
- Water quality.

Each resource was scored per Scenario according to whether utilization of the resource remained at current/present day levels or either increased or declined at each EWR site.

Present day GDP and employment figures per EWR site were calculated using present day water abstraction at each EWR site and economic water multiplier for each economic zone within the Middle Vaal WMAs. The relevant economic zones were:

- Middle Vaal WMA
- Vaal River main-stem;
- Rhenoster;
- Schoonspruit;
- Sand;
- Vet; and
- Vals.

Water use data were collected for various water users within the Middle Vaal WMA. Major water users within these WMAs are:

- Irrigated agriculture;
- Mining and manufacturing; and
- Domestic and/or household consumption

Relevant data were collected for each user category and used to estimate water use. These data were then modelled using the SAFRIM and WIM methodology (consistent with the Upper Vaal study) producing baseline economic impacts based on the economic zones identified. Irrigated agriculture in the Middle Vaal provided R315 million directly to GDP and 6,027 employment opportunities. While providing similar employment opportunities within the mining sector, the other industries within the Middle Vaal WMA provided significantly more employment opportunities and contributed more to total GDP than other industries within the Lower Vaal WMA.

The results of the socio-economic assessment indicated that significant deviations from present day demand for Scenario 8 were found for EWR R1 (Renoster), 14 (Vals), V1 and V2 (Vet). This implies that potentially significant economic impacts may occur as a consequence of applying the Ecological Reserve in the Renoster, Vals and Vet Rivers which are tributaries of the Vaal River. The results for the main stem showed that Scenario 8 caused more water to be pumped through the VRESAP pipeline and Sterkfontein Dam was operated at lower storage levels. The assurance of supply to users will, however, is not likely to be jeopardised by implementing the EWRs.

In terms of evaluating which Scenario is acceptable from a socio-economic perspective Scenario 8 was the only Scenario evaluated against present day water use. It is recommended that, due to the highly negative socio-economic impacts found in the Renoster, Vals and Vet tributaries, further and more detailed investigations may need to be conducted to more accurately assess the socio-economic costs and benefits of implementing the EWRs in these tributaries. Irrigated agriculture is a major economic activity in these tributaries and the Renoster, Vals and Vet tributaries account for approximately 21 000ha of agricultural production within the Middle Vaal WMA. Much of the annual crop yield is also made up of cereals such as maize and wheat which may negatively affect regional and potentially national food security. Possible further research into this could entail a financial and economic analysis of irrigated agriculture along these tributaries based on water allocation or costs scenarios the aim of which could be to assess the impacts of increasing water cost to irrigators and assessing at what levels costs affect profitability. Necessary trade-offs that could be made could also be identified by such a study. The traffic diagram below (Figure 5) provides a graphic representation of the overall socio-economic impacts of Scenario 8 in the Middle Vaal WMAs.

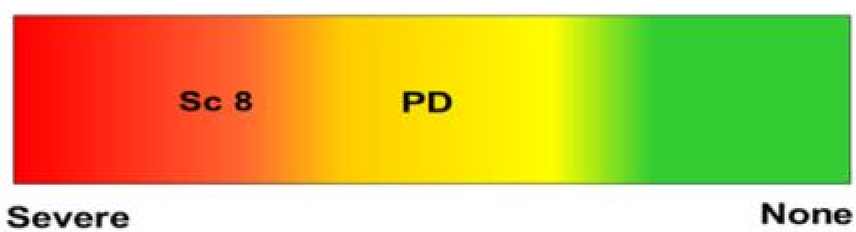


Figure 5: Traffic light diagram of overall socio-economic impacts of Scenarios 7 and 8 for Middle Vaal WMAs

The methodology used to assess the impacts on Ecosystems Goods and Services in this study was consistent with the approach used for the Upper Vaal WMA. Of the eight water allocation Scenarios identified, Scenarios 4, 5, 6, 7 and 8 were evaluated per EWR site. The approach investigated the impact of each Scenario on Fish, Riparian Vegetation, Recreation and Water Quality resources per EWR site. Overall it was found that by implementing the ER at each EWR site no negative impacts were found except for Scenario 5 at EWR site 14. These negative impacts were driven by impacts on fish species such as the, Smallmouth yellowfish (*Labeobarbus aeneus*), Orange-Vaal mudfish (*Labeo capensis*) and Moggel, (*Labeo umbratus*) and result from reduced flow levels leading to a decrease or disappearance of species from this reach. Scenario 5 cannot, therefore, be recommended as acceptable from an Ecosystems

Goods and Services perspective based on these negative impacts. Scenario 6 had the highest overall score for each resource in both the Middle and Lower Vaal WMAs and on this basis must be recommended as the most acceptable Scenario from an Ecosystems Goods and Services perspective. The traffic diagram below (Figure 6) provides a graphic representation of the overall impacts of each Scenario on Ecosystems Goods and Services in the Middle Vaal WMAs.

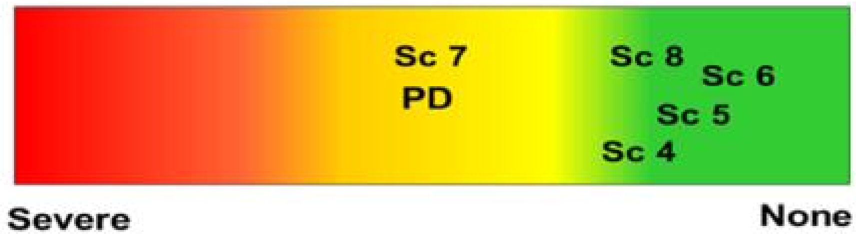


Figure 6: Traffic light diagram of overall Ecosystems Goods and Services impacts of Scenarios 4, 5, 6, 7 and 8 for Middle Vaal WMAs

The following final recommendations for the future management of the Middle Vaal (Table F) have been approved.

Table F: Final recommendations per EWR site

EWR site	**Recommendation**
12 Vaal (Regina)	Sign off for PES=REC=D
13 Vaal (Vermaasdrift)	Sign off for PES=REC=C/D
14 Vals	Sign off for PES=REC=C/D
15 Vet	Sign off for REC=C/D (in-stream PES) with recommendation that no more abstractions upstream are allowed as the EWRs below Erfenis and Allemanskraal Dams are currently not being met.

The final step in the Reserve process is to define the Ecological Specifications (Ecospecs) and monitoring requirements for the maintenance of the at each Ecological Water Requirement (EWR) site. The Ecospecs are intended to provide the quantifiable and enforceable descriptors of the quantity, quality and habitat and biotic integrity as they pertain to the ecological objectives for a particular water resource (in this case a particular river reach). These are the values of parameters (usually maximum concentrations) that should not be exceeded in order to meet the Ecological Category specified for the water resource.

The EcoSpecifications and Thresholds of Potential Concern (TPC's) for the maintenance of the ecological Reserve for each EWR site for components consisting of the drivers (geomorphology, physico-chemical variables and hydrology) and the response (riparian vegetation, fish and macroinvertebrates) were determined.

The TPCs are "triggers" that indicate management action is required, and the monitoring activities that should be undertaken in order to measure the Ecospecs and TPCs are also described.

Monitoring activities that should be undertaken in order to measure the Ecospecs and TPCs are indicated per EWR site. These monitoring programmes should be rolled out as part of the implementation of the Vaal River catchment Reserve study.

The derived Ecospecs for the maintenance of the Reserve for each EWR sites should not be exceeded in order to maintain the water driver and response components of the Recommended Ecological Category (REC).

Table G is a summary of the proposed monitoring frequency for the Ecological Reserve for the Middle Vaal EWR sites 12 to 15.

Table G Summary of proposed monitoring frequency for the Ecological Reserve for the Middle Vaal

Reserve component	**Monitoring Frequency**
Hydrology	Daily monitoring at closest DWA weir
Water Quality	Monthly, Quarterly (EC and Chlorophyll -a)
Geomorphology	• Every 2nd year: Daily hydrology and Fixed-point photography • Every 5 – 10 years: Bed material composition; Cross-sections and Aerial photographs
Fish	Monitoring should be conducted twice annually. If only once annually then the intermediate dry –wet season would be preferred.
Macroinvertebrates	Wet and dry season sampling
Riparian Vegetation	Monitoring should be conducted annually during the wet season (Spring to early Summer). Monitoring may be reduced to one survey every two to three years, however, any significant, change should precipitate immediate surveys which should be conducted annually for at least three years in order to monitor the change and determine whether it was a stochastic event or the beginning of a trend

As part of a Ecological Water Resources Monitoring (EWRM) programme the Rapid Habitat Assessment Method (RHAM) should be included as the application of this method will improve the confidence in hydraulic data especially at EWR 13 and allow for more clarity on the hydrological issues of the Middle Vaal River. The RHAM was developed during 2007 - 2009 and it is recommended that a RHAM survey is undertaken at sites where applicable during EWRM. It is foreseen that due to the size and nature of the Vaal River, the RHAM for wadeable rivers might not be possible at all sites. The semi - wadeable (still to be tested) RHAM could be applicable. RHAM data may provide additional information on habitat suitability and the biota associated with this habitat. Due to the hydraulic data being unsuitable for use, it is not recommended that any additional improvements in confidence in determining the EWRs are attempted. This would require new cross-sections and new hydraulic modelling which is a serious investment. Detailed monitoring with photopoint monitoring at KNOWN flows is strongly recommended.

If this programme is to be implement then the suggested monitoring frequency in Table G would altered and the RHAM monitoring would be used a s screening approach. If the TPC are triggered then the proposed monitoring in Table G would then be initiated.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRYNOMS AND ABBREVIATIONS

BAEN	*Labeobarbus aeneus*
BBM	Building Block Methodology
BKIM	*Labeobarbus kimberleyensis*
CD: RDM	Chief Directorate: Resource Directed Measures
DRIFT	Downstream Reponse to Imposed Flow Transformation
DRM	Desktop Reserve Model
D: NWRP	Directorate: National Water Resource Planning
D: RQS	Directorate: Resource Quality Services
DWAF	Department of Water Affairs and Forestry
DWA	Department of Water Affairs (Name change 2009)
EC	Ecological Category
EIS	Ecological Importance and Sensitivity
EWR	Ecological Water Requirements
EWRM	Ecological Water Resource Modelling
FCS	Fast over Coarse Substrate (Macroinvertebrate habitat)
FD	Fast Deep Fish Habitat
FFHA	Fish Flow Habitat Assessment model
FI	Fast intermediate fish habitat
FS	Fast shallow fish habitat
FVS	Fast very shallow fish habitat
GDP	Gross Domestic Product
GGP	Gross Geographic Product

HFSR	Habitat Flow Stressor Response
IHI	Index of Habitat Integrity
MAR	Mean Annual Runoff
MCM	Million cubic meters
NMAR	Natural Mean Annual Runoff
NWA	National Water Act
PES	Present Ecological State
PMAR	Present Mean Annual Runoff
PD	Present Day
QHI	Quick Habitat Integrity
RHAM	Rapid Habitat Assessment Method
REC	Recommended Ecological Category
RU	Resource Unit
SD	Slow deep fish habitat
SPATSIM	Spatial and Time Series Information Modelling
SCI	Socio Cultural Importance
SCS	Slow over coarse substrate (Macroinvertebrate habitat)
SS	Slow shallow fish habitat
ToR	Terms of Reference
Veg	Vegetation
VFCS	Very fast over coarse substrate (Macroinvertebrate habitat)
WMA	Water Management Area
WWTW	Waste Water Treatment works

GLOSSARY

DROUGHT FLOW	The minimum flow required facilitating the survival of the riverine ecosystem in a particular condition and over short, infrequent periods, when users are subject to water restrictions. Drought flows in the Vaal River will be defined as low-flows that occur less than x % of the time under natural conditions for each month.
ECOLOGICAL CATEGORY	A category indicating the potential management target for a river. Values range from Category A (unmodified, natural) to Category D (largely modified). This term replaces former terms used, namely: Ecological Reserve Category (ERC), Desired Future State (DFS) and Ecological Management Class (EMC). The reasons for these changes are explained in the proceedings of a workshop to clarify the terminology used in Reserve determinations (DWAF 2003). It should be noted that a distinction is made between Management Classes, which form part of the National Classification System, and Ecological Categories, which forms part of the Ecological Water Requirement assessment.
ECOSPECS	Clear and measurable specifications of ecological attributes (e.g. water quality, flow, biological integrity) that defines the Ecological Category. The purpose of Ecospecs is to establish clear goals relating to resource quality (Kleynhans 2003).
ECOSTATUS	An overall assessment of the Ecological Category (A-F), based on rule-based integration of specialist indices (water quality, fish, etc). EcoStatus refers to 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 and its capacity to provide a variety of goods and services" (Iversen *et al.* 2000, *In* IWR Environmental 2003).
ECOLOGICAL WATER REQUIREMENTS (EWR)	The flow patterns (magnitude, timing and duration) and water quality needed to maintain a riverine ecosystem in a particular condition. This term is used to refer to both the quantity and quality components.

INSTREAM FLOW REQUIREMENTS (IFR)	The flow patterns (magnitude, timing and duration) needed to maintain a riverine ecosystem in a particular condition. This term is used to refer to the quantity component only of Ecological Water Requirements.
MAINTENANCE FLOW	The flow required to meet the requirements of the riverine ecosystem at a particular site and maintain the resource base in a particular condition during "normal" climatic years. The distinction between "normal" and "drought" was based on an examination of monthly flow duration curves
PRESENT ECOLOGICAL STATE (PES)	The degree to which ecological conditions of an area have been modified from natural (reference) conditions. The measure is based on water quality variables, biotic indicators and habitat information collected 1 to 3 years prior to the assessment. Results are classified on a 6-poin scale, from Category A (*Largely Natural*) to Category F (*Critically Modified*).
REFERENCE CONDITION	Natural ecological conditions, prior to human development.
RESERVE	The quantity and quality of water required (a) to satisfy basic human needs by securing a basic water supply, as prescribed under the Water Services Act, 1997 (Act No. 108 of 1997), for people who are now or who will, in the reasonably near future, be (i) relying upon; (ii) taking water from; or (iii) being supplied from, the relevant water resource; and (b) to protect aquatic ecosystems under the National Water Act, 1998 (Act No. 36 of 1998) in order to secure ecologically sustainable development and use of the relevant water resource. The Reserve refers to the modified Ecological Water Requirement, where operational limitations, and stakeholder consultation are taken into account.
RESOURCE QUALITY OBJECTIVE	Quantitative and auditable statements about water quantity, water quality, habitat integrity and biotic integrity that specify the requirements (goals) needed to ensure a particular level of resource protection. This term takes into account the management *classes* and the requirements of other users. These components are not addressed in this project

RESOURCE UNIT	Stretches of river that are sufficiently ecologically distinct to warrant their own specification of Ecological Water Requirements, and that can be practically managed as a single unit.

1 INTRODUCTION

1.1 Background

Chapter 3 of the National Water Act (NWA) (Act No. 36, 1998) provides for the protection of water resources of the country through the implementation of Resource Directed Measures (RDM), based on the guiding principles of sustainability and equity. In terms of the Act, before any authorization to utilise a particular water resource can be granted, it is necessary to determine the Reserve for the relevant ecological component of the resource that will be impacted by the proposed water use. The Reserve can be defined as, 'the quantity, quality and reliability of water needed to sustain both basic human needs and aquatic ecosystems.

According to the Act all Reserve determinations that are currently determined and approved by the Department of Water Affairs (DWA) are preliminary Reserve determinations and the associated recommended class is a preliminary class (section 17(1)), until a system for the classifying of water resources has been prescribed.

The Chief Directorate: Resource Directed Measures (CD:RDM) is tasked with the responsibility of ensuring that the Reserve requirements, which have priority over other uses in terms of the Act, are determined before any new water uses are authorised. The Reserve requirements must be met, before the requirements for economic development or water uses are satisfied so as to ensure that the long-term integrity of ecosystems are not comprised or severely impacted upon'. As the Department of Water Affairs (DWA) is the custodian of the nation's water resources, it is their responsibility to ensure the adequate protection and effective management of these resources.

The CD: RDM initiated the Comprehensive Reserve Determination Study for selected water resources (rivers, wetlands and groundwater) in the Middle Vaal Water Management Area (WMA). The purpose of the Comprehensive Reserve Determination Study for the selected water resources of the Middle Vaal WMA is to determine the ecological and basic human needs water quantity and quality Reserve at an intermediate level of confidence. The final step in this process is to define the Ecological Specifications (Ecospecs) and monitoring requirements for the maintenance of the at each Ecological Water Requirement (EWR) site.

The results of the Comprehensive Reserve determination study will assist the DWA to make more informed decisions regarding the authorization of future water uses, operation and management of the system and the evaluation of the magnitude of the impacts of the present and proposed developments.

1.2 Purpose of this report

This report summarises the main components of the intermediate assessment of the Ecological Water Requirements (EWR) component of the Reserve that was commissioned by the CD: RDM. The study was conducted over a three-year period between August 2007 and October 2010. The study produced several reports, as indicated in the document index. This Main Report provides a brief overview of the study. For more details refer to the individual specialist reports.

1.3 Objective of study

The study objective was to determine an Ecological Reserve for the system which best meets the level of resource protection taking into account the legal, socio economic and sustainability goals/needs. A wetland and groundwater scoping assessment was also undertaken with the final product being a recommendation for what level of further study should be undertaken (if any).

An additional requirement of the study was the application of specialist and technical capacity building throughout the project with an emphasis on Historically Disadvantaged Individuals (HDIs).

1.4 Study area

The Middle Vaal WMA forms part of the integrated Vaal River System, and falls within the C drainage region of South Africa. The Middle Vaal WMA is one of the three cascading WMAs in the Vaal River System catchment, which includes the drainage area of the Vaal River from its headwaters to the confluence of the Vaal and Orange Rivers.

1.5 Overview and Background to the Middle Vaal WMA

The Middle Vaal WMA covers a catchment area of 52 563 km^2, and includes parts of the Free State and North-West Provinces. The Vaal River flows in a westerly direction to the Lower Vaal WMA. It is the middle WMA within the Vaal River System, with water being transferred *via* the Vaal River through this WMA to Bloemhof Dam, from the Upper Vaal WMA to the Lower Vaal WMA. The Middle Vaal WMA comprises eight sub-catchments as listed in Table 1. The WMA consists of the C24, C25, C41, C42, C43, C60 and C70 tertiary catchments.

Table 1: Sub-catchments and related quaternary drainage regions within the Middle Vaal WMA

<table>
<tr><th>PRIMARY CATCHMENT</th><th>SUB-CATCHMENT AREAS</th><th>QUARTENARY CATCHMENTS</th><th>AVERAGE GROSS AREA (Km^2)</th></tr>
<tr><td rowspan="9">C</td><td>Renoster</td><td>C70A-K</td><td>6656</td></tr>
<tr><td>Vals</td><td>C60A-J</td><td>7871</td></tr>
<tr><td>Schoon Spruit</td><td>C24C-G</td><td>5644</td></tr>
<tr><td>Middle Vaal</td><td>C24A-B, C24H-J, C25A-C</td><td>8281</td></tr>
<tr><td>Bloemhof</td><td>C25D-F</td><td>4959</td></tr>
<tr><td>Allemanskraal</td><td>C42A-E</td><td>3628</td></tr>
<tr><td>Erfenis</td><td>C41A-E</td><td>4724</td></tr>
<tr><td>Sand</td><td>C42F-L</td><td>3927</td></tr>
<tr><td>Vet</td><td>C41F-J, C43A-D</td><td>6873</td></tr>
</table>

The climate in the Middle Vaal WMA can vary considerably from west to east. The average temperature for the WMA is 16˚C, with the mean annual temperatures ranging between 18˚C in the west to 14˚C in the east. Mean annual precipitation per year ranges between 500 mm in the west and 700 mm in the east of the WMA. Mean annual evaporation ranges from 1 800 mm in the east to a high of 2 600 mm per year in the dry western parts of the WMA, and is well in excess of rainfall.

The western parts of the WMA are characterised by pans. The WMA is dominated by the "pure grassveld" veld type with sparse bushveld in patches. The northern areas have some regions of "false grassveld", while the area upstream of Bloemhof Dam includes some "tropical bush and savanna". Maize, wheat and fodder crops are the main crops in the WMA.

Current land use in the WMA is characterised by extensive dry land cultivation in the central parts of the WMA. The largest urban areas are Klerksdorp (North West Goldfields) Welkom and Kroonstad (Free State Goldfields). Irrigation is practiced downstream of dams and along the main tributaries and at locations along the Vaal River. The WMA is characterised by a large number of goldmines.

The surface flow of the Vaal River, most of which originates in the Upper Vaal WMA, represents the bulk of the surface water in the Middle Vaal WMA. The Vaal River is fed by a number of tributaries of which the most significant are the Renoster, Schoonspruit, Vals and Vet Rivers. Vlei areas occur along the lower Vet River and in the upper Schoon Spruit catchment. The surface water flows that originate within the WMA are highly seasonal and intermittent.

The surface water occurring in the WMA has been developed to its potential and all water is being fully utilised. There are several large dams that have been developed (Table 2) in the WMA.

Table 2: Major Dams in the Middle Vaal WMA

DAM NAME	QUATERNARY CATCHMENT	RIVER
Bloemhof	C91A	Vaal
Allemanskraal	C42E	Sand
Bloemhof	C60D	Jordaan Spruit
Erfenis	C41E	Vet
Johan Neser	C24G	Schoonspruit
Klipplaatdrift	C25A	Vaal
Koppies	C70C	Renoster
Marquard	C41A	Laai Spruit
Rietspruit	C24D	Schoonspruit
Three Sisters	C42F	Sand
Uniefees	C70C	Eland Spruit

The Middle Vaal WMA's water quality and flow is mainly controlled by activities that take place in the Upper Vaal WMA. The Middle Vaal WMA is dependent on the Upper Vaal WMA for meeting the bulk water requirements of its mining, industrial and urban sectors. Large quantities of water are transferred into the WMA to augment local water resources. These upstream activities include releases from the Vaal Dam and Vaal River Barrage, waste water treatment works discharges, urban runoff and gold mining activities on the Witwatersrand. In the Middle Vaal WMA discharges and decants from gold mining activities in the Mooi and Koekemoer Spruits have an impact on the continued salinity build up in the Vaal River. These impacts are subject to many catchment studies that have been undertaken by DWAF as well as a current Integrated Water Quality Management Plan for the Vaal River system. Management of water quality and quantity in the Middle Vaal WMA is therefore integrally linked to both the Upper and Lower Vaal WMAs.

The Middle Vaal WMA is rural in nature with the land use typically characterised by extensive livestock farming, dry land agriculture and some irrigation farming. The economy of the Middle Vaal WMA contributes about 4% of the GDP of South Africa with the most dominant economic activity being the mining sector, contributing more than 45% of the GDP in the WMA, trade (12,3%), and agriculture (8,9%) (DWAF, 2003). Due to a decline in gold mining activity, a decline in population is also projected for the WMA, with a concomitant effect on the regional economy. Manufacturing activities in the WMA relate to the mining and agriculture sectors as well as items for local consumption. No dramatic changes to the economy of the WMA are foreseen for the medium term. The agricultural sector in the region is relatively stable and will continue to make an important contribution to the regional economy. A minimal change in water requirements is therefore projected.

It is imperative that integration takes place with the Upper Vaal Reserve Study as the Middle Vaal's water quality, quantity and ultimately ecological status is dependent on this upper water management area.

1.6 Overview and Background to the Modder Riet catchment of the Upper Orange WMA

The Modder Riet catchment of the Upper Orange WMA is part of the C drainage region and thus forms part of the Vaal River System. The catchment is situated in the Free State and Northern Cape Provinces has a catchment area of 35 000 km^2. The Modder and Riet Rivers are the only major rivers in the catchment, which drain into the Vaal River which subsequently flows into the Orange River. The catchment includes Kalkfontein, Rustfontein, Tierpoort, Groothoek and Krugersdrift Dams.

Land use in the catchment is related agricultural activities, urbanisation and mining and industrial activities. Agricultural use comprises primarily the irrigation of crops and activities are concentrated around the dams in the catchment. Livestock watering also occurs, but to a lesser extent. The major urban centres in the catchment are Bloemfontein, Botshabelo and Thabu Nchu whose collective population is 1.2 million people. The Modder River is a major source of water to these urban areas. Most industries in the Modder and Riet catchments are centred around Bloemfontein and use treated water from the municipal supply system.

The Riet River generally flows in a north-westerly, to the confluence with the Vaal River. The Tierpoort dam and Kalkfontein dam are situated on the tributaries of the Riet River. The Modder River is the main tributary of the Riet River and joins the Riet River just upstream of Ritchie. The Krugersdrift Dam is located on the Modder River. Most of the natural runoff into the Modder River is from above the confluence of the Modder and Klein Modder Rivers. The rest of the Modder River catchment is very flat and very little runoff occurs. There is a transfer of water from the Caledon River to the Modder River for the supply of drinking water to Bloemfontein.

Selected Environmental Water Requirement (EWR) sites (EWR 12 – 15) are indicated in Table 3 and in Figure 1. A rapid Reserve Determination was also undertaken on the Klein Vet River. The reason why this site was added was for potential extrapolation purposes.

Table 3: Selected EWR sites for the Middle Vaal catchment

EWR Site number	EWR site name	River	National RHP[1] site	Coordinates		EcoRegion (Level II)	Geomorphic zone	Altitude (m)	RU[2]	Quaternary catchment	Hydrological gauge
				Latitude	Longitude						
EWR12	Vaal River: Vermaasdrift	Vaal	C2-Vaal Orkne	S26.93615	E26.85025	11.01	E: Lower Foothills	1348	MRU Vaal F	C24A	C2H007
EWR13	Vaal River: Regina bridge	Vaal	C2-Vaal Orkne	S27.10413	E26.52185	11.08	E: Lower Foothills	1285	MRU Vaal G	C24J	C2H061
EWR14	Vals River: Proklameersdrift	Vals	C6Vals-Prokl	S27.48685	E26.81320	11.07	E: Lower Foothills	1400	MRU Vals B	C60J/C60G	C6H003
EWR15	Vet River: Fisantkraal	Vet	C4-Vet-Hoops C4-Vet-Erfen	S27.93482	E26.12569	11.08	E: Lower Foothills	1247	MRU Vet C	C43A	C4H002
Rapid EWR – RE-EWR 3	Klein-Vet, just downstream of Winburg	Klein Vet	C4GVet-V4	S28.564708	E26.943946	11.03	E: Lower Foothills	1367	MRU Vet A	C41A	

[1]: River Health Programme; [2]: Resource Unit

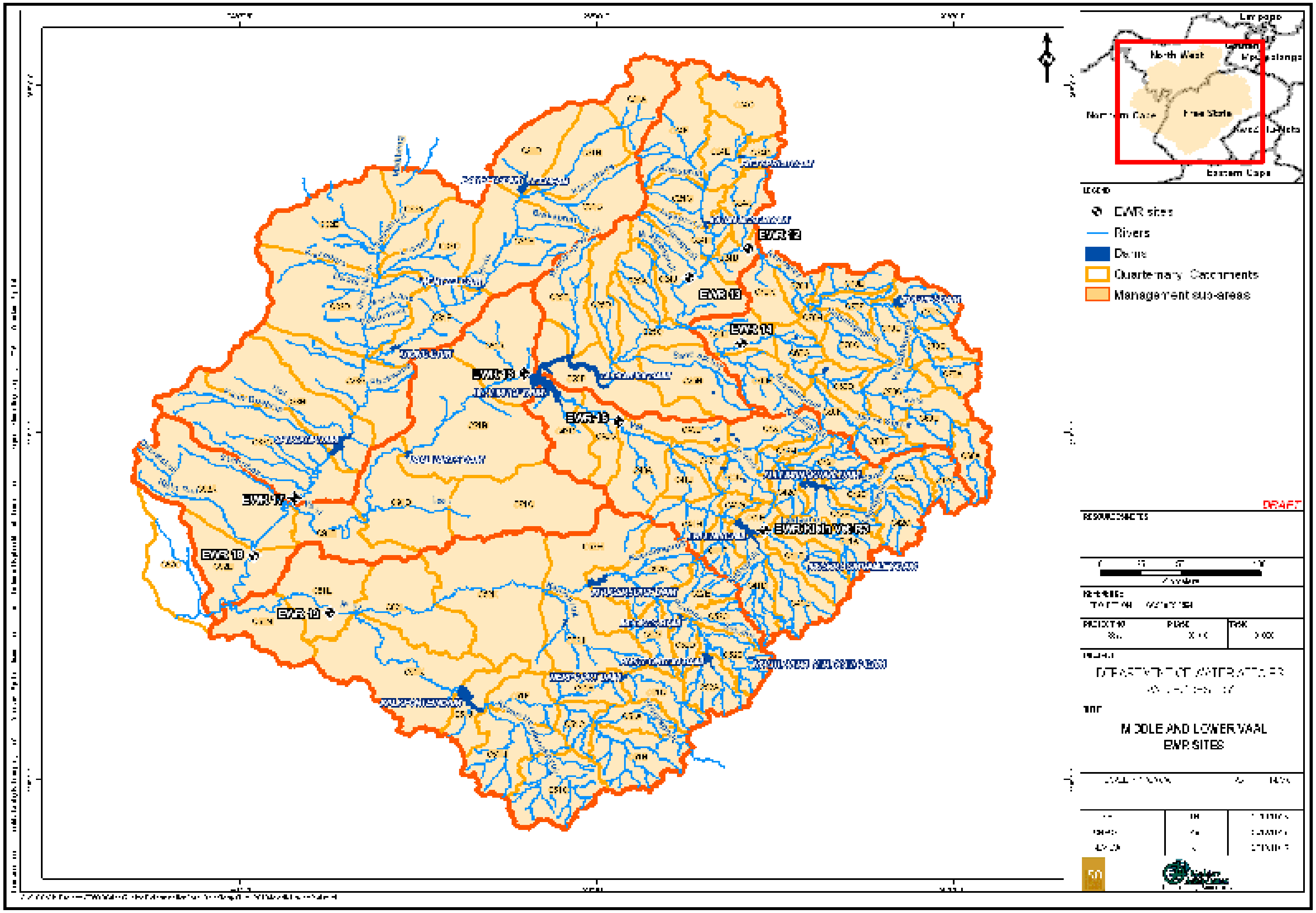


Figure 1: Resource Units and selected EWR sites for the Middle and Lower Vaal catchment

2 PROCESS

The generic eight step Ecological Reserve procedure is shown in Figure 2 (DWA, 2003) was followed in order to address the objectives:

- A set of Ecological Water Requirement (EWR) scenarios was generated to test through the application of a yield model. Each scenario represents a possible flow regime, intended to have specific outcomes linked to the Reserve. Scenarios specify how much water is required, where and when, and take cognizance of the likely water quality consequences.
- Based on the impacts of the EWR scenarios a set of flow scenarios, called Operational Scenarios, was generated and tested. These scenarios are realistic scenarios as impacts on users and constraints such as outlet sizes of dams are considered. Decision makers will select one of these scenarios as the Reserve.
- The likely impact of the Operational Scenarios on the available yield was determined.
- The likely impact of the Operational Scenarios on the aquatic ecology was determined.
- The likely economic impact of selected Operational Scenarios was determined.
- The likely impact of selected Operational Scenarios on the services provided by the riverine system was determined.

This process is consistent with the Resource Directed Measures (RDM) protocol. Best practice was followed, based on the most recent RDM developments. Dr’s Kleynhans and Jooste, as well as Ms Thirion (all from DWAF-RQS, where consulted with throughout the project to ensure consistency in methods applicability as well as to make sure that the most recent methods were applied). All changes in RDM protocols, during the course of the study, were incorporated within the existing budget and the study programme was amended to take cognizance of new requirements.

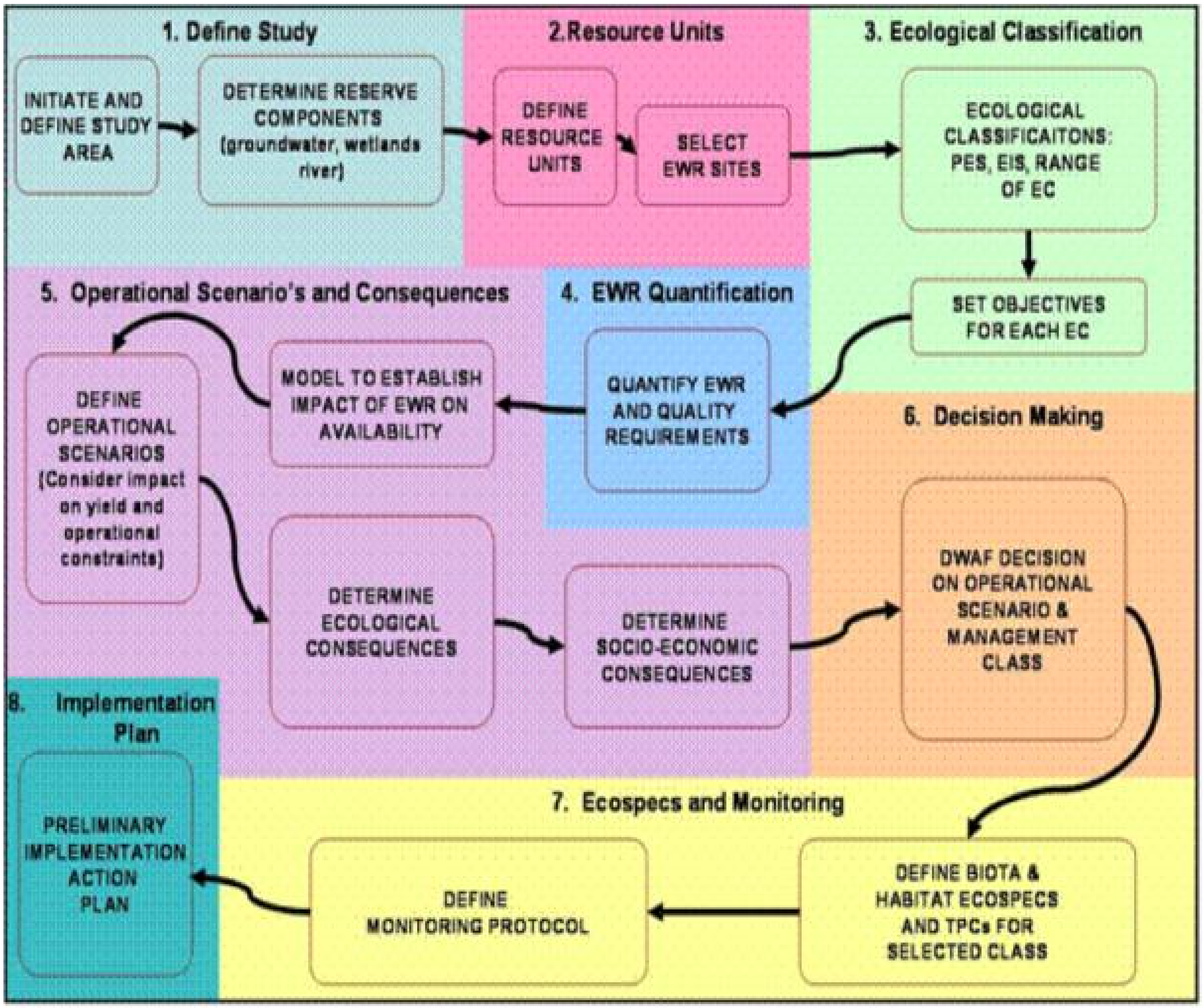


Figure 2: Generic procedure for the determination of the ecological Reserve

2.1 Level of detail of study

The study was designed to follow, as far as practically possible, a Comprehensive Ecological Reserve Determination approach to provide the highest confidence possible. The individual major components were addressed at different levels, depending on data availability and the importance of the component in the study area. For each, the present project status, the level of detail, and the specialist fields in which capacity building took place, are indicated.

The Wetland/Pans Assessment study was undertaken a desktop level of assessment.

The following separate studies were undertaken by other consulting teams and their findings used in this assessment:

- Groundwater assessment of the Vaal
- Department of Water Affairs (DWA), 2010. Resource Directed Measures: Comprehensive Reserve determination study for selected water resources in the Upper, Middle and Lower Vaal River Management Areas. Vaal River System Water Quality Report. Report no: RDM/ A000WMA3/01/CON/0408. Pretoria, South Africa.
- Water Resource Yield Model (overall model of the Vaal that was managed by WRP); and
- Conningarth modeled the overall Goods and Services for the Vaal Catchment to maintain a consistent approach.

Table 4 indicates the level of study the Reserve components and the areas that capacity building was undertaken.

Table 4: Components/Tasks addressed within the study

Study components	Level	Capacity Building
Project Management		Project team members
Inception Report		Project team members
Resource Units	Comprehensive	Project team members
Wetland Scoping Report	Scoping/Desktop	Project team members
Socio-economic assessment		Project team members
Ecological Water Requirement scenarios (River quantity and quality)	Comprehensive	Hydrology, aquatic invertebrates, riparian vegetation, fish
Ecospecs and monitoring	Comprehensive	Hydrology, aquatic invertebrates, macro-invertebrates, vegetation, fish
Capacity building	Comprehensive	Regional Office training, project team members, CD RDM

2.2 Assumptions and limitations

Basic Human Needs: The Basic Human Needs component of the Reserve was assessed based on 1991 census data and verified extensively in 1994. The latest census data has not been disaggregated to quaternary catchment scale by DWA and thus could not be used.

Stakeholders: A stakeholder involvement programme was not included. The study team did however produce two background information documents, one to announce the study initiation and the second to notify stakeholders of the study results. The BIDs were distributed electronically to stakeholders databases in the catchment areas.

EWR Sites: EWR sites could not be selected in all Resource Units because of funding constraints (4 sites were selected in the Middle Vaal catchment).

Hydraulics: Confidence in flow assessments was low to medium due to the narrow range in observed data for hydraulic calibration purposes. This was due to the systems being highly regulated.

Hydrology: Natural and Present Day flows were generated by WRP and used as is in this study. Observed data used included in this assessment was of stations that would best represent flows at each of the sites, therefore proximity to the site as well as availability of data in long enough period for meaningful statistical at an overview level to be determined, determined station selection. However it should be noted that observed data has its own problems, with respect to capture, accuracy and reliability of the data. These are however problems that reduce the confidence in the observed data. In the absence of any other data that can be used to assess the current hydrological situation, set aside the simulated present day flows, the observed data is to a large extent useful. Careful consideration and knowledge of the system, climate and historical events such as big floods of 1987 enable for the informed use of the observed data. To a larger extent the observed data used in this assessment at the different sites agrees with the simulated present day flows, with highs and lows as would be expected when comparing simulated flows versus observed flows. The exception is station C5H016 and C9H010 which deviate very sharply for the present day flows and this is attributed to the fact that the high flows (i.e. very wet years) were not sufficiently captured. The hydrology assessment focused on the generation for flow duration curves, monthly flow distribution and rating of the confidence we have in the hydrology in relation to low flows, zero flows, moderate flows, high flows and seasonality changes in the flows.

The Water Resource Yield Model was used to assess the impact on yield of the recommended and alternative EWRs. A limitation of the model is that output is presented as monthly flows. This makes it difficult to distinguish between high and low flow components that were specified as EWR requirements during months where both low flows and high flows were specified.

Classification System. No classification system as required by the National Water Act exists for integrating the results of the ecological and socioeconomic consequences to decide on the Management Class.

Monitoring Plan. This report provides the basis for developing a monitoring plan, but it does not address monitoring requirements or implementation as this requires the development of operational rules, negotiation with and commitment by all relevant management agencies, and a comprehensive Decision

Support System that allocates responsibilities, and specifies the actions that should be taken in the event of non-compliance. These aspects fell beyond the scope of this study.

3 DELINEATION

3.1 Background

The CD: RDM identified the Integrated Vaal River System, with the focus of this study, the Middle Vaal Water Management Area (WMA) as requiring a comprehensive Reserve assessment as to provide input to the Reconciliation studies and the integrated water quality management plan for the Vaal River studies undertaken by the National Water Resources Planning Directorate (D: NWRP) of the DWAF. These studies require higher levels of confidence in the Reserve determination results as is currently available. This will assist the DWAF to make informed decisions regarding the authorization of future water use and the magnitude of the impacts of the present and proposed developments.

A Desktop EcoClassification will serve as a scoping phase to investigate the WMA at a desktop level and at the scale of quaternary catchments and serves as the basis for most other tasks in the Reserve determination process. This scoping assessment provides an overview of the WMA and a better understanding when focussing on the EWR sites and the sections of rivers where comprehensive assessments will be undertaken. The output of the information also identifies areas of potential concern based on an integrated importance (combination of Ecological Importance and Sensitivity, Socio-Cultural Importance and Present Ecological State).

