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Mozambique
National Directorate of Water

Environmental and Social Impact Assessment (ESIA) for Completion of the Corumana Dam

Volume 1:
Biophysical Environment (EIA)

Draft

April 2011

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LIST OF ABBREVATIONS

ARA-Sul	Southern Regional Water Administration / Administração Regional de Águas do Sul
DNA	National Directorate of Water / Direcção Nacional de Águas
DNAIA	National Directorate for Environmental Impact Assessment / Direcção Nacional de Avaliação de Impacto Ambiental
DWA	Department of Water Affairs
EAS	Simplified Environmental Study / Estudo Ambiental Simplificado
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
EPDA	Environmental Pre-feasibility Study and Scoping Definition / Estudo de Pré-viabilidade Ambiental de Definição de Âmbito
EWR	Environmental Water Requirements
FAII	Fish Assemblage Integrity Index
FSL	Full Supply Level
GDP	Gross Domestic Product
GIS	Geographic Information System
GPS	Global Positioning System
GoM	Government of the Republic of Mozambique
I&AP	Interested and Affected Parties
IIMA	Tripartite Interim Agreement for Co-operation on the Protection and Sustainable Utilization of the Incomati and Maputo Watercourses
KNP	Kruger National Park
LA	Environmental Licence / Licença Ambiental
MAR	Mean Annual Runoff
MICOA	Ministry for Coordination of Environmental Affairs / Ministério para a Coordenação da Acção Ambiental
Mm^3	Million cubic meters
RLC	Regulations for Licences and Concessions
SASS5	South African Scoring System
SGB	Sabie Game Park
SIA	Socio-economic Impact Assessment
SMEC	Snowey Mountain Engineering Consultants
TDS	Total Dissolved Solids
ToR	Terms of Reference
VEGRAI	Vegetation Response Assessment Index
WP	Water Policy
WRMS	Water Resources Management Strategy

1 Executive Summary

The Government of the Republic of Mozambique has initiated a National Water Resources Development Program to strengthen the role of the water resources sector in sustaining economic growth and reducing poverty. The National Water Policy (Política de Águas), the National Water Resources Management Strategy (Estratégia Nacional de Gestão de Recursos Hídricos - ENGRH) and the Regulations for Licenses and Concessions (Regulamento de Licença e Concessões de Água - RLCA) informs the Program's planned investments to address persistent impacts associated with high hydroclimatic variability and recurrent floods and droughts.

As part of the Program, the Government of the Republic of Mozambique is planning for and undertaking a series of large infrastructure improvements to substantially improve both the quality and quantity of water supply to its greater capital area of Maputo. Under the auspices of the Tri-Partite Technical Committee of the Interim IncoMaputo Agreement and with several years of feasibility analysis, the rehabilitation and completion of the Corumana Dam has been identified as the next source of bulk water supply for Maputo. In realizing the potential of the infrastructure, the Government is being supported by the World Bank. As part of Project preparation, the Government has carried out an Environmental Impact Assessment in line with national legislation and World Bank safeguard policies.

This is the first of four volumes prepared as part of the Environmental and Social Impact Assessment (ESIA) for the completion of the Corumana Dam. The Environmental Impact Assessment (EIA) has been developed to address the impacts on the biophysical environment from the planned completion of the Corumana Dam, located in Maputo Province's Moamba District in southern Mozambique. Volume 2 presents the Social Impact Assessment (SIA) to provide an overview of the socioeconomic issues of project affected communities. The SIA addresses the social considerations required for a standard EIA (in compliance with World Bank Operational Policy 4.01, Annex B). The Environmental Management Plan (EMP) is presented in Volume 3. The EMP outlines the mitigation measures necessary to reduce the known negative impacts on the biophysical environment resulting from the completion of the Corumana Dam. Aspects related to resettlement and community development are addressed in the Resettlement Action Plan, the RAP (Volume 4).

1.1 The Project

The Corumana Dam is an existing embankment dam (inclined core rock fill dam with a 45 m height and 3,050 m crest length) constructed between 1983 and 1989. The dam is located on the Sabíe River immediately downstream of the border with the Republic of South Africa and approximately 90 km north-west of Mozambique's capital Maputo in the Moamba District of Maputo Province (25°13'10.10"S and 32° 8'2.31"E). The dam was not completed in 1989 due to lack of funding and the civil war.

The Project involves completing the dam and increasing the full supply level (FSL) of the reservoir from the current 111 masl to 117 masl, with a flood surcharge water level of approximately 120 masl. Increasing the FSL of the reservoir's originally intended capacity will increase the dam's current storage from 720 Mm^3 at present to an estimated 1,240 Mm^3. Raising the FSL to only 115 masl was also assessed in this EIA as an alternative option.

Completion of the Corumana Dam involves civil and hydromechanical works, consulting services for design and supervision and technical assistance. These activities will be completed by the Direcção Nacional de Águas, DNA (National Directorate of Water) who owns the dam through the Government Ministry of Public Works and Housing, and the Administração Regional de Águas do Sul, ARA-Sul (Southern Regional Water Administration) manages and operates the dam.

Specific infrastructure improvements involve the addition of the following elements:

- Six crest radial spillway gates and ancillary hydromechanical equipment;
- Repair works of concrete pillars/abutments;
- Strengthening works on the existing dam; and
- Construction of saddle wall with a fuse plug emergency spillway;

The dam was originally constructed for improving flood control, regulation for downstream irrigation abstractions and hydropower production.

1.2 Existing Environment

1.2.1 Hydrology

The Sabíe River is a perennial river that flows from the Republic of South Africa into the Corumana reservoir. Downstream of the dam the Sabíe River flows south-westwards and joins the Incomati River.

Upstream of the Corumana reservoir, the Sabíe River is situated in an incision in bedrock, which has created channels that have a "floodplain" restricted to the width of incision into bedrock. The river has multiple channels, with water flowing over roughened bedrock slabs, gravel and through deep pools.

Annual flow volumes of the river are highly variable with some years characterised by very low flows, while other years display runoff volumes equivalent to up to six times the MAR. The majority of flow occurs during the summer rainfall season (November to April) with over 80% of flow occurring from December to April.

1.2.2 Hydrogeology and groundwater

Groundwater resources are limited in the area except along fault zones, dyke contact zones and in alluvial valleys. Dykes are present and adequate groundwater occurrence can be expected at scientifically selected drill sites.

High sodium and chloride values for the water in the reservoir and groundwater are encountered and unacceptable high salinity and fluoride are found in the groundwater. Fluoride, sodium chloride and total dissolved solids (TDS) values exceed the maximum allowable limits for human use for Mozambique.

1.2.3 Terrestrial ecology

Vegetation

The Corumana reservoir is situated within the Maputaland Centre of Plant Endemism (MCPE). This area extends north from coastal KwaZulu-Natal (from about Richards Bay) well into southern Mozambique. The MCPE is a focuspoint of high plant endemism that supports between 2,500 and 3,000 vascular plant species of which at least 203 taxa are endemic or near-endemic to the centre. The Corumana reservoir is situated at the northern edge of the core area of the MCPE.

Three different types of vegetation landscape types are encountered around the Corumana reservoir, namely: i) *Sclerocarya birrea* / *Acacia nigrescens* Savanna; ii) Lebombo South Landscape; and, iii) Floodplain Grassland that formed through previous inundation of the Sabíe River valley when the dam was established in the late 1980s.

The *Sclerocarya birrea* / *Acacia nigrescens* Savanna landscape potentially supports three highly threatened species in areas that could be inundated (*Adenium swazicum*, *Ipomoea venosa*, *Turbina longiflora*) by completion of the Corumana Dam. Three threatened plant species were confirmed to occur within the project area, but outside of the potential area of inundation: *Triaspis hypericoides* (Vulnerable), *Afzelia quanzensis* (Near Threatened) and *Dalbergia melanoxylon* (Near Threatened).

Birds

Over 180 bird species have been recorded within the general vicinity of the Corumana reservoir. Bird species observed during fieldwork around the dam can be separated into five avian assemblages: Woodland, Thicket, Riparian Vegetation, Floodplain Grassland and Open Water. The most important landscape/habitat for threatened birds is *Sclerocarya birrea* / *Acacia nigrescens* Savannah, in which two IUCN Red Data species were confirmed to occur (Bateleur, European Roller; both of which are Near Threatened).

Mammals, reptiles and amphibians
The only area around the Corumana reservoir with populations of large mammals is the Sabie Game Park, a privately run hunting reserve on the north-western shores of the reservoir. This park is a private conservation area and does not have any official protected area status in Mozambique. The SGP's legal boundary on the reservoir side is equivalent to the original intended FSL of the Corumana reservoir. Currently it has access to approximately 16 km of shoreline where large mammals can access grazing and predators can engage in hunting along the floodplain. These mammals include the following globally threatened species: African Elephant, Hippopotamus, White and Black Rhinos, Lion and Leopard. Around the rest of the Corumana reservoir, the only mammals likely to still occur in the marginal vegetation are rodents, small carnivores and possibly small antelope such as Common Duiker and Steenbok. African Clawless Otter Scat was found at several localities close to the water's edge.

The only Red Data reptile species potentially occurring in the study area according to data on the IUCN Redlist website is *Kinixys natalensis* (the Natal Hinged Tortoise), which has a status of Near Threatened. This is a terrestrial species unlikely to occur close to the dam and is not expected to occur in the floodplain area. No IUCN Red Data amphibians are likely to occur within the study area.

Protected areas
In South Africa, the Kruger National Park has national protected status and forms part of the border with Mozambique.

1.2.4 Aquatic/riparian ecology

The assessment of the present state of the riparian vegetation, macroinvertebrates and fish fauna in the Sabíe River in the region of the Corumana reservoir may be described for the upstream environment as Largely Natural with few modifications and for the downstream environment as Moderately to Seriously Modified, with a loss and change in habitats and biota and with ecosystem function changed.

Vegetation
The aquatic/riparian vegetation in the Sabíe River upstream of the Corumana reservoir, in the Kruger National Park, is dominated by *Phragmites mauritianus* and *Miscanthus junceus* in the marginal zone and by *Euclea natalensis angustifolia* and *Kigelia africana* in the non-marginal zone. The invasion by alien plant species is low. There is a relatively widespread presence in the marginal zone of *Pistia stratiotes* (Water Lettuce) and *Azolla filiculoides* (Water Fern). The vegetation may be described as Largely Natural with few modifications. A small change in habitats and biota has taken place, with ecosystem function essentially

unchanged. No protected, red listed, endangered or endemic species were collected (IUCN Red List).

Downstream of the reservoir, the aquatic/riparian vegetation in the Sabíe River may be described as Largely Modified. A large loss of habitats, biota and basic ecosystem function has occurred. No protected, red listed, endangered or endemic species were collected (IUCN Red List). All the species collected may be classified as of Least Concern. Woody species include *Acacia xanthophloea*, *Ficus capreifolia* and *F. sycomorus*. Non-woody species include *Phragmites mauritianus, Sporobolus africanus, Paspalum dilatatum* and *P. scrobiculatum.* The presence of alien plant species was found to be significant. Alien species include *Psidium guajava* (guava), *Mangifera indica* (mango) and *Musa acuminata* (banana).

Aquatic macroinvertebrates
The macroinvertebrate fauna upstream of the dam can be characterised as Unmodified, Natural. Important taxa include the *Heptageniidae* (flat-headed mayflies), *Calopterygidae* (damselflies) and *Pyralidae* (aquatic caterpillars).

The macroinvertebrate fauna downstream of the dam was classified as Seriously Modified.

The fish fauna
At the sampling station in the Sabíe River upstream of the reservoir, six species of fish were sampled: *Barbus polylepis* (Small-scale Yellowfish), *Hydrocynus vittatus* (Tigerfish), *Clarias gariepinus* (Sharptooth Catfish), *Tilapia sparrmanii* (Banded Tilapia), *T. Rendalli* (Redbreast Tilapia) and *Glossogobius callidus* (the River Goby).

Downstream of the dam, the following species were collected or sampled: *Labeo cylindricus* (Redeye Labeo), *H. Vittatus* (Tigerfish), *Synodontis zambezensis* (Brown Squeaker), *Aplocheilichthys johnstoni* (Johnston's Topminnow), *T. Sparrmanii* (Banded Tilapia), *Oreochromis mossambicus* (Mozambique Tilapia) and *G. Callidus* (the River Goby).