3.2 Approach

The objective of the EWR study is to provide information at two levels of detail, i.e. at scoping or desktop level, as well as a more detailed assessment. This report presents the results of the Desktop assessment of the EcoClassification process for each quaternary catchment. The term used for Ecological Classification "EcoClassification" (Kleynhans *et al*., 2005) refers to the determination and categorisation of the Present Ecological State (PES) - or health or integrity - of various biophysical attributes of rivers, compared with the natural or close to natural reference condition. The purpose of EcoClassification is to gain insight into the causes and sources of the deviation of the PES from the reference condition. This provides the information needed to derive the desirable and attainable future ecological objectives for the river. The state of the river is described in terms of Ecological Categories (A to F).

The EcoClassification process also includes an assessment of Ecological Importance and Sensitivity (EIS), and Socio-Cultural Importance (SCI). These are described in terms of Low to Very High (EIS) and Minimal to Very High (SCI). All assessments include a confidence rating that may range from 1 (low confidence) to 5 (high confidence).

3.3 Ecological Importance and Sensitivity

The ecological importance of a river is an expression of its contribution 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) (Resh *et al*., 1988; Milner, 1994).

Standard EIS models are used, irrespective of the level of assessment. The data which is used to populate the models vary, dependant on the level.

No areas of Very High EIS are present in the WMA. The few areas of high EIS are the following:

- C70G, C70H, C70J and C70K (Renoster River system) due to the presence of the endangered rock catfish (*Austroglanis sclateri*)

- C24B (Vaal River) due to the presence of the endangered rock catfish (*A. sclateri*).

- C24D (Rietspruit River) due to the presence of the Schoonspruit provincial reserve, the location of the Schoonspruit dolomitic eye, and the presence of the endangered rock catfish (*A. sclateri*).

- C25A (Klipspruit River) due to probable high species diversity, including rock catfish (*A. sclateri*) the site of the Wolvespruit Nature Reserve.

Most of the rest of the quaternary catchments were rated as moderate. The confidence of the evaluation ranged mostly from moderate to high with approximately 30% as low.

A summary of the EIS is shown in Figure 3, and a summary of the integrated importance is shown in Figure 4.

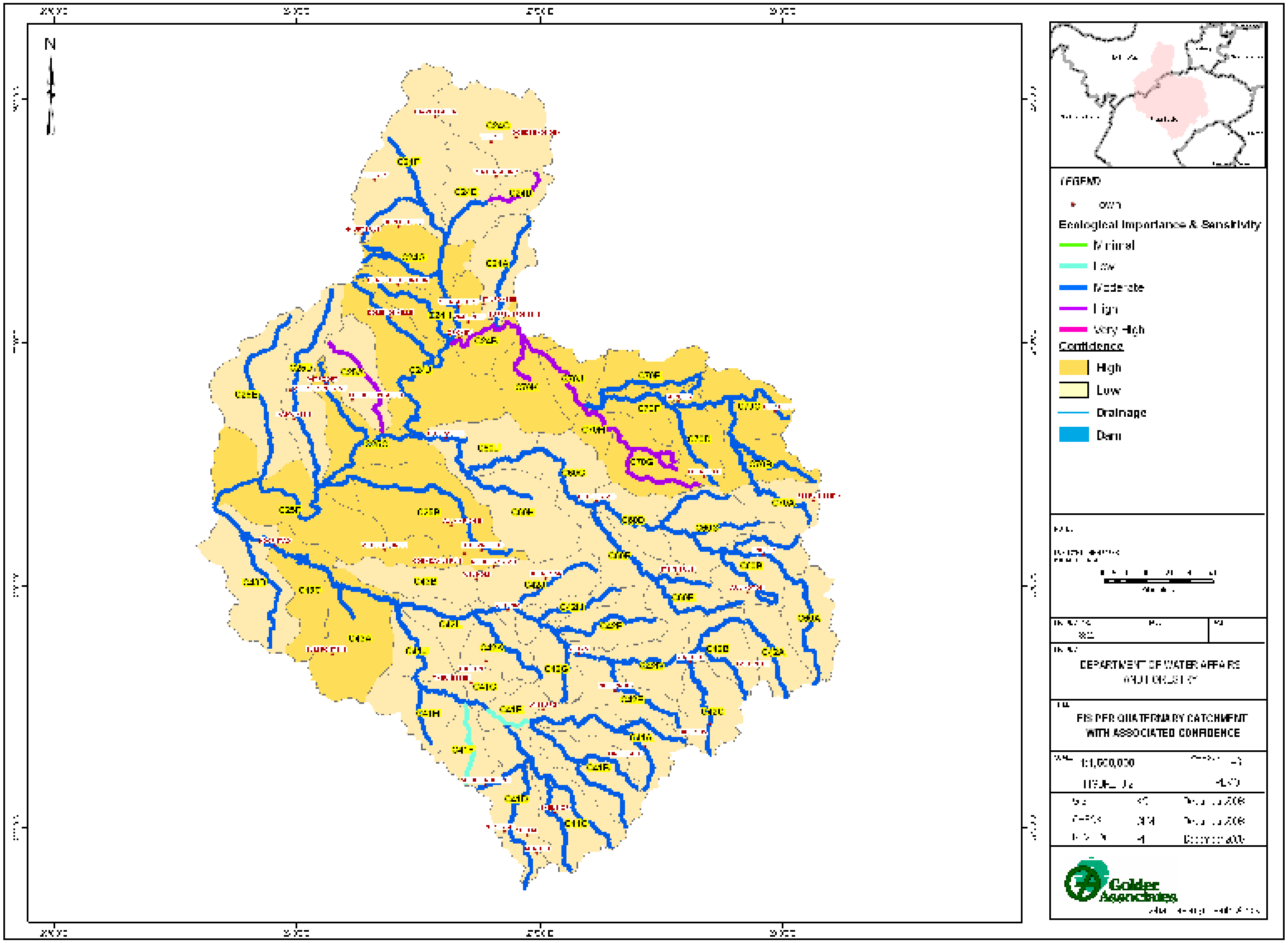


Figure 3: Summary of the Ecological Importance and Sensitivity (EIS) of the Middle Vaal Catchment

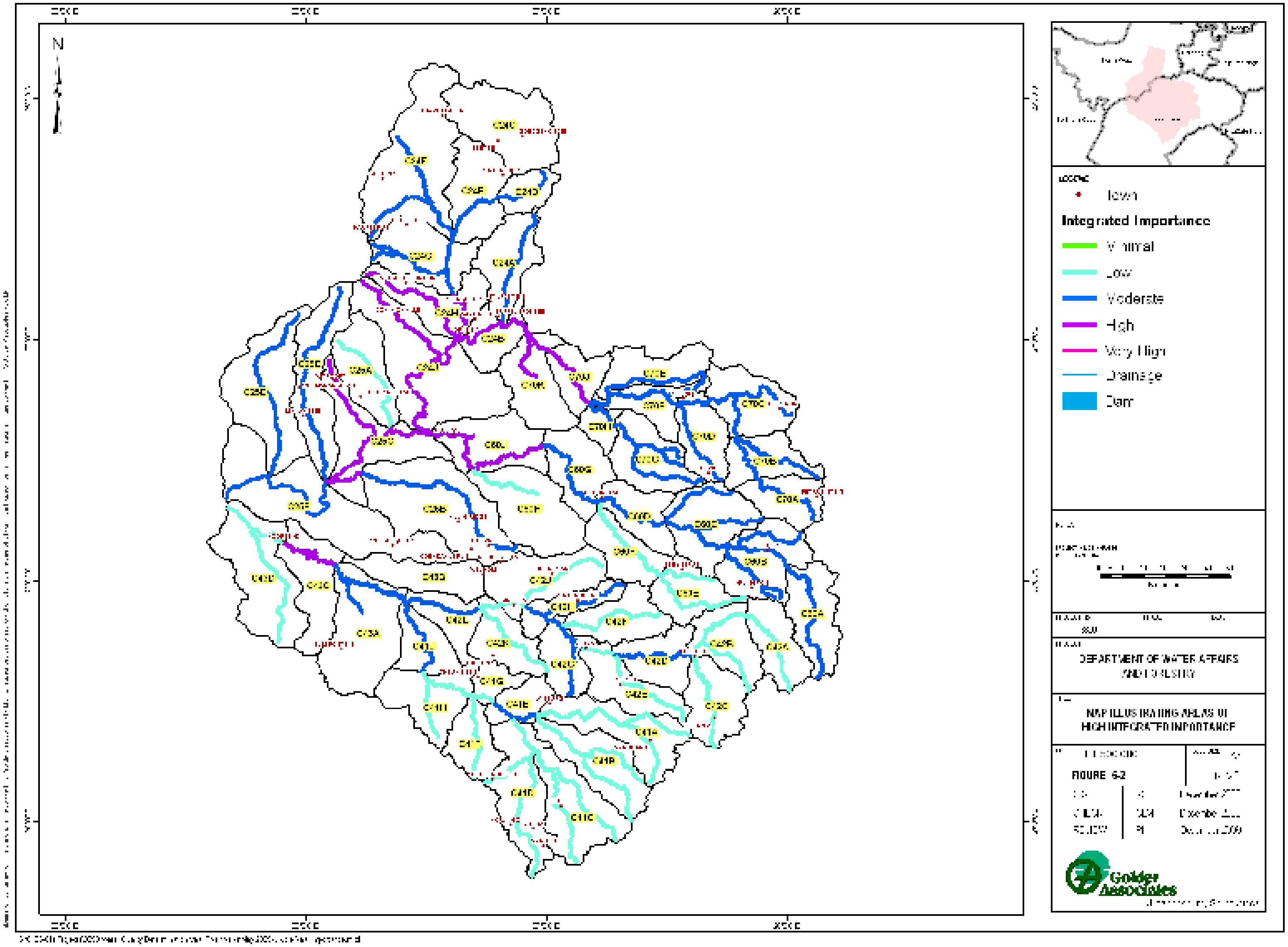


Figure 4: Summary of the integrated importance of the Middle Vaal Catchment

3.4 Socio-Cultural Importance

The SCI was determined from:

- A site visit that covered points along the river; and
- Extrapolation to sites not visited by reference to available literature, as well as to existing mapping.

The SCI was generated by scoring each quaternary, based on the following features:

- Ritual Use (e.g., ceremonial purposes, spiritual/religious activities.).
- Aesthetic Value.
- Resource Dependence (it refers to the goods and services delivered by the river system and peoples dependence on these components).
- Recreational Use.
- Historical/Cultural Value (e.g., sites of historic battles, craters dues to meteorites etc)).

Scores were then weighted to reflect the adjudged importance of each component relative to the other. The Resource Dependence component was given the highest weighting, because this component is designed to reflect the importance of a healthy riverine system to people who are often in the grips of poverty, and for whom the availability of such resources is a question of survival.

Areas dominated by relatively low population densities and given over to commercial farming enterprises (typically the upper parts of the catchment) as well as portions of the middle catchment tended to score relatively low in terms of SCI. An obvious exception is recreational use. Portions of the WMA with water related recreational activity scored slightly higher. Areas dominated by mining and industrialisation also scored generally low in terms of SCI. It should be emphasised that low SCI score does not indicate low economic importance. In terms of economic importance the Middle Vaal catchment is obviously critical to the RSA due to the gold mining in the KOSH area.

A summary of the SCI is shown in Figure 5.

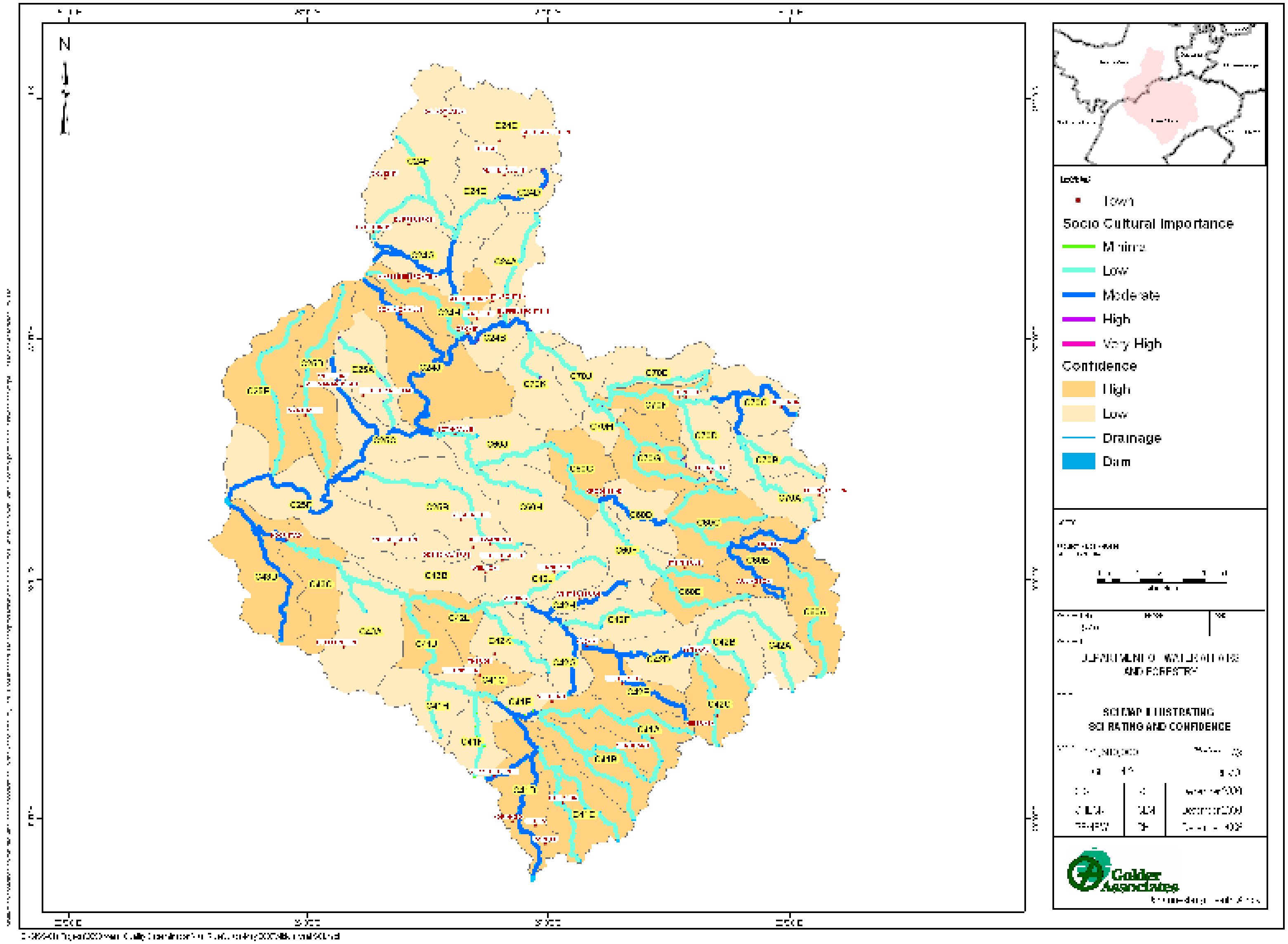


Figure 5: Summary of the Socio Cultural Importance (SCI) of the Middle Vaal Catchment

3.5 Present Ecological State

The PES of the river is expressed in terms of various components, i.e., **drivers** (Physico-chemical variables, geomorphology, hydrology) and **biological responses** (fish, riparian vegetation and aquatic invertebrates), as well as an integrated state, the EcoStatus.

A Desktop Level EcoStatus assessment was designed for use when assessments for planning purposes on large scale have to be undertaken. As the name indicates, this is done at desktop level, and is therefore based on available information and expert judgement. However, due to the lack of relevant information in some of the areas, a site visit was undertaken during this study to provide additional information.

The bulk of the rivers in WMA 9 are in a B/C and C category. Please note again that this does not include all the smaller tributaries. The rivers in a B category are the following:

- C70K: Renoster River
- C24C: Upper Schoonspruit (including the Schoonspruit eye)

This means that there are very few rivers in this large WMA which are potentially still in a good condition. The reason for this is the high utilisation of the catchment due to mining, irrigation and the urban sprawl of Gauteng. Water quality issues are prevalent in many streams as well as increased flows, i.e. more than natural.

A summary of the PES is shown in Figure 6. A summary of the Ecological Water Requirement (EWR) hotspots is shown in Figure 7.

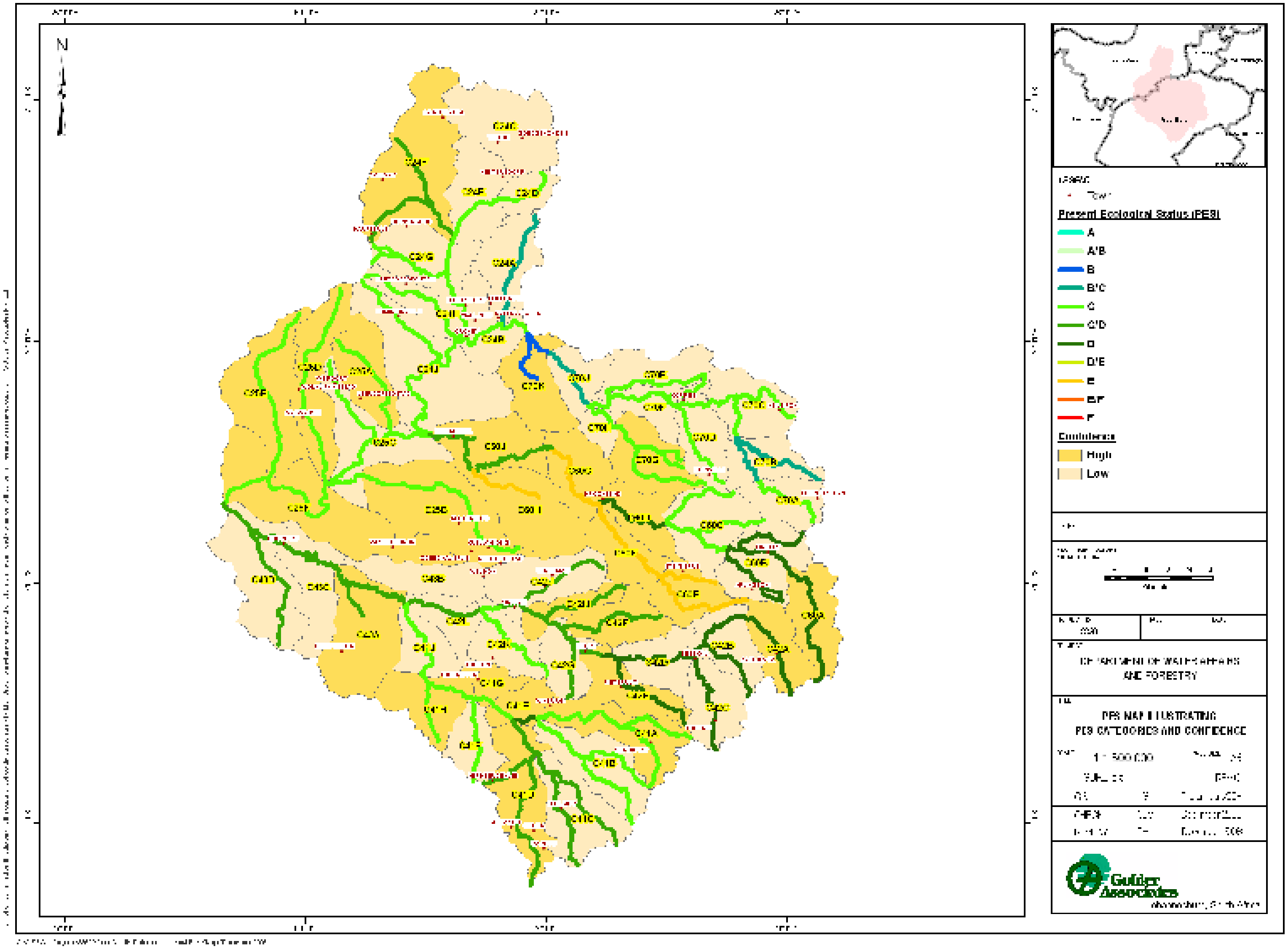


Figure 6: Summary of the Present Ecological Status (PES) of the Middle Vaal Catchment

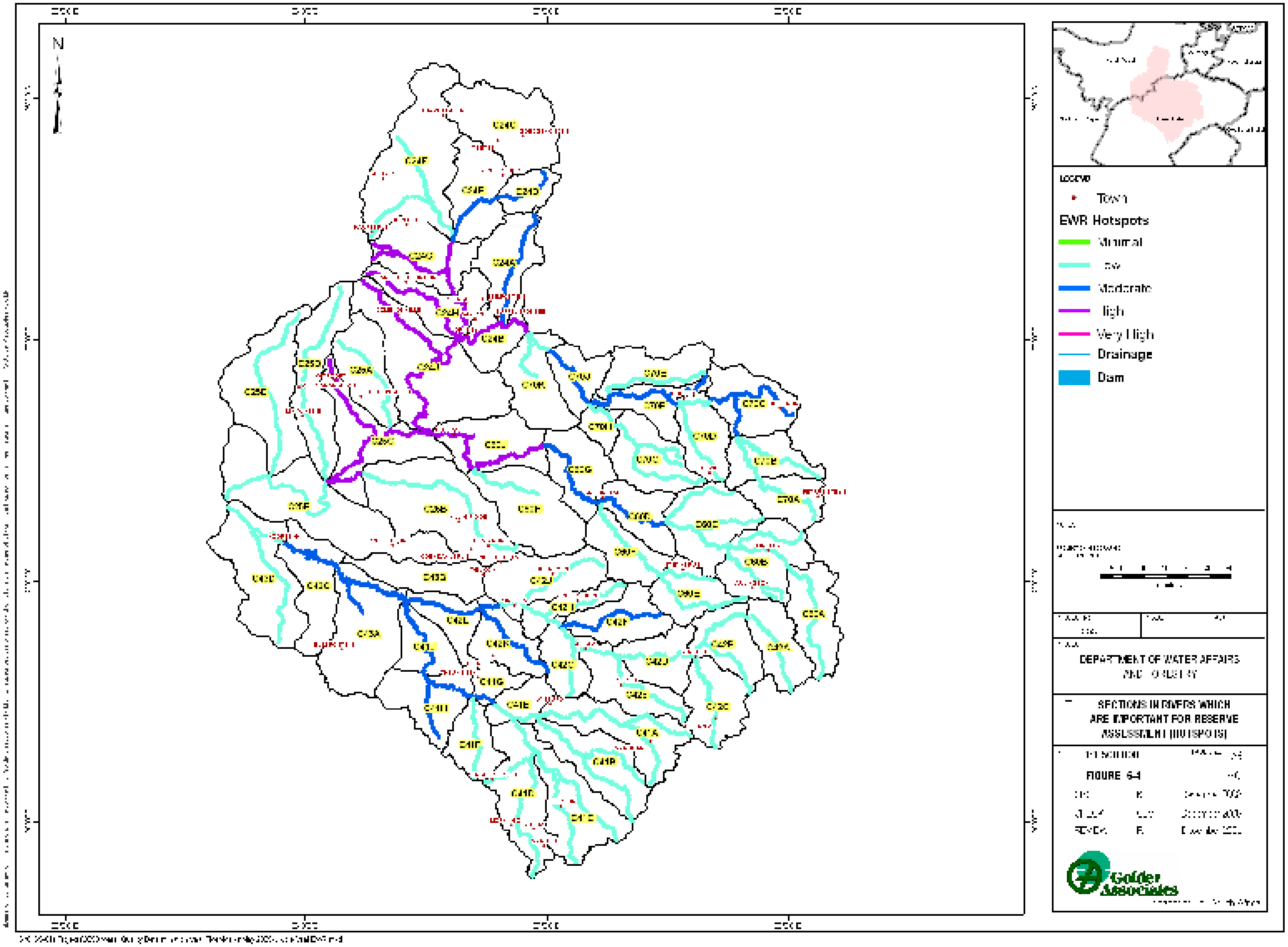


Figure 7: Summary of the Ecological Water Requirement (EWR) hotspots of the Middle Vaal Catchment

3.6 Recommendations

An evaluation has been undertaken comparing areas of Integrated Importance which consists of Ecological, Socio-Cultural and Present Ecological State, with an importance evaluation of Water Resource Use. All quaternary catchments with either a high (3) or very high (4) rating were identified and are illustrated in the map below. These quaternary catchments would require EWR of reasonably high confidence and detailed studies are therefore recommended. This information will play an important role in identifying the areas where EWR sites are to be selected.

4 RESOURCE UNITS

4.1 Background

The Chief Directorate: Resource Directed Measures (RDM) has initiated the Comprehensive Reserve Determination Study for the Integrated Vaal River System: Middle Vaal Water Management Area (WMA) surface water quantity. The purpose of the Comprehensive Reserve Determination Study for the water resources of the Middle Vaal WMA is to determine the ecological and basic human needs water quantity Reserve for the rivers and pans in the WMA.

The Reserve studies require higher levels of confidence in the results as is currently available. This will assist the Department of Water Affairs and Forestry (DWAF) to make informed decisions regarding the management and operation of the system, authorisation of future water use and the magnitude of the impacts of the present and proposed developments.

As part of the Reserve Determination process it is necessary to define the study area for the comprehensive assessment and to delineate key rivers of the study area into Resource Units (RU). Each RU represents a homogenous area which requires its own specification of the Reserve.

4.2 Delineation Approach

The process followed was that described in the updated Reserve manuals (Louw and Hughes, 2002).

Resource Units are required as it would not be appropriate to set the same numerical Reserve for the headwaters of a river as for the lowland reaches. The breakdown of a catchment into RUs for the purpose of determining the Reserve for rivers is therefore done primarily on a biophysical basis within the catchment and called Natural Resource Units (NRUs). Management requirements (DWAF, 1999, volume 3) also play a role in the delineation. Furthermore, the type of disturbance/impact on the river plays a role to select homogenous river reaches from a biophysical basis under present circumstances. These are called Management Resource Units (MRUs). MRUs can be further delineated in even smaller assessment units called Reserve Assessment Units (RAUs). It is preferable to select a EWR site within each MRU, and if possible, be selected within the RAU.

The following is considered for selection of MRUs:

- Geomorphological zones;
- EcoRegions (Level II);
- Land cover;
- System operation and presence of dams;
- Water quality;

- Local knowledge.

4.3 Delineation Results

The results are tabled below.

MRU	Delineation	Quartenary Catchment
	VAAL RIVER	
MRU Vaal F	From start of WMA at Vermaasdrift on Vaal River to upstream confluence with Schoonspruit	C24B
MRU Vaal G	From Schoonspruit confluence to Regina Bridge (weir)	C24J
MRU Vaal H	From downstream Regina Bridge to Klipplaatdrift	C24J
MRU Vaal I	From Klipplaatdrift to Bloemhof Dam	C24J, C25C
MRU Vaal J	Bloemhof Dam	C25E, C25F, C43D, C91A
	TRIBUTARIES	
	RHENOSTER RIVER	
MRU Rhenoster A	From origin to upstream Koppies Dam	C70A, C70B, C70C
MRU Rhenoster B	Koppies Dam	C70C
MRU Rhenoster C	From downstream Koppies Dam to confluence with Vaal River	C70E, C70D, C70F, C70G, C70H, C70J, C70K
	KOEKEMOERSPRUIT	
MRU Koekemoerspruit A	From origin to confluence with Vaal River	C24A
	SCHOONSPRUIT	
MRU Schoonspruit A	From eye to Kalk Dam	C24C, C24E
MRU Schoonspruit B	From Kalk Dam to Klerkskraal Dam	C24D, C24E, C24F, C24G
MRU Schoonspruit C	Klerkskraal Dam	C24G
MRU Schoonspruit D	From Klerkskraal Dam to confluence with the Vaal River	C24H
	VALS RIVER	
MRU Vals A	Origin of the Vals river to Kroonstad (Kroonvaal weir)	C60A, C60B, C60C, C60D, C60E, C60F
MRU Vals B	From confluence at Kroonstad to Vaal River confluence	C60G, C60H, C24J
	VET RIVER	
MRU Vet A	Origin of Vet River to Erfenis Dam	C41A, C41B, C41C
MRU Vet B	Erfenis Dam	C41E
MRU Vet C	Erfernis Dam to confluence with Sand River	C41G, C41H, C41J
MRU Sand A	Origin of Sand River to Allemanskraal Dam	C42A, C42B, C42C, C42D
MRU Sand B	Allemanskraal Dam	C42E
MRU Sand C	Allemanskraal Dam to confluence with Vet River	C42F, C42G, C42H, C42J, C42K, C42L
MRU Vet D	From confluence with Sand River to Bloemhof Dam	C43A, C43C, C43D
	MAKWASSIE RIVER	
MRU Makwassie A	From origin to confluence with Vaal River	C25D
	SANDSPRUIT	
MRU Sandspruit A	From origin to confluence with Vaal River	C25B, C25C

4.4 Ecological Water Requirement (EWR) Sites

The selection of EWR sites is guided by a number of considerations. The key considerations are:

- The suitability of the sites for accurate hydraulic modelling throughout the range of possible flows, especially low flows.
- Accessibility of the sites.
- An area or site that could be critical for ecosystem functioning. These are often represented by riffle units, where low flow conditions or the cessation of flow constitutes a break in the functioning of the river, and consequently, the biota dependant on this habitat and/or perennial flow are adversely affected. Pools are not considered critical habitats in perennial system since they are still able to function or at least maintain life during periods of no flow.

The rationale and assessment of the recommended EWR sites within the MRUs as identified in the study are detailed Table 5.

Table 5: Assessment of MRU and recommendations on EWR sites

MRUs	Assessment of Resource Unit	Recommendations on EWR site
VAAL RIVER		
MRU Vaal F	The unit is it just downstream Upper Vaal WMA (downstream of the Mooi River confluence) so it is important to understand the influence of the Upper Vaal WMA. The river reach does include similar land use and has is considered a high priority as it forms the upper most reach of the Middle Vaal River. Importance of the MRU was rated as 3 thus it does warrant a selection of a comprehensive EWR site. Site is Easy to access. It is a single channel and has a gauging weir for flow records.	EWR site 1 at Vermaasdrift was selected. Site will account for influences from the Upper Vaal WMA.
MRU Vaal G	Importance of this reach was rated as a 3, and it is downstream of the Schoonspruit catchment a major influence in the system. The weir captures major water quality impacts from the upper and middle Vaal catchments - an EWR site should be selected. Site is Easy to access. It is a single channel and has a gauging weir for flow records.	EWR site 2 at Regina Bridge was selected. It is the 'middle site' in the Vaal River. As it is close to the downstream section of this MRU, it is situated ideally to address all impacts upstream Regina Bridge.
MRU Vaal H	No major characteristic features, habitat and biota diversity or major operational influences occur in this reach to warrant a selection of an EWR site. However reach was rated as an importance of 3 as it was noted that the sustainability of Vaal River upstream of Bloemhof Dam should be maintained.	No EWR site selected. Management at EWR site 2 will address requirements in this MRU and maintain sustainability.
MRU Vaal I	Bloemhof Dam forms the lower delineation area of the reach. While the importance of this reach was rated as a 3, the lower level of the reach is inundated with Bloemhof Dam water which is not conducive for a suitable EWR site.	No EWR site was selected.
MRU Vaal J	RU comprises Bloemhof Dam. It forms an operational break in the system. Importance was rated as a 1.	No EWR site was selected.
RHENOSTER RIVER		
MRU Rhenoster A	Includes one geomorphic zone and land cover type. No	No EWR site was selected.

MRUs	Assessment of Resource Unit	Recommendations on EWR site
	major characteristic features, habitat and biota diversity or major operational influences occur in this reach. Koppies Dam forms lower boundary of MRU. The reach has a low priority rating thus does not warrant the selection of an EWR site.	
MRU Rhenoster B	The dam is delineated as a unit. It forms an operational break in the system. The reach has a moderate priority rating.	No EWR site was selected.
MRU Rhenoster C	No significant changes occur along these lower reaches below the Dam. No significant habitat and biota diversity. Importance rating is 2 in the lower reaches of the river (upstream confluence with the Vaal River).	No EWR site was selected.
KOEKEMOERSPRUIT		
MRU Koekemoerspruit A	There are no characteristic features, significant changes or physical structures in the system. Flow is dominated by mine water discharge. Habitat is significantly impacted by land use impacts. Land use is also similar (mining). The reach has a low priority rating thus does not warrant the selection of an EWR site.	No EWR site was selected.
SCHOONSPRUIT		
MRU Schoonspruit A	The Schoonspruit eye has a high importance rating and high EIS, and does warrant the selection of an EWR site. However due to the lack of any opportunity for changes in operation, the selection of EWR site is not proposed.	An intermediate Reserve determination study was undertaken on the Schoonspruit through a previous DWAF study. Thus no EWR sites were selected.
MRU Schoonspruit B	The reach has a low importance rating. MRU is delineated by two dams. System is highly regulated. A EWR site is not proposed.	
MRU Schoonspruit C	The dam is delineated as a unit. It forms an operational break in the system. The reach has a moderate priority rating. The Dam is not representative of site requirements.	
MRU Schoonspruit D	There is an increase in return flows from these areas into the Schoonspruit. This reach did score a high priority rating (3) in terms of management of the system.	
VALS RIVER		
MRU Vals A	The weir forms a break in the system and creates a delineation between the upper and lower reaches of the Vals river system. This MRU is largely rural in nature. No significant changes occur along these upper reaches below. No significant habitat and biota diversity. The importance rating was low.	No EWR site was selected.
MRU Vals B	Ecoregion level does change from the upper reaches. Catchment did receive a priority rating of 3 requiring the integrity of the river to be maintained upstream of the confluence with the Vaal River. MRU should be considered for the selection of an EWR site. Site is easy to access and has a gauging weir for flow records. However hydraulics is complex (two channels, standing pools).	EWR site 3 selected at Proklameersdrift.
VET RIVER		
MRU Vet A	The Dam forms the lower delineation boundary of the unit. Upper most reach of river. Region has a low priority rating.	No EWR site was selected on Vet River. However Rapid EWR site was selected on Klein- Vet just downstream of Winburg.
MRU Vet B	Erfenis Dam is delineated as a resource unit. It forms an operational break in the system. The Dam is not representative of site requirements.	No EWR site was selected.

MRUs	Assessment of Resource Unit	Recommendations on EWR site
MRU Vet C	No significant changes in land use, however MRU does include two Eco-regions. System is regulated by dam. Reach was rated as a moderate priority rating.	No EWR site was selected.
MRU Sand A	Includes three Eco-regions in upper reaches. Region has a low priority rating.	No EWR site was selected.
MRU Sand B	Allemanskraal Dam is delineated as a resource unit. It forms an operational break in the system. The Dam is not representative of site requirements.	No EWR site was selected.
MRU Sand C	Area is impacted by return flows from the urban centres, bulk water users and irrigation. System is regulated by dam. Catchment area has a low to moderate priority rating.	No EWR site was selected.
MRU Vet D	Area has a moderate priority rating (2). Assessment requires the integrity of the Vet river to be maintained upstream of the confluence with the Vaal River. MRU should be considered for the selection of an EWR site. Single low flow channel and gauging weir for flow records is present.	EWR site 4 selected at Fisantkraal.
MAKWASSIE		
MRU Makwassie A	The river is under stress but it has a low priority rating. Assessment was undertaken to identify a possible site. However no suitable site could be found.	No EWR site was selected.
SANDSPRUIT		
MRU Sandspruit A	There are no characteristic features, significant habitat or biota diversity, significant changes or physical structures in the catchment. MRU has a low priority rating thus does not warrant the selection of an EWR site.	No EWR site was selected.

The site information and photographs of the selected EWR sites are shown in Table 6.

Table 6: Locality and characteristics of the Middle Vaal WMA EWR sites

Site information	EWR sites	Site
EWR number and name River National RHP site Decimal degrees: EcoRegion (Level II) Geomorphic Zone Altitude (m) RU Quaternary Hydrological gauge	**EWR 1 Vermaasdrift** Vaal C2-Vaal Orkne S26.93615; E26.85025 11.01 Lower Foothills 1348 Vaal F C24A C1H007	
EWR nr and name River National RHP site Decimal Degrees EcoRegion (Level II) Geomorphic Zone Altitude (m) RU Quaternary Hydrological gauge	**EWR 2 Regina Bridge** Vaal C2-Vaal Orkne S27.10413; E26.52185 11.08 Lower Foothills 1285 Vaal G C24J C2H007	

Site information	EWR sites	Site
EWR nr and name River National RHP site Decimal Degrees EcoRegion (Level II) Geomorphic Zone Altitude (m) RU Quaternary Hydrological gauge	**EWR 3 Proklameersdrift** Vals C6 Vals-Prokl S27.48685; E26.81320 11.07 Lower Foothills 1400 Vals B C60J C6H001	
EWR nr and name River National RHP site Decimal Degrees EcoRegion(Level II) Geomorphic Zone Altitude (m) RU Quaternary Hydrological gauge	**EWR 4 Fisantkraal** Vet C4-Vet-Hoops S27.93482; E26.12569 11.08 Lower Foothills 1247 Vet C C43A C4H004	
EWR nr and name River National RHP site Decimal Degrees EcoRegion(Level II) Geomorphic Zone Altitude (m) RU Quaternary Hydrological gauge	**Rapid EWR** Klein-Vet C4G Vet-V4 S28.564708; E26.943946 11.03 Lower Foothills Vet A C41A	

The sites selected are indicated in Table 7 and illustrated in **Figure 8** with the MRUs.

Table 7 : Description of the chosen EWR sites in the Middle Vaal.

EWR Site number	EWR site name	River	National RHP site	Coordinates	Ecoregion (Level II)	Geomorphic zone	Altitude (m)	RU	Quaternary catchment
EWR1	Vaal River: Vermaasdrift	Vaal	C2-Vaal Orkne	S26.93615 E26.85025	11.01	E: Lower Foothills	1348	MRU Vaal F	C24A
EWR2	Vaal River: Regina bridge	Vaal	C2-Vaal Orkne	S27.10413 E26.52185	11.08	E: Lower Foothills	1285	MRU Vaal G	C24J
EWR3	Vals River: Proklameersdrift	Vals	C6Vals-Prokl	S27.48685 E26.81320	11.07	E: Lower Foothills	1400	MRU Vals B	C60J/C60G
EWR4	Vet River: Fisantkraal	Vet	C4-Vet-Hoops C4-Vet-Erfen	S27.93482 E26.12569	11.08	E: Lower Foothills	1247	MRU Vet C	C43A
Rapid EWR	Klein-Vet, just downstream of Winburg	Klein Vet	C4GVet-V4	S28.564708 E26.943946	11.03	E: Lower Foothills		MRU Vet A	C41A

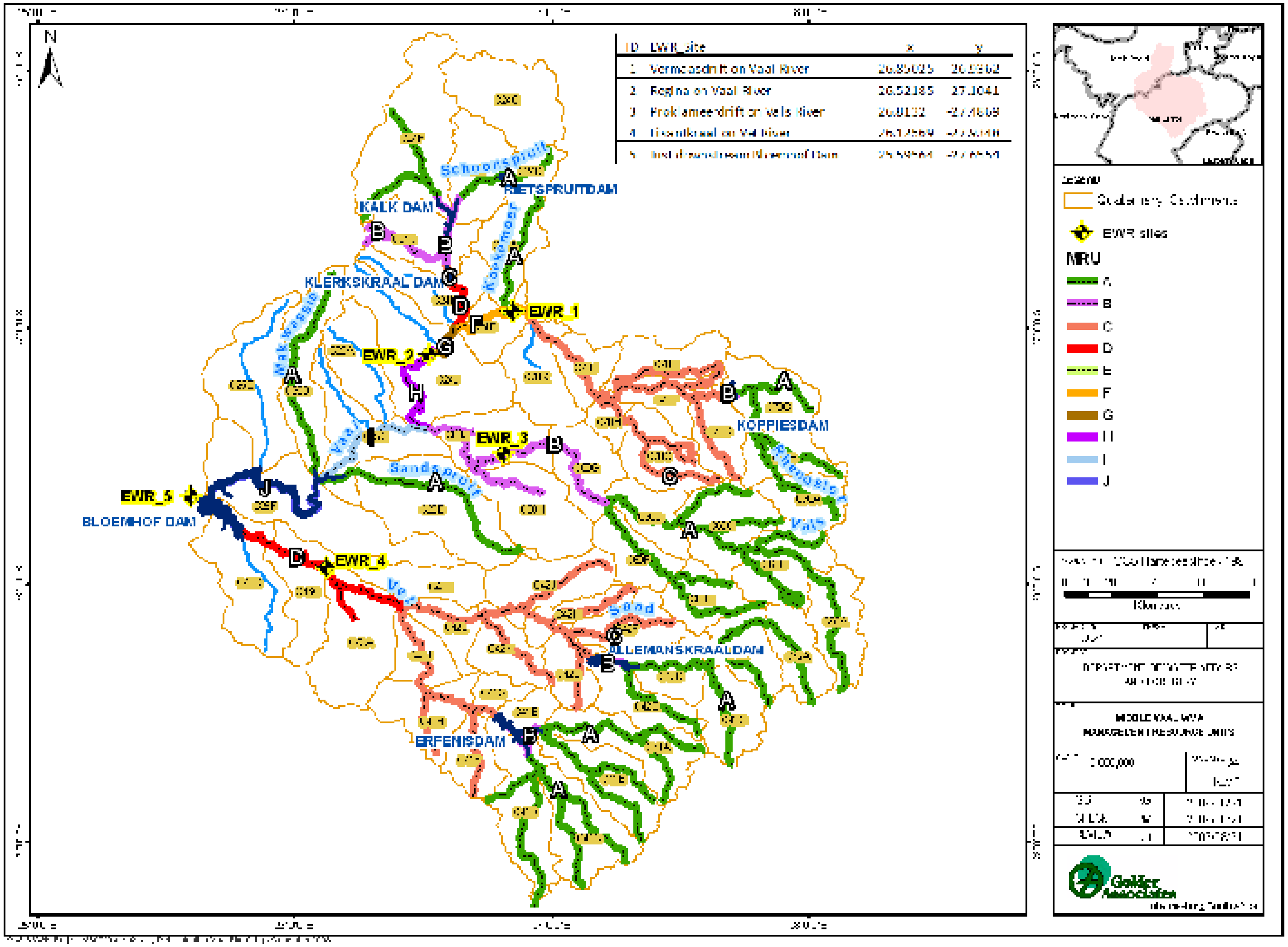


Figure 8: Summary of the Resource Units and the Ecological Water Requirement (EWR) sites

5 BASIC HUMAN NEEDS

5.1 Introduction

The National Water Act (Act No. 36 of 1998) (NWA) is founded on the principle that National Government has overall responsibility for and authority over water resource management for the benefit of the public without seriously affecting the functioning of the water resource systems. In order to achieve this objective, Chapter 3 of the NWA provides for the protection of water resources through the implementation of resource directed measures (RDM). As part of the RDM, a Reserve has to be determined for a significant water resource, as means to ensure a desired level of protection.

In this the CD:RDM has initiated the Comprehensive Reserve Determination Study for the Integrated Vaal River System: Middle Vaal Water Management Area (WMA) surface water quantity (technical component). The purpose of the Comprehensive Reserve Determination Study for the water resources of the Middle Vaal WMA is to determine the ecological and basic human needs water quantity Reserve for the rivers and pans in the WMA at the highest possible level of confidence given data, budget and time constraints.

As part of the Reserve Determination process it is necessary that the Basic Human Needs (BHNR) requirements is determined to understand the likely direct users of the surface water resources of the catchment so these uses are quantified and accounted for in the Reserve. This task is therefore focused on understanding and determining for the water resources in Middle Vaal WMA the BHNR component.

The Reserve is defined in terms of the National Water Act, Act No. 36 of 1998 as: “The quantity and quality of water required to satisfy basic human needs and to protect aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant water resource”.

In terms of the above definition the Reserve comprises two distinct components viz.:

- The Basic Human needs (BHNR), and
- The Ecological Reserve.

The focus of this task is to determine the BHNR for the Middle Vaal WMA.

The BHNR provides for the essential needs of individuals served by the water resource in question and includes water for drinking, food preparation and for personal hygiene. A life-line amount of 25 litres per person per day has been adopted for the BHNR by DWAF which is aligned to the Reconstruction and Development Programme (RDP) targets of Government of 25 litres per person per day, as well as the World Health Organisation minimum standards.

5.2 Approach

The process followed in determining the BHNR for the Middle Vaal WMA was as per that specified by the CD: RDM. The BHNR was analysed using the following factors:

- The population of those either living within the catchment or directly dependant on the water resources in the catchment. The river has been used as a geographical cue to demarcate populations potentially dependant on the water source. In effect, a 5 km buffer either side of the river is drawn and only the populations within this strip are deemed to be part of BHNRR calculations.

- The per capita requirements (litres/day) of the that population based on the life line amount of 25 litres per person per day; and

- The virgin mean annual runoff (vMAR) of the catchment areas in question.

In terms of the above factors the following applied terms of the Middle Vaal WMA.

5.2.1 Population

The basic human needs Reserve was calculated from population water requirements provided by Chief Directorate: Water Services, Directorate: Community Water Planning. The population figures used were based on the 1991 census and extensive field verification project initiated in 1994. The total population of the quaternary catchment was used to calculate the basic human needs Reserve at the outlet of the quaternary catchment. Although the population figures from the 2001 National census are available, these figures are only available at a municipal demarcation boundary level. The DWAF has not yet disaggregated the population figures to quaternary catchment boundary level as per personal communication of the Sub-directorate Systems Analysis.

5.2.2 Per capita requirements

The next step in the analysis is to multiply population figures by possible BHNRR water quantity targets. As such, from the population figures available a BHNRR can be a calculated. It should be noted that there is no “official” BHNRR figure. The RDP target (Target 1), of 25 litres per person per day is conventionally is used by DWAF as the basic human need requirement.

5.2.3 Percentage of Mean Annual Runoff

The final step of the process is to determine what percentage of virgin Mean Annual Runoff (MAR) BHNR comprises. While the virgin MAR is preferred in the case of the Middle Vaal WMA, the virgin

MAR for each quaternary catchment was not available. The gross MAR per quaternary catchment was thus used (WRC, 1994).

5.3 The Results

The BHNR calculated for the Middle Vaal WMA is presented below in **Table 8**. The results of the analysis are also presented in Figure 9 and Figure 10.

Table 8: BHNR required for Middle Vaal

QUATERNARY		TOTAL POPULATION	Per Capita need (litres/day)	Per Capita need (MCM/ Annum)	Gross MAR	%MAR
C70A	**C70A Total**	**18,750**	25	0.17	23.6	**0.72**
C70B					22.3	
C70C	**C70C Total**	**37,000**	25	0.34	29.7	**1.14**
C70D	**C70D Total**	**6,377**	25	0.06	8.5	**0.68**
C70E					21.9	
C70F	**C70F Total**	**14,978**	25	0.14	17.4	**0.79**
C70G					24.9	
C70H					7.3	
C70J					15.7	
C70K	**C70K Total**	**33,138**	25	0.30	24.8	**1.22**
C24A	**C24A Total**	**89,400**	25	0.82	30.9	**2.64**
C24B	**C24B Total**	**23,000**	25	0.21	16.8	**1.25**
C24C	**C24C Total**	**4,140**	25	0.04	31.2	**0.12**
C24D	**C24D Total**	**30**	25	0.00	10.1	**0.00**

QUATERNARY		TOTAL POPULATION	Per Capita need (litres/day)	Per Capita need (MCM/ Annum)	Gross MAR	%MAR
C24E	**C24E Total**	**27,650**	25	0.25	20.6	**1.22**
C24F	**C24F Total**	**25,150**	25	0.23	50.2	**0.46**
C24G	**C24G Total**	**280**	25	0.00	25.3	**0.01**
C24H	**C24H Total**	**284,959**	25	2.60	5.9	**44.07**
C24J	**C24J Total**	**1,656**	25	0.02	12	**0.13**
C60A					34.4	
C60B	**C60B Total**	**37,950**	25	0.35	36.1	**0.96**
C60C					27.1	
C60D	**C60D Total**	**120,000**	25	1.10	15.1	**7.25**
C60E	**C60E Total**	**6,695**	25	0.06	16	**0.38**
C60F					16.3	
C60G	**C60G Total**	**32,000**	25	0.29	16.4	**1.78**
C60H					4.2	**0.00**
C60J	**C60J Total**	**65,000**	25	0.59	4.3	**13.79**
C25A	**C25A Total**	**10,530**	25	0.10	5.6	**1.72**
C25B	**C25B Total**	**127,200**	25	1.16	9.4	**12.35**
C25C	**C25C Total**	**2,185**	25	0.02	6.6	**0.30**
C25D	**C25D Total**	**35,330**	25	0.32	6.6	**4.88**

QUATERNARY		TOTAL POPULATION	Per Capita need (litres/day)	Per Capita need (MCM/ Annum)	Gross MAR	%MAR
C25E	**C25E Total**	**6,300**	25	0.06	7.2	**0.80**
C25F	**C25F Total**	**41,230**	25	0.38	8.1	**4.64**
C41A	**C41A Total**	**37,000**	25	0.34	60	**0.56**
C41B					55.7	
C41C	**C41C Total**	**12,830**	25	0.12	59.5	**0.20**
C41D	**C41D Total**	**12,246**	25	0.11	48	**0.23**
C41E					13.5	
C41F					19.4	
C41G	**C41G Total**	**36,600**	25	0.33	10.1	**3.31**
C41H					31.8	
C41J					19.3	
C42A	**C42A Total**	**6,800**	25	0.06	29.2	**0.21**
C42B					22.2	
C42C	**C42C Total**	**20,465**	25	0.19	31.7	**0.59**
C42D					16.8	
C42E					20.4	
C42F					24.2	
C42G					16.2	

QUATERNARY		TOTAL POPULATION	Per Capita need (litres/day)	Per Capita need (MCM/ Annum)	Gross MAR	%MAR
C42H	**C42H Total**	**94,200**	25	0.86	12.1	**7.10**
C42J	**C42J Total**	**350,500**	25	3.20	25.7	**12.44**
C42K					15.9	
C42L					11.6	
C43A	**C43A Total**	**34,600**	25	0.32	6	**5.26**
C43B					3.3	
C43C	**C43C Total**	**14,000**	25	0.13	3.2	**3.99**
C43D	**C43D Total**	**900**	25	0.01	4.9	**0.17**

MCM: million cubic metres, MAR: mean annual runoff

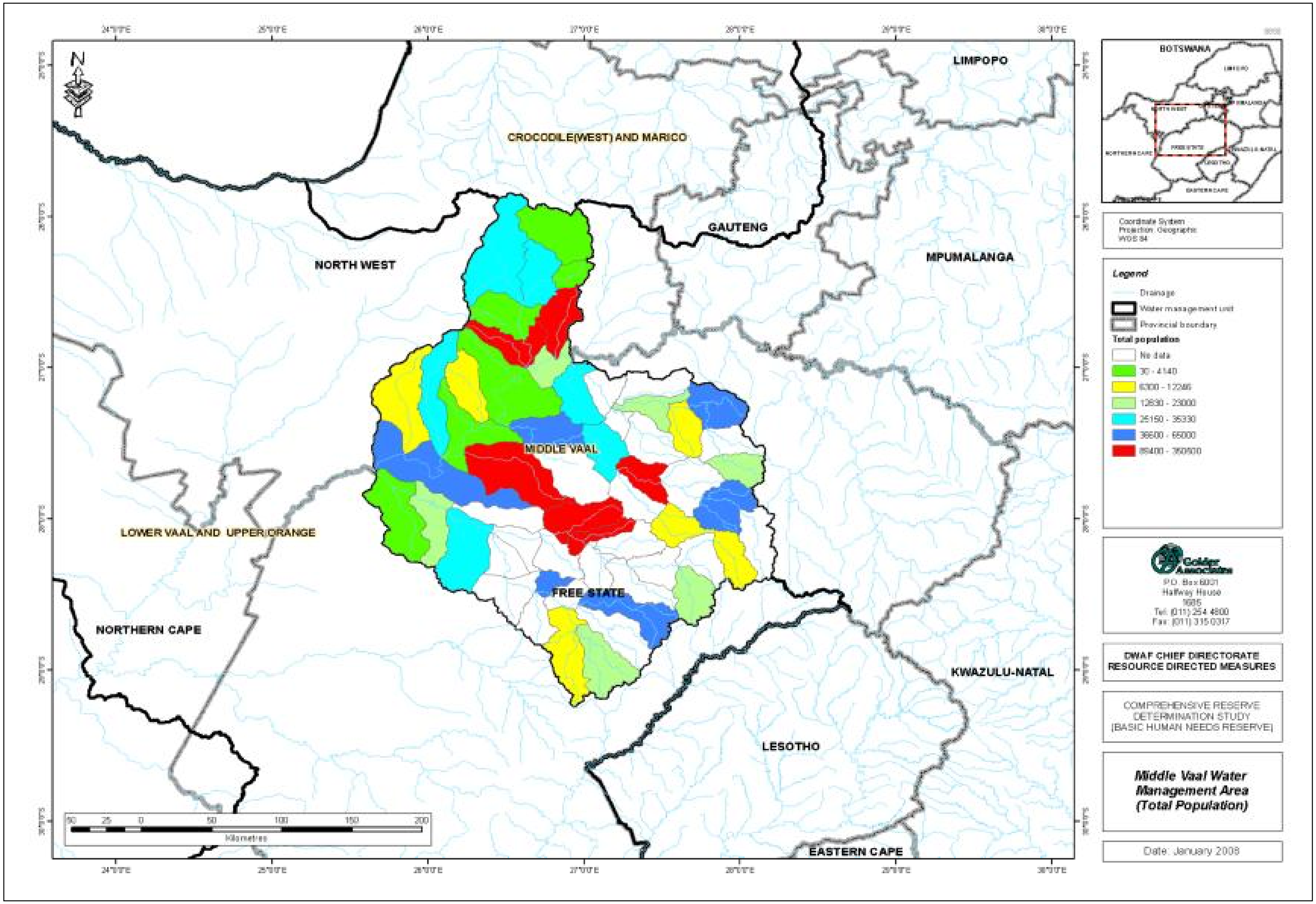


Figure 9: Population distribution within quaternary catchments in the Middle Vaal WMA

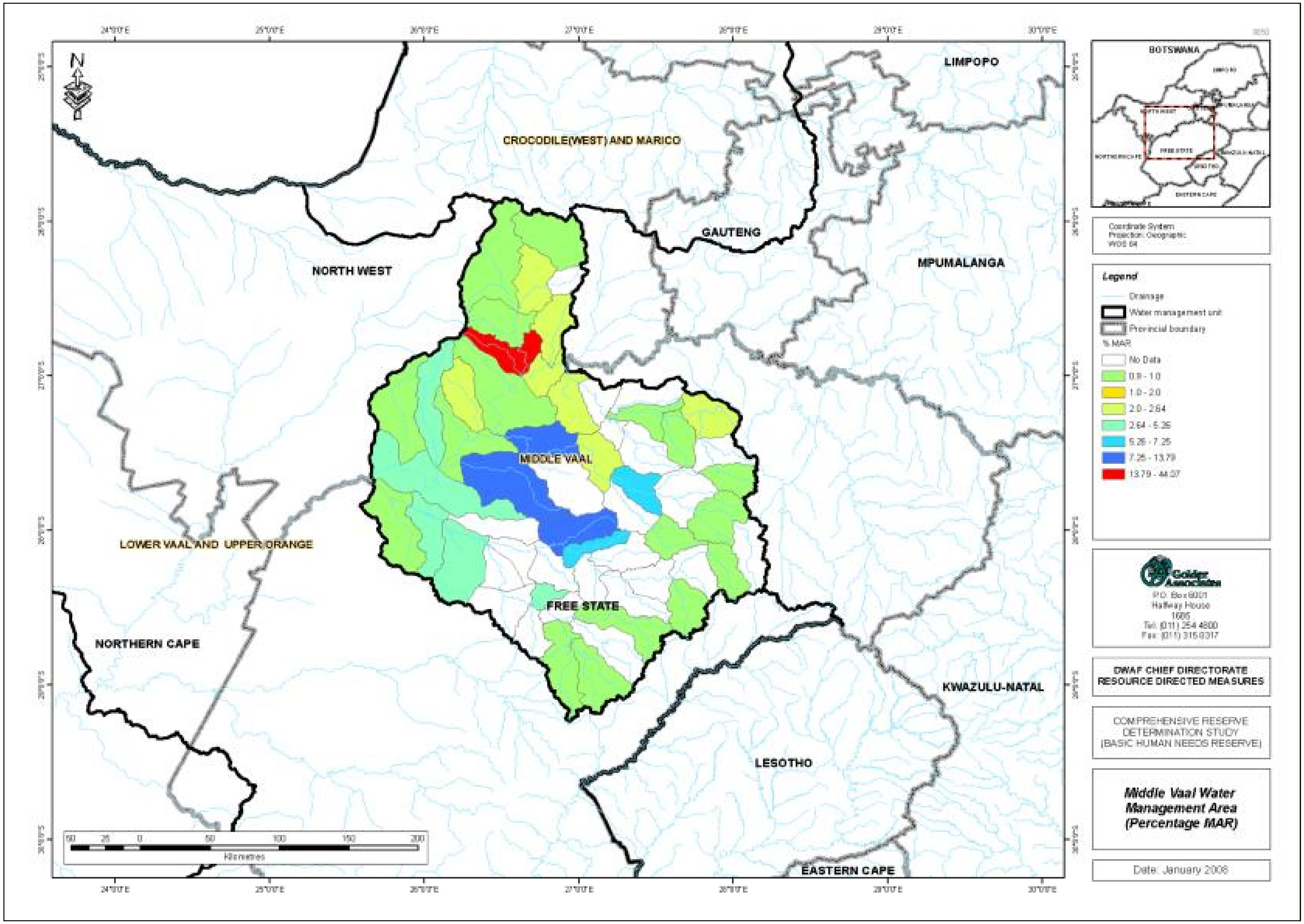


Figure 10: % MAR the BHNR comprises per quaternary catchment in the Middle Vaal WMA

6 PANS/WETLAND SCOPE

6.1 Desktop Methodology

To locate wetlands and pans, data from the National Spatial Biodiversity Assessment (NSBA) and the South African National Biodiversity Institute (SANBI) was used. Data from the National Land Cover 2000 (NLC 2000) was used as a tool to guide wetland and pan identification and on screen delineation.

The DWAF Rivers shape file was then overlaid with the Wetland Probability shape file (NLC2000). All the wetlands that intersect with rivers were removed from the Wetland Probability shape file. To do this a 100m buffer was generated around rivers and all wetlands within this buffer or intersected with the buffer were removed from the Wetland Probability shape file. Thus the wetlands that fell within river channels and their surroundings were excluded. These areas will be addressed by the monitoring points in the river.

Environmental Impact Studies on some of the wetlands provided valuable information, especially those related to dolomitic eyes in the study area. Ramsar status information (Ramsar, 1975) and Important Bird Areas (Barnes, 1998) information was very useful in providing biodiversity data. After GIS buffer analysis the wetland size, biodiversity as well as desktop information was used to prioritize the wetlands to a list of 22 wetlands and pans. The 22 wetlands and pans were described and discussed in a workshop attended by wetland specialists, officials of the Department of Environmental Affairs and Tourism and the Department of Water Affairs and Forestry held during 14 November 2007 in Parys.

Site knowledge was used to add wetlands and pans or remove wetlands and pans from the list until a shortlist of priority wetlands for further study and investigation was produced. This list will be proposed in this document for further investigation.

6.2 Classifying the wetlands

Wetlands and pans are described in terms of their position in the landscape, and the classification was done according to its hydro-geomorphic setting (Kotze, Marneweck, Batchelor, Lindley & Collins, 2004).

Due to the course nature of this research, the lack of substantial data and very little ground truthing opportunity, a detailed classification was not viable. A general description of the wetlands and pans that can be expected in the catchments is based on a rough delineation and assessment exercise. By making use of the scoring system in Wetland-Assess the generic expected goods and services of the wetland types are described and discussed.

6.3 Current status of the wetlands

Since no baseline information on the status of these wetlands and pans is available, a generic attempt in assessing the current status or integrity of the wetlands was done. Basic principles of the Present Ecological Status (PES) were used to give guidance in this regard (WRC, 2008). Further, the procedure for determination of Resource Directed Measures for Wetland Ecosystems (DWAF, 1999) provided the basic criteria followed.

Land use activities in and around the different types of wetlands was used to make assumptions from and to supplement findings.

6.4 Requirements for wetland Reserve determination in the Middle and Lower Vaal River Catchments

The Department of Water Affairs and Forestry (DWAF) is the custodian of all South Africa's water resources, including wetlands. Wetland Reserve (environmental flow determination) studies are increasingly required to be undertaken by or on behalf of DWAF (Wet-priorities).

Wetlands and pans need to be prioritized, especially those that provide essential goods and services (directly or indirectly) to the area. Other aspects that will contribute towards prioritizing of wetland systems for this purpose would be:

- Wetlands with high conservation values;
- Wetlands functional attributes (goods and services);
- Wetlands that are ecologically important;
- Present health and integrity of wetlands (threats); and
- Representative wetlands of the area.

6.5 Results

6.5.1 Wetland Types and distribution

For this report a wetland is an area of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt (Ewart-Smith, Ollis, Day and Malan. 2006).

Palustrine wetlands do occur in the study area and refers to non-tidal wetlands dominated by emergent plants (e.g. reeds), shrubs or trees and includes a variety of systems commonly described as marsh, floodplain, vlei or seep (Ewart-Smith, *et al.* 2006).

A total of 347 699 palustrine wetlands and pans were identified in the Middle and Lower Vaal Catchment areas (Figure 11). All six palustrine wetland types occur in the study area: floodplain, valley bottom with a channel, valley bottom without a channel, hill slope seepage feeding a watercourse, hillslope seepage not feeding a watercourse and depressions that includes pans. This classification is based on their hydro-geomorphic setting (Kotze, *et al,* 2004).

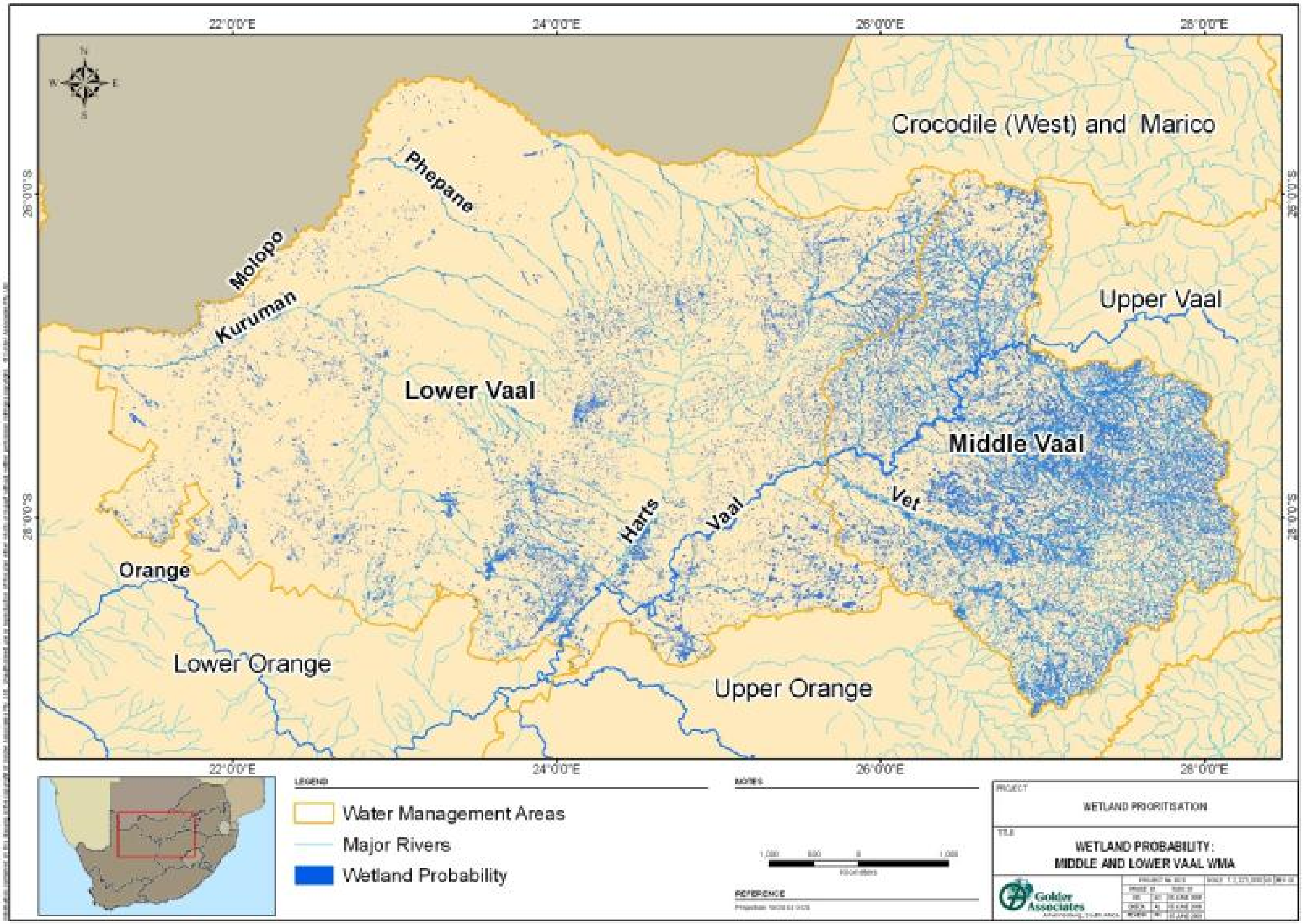


Figure 11: Map indicating wetlands and pans occurring in the Middle and Lower Vaal river catchments

6.5.2 Pans

Pans are fairly widespread in the study area, although they occur in clumps in some areas (Figure 11). Most pans in the study area are inundated ephemerally and irregularly. The most ubiquitous wetlands seem to be endorheic pans. The term endorheic refers to the closed (no outlet) nature of the drainage system of pans. These are characterized by saline deposits on their floors, and many have been mined for salt in the past. Pans in the study area tend to be large, dry, floodplain-like features, elongated along river courses (McCartney, Cairncross, Huizenga & Batchelor, 2007).

6.5.3 Dolomitic Eye Systems

The eye systems occurring in the study area, such as the Kuruman Eye (Figure 12) and the Ventersdorp Eye, can according to the National Wetland Classification System for South Africa, based on the Cowardin system of the United States of America (Cowardin, Carter, Golet & LaRoe, 1979), be classified as Palustrine Persistent Emergent Wetlands. According to the Ramsar Classification System these eyes are non-forested peatlands. This type of wetland is dominated by emergent plant species, which normally remain standing at least until the beginning of the next growing season (Cowardin *et al*. 1979).

Figure 12: The Kuruman Eye dolomitic spring feeding into a reed and water lily dominated wetland downstream

The dominance and abundance of emergent plant species such as *Phragmites australis* support this classification. At a finer level of classification, these wetlands can also be classified as valley-bottom fens. The dominance of reeds may be a recent directional change in the structure and composition of the wetland that may have been caused by increased sediments and/or changes in the available nutrients in the ground or surface water entering these wetlands (Engelbrecht & Linström, 2007).

Some of these wetlands differ to the majority of other Highveld systems because of the abundance and depth of peat, the aridity of the surrounding landscapes and the influence of karst and dolomitic springs in the region, which supply a constant source of groundwater to these systems. Most of the time the large monospecific stands of the common reed *Phragmites australis* and *Carex acutiformis* indicate a mature fen with a very uniform hydrological regime that is not subjected to any extreme hydrological disturbances that would have created a mosaic of different habitats and associated plant species. The abundance and depth of peat demonstrate that these systems have been perennially inundated for many years and have been subjected to a very stable low energy hydrological regime for a long time.

6.6 Likely ecosystem services provided by the Pans and wetlands

6.6.1 Pans and Depressions

By their physical presence and shape, and the vegetation they support, pans may act as sediment traps. Pans can be very productive and it may be because they provide abundant supplies of both nutrients and water in a stable environment.

Pans also provide important habitat for the life cycles of a significant number of species. The pans edge, characterized by emergent plants including sedges, grasses and herbaceous species that is usually <1m tall and the shallow open water (<1.5 m) containing floating or submerged aquatic plants, provides an area of highest biodiversity in an otherwise species poor habitat, dominated by reeds. The above-mentioned area provides a refuge for a variety of species such as fish, small mammals, and birds. This is a benefit of the pan in terms of biodiversity protection.

Pans are also important stopover sites for waterfowl, with over 320 recorded species including Palearctic species, Red Knot *Calidris canutus* and Black Godwit *Limosa limosa* visiting the Barberspan. Species present include all indigenous waterfowl species except the Tropical Dwarf Goose *Nettapus auritus*. Barberspan is the only locality in South Africa where the Pintail *Anas acuta* has been recorded. Some waterfowl species breed in the wetland.

Pans have aesthetic significance as a landscape component. While these pans are an aesthetically pleasing landscape feature in the area, they do not appear to be perceived as having any particular value by the overall community. Biodiversity in the form of water birds does attract birdwatchers. This may become important to planners and entrepreneurs to attract tourists. A camping and picnic site, a trail and bird hides have been established on and around some pans. Pans are popular angling sites and recreational areas in the study area.

6.6.2 Dolomitic eye systems

Wetland benefits are those functions, products, attributes and services provided by the ecosystem that have a value to humans in terms of worth, merit, quality and importance. These benefits may be derived from outputs that can be consumed directly, indirect uses that arise from the attributes or functions occurring within the ecosystem, or possible future direct outputs or indirect uses.

6.6.3 Wetland Benefits

These wetlands, in this case the dolomitic eye systems; contribute towards the bigger ecosystem services by means of the following wetland functions:

- Water supply
- Flow regulation
- Erosion control
- Sediment and nutrient removal and/or retention
- Maintenance of Biodiversity Significant For Conservation
- Socio-cultural significance
- Carbon Sink
- Good representative example of a specific class of wetland

The Wet-EcoServices (Kotze et al, 2006) assessment tool was used to indicate the most likely ecosystem services of a dolomitic eye system (Figure 13). Dolomitic eye wetlands (this includes the eye and the peat/reed valley bottom area downstream) contribute in particular towards ecosystem services such as streamflow regulation, nitrate removal, erosion control, carbon storage, and the maintenance of biodiversity.

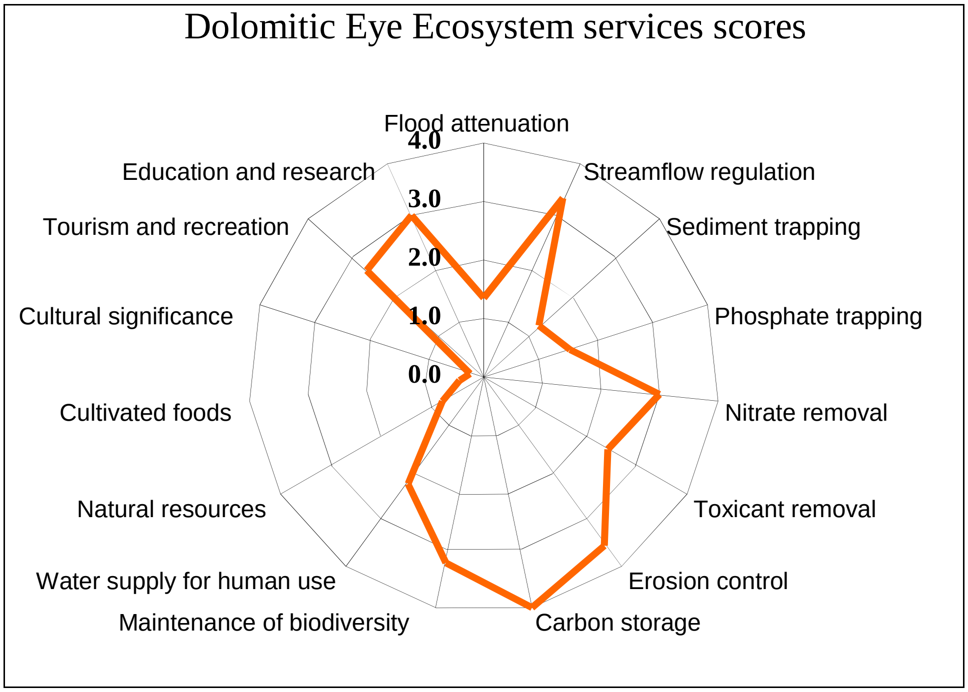


Figure 13: Wetland ecosystem services scores most likely performed by dolomitic eyes in the Middle and Lower Vaal River Catchments

6.7 Threats to the Pans and wetlands

Several anthropogenic threats to Pan Ecosystems and their associated biota have been identified and in some cases quantified.

6.7.1 Agricultural developments

A major threat to endorheic pans comes from agricultural development. Many pans in crop farming regions are surrounded by fields that often encroach onto the periphery of these wetlands and even impinge into the actual basins of smaller, well vegetated pans. Such pans are subjected to contamination and eutrophication by pesticides and fertilizers. The endorheic nature of pans exacerbates this problem and toxic substances concentrate in their basins. Poisons in particular pose a serious threat to wildlife. Ploughing, overgrazing and excessive trampling b livestock damages the shore vegetation, increase wind erosion and leads to the siltation of pan basins. Many pans are dammed or excavated to provide a water supply for livestock. The construction of fence lines across pan basins to control livestock movements is ubiquitous and these structures are a danger to flying water birds that frequently collide with or are becoming entangled in them.

6.7.2 Water pollution

The release of untreated sewage into aquatic systems has got detrimental effects on biota downstream thereof and especially in pans because of its endorheic nature. This is a major problem since raw sewage is being dumped into river systems in the study area. Barberspan especially is at risk because the Harts River is diverted to flow into the pan. This can result in the pan to become a sewage settling pond.

6.7.3 Urbanization

Factors associated with urbanization, such as recreational and residential developments, are encroaching rapidly on my pans. Such developments directly disturb wildlife and lead to excessive littering. In urban areas, pans provide convenient sites for municipal dumps. Rubble is frequently dumped in pan basins to provide a foundation for constructions. Farm dumps in pan located in rural areas, however, are usually insignificant. In many rural areas homesteads are frequently built close to pans and this increases littering and disturbance to wildlife.

6.7.4 Road-building operations

Another major threat, particularly in the central Highveld, is road construction. Pan are frequently seen as ‘lines of least resistance’ by road planners.

6.8 Reference conditions of the wetlands

6.8.1 Dolomitic springs with associated wetland habitat downstream

These wetlands most likely developed under very constant flow conditions provided by dolomitic springs in and around the wetland. Rainfall events in the catchments of these wetlands contribute little to the available water in the systems. Flood conditions in these systems are also an unlikely event, except maybe during extreme rainfall events (Engelbrecht & Linstrom, 2007).

Unregulated wetland fires occur and layers of ash occur in the upper portions of the peat indicating recent desiccation. Fences and grazing have a minor impact on these wetlands. Adjacent agricultural activities and roads in and around the wetland have increased the presence of invasive exotic plant species. Some invasive species do occur in some of these peat wetlands, especially in the disturbed areas on the perimeter.

Although most of these wetlands are still in a very good condition, these wetlands are presently dominated by an almost monotypic stand of reeds. Available information suggests that this may be the result of recent directional change from a more diverse wetland with a mosaic of vegetation patches to an almost uniform reed dominated wetland.

Because of stable hydrological conditions and a history of anthropogenic disturbance in and adjacent to these wetlands, directional changes from floristically more diverse systems towards an almost monotypic reed dominated system may have occurred. However, several habitat types and vegetation communities still occur in these systems, such as:

- Active channels with some floating leafed, short emergent vegetation and small pockets of open water. The common reed (*Phragmites australis*) can dominate the vegetation in this habitat and it can contain patches of species such as *Typha capensis, Juncus effusus* and *Juncus punctorius.* The alien invasive watercress *(Rorippa nasturtium-aqauticum)* can also occur in this habitat type.

- The permanently wet habitat type consists mainly of tall emergent species dominated by the common reed *Phragmites australis.* This habitat type is mostly underlain with clayey course.

- A narrow but ecologically extremely important transitional grass-sedge dominated transitional zone occurs between wetland and terrestrial habitats.

- A grass-sedge wetland area occurs containing a mixture of wetland grass, sedges and other facultative hydrophytic species. The buttercup *Ranunculus multifidus* and *Ranunculus meyeri* can be common in this habitat type.

- Seepage areas can occur along the margin of these wetlands with the presence of both seasonally and temporary wet zones. Within these, semi-circular monospecific stands of Cottonwool grass *Imperata cylindrica* can be common.

- Natural open water habitat largely associated with dolomitic springs in the wetland. A characteristic deposit of white sulphur reducing bacteria normally occur in the substrate of the eyes.

- Typical riparian species associated with rocky habitat occurs around the eyes.

- Terrestrial habitat occurs adjacent to the wetland area.

6.8.2 Pans

Pans and depressions are of ecological importance as part of the broader landscape of arid regions and of further ecological interest within the pans themselves for their own biota, specifically during the periods that they hold water, and because of the briefness of those periods and the limited availability of water. Hydrological variability is a predominant feature affecting the ecology of pans. The physical and chemical properties of the substrata and water of pans therefore varies seasonally and regionally.

Furthermore, within each inundation considerable changes in the physical and chemical properties of the pans also take place (Allan, Seaman & Kaletja, 1996).

6.9 Present ecological state and ecological importance and sensitivity of the pans and wetlands

Pans have received little attention and this applies in particular to pans associated with the study area. As a result little research or conservation effort has been focused on these ecosystems and there has been an underestimation of their conservation value, despite their unique nature. Their importance, which extends far beyond their value as wildlife refuges, and the vulnerability of these ecosystems motivate strongly for the detailed study and protection of these resources.

Groundwater dependent ecosystems, like dolomitic eyes, are facing increasing pressure from consumptive uses for agriculture, mining, urban and commercial developments. Collectively, anthropogenic changes in the groundwater regime pose a significant, but largely unknown threat to groundwater dependent ecosystems.

6.10 Priority wetland and pans that require reserve assessments

Wetlands identified were classified and listed according to size, IBA status, Ramsar criteria consideration, uniqueness in the study area and threats. The wetland polygons in the study area were sorted by size and the largest were investigated and assessed on Google Earth (Google, 2007). Aspects that can possible influence the wetland functionality and integrity was identified. A cross reference was then made between the larger wetlands found on GIS with those received via correspondence from specialists. From the above process a list of ~21 wetlands was generated. The identified wetlands were presented at a workshop with the specialist whereby the proposed list of 21 wetlands was discussed and adapted to 9 wetlands according the specialists' experience in the field (Table 9 and Figure 9).

Table 9: Priority Wetlands and Pans identified in the Middle Vaal River Catchments

Catchment Area	Priority Wetlands	Reasons	Location (GPS)
Middle Vaal	Witpan	Flamingo roosting	Lat -27.83849 Lon 26.44054
	Annaspan	Flamingo roosting	Lat -28.53552 Lon 25.79727
	Schoonspruit/Ventersdorp	Dolomitic Eye & peatland.	Lat -26.30686 Lon 26.83603

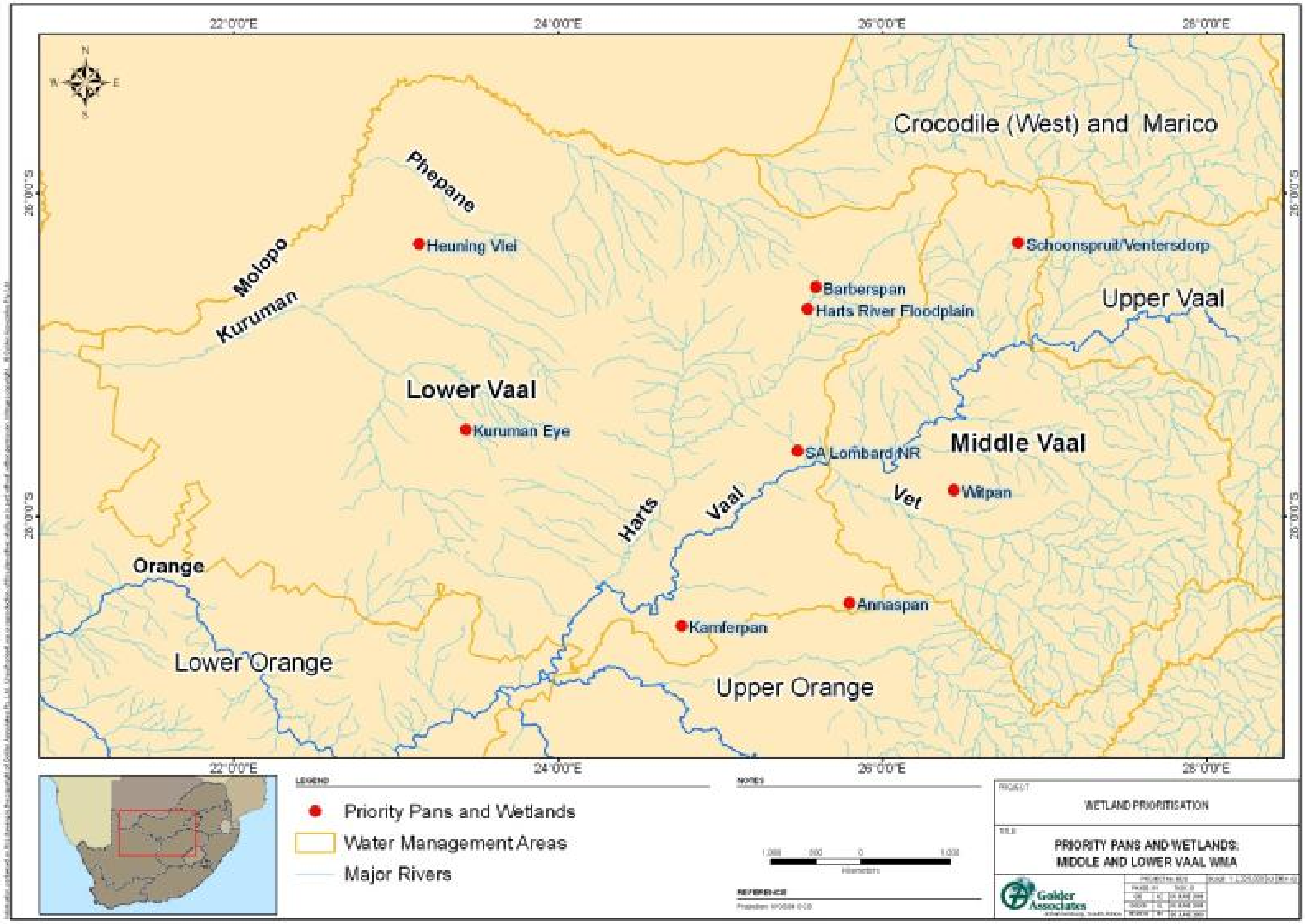


Figure 14: Priority Pans and Wetlands in the study area

6.11 Conservation and management recommendations

Much remains to be done concerning the conservation of pans and wetlands. The entire network of pans requires conservation, so that there is always some suitable habitat available to act as refuge for the species adapted to these ecosystems somewhere within their ranges. Management strategies aimed at land in private ownership, is as important as land acquisition for formal nature reserves. However, some of the larger, and perhaps a suite of representative, pans should be given formal conservation protection if for no other reasons than for their tourism and education potential. Consideration should be given to including many of the more important pans in the formal nature reserve system, including municipal reserves. It is important that pans set aside as reserves in the latter areas are managed as nature areas and not as city parks with their attendant planting of alien trees and lawns, uncontrolled disturbance.