Three of the species of fish collected at the two sampling stations established for the ESIA migrate during their life history for feeding (*H. vittatus*) and spawning (*L. cylindricus*, *H. vittatus*, *C. gariepinus*) purposes. Of the 40 species of fish that potentially occur at the sampling site, *Anguilla mossambica, A. bengalensis labiata*, *A. marmorata*, *Labeo rosae*, *L. ruddi*, *L. congoro* and *L. molybdinus* have a significant requirement at some stage during their life cycle for migration. All species collected are classified as Least Concern by the IUCN red data list (IUCN, 2010), except *O. mossambicus*, which is Near Threatened. The *Chetia brevis* (Orange-fringed Large-mouth) is listed as Endangered.

1.3 Impact Assessment and Mitigation Measures

1.3.1 Positive impacts

Raising the FSL of the Corumana reservoir will have a number of positive effects:

- Additional water will increase the yield from Corumana Dam to augment water supply available for potential use or transfer to the Greater Maputo Metropolitan Area. The "Tripartite Interim Agreement for Co-operation on the Protection and Sustainable Utilization of the Incomati and Maputo Watercourses Agreement" (IIMA) states that 87.6 Mm^3/a of water is reserved for the city of Maputo from the Incomati and Maputo basins; the additional storage in the Corumana reservoir would assist in meeting those allocations;

- Improved regulation will increase the reliability of water available for irrigation during low flow periods and allow for limited expansion;

- Although not a direct project related impact, the incremental yield available for augmentation of water supply to the Greater Maputo Metropolitan Area has the potential to reduce the incidences of waterborne diseases and increase the welfare of local people by allowing the expansion of the area covered with water supply system;

- The project will provide conditions for increasing hydropower generation by nearly 4.8 GWh/year in firm energy;

- The new inundated areas in the reservoir will potentially enlarge the existing fishery in the reservoir. It has been estimated that a net increase in the total size of the fishery of up to 2% can be expected; and

- The construction work will create employment opportunities by requiring local and regional labour.

These impacts are described in more detail in the ESIA's Volume 2 Socioeconomic context (Social Impact Assessment).

1.3.2 Negative impacts

The assessed negative impacts have been classified with respect to their severity on ecological features and issues using a procedure applied internationally and in South Africa. The method operates with the following impact classes: Large impact, Medium impact, Low impact, Very low impact and No impact.

Hydrology

The following potential adverse impacts on hydrology and the associated mitigation measures were identified:

- The full supply level of 117 masl is estimated to be achieved 10% of the time (1 in 10 years) with the the lowest ground level in the Sabíe River gorge estimated at roughly 117 masl.

- During a 1 in 200 year return period flood event, and at increased FSL of 117 masl, the backwater effect (upstream inundation in a flood event) extends approximately 1,195 m into South Africa and is confined to the river channel. This is considered a **Medium Impact**. The backwater effects of the 1 in 200 year return period flood event for the present FSL of 111 masl will extend 690 m into South Africa. During the floods of February 2000 the maximum spillway discharge was 1,940 m^3/s which corresponded to a 1 in 100 year inflow (Lahmeyer 2003). The backwater effect for an alternative scenario of a FSL of 115 masl during a 1 in 200 year return period flood event extends approximately 1,050 m into South Africa. This is also considered a Medium Impact. To diminish the upstream inundation during a 1 in 200 year return period flood event, the dam gates could be operated so that inflow equals outflow during a major flood event which would maintain the dam level at 117 masl.

- For a 1 in 200 year flood event, the zone of induced sedimentation caused by the increased FSL to 117 masl extends approximately 1,080 m into South Africa. This is considered a **Medium Impact**. It should be noted that over the next 50 years, due to sediment build up in the upper part of the dam basin, sedimentation may migrate further upstream. For an alternative scenario of a FSL of 115 masl, the extent of induced sedimentation was found to be approximately 935 m into South Africa. This is also considered a Medium Impact.

  The geographic location of the Corumana Dam requires that any measures to mitigate the impacts of sedimentation, such as improved land management practices and restoration of riparian vegetation, would need to be carried out in South Africa. While DNA and ARA-Sul cannot enforce such measures, the cooperative structures under the Interim IncoMaputo Agreement provide a mechanism to facilitate to improve land management at the basin level and need to be pursued.

- Increasing the FSL of the Corumana reservoir to 117 masl increases the historical firm yield, reduces the spillage and results in higher evaporation losses, and a reduction in annual downstream flows from the dam on the order of 5.1% (yield and spillage). This is considered a **Low Impact**.

- A result of the increased storage capacity of an increased FSL would be that smaller floods (i.e., the 1 in 10 year flood) would be absorbed as long as the reservoir was below the FSL. If the 1 in 10 year flood is absorbed by increasing the full supply level this could lead to the narrowing of the downstream river channel and an increase in riparian vegetation. This is considered a **Medium Impact**. A reduction in sediment carrying floods could also lead to increased erosion of the river channel immediately downstream of the dam wall. An area that is particularly vulnerable is around the road bridge approximately two kilometres downstream of the Corumana spillway. To mitigate the impacts to downstream channel morphology, environmental releases from the dam should be planned for in the operation and maintenance of the dam.

Hydrogeology
The following potential negative impacts on hydrogeology and mitigating measures were identified:

- Seepage from the dam was observed downstream of the dam embankment wall. Increasing the FSL by six meters can increase pressure on the seepage areas and increase flow. If not mitigated, this is considered a Large Impact. However, the project involves strengthening the dam to prevent seepage and so **No Impact** can be expected. Geotechnical investigations are being carried out as part of a separate Technical Services and Dam Safety contract to assess the extent of remedial works needed to strengthen the dam and prevent seepage at the observed site

- The other concern from a geohydrological viewpoint is seepage through the planned saddle wall on the southern side of the reservoir. Monitoring boreholes will be required to establish background water levels in the downstream area of the saddle dam wall. Seepage through the saddle dam wall and/or pressure on the groundwater levels may impact on the agricultural activities and settlements. Mitigation measures to address the dam safety aspects relating to seepage are being addressed as part of a separate Technical Services and Dam Safety study.

Terrestrial ecology
The following potential impacts on terrestrial ecology and associated mitigation measures were identified:

- Increasing the FSL of the reservoir will inundate terrestrial habitats thus leading to a loss surrounding the present reservoir. The following areas of natural habitat around the Corumana reservoir will be affected by inundation after the increasing the FSL to 117 masl: i) 888 ha of *Sclerocarya birrea – Acacia nigrescens* Savanna; ii) 445 ha of Lebombo South Landscape; and iii) 274 ha Floodplain Grassland. Raising the FSL to 115 masl will affect a total terrestrial area that is 40% smaller. The following areas will be affected by inundation: i) 469 ha of *Sclerocarya birrea – Acacia nigrescens* Savanna; ii) 214 ha of Lebombo South Landscape; and iii) 242 ha Floodplain Grassland. The hydrological modelling has showed that a FSL of 115 masl or 117 masl will rarely be obtained (i.e. in only about 10% of the time), so some of the affected area will only be affected part of the time. Riparian vegetation along a narrow stretch of the river channel extending some 730 m into Kruger National Park in South Africa will be inundated when increasing the FSL to 117 masl. The affected stretch will be reduced to 450 m for the alternative FSL of 115 masl. In case of a 1 in 200 years flood, riparian vegetation will be affected along stretches extending approximately 1,195 metres for the FSL of 117 masl and 1,050 metres for the FSL of 115 masl into the Kruger National Park. The inundation of terrestrial vegetation is considered a **Medium Impact**. This does not represent "significant" loss of natural habitats, as per the World Bank's Natural Habitats Policy (OP4.04).

- Three threatened plant species potentially occur in the area that will be inundated when the FSL is increased to 117 masl and/or 115 masl as assessed by the ESIA: *Adenium swazicum* (Endangered), *Ipomoea venosa* (Vulnerable) and *Turbina longiflora* (Vulnerable). It is possible that these species were overlooked during fieldwork because of the large areas that had to be covered. This is considered a **Medium Impact**. A proposed mitigation measure is a detailed survey during the finalization of the EMP that could identify the location of these species in areas of terrestrial vegetation likely to be flooded at 120, 117 and 115 masl with a view to consider relocation of the plants to suitable representative habitat outside of the full supply level options assessed.

- Floodplain Grassland is likely to play an important role in the grazing dynamics of the herbivores in Sabie Game Park, particularly as grazing potential decreases in the dry season. This winter grazing will be lost until Floodplain Grassland re-establishes in the future. Re-establishment of Floodplain Grassland is expected to be quite fast. This is considered a **Medium Impact**.

- The construction activities involved in this project will result in areas of bare soil being exposed, which are vulnerable to colonisation by invasive plant species. A number of potential invasive species are already present in the vicinity of Corumana reservoir, in particular the aggressive invasive alien herb *Parthenium hysterophorus*. A seed bank is already present from which species such as this herb could easily spread. An increased surface area of the reservoir would also result in an increase in the potential area of infestation for four invasive aquatic plants that already occur in the Corumana reservoir: *Pistia stratiotes* (Water Lettuce), *Eichhornia crassipes* (Water Hyacinth), *Azolla filiculoides* (Red Water Fern) and *Salvinia molesta* (Kariba Weed). Recommendations for suitable mitigation measures to be implemented as part of the project are included in the EMP to address the potential problem of invasive plant species in the Corumana reservoir. However, at present the South African National Parks Board is controlling alien plants in the river systems of Kruger National Park. Therefore, this is considered **Low Impact**.

- After completion, the footprint of the saddle dam will cover an area of approximately 0.1 km^2 of Floodplain Grassland, which will be permanently lost. This is considered to be a **Low Impact**. In addition, the excavation of the emergency spillway that will be activated in a 120 masl flood scenario (1 in 1,000 year return period event) will temporarily remove approximately 0.4 km^2 of grassland. After completion of excavation, the grassland will be re-established by invasive grass species from the surrounding area. However, during and immediately after the excavation the area is subject to erosion especially during rainfall. The eroded material will be discharged to the reservoir and deteriorate the water quality in terms of increased suspended solids. This is considered to be a **Low Impact**.

- In case of a 1 in 1,000 year flood, the saddle dam fuse plug emergency spillway activation will cause the temporary flooding of areas with Floodplain Grassland and *Sclerocarya-Acacia* Savanna south of the Corumana reservoir. A discharge channel will be constructed to chanelize releases on the emergency spillway down towards to the Sabíe River downstream Corumana Dam. This impact is considered to be **Low Impact**.

Aquatic/riparian ecology
The following potential impacts on Aquatic/Riparian ecology and mitigation measures were identified:

- The fact that the Corumana Dam has been in operation since 1989 would imply that any significant threat to the aquatic and riparian biota and habitats, in general, has already occurred. In the case of the aquatic and riparian vegetation and the aquatic macroinvertebrate fauna, no habitats or species of conservation importance or concern were collected or identified (IUCN Red List). Given that the dam has been existence for some time, it is plausible that there will be no new threat to migrating fish species. The impacts of increasing the FSL of the reservoir to either 115 masl or 117 masl on aquatic/riparian ecology is considered as a **Low Impact**.

- Backwater effects and induced sedimentation in the Sabíe River upstream of the Corumana reservoir due to increasing the FSL of the reservoir (to either 115 or 117 masl) will, during flood events, affect riparian vegetation upstream of the reservoir. However, change in riparian vegetation has already undergone a significant, natural, change in the recent past, as a consequence of the impact of the presence of the reservoir since construction was completed in 1989 and the 1 in 100 year flood in 2000 . The change in state would have been from a tree, shrub and reed state, with high abundance and cover, to the present, open one, with fewer large trees and a change to a reed dominated state. Inundation at the site will clearly lead to the loss of habitats, but the impact on the non-marginal zone will not be as significant, given that no plants of high conservation value (all those collected may be classified as Least Concern) were observed at the assessed area. The area is open with low woody and non-woody abundance and cover. The impact of backwater effect on riparian vegetation can be a considered a **Low Impact**. It is proposed that longer term monitoring be supported under the project in appropriate localities in the upstream reach in conjunction with the Kruger National Park to study and monitor the hydrological, geomorphological and biotic changes that occur.

- Induced sedimentation due to increasing the FSL of the dam may also affect the upstream macroinvertebrate fauna in the Sabíe River which was classified as unmodified and natural at the survey site; perhaps even reflecting a state close to the pristine one. However, as only a small area compared to the pristine areas upstream will be affected this is considered a **Low Impact**. Impacts on fish populations upstream have also been classified as a **Low Impact**. It is proposed that longer term monitoring be supported under the project in appropriate localities in the upstream reach in conjunction with the Kruger National Park to study and monitor the hydrological, geomorphological and biotic changes that occur.