Legislation and its effective enforcement should be considered to halt the wanton environmental degradation of pans and other wetlands in the study area. The education of landowners and other parties who impact on these systems, as to full value of wetland habitats has been sorely neglected. For example, trampling by livestock transforms well-vegetated pan shorelines to open mud. Vegetated shorelines provide important feeding and/or breeding site for many birds, and probably other organisms. Landowners could be persuaded to permanently fence off large areas of shoreline so as to promote diversity of habitats and, for example, bird species. This would be especially valuable n creating breeding habitat for ducks.

Systematic and representative monitoring projects need to be established to maintain a constant watch over the environmental health of pans. Such monitoring needs to be pro-active and identify threats from developments while these are still in the early planning stages.

A particularly topical issue at present is the problem of aerial spraying of problem seedeater flocks with avicedes. Large flock of these species frequently roost in pan reed beds, and the potential exists for a major ecological disaster to non-target species should any of these sites be sprayed. Such operations should be banned at pans and indeed at any wetland sites.

Basic management actions should be taken to project pans and wetlands in the study area, such as:

- Correct burning regimes of pan shores should be implemented to promote its vitality. This will remove moribund and/or unacceptable grass material; and to eradicate and/or prevent the encroachment of undesirable plants.

- Many wetlands have been degraded by invasive exotic vegetation. Given the high hydrological/functional importance of these pans and wetlands, an urgent rehabilitation programme should be investigated in cooperation with Working for Wetlands.

- Buffer zones between pans/wetlands and roads, agricultural activities, developments, mining activities, etc. This will protect the water resources and promote the integrity of these systems.

- Investigate the laying out of roads in and around pans/wetlands. If possible, roads should be closed and rehabilitated in pan/wetland areas.

6.12 Way forward

Very little information with regards to wetlands in the Middle Vaal River catchments exists. Be it a wetland inventory or baseline data or general information. Further studies with regards to completing a wetland inventory are necessary and should include the verification of the existence of wetlands in some areas and to at least indicate the priority wetlands. Thus infield verification will be necessary.

Infield verification should also include Ecological Integrity and Sensitivity (EIS) Category assessments and Wetland Habitat Integrity (PES) assessment where applicable; this information will add value to future Ecological Reserve assessments.

Candidate wetland sites (Table 9) for determining an Ecological Reserve should occur in an area where impacts on the aquifer are high and the aquifer is vulnerable to drought (Marneweck, 2006). Impacts can be in the form of draining channels, water abstraction, mining activities, wrong burning regimes, etc. The level of determining the Reserve is still to be determined. However, given the groundwater component of the dolomitic eye systems, some of the valley bottom systems, endorheic pan, etc. would require further refinement of existing Reserve determination methods.

7 HYDROLOGY

7.1 Introduction

The location of the EWR sites (EWR12 to EWR 15), the quaternary catchment boundaries, rivers and major urban areas of Gauteng are shown in Figure 15. Sites EWR12 and EWR13 are on the Vaal River, site EWR 14 on the Vals River, site EWR15 on Vet River.

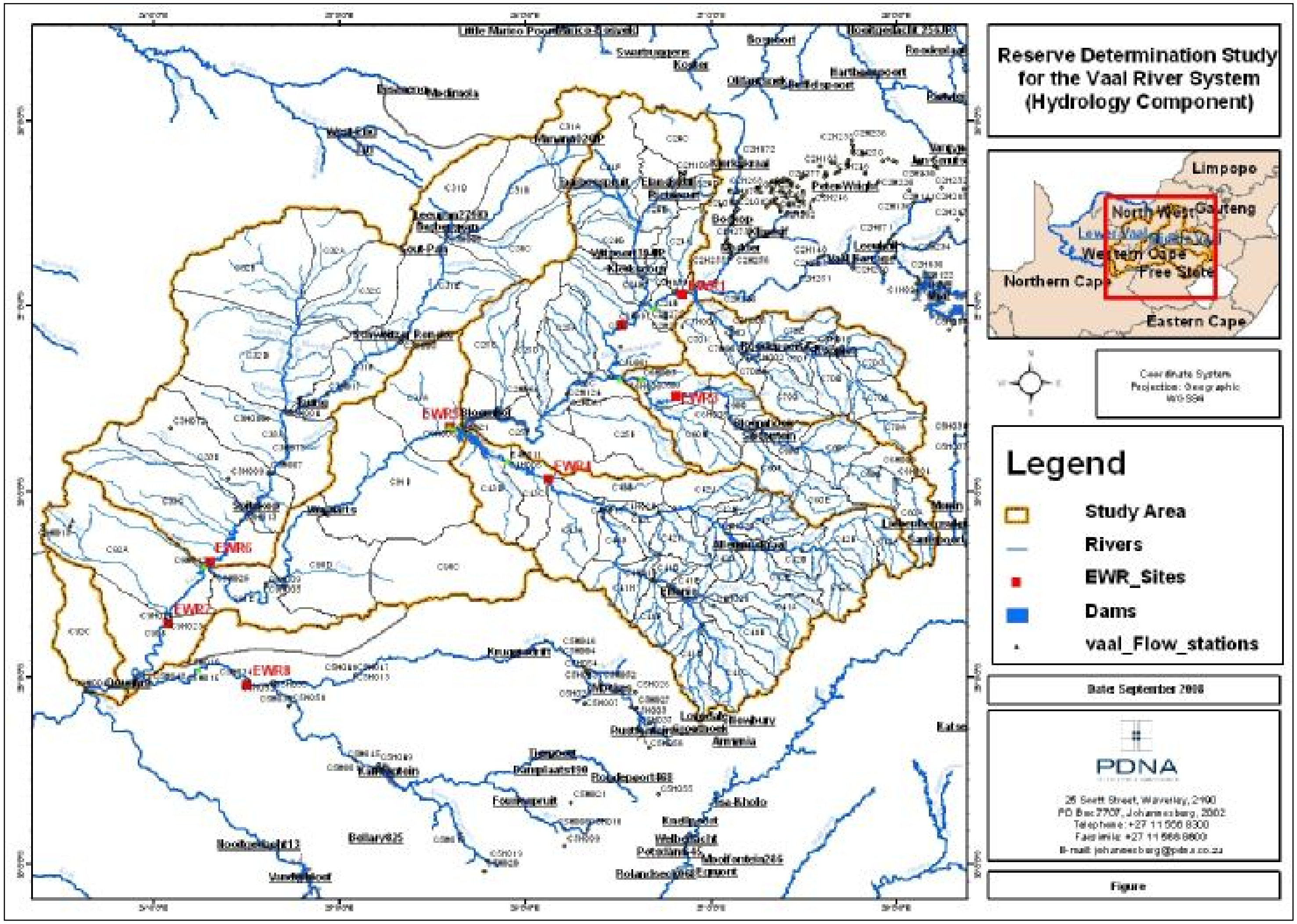


Figure 15: EWR sites and quaternary catchments

7.2 Approach

During the data collection phase of the project, any existing hydrology for the catchment was collected, with particular emphasis on hydrological data that has been used in previous yield modelling on the catchment.

The data was evaluated by the PSP and recommendations made to the client should any further hydrology be required to be developed for the project.

Both simulated naturalised and present day hydrological data was presented at the level of monthly flows. Daily flow conditions will be represented by observed data where recorded. Observed daily flow data (using DWAF rating curves) from selected flow gauging stations will be used where available. Where necessary simulated 'naturalised" daily flow data, using observed daily flow records from reliable gauging stations will be used.

Disaggregation of the catchment at the proposed EWR sites was carried out and hydrological modelling for the various EWR sites and the catchment as a whole will be performed using the models specified in the DWAF "Guidelines for Decision Support Models for Water Use Evaluation". If an adequate amount of reliable daily streamflow data is available, a daily rainfall-runoff model will be calibrated and used. If unavailable, then monthly modelling will be applied.

The spatial and time-series distribution of flows was studied and will take into account flow volumes, timing, flow patterns, flow levels, seasonal and inter-annual flow variability together with flood and drought cycles. Current flow regimes as well as naturalised flows, to represent the virgin hydrology of the catchment, will be studied. The hydrologist will prepare monthly base flows as well as the frequency and size of "freshes", average annual floods, drought and other high flow events, together with their frequency, in as much detail as possible, to represent what has been naturally experienced in the flow reach.

During the specialist workshops the hydrologist presented the time series of flow regimes to assist the other specialists in making decisions about the ecological water requirements and ensuring that they do not set flows that are unrealistic from the point of view of what would be expected to occur in the river under natural conditions.

The outcome of the specialist workshops was the required flows for various scenarios and will include:

- Maintenance low flows expressed in m^3 s-1
- Maintenance high flow events defined as peak flows in m^3 s-1 and durations in days
- Drought low flows expressed in m^3 s-1
- Drought high flow events defined as peak flows in m^3 s-1 and durations in days
- Flood events defined as peak flows in m^3 s-1 and durations in days

The monthly hydrology from the systems model (was supplied by WRP.) for each EWR site (present and naturalised flows) will be used and will be set up in SPATSIM. No additional systems modelling will be undertaken by this study.

This information was relayed to the water resources analysts (systems modellers), who will determine what the impacts that these requirements have on the yield of the catchment.

The Scenario Planning phase was designed to resolve any disparities between the EWR and the required yield and could involve reassessment of the workshop results, redefinition of the EWR assurance rules, a change in management class or considerations and proposals relating to the water supply schemes in the catchment.

Data to be provided:

- cumulative variance of total runoff MAR for each site
- seasonal distribution of simulated monthly naturalised and present day flows at each EWR Site
- whisker-box plots of "virgin" daily averages at each EWR Site
- monthly flow duration curves for “virgin" daily averages at each EWR Site
- flood frequency curves based on annual maxima for each EWR Site
- simulated naturalised monthly flows at selected gauging stations
- simulated present day flows at selected gauging stations

From the above, for the selected critical periods and in conjunction with the specialists requirements, flow-duration curves, exceedance diagrams and flow-stress data will be generated at each of the sites.

7.3 Results

The highest and lowest low flow months selected as the key months are February (wet) and August (dry). The key assurance percentages selected for which stress requirements had to be set were for:

- 95%: Representing droughts for both wet and dry months. This would represent 5% on the stress duration graphs.
- 45%: Representing maintenance flows for both wet and dry months. This would represent 55% on the stress duration graphs.
- Any additional points which had specific significance in terms of flow or stress requirements.

The level of confidence in the hydrology data varied and in many cases the present day data and observed data was used in case of each other.

7.3.1 HAI for EWR12 – Vermaasdrift on Vaal River

Table 10 provides the best estimates of HAI based on these data. The confidence rating is based on the interpretation of the simulated flows and not on the confidence in the simulations. The seasonality rating has been set at 0, as there is not shift in the monthly flows, as shown in Figure 3, even though the observed data seems to suggest at shift of the peak month from February to March. This is because the length of the observed as shown in Figure 16, which inevitable skews the distribution. There is a DWAF gauging station downstream of this site (C2H007, area of 63437 km^2 and data for 1938 to 2008).

Table 10: HAI details for site EWR12

HYDROLOGY DRIVER ASSESSMENT INDEX		
HYDROLOGY METRICS	**RATING**	**CONFIDENCE**
LOW FLOWS	1.00	4.00
ZERO FLOW DURATION	0.00	3.00
SEASONALITY	0.00	4.00
MODERATE EVENTS	4.00	3.00
EVENT HYDROLOGY(HIGH FLOWS-FLOODS)	4.00	3.00

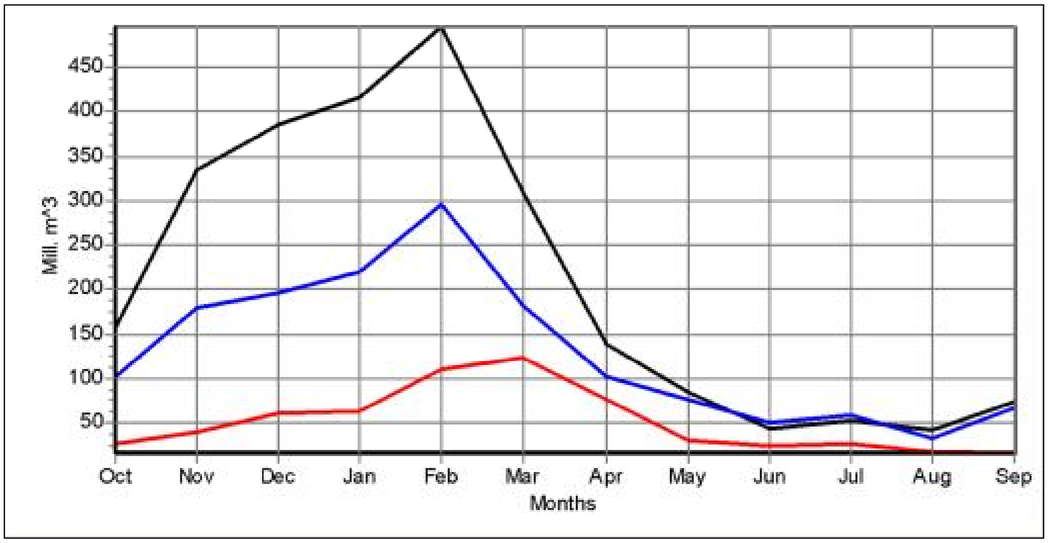


Figure 16: Seasonal distributions (data 1920 to 1994 for Natural and Present Day, 1938 to 2008 for Observed) for site EWR1 (Black = Natural, Blue = Present Day, Red = Observed).

7.3.2 HAI for EWR13 – Regina Bridge on Vaal River

Moderate to high flows are impacted at this site. There is a DWAF gauging stations at C2H061 (79903 km^2 and data from 1972 to 2007). In terms flows the observed record and the simulated present day flows are reasonably consistent. Table 11 provides the best estimates of HAI based on these data. There is no indication of seasonality shift, which is also confirmed by the observed flows, which in this case there was a reasonable long record as shown in Figure 17.

Table 11: HAI details for Site EWR13

HYDROLOGY DRIVER ASSESSMENT INDEX		
HYDROLOGY METRICS	**RATING**	**CONFIDENCE**
LOW FLOWS	1.00	4.00
ZERO FLOW DURATION	1.00	3.00
SEASONALITY	0.00	4.00
MODERATE EVENTS	4.00	3.00
EVENT HYDROLOGY(HIGH FLOWS-FLOODS)	4.00	3.00

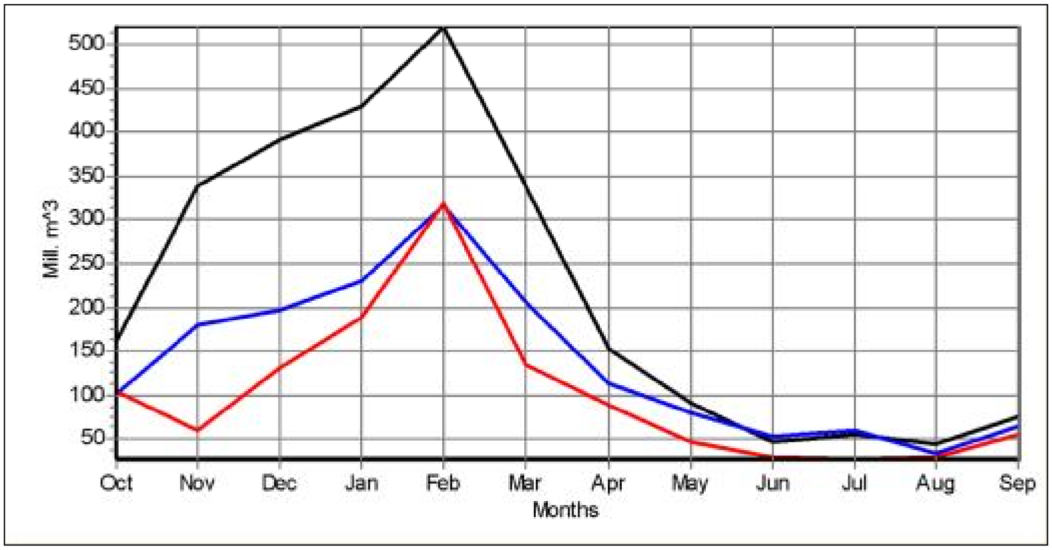


Figure 17: Seasonal distributions (data 1920 to 1994 for Natural and Present Day, 1972 to 2007 for Observed) for site EWR2 (Black = Natural, Blue = Present Day, Red = Observed).

7.3.3 HAI for EWR14 – Proklameerdrift on Vals River

Figure 18 illustrates that the full range of flows are impacted at this site, but not as severely as at the previous sites. There is a DWAF gauge (C6H003, area of 7765 km^2, with data for 1967 to 2005) just downstream of this site. The observed data are consistent with the simulated present day flows. Table 12 provides the estimates of HAI based on the simulated data..

Table 12: HAI details for Site EWR14

HYDROLOGY DRIVER ASSESSMENT INDEX		
HYDROLOGY METRICS	**RATING**	**CONFIDENCE**
LOW FLOWS	5.00	4.00
ZERO FLOW DURATION	0.00	3.00
SEASONALITY	0.00	4.00
MODERATE EVENTS	4.00	3.00
EVENT HYDROLOGY(HIGH FLOWS-FLOODS)	2.00	3.00

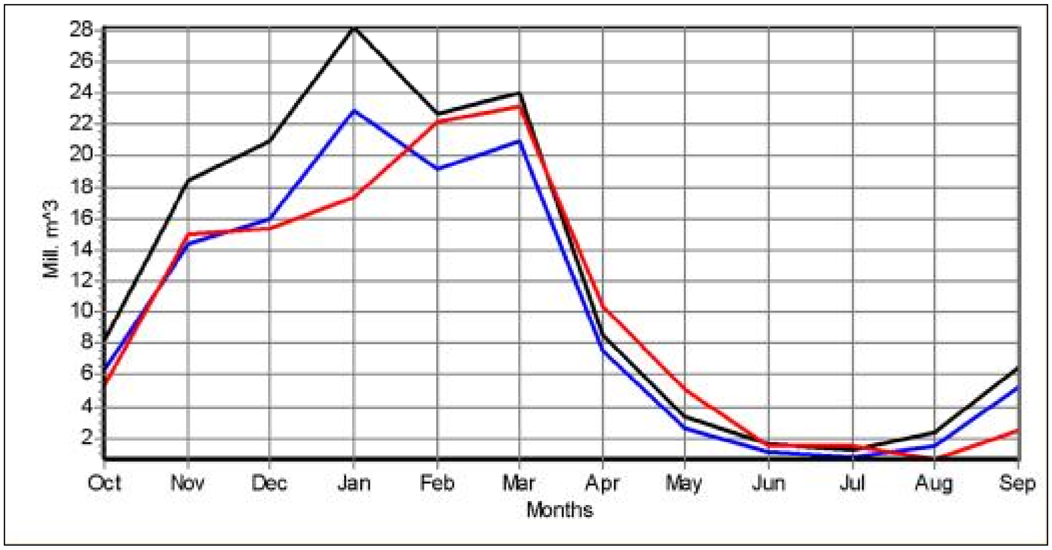


Figure 18: Seasonal distributions (data 1920 to 1994 for Natural and Present Day, 1967 to 2005 for Observed) for site EWR3 (Black = Natural, Blue = Present Day, Red = Observed).

7.3.4 HAI for EWR15 – Fisantkraal on Vet River

This site is located close to the gauging weir (C4H002 – 17 599 km^2 – data for 1935 to 1972). The estimates of HAI based on the simulated data are provided in Table 13. The greater part of the impact at this site is on the moderate to high flows as observed in Figure 19. The seasonality at this site also has a rating of zero when the natural and present day flows are compared. However the observed shows a peak in February compared to a peak in March for the natural and present day flows.

Table 13: HAI details for Site EWR15

HYDROLOGY DRIVER ASSESSMENT INDEX		
HYDROLOGY METRICS	**RATING**	**CONFIDENCE**
LOW FLOWS	3.00	4.00
ZERO FLOW DURATION	0.00	3.00
SEASONALITY	0.00	4.00
MODERATE EVENTS	5.00	3.00
EVENT HYDROLOGY(HIGH FLOWS-FLOODS)	4.00	3.00

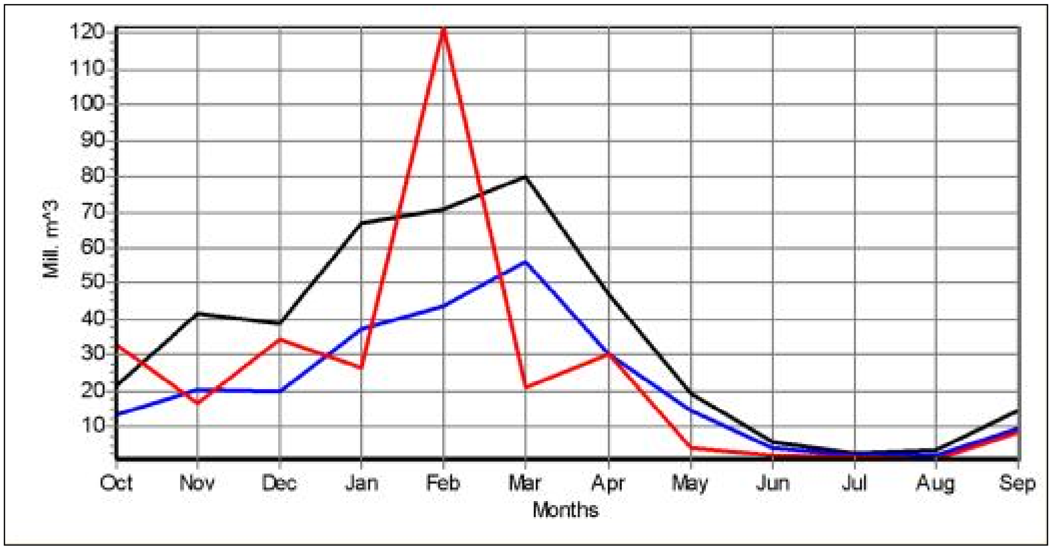


Figure 19: Seasonal distributions (data 1920 to 1994 for Natural and Present Day, 1935 to 1972 for Observed) for site EWR4 (Black = Natural, Blue = Present Day, Red = Observed).

7.3.5 Natural and Present Day flow summary of the EWR sites

The natural MARs as provided by PDNA (Volume 2) are given in Figure 14. The final flow requirements are expressed as a percentage of the natural MAR in Figure 15.

Table 14: Natural and PD MARs of the EWR sites

Site	Virgin MAR	Present MAR
EWR 12	2546.392	1574.637
EWR 13	2654.289	1638.37
EWR 14	145.794	118.04
EWR 15	413.036	253.15
Rapid EWR	49.564	

A summary of the MAR at the Lower Vaal EWR sites is shown in Figure 37.

8 GEOMORPHOLOGY

8.1 Introduction

The availability of hydrological data enabled potential bed material transport (PBMT) modelling to be undertaken at the EWR (Environmental Water Requirement) sites. This modelling usually greatly improves the confidence of flow requirements for geomorphology in bedload dominated rivers, as the results can be used in conjunction with the more traditional methods of using sedimentary and morphological cues to determine EWR requirements for bed and channel maintenance.

8.2 Approach

Flow requirements for the maintenance of channel form, or geomorphology, can generally be determined using one, or a combination, of two possible approaches. The first relies on specialist knowledge and experience to identify alluvial morphological cues at the site and within the reach which are associated with regular flooding return frequencies (such as active, seasonal and ephemeral paired benches and terraces). The second approach uses the catchment hydrology and site-specific hydraulic characteristics to model the long term potential sediment movement within the river to identify so-called geomorphologically effective discharges. These are ranges of flows which are responsible for a disproportionately large amount of the long term sediment transport (geomorphic work) which is happening at the site.

8.2.1 Morphological Cues

The rivers in this study area are very low energy systems. Low shear stresses; even at high flood flows; mean that under natural conditions the ability of the river to flush sediments and scour the bed is very limited. The system is however relatively sediment poor (hence the bedrock bases and lack of mobile larger sediment components), and yields of bedload from the catchment are dampened by the low slopes. These low energy characteristics explain why, even with the highly altered flow regime and grossly elevated baseflows, the islands in these lower reaches have remained relatively stable. This is due to the limited capacity of the river to erode.

The limited availability of bedload; reduction in flood flows; trapping of sediment in the numerous dams and weirs along the main stem and tributaries and high degree of physical anthropogenic bank disturbance (particularly at our EWR sites which have been usually selected at or very close to bridge crossings) means that morphological cues (benches and terraces correlated with significant flood return intervals) are consequently poorly developed or absent.

8.2.2 Sediment Transport Modelling

The form (morphology) of a river channel is dependent on the interaction between the supply of sediment from its catchment, and the ability, or capacity, of that section of the river to transport the sediment it is supplied with. The ability of the river to move sediment is referred to as its sediment transport capacity. Sediment supply and sediment transport capacity interact such that:

- where sediment supply is less than the sediment transport capacity, there is an excess of erosive energy, resulting in net erosion, causing the river channel to erode its bed/banks and incise; but

- where sediment supply is greater than sediment transport capacity, there is an excess of sediment, resulting in net deposition and the development of an aggrading river/floodplain environment.

The interactions described above are generally considered over very long timescales. The Elefantes and Limpopo Rivers in Mozambique are primarily alluvial river systems, meaning that, in the very long term (hundreds to thousands of years), sediment supply is greater than the transport capacity of the river channel.

Over shorter timescales, which are of more interest to river managers (years and decades in southern Africa), studies in southern African rivers have demonstrated that rivers experience periods of metastability or quasi-stability interrupted by periods of rapid change (Rountree *et al*, 2001; Rountree and Rogers, 2004; Parsons *et al*, 2006). During these timescales, it is the discharge of water and sediment supply that determines channel form. Where changes in these driving factors occur, the channel form will adjust in sympathy with the imposed change. This is of significance as the channel form provides the physical habitat for riverine biota.

Where key sediments are required to be moved or flushed, entrainment velocities required to achieve movement of the key sediments can be derived from the hydraulic data.

8.2.3 Geomorphologically Effective Flows

Geomorphologically effective flows are those discharges that, over the longer term, are responsible for transporting disproportionately larger proportions of the sediment load (relative to their duration). These are essentially the flows that do the most "work" in determining the sediment transport capacity of the channel, and therefore influencing its form.

The calculation of these flows is essentially the sediment transport potential of a particular flow event, multiplied by its duration, which yields its potential contribution to the sediment transport of the system in the long term. The theoretical position taken in these methods is that two sets of discharges are significant in maintaining channel form in southern African rivers:

- a set of gemorphologically effective discharges in the 5-0.1% range on the 1-day daily flow duration curve, which transport a disproportionately large volume of the sediment in the longer term, and

- larger 're-set' flood events such as the flood events of 2000, which can reshape the channel and remove vegetation from the banks and floodplain.

The theoretical basis for these assumptions is presented in Dollar & Rowntree (2003). These methodologies have been used in various ecological flow determination studies in South Africa (e.g. on the Thukela, Elands, Letaba, Waterval and Inkomati Rivers) and Mozambique (e.g. the lower Zambezi River). Whilst it is possible to manage flows in the 5 to 0.1% range of the flow duration curve, the large "re-set" events are not manageable events. The focus of flow requirement assessments is therefore focussed on the 5 to 0.1% range of flows.

The methods employed to determine geomorphologically effective flows for each of the sites are described below.

The observed daily flows from nearby gauges, together with the regional slope (Table 1), rating curves (provided by the hydraulician) and sediment characteristics for the site or reach were used to model potential bed material transport at each site under the recent (over the observed flow record) flow conditions, using Yang's (Yang, 1973) total load equations to determine the effectiveness of discharges. This modelling technique assumes:

- The bed material sampled at the site is representative of the supply of bed material to the channel (hence potential bed material load as opposed to bed load);
- Bed material sampling can be averaged at each EWR site and used to represent the cross-section;
- The supply of bed material to each EWR site is based on the existing bed material and its size distribution, and is available for transport at all discharges; and that
- Average conditions can be used.

A full, detailed description of the technique can be found in Dollar & Rowntree (2003).

Although the Vaal is not strongly bedload system, maintenance of the bed habitats is important for biota. In this study we focussed on the mobile component of the bed material at each site (since many sites are located on atypical bedrock riffle areas, and most of the large boulders and cobbles are likely to be *in situ* weathered material rather than fluvially transported sediment, as evidenced by the angular nature of these larger rocks). This approach was adopted for sites where reliable hydrological (flow) records existed.

8.3 Results

8.3.1 Flood motivations for EWR 12

FLOODS		**GEOMORPHOLOGICAL MOTIVATIONS**	**FREQUENCY**		
Class	**Size (daily avg)**		**PES**	**REC**	**AEC**
II	50	This flow class is responsible for transporting about 15% of the fine bed material. These flows will clean the gravels and cobbles at the site and inundate the lower bench.	3	4	
III	100	This flow class is responsible for transporting about 15% of the fine bed material. These flows will scour the gravels and cobbles.	1	2	
	340	This flow class represents the effective discharge for the site. It is responsible for the bulk (more than 25%) of the sediment transport. These	1:2	1:1	

IV		flows will scour and activate the gravels and cobbles.			
Confidence:		**Comments**			
2		Flows for geomorphology are set using the results from Potential Bed Material Transport (PBMT) modelling only. High flow hydraulics are reliable for the site, and a long gauge record of observed flows was used to undertake the modelling. No morphological cues exist at the site to verify the effective flow classes identified through the PBMT modelling			

8.3.2 Flood motivations for EWR 13

FLOODS		**GEOMORPHOLOGICAL MOTIVATIONS**	**FREQUENCY**		
Class	**Size (daily avg)**		**PES**	**REC**	**AEC**
IV	520 (daily avg)	This flow class represents the effective discharge for the site. It is responsible for the bulk (about 50%) of the sediment transport. These flows will scour the bed and clean out gravel and cobble areas.	1:3		
V	1500	This flow class is responsible for about 40% of the PBMT. Although extremely infrequent, these very large flood events are important for scouring the reach.	1:10		
Confidence:		**Comments**			
2		Flows for geomorphology are set using the results from Potential Bed Material Transport (PBMT) modelling only. High flow hydraulics are reliable for the site, and a long gauge record of observed flows was used to undertake the modelling. No morphological cues exist at the site to verify the effective flow classes identified through the PBMT modelling			

8.3.3 Flood motivations for EWR 14

FLOODS		GEOMORPHOLOGICAL MOTIVATIONS	FREQUENCY		
Class	Size (daily avg)		PES	REC	AEC
I	3	This flow class accounts for about 20% of the PBMT of the fines at the site. This flow will frequently activate the bed and flush some fines.	4	5	3
IV	35	This flow class represents the effective discharge for fines and small gravels at the site. It is responsible for the bulk (more than 40%) of the sediment transport. These flows will scour the bed.	1:1	1:1	1:2
V	200	This flow class is responsible for about one quarter of the transport of fines, and is the effective discharge for the coarser gravels.	1:10	1:10	1:10
Confidence:		**Comments**			
2		Flows for geomorphology are set using the results from Potential Bed Material Transport (PBMT) modelling only. High flow hydraulics are reliable for the site, and a long gauge record of observed flows was used to undertake the modelling. No morphological cues exist at the site to verify the effective flow classes identified through the PBMT modelling			

8.3.4 Flood motivations for EWR 15

FLOODS		GEOMORPHOLOGICAL MOTIVATIONS	FREQUENCY		
Class	Size (daily avg)		PES	REC	AEC
IV	70	This flow class is the effective discharge for all sediment sizes (fines, gravels and cobbles). This flood activates the bed.	1:1	1:1	
V	300	Overtopping in sections to activate floodplain, recharge floodplain lakes and pans, maintain floodplain wetlands	1:5	1:5	

Confidence:	Comments
3	Flows for geomorphology are set using the results from Potential Bed Material Transport (PBMT) modelling only. High flow hydraulics are reliable for the site, and a long gauge record of observed flows was used to undertake the modelling. No morphological cues exist at the site to verify the effective flow classes identified through the PBMT modelling The main problem at this site is the increased sediments due to catchment degradation. Flows cannot be used to improve the condition of the site – the floods are still largely natural at the site anyway. Floods for the AEC (up) category do not differ from PES.

9 HYDRAULICS

9.1 Introduction

Assessment of the ecological Reserve for rivers required the determination of Environmental Water Requirements (EWR) for protection of aquatic ecosystems. EWR tend to quantify the water needs of the various biotic components in terms of relations between flow magnitude and timing. These relations include the frequency, duration, timing and rate of change of flows, and the specification of flows for the ecological Reserve aims to replicate important aspects of the natural hydrological regime (Hirschowitz ***et al***, 2007).

The results of hydraulic analyses and modelling form the essential link between the way in which the hydrologists, engineers and water managers express the flow of water in the river in terms of flow rate, and the way in which river ecologists express the water requirements of the river ecosystem itself in terms of variables like the flow depth and flow velocity (Birkhead, 2002).

The role of hydraulics and the procedure for generating hydraulic information has been documented for different levels of Reserve determinations (Department of Water Affairs and Forestry, 1999). A procedure for using standard hydraulic information as the basis for quantifying hydraulic habitat has been described by Jordanova et al., 2004. Further development regarding the use of hydraulic information for prediction the abundance and composition of hydraulic habitats has been carried out (Hirschowitz *et al*, 2007). HABitat-FLOw (HABFLO) simulation software has been developed to provide a working model that automates the prediction of habitat-type abundance and composition for fish and macroinvertebrates (Hirschowitz et al, 2007). The model has been used for prediction of hydraulic habitats for fish and macroinvertebrates.

9.2 Approach

The product of the hydraulics work comprises series of relationships between flow rate, and flow depth, flow velocity, wetted perimeter and flow area (Tharme, R.E. & King J.M, 1998). These relationships have to be determined for EWRs cross-sections at each selected site. In order to satisfactorily characterise the hydraulic relationships for Reserve determination study, field data, including discharge, water stage, and slope have to be collected for a range of flows over the hydrological season. Through the hydraulic modelling, using measured cross-sectional and flow data relationships (discharge and flow depth), biologically useful parameters (wetted perimeter, flow area and flow velocity) will be developed. These relationships will be presented graphically and in a tabulated format. The methodology of generating hydraulic information for determining the water quantity component of the Comprehensive Ecological Reserve is based on the RDM for Protection of Water Resources: River Ecosystems, Appendix R 17 (Birkhead, A.L. 2001).

9.3 Results

Surveyed EWR cross-sectional profile for each EWR site is shown in Figure 20 to Figure 23.

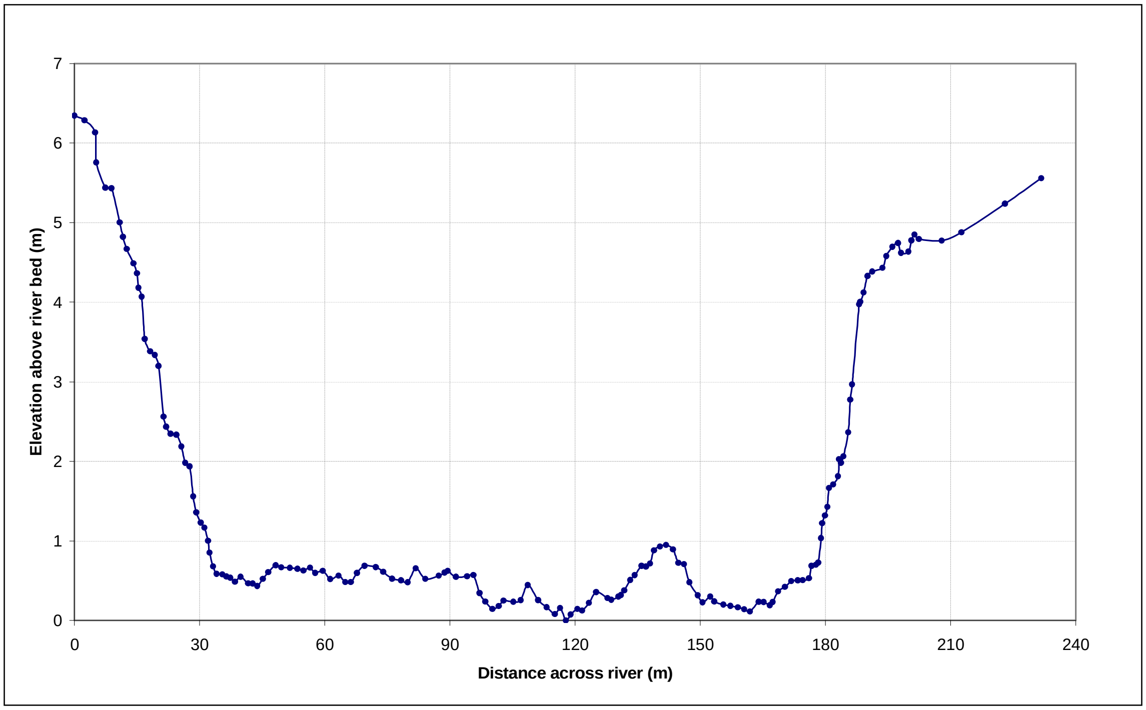


Figure 20: Cross-sectional profile for EWR 1 on the Vaal River.

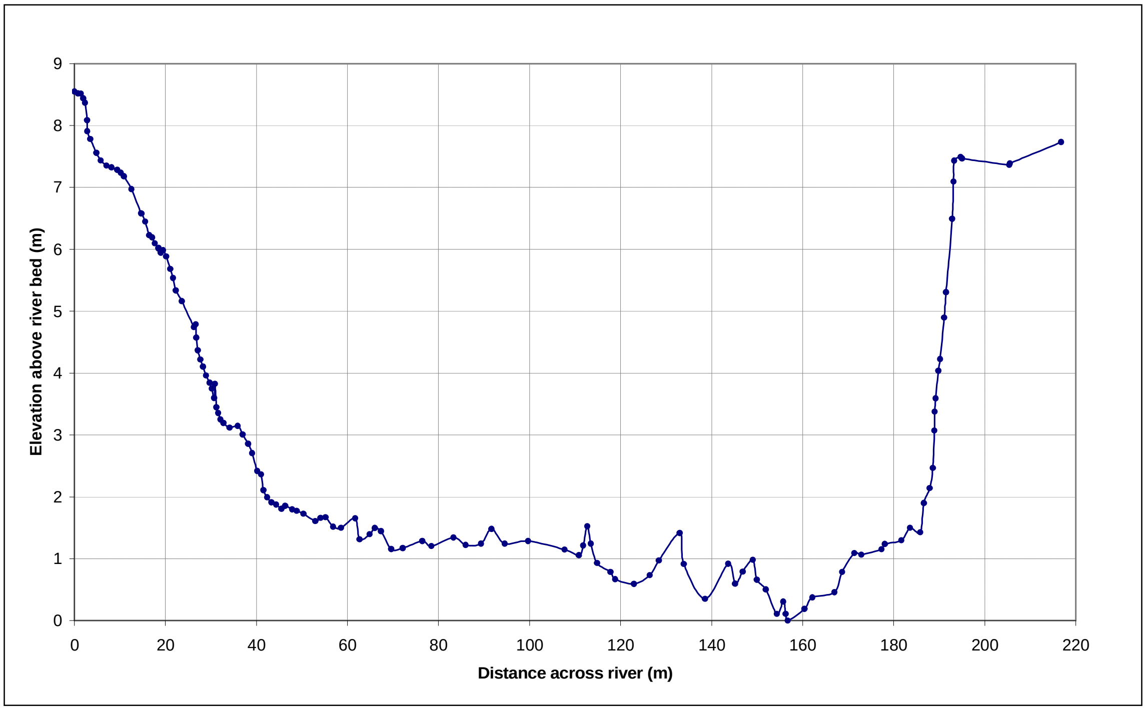


Figure 21: Cross-sectional profile for EWR 2 on the Vaal River

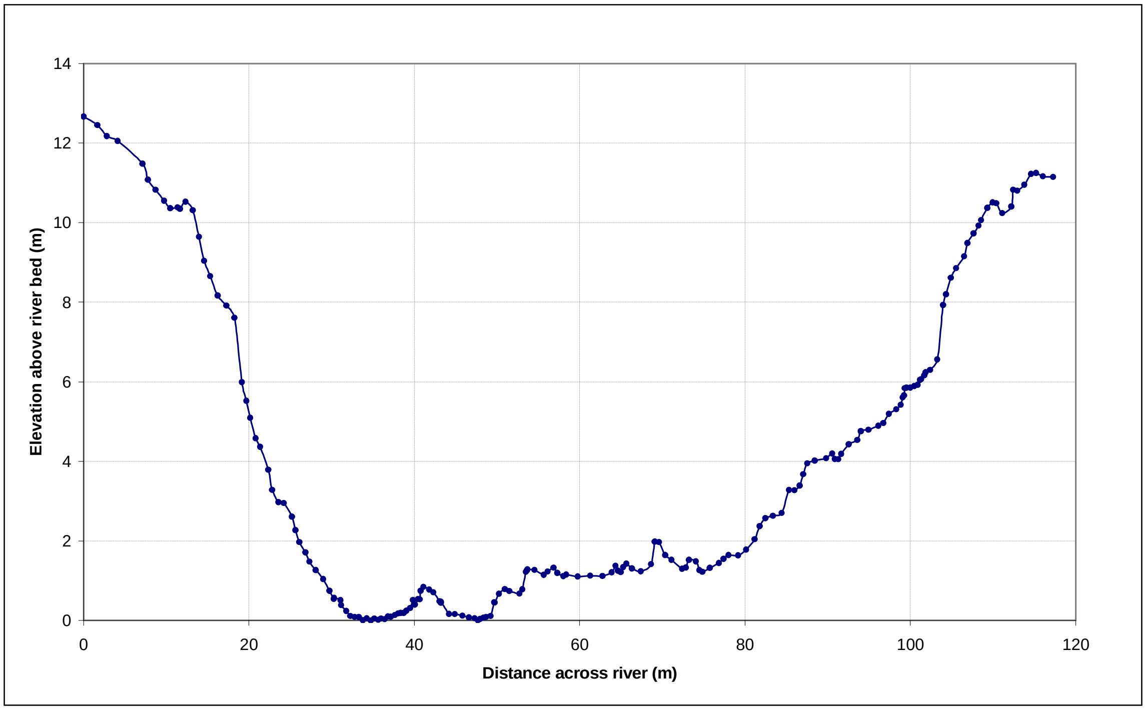


Figure 22: Cross-sectional profile for EWR 3 on the Vals River

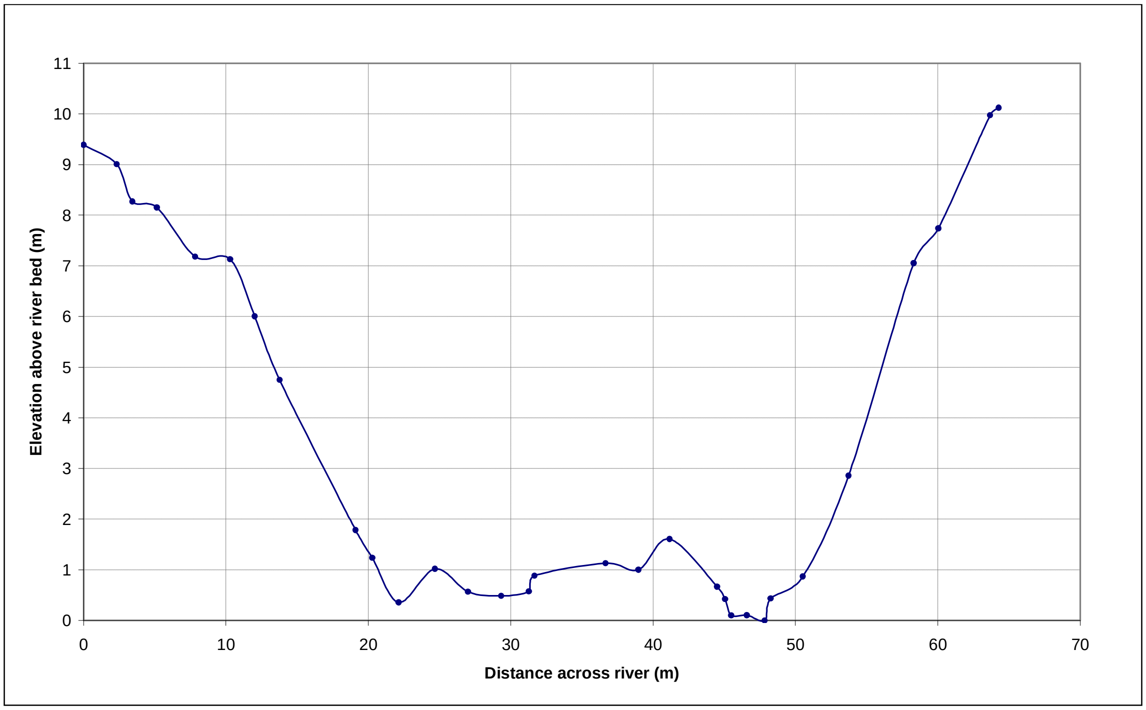


Figure 23: Cross-sectional profile for EWR 4 on the Vet River

9.3.1 Hydraulic data collected

The stage-discharge data collected at the EWR sites together with the dates when the data were collected are provided in Table 15.

Table 15: Hydraulic data collected at EWR sites

River	Site no.	Date	Discharge Q (m^3/s)	Max. flow depth, y (m)	Slope
Vaal	EWR 1	25.09.2007	15.70	0.99	0.0010
		25.06.2008	22.60	1.03	0.0014
		24.08.2008	20.40	1.02	0.0014
Vaal	EWR 2	25.09.2007	11.50	2.20	0.00021
		24.06.2008	24.80	2.36	0.00021
		24.08.2008	23.00	2,34	0.00021
Vals	EWR 3	26.06.2008	0.35	0.51	0.0098
		24.08.2008	0.28	0.49	0.0062
Vet	EWR 4	04.07.2008	0.53	0.43	0.0142
		25.08.2008	0.20	0.26	0.0142

9.3.2 Modelling

Flow resistance in natural channels is generally a function of stage, particularly at low flows where the flow depth is of the same order of magnitude as the size of the roughness elements constituting the bed (Birkhead et al., 1997; Broadhurst et al., 1997). With increased discharge, the local hydraulic controls become inundated, resulting in a tendency towards uniform water surface gradients and asymptotic resistance coefficient values (Birkhead et al., 2002). The observed rating data at the EWR sites were extended using the Manning's n resistance relationship and regional bed slopes. The regional bed slopes were obtained from a geomorphologist of the team (Table 16). The values of Manning's n resistance coefficients required for extending of the observed rating data were estimated using experience and existing resistance coefficients given in the literature (Barnes, 1967; Hicks and Mason, 1991 and Chow, 1959). The modelled stage-discharge data are given in Table 17.

Table 16: Regional channel slope

River	Site no.	Regional Channel slope
Vaal	EWR 1	0.00041
Vaal	EWR 2	0.00028
Vals	EWR 3	0.000656
Vet	EWR 4	0.00028

Table 17: Hydraulic data used to extend the measured rating data

River	Site no.	Discharge (m^3/s)	Manning's resistance, *n*	Max. flow depth, *y* (m)	Energy slope, *S*	Ave. velocity *v* (m/s)
Vaal	EWR 1	5.90	0.110	0.75	0.001	0.13
		640.00	0.030	3.50	0.00041	1.34
Vaal	EWR 2	0.50	0.280	1.39	0.000021	0.01
		345.00	0.030	3.50	0.00028	0.96
Vals	EWR 3	88.00	0.050	3.00	0.000656	0.75
		465.00	0.030	5.00	0.000656	1.84
Vet	EWR 4	0.07	0.060	0.15	0.0142	0.35
		4.15	0.085	1.00	0.0070	0.51
		60.00	0.031	3.00	0.00028	0.82

10 ECOLOGICAL CLASSIFICATION

10.1 Overview and objectives

EcoClassification (the term used for Ecological Classification) refers to the determination and categorisation of the Present Ecological State (PES - health or integrity) of various biophysical attributes of rivers compared to the natural/close to natural, reference condition. The purpose of EcoClassification is to gain insights 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 but attainable future ecological objectives for the river. The EcoClassification process also supports a scenario-based approach where a range of ecological endpoints (Ecological Categories) has to be considered. For each of these, a flow (EWR) scenario must be described.

EcoClassification must not be confused with the Classification System as indicated in the National Water Act. The Classification System considers a range of different issues in Integrated Water Resources Management in the process of determining the class of a river, one of which is ecological.

10.2 Method

The following process was applied to each Resource Unit:

- **Reference Conditions**: Reference conditions were described for the main ecological drivers (hydrology, geomorphology and water quality) and ecological responses (riparian vegetation, aquatic invertebrate and fish).
- **Present Ecological State:** The Present Ecological States (PES) for each of the drivers and the responses were assessed, and the results integrated into an overall assessment of PES, referred to as the EcoStatus.
- **Changes in PES**: An assessment was made as to whether the PES is stable under current development conditions, or whether it is changing.
- **Causes and Origins**. The causes and origins for the PES were identified, and specified as flow or non-flow related.
- **Ecological Importance and Sensitivity**: The Ecological Importance and Sensitivity (EIS) of the biota and habitats were assessed.
- **Recommended Ecological Category (REC)**: A realistic Ecological Category was recommended for each component as well as for the overall EcoStatus, based on a consideration of the PES and EIS,
- **Alternative Categories**: Alternative categories, “up” and “down”, were identified, where appropriate.

The results of the EcoClassification process were expressed in terms of Ecological Categories (ECs) ranging from Category A (Natural) to Category F (Critically Modified) (Figure 24). The categories represent a range along a continuum, so boundary categories (i.e. Category B/C) represent a condition at the border between Categories B and C. The six-point classification system (A to F) will be converted into a descriptive terminology when applied to Management Classes, which are the output of the Classification System procedures, as referred to in the National Water Act (Act 36 of 1998). The flow diagram, Figure 25, (adapted from DWAF, 2001) illustrates the process.

The results of the process, *i.e.* the PES and EC are provided as different river categories ranging from A (near natural) to F (critically modified). These will be converted to a descriptive terminology (still to be determined, but illustrated as Good, Fair, Poor etc.) when applied to Management Classes that are the output of the Classification System procedures (as referred to in the National Water Act, Act 36 of 1998, which is currently being developed). The interface between ECs and management Classes are provided in Figure 24.

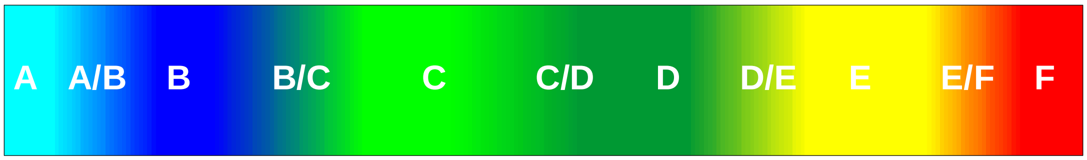


Figure 24: Illustration of the distribution of Ecological Categories (A to F) on a continuum and the relationship with Management Classes

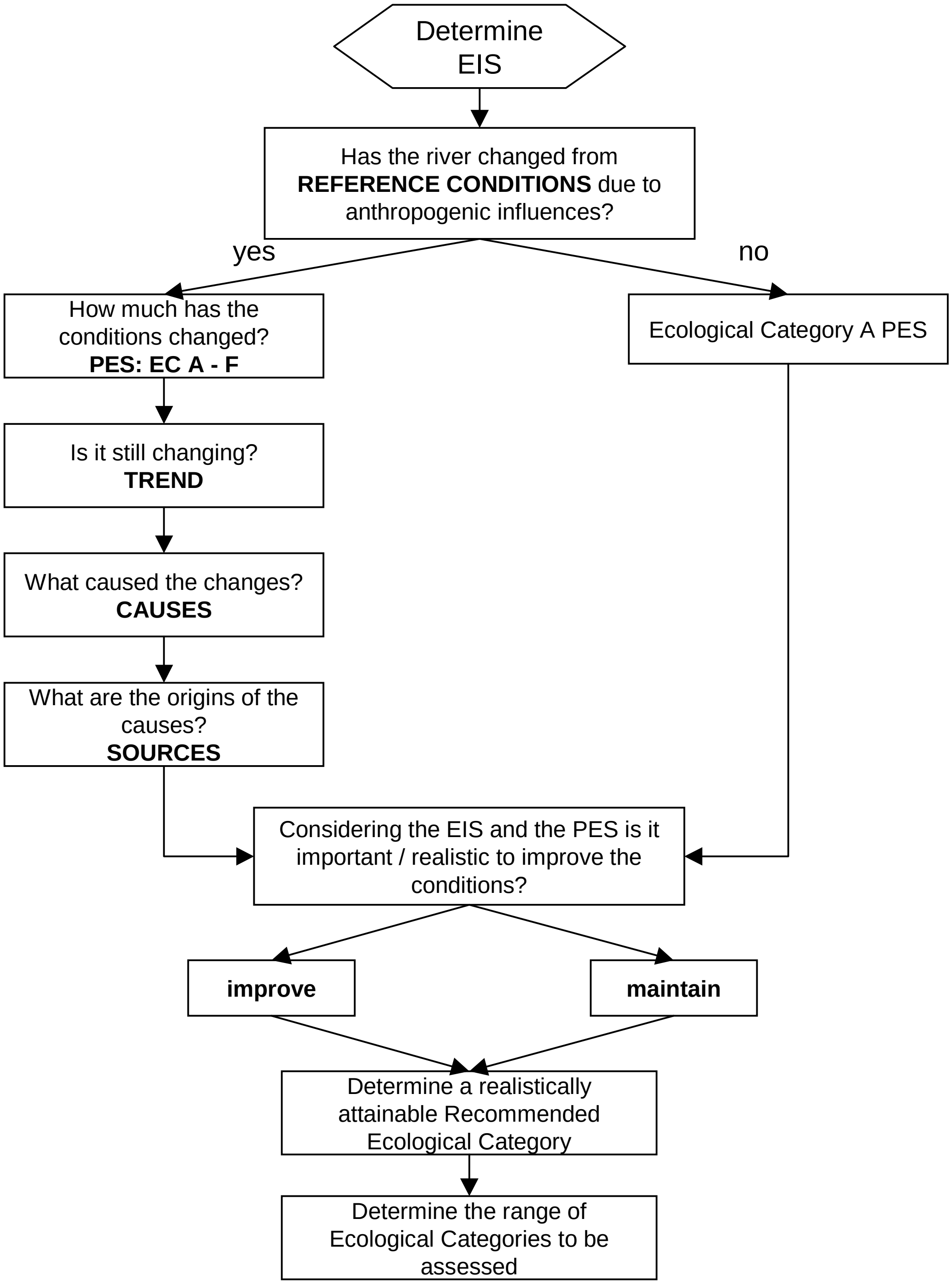


Figure 25: Flow diagram illustrating the information generated to determine the range of ECs for which EWRs will be determined

The range of Ecological Categories (ECs) for which flow scenarios were provided are guided by the rules as shown in Table 18. This must be seen as guidelines to determine a realistic range of ECs, which can be addressed within the scenario-approach.

Table 18: Guidelines for the range of Ecological Categories (ECs) to be addressed

PES	Alternative EC	
	Increase (Up)	Decrease (Down)
A	N/A	N/A
A/B	N/A	B/C
B	N/A	C
B/C	B	C/D
C	B	D
C/D	B/C	D
D	C	N/A
D/E	D	N/A
E	D	N/A
E/F	D	N/A
F	D	N/A

10.3 Results of the ecological classification process

The Eco Status and Ecological Importance and Sensitivity for the Middle Vaal varied and this was due to water quality and flow changes. The difficulty in improving the REC is due to the Vaal River system being operated as a water supply scheme for irrigation and drinking water and not for ecological sustainability purposes. The Ecostatus results are summarised in Figure 27.

EWR 12

Components	PES	EIS	REC[1]
Hydrology	D	MODERATE	D
Physico-chemical	D/E		D/E
Geomorphology	C/D		C/D
Fish	C/D		C/D
Invertebrates	D		D
INSTREAM	C/D		C/D
Riparian vegetation	D		D
ECOSTATUS	D		D

EWR 13

Components	PES	EIS	REC
Hydrology	C	MODERATE	C
Physico-chemical	D		D
Geomorphology	C		C
Fish	C/D		C/D
Invertebrates	C		C
INSTREAM	C		C
Riparian vegetation	C/D		C/D
ECOSTATUS	C/D		C/D

EWR 14

Components	PES	EIS	REC
Hydrology	D	MODERATE	D
Physico-chemical	C/D		C/D
Geomorphology	B/C		B/C
Fish	D		C/D
Invertebrates	C		C/D
INSTREAM	C/D		C/D
Riparian vegetation	D		D
ECOSTATUS	C/D		C/D

EWR 15

Components	PES	EIS	REC
Hydrology	C	MODERATE	C
Physico-chemical	C		C
Geomorphology	C		C
Fish	C		C
Invertebrates	D		D
INSTREAM	C/D		C/D
Riparian vegetation	C/D		C/D
ECOSTATUS	C/D		C/D

Figure 26 Summary of PES, EIS and REC for the EWR sites in the Middle Vaal

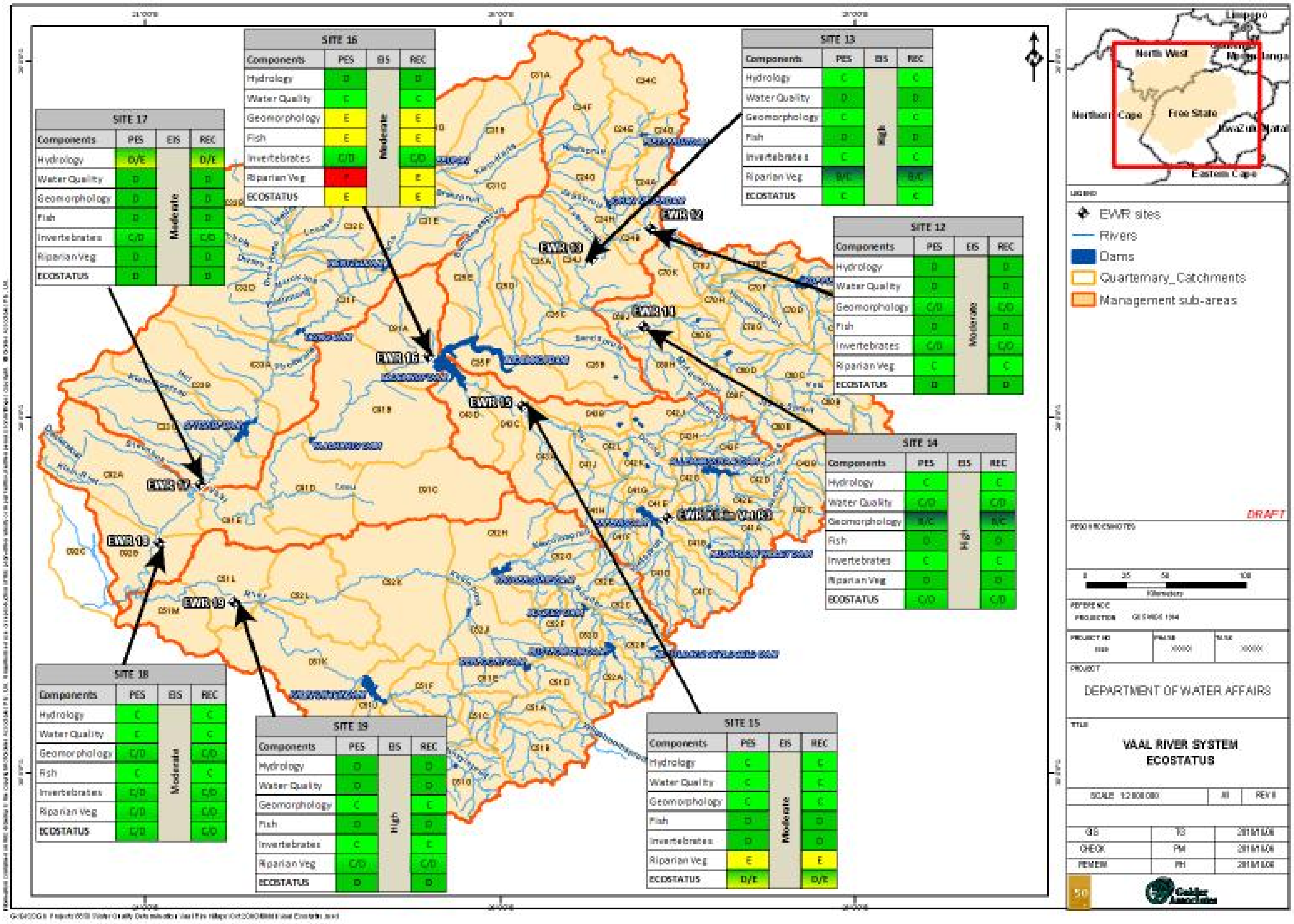


Figure 27: Summary of the Ecostatus of the EWR sites within the Middle and Lower Vaal Catchments

The hydrology of the Middle Vaal WMA is impacted in the main stem of the Vaal by the Vaal Dam and Vaal Barrage (completed in 1919). The flow regime in the main stem of the Vaal is impacted by the following:

- Vaal Dam storage
- Releases from Vaal Dam to dilute salts to 600 mg/L TDS (mainly in winter)
- Releases from Vaal Dam and Vaal River Barrage to supply the Vaal Hartz irrigation scheme (completed 1938)
- Interbasin transfers into the Vaal from Lesotho and Grootdraai Dam

This altered flow regime has resulted in increased winter base flows in the Middle Vaal River and smaller floods being reduced in summer.

Due to this regulation having being implemented in varying degrees for 90 years the aquatic organisms have adapted and the river banks are stable.

In the Vals and Vet Rivers the hydrology has changed due to increase irrigation usage, upstream dams and urban requirements. These rivers have less flow in winter as well as summer due to these anthropogenic changes.

11 ECOLOGICAL WATER REQUIREMENTS

11.1 Approach

This section of the report was revised in 2012 after review and is taken from DWA 2012 (report produced by Koekemoer Aquatic Services and Rivers for Africa (Pty) Ltd).

During the reassessment of the Ecological Water Requirement (EWR) scenario results the following constraints in the determination of EWRs were identified:

- Most of the specialists involved in the reassessment of the results were not involved in the Reserve study and therefore did not undertake the biological surveys and have not seen the EWR sites.

- Cross-sections at key EWR 13 was placed through a pool which resulted in hydraulic modelling results which could not be used.

- The hydraulic look-up tables did not include data with zero discharge in most cases which did not allow for the investigation of discharges which lie in this range. Therefore the lookup tables will not provide information for low flows below the depth of the pools. These depths are required to set low and drought flows in the fast flowing areas such as riffles.

- A range of photos at different discharges of the EWR sites were unavailable. This would have been especially useful at the sites with cross-sections through pools where biomonitoring was undertaken at downstream rapids and riffles.

- EWR sites with flows more than natural are difficult to assess without future scenarios being provided.

11.1.1 EWR Determination: Low flows

The Habitat Flow Stressor Response method (HFSR) (IWR S2S, 2004; O'Keeffe *et al.*, 2002), a modification of the Building Block Methodology (BBM; King and Louw, 1998) was used to determine the low (base) flow EWRs. This method is an accepted DWA method for determining EWRs.

11.1.2 Stress Indices

The basic approach was to set stress indices for fish and macroinvertebrates (referred to as inverts in this report) to aid in the determination of low flow requirements. The stress index describes the consequences of flow reduction on flow dependent biota and was determined by first assessing the response of habitat to flow reduction.

11.1.3 Habitat response

The stress index was described as an instantaneous response of habitat to flow in terms of a 0 to 10 index relevant for the specific site where:

- 0 - Optimum habitat with least amount of stress possible for the indicator groups (fixed at the natural maximum base flow which is based on the 10% annual value using separated natural base flows).

- 10 - Zero discharge (Note: Surface water may still be present). Maximum stress on indicator group.

- 2 to 9: Gradual decrease in habitat suitability and increase in stress as a result of decreased discharge.

The instantaneous response of fish habitat for spawning and nursery habitat, abundance, cover, connectivity, and water quality were derived by considering (amongst others) rated velocity depth classes (in terms of abundance) to flow changes based on a 0 - 5 scale where:

0 = Velocity - depth class is absent under the specific flow condition.

1 = Velocity - depth class is rare under the specific flow condition.

2 = Velocity - depth class is sparse under the specific flow condition.

3 = Velocity - depth class occurs moderately under the specific flow condition.

4 = Velocity - depth class occurs abundantly under the specific flow condition.

5 = Velocity - depth class is very abundant under the specific flow condition.

Fish habitat was then rated according to a 0 – 5 scale where:

0 = No habitat available.

1 = Very low occurrence

2 = Low occurrence

3 = Moderate occurrence

4 = Large/Good occurrence

5 = Optimum occurrence

11.1.4 Biotic response

The second step was to determine the biotic stress index which describes the instantaneous response of biota to change in habitat (and therefore flow) in terms of a 0 – 10 stress index. The description of the changes of habitat at each stress level (as described in the habitat stress index) was then related to the response of the fish and macroinvertebrate indicators. The biota stress index was described separately for fish and macroinvertebrates. The zero stress, representing optimum habitat, would therefore represent a situation of zero stress to biota with the maximum abundance of species present under these conditions.

The stress index therefore describes the habitat conditions and biota response for fish and macroinvertebrates at a range of low flows. The fish and macroinvertebrate stress-flow relationship will not be the same as the responses to the same flow and will/can result in different stress for fish and macroinvertebrates.

11.1.5 Integrated stress

Due to the constraints mentioned at the beginning of the chapter, a simplified approach was followed whereby the fish stress profile was accepted as the integrated stress profile. The invertebrate stress profile was only used to assess and interpret flow requirements.

11.1.6 Determination of stress requirements

A simplified approach was followed to allow for problems associated with the constraints. The Fish Flow Habitat Assessment (FFHA) model was applied to determine the fish EWR. These flows were then assessed by the invertebrate specialists who either accepted or modified the flows if it was required. Finally the riparian vegetation specialist checked the requirements and verified whether these requirements pose any problems for the vegetation state.

11.1.7 High flows

High flows were not reassessed and the original high flows determined during the Ecological Reserve process were accepted. The high flows are provided in Appendix A with a summary of the approach.

11.1.8 Final flow requirements

The low and high flows were combined to produce the final flow requirements for the Recommended Ecological Category (REC) as:

- An EWR table, which shows the results of high flows and low flows for each month separately. Floods with a frequency higher than 1:1 are included.

- An EWR rule table which provides the recommended EWR flows as a duration table, showing flows which should be provided when linked to a natural trigger (natural modelled hydrology in this case). EWR rules are supplied for total flows as well as for low flows only.

The low flow EWR rule table is useful for operating the system, whereas the EWR table must be used for operation of high flows.

11.2 EWR 12 (VERMAASDRIFT, VAAL RIVER): DETERMINATION OF STRESS INDICES

11.2.1 Indicator species or group

Fish indicator group

The preferred optimal habitat of *Labeobarbus kimberleyensis* (BKIM) is Slow Deep (SD), Fast Intermediate (FI) and Fast Deep (FD) with suitable cover provided by substrate and water column depth. The spawning habitat requirement of this species is FD and Fast Shallow (FS) habitats with good quality substrate (gravel and other suitable rocky habitats), flowing water, well oxygenated and low sediments loads. The breeding season extends from mid to late summer. The species requires substrate (gravel/cobbles) in flowing water (FS and FI) to spawn. Flows should last long enough for the embryos to develop and hatch out. The incubation period for BKIM is two to three days and larvae become mobile after a further three to four days at 23 - 25°C. Larvae require SD habitats with substrate, while juveniles prefer FI and SD over substrate.

Macroinvertebrate indicator group

Hydropsychidae 2 spp. was used as indicator taxa. This taxa shows a strong preference for flows >0.6 m/s, as well as for cobbles and occurred at the site in previous site assessments (2007/02/19 and 2007/11/28).

11.2.2 Stress flow index

The species stress discharges in **Table 19** and **Table 20** indicate the discharge evaluated by specialists to determine the biota stress.

Table 19: EWR 12: Fish stress index and summarised habitat/biotic responses

Fish stress	**Flow (m^3/s)**	**Habitat and/or biotic responses**
0	50	Habitat for spawning, nursery areas, maintenance of cover and abundance, connectivity and water quality optimal. Habitat diversity high with all velocity-depth categories represented.
1	32.2	Habitat for spawning, nursery areas, maintenance of cover and abundance, connectivity and water quality sub-optimal. Abundance of FD habitats reduced to level where a reduction in cover and abundance of indicator species can be expected to occur.
2	26.6	Habitat for spawning, nursery areas, maintenance of cover and abundance, connectivity and water quality very good. Further decrease in especially FD habitat expected to result in reduced abundance of indicator species.
3	22.8	Habitat for spawning, nursery areas, maintenance of cover and abundance, connectivity and water quality good. At this flow FD habitat is almost reduced by half from reference wet season maximum base flow (reference), and hence a notable reduction in abundance of indicator species may be expected.
4	18.3	Habitat for spawning, nursery areas, maintenance of cover and abundance, connectivity and water quality moderate to good. Although most requirements of the indicator species are still adequately met, reduction in the abundance of habitats is expected to result in decreased abundance of indicator species.
5	15.1	Habitat for spawning, nursery areas, maintenance of cover and abundance, connectivity and water quality of moderate suitability. Fast habitats (especially FD) highly reduced with slow habitats becoming the more dominant habitat component.
6	12.1	Habitat for spawning, nursery areas, maintenance of cover and abundance, connectivity and water quality of low to moderate suitability. Most requirements will still be maintained but indicator assemblage will be notably reduced from natural condition state.
7	7.2	Habitat for spawning, nursery areas, maintenance of cover and abundance, connectivity and water quality of low suitability.
8	4.6	Habitat for spawning, nursery areas, maintenance of cover and abundance, connectivity and water quality of very low to low suitability. Low abundance of fast flowing habitats for indicator species, with low suitability of especially spawning habitats.

Fish stress	Flow (m^3/s)	Habitat and/or biotic responses
9	2.1	Habitat for spawning, nursery areas, maintenance of cover and abundance, connectivity and water quality of very low suitability. Very low suitability where spawning and nursery habitats as well as water quality may be completely unsuitable.
10	0	Habitat for spawning, nursery areas, maintenance of cover and abundance, connectivity and water quality absent.

Table 20: EWR 12: Macroinvertebrate stress index and summarised habitat/biotic responses

Invertebrate stress	Flow (m^3/s)	Habitat and/or biotic responses
0	50.1	
1	38.8	Ave. velocity. 0.3 m/s, maximum velocity 0.96 m/s, 10% fast over coarse substrate (FCS), 3% very fast over coarse substrate (VFCS), and 1% vegetation (VEG).
2	32.3	Ave. velocity. 0.27 m/s, maximum velocity 0.9 m/s, 9% FCS, 3%VFCS, and 1% VEG.
3	25.3	Ave. velocity. 0.24 m/s, maximum velocity 0.82 m/s, 8% FCS, 2%VFCS, and 1% VEG.
4	17.2	Ave. velocity. 0.21 m/s, maximum velocity 0.69 m/s, 6% FCS, 1%VFCS, and 1% VEG.
5	11.2	Ave. velocity. 0.17 m/s, maximum velocity 0.6 m/s, 4% FCS, and 1%VFCS.
6	9.5	Ave. velocity. 0.16 m/s, maximum velocity 0.56 m/s, 4% FCS, and 1%VFCS.
7	7.2	Ave. velocity. 0.14 m/s, maximum velocity 0.5 m/s, 4% FCS.
8	4.7	Ave. velocity. 0.12 m/s, maximum velocity 0.41 m/s, 3% FCS.
9	2.7	Ave. velocity. 0.1 m/s, maximum velocity 0.35 m/s, 2% FCS.

Invertebrate stress	Flow (m^3/s)	Habitat and/or biotic responses
10	0	

11.2.3 EWR 12 (VERMAASDRIFT, VAAL RIVER): DETERMINATION OF EWR SCENARIOS

The Present Ecological State (PES) EcoStatus was incorrectly documented in DWA (2010a) as a D EC. According to the EcoStatus model, provided as part of the electronic information, the EcoStatus was actually a C or C/D (very low C verging on C/D). However, based on the review and suggested changes for vegetation, it was likely that the correct PES EcoStatus is a D and therefore this category was used in further Classification steps. The Ecological Importance and Sensitivity (EIS) was MODERATE or lower, and there was agreement that the EIS would not warrant an improvement of the PES.

Most significant flow related problems were:

- Changes in the flow regime which resulted in more flows in the dry season than natural and less flows in summer than natural. This was most probably due to a significant decrease in floods and decrease in base flows due to the Vaal Dam and other dams upstream.

The most significant non-flow related problems were:

- Deteriorated water quality due to mining and waste water treatment works (WWTW) discharge.

The revised EcoClassification results are summarised in the **Table 21** below. The Ecological Categories (ECs) in red refer to those that have changed in category from the Reserve study undertaken during 2007 - 2010.

Table 21: EWR 12: Summary of EcoClassification results

EWR 12			
Components	**PES**	**EIS**	**REC[1]**
Hydrology	D	MODERATE	D
Physico-chemical	D/E		D/E
Geomorphology	C/D		C/D
Fish	C/D		C/D
Invertebrates	D		D
INSTREAM	C/D		C/D
Riparian vegetation	D		D
ECOSTATUS	D		D

1 Recommended Ecological Category

EWR site	ECOCLASSIFICATION			
	Original PES	Refined PES	Original REC	Refined REC
EWR 12	D	Modified D	D	Modified D

11.2.4 Hydrological considerations

The driest and wettest months were identified as August and February respectively. Droughts were set at 95% exceedance (flow) and 5% exceedance (stress). Maintenance flows were set at 40% exceedance (flow) and at 60% exceedance (stress).

For the application of the Desktop Reserve Model (DRM) the Present Day (PD) hydrology was used as reference hydrology because PD hydrology was higher than natural during the dry season. Therefore the EWRs were set higher than natural and the DRM cannot accommodate this situation as the program will keep on decreasing the flows down to natural. As all flows that were set were less than PD, PD could therefore be used as the reference. This also meant that PD hydrology would guide the seasonal distribution of the EWRs which was acceptable as the objectives for this site and other sites where PD was higher than natural (**EWR sites 12, 13, 15**) was to set a realistic flow regime considering the present conditions. This matched the overall objective of maintaining the PES which is a function of the PD hydrology at these sites.

11.2.5 Low flow requirements (in terms of stress)

The stress index was used to identify required stress velocities at specific durations for the wet and dry month/season. The flow requirements are based on the instream C/D rather than the EcoStatus. This is because the EcoStatus of a D EC differs from the Instream EC due to the degraded riparian vegetation component as a result of non-flow related issues which included alien species.

11.2.6 Low flow (in terms of stress) requirements

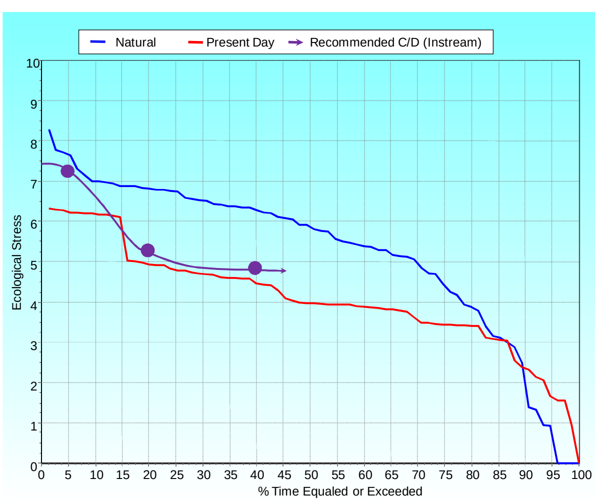
The flow requirements for the Instream EC of a C/D are provided in **Table 22** and graphically illustrated in **Table 28**. The results were plotted for the wet and dry season on stress duration graphs and compared to the DRM low flow estimates for the same EC. The stress requirements (as a 'hand drawn line') are illustrated in Figure 22.

Table 22: EWR 12: Species and integrated stress requirements as well as the final integrated stress and flow requirement

Stress Duration	Fish Stress requirement	Fish Flow requirement	Invert Flow requirement	Final* stress requirement	Flow requirement (m^3/s)
Instream PES and REC: C/D			**FISH: C/D**	**INVERTEBRATES: D**	
DRY SEASON - JUL					
5%	7.3	6.5	Sufficient flow to maintain invert condition	**7.3**	**6.5**
20%	5.3	14.2		**5.3**	**14.2**
40%	4.9	15.5		**4.9**	**15.5**
WET SEASON - FEB					
5%	6.5	9.6	Sufficient flow to maintain invert condition	**6.5**	**9.6**
20%	4.1	17.9		**4.1**	**17.9**
40%	2.3	25.7		**2.3**	**25.7**

* Final refers to the final stress selected as the EWR requirement, i.e., the lowest stress.

Dry season (July) **Wet season (February)**



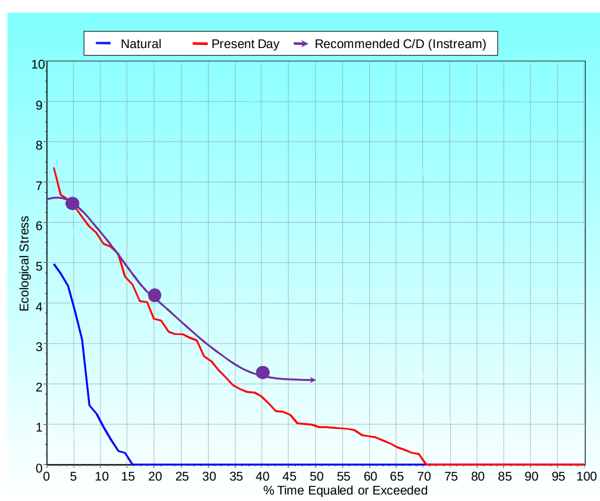


Figure 28: EWR 12: Stress duration curve for a PES and REC

As there was sufficient flow to maintain the invertebrates, **Table 23** provides the summarised motivations for the final requirements of the fish only.

Table 23: EWR 12: Summary of motivations

Month	% Stress duration	Stress	Flow (m^3/s)	Comment
In-stream PES and REC: C/D		**FISH: C/D**		**INVERTEBRATES: D**
Jul	5% drought	7.3	6.5	**Fish:** This flow is similar to the reference drought flow for this site. At this flow adequate habitats will be maintained for the indicator species.
	40% maintenance	4.9	15.5	**Fish:** The flow under present conditions is notably higher than under natural conditions. Theoretically a reduction in flow will therefore move towards an improvement as it will become closer to natural. It is however estimated that the habitat conditions (especially vegetation) have adapted due to the long duration of exposure to the flows occurring under present conditions. This stated flow is an estimated lower limit flow where the present state of the indicator species will be maintained, i.e. a further decrease in flow may result in a change in the EC.
Feb	5% drought	6.5	9.6	**Fish:** Adequate habitats will be provided to at least meet the minimum requirements for spawning, nursery habitats, migration and connectivity depths.
	40% maintenance	2.3	25.7	**Fish:** This maintenance flow will be lower than natural and present, but habitat conditions will not be altered significantly from present to allow a change in the EC of the indicator species. Stress levels will be low and most habitat requirements will be in a good condition.