- Increasing the FSL of the reservoir is predicted to increase the existing fishery in the reservoir. This is because the lacustrine environment will not change. It has been estimated that a net increase in the total size of the fishery of up to 2% can be expected. The only plausible negative impact on the development of the fish fauna in the new inundated area may be the inability of fish populations with a more specialized life history to adjust to the environmental changes that will occur over a period of years. The common artisanal species present in the reservoir are generalists, and therefore able to better withstand environmental conditions in the reaervoir, including the *Clarias gariepinus* (Sharptooth Catfish), the *Cyprinus carpio* (Carp) and the *Oreochromis mossambicus* (Mozambique Tilapia). This negative impact can be considered a **Very Low Impact**.

- The estimated reduction of downstream flow by 5.1% resulting from increasing the FSL of the reservoir to 117 masl is not significant enough to affect biota negatively downstream. The aquatic and riparian environments downstream of the dam have been shown to be impacted significantly by anthropogenic activities. The riparian vegetation may be described as Largely Modified, macroinvertebrate fauna as Seriously Modified and the fish fauna as Moderately Modified. Therefore, the impacts on aquatic flora and fauna downstream as a result of increased erosion of the river channel immediately downstream of the dam wall can be considered a **Low Impact**. Longer term monitoring of impacts should be carried out downstream during the project and used to developed monitoring protocols and capacity within ARA-Sul, as indicated in the EMP.

Construction Impacts

The application of improper construction methodologies and outdated machinery as well as improper handling, storage, use and disposal of construction materials and wastes during construction could result in pollution of soil, groundwater, surface water and air. Such impacts are considered **Low Impact** and will be mitigated through the Construction and Workers Camp Environmental Management Plan as described in the EMP presented in the EISA's Volume 3.

Waterborne disease

The increase of the size of the reservoir could lead to a further increase in the prevalence rates of intestinal and urinary bilharzia and malaria as observed in many other reservoirs in Africa. These are serious public health impacts that would need to be monitored and treated if they arise. The impact risk for an increase in prevalence rates of waterborne diseases is considered **Medium Impact**.

Physical Cultural Heritage
The only sites with cultural and historical value around the Corumana Dam are the Mahungo and Malengane mounts where massacres occurred during the war of 1976-1992. In addition, family graves are considered sacred places for which any affected will be dealt with under the Resettlement Action Plan.

Additional survey and salvage of archeological items and fossils, as well as routines for chance finds procedures for archeological relics and other physical cultural resourcse, will be dealt with under the Environmental Management Plan.

1.4 Environmental Management Plan

Volume 3 presents the Environmental Management Plan (EMP) for the completion of the Corumana Dam. The purpose of the EMP is to ensure that (i) any negative environmental impacts as a result of the completion of the Corumana Dam and increasing the reservoir capacity are avoided or mitigated to an acceptable degree, and (ii) any positive environmental impacts are enhanced where feasible. The EMP is intended to ensure that all aspects of the project comply with relevant Mozambican legislation, World Bank Operational Policies (including safeguard policies), and generally accepted international standards of good environmental practice. The EMP also seeks to ensure that measures identified in the EIA for mitigating adverse environmental impacts will be properly implemented.

The EMP outlines provisions for environmental management of construction activities and details specific provisions to be addressed by the contractors. These will be revised during year 1 of project implementation, in parallel with the Final Design of the Corumana Dam civil works and included as part of the bidding documentation.

The EMP outlines several plans required to be prepared. These are directed toward longer term support for the operation phase of the reservoir. This includes an Inundation Preparation Plan and implementation of a Reservoir Management Plan to strengthen capacity in ARA-Sul for longer-term environmental management measures. These will be supported by an Environmental Monitoring Plan. The project includes financial provisions for an independent consulting firm to be retained by DNA to assist ARA-Sul to implement these activities that will be used to enhance onsite capacity and sustainability of proposed mitigation measures.

1.5 Public Consultation Process

A Public Consultation Process was undertaken in order to identify key issues of concern and possible solutions, as well as accessing relevant local or traditional knowledge. Detailed reports on the Public Consultation Process are provided in Volume 2, Socioeconomic context (Social Impact Assessment). The Process included the following consultations presented here in chronological order:

- Prior to the start of the EIA/SIA process a series of public consultations were held by DNA and ARA-Sul on the Terms of Reference in 2009. (Public hearing, meetings and interviews with Government officials and Kruger National Park);

- Meetings with government officials on September 22, September 27 and October 22, 2010;

- Workshop organised by DNA to present and discuss the EPDAs/ToR for the EIA and SIA on October 20, 2010. Participants included ARA-Sul, MICOA, Ministry of Agriculture and representatives from Department of Water Affairs in South Africa and the World Bank;

- Disclosure of the EPDAs/ToR to the borrower (DNA) and Interested and Affected Parties (I&APs) on October 22, 2010;

- Public notification in Journal Noticias and Radio Mozambique on October 26, 2010 regarding Public Consultation meetings on the EPDAs/ToR for the EIA and SIA;

- Public Consultation meeting at Corumana on November 8, 2010;

- Consultation with Interested and Affected Parties (I&APs) November 24, 2010; and

- Workshop and presentation on the findings of the EIA, SIA and EMP with DNA, ARA-Sul, Department of Water Affairs in South Africa and Kruger National Park in Nelspruit, South Africa, on February 9, 2011.

- Public consultation and presentation of findings at Corumana Dam site with I&APs and members of project affected communities on April 13, 2011.

Overall, most of the responses from the various consulatations were on socio-economic issues and are descried in the SIA. The following issues raised in the consultations relate to the biophysical environment:

- Kruger National Park conveyed that they would be grateful if the following concerns could be investigated (Consultation Data Sheet submitted November 2010):

  i. A survey on how far the water will push up into the Sabíe River when the Corumana Dam is full;

  ii. Model the expected sediment deposition patterns in the Sabíe River – also upstream from the full supply mark;

  iii. Ecological impact of inundation and sediment deposition;

iv. Changes in Biodiversity and dynamics as a result of inundation and sedimentation;

v. Describe the loss of geomorphological features and quantify the loss in terms of uniqueness of such features;

vi. Water quality at the inlet of the dam and outlet of the dam;

vii. Chemical quality in/of the sediments at the inlet, dam wall and outlet; and

viii. The socio-economic benefit that Mozambique will derive from additional yield of water.

Kruger National Park was particularly interested in the model results regarding the approximate extent of backwater effect and increased sedimentation into the Park as a result of raising the full supply level of the reservoir, in order to assess the need for relocation of habitats for endangered species such as breeding places for crocodiles in the Park. The South African Department of Water Affairs (DWA) also raised the issues regarding modelling of environmental effects in Kruger National Park as a result of the raising of the full supply level and the socio-economic benefits for Mozambique from the new water yield when future investments permit water transfer to Maputo.

- The issues raised by the Kruger National Park and DWA have to a large extent been included in the EIA. However, chemical measurements of water and sediment quality were not included. In accordance with ToR the present water and sediment quality was assessed from the composition of the aquatic macroinvertebrates (SASS5). The Environmental Management Plan proposes that chemical analyses of water and sediment quality are included in the long-term monitoring supported under project implementation to allow for monitoring before, during and after construction works as part of the capacity development within ARA-Sul. Breeding places for crocodiles in the Sabíe River in Kruger National Park with the potential impact area were not observed in this study, but the proposed monitoring programme outlined in the EMP includes survey and monitoring of locations of habitats for endangered species, including breeding places for crocodiles within the potential impact area. The EMP recommends that any breeding places are identified before the construction work starts;

- The Sabie Game Park representatives conveyed that the Park is struggling with poachers who enter illegally via the reservoir, with the help of local fishermen. If the water level increases, poachers are expected to be able to penetrate further into the park and the problem may worsen.

- The president of Corumana Community Fishing Council (CFC) raised the issue of clearance of trees in the future inundated areas. This, according to CFC, would be beneficial for the fishing community and the fishermen feel that they could avoid high maintenance costs on fishing nets, which will be easily trapped and broken by roots and tree branches left in the shallow waters. The CFC president suggested that trees in the Jone and Fungotine fishing areas should be cleared prior to inundation. Assessing the best way to address these concerns of the CFC will be developed in the Inundation Preparation Plan which will be included as part of the final EMP.

1.6 Conclusion

Most of the assessed negative impacts were classified as **Low Impact** (11 were identified). Seven were classified as having **Medium Impact**, one as having **Very Low Impact** and one **No Impact**. Assessment of any potential impact on physical cultural heritage is also mentioned in the overview table below but addressed in more detail in the ESIA's "Volume 2: Socioeconomic context (SIA)". The assessed impacts are presented in the table 1-1 below organized according to the different level of impact.

The decision on whether the project should be allowed to proceed will take into consideration all the environmental, social, economic, technical and political issues. From the environmental perspective, the associated impacts been identified can be addressed through the mitigation measures outlined in the EIA and the EMP and do not present any barrier to proceeding with the proposed project.

Table 1-1 Overview table of impact classification and details

No	Risk	Impact	Details	Mitigation
1	Backwater effect in Sabíe River (i.e., upstream inundation in a flood event) within the Republic of South Africa as a result of raising the FSL.	Medium	At a FSL of 117 masl the backwater effect is estimated to be 730 m into South Africa. The affected stretch would be 450 m for the alternative FSL of 115 masl. In a -1-in-200 year return period flood at FSL 117 masl, the backwater effect could reach approximately 1,195 m into South Africa and be confined to the river channel. In the same 1-in-200 year return period flood at FSL of 115 masl, the backwater effect could reach 1,050 m into South Africa and be confined to the river channel.	Operating Rules of the dam allow for draw down of the reservoir, particularly during flood conditions, to diminish upstream inundation.
2	Induced sedimentation as a result of raised FSL to 115 or 117 masl.	Medium	In a 1 in 200 year return period flood, the zone of induced sedimentation caused by a FSL of 117 masl could extend 1,080 m into South Africa. In the same 1 in 200 year return period flood at FSL of 115 masl, the zone of induced sedimentation could reach 935 m into South Africa.	Operating rules of the dam allow for draw down of the reservoir, particularly during flood conditions, to diminish upstream inundation.
3	Inundation and loss of terrestrial habitats.	Medium	Increasing the FSL of the reservoir will inundate terrestrial habitats thus leading to a loss surrounding the present reservoir. The following areas of natural habitat around the Corumana reservoir will be affected by inundation after raising the FSL to 117 masl: i) 888 ha of Sclerocarya birrea – Acacia nigrescens Savanna; ii) 445 ha of Lebombo South Landscape; and iii) 274 ha Floodplain Grassland. Raising the FSL to 115 masl would affect a total terrestrial area that is 40% smaller. The following areas of natural habitat around the Corumana reservoir would be affected by inundation after raising the FSL to 115 masl: i) 469 ha of Sclerocarya birrea – Acacia nigrescens Savanna; ii) 214 ha of Lebombo South Landscape; and iii) 242 ha Floodplain Grassland. The hydrological modelling has showed that FSL 115 masl or 117 masl will rarely be obtained (i.e. in only about 10% of the time), so some of the affected area will only be affected part of the time. Riparian vegetation along a narrow stretch of the river channel extending some 730 m into South Africa (where Kruger National Park lies) will be inundated at a FSL of 117 masl. The	Floodplain Grassland is expected to re-establish on higher ground along the new reservoir shoreline. The two main terrestrial natural habitat types that would be lost through reservoir inundation (Sclerocarya birrea – Acacia nigrescens Savanna and Lebombo South Landscape) occur extensively in the Kruger National Park, the existing Sabie Game Park, and in the area of the proposed Ingwe Game Park, such that measures to ensure further protection of these habitat types outside the reservoir inundation zone are not considered necessary.

No	Risk	Impact	Details	Mitigation
			affected stretch would be 450 m for a FSL of 115 masl.	
4	Narrowing of the downstream river channel and increase in riverine vegetation as a result of raising the FLS to 115 or 117 masl.	Medium	Increased storage capacity following completion could mean smaller floods (i.e., 1 in 10 year return period flood) would be absorbed. A reduction in sedimentation carrying floods could lead to increased erosion immediately downstream of the dam wall. An area that is particularly vulnerable to erosion is around the road bridge approximately 2 km downstream of the dam.	Environmental water release requirements incorporated into the dam's operating rules Implementation of environmental flow program and monitoring plan
5	Loss of some individuals of three threatened plant species as a result of inundation.	Medium	Three threatened plant species potentially occur in the area to be inundated: Adenium swazicum (Endangered), Ipomoea venosa (Vulnerable) and Turbina longiflora (Vulnerable).	Intensive survey to locate any invididuals of these threatened plant species within the future inundations zone, followed by relocating individual plants whenever feasible to suitable, protected habitats.
6	Impact on grazing potential in Sabie Game Park due to inundation of Floodplain Grassland.	Medium	Floodplain Grassland likely plays an important role in the grazing dynamics of herbivores, particularly as grazing potential decreases in the dry season. While re-establishment of grassland is expected to be quite fast there will be a temporary loss in winter grazing until it re-establishes under new operating conditions.	Ensuring adequate Floodplain Grassland along the reservoir shoreline for wildlife and livestock will be among the key technical criteria used in the environmental flow requirements to inform development of the new Operating Rules for the dam.
7	Increase in prevalence rates of waterborne diseases.	Medium	African reservoirs are known for causing significant increases in intestinal and /or urinary bilhariza (aka schistosomiasis) and malaria.	A baseline of these waterborne diseases will be established before the complete inundation of the reservoir; monitoring of these waterborne diseases will be carried out in the years following complete inundation. If required, both types of bilharzia can be easily treated with the drug Praziquantel, while malaria can be effectively controlled through the distribution and use of impregnated mosquito nets.
8	Reduction in annual downstream flow as a result of increased FSL	Low	Increases in the historical firm yield, reduced spillage and higher evaporation losses (yield and spillage) are estimated to decrease downstream flows by approximately 5.1%.	Environmental water release requirements incorporated into Operating Rules. Implementation of environmental water releases and monitoring programs.
9	Invasion of non-native species on bare soil and in dam reservoir.	Low	A number of potential invasive species are present in the vicinity of the reservoir, including Parthenium hysterophorus as an alien herb and seed bank. Increased reservoir area might possibly result in increased infestation of aquatic plants currently present (Water Lettuce Pistia stratiotes; Water Hyacinth Eichhornia crassipes; Red Water Fern Azolla filiculoides; and Kariba Weed Salvinia molesta), particularly if eutrophic conditions develop.	Monitoring measures to be implemented will be specified in the Reservoir Management Plan, including a longer- term contigency plan to be developed with ARA-Sul. Basin wide collaboration through TPTC and upstream with the SANParks biocontrol program, to be put in place. Currently, the South African National Parks Board (SANParks) is controlling alien plants in the river systems of

No	Risk	Impact	Details	Mitigation
				Kruger National Park.
10	Threat to aquatic and riparian biota and habitats as a result of increased FSL.	Low	No habitats or species of conservation importance or concern were collected or identified (IUCN Red List). Since Corumana Dam has been in place and the reservoir has been in operation since 1989, there is no new threat to migrating fish species.	Environmental Monitoring Plan provides for regular biological monitoring in the reservoir and downstream of the Corumana Dam.
11	Negative environmental footprint from construction of the saddle dam with fuse plug emergency spillway.	Low	The saddle dam will cover an area of approximately $0.1km^2$ (10 ha) of Floodplain Grassland.	Relatively small area of habitat loss with no specific mitigation measures. Habitat is well represented in the project area.
12	Temporary loss of habitat in footprint of emergency spillway and temporary impacts of erosion.	Low	Excavation for the emergency spillway will temporarily remove approximately $0.4 km^2$ (40 ha) of Floodplain Grassland. During and immediately after, the area is vulnerable to erosion which may lead to increased suspended solids in runoff. In the long term, however, surrounding grass species are likely to re-establish themselves in the exposed area.	Construction and Workers Camp Mangement Plan requires contractors to plan all excavations, topsoil and subsoil storage so as to minimize runoff and erosion. Managed re-vegetation—using native plant species--by the Contractor of this area will assist natural restoration.
13	Inundation of habitats following activation of the fuse plug and emergency spillway.	Low	1 in 1,000 year return period flood would activate the fuse plug and channel water through the emergency spillway causing temporary flooding of areas with Floodplain Grassland and Sclerocarya-Acacia Savanna south of Corumana reservoir.	A channel will be constructed as part of the project to discharge releases from the emergency spillway to Massecate River and into the Sabíe River downstream of the Corumana Dam.
14	Backwater effect on riparian vegetation as a result of increased FSL.	Low	Backwater effects and induced sedimentation due to increasing the FSL of the dam will affect riparian vegetation upstream the reservoir during flood events. This area was severely affected as a result of the 1 in 100 year flood in 2000. Impact on the non-marginal zone not considered significant given that all plants collected were classified as Least Concern. No plants of high conservation value were observed at the assessed area.	Environmental Monitoring Plan provides for continued monitoring to allow for long term assessment. The new Operating Rules for the Corumana Dam are expected to minimize the frequency and duration of any backwater flooding within the Kruger National Park.
15	Negative impact on upstream macroinvertebrate fauna as a result of increasing the FSL.	Low	An increased FSL to 115 or 117 masl may induce sedimentation and inundation upstream. However, impact is considered to be low as extent of sedimentation and inundation is expected to be over a small area confined within the existing channel.	Environmental Monitoring Plan includes assessment of macroinvertebrates and how they respond to any long-term negative impacts
16	Negative impact on upstream fish populations due to induced sedimentation at higher FSL	Low	An increased FSL to 115 or 117 masl may induce sedimentation and inundation upstream. However, impact is considered to be low as extent of sedimentation and inundation is expected to be over a small area confined within the existing channel.	Environmental Monitoring Plan includes fish monitoring to assess and respond to any long term negative impacts
17	Negative impact of reduced downstream flows on aquatic and riparian environments and increased	Low	The aquatic and riparian environments downstream the dam have been shown to be impacted significantly by anthropogenic activities. Riparian vegetation described as Largely Modified,	Environmental Monitoring Plan provides for downstream assessment of any longer-term changes in aquatic and riparian ecosystems.

No	Risk	Impact	Details	Mitigation
	erosion as a result of increasing the FSL.		macroinvertebrate fauna Seriously Modified and fish fauna as Moderately Modified. The estimated 5.1% reduction in downstream flows at FSL 117 masl is not expected to have a significant negative impact. The impacts on aquatic flora and fauna downstream as a result of increased erosion of the river channel immediately downstream of the dam wall is considered a Low Impact.	
18	Construction impacts.	Low	The application of improper construction methodologies and outdated machinery as well as improper handling, storage, use and disposal of construction materials and wastes during construction could result in the pollution of soil, groundwater and air.	Construction and Workers Camp Management Plan, along with the Construction EMP (CEMP) to be prepared and implemented by the Contractor, outlines necessary measures to manage and mitigate negative construction impacts.
19	Negative impact on ability of fish populations to adjust as a result of increasing FSL.	Very Low	Increasing the FSL of the reservoir will most likely enlarge the existing fishery in the reservoir (estimated net increase of total size of fishery is expected to increase by 2%). The common artisanal species present in the reservoir are environmental generalists (Sharptooth Catfish Clarias gariepinus; Common Carp Cyprinus carpio; and Mozambique Tilapia Oreochromis mossambicus). Although the reservoir will expand in area, it is unlikely to undergo changes that would signficantly harm existing fish populations, including of the species with more specialized ecological requirements.	Implementation of the Fisheries Program as part of the Reservoir Management Plan includes includes regular monitoring, improved zoning to protect fish breeding habitats, and improved management.
20	Increased seepage from the dam embankment.	No	Seepage from the dam has been observed on the downstream side of the embankment. Increasing the FSL to 117 masl could increase the pressure on the seepage area and increase flow. However, the project will reduce this impact to none through the dam safety assessment and design contract for the dam works to be financed by the project.	Geotechnical investigations carried out as part of Dam Safety Audit during project preparation. Remedial measures to be financed under project implementation Dam safety Panel of Experts appointed to advise on safety aspects
21	Loss of physical cultural heritage	-	The only sites with cultural and historical value around the Corumana Dam are the Mahungo and Malengane mounts where massacres occurred during the war of 1976-1992. Family graves are considered sacred places.	Additional survey and salvage of archeological items and fossils as part of the Inundation Preparation Plan Construction and Workers Camp Mangement Plan includes chance finds procedures for archaeological relics, fossils, or other physical cultural resources that might be uncovered during construction. Resettlement Action Plan provides for addressing family graves

2 Introduction

2.1 Background

The water resources sector in Mozambique is one of the Government's key focal areas in its efforts to sustain economic growth and address poverty. A series of progressive reforms have resulted in the recent approval of the Water Policy (WP, Política de Águas), Water Resources Management Strategy (WRMS, Estratégia Nacional de Gestão de Recursos Hídricos) and Regulations for Licenses and Concessions (RLC, Regulamento de Licença e Concessões de Água). Despite the success of these efforts, the country faces a number of constraints. These include, in particular, securing sources for bulk water supply to the greater urban area of Maputo, adapting to high hydroclimatic variability and managing recurrent floods and droughts.

There is a strong correlation between economic performance and rainfall as a result of limited storage facilities and underdeveloped flood control infrastructure. For example, it has been estimated that major floods and droughts reduce GDP growth by an average of 1.1 percentage points annually. Furthermore, water balance calculations of the current water supply system for Maputo indicates that by 2015, additional sources need to be made available to meet a deficit that is estimated to grow to 120-150 Mm^3 per year by 2030 as well as serve the increasing demand in newly included areas (the Master Plan of the Supply of Water to the Area of Great Maputo, FIPAG, 2011). A number of studies have established completion of the Corumana Dam as the first step in augmenting water supply for the greater metropolitan area of Maputo (2009). In october 2009 the report "Water Supply Strategies for Greater Maputo Area until 2030" completed under the auspices of the Tri-Partite Technical Committee of the Interim IncoMaputo Agreement included a preliminary screening of potential environmental and social impacts which showed completion of Corumana as one of the best of the large infrastructure options.

The Government of the Republic of Mozambique (GoM) has initiated a National Water Resources Development Project (hereafter "Project") to address several of these issues with support from the World Bank. The project is now under preparation and will undertake a number of critical infrastructure interventions and assistance to strengthen technical and institutional planning. This report includes the EIA of the completion of the Corumana Dam which is an existing embankment dam with a height of 45 m, a crest length of 3,050 m and which has been under operation since 1989. The Dam will be completed by the installation of six spillway gates and a saddle dam with a fuse plug emergency spillway.

This EIA report deals with the potential impacts on the biophysical environment as a result of the completion of Corumana Dam. In parallel, an Environmental Management Plan (EMP) has been prepared to outline the most appropriate mitigation measures necessary to manage the expected impacts at this stage (ESIA - Volume 3). As the detailed technical designs for the infrastructure improvements are developed, at the onset of the Project, the EMP will be finalized so as to better meet confirmed needs for managing the environmental concerns. A Social Impact Assessment has been prepared to address the socioeconomic considerations associated with the proposed investment (ESIA – Volume 2) as well as to inform development of the Resettlement Action Plan, the RAP (ESIA – Volume 4) developed as part of project preparation. The ESIA for the completion of Corumana Dam hence includes four volumes:

- Volume 1: Biophysical environment (Environmental Impact Assessment)
- Volume 2: Socioeconomic context (Social Impact Assessment)
- Volume 3. Environmental Management Plan
- Volume 4: Resettlement Action Plan

2.2 Objectives of the EIA

Environmental Impact Assessment (EIA) is a systematic process to identify, predict and evaluate the environmental effects of proposed actions and projects. The objectives of the EIA process are to:

- Provide information for decision-making on the environmental consequences of the project;
- Comply with all legal requirements in force in Mozambique, to obtain the Environmental License;
- Identify possible adverse environmental impacts of the project and assess their severity;
- Avoid serious and irreversible damage to the environment;
- Identify appropriate enhancement and mitigation measures of identified impacts;
- Inform development of the Environmental Management Plan to be implemented before, during and after construction.
- Inform the public and obtain their opinion and local knowledge during a Public Consultation process.

A list of report preparers is attached in Appendix 1.

3 Description of the Project

3.1 The existing Corumana Dam

The Corumana Dam is an existing, inclined core rock fill embankment dam that was established during the period 1983-1989. The dam is situated in the Moamba district on the Sabíe River at the border to the Republic of South Africa, approximately 90 km north-west of Maputo.

Ownership

The Government of Republic of Mozambique owns the dam through the Direcção Nacional de Águas, DNA (the National Directorate for Water) of the Ministry of Public Works and Housing. Operation, management and maintenance of the dam are the responsibility of the Administração Regional de Águas do Sul, ARA-Sul (Southern Regional Water Administration).

Purpose of the Dam

The original purposes of the dam were the regulation of flow in the Sabíe River for improved flood control, the provision of irrigation water along the Sabíe and Incomati rivers downstream thereof and generation of hydroelectric energy.