It must be noted that the above recommended flow regime for a C/D instream condition is only one of many scenarios that can result in a C/D EC. The C/D Instream condition is mainly due to more flows in the dry season than natural and less flows in summer than natural. The situation in the dry season is that the river condition will improve as water is removed from the system and then at some point the river condition will start degrading again. However, this had to be linked to what happens during the wet season. There are many iterations around this situation that could all result in the same state. The assumption that was made during setting the recommended flows was that flows would decrease during both seasons. The decrease in flows during the dry season therefore refers to the decreased flows that will still maintain the C/D, as a further decrease will start improving the system (again depending on what occurs in the wet season). With this in mind, an assessment was also made of how much more flows can be released down the river during the dry season before problems would be experienced. Again this was difficult to determine, as the impact of increased flows in the dry season is dependent on what happens during the wet season. An estimate of approximately 23 m^3/s was thought to result in a change in the proportion of slow to fast habitats which could negatively affect the fish indicator species during the dry season. Yellowfish (BKIM), as semi-rheophilic species, prefer SD habitats (with inflow of fast habitats to maintain water quality), during the dry season.

11.2.7 Riparian vegetation flow requirements

The low flow requirements were checked (and modified if necessary) to ensure that it catered for any riparian vegetation (specifically marginal) requirements.

In the absence of surveyed vegetation data, assumptions were that sedges (*Cyperus longus* and *C. denudatus*) and *Gomphostigma virgata* grow at an elevation above the channel bed of about 0.8 to 0.9 m (as evident from site photos and cross-sectional profile – see **Figure 30** below), and that the tree line occurs about 1 m above that i.e. at elevations of approximately 2 m above the channel bed. The discharge required to inundate the base of these communities is 10 to 12 m^3/s for the marginal zone vegetation and about 115 m^3/s for the tree line (indicated mostly by *Salix babylonica* in site photos).

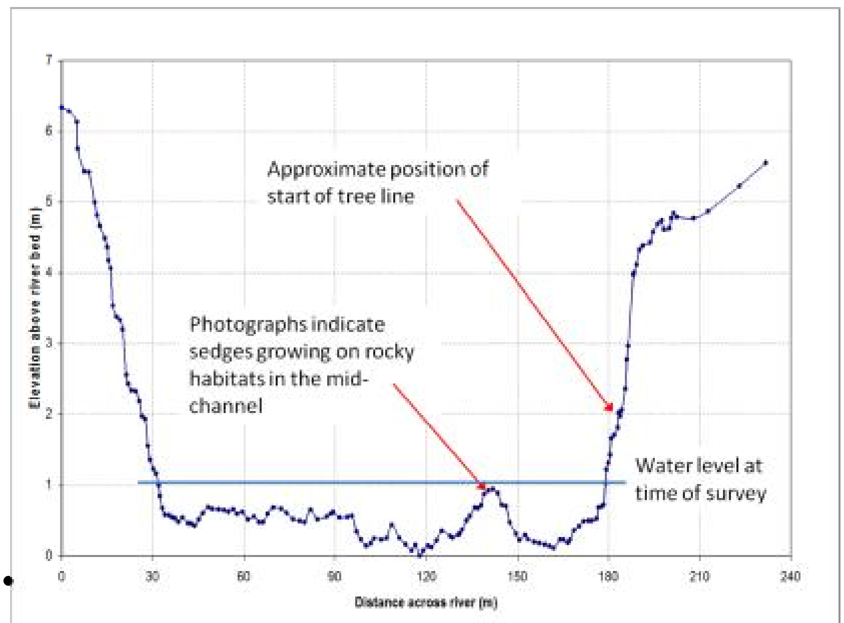


Figure 29: Assumed riparian vegetation situated along the cross section at EWR 12

The low flows set by instream faunal requirements are provided in **Table 24**.

Table 24: Verification of low flow requirements for riparian vegetation

Season	Stress	Flow (m^3/s)	Elevation (m)	Comment
Dry (Jul)	5	6.5	0.78	The marginal zone vegetation is inundated from 10.5 m^3/s at an elevation above the bed of 0.88 m. This means that the dry season drought flow is a mere 10 cm below the lowest limit of sedges, which seems high for a drought flow and is not likely to cause undue stress to the marginal zone vegetation.
	40	15.5	0.99	This flow results in about 10 cm of inundation of the marginal zone vegetation, which in the dry season will constitute slight inundation stress. No changes to the present state of the vegetation are envisioned however, especially as the PES for riparian vegetation is a D EC.
Wet (Feb)	5	9.6	0.86	Same comment as dry season drought is applicable.
	40	25.7	1.17	Marginal zone vegetation is inundated to between 20 and 30 cm, and bank woody species will have soil saturation at rooting level. These flows will meet increased transpiration demands of vegetation in the growing and reproductive season. Flows of up to 35 m^3/s will have the same effect and within this range, the PES is not likely to change.

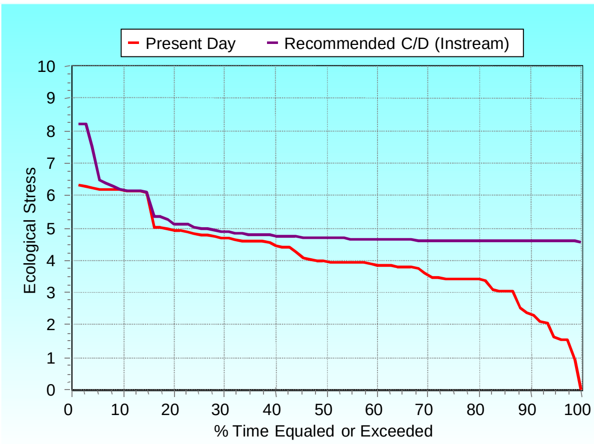
11.2.8 Final low flow requirements

To produce the final results, the DRM results for the specific category were modified according to specialists' requirements provided in **Figure 30**. There are a range of options one can use to make these modifications, such as changing the total volume required for the year, specific monthly volumes, either drought or maintenance flow durations, seasonal distribution and changing the category rules and shape factors. The following changes were required:

Parameter	FEB		JUL	
	DRM	EWR	DRM	EWR
High flow factors	-9	-9	0	0
Low Flow DC Shape	9	5	8	2
DC Upper % Shift	91	95	98	98
DC Lower % Shift	0	10	0	0

DC Low Flow Max.	130	69	130	0
High Flow DC Shape	9	9	8	8

Dry Season (July)



Wet Season (February)

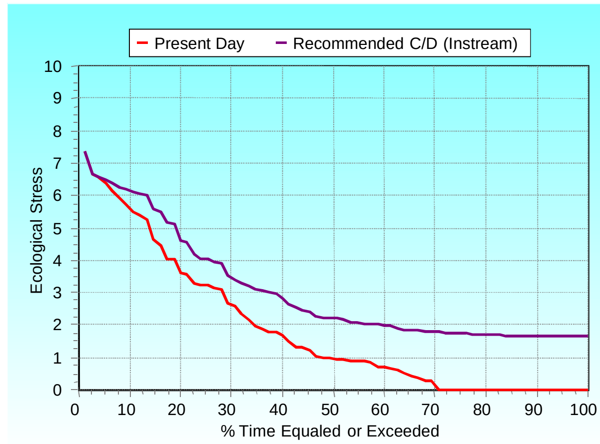


Figure 30: EWR 12: Final stress requirements for low flows

11.2.9 Final flow requirements

As Present Day (PD) hydrology was used as reference flows in the DRM, the comparative percentages of the EWR are provided for both natural (virgin) and PD hydrology. The percentages of Mean Annual Runoff (MAR) for an EC are not comparable to the percentages where the PD hydrology is lower than natural. As explained previously the specialists have attempted to provide a range from PD to the point where the PES (REC) will change. Obviously the percentages compared to natural are going to be very high as the set flows were higher than natural in certain seasons. This will be relevant for all the sites were PD hydrology is higher than natural (i.e. **EWR sites 12, 13, 15**).

The low and high flows were combined to produce the final flow requirements for the PES/REC EC as:

- An EWR table, which shows the results for each month for high flows and low flows separately (Table 25). Floods with a high frequency were not included in the modelled results as they cannot be managed.

- An EWR rule table which provides the recommended EWR flows as a duration table, linked to a natural trigger (natural modelled hydrology in this case). EWR rules were supplied for total flows as well as for low flows only (**Table 25**

The low flow EWR rule table is useful for operating the system, whereas the EWR table must be used for operation of high flows.

Table 25: EWR 12: EWR table (m^3/s) for PES and REC (In-stream): C/D

Desktop version:		**2**	**Virgin MAR (MCM)**	**2546.39**
			Present Day MAR (MCM)	**1574.637**
BFI index	**0.390**	**Distribution type**		**Vaal**
MONTH	**LOW FLOWS**		**HIGH FLOWS**	
	Maintenance (m^3/s)	**Drought (m^3/s)**	**Daily average (m^3/s) on top of base flow**	**Duration (days)**
OCTOBER	16.512	6.605	50	7
NOVEMBER	20.082	8.033		
DECEMBER	20.664	8.265		
JANUARY	23.115	9.246	50	7
FEBRUARY	25	10	50 100 350	7 5 10
MARCH	23.516	9.406		
APRIL	19.866	7.946		
MAY	17.118	6.847		
JUNE	15.792	6.317		
JULY	15.341	6.136		
AUGUST	12.045	4.818		
SEPTEMBER	13.163	5.265		
TOTAL MCM	582.745	233.094	250.042	

% OF VIRGIN	22.89	9.15	9.81
% OF PD	37.01	14.8	15.88
Total EWR	832.786		
% of VIRGIN MAR	32.71		
% of PD MAR	52.89		

Table 26: EWR 12: Assurance rules (m^3/s) for PES and REC (In-stream): C/D

Desktop Version 2, Printed on 7/17/2012

Summary of IFR rule curves for: EWR 1 Generic Name (EWR 12)

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: Vaal REC = C/D

Data are given in m^3/s mean monthly flow

% Points

Month 10% 20% 30% 40% 50% 60% 70% 80% 90% 99%

Oct 16.410 16.195 15.675 14.643 12.995 10.915 8.905 7.480 6.792 6.667

Nov 55.803 47.298 40.090 33.105 23.422 17.999 13.516 10.865 9.787 6.929

Dec 19.535 19.261 18.510 16.971 14.627 12.018 9.938 8.783 8.357 8.117

Jan 59.668 51.470 44.369 37.035 26.505 19.895 14.643 11.818 10.831 9.233

Feb 209.427 75.405 56.225 39.397 33.404 29.357 24.434 20.176 13.910 8.747

Mar 24.565 24.227 23.329 21.494 18.631 15.265 12.333 10.483 9.667 9.173

Apr 19.942 19.690 19.088 17.901 15.990 13.533 11.077 9.239 8.273 8.021

May 17.665 17.408 16.827 15.727 14.013 11.853 9.704 8.074 7.185 6.915

Jun 19.845 19.477 18.682 17.235 15.054 12.376 9.761 7.800 6.731 6.402

Jul	16.978	16.653	15.979	14.798	13.065	10.971	8.932	7.383	6.510	6.205
Aug	14.557	14.310	12.634	10.585	10.107	9.252	7.343	5.904	5.119	4.879
Sep	12.292	12.130	11.749	11.011	9.850	8.392	6.973	5.944	5.425	5.309

Reserve flows without High Flows

Oct	16.432	16.362	16.229	15.983	15.535	14.736	13.362	11.151	8.065	6.667
Nov	19.194	19.115	18.967	18.687	18.169	17.234	15.610	12.978	9.341	6.929
Dec	19.547	19.440	19.210	18.745	17.866	16.344	14.016	11.087	8.555	8.117
Jan	24.177	24.049	23.766	23.172	22.014	19.957	16.758	12.732	9.339	9.233
Feb	28.384	28.241	27.934	27.316	26.140	24.072	20.800	16.378	11.831	8.747
Mar	24.580	24.446	24.168	23.621	22.605	20.855	18.142	14.539	10.882	9.173
Apr	19.968	19.884	19.730	19.447	18.938	18.040	16.506	14.033	10.487	8.021
May	17.713	17.660	17.572	17.424	17.171	16.727	15.927	14.434	11.462	6.915
Jun	19.947	19.906	19.846	19.101	18.140	17.130	16.883	16.073	13.592	6.402
Jul	17.090	17.056	17.007	16.932	16.814	16.621	16.088	15.338	11.335	6.205
Aug	14.619	14.590	12.634	10.585	10.107	9.513	9.147	8.759	8.509	4.879
Sep	12.317	12.283	12.224	12.125	11.852	11.107	9.448	8.248	6.944	5.309

Natural Duration curves

Oct	63.176	40.237	33.445	28.819	22.517	20.404	17.466	15.550	12.817	7.807
Nov	119.973	84.001	46.728	38.900	32.269	28.650	24.117	19.201	14.745	6.929
Dec	150.370	83.774	53.390	45.445	37.997	30.122	25.732	21.759	19.153	8.117
Jan	251.818	114.412	75.978	47.510	43.201	35.618	25.877	19.736	16.103	9.233
Feb	452.579	75.405	56.225	39.397	33.404	29.357	24.434	20.176	13.910	8.747
Mar	184.356	70.979	39.987	34.446	27.192	22.282	18.963	17.421	12.761	9.173

Apr	82.153	47.133	32.928	28.939	24.749	22.361	21.165	18.198	15.556	10.802
May	33.878	25.833	20.882	19.560	18.380	17.581	15.927	14.777	12.754	11.443
Jun	25.675	22.971	20.621	19.101	18.140	17.130	16.883	16.073	13.592	12.288
Jul	25.358	20.964	20.613	18.907	18.410	16.891	16.088	15.338	11.335	10.708
Aug	19.967	16.338	12.634	10.585	10.107	9.513	9.147	8.759	8.509	7.635
Sep	31.188	25.606	17.936	13.646	11.852	11.107	9.448	8.248	6.944	6.389

11.3 EWR 13 (REGINA BRIDGE, VAAL RIVER): DETERMINATION OF EWR SCENARIOS

Based on the review (DWA, 2010a) and suggested changes, the correct PES EcoStatus was a C/D and therefore this category would be used in further Classification steps. The EIS was MODERATE and not HIGH as documented in DWA (2010a). The REC was therefore set to maintain the PES in a C/D.

The most significant flow related problems were:

- Changes in the flow regime which resulted in decreased flows in the wet season. However this was most probably due to a decrease in floods due to the Vaal Dam and other dams upstream. Increased PD flows above natural occurred in certain months e.g. June and July.

The most significant non-flow related problems were:

- Deteriorated water quality due to mining and WWTW discharge as well as increased nutrients due to agriculture.

The revised Eco-Classification results are summarised in the Table 27 below. The ECs in red refer to those that have changed in category from the Reserve study undertaken during 2007 - 2010.

Table 27: Summary of Eco-Classification results

EWR 13			
Components	**PES**	**EIS**	**REC**
Hydrology	C	MODERATE	C
Physico-chemical	D		D
Geomorphology	C		C
Fish	C/D		C/D
Invertebrates	C		C
INSTREAM	C		C
Riparian vegetation	C/D		C/D
ECOSTATUS	C/D		C/D

EWR site	ECOCLASSIFICATION			
	Original PES	Refined PES	Original REC	Refined REC
EWR 13	C	C/D	C	C/D

11.3.1 EWR Requirements

The cross-section at EWR 13 was placed through a pool. This is extremely problematic in that zero flow does not equate to zero depth. Furthermore, the biological surveys were undertaken at a multi-channel area with riffles further downstream. The biota found at the site and the habitats they require and utilize were not representative of the conditions in the pool. The previous assessment undertaken by Golder and Associates resulted in an EWR of very low flows. This would be as a result of the hydraulics as even though the discharges decrease significantly, the velocities will hardly change and the depth will not decrease significantly due to pooled water. The wet season requirements were much too high and set above the maximum base flows and more than PD flows. This did not make sense and again was a result of interpreting the hydraulics and not assessing the actual situation of the pool. In a pool, discharge has to increase significantly before velocities will increase sufficiently to cater for the requirements of macroinvertebrate taxa that do not occur in the pool.

Taking this into account, the cross-section and hydraulic data could not be used to set EWRs. It was noted that the PD flows were very similar to EWR 12. The same indicator taxa and habitats as present at EWR 12 occurred in the reach represented by EWR 13. It was therefore decided to extrapolate the EWRs set at EWR 12 to EWR 13. The changes were made proportionately to the changes in the modelled PD flows between EWR 12 and 13 and the approach is outlined below.

11.3.2 Extrapolation methodology

The following approach was used in generating the EWR table as well as the EWR rule table:

1. The desktop model (with the PD hydrology) was run at EWR 12 for a C/D Instream EcoStatus.

2. The drought and maintenance flows for the wettest and driest months used at the percentiles used for setting flows at EWR 12 were noted.

3. The desktop model was then run for EWR 13 for a C/D EcoStatus using EWR 13 Present Day hydrology.

4. The same flow ranges as noted at EWR 12 were used and the proportional change at EWR 12 between the desktop generated flows and the EFR requirements were calculated (**Table 28**).

5. The calculated proportion was used to determine what the flows should be at EWR 13 compared to the desktop generated flows. The EFR/ DRM ratio was then used to multiply the EWR13 DRM to determine an estimate of EWR13 EWR (**Table 27**).

Table 28: Proportional change at EWR 12 between the desktop generated flows and the EFR requirements

Changes	PES and REC: C/D		EFR/DRM (Proportional change)
	DRM	EFR	
MLIFR - Maintenance low flow	8.70	37.01	4.254023
DLIFR - Drought low flow	5.60	14.8	2.642857
MHIFR - Maintenance high flow	3.28	15.88	4.841463
Long-term % of virgin MAR (PD)	17.58	52.89	3.008532

Table 29: Extrapolated results for EWR 13

Changes	PES and REC: C/D	
	DRM	EFR
MLIFR - Maintenance low flow	8.42	35.82
DLIFR - Drought low flow	5.37	14.19
MHIFR - Maintenance high flow	3.63	17.57
Long-term % of virgin MAR (PD)	17.42	52.41

6. The flows were adjusted accordingly to create a match to the requirements EWR 13. These adjusted low flows now represented flows at EWR 13 and follow the same trend as those set at EWR 12.

7. These flows were saved in SPATSIM after which the floods/high flow requirements set for EWR 13 were included. The specialist specifies floods needed to be adjusted in order to match what was estimated from the proportional estimate.

8. As a final output the EWR table as well as the EWR rule table was generated.

11.3.3 Final flow requirements

The low and high flows were combined to produce the final flow requirements for the PES/REC EC as:

- An EWR table, which shows the results for each month for high flows and low flows separately (**Table 30**). Floods with a high frequency were not included in the modelled results as they cannot be managed.

- An EWR rule table which provides the recommended EWR flows as a duration table, linked to a natural trigger (natural modelled hydrology in this case). EWR rules were supplied for total flows as well as for low flows only (**Table 30**).

The low flow EWR rule table is useful for operating the system, whereas the EWR table must be used for operation of high flows.

Table 30: EWR 13: Extrapolated EWR table (m^3/s) for PES and REC: C/D

Desktop version:		**2**	**Virgin MAR (MCM)**	**2654.289**
			Present Day MAR (MCM)	**1638.37**
BFI index	**0.371**	**Distribution type**	**Vaal**	
MONTH	**LOW FLOWS**		**HIGH FLOWS**	
	Maintenance (m^3/s)	**Drought (m^3/s)**	**Daily average (m^3/s) on top of base flow**	**Duration (days)**
OCTOBER	15.699	4.267	50	7
NOVEMBER	19.331	5.228		
DECEMBER	20.017	6.302		
JANUARY	22.892	7.008	50	7
FEBRUARY	30.526	5.155	50 100 520	7 5 10
MARCH	24.303	4.865		

APRIL	20.149	9.749		
MAY	17.091	10.756		
JUNE	15.515	12.315		
JULY	15.072	10.633		
AUGUST	11.367	6.907		
SEPTEMBER	12.12	4.803		
TOTAL MCM	586.47	231.56	273.352	
% OF VIRGIN	22.10	8.72	10.30	
% OF PD	35.80	14.13	16.68	
Total EWR	859.82			
% of VIRGIN MAR	32.40			
% of PD MAR	52.48			

Table 31: EWR 13: Extrapolated EWR table (m^3/s) for PES and REC: C/D

Desktop Version 2, Printed on 7/17/2012

Summary of IFR rule curves for: EWR 2 Generic Name (EWR 13)

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: Vaal REC = C/D

Data are given in m^3/s mean monthly flow

% Points

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	37.868	37.255	32.695	27.826	21.386	19.153	16.249	10.426	6.507	5.175

Nov	67.873	61.179	49.718	37.670	30.818	27.600	21.346	13.419	8.459	5.274
Dec	49.470	46.701	43.948	40.720	34.931	29.636	22.481	14.785	8.937	6.519
Jan	54.380	51.584	48.745	45.300	39.051	32.951	24.688	15.897	9.470	7.781
Feb	151.606	120.871	56.494	41.650	33.275	29.460	24.161	19.304	12.847	7.622
Mar	59.406	58.778	40.968	34.801	29.458	24.212	18.373	16.711	8.568	6.545
Apr	43.181	42.748	35.610	29.633	24.475	22.901	20.887	17.526	12.105	9.892
May	30.701	26.732	21.390	19.601	18.787	17.832	16.263	13.812	11.547	10.882
Jun	26.454	23.588	21.265	19.614	18.630	17.708	17.342	14.937	13.061	12.418
Jul	25.762	21.588	20.759	19.108	18.567	17.029	15.381	12.751	11.269	10.750
Aug	19.571	15.838	12.026	10.122	9.532	8.953	8.576	8.154	7.409	6.989
Sep	27.201	24.190	16.713	12.145	10.417	9.614	7.940	6.755	5.440	4.892

Reserve flows without High Flows

Oct	28.199	28.020	27.698	27.120	21.386	19.153	16.249	14.385	9.936	4.418
Nov	33.793	33.594	33.227	32.556	30.818	27.600	22.809	17.716	11.266	5.274
Dec	34.032	33.853	33.515	32.882	31.718	29.619	24.817	19.989	11.405	6.476
Jan	38.932	38.732	38.348	37.621	36.261	33.775	24.903	18.869	11.895	7.208
Feb	51.602	51.327	50.791	41.650	33.275	29.460	24.161	19.304	12.339	5.445
Mar	41.297	41.058	40.602	34.801	29.458	24.212	18.373	16.711	10.386	5.093
Apr	35.257	35.076	34.740	29.633	24.475	22.901	20.887	19.120	14.350	9.892
May	30.754	26.732	21.390	19.601	18.787	17.832	16.263	14.576	12.720	10.882
Jun	26.454	23.588	21.265	19.614	18.630	17.708	17.342	16.535	14.059	12.418
Jul	25.762	21.588	20.759	19.108	18.567	17.029	16.170	15.416	11.402	10.750
Aug	19.571	15.838	12.026	10.122	9.532	8.953	8.576	8.154	7.878	6.989

Sep	22.366	22.224	16.713	12.145	10.417	9.614	7.940	6.755	5.440	4.892

Natural Duration curves

Oct	65.838	39.247	32.695	27.826	21.386	19.153	16.249	14.385	11.645	6.575
Nov	118.758	84.892	49.718	37.670	30.818	27.600	22.809	17.716	13.260	5.274
Dec	153.401	86.279	55.724	45.557	37.959	30.122	24.817	20.419	17.604	6.519
Jan	252.834	116.484	87.134	46.909	43.705	35.293	24.903	18.869	14.531	7.781
Feb	465.654	120.871	56.494	41.650	33.275	29.460	24.161	19.304	12.847	7.622
Mar	200.627	84.099	40.968	34.801	29.458	24.212	18.373	16.711	11.443	8.042
Apr	104.097	54.452	35.610	29.633	24.475	22.901	20.887	19.120	15.193	9.892
May	36.436	26.732	21.390	19.601	18.787	17.832	16.263	14.576	12.720	11.018
Jun	26.454	23.588	21.265	19.614	18.630	17.708	17.342	16.535	14.059	12.681
Jul	25.762	21.588	20.759	19.108	18.567	17.029	16.170	15.416	11.402	10.775
Aug	19.571	15.838	12.026	10.122	9.532	8.953	8.576	8.154	7.878	6.989
Sep	29.715	24.190	16.713	12.145	10.417	9.614	7.940	6.755	5.440	4.892

11.4 EWR 14 (PROKLAMEERSDRIFT, VALS RIVER): DETERMINATION OF STRESS INDICES

11.4.1 Indicator species or group

Fish indicator group

Labeobarbus aeneus (BAEN) has a maximum size of approximately 50 cm. Its optimal preferred general habitat is SD, FS and FD with suitable cover provided by substrate and water column depth. This spawning habitat requirement of this species is FD and FS habitats with good quality substrate (gravel and other suitable rocky habitats). The eggs and embryos require FS habitats with substrates, with flows lasting long enough for the eggs to hatch (3 – 8 days) and embryos to develop (still within the gravel substrates). Larvae require SD habitats with substrate, while juveniles prefer FS and Slow Shallow (SS) over substrate, and seek refuge in SD at night.

Macroinvertebrate indicator group

Hydropsychidae 2 spp. was used as indicator taxa (refer to Section 3.1.3) and occurred at the site in previous site assessments (2007/10/01 and 2008/02/02).

11.4.2 Stress flow index

The species stress discharges in **Table 32**and **Table 33** indicate the discharge evaluated by specialists to determine the biota stress.

Table 32: EWR 14 Fish stress index and summarised habitat/biotic responses

Fish stress	Flow (m^3/s)	Habitat and/or biotic responses
0	3.8	Habitat suitability will be optimal and comparable to wet season conditions that may have occurred at the site under reference (pre-disturbance) conditions.
1	3.5	Habitat suitability close to optimal but slightly reduced due to decreased abundance of fast habitats.
2	3.0	Habitat suitability will become very good as adequate diversity of especially fast habitats will be available to meet the requirements of all life stages and processes of the indicator species.
3	2.15	Increased availability of fast habitats will improve the suitability for all aspects assessed, being of overall good condition.
4	1.2	More diverse fast habitats (fast very shallow (FVS), FS, FI and FD) will become available and provide more adequate habitats (still of moderate suitability) to meet the requirements of the indicator species.
5	1.0	Some FS and FD habitats will become available and provide habitat of moderate suitability for all aspects considered (spawning, nursery, abundance and cover, connectivity and water quality).
6	0.8	According to the hydraulic information, some FD habitats (94%) will become available at this flow. This together with the slow habitats available at the site will provide habitat of low suitability for all other requirements considered (e.g. nursery habitats, abundance and cover, connectivity and water quality).
7	0.5	Limited fast habitats will become available at this flow, allowing limited spawning habitats (very low suitability), while the rest of the habitat requirements are of low suitability.

Fish stress	Flow (m^3/s)	Habitat and/or biotic responses
8	0.4	Habitat suitability very low for all life-stages and requirements of indicator species. Very limited FVS habitats may become available.
9	0.3	Habitat unsuitable for spawning, and very low suitability to provide for nursery areas, cover, connectivity and water quality to maintain abundance. No fast habitats available on cross section.
10	0	Habitat unsuitable to provide for spawning, nursery areas, cover, maintenance of connectivity and water quality of indicator fish species.

Table 33: EWR 14: Invertebrate stress index and summarised habitat/biotic responses

Invertebrate stress	Flow (m^3/s)	Habitat and/or biotic responses
0	3.8	
1	3.5	Ave. velocity 0.2 m/s; max. velocity 0.68 m/s; 7% FCS, 2%VFCS, 6% VEG.
2	3	Ave. velocity 0.19 m/s; max. velocity 0.63 m/s; 6% FCS, 1%VFCS, 6% VEG.
3	2.1	Ave. velocity 0.16 m/s; max. velocity 0.54 m/s; 5% FCS, 1%VFCS, 6% VEG.
4	1.5	Ave. velocity 0.13 m/s; max. velocity 0.46 m/s; 4% FCS, 5% VEG.
5	1.0	Ave. velocity 0.11 m/s; max. velocity 0.37 m/s; 3% FCS, 5% VEG.
6	0.6	Ave. velocity 0.08 m/s; max. velocity 0.29 m/s; 1% FCS, 4% VEG.
7	0.5	Ave. velocity 0.07 m/s; max. velocity 0.26 m/s; 10% slow over coarse substrate (SCS), 4% VEG.
8	0.2	Ave. velocity 0.05 m/s; max. velocity 0.19 m/s; 8% SCS, 3% VEG.
9	0.1	Ave. velocity 0.03 m/s; max. velocity 0.1 m/s; 1% SCS, 2% VEG.
10	0	

11.5 EWR 14 (PROKLAMEERSDRIFT, VALS RIVER): DETERMINATION OF EWR SCENARIOS

Based on the adjusted PES EcoStatus of DWA (2010a) the EC remained a C/D. The revised EIS was MODERATE and not HIGH as documented in DWA (2010a), and the REC was set to maintain the PES.

The most significant flow related problems were:

- Changes in the flow regime which resulted overall in decreased flows. However PD flow could possibly be higher than what the abstraction indicated due to irrigation return flows.

The most significant non-flow related problems were:

- Discharges from WWTWs and irrigation return flows.

The revised EcoClassification results are summarised in the **Table 34** below. The ECs in red refer to those that have changed in category from the Reserve study undertaken during 2007 - 2010.

Table 34: Summary of EcoClassification results

EWR 14			
Components	**PES**	**EIS**	**REC**
Hydrology	D	MODERATE	D
Physico-chemical	C/D		C/D
Geomorphology	B/C		B/C
Fish	D		C/D
Invertebrates	C		C/D
INSTREAM	C/D		C/D
Riparian vegetation	D		D
ECOSTATUS	C/D		C/D

EWR site	**ECOCLASSIFICATION**			
	Original PES	**Refined PES**	**Original REC**	**Refined REC**
EWR 14	C/D	Modified C/D	C/D	Modified C/D

11.5.1 Hydrological considerations

The driest and wettest months were identified as July and March respectively. Droughts were set at 95% exceedance (flow) and 5% exceedance (stress). Maintenance flows were set at 40% exceedance (flow) and at 60% exceedance (stress).

11.5.2 Low flow requirements (in terms of stress)

The stress index was used to identify required stress velocities at specific durations for the wet and dry month/season.

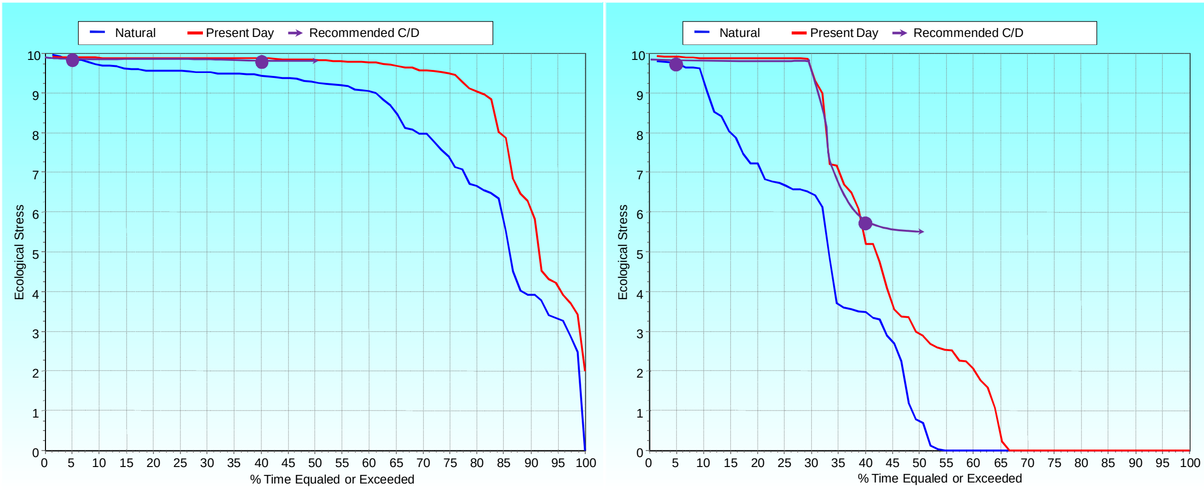
11.5.3 Low flow (in terms of stress) requirements

The flow requirements for the PES/REC EC of a C/D are provided in **Table 35**and graphically illustrated in **Figure 31**. The results were plotted for the wet and dry season on stress duration graphs and compared to the DRM low flow estimates for the same EC. The stress requirements (as a 'hand drawn line') are illustrated in **Table 31**.

Table 35: EWR 14: Species and integrated stress requirements as well as the final integrated stress and flow requirement

Stress Duration	Fish Stress requirement	Fish Flow requirement	Invert Flow requirement	Final* stress requirement	Flow requirement (m^3/s)
PES and REC: C/D		**FISH: C/D**		**INVERTEBRATES: C/D**	
DRY SEASON - JUL					
5%	9.9	0.028	Sufficient flow to maintain invert condition	**9.9**	**0.028**
20%	9.9	0.028		**9.9**	**0.028**
40%	9.87	0.037		**9.87**	**0.037**
WET SEASON - MAR					
5%	9.89	0.030	Sufficient flow to maintain invert condition	**9.89**	**0.030**
20%	9.89	0.03		**9.89**	**0.03**
40%	5.87	0.80		**5.87**	**0.80**

* Final refers to the final stress selected as the EWR requirement, i.e., the lowest stress.



Dry season (July) **Wet season (March)**

Figure 31: EWR 14: Stress duration curve for a PES and REC

As there was sufficient flow to maintain the invertebrates, **Table 35** provides the summarised motivations for the final requirements of the fish only.

Table 36: EWR 14: Summary of motivations

Month	**% Stress duration**	**Stress**	**Flow (m³/s)**	**Comment**
Instream PES and REC: C/D FISH: C/D INVERTEBRATES: C/D				
Jul	5% drought	9.90	0.028	**Fish:** Although this flow will result in very high stress levels for indicator species, it resembled a very high stress under natural flow during dry season droughts. Habitat suitability will be very low and just adequate to allow survival of the indicator species in stressed conditions.
	40% maintenance	9.87	0.037	**Fish:** This flow will result in high stress to the indicator fish species. Flows were however also very low under natural conditions and would have resulted in high stress levels (>9) under natural conditions. The habitat suitability for the indicator species will therefore be poor under these flows but adequate to maintain the indicator species during the dry season. The indicator species (BAEN) is a semi-rheophilic fish species that can survive in pools during the dry season, and hence the flows should be adequate to maintain adequate depth and water quality in some pools during the dry season.

Month	% Stress duration	Stress	Flow (m^3/s)	Comment
Mar	5% drought	9.89	0.03	**Fish:** Habitat suitability will be very low under these flows and no fast habitats will be available. Hence habitat will be unsuitable for especially spawning and nursery areas, but suitable to maintain the indicator fish assemblage. Based on the natural hydrology, stress would have been very high (>9) during droughts under natural conditions.
	40% maintenance	5.87	0.80	**Fish:** Although this stress level is relatively high, it will provide adequate fast habitats to meet the habitat requirements (for spawning, nursery, abundance and cover, connectivity and water quality) of the indicator fish species and should be adequate to maintain the present state.

11.5.4 Riparian vegetation flow requirements

The low flow requirements, set by the instream biotic components were checked (and modified if necessary) to ensure that it catered for any riparian vegetation (specifically marginal) requirements.

In the absence of surveyed vegetation data, assumptions are that sedges (*C. longus* and *C. denudatus*) and *Phragmites australis* grow at an elevation above the channel bed of about 0.6 to 0.9 m (as seen from photos – see Figure 32 below). The discharge required to inundate the base of these marginal zone communities is 0.6 to 2 m^3/s, and the first flood class is 3 m^3/s (daily average), required four times per annum which will inundate the marginal zone.

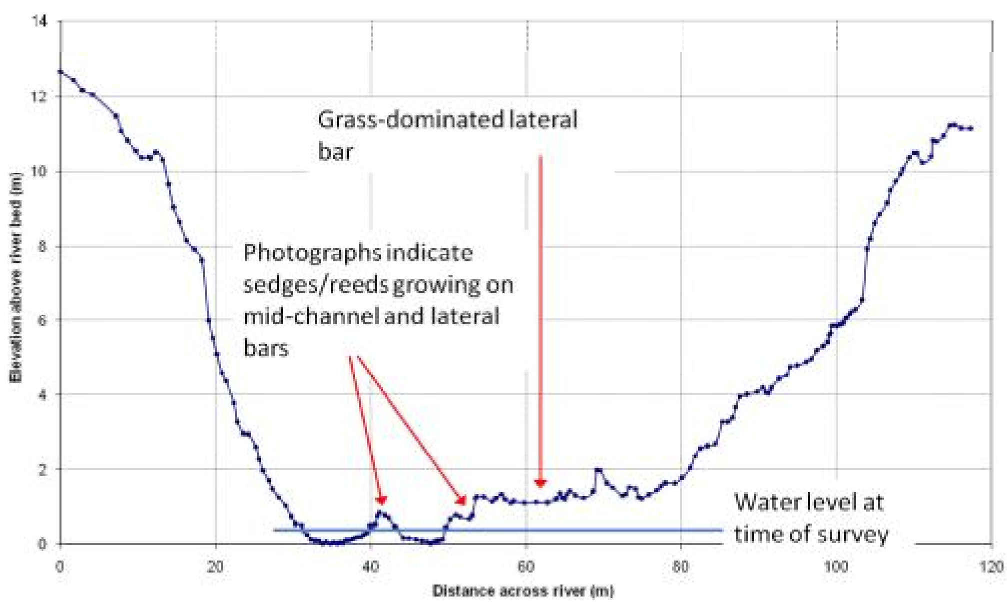


Figure 32: Assumed vegetation distribution at EWR 14

The low flows set by in-stream faunal requirements are provided in **Table 35**.

Table 37: Verification of low flow requirements for riparian vegetation

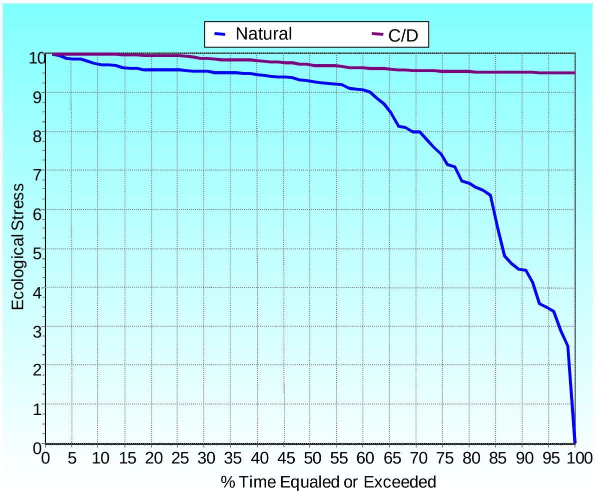
Season	Stress	Flow (m^3/s)	Elevation (m)	Comment
Dry (Jul)	9.9	0.028	0.2	Marginal zone vegetation rooting level is approximately 40 to 70 cm above water level. Some drought stress mortality is expected, especially of higher elevation individuals.
	9.87	0.037	0.25	Marginal zone vegetation rooting level is approximately 30 to 60 cm above water level. Some drought stress will occur, but flows should be sufficient to maintain acceptable proportion of survival.
Wet (Mar)	9.89	0.03	0.25	Marginal zone vegetation rooting level is approximately 35 to 65 cm above water level. Some drought stress mortality and reproductive failure is expected, especially of higher elevation individuals.
	5.87	0.8	0.7	Marginal zone vegetation is inundated up to 10 cm, which will prevent expansion towards the channel and maintain growing season transpiration demands. Flows of up to 2 m^3/s will also inundate the marginal zone and likely maintain the PES.

11.5.5 Final low flow requirements

To produce the final results, the DRM results for the specific category were modified according to specialists' requirements provided in **Figure 33**. There are a range of options one can use to make these modifications, such as changing the total volume required for the year, specific monthly volumes, either drought or maintenance flow durations, seasonal distribution and changing the category rules and shape factors. The following changes were required:

Parameter	MAR		JUL	
	DRM	EWR	DRM	EWR
High flow factors	1	1	0	0
Low Flow DC Shape	9	7	8	8
DC Upper % Shift	93	98	98	98
DC Lower % Shift	0	30	0	0
DC Low Flow Max.	130	183	130	0
High Flow DC Shape	9	9	8	8

Dry Season (July)



Wet Season (March)

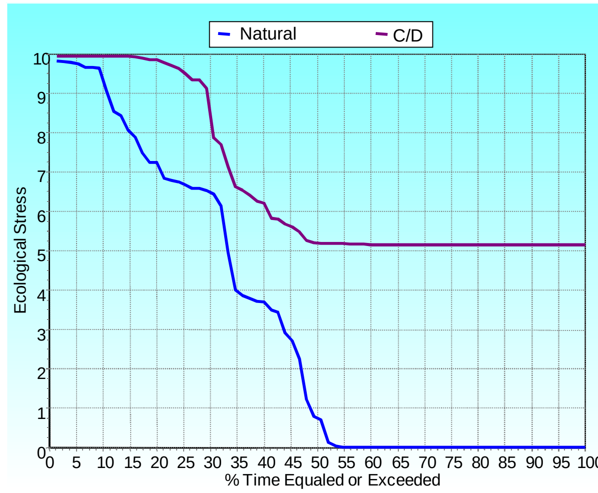


Figure 33: EWR 14: Final stress requirements for low flows

11.5.6 Final flow requirements

The low and high flows were combined to produce the final flow requirements for the PES/REC EC as:

- An EWR table, which shows the results for each month for high flows and low flows separately (**Table 38**). Floods with a high frequency were not included in the modelled results as they cannot be managed.