Previous resettlement

The construction of the Corumana Dam between 1983 and 1989 led to the relocation of the communities of the locality of Matunganhane situated along the Sabíe River upstream the dam around the reservoir. Local displacement also occurred as a result of the civil war in the 1980s. More recent resettlement has also taken place in 2002 when the Sabie Game Park (SGP) was established on the northern shore of the reservoir where the community of Magonela was relocated and a new community, Ndindiza, was created.

Characteristics of the existing dam

The existing dam has a height of 45 m and the inclined core rock fill embankment has a crest length of 3,050 m. The dam has a spillway with six un-gated openings, a concrete chute and a stilling basin at the right abutment. Two concrete ducts for water releases are located under the dam with a control tower at the inlets for operation of trash screens and emergency gates. The dam is operated at 111 masl, the elevation of the spillway sill with a reservoir capacity of approximately 720 Mm^3. The originally intended height (with spillway gates) is 117 masl with an estimated reservoir capacity of 1,240 Mm^3.

Location of the dam

25°13'10.10"S : 32° 8'2.31"E
Southern Mozambique, Maputo Province, Moamba District
Sabíe River, major tributary of the Incomati River

3.2 Completion of Corumana Dam (the Project)

The Corumana Dam is an existing 45 m high embankment dam that was constructed during 1983 to 1989. The dam is situated on the Sabíe River, immediately downstream of the border with the Republic of South Africa approximately 90 km north-west of Mozambique's capital Maputo in the Moamba District.

A tripartite study by Mozambique, South Africa and Swaziland under the auspices of the IIMA on the Augmentation of Water Supply to the City of Maputo and its Metropolitan Area (October 2009) identified completion of the Corumana Dam as one of the priority interventions. The Master Plan for the Greater Maputo Water Supply System (February 2011) has also confirmed that completion of the Corumana Dam must be regarded as the first choice for the next step in water resources development given the lower risk in time and cost and the more immediate possibility of implementation.

The Environmental Impact Assessment and a Technical Services and Dam Safety assignment undertaken during preparation have both undertaken hydrological analyses to determine the potential impacts of the increased reservoir and the extent of possible back flooding. Alternative operating levels for the reservoir were assessed.

The dam was intentionally constructed for improving flood control, regulation for downstream irrigation abstractions and provide hydropower production. Since 1989, it has been in operation but resources were insufficient to install the six spillway gates and complete the hydro-mechanical works. As a result, it is being operated at the level of 111 masl, corresponding to the elevation of the spillway sill, seven meters below the designed full supply level of 117 masl. Mean inflow is approximately 17.6 m^3/s of which 9.5m^3/s can be released as firm water yield. Increasing the water level from 111 masl to its originally intended level of 117 masl could increase the reservoir capacity from 720 Mm^3 to 1,240 Mm^3, thereby increasing the incremental safe yield to provide bulk source for water supply for Maputo.

The proposed completion of the Corumana Dam includes civil and hydro-mechanical works, consulting services for design and supervision and technical assistance. These activities will be completed by Direcção Nacional de Águas, DNA (the National Directorate for Water) who owns the dam through the Government Ministry of Public Works and Housing, and the Administração Regional de Águas do Sul, ARA-Sul (Southern Regional Water Administration) who administrates and operates the dam. The specific infrastructure improvements involve the addition of the following elements:

- Six crest radial spillway gates and ancillary hydro-mechanical equipment;

- Repair works of concrete pillars/abutments;
- Strengthening works on the existing dam; and
- Construction of saddle wall with a fuse plug emergency spillway.

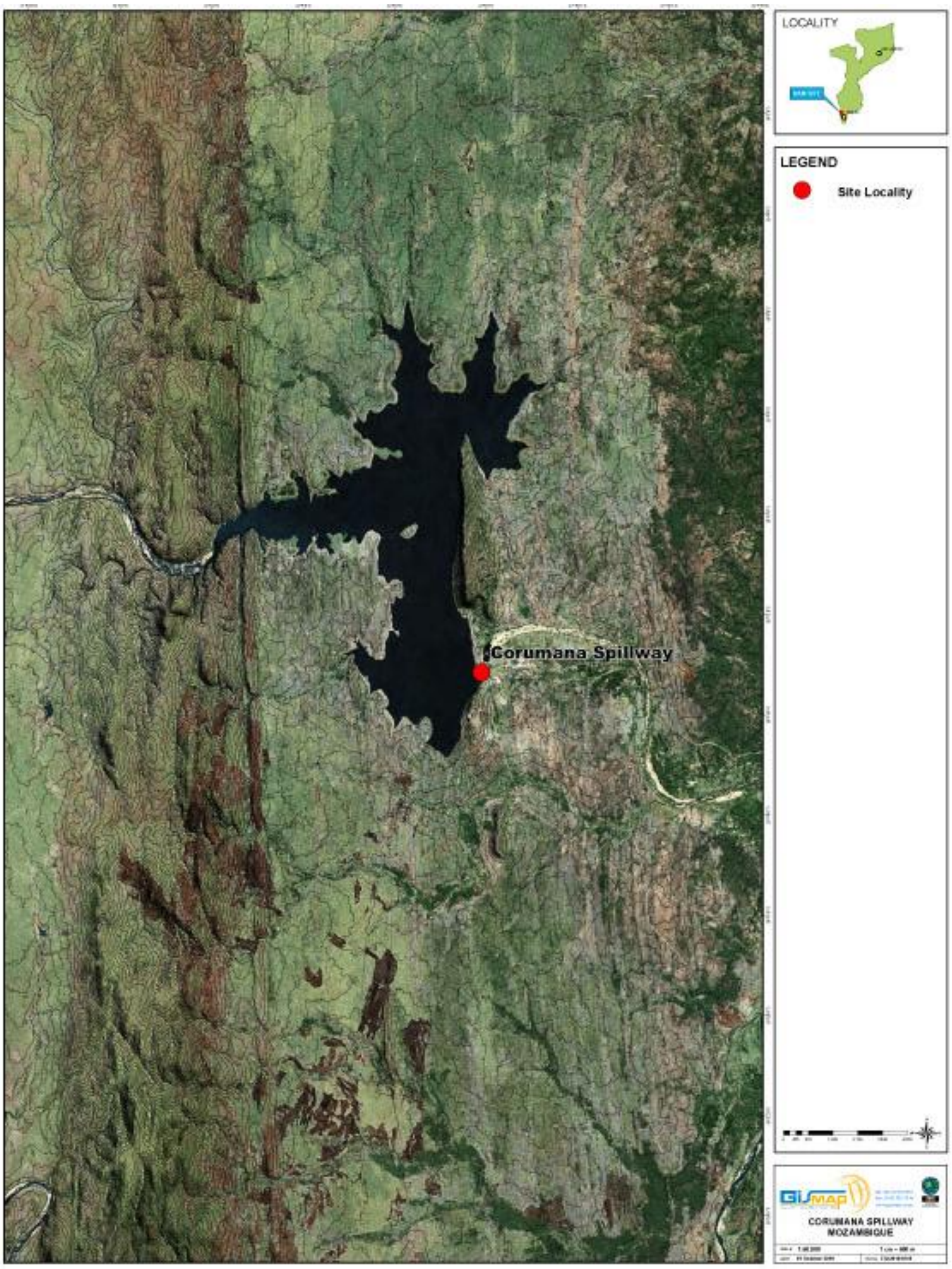


Figure 3-1 Corumana Dam site (Source: Google earth)

Figure 3-2 Close up of the Corumana Dam site (Source: Google earth)

Figure 3-3 Corumana Dam. Dam piers on spillway crest and overhead concrete beam for installation of six radial gates were already constructed in 1983-89.

3.2.1 Radial gates

Increasing the FSL of the dam will be achieved by installing six radial gates on the spillway crest. Each gate will span an 18 m opening between 4.5 m wide concrete piers. Each of the gates will be driven by two hydraulic hoists. Stoplogs, travelling hoist and necessary electrical equipment will be installed as well.

The concrete piers were constructed in 1983-89. These piers have blockouts in the reinforced concrete for the following items which will have to be installed prior to the instalment of the radial gates:

- Radial gate trunnion support beams;
- Upper hydraulic servomotor supports;
- Foundations for the stoplog hoist superstructure foundation;
- Guide plates and seal plates for the stoplogs; and
- Seal plates for the radial gates.

The existing structures have been subject to weathering for some twenty years. In order to ensure that the existing concrete is capable of supporting the addition of the gates the concrete will be tested and any needed repairs will be carried out. Any rusted components will also be replaced.

3.2.2 Saddle Wall and fuse plug emergency spillway

As a mitigating measure against extreme flooding to the 120 masl (1 in 1,000 year return period event), a saddle dam with fuse plug emergency spillway will be constructed some 3 km south of the Corumana Dam. At this site there is a natural saddle with a topographical elevation of 118.3 masl at its lowest point. With the existing dam crest at 122.5 masl water would be spilled out of the reservoir in this area during flooding, as the fuse plug is activated and emergency spillway utilized. Final designs of the saddle dam and emergency spillway will be developed during early Project implementation.

3.2.3 Auxiliary Facilities

Temporary worker construction camps and storage facilities will have to be established. These facilities will operate for approximately 24 months the expected duration of the construction work. At this stage of the project, the location and layout of these facilities have not been decided and planned. In addition, access roads for the transport of material and machinery may have to be constructed. Further details will be developed under the Construction and Workers Camp Environmental Management Plan.

3.3 Alternatives

3.3.1 Project alternatives

As outlined above, the Government of the Republic of Mozambique has embarked on an ambitious set of interventions to meet water demand for economic growth and poverty alleviation. Water supply coverage in the greater metropolitan area of Maputo will expand drastically and additional sources for bulk water supply will be indentified and in operation in the next decade. Unless additional sources of supply are secured the Greater Maputo Metropolitan Area is predicted to experience a shortage of water by 2015.

The study of project alternatives usually involves a systematic comparison of feasible options to the proposed project site, technology, design and operation. This includes a consideration of the "no project" option. With existing sources of supply fully commited and the yield from the existing Corumana Dam insufficient to meet increasing demands, the no project option would result in predicted shortages in water supply to the Greater Maputo Metropolitan Area by 2015. This would have significant implications for economic growth and development, reduce the quality of service, increase the cost to the most vulnerable sections of society without access to piped water supplies and the incidence of water borne disease. When comparing the alternative options, attention is given to the potential environmental impacts associated with the project, the feasibility of mitigating these impacts, the associated capital and recurrent costs, suitability of the proposed measures under the local conditions and the institutional, training and monitoring requirements.

In this instance, completion of the Corumana Dam has been identified as the first of a series of measures required to secure water for the Greater Maputo Metropolitan Area. This is based on projections of water demand for the GMMA and predictions that this will surpass the existing production capacity by 2015 (Figure 3-4). The total water demand for the GMMA (served and unserved areas) is estimated to increase to 84 million m^3/year (230,208 m^3/day) by 2015, to 107.4 million m^3/year by 2020 (294,253 m^3/day), and to 167.1 million m^3/year by 2030 (457,739 m^3/day)[1]. The current water balance calculations indicate that the estimated total water demand of the GMMA is approximately 60.1 Mm^3/yr as of 2007 (165,564 m^3/day).

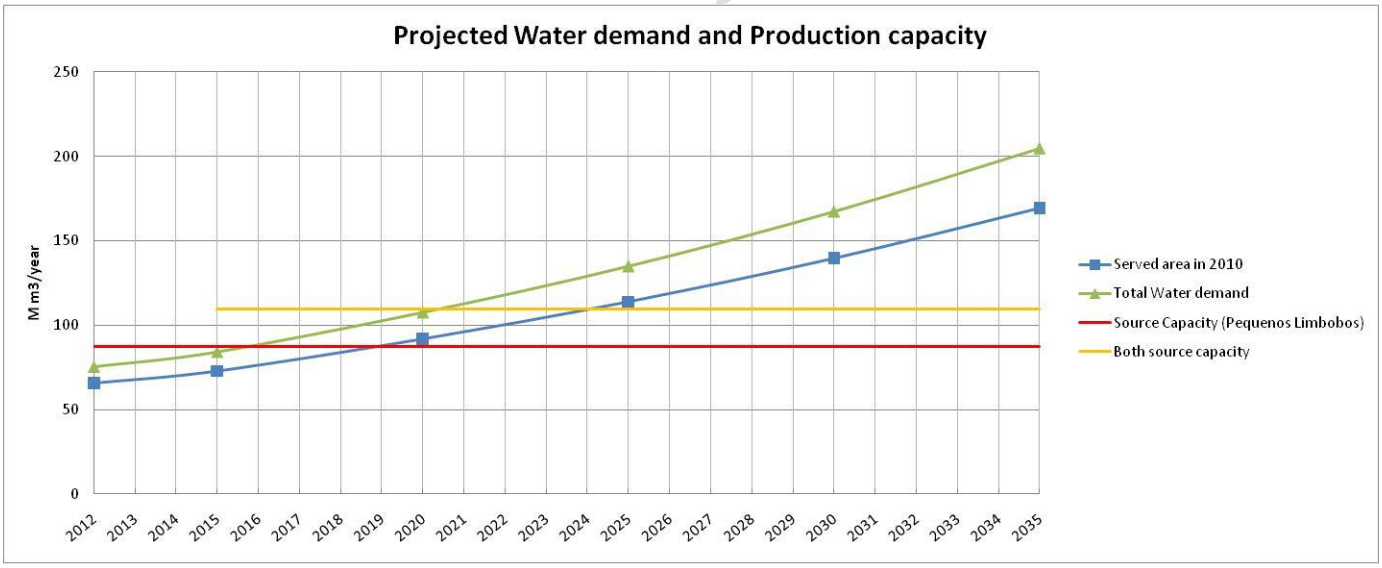


Figure 3-4 Projected Water Demand and Production Capacity[2]

The main water supply system primarily sources water from the intake from the Umbeluzi River with adjacent water treatment plant (WTP) downstream of the

[1] Draft Master Plan of the Supply of Water to the Area of Great Maputo, 2010.

[2] Ibid.

Pequeños Libombos Dam[3] (57 million m^3/year) but also from groundwater sources from a number of independent systems in the northern part of the city and in the Catembe peninsula (10 million m^3/year)[4]. If shortages are to be avoided in 2016 then additional sources of water are immediately required to serve the rapidly expanding new areas and meet a deficit that is predicted to grow to 120-150 Mm^3 per year by 2030. Completion of the Corumana Dam has been identified as the only short-term option capable of providing sufficient water to augment supply before the predicted shortage in 2016.

Identification of the completion of the Corumana Dam has been determined through a number of assessments over the past decade. These have assessed various possible options for augmenting water supply for the GMMA, including the following: i) surface water conveyed from the nearby Umbeluzi, Incomati and Maputo rivers; ii) groundwater from aquifers within or adjacent to the City of Maputo; iii) desalination of sea water; iv) re-use of water; and v) piped water from distant sources such as the Limpopo River. Acknowledging the high unaccounted for losses all studies have emphasized the need for complementary water demand management.

Hydrological water balance and reservoir operation simulations were done under the initial feasibility study for “Raising of the Full Supply Level of Corumana Dam” (Lahmeyer, 2003) and the tripartite study “Water Supply Strategies for Greater Maputo Area until 2030” (SWECO, 2009). Along with the “Master Plan for the Greater Maputo Water Supply System”, which is currently being finalised, they conclude that completion of the Corumana Dam is the most viable, short term option for the augmentation of the Maputo metropolitan water supply system. Other options, such as development of the Moamba Major Dam and off-channel storage on the Maputo River, will also be needed in the medium term to meet escalating demands. The ongoing Technical Services and Dam Safety Consulted, done in parallel with the EIA and the SIA, is confirming the safe reservoir yield and the economic implications done in previous assessments.

The October 2009 tripartite study on “Water Supply Strategies for Greater Maputo Area until 2030” (SWECO, 2009) included an environmental and social screening of the various alternatives. This was based on an analysis of selected impacts for both social and environmental components and included the minimum impacts that must be taken into consideration in order to rate the best alternatives as per a cause and effect matrix. The cause and effect matrix allowed the identification and rating of causes and effects from a specific project on the social and biophysical environment. An analysis of potential impacts on the social environment was based on local livelihood and basic conditions, such as housing, productive systems and subsistence, access to education, health services and public infrastructure as well as socially organized groups with certain standards of living. The environmental impacts were chosen based on project characteristics and location, with the physical location assessed in relation to the natural envi-

3 The Pequeños Libombos Dam also supplies approximately 28 million m^3/year for downstream irrigation. This volume is estimated to increase to 37 million m^3/year by 2030.
4 Assessments of groundwater supplies currently serving the areas of Inhaca and Catembe indicate sufficient water sources to meet local demand until 2030.

ronment and impacts linked to the potential loss of species, or affects on ecosystem functions. A matrix was then developed by selecting eight variables for both social and environmental components.

Among the alternatives considered to have reasonable costs, completion of the Corumana Dam was among three with moderately negative environmental and social impacts (Figure 3-5). It was also the only one considered to be sufficiently advanced in preparations to meet the then forecasted demand shortages by 2016. Other options, such as the transfers from the Maputo River are still at the identification phase and need more detailed investigations. The reuse of wastewater and desalinisation (and with auxiliary collection, treatment and distribution system) are deemed having high costs compared to the options available and evaluations[5]. Likewise, groundwater abstractions to the far north of Maputo is also deemed insufficient to meet the bulk water supply need in the medium term. While the “no project” option of using the existing Corumana Dam is considered to have lower environmental impacts, it cannot meet the water supply demands at the level of assurance required with the current capacity. The absence of the spillway gates also limits the ability to regulate downstream flows and thus increases the susceptibility to flood events.

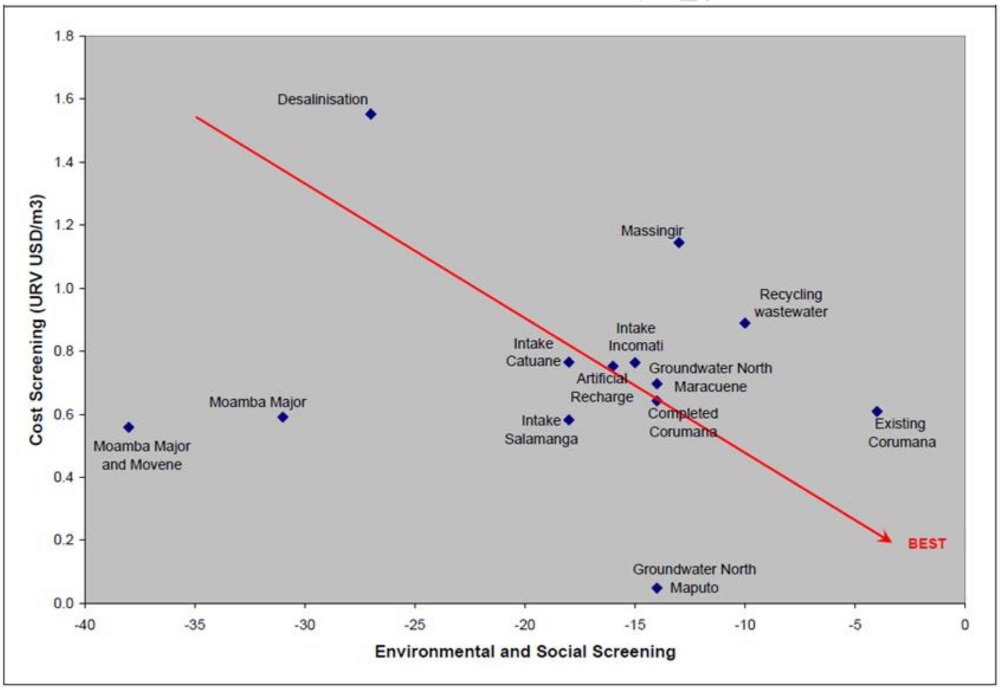


Figure 3-5 Cost estimate for gross list of water supply alternatives in 2009 USD value plotted against combined scores for environmental and social impacts.

[5] Maputo Water Supply Project – Draft Master Plan for the Greater Maputo Water Supply (2010)

3.3.2 Operational Alternatives

Within this context, the terms of reference for the environmental and social impact assessment were focused on those issues specific to completion of the Corumana Dam. During the scoping phase concerns had been acknowledged in relation to the potential backflooding effects resulting from an increase in the current operating level of 111 masl to the full supply level of 117 masl. In order to assess alternative options for meeting the water requirements of the GMMA from within the Corumana Dam, the assessment therefore considers an alternative option of increasing the current operating level of 111 masl to a full supply level of 115 masl to elucidate to what extent backwater effects and flooding of terrestrial habitats could be avoided or minimised.

4 Regulatory framework

4.1 EIA and Environmental Audit

According to the national Environment Act (Law No. 20/97 of 1 October) all public and private activities with the potential to influence the environmental components, must be preceded by an Environmental Impact Assessment (EIA) with a view to obtaining an Environmental License (EL) issued by the authority responsible for environmental licensing of various activities which is the Ministry for Coordination of Environmental Affairs (MICOA) through its National Directorate for Environmental Impact Assessment (DNAIA). This Law is based on the precautionary principle that focuses on preventing the occurrence of significant or irreversible negative environmental impacts, regardless of the existence of scientific certainty about the occurrence of such impacts on the environment.

The Environment Law defines the procedure for environmental impact assessment as a prevention tool for environmental management of projects and supports the Government of the Republic of Mozambique in decision making regarding the allocation of environmental permit for project development. The environmental license precedes any other legal license required. The Process of Environmental Impact Assessment is regulated by Decree No. 45/2004 of September 29 which recently (November 2008) has been updated in some of its provisions through the Decree No. 42/2008 of 4 November.

The Processes of Environmental Audit and Environmental Inspection are regulated, respectively, by Decree No. 32/2003 of August 20 and No. 11/2006 of July 15. The Regulation on Environmental Audit Process (Decree No. 32/2003 of August 20) indicates that any public or private activity can be subjected to public environmental audits (held by MICOA) or private (internal). The audited entity shall provide to the auditors full access to the sites to be audited, as well as all information requested. Meanwhile, the Regulation on Environmental Inspections (Decree No. 11/2006 of July 15) governs the legal mechanisms for inspection of public and private activities, which directly or indirectly are likely to cause negative environmental impacts. This law aims to regulate the activity of supervision, control and surveillance of compliance with environmental protection at national level.

MICOA has classified the Water Resources Development Project and the completion of the Corumana Dam Project activity as a Category A project and sub-project under the Regulation of the Process of Environmental Impact Assessment (Decree No. 45/2004 of September 29).

According to Decree No. 45/2004 of 29 September and the General Directive for Environmental Impact Studies (Ministerial Diploma 129/2006 of 19 July) Category A projects require that a Pre-Feasibility Study and Scoping Definition (EPDA) report and terms of reference (EPDA/ToR) be prepared and submitted for consideration and possible approval by the National Directorate for Environmental Impact Assessment (DNAIA). After the approval of the EPDA and ToR, the detailed EIA study will be undertaken and the Environmental Management Plan (EMP) of the project developed. Approval of the EIA and EMP reports will result in the issuance of an Environmental Licence (LA) by MICOA.

A Draft EPDA/ToR report for the Corumana Dam EIA was submitted to MICOA on 5 October 2010 for consultation and a final version for approval on 17 January 2010. MICOA approved the ToR and approved the final EDPA on February 22 2011.

4.2 International Conventions

In August 2002 the Republic of South Africa, the Kingdom of Swaziland and the Republic of Mozambique signed the Tripartite Interim Agreement for co-operation on the protection and sustainable utilization of the water resources of the Incomati and Maputo watercourses. This agreement is relevant to the Corumana Dam situated on the Sabíe River, a major tributary to the Incomati River. The Agreement states that the parties shall, individually and, where appropriate, jointly develop and adopt technical, legal, administrative and other reasonable measures in order to:

i) Prevent, reduce and control pollution of surface and ground waters and protect and enhance the quality status of the waters and associated ecosystems for the benefit of present and future generations;

ii) Prevent, eliminate, mitigate and control transboundary impacts

iii) Co-ordinate management plans and planned measures;

iv) Promote partnership in effective and efficient water use;

v) Promote the security of relevant water related infrastructures and prevent accidents;

vi) Monitor and mitigate the effects of floods and droughts;

vii) Provide warning of possible floods and implement agreed upon urgent measures during flood situations;

viii) Establish comparable monitoring systems, methods and procedures;

ix) Exchange information on the water resources quality and quantity and the use of water;

x) Promote the implementation of the Agreement according to its objectives and defined principles;

xi) Implement capacity building programmes; and

xii) Co-operate with SADC organs and other shared watercource institutions; the Joint body for co-operation between the parties is The Tripartite Permanent Technical Committee (TPTC).