- An EWR rule table which provides the recommended EWR flows as a duration table, linked to a natural trigger (natural modelled hydrology in this case). EWR rules were supplied for total flows as well as for low flows only (**Table 39**).

The low flow EWR rule table is useful for operating the system, whereas the EWR table must be used for operation of high flows.

Table 38: EWR 14: EWR table for PES and REC: C/D

Desktop version:		**2**	**Virgin MAR (MCM)**	**145.79**
			Present Day MAR (MCM)	**118.04**
BFI index	**0.255**	**Distribution type**	**Vaal**	
MONTH	**LOW FLOWS**		**HIGH FLOWS**	
	Maintenance (m^3/s)	**Drought (m^3/s)**	**Daily average (m^3/s) on top of base flow**	**Duration (days)**
OCTOBER	0.153	0.003		
NOVEMBER	0.276	0.005	3 10	3 2
DECEMBER	0.333	0.006	10	2
JANUARY	0.447	0.008	3 10	3 2
FEBRUARY	0.484	0.008	3 10	3 2

			30	3
MARCH	0.444	0.008	3 10	3 2
APRIL	0.285	0.005		
MAY	0.166	0.003		
JUNE	0.112	0.002		
JULY	0.087	0.002		
AUGUST	0.095	0.002		
SEPTEMBER	0.133	0		
TOTAL MCM	7.880	0.136	16.969	
% OF VIRGIN	5.41	0.09	11.64	
% OF PD	6.68	0.12	14.38	
Total IFR	24.849			
% of VIRGIN MAR	17.04			
% of PD MAR	21.05			

Table 39: EWR 14: Assurance rules (m^3/s) for PES and REC: C/D

Desktop Version 2, Printed on 2012/10/10

Summary of IFR rule curves for: EWR3 Generic Name (EWR 14)

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: Vaal REC = C/D

Data are given in m^3/s mean monthly flow

% Points

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.299	0.289	0.270	0.112	0.030	0.026	0.026	0.022	0.011	0.005
Nov	4.725	3.748	2.542	1.246	0.332	0.031	0.027	0.027	0.023	0.019
Dec	0.749	0.717	0.649	0.535	0.385	0.232	0.030	0.026	0.015	0.011
Jan	2.776	2.327	1.905	1.466	0.896	0.557	0.295	0.034	0.026	0.019
Feb	7.866	6.257	4.787	3.664	2.059	1.339	0.219	0.041	0.029	0.025
Mar	3.671	3.528	3.225	2.715	2.033	0.952	0.194	0.037	0.034	0.026
Apr	0.604	0.585	0.546	0.477	0.377	0.257	0.145	0.063	0.020	0.009

May	0.323	0.313	0.292	0.205	0.116	0.067	0.045	0.037	0.013	0.005
Jun	0.202	0.196	0.183	0.161	0.128	0.089	0.051	0.023	0.008	0.003
Jul	0.154	0.149	0.123	0.067	0.052	0.037	0.034	0.019	0.007	0.003
Aug	0.172	0.037	0.034	0.034	0.034	0.030	0.030	0.020	0.007	0.003
Sep	0.249	0.039	0.031	0.029	0.027	0.027	0.027	0.022	0.005	0.002

Reserve flows without High Flows

Oct	0.301	0.297	0.289	0.112	0.030	0.026	0.026	0.022	0.022	0.005
Nov	0.600	0.595	0.585	0.568	0.332	0.031	0.027	0.027	0.023	0.009
Dec	0.757	0.750	0.737	0.714	0.674	0.549	0.030	0.026	0.022	0.011
Jan	1.047	1.037	1.019	0.986	0.929	0.830	0.295	0.034	0.026	0.015
Feb	1.134	1.123	1.104	1.070	1.010	0.907	0.219	0.041	0.029	0.015
Mar	1.041	1.031	1.014	0.985	0.934	0.847	0.194	0.037	0.034	0.014
Apr	0.608	0.600	0.585	0.558	0.513	0.419	0.166	0.077	0.039	0.009
May	0.324	0.318	0.307	0.205	0.116	0.067	0.045	0.037	0.026	0.005
Jun	0.203	0.198	0.188	0.171	0.144	0.108	0.068	0.033	0.011	0.003
Jul	0.154	0.149	0.123	0.067	0.052	0.037	0.034	0.019	0.007	0.003
Aug	0.172	0.037	0.034	0.034	0.034	0.030	0.030	0.028	0.010	0.003
Sep	0.250	0.039	0.031	0.029	0.027	0.027	0.027	0.027	0.013	0.002

Natural Duration curves

Oct	5.731	2.027	0.754	0.112	0.030	0.026	0.026	0.022	0.022	0.019
Nov	15.150	5.768	2.542	1.246	0.332	0.031	0.027	0.027	0.023	0.019
Dec	23.955	8.386	3.842	2.610	1.549	0.549	0.030	0.026	0.022	0.019
Jan	16.753	11.111	6.556	5.753	2.901	1.363	0.295	0.034	0.026	0.019

Feb	24.826	12.674	4.787	3.770	2.836	1.786	0.219	0.041	0.029	0.025
Mar	24.944	7.542	4.813	3.114	2.248	0.952	0.194	0.037	0.034	0.026
Apr	9.109	4.097	2.091	1.304	0.648	0.419	0.166	0.077	0.039	0.027
May	2.177	1.120	0.433	0.205	0.116	0.067	0.045	0.037	0.034	0.029
Jun	1.377	0.467	0.270	0.197	0.170	0.150	0.139	0.131	0.124	0.112
Jul	0.810	0.284	0.123	0.067	0.052	0.037	0.034	0.034	0.033	0.029
Aug	0.978	0.037	0.034	0.034	0.034	0.030	0.030	0.030	0.030	0.026
Sep	1.439	0.039	0.031	0.029	0.027	0.027	0.027	0.027	0.027	0.023

11.6 EWR 15 (FISANTKRAAL, VET RIVER): DETERMINATION OF STRESS INDICES

11.6.1 Indicator species or group

Fish indicator group

Refer to Section 11.5.1 (EWR 14).

Macroinvertebrate indicator group

Elmidae were used as indicator taxa. These taxa show a strong preference for the cobble biotope, with a moderate preference for flow velocities between 0.3 – 0.6 m/s, i.e. the moderate velocity range. These taxa occurred at the site during previous assessments (2007/10/01 and 2012/01/03).

11.6.2 Stress flow index

The species stress discharges in **Table 40** and **Table 41** indicate the discharge evaluated by specialists to determine the biota stress.

Table 40: EWR 15: Fish stress index and summarised habitat/biotic responses

Fish stress	**Flow (m^3/s)**	**Habitat and/or biotic responses**
0	9.5	Habitat suitability will be optimal and comparable to wet season conditions that may have occurred at site under reference (pre-disturbance) conditions.

Fish stress	Flow (m^3/s)	Habitat and/or biotic responses
1	7.6	Habitat suitability close to optimal but slightly reduced due to lower than natural abundance of fast habitats.
2	5.5	Habitat suitability will be very good and meets the requirements of all life stages and processes of the indicator species.
3	2.9	Overall increase in especially fast habitats will result in improved habitat suitability, being of overall good condition.
4	1.5	Increase availability (abundance) of habitat will provide more adequate habitats (still of overall moderate suitability) to meet the requirements of the indicator species.
5	1.0	An improvement in overall abundance of fast habitats will result in a notable improvement in the suitability of the habitat for the indicator species. Habitat suitability should be moderate for all aspects considered (spawning, nursery, abundance and cover, connectivity and water quality).
6	0.5	All fast habitats will be available for fish (FVS to FD) in moderate abundance. The habitats should be overall of low suitability for all aspects considered (e.g. spawning, nursery habitats, abundance and cover, connectivity and water quality).
7	0.4	All fast habitats will be available for fish (FVS to FD), albeit in relative low abundance. Habitat suitability for spawning habitats will still be very low, while the rest of the habitat requirements are of low suitability.
8	0.2	Habitat suitability very low for all life-stages and requirements of indicator species. Some FI, FS and FVS available (no FD).
9	0.1	Habitat of very low suitability for spawning, to provide for nursery areas, cover, connectivity and water quality and to maintain abundance of indicator species. Fast habitats limited to FVS and FS (no FI and FD).
10	0	Habitat unsuitable for provision of spawning, nursery areas, cover, maintenance of connectivity and water quality of indicator fish species.

Table 41: EWR 15: Invertebrate stress index and summarised habitat/biotic responses

Invertebrate stress	Flow (m^3/s)	Habitat and/or biotic responses
0	9.5	
1	6.9	Max. depth 1.2 m; ave. depth 0.47 m; ave. velocity; 0.53 m/s; max. velocity 1.53 m/s. 13% FCS, 14%VFCS, 3% VEG.
2	4.9	Max. depth 1.05; ave. depth 0.4; ave. velocity; 0.54 m/s; max. velocity 1.58 m/s. 12% FCS, 15%VFCS, 3% VEG.
3	3.3	Max. depth 0.90; ave. depth 0.37; ave. velocity; 0.54 m/s; max. velocity 1.59 m/s. 12% FCS, 15%VFCS, 3% VEG.
4	2.1	Max. depth 0.75; ave. depth 0.29; ave. velocity; 0.54 m/s; max. velocity 1.65 m/s. 12% FCS, 15%VFCS, 3% VEG.
5	1.5	Max. depth 0.65; ave. depth 0.23; ave. velocity; 0.55 m/s; max. velocity 1.63 m/s. 12% FCS, 16%VFCS, 3% VEG.
6	0.8	Max. depth 0.5; ave. depth 0.25; ave. velocity; 0.59 m/s; max. velocity 1.73 m/s. 11% FCS, 17%VFCS, 5% VEG.
7	0.5	Max. depth 0.4; ave. depth 0.27; ave. velocity; 0.52 m/s; max. velocity 1.57 m/s. 12% FCS, 14%VFCS, 6% VEG.
8	0.2	Max. depth 0.25; ave. depth 0.16; ave. velocity; 0.4 m/s; max. velocity 1.24 m/s. 15% FCS, 8%VFCS, 3% VEG.
9	0.1	Max. depth 0.15; ave. depth 0.07; ave. velocity; 0.35 m/s; max. velocity 1.02 m/s. 16% FCS, 6%VFCS.
10	0	

11.6.3 EWR 15 (FISANTKRAAL, VET RIVER): DETERMINATION OF EWR SCENARIOS

Based on the review and suggested changes for vegetation and fish, the PES EcoStatus was a C/D and not a D/E as reported in DWA (2010a). The EIS was MODERATE and therefore the REC was set to maintain the PES.

The most significant flow related problems were:

- A decrease in all the flow components, especially in the moderate to high flows. This was due to Allemanskraal Dam (Sand River) and Erfenis Dam (Vet River) higher up in the catchment. Base flows have also been reduced, mainly due to run-of-river abstractions for irrigation downstream of the dams.

The revised EcoClassification results are summarised in the **Table 42** below. The ECs in red refer to those that have changed in Category from the Reserve study undertaken during 2007 - 2010.

Table 42: Summary of EcoClassification results

EWR 15			
Components	**PES**	**EIS**	**REC**
Hydrology	C	MODERATE	C
Physico-chemical	C		C
Geomorphology	C		C
Fish	C		C
Invertebrates	D		D
INSTREAM	C/D		C/D
Riparian vegetation	C/D		C/D
ECOSTATUS	C/D		C/D

EWR site	**ECOCLASSIFICATION**			
	Original PES	**Refined PES**	**Original REC**	**Refined REC**
EWR 15	D/E	C/D	D	C/D

11.6.4 Hydrological considerations

The driest and wettest months were identified as August and February respectively. Droughts were set at 95% exceedance (flow) and 5% exceedance (stress). Maintenance flows were set at 40% exceedance (flow) and at 60% exceedance (stress). For the application of the DRM the PD hydrology was used as reference hydrology because PD hydrology was higher than natural during the dry season. Refer to Section 4.2 for detailed discussion.

11.6.5 Low flow requirements (in terms of stress)

The stress index was used to identify required stress velocities at specific durations for the wet and dry month/season.

The flow requirements for the PES/REC are provided in **Table 43** and graphically illustrated in **Figure 34**. The results were plotted for the wet and dry season on stress duration graphs and compared to the DRM low flow estimates for the same EC. The stress requirements (as a 'hand drawn line') are illustrated in **Figure 34**.

Table 43: EWR 15: Species and integrated stress requirements as well as the final integrated stress and flow requirement

Stress Duration	Fish Stress requirement	Fish Flow requirement	Invert Flow requirement	Final* stress requirement	Flow requirement (m^3/s)
PES and REC: C/D		**FISH: C**		**INVERTEBRATES: D**	
DRY SEASON - JUL					
5%	7.58	0.26	Sufficient flow to maintain invert condition	**7.58**	**0.26**
20%	6.53	0.42		**6.53**	**0.42**
40%	5.94	0.50		**5.94**	**0.50**
WET SEASON - MAR					
5%	5.59	0.68	Sufficient flow to maintain invert condition	**5.59**	**0.68**
20%	4.58	1.19		**4.58**	**1.19**
40%	3.63	2.00		**3.63**	**2.00**

* Final refers to the final stress selected as the EWR requirement, i.e., the lowest stress.

The situation at EWR 15 is similar to EWR 12 in that higher PD flows than natural exists at EWR 15. The specific scenario provided on which the EWR scenario assessment is based on is flows that are decreased from PD flows. In essence a range of flows is described at the durations where more flows than natural occur. This range will be from the PD flows, to the flows described in the above table and on which the EWR estimate is based. It is acknowledged that flows can be increased from the present dam releases, but there are not specific indicators to clearly determine an upper range. In this situation, it would be easier to evaluate any such a scenario if it ever becomes a possibility.

Dry Season (July) **Wet Season (March)**

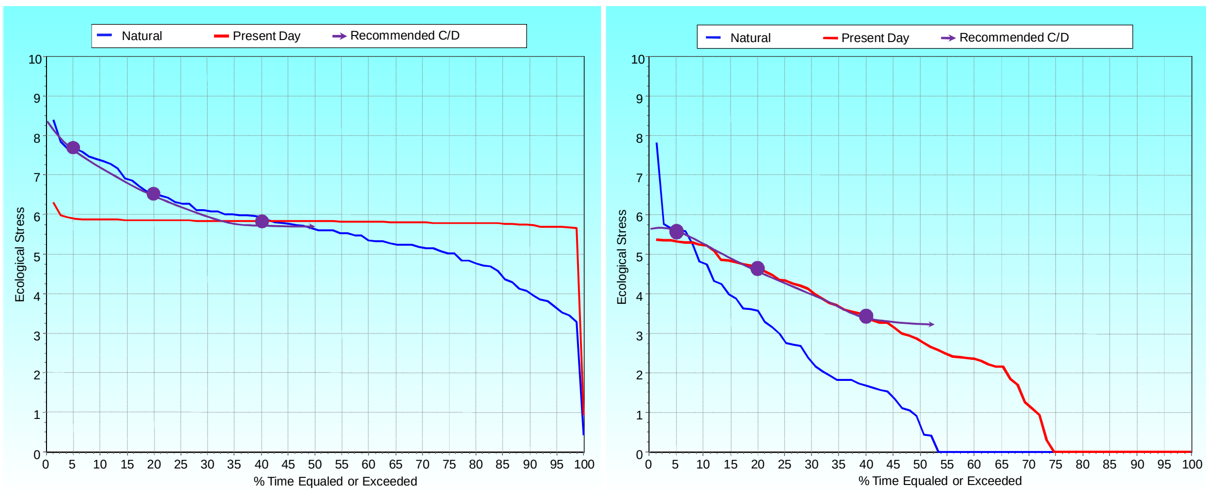


Figure 34: EWR 15: Stress duration curve for a PES and REC

As there was sufficient flow to maintain the invertebrates, **Table 44** provides the summarised motivations for the final requirements of the fish only.

Table 44: EWR 15: Summary of motivations

Month	**% Stress duration**	**Stress**	**Flow (m^3/s)**	**Comment**
PES and REC: C/D		**FISH: C**		**INVERTEBRATES: D**
Jul	5% drought	7.58	0.26	**Fish:** Based on the hydrology, there is more flow at this site under present conditions than under natural conditions, and hence lower stress than under natural conditions. The approach followed was therefore to use the reference stress (flow) as a benchmark to set the dry season drought flows. It is therefore estimated that drought flows could be reduced to the level of natural flows (0.26 m^3/s) but should not be allowed lower than this. This is because the other flow

Month	% Stress duration	Stress	Flow (m^3/s)	Comment
				durations (lower flow durations) have lower flows under present conditions compared to natural and hence higher stress. There is therefore a risk that should the stress be increased to more than natural during drought conditions, the overall EC may be reduced. Habitat suitability at this flow is therefore estimated to be adequate to maintain the PES (should the maintenance flows be met).
	40% maintenance	5.94	0.50	**Fish:** The PD flows are higher than under natural conditions (in the higher flow duration scale, including 60% and 95% durations). The approach was therefore followed to use the natural flows as a gauge to determine the maintenance flow to maintain the PES. The flows, and stress level, recommended are therefore close to natural conditions during dry season and should be adequate to maintain the PES. It must however be emphasized that the lower flow durations will follow the PD curve as a guide. The habitat suitability for the indicator species at this flow is therefore expected to be more than adequate to maintain the indicator species during the dry season.
Mar	5% drought	5.6	0.68	**Fish:** A similar scenario as described above for the dry season exists for the wet season drought, where there is currently more flow than natural during this flow duration period. The flow set to maintain the PES during wet season droughts is therefore taken as the reference (natural) flow for this period. Habitat suitability will be moderate at this flow/stress level, and suitable to maintain the indicator fish assemblage.
	40% maintenance	3.6	2.0	**Fish:** This recommended flow is only slightly lower than the PD flow. Further decrease can however not be allowed due to the fact that increased stress may now occur on the drought end of the scale (when reduced from present towards natural flows). This stress level is therefore low and will allow very good habitat suitability to maintain the indicator species. This is however the most important season to ensure a healthy assemblage (spawning and nursery period), and therefore important to ensure the maintenance of the PES overall.

11.6.6 Riparian vegetation flow requirements

The low flow requirements, set by the instream biotic components were checked (and modified if necessary) to ensure that it catered for any riparian vegetation (specifically marginal) requirements.

In the absence of surveyed vegetation data, assumptions were that sedges (*C. longus* and *C. denudatus*) grow in a narrow band along the active channel as well in the lower lying seasonal channel/back-water, at an elevation above the channel bed of about 0.4 to 0.8 m (as seen from photos – see **Figure 35** below). The discharge required to inundate the base of the marginal zone community was 0.5 to 2.4 m^3/s. *Salix mucronata* is likely to occur in the region of 1.6 m above the channel bed, which requires a flow of about 14 m^3/s for inundation to begin. A Class 1 flood was not specified originally for vegetation. This was reviewed and details are provided in Appendix A.

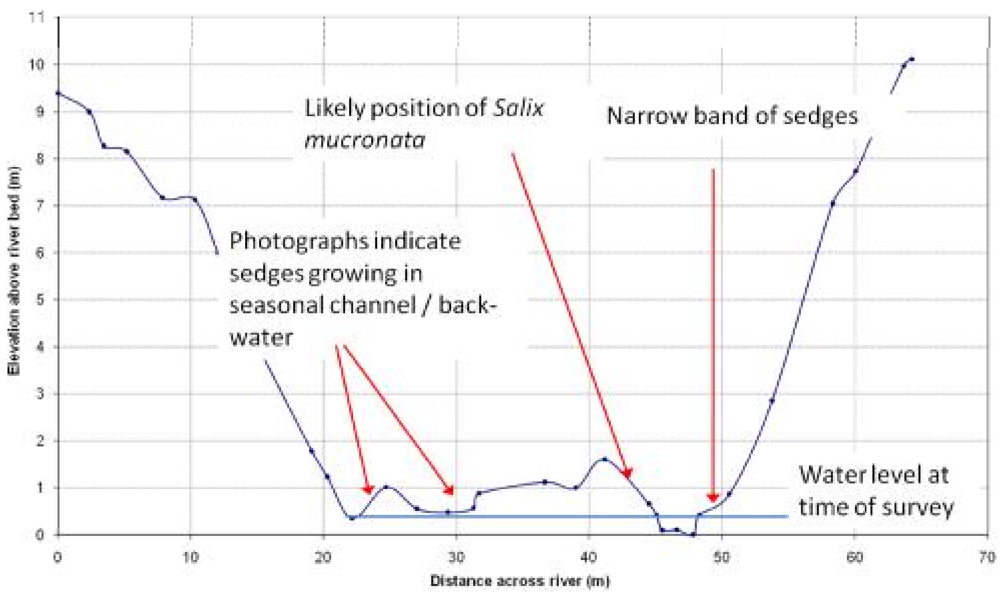


Figure 35: Assumed vegetation distribution at EWR 15

The low flows set by instream faunal requirements are provided in **Table 45**.

Table 45: Verification of low flow requirements for riparian vegetation

Season	Stress	Flow (m^3/s)	Elevation (m)	Comment
Dry (Jul)	7.58	0.26	0.3	Marginal zone vegetation rooting level was approximately 10 to 50 cm above water level. Some drought stress mortality is expected, especially of higher elevation individuals.
	5.94	0.5	0.42	Marginal zone vegetation rooting level was approximately 0 to 40 cm above water level. Flows are sufficient to maintain high proportion of

Season	Stress	Flow (m^3/s)	Elevation (m)	Comment
				survival.
Wet (Mar)	5.6	0.68	0.48	Marginal zone vegetation rooting level was partially inundated (up to 10 cm below water level) and ranging to 30 cm above water level. This is not really a drought flow for vegetation and no drought stress is likely to occur. Marginal and lower zone vegetation will continue to flourish as if a maintenance flow was occurring.
	3.6	2	0.74	Marginal and lower zone vegetation is inundated up to 35 cm, which will prevent expansion towards the channel and maintain growing season transpiration demands. Flows could be increased up to 1.2 m^3/s and still maintain the PES.

11.6.7 Final low flow requirements

To produce the final results, the DRM results for the specific category were modified according to specialists' requirements. There are a range of options one can use to make these modifications, such as changing the total volume required for the year, specific monthly volumes, either drought or maintenance flow durations, seasonal distribution and changing the category rules and shape factors. The following changes were required:

Parameter	MAR		JULY	
	DRM	EWR	DRM	EWR
High flow factors	1	1	0	0
Low Flow DC Shape	9	4	8	4
DC Upper % Shift	93	100	98	100
DC Lower % Shift	0	20	0	10
DC Low Flow Max.	130	260	130	200
High Flow DC Shape	8	15	8	4

Dry Season (July) **Wet Season (March)**

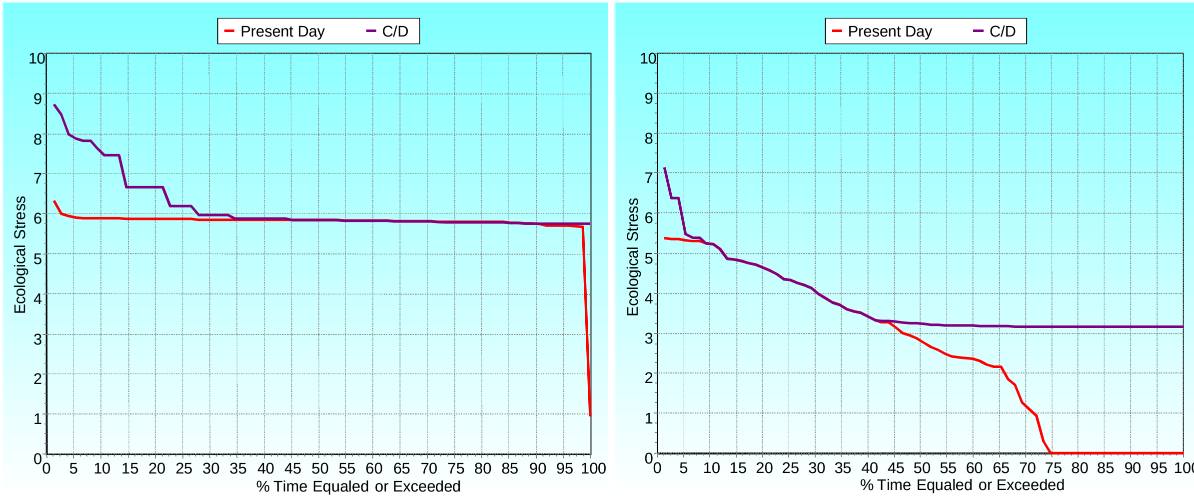


Figure 36: EWR 15: Final stress requirements for low flows

11.6.8 Final flow requirements

As PD hydrology was used as reference flows in the DRM the comparative percentages of the EWR are provided for both natural (virgin) and PD hydrology. The low and high flows were combined to produce the final flow requirements for the PES/REC EC as:

- An EWR table, which shows the results for each month for high flows and low flows separately (**Table 45**). Floods with a high frequency were not included in the modelled results as they cannot be managed.
- An EWR rule table which provides the recommended EWR flows as a duration table, linked to a natural trigger (natural modelled hydrology in this case). EWR rules were supplied for total flows as well as for low flows only (**Table 46**).

The low flow EWR rule table is useful for operating the system, whereas the EWR table must be used for operation of high flows.

Table 46: EWR 15: EWR table (m^3/s) for PES and REC: C/D

Desktop version:	**2**	**Virgin MAR (MCM)**	**413.04**
		Present Day MAR (MCM)	**253.152**
BFI index	**0.266**	**Distribution type**	**Vaal**
MONTH	**LOW FLOWS**	**HIGH FLOWS**	

	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s) on top of base flow	Duration (days)
OCTOBER	0.25	0.142		
NOVEMBER	0.42	0.135	5 20	7 2
DECEMBER	0.446	0.071	5 20	7 2
JANUARY	0.67	0.34	5 20 70	7 2 5
FEBRUARY	0.857	0.327	5	7
MARCH	0.849	0.213	5	7
APRIL	0.701	0.17		
MAY	0.403	0.269		
JUNE	0.227	0.177		
JULY	0.129	0.129		
AUGUST	0.13	0.13		
SEPTEMBER	0.19	0.19		
TOTAL MCM	13.766	5.999	32.309	
% OF VIRGIN	3.33	1.45	7.82	
% OF PD	5.44	2.37	12.76	
Total IFR	46.075			

% of VIRGIN MAR	11.16
% of PD MAR	18.20

Table 47: EWR 15: Assurance rules (m^3/s) for PES and REC: C/D

Desktop Version 2, Printed on 7/27/2012

Summary of IFR rule curves for: EWR4 (EWR 15)

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: Vaal   REC = C/D

Data are given in m^3/s mean monthly flow

% Points

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.711	0.710	0.703	0.690	0.664	0.617	0.539	0.422	0.279	0.166
Nov	9.932	8.041	3.773	2.527	1.705	1.096	0.829	0.691	0.613	0.515
Dec	1.357	1.353	1.296	1.126	0.825	0.492	0.252	0.133	0.090	0.079
Jan	21.747	11.720	6.668	4.951	3.446	2.698	1.618	1.161	0.877	0.638
Feb	2.778	2.778	2.650	2.202	1.476	0.850	0.517	0.391	0.351	0.342
Mar	7.213	7.213	6.878	4.742	3.543	2.028	1.049	0.655	0.526	0.492
Apr	2.133	2.127	2.046	1.810	1.381	0.884	0.500	0.292	0.209	0.184
May	1.167	1.162	1.124	0.952	0.806	0.640	0.457	0.344	0.293	0.277
Jun	0.610	0.607	0.595	0.566	0.510	0.426	0.330	0.247	0.198	0.180
Jul	0.315	0.314	0.312	0.309	0.302	0.291	0.272	0.240	0.192	0.138
Aug	0.330	0.328	0.322	0.307	0.280	0.241	0.198	0.161	0.139	0.131
Sep	0.502	0.500	0.496	0.488	0.471	0.441	0.390	0.317	0.236	0.192

Reserve flows without High Flows

Oct	0.711	0.710	0.706	0.697	0.681	0.651	0.598	0.506	0.360	0.189
Nov	1.236	1.234	1.226	1.209	1.178	1.096	0.829	0.691	0.531	0.190
Dec	1.357	1.355	1.346	1.327	1.290	1.219	1.085	0.847	0.466	0.079
Jan	2.106	2.105	2.093	2.067	2.016	1.916	1.726	1.161	0.831	0.351
Feb	2.778	2.778	2.762	2.729	2.663	2.331	1.546	1.215	0.885	0.342
Mar	2.532	2.532	2.518	2.488	2.430	2.317	1.508	1.198	0.870	0.332
Apr	2.133	2.131	2.117	2.091	1.833	1.416	1.030	0.837	0.741	0.337
May	1.167	1.165	1.159	0.952	0.806	0.698	0.653	0.620	0.605	0.374
Jun	0.610	0.608	0.603	0.592	0.570	0.531	0.466	0.371	0.260	0.180
Jul	0.315	0.314	0.311	0.305	0.295	0.278	0.251	0.212	0.167	0.134
Aug	0.330	0.329	0.326	0.321	0.310	0.292	0.261	0.218	0.168	0.131
Sep	0.502	0.500	0.496	0.488	0.471	0.441	0.390	0.317	0.236	0.192

Natural Duration curves

Oct	5.458	2.722	1.456	1.225	0.747	0.683	0.638	0.616	0.590	0.571
Nov	17.708	9.942	3.773	2.527	1.705	1.096	0.829	0.691	0.613	0.571
Dec	16.054	8.098	4.103	3.192	2.438	1.889	1.113	0.881	0.661	0.620
Jan	38.482	11.720	6.668	4.951	3.446	2.890	2.001	1.161	0.877	0.638
Feb	51.372	23.280	9.788	5.783	3.679	2.331	1.546	1.215	0.885	0.682
Mar	40.121	17.671	7.389	4.742	3.543	2.445	1.508	1.198	0.870	0.803
Apr	39.032	14.653	4.730	2.832	1.833	1.416	1.030	0.837	0.741	0.667
May	9.065	4.439	1.217	0.952	0.806	0.698	0.653	0.620	0.605	0.590
Jun	2.141	1.200	0.872	0.760	0.687	0.671	0.652	0.648	0.633	0.610

Jul	0.605	0.582	0.575	0.564	0.556	0.553	0.549	0.541	0.538	0.478
Aug	1.538	0.706	0.624	0.579	0.560	0.549	0.541	0.538	0.530	0.530
Sep	3.318	1.385	0.799	0.799	0.791	0.787	0.775	0.756	0.714	0.621

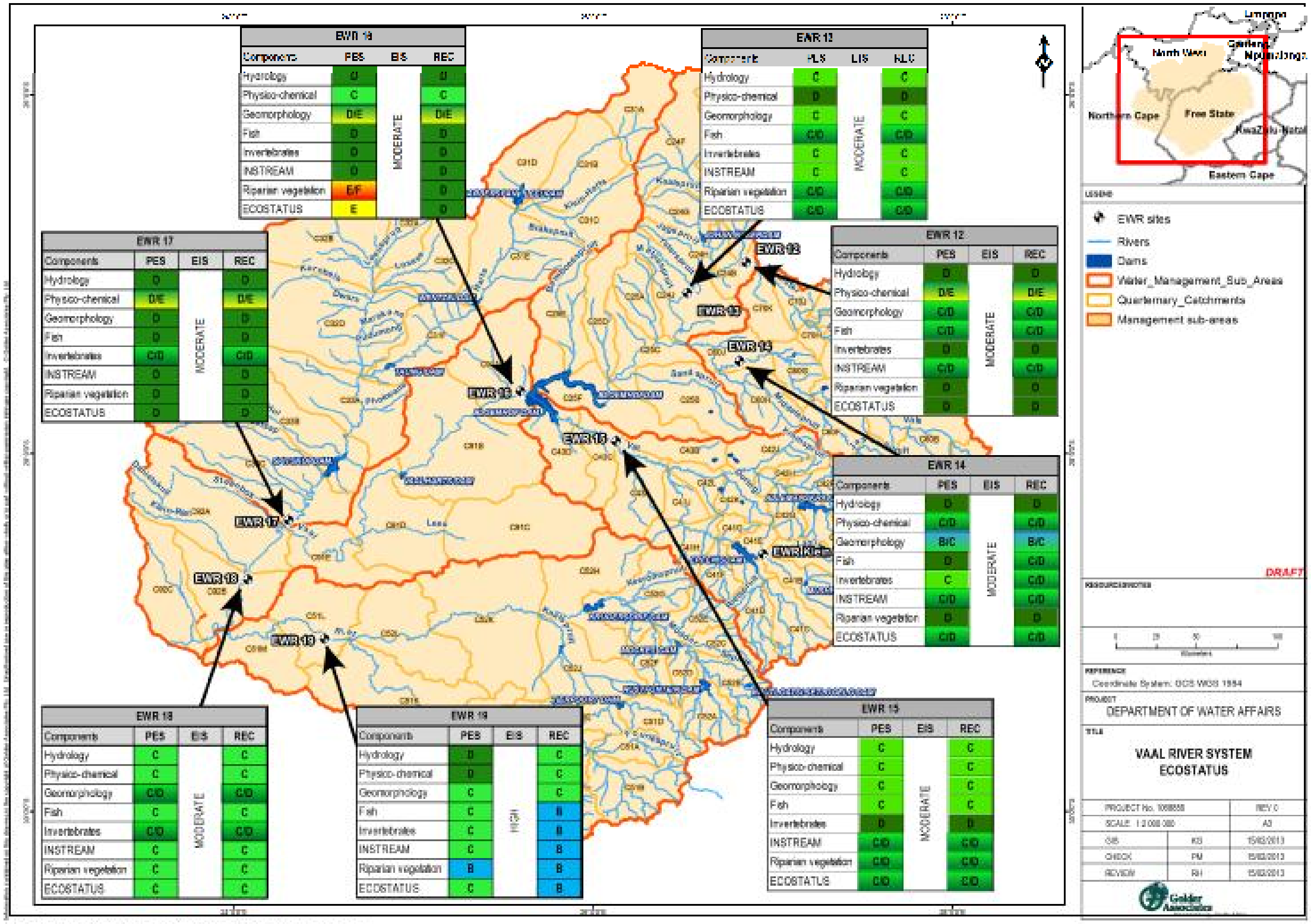


Figure 37: Summary of the MAR at the EWR sites within the Middle and Lower Vaal Catchments

12 WATER QUALITY

The water quality of the Vaal River in the Middle Vaal WMA was generally poor due to high dissolved salts and high nutrients, e.g. the Vaal River at Orkney (C2H007) was characterised by unacceptable high EC (90 mS/m; ~630 mg TDS/ℓ), P concentration (0.224 mg/ℓ) and pH (9.11).

The water quality in the Renoster River (C7H006) and Sandspruit (C2H067) was fair in terms of salts (331 & 373 mg/ℓ), but poor in terms of nutrients, 0.080 and 0.118 mg PO4-P/ℓ respectively.

Koekemoerspruit (C2H139) and Skoonspruit (C2H073) are hotspot areas with unacceptable high salts concentrations, 1 760 and 987 mg/ℓ respectively. The salt load evidently originates from the mining activities and the high nutrients draining from the KOSH urban area.

Another problem area is the Sand River at Bloudrift (C4H016) with unacceptable high salts (2 415 mg/ℓ) from the Welkom-Virginia gold mines and very high nutrients (nitrate, 1.05; P, 0.50 mg/ℓ), evidently from poorly treated sewage effluent.

The water quality in the Vals River at Kroonstad (C6H007) was fair with ideal ammonia, sulphate and nitrate concentrations, acceptable pH (8.39), and salts (316 mg/ℓ), but with unacceptable high phosphate concentration (0.080 mg/ℓ). However, the Vals River at Bothaville (C6H002) was in a poor state with high salts concentration (837 mg/ℓ), probably originating mainly from seepage water and return flows from irrigation, unacceptable high pH (8.69) and phosphate concentration (0.90 mg/ℓ).

The water quality in Erfenis Dam (C4R002) was generally good except for the very high phosphate concentrations (0.126 mg/ℓ) that indicate a serious potential for algal productivity. However, the water quality in the lower section of the Vet River (C4H004) was poor with high salts (666 mg/ℓ) and high nutrients concentrations (phosphate, 0.088 mg/ℓ).

All the parameters in Heuningspruit at Dankbaar Mispah (C7H003) were ideal, except for the unacceptable P concentrations (0.194 mg/ℓ) that results in a poor quality. A summary of the Water Quality (WQ) PES is shown in Figure 38.

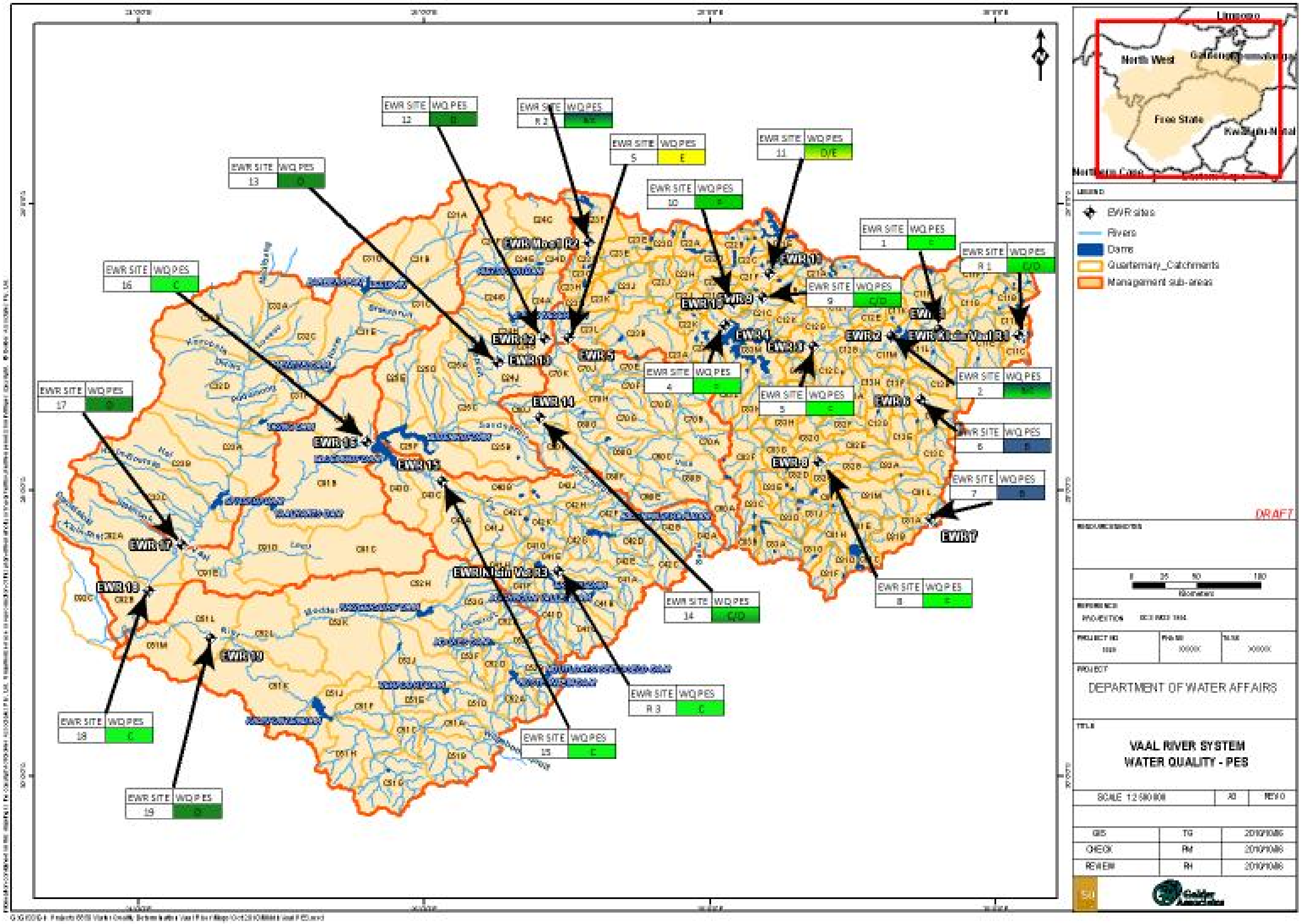


Figure 38: Summary of the Water Quality PES of the EWR sites within the Upper, Middle and Lower Vaal Catchments

12.1 Impacts of the mining activities and mine closure

The economy of the Middle Vaal WMA is dominated by the mining sector, with a contribution of 45.6 % to GGP, particularly gold mining. However, discharges from mines impact significantly on both the hydrology and water quality of the Middle Vaal system. The impacts from the gold mining activities on groundwater have been recognised as early as 1960 when localised dewatering became an issue at Stilfontein Gold Mine. Only more recently have the impacts on the quality of the groundwater and the interaction with the Vaal River becomes a concern. The largest volumes are abstracted at Stilfontein Gold Mine's Margaret Shaft. Although Stilfontein's underground operations has ceased for more than ten years, pumping at Margaret shaft continues for the safety of the downstream mines. The volume of water abstracted daily is estimated at 32 Mℓ/d. The water is utilized by a number of users and any excess is discharged to the Koekemoer Spruit. Groundwater is also abstracted from other operating shafts in the KOSH mining area for safety and the water is utilized as process water Due to the large quantities of water present in the mined Witwatersrand rocks, a large quantity of water (120 -150 Mℓ/d) is pumped to the surface for accessibility each day. This groundwater however has average conductivities of 500 mS/m (~3 500 mg/ℓ) and cannot be used for drinking or irrigation purposes (DWAF, 2004g).