In addition to the Tripartite Interim Agreement for the Incomat River Basin, Mozambique is a signatory to a number of international agreements which will be abided by, as relevant, during the course of implementing the proposed project. These include:

– Agreement, of August 7, 2000, SADC Revised Protocol on Shared Watercourses;
– Resolution 18/81, of 30 December, ratifying the African Convention of Nature and Natural Resource conservation;
– Resolution 8/93, of 08 December, ratifies the Vienna Convention on Ozone Protection of 22 March 1985 along with the London and Copenhagen amendments;
– Resolution 1/94, of 24 of August, ratifies the UN Climate Change Convention of June 1992;
– Resolution 2/94, of 24 August, ratifies the UN Convention on Biological Biodiversity;
– Resolution 17/96, of 26 November, ratifies the East Africa Marine Protection, Management and Development Convention;
– Resolution 52/2001, of 6 November, ratifies the International Convention and Protocol on Civil Responsibility for Hydrocarbon Pollution;
– Resolution 5/2003, of 18 February, ratifying the International Convention for the Prevention of Pollution by Shipping 1973 and Protocol 1978 – MARPOL 1973-1978;
– Resolution 6/2003, of 18 February ratifying the International Convention on the Preparation, Combat and Cooperation against Hydrocarbon Pollution, 1990-OPRC 90;
– Resolution 45/2003, of 05 November, the Convention on Tropical Areas of International Importance with serve as Habitats for Aquatic Birds;
– Resolution 10/2004, of 28 July 2004, ratifies the Kyoto Protocol on Climate Change; and
– Resolution 56/2004, of 31 December Ratifies the Stockholm Convention on Persistent Organic pollutants.

4.3 World Bank Safeguard Policies

The World Bank's ten environmental and social operational policies (also called safeguard policies) are essential for preventing and mitigating undue harm to people and the environment in all Bank-financed operations. The ten operational safeguard policies are listed below. Those policies that are triggered by the project are specified accordingly:

Safeguard Policy	**Triggered**
Environmental Assessment (OP/BP 4.01)	yes
Natural Habitats (OP/BP 4.04)	yes
Forestry (OP/BP 4.36)	no
Pest Management (OP/BP 4.09)	no
Physical Cultural Resources (OP/BP 4.11)	yes
Indigenous Peoples (OP/BP 4.10)	no
Involuntary Resettlement (OP/BP 4.12)	yes
Safety of Dams (OP/BP 4.37)	yes
Projects on International Waterways (OP/BP 7.50)	yes
Projects in Disputed Areas (OP/BP 7.60)	no

4.3.1 Environmental Assessment (OP/BP 4.01)

In World Bank operations, the Environmental Assessment OP 4.01 helps establish level of necessary environmental assessment and appropriate classification into one of three categories. *Category A* projects are deemed to have significant adverse environmental impacts that are sensitive, diverse, or unprecedented. For a Category A project, the borrower is responsible for preparing a report, normally an EIA. *Category B* projects are deemed to potentially adverse environmental impacts on human populations or environmentally important areas—including wetlands, forests, grasslands, and other natural habitats—but that these are less adverse than those of Category A projects. *Category C* projects are deemed to have minimal or no adverse environmental impacts and no environmental impact assessment is necessary. The Project activity to complete the Corumana Dam has been classified *Category A.*

In complying with *Environmental Assessment* OP 4.01, paragraph 8(a) Environmental Screening, a Category A Project should ensure that an environmental assessment (EA) is initiated as early as possible in project processing and is integrated closely with the economic, financial, institutional, social, and technical analyses of a project. The commissioning of environmental assessment work is the responsibility of the Borrower and the World Bank reviews the findings and recommendations of the environmental assessment to determine whether they provide an adequate basis for processing the project for Bank financing. When the borrower has completed or partially completed the environmental assessment work, the World Bank reviews the EA to ensure its consistency with this policy.

The environmental assessment is meant to improve decision making and that potentially affected people and stakeholders have been properly consulted. To meet these objectives, the World Bank policy defines procedures to: (a) identify the level of environmental risk (screening) associated with a project, (b) assess the potential environmental impacts associated with the risk and how they should be reduced to acceptable levels (environmental assessment and management), (c) ensure the views of local groups that may be affected by the project are properly reflected in identifying the environmental risk and managing any impacts (public consultation), (d) make certain that the procedures followed in the environmental assessment process are adequately disclosed and transparent to the general public (disclosure) and (e) includes measures for implementation and supervision of commitments relating to findings and recommendations of the environmental assessment (i.e. the Environmental Management Plan, EMP).

4.3.2 Pest Management (OP/BP 4.09)

The World Bank supports strategies that promote integrated pest management approaches (such as biological control, cultural practices, and the development and use of crop varieties that are resistant or tolerant to the pest). There are no concerns with Pest Management in the Project, and the OP 4.09 is thus not triggered.

4.3.3 Natural Habitats (OP/BP 4.04)

The World Bank supports the protection, maintenance, and rehabilitation of natural habitats and their functions in its economic and sector work, project financing, and policy dialogue and expects borrowers to apply, a precautionary approach to natural resource management. In compliance with the OP 4.04, a World Bank financed project shall: i) promote and support natural habitat conservation and improved land use and the rehabilitation of degraded natural habitats; ii) prevent any significant conversion or degradation of critical natural habitats[6]; and iii) wherever feasible sited on lands already converted (excluding any lands that in the Bank's opinion were converted in anticipation of the project).

The Natural Habitats safeguard seeks to ensure that World Bank supported infra-structure and other development projects take into account the conservation of biodiversity, as well as the numerous environmental services and products which natural habitats provide to human society. The policy strictly limits the circum-stances under which any Bank supported project can damage natural habitats

[6] Significant conversion is the elimination or severe diminution of the integrity of a critical or other natural habitat caused by a major, long-term change in land or water use.

(land and water areas where most of the native plant and animal species are still present). Specifically, the policy prohibits Bank support for projects that would lead to the significant loss or degradation of any Critical Natural Habitats, including those that are legally protected, officially proposed for protection or unprotected but of known high conservation value. Natural habitats are defined as land and water areas where the biological communities of ecosystems are formed largely by native plant and animal species, and human activity has not essentially modified the area's primary ecological functions.

The Project investments trigger OP 4.04, the impacts of which have been identified in the the EIA and the associated mitigation measures of which have been outlined in the EMP.

4.3.4 Forestry (OP/BP 4.36)

Any World Bank involvement in the forestry sector aims to reduce deforestation, enhance the environmental contribution of forested areas, promote afforestation, reduce poverty, and encourage economic development. The project will not impact forestry resources and does not trigger OP 4.36.

4.3.5 Physical Cultural Resources (OP/BP 4.11)

OP 4.11 addresses physical cultural resources, which are defined as movable or immovable objects, sites, structures, groups of structures, and natural features and landscapes that have archaeological, paleontological, historical, architectural, religious, aesthetic, or other cultural significance. Physical cultural resources may be above or below ground, or under water. Their cultural interest may be at the local, provincial or national level, or within the international community.

The World Bank assists countries in avoiding or mitigating adverse impacts on physical cultural resources from development projects that it finances. The impacts on physical cultural resources resulting from project activities, including mitigating measures, may not contravene either the borrower’s national legislation, or its obligations under relevant international environmental treaties and agreements.

The proposed project triggers OP 4.11 Identification of physical cultural resources has been treated in the Social Impact Assessment, with provisions for ‘chance finds’ procedures described in the EMP to ensure that any physical cultural resources discovery during project implementation is dealt with in accordance with the policy and Mozambique legislation regarding physical cultural resources, which is clear and explicit (Law No.10/88 of December 1988 Património Cultural, The National Heritage Protection Law).

4.3.6 Involuntary Resettlement (OP/BP 4.12)

OP 4.12 on involuntary resettlement applies in those situations involving acquisition of land and involuntary restrictions of or changes in access to resources. The policy applies whether or not affected persons must move to another location.

Furthermore, involuntary resettlement should be avoided to the extent feasible, and any adverse social and economic impacts should be minimized and mitigated. The policy also promotes consultation of displaced people in resettlement planning and implementation, and its key economic objective is to assist displaced persons in their efforts to improve or at least restore their incomes and standards of living after displacement. The policy prescribes compensation and other measures to achieve its objectives and requires that project proponents prepare adequate planning instruments (Process Framework, Resettlement Policy Framework, and Resettlement Action Plan) prior to Bank appraisal of proposed projects.

The Project triggers the policy and the details of any involuntary resettlement are comprehensively dealt with in the Social Impact Assessment (SIA) and the Resettlement Action Plan (RAP) developed in compliance with the policy. The RAP will address any issues involving i) relocation, the loss of shelter, the loss of assets or access to assets important to livelihoods; ii) the loss of income sources or means of livelihood; and/or iii) the loss of access to locations that provide higher incomes or lower expenditures to businesses or persons.

4.3.7 Indigenous Peoples (OP/BP 4.10)

OP 4.10 on indigenous peoples underscores the need for borrowers and the World Bank to identify any indigenous peoples, consult with them, ensure that they participate in, and benefit from World Bank funded operations in a culturally appropriate way and that adverse impacts on them are avoided, or where not feasible, minimized or mitigated. OP 4.10 is not triggered by the Project.

4.3.8 Safety of Dams (OP/BP 4.37)

Dam safety is a matter of significant importance in many countries in the world today because of the presence of a large number of dams, existing, under construction or planned. The safe operation of dams has significant social, economic, and environmental relevance. OP 4.37 requires that experienced and competent professionals design and supervise construction, and that the borrower adopts and implements dam safety measures through the project cycle.

OP 4.37 is triggered by this project and will be addressed according to Bank policies and guidelines, including preparation of Dam Safety Studies. A dam safety assessment is being carried out as part of the Technical Services and Dam Safety Consultancy, and other necessary long term safety measures are planned.

4.3.9 Projects on International Waterways (OP/BP 7.50)

The OP 7.50 applies to any river or body of surface water that flows through two or more states whether World Bank members or not. This policy applies to irrigation systems, dams and flood control measures. If such a project is proposed, the World Bank requires the beneficiary state to formally notify the other co-riparians of the proposed project and its Project Details. OP 7.50 is triggered by this Project and riparian notification is required.

The Sabíe River is a major tributary in the Incomati River Basin. The Basin is shared with the Republic of South Africa and the Kingdom of Swaziland. The "Tripartite Interim Agreement for Co-operation on the Protection and Sustainable Utilization of the Incomati and Maputo Watercourses" (IIMA) was signed by Mozambique, South Africa and Swaziland in August 2002 and governs cooperation between the three riparians. The IIMA aims to promote co-operation among the signatories so as to ensure the protection and sustainable utilization of the Incomati and Maputo watercourses.

The Government of the Republic of Mozambique has presented its intention to proceed with the completion of the Corumana Dam within the regular meetings of the Tripartite Permanent Technical Committee (TPTC), established under the IIMA. A formal written riparian notification of the proposed activities was given by the GoM to the other two riparians in 2009 and letters of no objection from both the Republic of South Africa and the Kingdom of Swaziland have been received.

4.3.10 Projects in Disputed Areas (OP/BP 7.60)

Projects in disputed areas may affect relations between the World Bank and its borrowers, and between the claimants to the disputed area. Therefore, the World Bank will only finance projects in disputed areas when either there is no objection from the other claimant to the disputed area, or when the special circumstances of the case support World Bank financing, notwithstanding the objection. OP 7.60 is not triggered by the project.

4.4 Public Consultation Process

A Public Consultation Process was undertaken in order to identify key issues of concern and possible solutions, as well as accessing relevant local or traditional knowledge pertinent to project design and implementation. Detailed reports on the Public Consultation Process held thus far are presented in Volume 2: Socio-economic context (Social Impact Assessment).

The aim of the Public Consultation Process is:

- To ensure that Interested and Affected Parties (I&APs) are informed about the main characteristics of the project;
- To publicize the methodology to be followed in the environmental impact study;
- To give Interested and Affected Parties the opportunity to raise issues, concerns and suggestions for proposed mitigation measures and to contribute with local knowledge regarding identification of potential impacts; and

- To clarify any doubts and questions that may arise in the course of the EA exercise.

When the Republic of South Africa sent is No-Objection notification on the Project, they requested "constant feedback and regular consultation with the respective bodies, namely the Department of Water Affairs, the South African National Parks and the affected municipalities". This requests have been addressed by the GoM throughout project preparation and will continue to be addressed during Project implementation through the Tripartite Permanent Technical Committee meetings under the IncoMaputo Agreement.

The details of the public consultation process are elaborated in Volume 2: Socioeconomic context (Austral COWI 2011). A chronological overview of consultation process that involved aspects pertaining to the environmental impact assessment are given below.