Water quality in the Vaal River is of serious concern because of high salinity and nutrient content, which mainly results from urban and industrial return flows as well as mining activities in the Upper Vaal WMA. The closure of mines may have further water quality impacts.

12.2 Management of wastewater treatment works discharges

A large proportion of the sewage emanating from SA urban areas is not treated properly prior to discharge, because the sewer systems are incomplete, or sewage treatment plants are overloaded (Oberholster & Ashton, 2008; Green Drop, 2009a).Matjhabeng Local Municipality (Welkom, Odendaalsrus, Virginia, Hennenman, Allanridge and Ventersburg) with 11 sewage purification plants and the Moqhaka municipality (Kroonstad, Maokeng, Steynsrus and Viljoenskroon) have failed to present information to DWA for the Green Drop certification and are classified with zero Green Drop scores. These local municipalities have been implicated for polluting the local rivers and lakes with poorly treated sewage and occasionally raw sewage spills.

Municipal wastewater treatment plants, not complying with effluent standards and informal, unsewered human settlements along the river banks or in the close vicinity of the Vaal River, pose a threat to regional water quality, especially eutrophication (nutrient enrichment) and human health. There is a general non-compliance to phosphate RWQO throughout the WMA.

Sewage wastewater, by its nature, is teeming with microbes. Therefore, from a social perspective, the discharge of sewage effluent into the natural environment can have negative impacts on human health, primarily from bacteriological and other forms of pathogens that survive the biological treatment process and inadequate disinfection of the effluent. Water related diseases kill a child every 8 seconds, and are responsible for 80 % of all illnesses and deaths in the developing world (UNEP/WHO, 2006).

However, Municipal wastewater effluent is also one of the impacts that is most easy to mitigate because they are easily identified, measured, and susceptible to control by policies and regulation.

12.3 Eutrophication

The Vaal River in the Middle Vaal WMA experience regular algal blooms and has been classified as hypertrophic (nutrient over-enriched), that cause several problems to man and the environment. Eutrophication effects and problems are profound in the Vaal River and have become a matter of major concern to all water users. The impacts of eutrophication are ecological, social and economical. Infestations of alien vegetation are also found along the Vaal River (DWAF, 2009d).

Erfenis, Koppies and Allemanskraal Dams are classified as oligotrophic, however, toxic cyanobacterial incidents have been recorded. Bloemhof Dam is eutrophic and experience cyanobacterial blooms usually dominated by Microcystis spp. and Oscillatoria sp. (Van Ginkel, 2004).

Cyanobacterial blooms (frequency and intensity) in the Vaal River are increasing. As cyanobacterial blooms become more common, the likelihood grows that people will be exposed to increased doses of toxins and the risk of animal die-offs grows as well (DWAF, 2009d).

12.4 Urbanisation

Over 75 % of the population in the WMA are classified as living in urban areas, and about 25 % as rural. Most of the population are concentrated in the main urban and mining centres of Klerksdorp, Orkney and Stilfontein in the Middle Vaal sub-area; Welkom and Virginia in the Sand-Vet sub-area, as well as Kroonstad (which is not a mining town) in the Rhenoster-Vals sub-area. South Africa’s freshwater resources are under increasing stress from a growing population and an expanding economy.

12.5 Water transfers and availability

Substantial transfers take place from the Upper Vaal to the Middle Vaal (790 Mm^3/a). However, there are no large control structures with respect to the regulation of flow in the Vaal River within the Middle Vaal WMA, and both the quantity and quality of water in the Vaal River are largely influenced by management practices in the Upper Vaal WMA. There are existing weirs on the Vaal River at Orkney and Balkfontein. Water from tributaries as well as from groundwater in the water management area is fully utilised, mainly for irrigation and for towns remote from the Vaal River (DWAF, 2003b).

12.6 Hydrology

The hydrology of the Middle Vaal WMA is impacted in the main stem of the Vaal by the Vaal Dam and Vaal Barrage (completed in 1919). The flow regime in the main stem of the Vaal is impacted by the following:

- Vaal Dam storage
- Releases from Vaal Dam to dilute salts to 600 mg/L TDS (mainly in winter)
- Releases from Vaal Dam and Vaal River Barrage to supply the Vaal Hartz irrigation scheme (completed 1938)

- Interbasin transfers into the Vaal from Lesotho and Grootdraai Dam

This altered flow regime has resulted in increased winter base flows in the Middle Vaal River and smaller floods being reduced in summer.

Due to this regulation having being implemented in varying degrees for 90 years the aquatic organisms have adapted and the river banks are stable.

In the Vals and Vet Rivers the hydrology has changed due to increase irrigation usage, upstream dams and urban requirements. These rivers have less flow in winter as well as summer due to these anthropogenic changes.

13 DEVELOPMENT OF OPERATIONAL SCENARIOS

13.1 Overview and objective

The Ecological Water Requirement (quantity) scenarios developed are as sets of possible flows to achieve different river states (or Ecological Categories) for each EWR. This process did not consider whether these flows could be supplied or managed. To provide decision makers with more comprehensive information, it is necessary to examine each of the scenarios and their full range of implications. Thereafter, a process was followed to devise an optimised scenario (if necessary) that would have the least overall impact on the users and the ecology. All these operational scenarios were tested to determine the resulting state of the river, and the water quality consequences of each flow scenario were supplied.

The objectives of this task were to develop a range of operational scenarios that result in different impacts on different users. The impacts of incorporating the EWR on the ecology, system yield, services and overall economic activities could then be assessed.

13.2 Method

The purpose of this step (step 5) in the 8 step Reserve process is to predict the driver and biotic responses to each operational scenario, including natural and present day hydrology and derive the ecological categories for each EWR site. All information generated during steps 3 (ecoclassification) and step 4 (determination of Ecological Water Requirement) is used during this step.

The following steps were followed to determine the ecological consequences of the operational flow scenarios.

- The operational scenarios (DWA, 2010a) were modelled using the WRPM and a time series was provided for each scenario at each EWR site.

- The time series was converted to a flow duration table and both was provided to the physico chemical and geomorphology specialists.

- The impacts of these time series of the operational scenarios were analysed by the physico chemical and geomorphology specialists by completion of the Physico-chemical Assessment Index (PAI) and Geomorphology Assessment Index (GAI) models to predict the driver ecological category.

- The riparian vegetation specialist then assessed the response on the marginal and other riparian zones and supplied this information to the in-stream biotic specialists (macroinvertebrates and fish).

- Where required, the riparian vegetation specialist ran the Vegetation Response Assessment Index (VEGRAI) model to predict the ecological category for each operational scenario.

The following in-stream biotic assessment was then undertaken:

- Each time series was converted into a stress duration table and provided on a graph for the same months as evaluated during the EWR workshop.

- The requirements set for the low flow EWR scenarios for both fish and macroinvertebrates were copied onto these graphs.

- The operational scenarios were then compared to the EWRs set for the various ecological categories.

- If it was not obvious what the resulting category was, the stress and habitat implications for the operational scenario were investigated and the responses modelled in the Fish Response Assessment Index (FRAI) and Macro invertebrate response Assessment Index (MIRAI) to determine the ecological category.

- The VEGRAI, MIRAI and FRAI results were then used as input to the Ecostatus model to determine the resulting ecological category per operational scenario.

13.3 Results

Table 48 provides a summary of the operational scenarios that were modelled using the WRPM. Detailed information regarding the operational scenarios is documented in report RDM/C000/00/CON/0607.

Table 48: Summary of the operational scenarios evaluated

Sc No	Dev Level	EWR Status	Scenario description	Reasoning
1	2008	Excluded	Base scenario representing the status quo.	This is a new PRESENT DAY. This scenario was not evaluated, but differences from the old PD were noted and reasoning was provided.
4	2008	Included	Based on Scenario 1. EWR Scenario: With exception of EWR 4 and EWR 5, all EWRs in Vaal and one EWR in Thukela downstream of Driel Barrage were included.	Although EWRs are provided as a demand, it was still evaluated. One EWR site (e.g. in the Lower Vaal), could drive the requirements and result in unacceptable situations at EWR sites in the Upper Vaal (too much flow e.g.). NB: The EWR was included as a priority demand and this has a knock on effect on other users, and the operation rules of dams. This is relevant for all

Sc No	Dev Level	EWR Status	Scenario description	Reasoning
				scenarios where dams are included.
5	2020	Excluded	Sc 1 representing the future 2020 development conditions excluding the EWRs. Includes VRESSAP pipeline from Vaal Dam to Eastern Sub-system. Includes proposed Polihali Dam and conveyance infrastructure. Includes proposed re-use of mine water. Includes projected possible transfer to the Crocodile catchment.	Key scenarios. Includes most likely future developments and illustrates resulting flows at EWR sites. NO EWRs were included as a demand in the system. Basically, this is the WHAT IF scenarios, i.e., what if we manage the system in this manner without providing EWRs – will the EcoStatus change and if so, how much.
6	2020	Included	Based on Sc 5. EWR Scenario: With exception of EWR 4 and EWR 5, all EWRs in Vaal and one EWR in Thukela downstream of Driel Barrage were included.	Combination of Sc 5 and Sc 4.
7	Full utilization (Future development scenario)	Excluded	Scenario representing the full utilization of available water. Based on current infrastructure. Includes VRESSAP pipeline from Vaal Dam to Eastern Sub-system.	This is also a future scenario, but brings in new developments apart from the VRESSAP pipeline. Full utilisation means that there is allocated water, or water available in dams, which have not been used yet.
8	Full utilization (Future development scenario)	Included	Based on Sc 7. EWR Scenario: With exception of EWR 4 and EWR 5, all EWRs in Vaal and one EWR in Thukela downstream of Driel Barrage were included.	Combination of Sc 7 and Sc 4.

14 ECOLOGICAL CONSEQUENCES OF THE OPERATIONAL SCENARIOS

14.1 Overview and objectives

Ecological and water quality consequences of the various operational scenarios were assessed and are described in the sections below. The ecological evaluation is based on an assessment of the impact on the status or ECs recommended for each component. Information on the water quality assessment as a key driver is provided below, followed by the overall assessment.

14.2 Results

A summary of the scenario consequences are shown in Table 49.

Table 49: Scenario consequences

Main Stem	**Sc 1 PD REC**	**Sc 4**	**Sc 5**	**Sc 6**	**Sc 7**	**Sc 8**
12 Vermaasdrift	**D**	**C**	**C/D**	**C/D**	**D**	**C**
13 Regina	**C/D**	**C**	**C**	**C**	**C**	**C**
Tributaries						
14 Vals	**C/D**	**C/D**	**D**	**C/D**	**C/D**	**C/D**
15 Vet	**D/E**	**D**	**D/E**	**D**	**D/E**	**D**

Significant deviations between Scenario 7 and 8 were found for EWR R1 (Renoster), 14 (Vals), V1 and V2 (Vet). Negative economic impacts (in terms of GDP and employment) may occur as a consequence of applying the Ecological Reserve in the Renoster, Vals and Vet Rivers:

- Little impact on Ecosystem goods and services – negative impact at Vals River for Scenario 5
- Main stem of Vaal all scenario's meet PES and REC
- Tributaries Scenarios, 4, 7 and 8 meet PES and REC
- Water quality driver and management plans for nutrients and salts – aquatic ecosystem adapted
- Extra flows but main stem altered for many years
- Tributaries less water and water quality issues

At the presentation to the Department of Water Affairs Management Team on the 7th of October 2010 the following was agreed for the future Reserve management for the Middle and Lower Vaal:

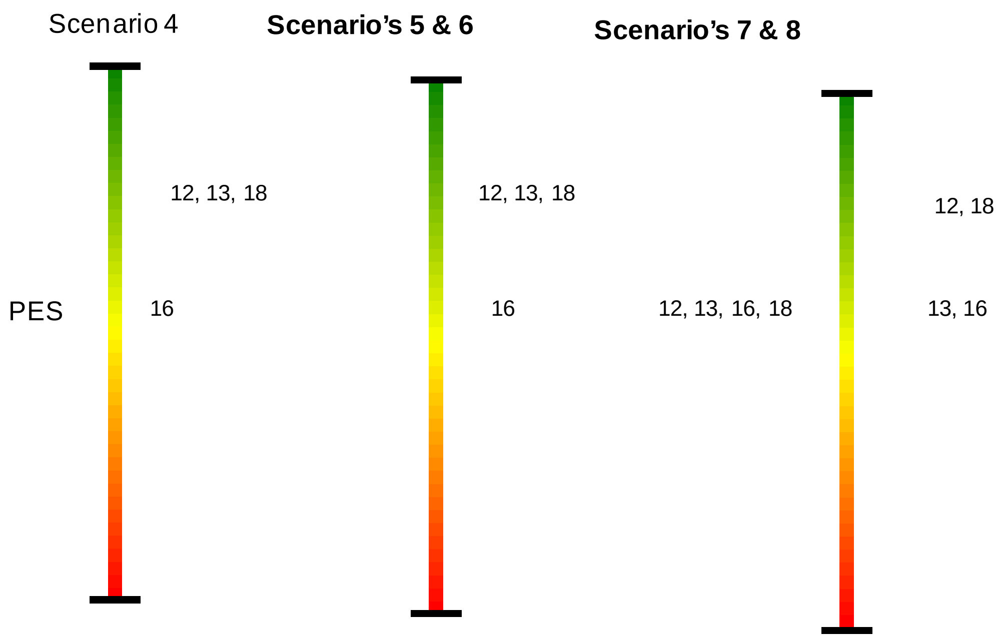


Figure 39 Summary of ecological consequences per scenario for the main stem of the Vaal EWR sites

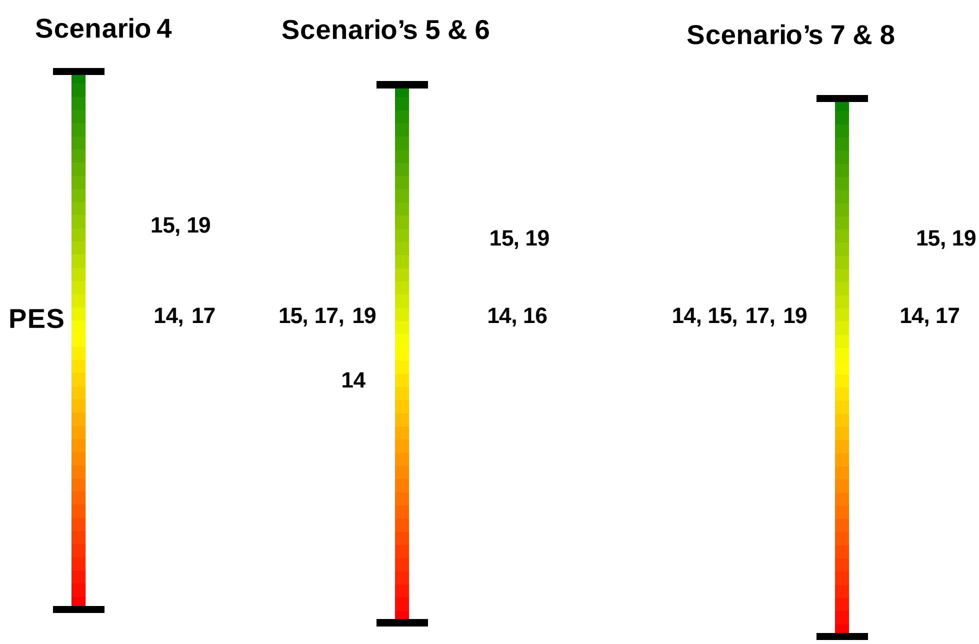


Figure 40Summary of ecological consequences per scenario for the tributaries of the Vaal EWR sites

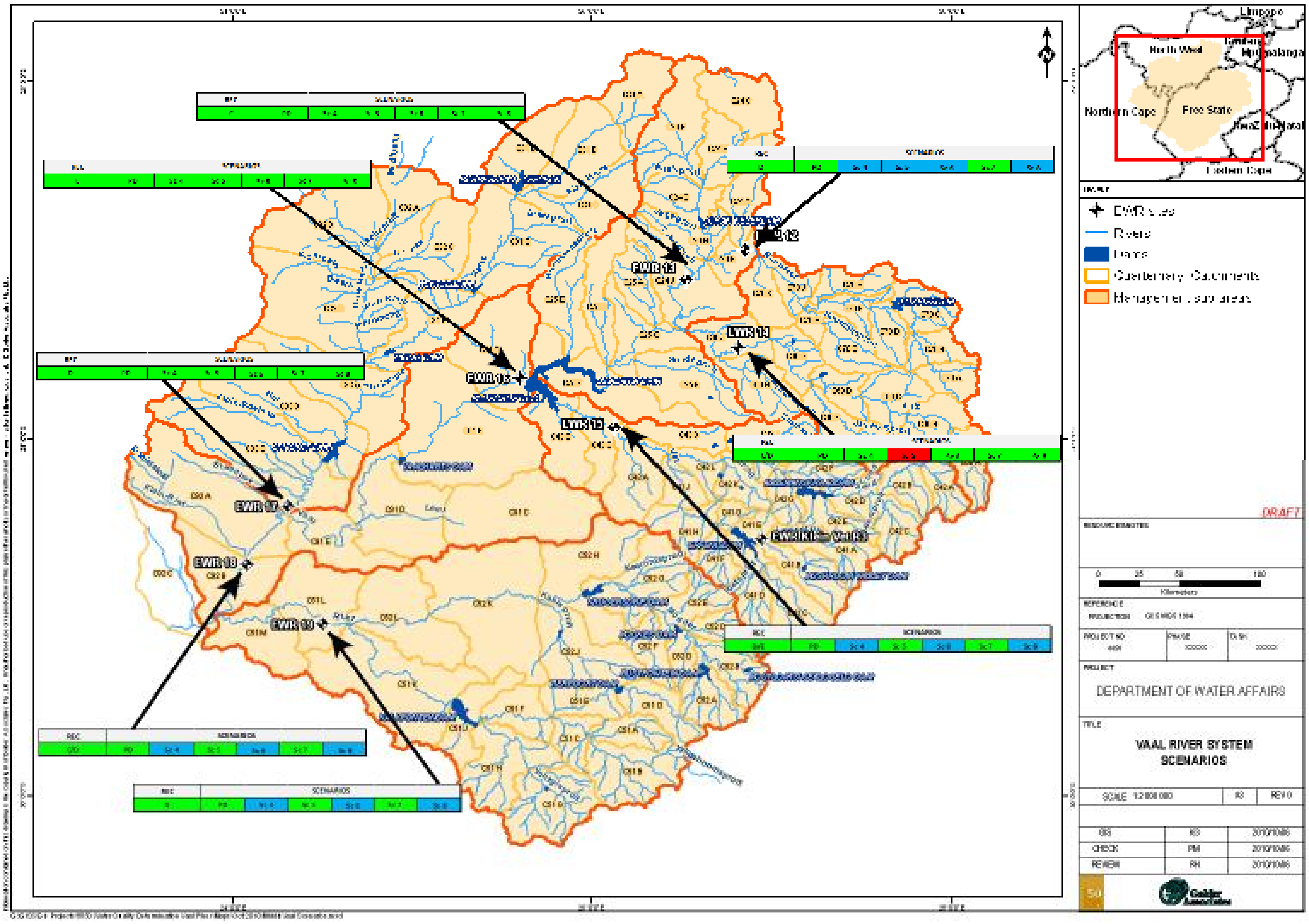


Figure 41: Summary of the Ecological Consequences for the Middle Vaal Catchment

15 SOCIO-ECONOMICS AND GOODS AND SERVICES

15.1 Introduction

Based on a similar approach used for the socio-economic impact assessment for the Upper Vaal WMA (as undertaken by Conningarth), the Middle and Lower Vaal WMAs were partitioned into defined economic zones. Several EWR sites were identified and establish along the Vaal River in the Upper, Middle and Lower Vaal WMAs within these economic zones in order to measure present day water use and to make predictions on future water use. These EWR sites were evaluated and identified according to criteria which included hydraulics, land use, regulation and accessibility. Eight EWR sites were then identified within the Middle and Lower Vaal WMAs and present day water use for various water users estimated. From the relevant socio-economic data collected for irrigated agriculture, mining and manufacturing and population within each WMA baseline economic indicators such Gross Domestic Product (GDP), employment and household income were generated for each economic zone using Water Multipliers. These baseline results were then adapted to account for water use (demand) at each of the eight EWR sites.

To assess the socio-economic impacts of either applying or not applying the Ecological Reserve, eight plausible water allocation scenarios were identified by the Project Team. Although all eight scenarios were analysed as part of the overall study, Scenario 8 (which included the EWR) was assessed relative to Scenario 7 specifically for the socio-economic component of the Project. The remaining scenarios were used to assess the impact of alternative options for the inclusion of the EWRs.

For the ecosystems services assessment, 5 water allocation Scenarios were assessed according to impacts on the following river resources:

- Fish;
- Riparian vegetation;
- Recreation; and
- Water quality.

Each resource was scored per Scenario according to whether utilization of the resource remained at current/present day levels or either increased or declined at each EWR site.

15.2 Approach

The methodology used to assess the impacts on Ecosystems Services is similar to the approach used in the Thukela Water Project: Reserve Determination Module (Mander *et al*., 2007). These are described in greater detail in the following section.

A description of the 8 water allocation scenarios used for the purposes of this study is provided in Table 50. Although all eight scenarios were analysed as part of the overall study, scenarios 7 (which excluded the EWRs) and 8 (which included the EWR) were assessed specifically for the socio-economic component of the Project as the water requirements were met for scenarios the remaining scenarios (and there was therefore no impact). The remaining scenarios were used to assess the impact of alternative options for the inclusion of the EWRs. For the ecosystems services assessment, impacts for scenarios 4, 5, 6, 7 and 8 were analyzed against the base Scenario (Scenario 1).

The evaluation of economic impacts takes into consideration the potential impacts of a particular development on the economic environment of a study area (which can be delineated according to impact intensity). More specifically, the way in which the direct benefits and costs of an intervention could affect the local, regional, or national economy can be assessed. The intervention can be in the form of new investment in infrastructure, new development, and adoption of a new policy or services, expansion of current operations. The types of economic impacts stimulated by an intervention are generally positive (in an economic sense) and include creation of additional jobs, generation of business sales and value-added, improved quality of life, an increase in disposable income, and growth of government revenue. For the purposes of this study, the economic intervention arises as a result of different water allocation scenarios, the economic impacts of which can be assessed per water allocation scenario. Three types of economic impacts are generally assessed:

The **direct** economic effects are generated when the new business creates new jobs and purchases goods and services to operate the new facility. Direct impact results in an increase in job creation, production, business sales, and household income;

The **indirect** economic effects occur when the suppliers of goods and services to the new businesses experience larger markets and potential to expand. Indirect impacts result in an increase in job creation, Gross Geographic Product (GGP), and household income; and

The **induced** economic effects represent further shifts in spending on food, clothing, shelter and other consumer goods and services as a consequence of the change in workers and payroll of directly and indirectly affected businesses. This leads to further business growth/decline throughout the local economy.

The approach to the socio-economic impact assessment component of the project is shown in Figure 42 below. The work consisted of defining the relevant economics zones per WMA, collecting data for major water users per WMA, inputting these data into the relevant macro-economic models and finally interpreting and assessing the results.

Two models were used to calculate the macro-economic impacts of water use in the different economic zones. This was necessitated by the difference in water sources in the two main economic zone types. In the tributaries the irrigation water is drawn from local sources with a large percentage, if not all, of the required demand for the mining and other urban requirements pumped from the main stem. The approach for this study was based on a similar approach used for the Upper Vaal WMA study where a particular WMA is partitioned into various economic zones. For this study, the economic zones were only used to calculate the baseline or present day economic impacts.

On the main stem the irrigation water, together with the rest of the water, is sourced from the river. A decision was taken by the project team that water demand quantities drawn from the main stem will be supplied by external sources if needed.

On the main stem of the river and for the urban, mining and industrial requirements on the tributaries, the South African Inter-industry Model (SAFRIM) was used to calculate the impact on the introduction of the EWR. For the irrigation from the tributaries the WIM was used to calculate the impact on the introduction of the EWR.

Ecosystem services are the outputs of ecological systems that generate quality of life or well being for people. An ecosystem service is a product that emerges from processes or features within largely natural environments, which enhances human wellbeing and is directly used by people. No longer is capital, skills or labour major constraints to human development - environmental quality is often the limiting factor. Natural capital and associated ecosystem services are now becoming scarce. This study also investigated the anticipated impacts of the various water allocation scenarios on several ecosystem goods and services. These goods and services were partitioned into several resources categories: fish, riparian vegetation, recreation and water quality

15.3 Results

Of the initial eight water allocation scenarios identified by the Project Team, the economic impacts of Scenarios 7 and 8 were modelled for several tributaries of the Vaal. Present day GDP and employment figures per EWR site were calculated using present day water abstraction at each EWR site and economic water multiplier for each economic zone within the Middle Vaal WMAs. The relevant economic zones were:

- Middle Vaal WMA
- Vaal River main-stem;
- Rhenoster;
- Schoonspruit;
- Sand;
- Vet; and
- Vals.

Water use data were collected for various water users within the Middle Vaal WMA. Major water users within these WMAs are:

- Irrigated agriculture;
- Mining and manufacturing; and
- Domestic and/or household consumption

Relevant data were collected for each user category and used to estimate water use. These data were then modelled using the SAFRIM and WIM methodology (consistent with the Upper Vaal study) producing baseline economic impacts based on the economic zones identified. Irrigated agriculture in the Middle Vaal provided R315 million directly to GDP and 6,027 employment opportunities.

The results of the socio-economic assessment indicated that significant deviations from present day demand for Scenario 8 were found for EWR R1 (Renoster), 14 (Vals), V1 and V2 (Vet). This implies that potentially significant economic impacts may occur as a consequence of applying the Ecological Reserve in the Renoster, Vals and Vet Rivers which are tributaries of the Vaal River. The results for the main stem showed that Scenario 8 caused more water to be pumped through the VRESAP pipeline and Sterkfontein Dam was operated at lower storage levels. The assurance of supply to users will, however, is not likely to be jeopardised by implementing the EWRs.

In terms of evaluating which Scenario is acceptable from a socio-economic perspective Scenario 8 was the only Scenario evaluated against present day water use. It is recommended that, due to the highly negative socio-economic impacts found in the Renoster, Vals and Vet tributaries, further and more detailed investigations may need to be conducted to more accurately assess the socio-economic costs and benefits of implementing the EWRs in these tributaries. Irrigated agriculture is a major economic activity in these tributaries and the Renoster, Vals and Vet tributaries account for approximately 21 000ha of agricultural production within the Middle Vaal WMA. Much of the annual crop yield is also made up of cereals such as maize and wheat which may negatively affect regional and potentially national food security. Possible further research into this could entail a financial and economic analysis of irrigated agriculture along these tributaries based on water allocation or costs scenarios the aim of which could be to assess the impacts of increasing water cost to irrigators and assessing at what levels costs affect profitability. Necessary trade-offs that could be made could also be identified by such a study. The traffic diagram below (Figure 42) provides a graphic representation of the overall socio-economic impacts of Scenario 8 in the Middle Vaal WMAs.

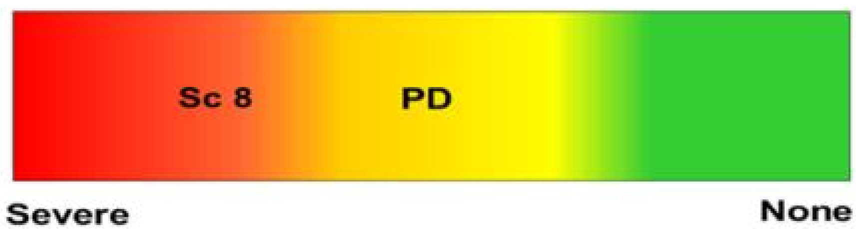


Figure 42: Traffic light diagram of overall socio-economic impacts of Scenarios 7 and 8 for Middle Vaal WMAs

The methodology used to assess the impacts on Ecosystems Goods and Services in this study was consistent with the approach used for the Upper Vaal WMA. Of the eight water allocation Scenarios identified, Scenarios 4, 5, 6, 7 and 8 were evaluated per EWR site. The approach investigated the impact of each Scenario on Fish, Riparian Vegetation, Recreation and Water Quality resources per EWR site. Overall it was found that by implementing the ER at each EWR site no negative impacts were found except for Scenario 5 at EWR site 14. These negative impacts were driven by impacts on fish species such as the, Smallmouth yellowfish (*Labeobarbus aeneus*), Orange-Vaal mudfish (*Labeo capensis*) and Moggel, (*Labeo umbratus*) and result from reduced flow levels leading to a decrease or disappearance of species from this reach. Scenario 5 cannot, therefore, be recommended as acceptable from an Ecosystems Goods and Services perspective based on these negative impacts. Scenario 6 had the highest overall score for each resource in both the Middle and Lower Vaal WMAs and on this basis must be recommended as the most acceptable Scenario from an Ecosystems Goods and Services perspective. The traffic diagram below (Figure 43 provides a graphic representation of the overall impacts of each Scenario on Ecosystems Goods and Services in the Middle Vaal WMAs.

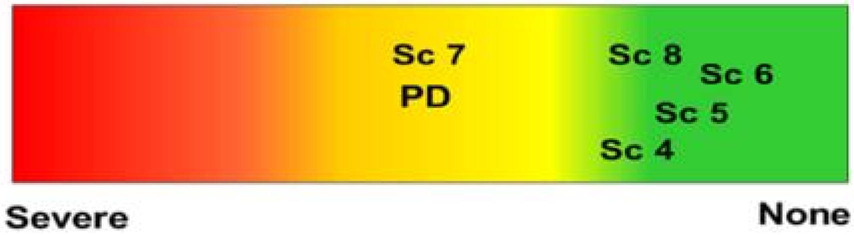


Figure 43: Traffic light diagram of overall Ecosystems Goods and Services impacts of Scenarios 4, 5, 6, 7 and 8 for Middle Vaal WMAs

16 ECOLOGICAL SPECIFICATIONS (ECOSPECS) AND MONITORING

16.1 Introduction

EcoSpecs are clear and measurable specifications of ecological attributes (e.g. water quality, flow, biological integrity) that define the Ecological Category and serve as an input to Resource Quality Objectives. The ecospecs are intended to provide the quantifiable and enforceable descriptors of the RQOs as they pertain to the ecological objectives for a particular resource (in this case a particular river reach).

Threshholds of Potential Concern (TPCs) are points along a continuum of change in selected Ecospecs, which prompt management action. Such action may involve attention to the causes of change or a reassessment of the validity of the ecospecs or TPCs, as part of an adaptive management strategy.

Ecological water resource monitoring (EWRM) consists of the combined monitoring for Ecological Reserve Monitoring (ERM) and the River Health Programme (RHP). The EWRM therefore measures whether the ecological objectives set according to the Ecological Reserve Process and the RHP (in terms of Ecological Categories and EcoSpecs) is being met.

The purpose of monitoring is to:

- Determine whether the ecological objectives (in terms of Ecological Categories and EcoSpecs) are being met;
- Identify the possible cause of the problem; and
- Determine the required actions according to a Monitoring decision support system to be followed if the ecological objectives are not being met.

16.2 Ecospecs

The following table is a summary of the proposed monitoring frequency for the Ecological Reserve for the Middle Vaal EWR sites 12 to 15 (Table 50).

Table 50 Summary of proposed monitoring frequency for the Ecological Reserve for the Middle Vaal.

Reserve component	Monitoring Frequency
Hydrology	Daily monitoring at closest DWA weir
Water Quality	Monthly, Quarterly (EC and Chlorophyll -a)
Geomorphology	• Every 2nd year: Daily hydrology and Fixed-point photography • Every 5 – 10 years: Bed material composition; Cross-sections and Aerial photographs
Fish	Monitoring should be conducted twice annually. If only once annually then the intermediate dry –wet season would be preferred.
Macroinvertebrates	Wet and dry season sampling
Riparian Vegetation	Monitoring should be conducted annually during the wet season (Spring to early Summer). Monitoring may be reduced to one survey every two to three years, however, any significant, change should precipitate immediate surveys which should be conducted annually for at least three years in order to monitor the change and determine whether it was a stochastic event or the beginning of a trend

It is important to note that the proposed Rapid Habitat Monitoring Programme (RHAM) has not be tested in the Middle Vaal.

If this programme is to be implement then the suggested monitoring frequency in Table 51 would altered and the RHAM monitoring would be used a s screening approach. If the TPC are triggered then the proposed monitoring would click in.

17 CAPACITY BUILDING

The team members that received training in this project are included in Table 51.

Table 51 : List of team members that received capacity building in the Middle Vaal

Mentee/trainee	Mentor	Skills Developed
Dr Jennifer Molwantwa	Dr Ralph Heath	General process, water quality
Lindo Hlongwane	Mark Rountree	General process, geomorphology, GAI
Peter Kimburg	Dr Ralph Heath, Dr Neels Kleynhans, Dr Pieter Kotze, Dr	General process, fish, FRAI, Habitat Flow

	Johan Engelbrecht	Stressor Response
Alvar Koning	Christa Thirion, Dr Rob Palmer, Dr Ralph Heath	General process, MARAI, macroinvertebrates, Habitat Flow Stressor Response
Adrian Hudson	James MacKenzie, Dr Ralph Heath	General process, VEGRAI,
Justin du Toit	Dr William Mullens (Conningarth), Rene Ford, Dr Ralph Heath, Greg Huggins	General process, socio-economics, goods and services
Mushoni Makatu	Prof Denis Hughes, Ken Haumann, Retha Stassen, Susan Swart, Dr Angelina Jordanova	General process, hydrology, HAI, Habitat Flow Stressor Response
Thulani Magagula	Prof Denis Hughes, Ken Haumann, Retha Stassen, Susan Swart, Dr Angelina Jordanova	General process, hydrology, HAI, Habitat Flow Stressor Response

The following are some learning's from members of the Golder Project Team whilst working on the socio-economic component of the Vaal Determination Study.

- The socio-economic and ecosystems services components of the Comprehensive Reserve Determination Study for the Vaal WMAs are relatively small but important components of the overall Reserve Determination Study in terms of their role in quantifying the broader social and ecosystems impacts. The overall Project Team were multidisciplinary and professionals in each of their respective fields. Important lessons learnt from being included in the Project Team include:

    - Communication amongst Project Team members: Given the scale and scope of Reserve Determination Study, effective communication amongst members of the Project Team has been vital to completing this work to an acceptably high standard. When the Project Team is large, however, communication becomes even more essential and on numerous occasions during this Project, difficulties in communicating had to be overcome.

    - Interdependence of Project components: Understanding how Project components are linked and how each component relates to one another is an important lesson learnt during this study. It is essential to understand the broader objectives of the Project and how the component one is responsible for may affect or influence the component of another Project Team Member.

    - Professional conduct and presentation: Interacting with Project Team members gives one an opportunity to learn about how to conduct and present oneself professionally and appropriately at Project Team meetings and workshops.

Members of the CD: RDM were part of the whole process from inception phase, site selection, workshops and review.

18 CONCLUSIONS AND RECOMMENDATIONS

18.1 Summary of Final Results

The results are summarised in the **Table 52** for the different EWR sites as a percentage of the Mean Annual Runoff of Present Day and Virgin flows.

Table 52 : Natural and PD MARs (MCM) of the EWR sites

EWR site	EC	NMAR (MCM)	PMAR (MCM)	Maintenance low flows (%NMAR)	Drought low flows (%NMAR)	High flows (%NMAR)	Long term mean (%NMAR)	Maintenance low flows (%PMAR)	Drought low flows (%PMAR)	High flows (%PMAR)	Long term mean (%PMAR)
EWR 12	C/D Instream PES, REC	2546.39	1574.64	22.89	9.15	9.81	32.71	37.01	14.8	15.88	52.89
EWR 13	C/D PES, REC	2654.26	1638.37	22.1	8.72	10.3	32.4	35.8	14.13	16.68	52.48
EWR 14	C/D PES, REC	145.79	118.04	5.41	0.09	11.64	17.04	6.68	0.12	14.25	21.05
EWR 15	C/D PES, REC	253.15	413.04	3.33	1.45	7.82	11.16	5.44	2.37	12.76	18.2

18.2 Conclusions

The confidence in the flow requirements set at the different EWR sites within the Middle Vaal Catchment were generally Low. This was mainly due to an array of problems encountered during the EWR assessment and a summary of these various problems are provided below.

Hydrology

For the application of the DRM the PD hydrology was used as reference hydrology because it was higher than natural during the dry season. Therefore the EWRs were set higher than natural and the DRM cannot accommodate this situation as the program will keep on decreasing the flows down to natural. As all flows that were set were less than PD, PD could therefore be used as the reference. This also meant that PD hydrology would guide the seasonal distribution of the EWRs which was acceptable as the objectives for these sites were to set a realistic flow regime considering the present conditions. This matched the overall objective of maintaining the PES which is a function of the PD hydrology at these sites.

Riparian vegetation

The riparian vegetation component was not surveyed along the hydraulic profile during the 2007-2008 Reserve determination study. In the absence of surveyed vegetation data assumptions had to be made regarding the presence of important vegetation indicators as well as inundation levels in order to check the low flow requirements, set by the in-stream biotic components, to ensure that the flows catered for any riparian vegetation (specifically marginal) requirements.

Hydraulic data

The cross-sections at EWR 13 were placed through a pool. This is extremely problematic, especially at EWR 13 because the zero flow did not equate to zero depth. Therefore the lookup tables did not provide information for low flows below the depth of the pools. These depths are required to set low and drought flows in the fast flowing areas such as riffles. Furthermore, the biological surveys were undertaken at a multi-channel area with riffles further downstream. The biota found at the site and the habitats they require and utilize were not representative of the conditions in the pool. The cross-section and hydraulic data could not be used to set EWRs. It was however noted that the PD flows were very similar to EWR 12 and that the same indicator taxa and habitats as present at EWR 12 occurred in the reach represented by EWR 13. It was therefore decided to extrapolate the EWRs set at EWR 12 to EWR 13. The changes were made proportionately to the changes in the modelled PD flows between EWR 12 and 13.

More recent data collected in 2010 as part of the ORASECOM biomonitoring study (ORASECOM, 2011a and b) was however available and aided in furthering the understanding of the habitat responses to flow changes.

18.3 Recommendations

The issues outlined in Section 18.2 can be addressed through Ecological Water Resources Monitoring (EWRM). As part of a EWRM programme the Rapid Habitat Assessment Method (RHAM) should be included as the application of this method will improve the confidence in hydraulic data especially at EWR 13 and allow for more clarity on the hydrological issues of the Middle and Lower Vaal River. The RHAM was developed during 2007 - 2009 and it is recommended that a RHAM survey is undertaken at sites where applicable during EWRM. It is foreseen that due to the size and nature of the Vaal River, the RHAM for wadeable rivers might not be possible at all sites. The semi - wadeable (still to be tested) RHAM could be applicable. RHAM data may provide additional information on habitat suitability and the biota associated with this habitat. Due to the hydraulic data being unsuitable for use, it is not recommended that any additional improvements in confidence in determining the EWRs are attempted. This would require new cross-sections and new hydraulic modelling which is a serious investment. Detailed monitoring with photopoint monitoring at KNOWN flows is strongly recommended.

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