4.4.1 Consultations organized

A series of public consultations were held by DNA and ARA-Sul on the Terms of Reference in 2009. These were announced through advertisements in the national newspapers. A public hearing was organized to discuss preparation of the Terms of Reference for the ESIA of the completion of Corumana Dam. Participation included representatives of the provincial government, district administrations, central government institutions, civil society and non-governmental organizations considered relevant for the water resources management and the environmental and social procedures to be considered in the process of the construction of hydraulic works.

Regular meetings were held with the Government officials (Table 4-1) including:

- Kick off meeting of the ESIA consultancy on 27 September 2010;

- Corumana Basin Management Unit (22 September and 22 October 2010); and

- Weekly Meetings with DNA starting on 27 September 2010.

Table 4-1. Government officials met and interviwed during the consultation process

Institution	Person met and inter-viewed	Position
National Director-ate of Water (DNA)	Jaime Matsinhe	National Director
	Suzana Saranga Laforte	Deputy National Director
	Delário Sengo	International Rivers Office
	Belarmino Chivambo	Head of Water Resources Department
	Panel of Experts	
ARA-Sul	Olinda de Sousa	General Manager
	Custódio Vicente	Head of Technical Department
Corumana Basin Management Unit	Humberto Guezi	Director UGBI
	Adriano Capange	Head of Corumana Technical Unit

On October 20, 2010, a workshop was organized by DNA in Maputo to present and discuss the initial findings of the two project preparation consultancies – the Environmental and Social Impact Assessments and the Technical Services and Dam Safety Study. Participants included technical staff from relevant national agencies, such as ARA-Sul, MICOA and the Ministry of Agriculture, as well as a representative from the Department of Water Affairs in South Africa. A team from the World Bank also participated.

On October 22, 2010, Portuguese and English versions of the Pre-Feasibility Study and Scoping Definition (EPDA) for Corumana Dam, were delivered to the borrower and DNA gave a written authorization for the preparation of the public consultation meetings. The EPDAs were delivered to:

- MICOA/DNAIA;
- National Water Directorate;
- ARA-Sul;
- Provincial Directorate for the Coordination of Environmental Action;

- Administrative Post of Corumana;
- Administration of the District of Moamba;
- Administrative Post of Sabíe;
- Directorate for the Incomati Basin Management Unit; and
- Kruger National Park, South Africa.

On October 26, 2010, Public announcements were advertised in Journal Noticias as well as through Radio Mozambique. The EPDA was delivered to the Watershed Management Unit in the Corumana area for public disclosure. The following stakeholders were invited to the public participation meeting at Corumana:

- Provincial Government (Provincial Directorates relevant to the project);
- Moamba Administration (District Administrator);
- District Services of Planning and Infrastructure;
- Economic Development Institutions;
- Project Proponents (DNA);
- Media;
- Community leaders; and
- Religious leaders.

On November 8, 2010 a public consultation meeting was held in the social centre of the residential complex of Corumana Dam. A total of 26 persons attended the meeting including representatives for Corumana communities (community leaders and religious leaders) , Corumana Community Fishing Council, Moamba District Administration and state institutions.

The meeting was held in Portuguese with translation into Changane. During the meeting Austral Cowi made a presentation focusing on the following:

- Presentation of the project;
- Objectives of the project;
- Main activities proposed for the project; and
- Potential positive and negative impacts on the biophysical and socio-economic environment.

The presentation was followed by a debate in which the local communities raised their issues, comments and concerns about the Project.

On November 24, 2010, consultations on the Project and the potential environmental impacts identified in the Pre-Feasibility Study and Scoping Definition (EPDA) for Corumana Dam was organized with a number of national Interested and Affected Parties. These included:

- Açucareira de Xinavane, Maragra Açúcar and Cofamosa (the latter has no active farms) - sugar growing companies in the area;

- Agri-Sul (Bananalândia) - banana producers;

- Electricity of Mozambique - the national electricity company that manages the 14.5 MW hydropower station at Corumana Dam; and

- Sabie Game Park - a private game park located on the northern side of the reservoir.

One of the key international I&APs is the Kruger National Park (KNP), located in South Africa on the upstream side of the Corumana reservoir. Consultation with the Park on the Project was done using the questionnaire where the Kruger National Park was able to raise any concerns or questions on the Project. (The questionnaires can be found in the SIA report).

On February 9, 2011, a consultation workshop was held at Bundu Lodge in Nelspruit in South Africa co-organized with the PRIMA project (Progressive Realisation of the IncoMaputo Agreement). The workshop was organised by the National Directorate of Water (DNA) of Mozambique and the Department of Water Affairs Republic of South Africa with the participation of representatives from the Provincial Government, District Administrations, Central Government Institutions and representatives from Kruger National Park. At this workshop the findings of the draft EIA were presented specially focusing on impacts of the project on Kruger National Park and the proposed mitigation measures to deal with any negative impacts to follow up to KNPs earlier stated concerns (2009 consultations) about the project`s impact on KNP.

On April 13, 2011, a public consultation was organized for I&APs and members of project affected communities at the Corumana Dam site to share the findings of the ESIA and to enable an open dialogue about the projected resettlement process.

4.4.2 Issues raised during consultations

Overall, most of the responses from I&AP`s were on socioeconomic issues which are dealt with in the SIA report. However, a summary of the issues and concerns raised during the consultations is given in Appendix 6 of the present report. The issues outlined below relates to the biophysical environment.

Kruger National Park conveyed that they would be grateful if the following concerns could be investigated (Consultation Data Sheet submitted November 2010):

- A survey on how far the water will push up into the Sabíe River when the Corumana Dam is full;
- Model the expected sediment deposition patterns in the Sabíe River – also upstream from the full supply mark;
- Ecological impact of inundation and sediment deposition;
- Changes in biodiversity and dynamics as a result of inundation and sedimentation;
- Describe the loss of geomorphological features and quantify the loss in terms of uniqueness of such features;
- Water quality at the inlet of the dam and outlet of the dam;
- Chemical quality in/of the sediments at the inlet, dam wall and outlet; and
- The socio-economic benefit that Mozambique will derive from additional yield of water.

Kruger National Park was particularly interested in the model results regarding the approximate extent of backwater effect and increased sedimentation into Kruger National Park as a result of raising the full supply level of the reservoir, in order for them to assess any need for relocation of habitats for endangered species such as breeding places for crocodiles in the Park.

The DWA also raised the issues regarding modelling of environmental effects in Kruger National Park of raising the full supply level and the socio-economic benefits for Mozambique from the new water yield ;

The issues raised by the Kruger National Park and DWA have to a large extent been included in the EIA. However, chemical measurements of water and sediment quality were not included. In accordance with ToR the present water quality was assessed from the composition of the aquatic macroinvertebrates (SASS5). It is proposed in the EIA that chemical analyses of water and sediment quality are included as part of the long term support under the EMP supporting the monitoring before, during and after construction works.

Breeding places for crocodiles in the Sabíe River in Kruger National Park with the potential impact area was not identified in this study, but the proposed monitoring programme outlined in the EMP includes recommendations for regular surveys during project implementation to support the monitoring of locations of habitats for endangered species, including breeding places for crocodiles within the potential impact area. The EMP recommends that any breeding places are identified before the construction work starts.

The Sabie Game Park representatives conveyed that the park is struggling with poachers who enter illegally via the reservoir, with the help of local fishermen. If the water level increases, poachers are expected to be able to penetrate further into the park and the problem would worsen.

During the Public Consultation meeting on November 8, 2010, the president of Corumana Community Fishing Council (CFC) raised the issue of clearance of trees in the future inundated areas. This, according to CFC, would be beneficial for the fishing community and the fishermen feel that they could avoid high maintenance costs on fishing nets, which will be easily trapped and broken by roots and tree branches left in the shallow waters. The CFC president suggested that trees in the Jone and Fungotine fishing areas should be cleared prior to inundation. Assessing the best way to address these concerns of the CFC will be developed in the Inundation Preparation Plan that will be embedded in the final EMP.

The Workshop held in Nelspruit on February 9, 2011 recommended:

- That it is ensured that all stakeholders from the Republic of South Africa are consulted up to the implementation of the project (especially KNP);

- That further studies to be carried out in connection with the implementation of the EMP on environmental flows and sediment and water quality aspects are presented and discussed with relevant South African Authorities (in particular KNP). In addition, results from LiDAR surveys should be presented.

5 Environmental Baseline

5.1 Introduction

This chapter provides a description of the biophysical environment in the project area. Relevant environmental baseline issues to be included in the EIA were identified during the scoping process and reported in the Environmental Pre-feasibility Study and Scope Definition (EPDA) for the Corumana Dam and the studies to be conducted were specified in the ToR elaborated during the scoping process. The baseline description is based on field studies, existing data and reports and information collected during the Public Consultation process. The following baseline studies were conducted:

- Hydrology study;
- Geology and hydrogeology baseline studies;
- Terrestrial ecology baseline study; and
- Aquatic ecology baseline study.

The methodologies applied and detailed presentation and discussion of the results of the different studies are presented in Appendix 2- 5. The major findings are presented below.

5.2 Climate

The climate in the project area is characterised by a wet season in November-March with peak rainfall in January. The average annual rainfall is 450 mm and the mean annual temperature is more than 22 ^{o}C.

5.3 Topography, Landscape and Geology

The Corumana Dam is located in the Lebombo Mountains on the Sabíe River at the border to the Republic of South Africa. The surrounding terrain is undulating with north/south running ridges and bottomlands. According to the Geological map of Mozambique the area is underlain by the extrusive rhyolite and granophyre formations of the Lebombo Group, Sequence Karoo. The geological map also indicates the presence of dolerite dykes mostly striking southwest northeast. The soils in the Lebombo Mountains can best be described as lithosols (i.e., shallow, acidic and sandy soils).

The geomorphology of the study area indicates a Late Palaeozoic to early Jurassic, history of erosion and sedimentation, comprising boulder beds, old red sands and younger coversands in a sequence of sea-level fluctuations. Continental uplift during the Holocene age led to the advance of the shoreline to its present position. This resulted in decreased river gradients which reduced their capability of maintaining an outlet to the sea. Smaller river mouths became blocked by littoral and aeolian processes and were permanently sealed by vegetation. Only large rivers and estuaries maintained a semi-permanent outlet.

A north south striking fault zone is also shown on the geological map, but detailed records of the seismicity of the study area are not known.

5.4 Hydrology

The Sabíe River is a perennial river that flows from the Republic of South Africa into the Corumana reservoir. Downstream of the dam the Sabíe River flows south-westwards and joins the Incomati River.

The Sabíe River upstream the Corumana reservoir is situated in an incision in bedrock, which has created channels that has a "floodplain" restricted to the width of incision into bedrock. The river has multiple channels, with water flowing over roughened bedrock slabs, gravel and through deep pools.

The Sabíe River system is a physically diverse river system, that displays marked changes in channel type, as the distribution of sediment over bedrock varies (Heritage et al, 2001). Sediment movement in the river is episodic, associated with summer rainfall events. Sand bed tributaries are reworked and thus contribute to the sediment loads in the micro channel. Low to medium flow conditions result in depositions colonised by vegetation (reed beds etc.), forming semi-permanent features such as sand banks (Roundtree, 1997).

The key hydrological indices for the Corumana Dam catchment are:

- Catchment area: 7,048 km^2
- Catchment Mean Annual Precipitation (MAP): 773 mm
- Mean Annual Evaporation (MAE) (Quaternary Catchment X33D): 1,453 mm
- Naturalised Mean Annual Runoff (MAR): 674.5 Mm^3

Figure 5-1 shows the annual flow volumes in the Sabíe River, based on developed simulated monthly flow sequences, for the period 1920 to 2004. The figure shows that the annual flow volumes are highly variable with some years characterised by very low flows, while other years display runoff volumes equivalent to up to six times the MAR. The majority of flow occurs during the summer rainfall season (November to April) with over 80% of flow occurring from December to April.

The regional authority Administração Regional de Àguas do Sul (ARA-Sul) is responsible for the operation and maintenance of Corumana Dam. The Direcção Nacional de Àguas (DNA) has the overall responsibility for the management of the lower Incomati basin situated in Mozambique (TPTC, 2010c).

The releases from Corumana Dam are currently being managed based on Basin Plans, which comprise yearly user plans submitted by the users to ARA-Sul. These plans form the basis of the Dam Discharge Plan which follows the principles of the recent study in 2010 by Consultec in Association with SWECO on Operating Rules of Corumana, Massingir and Pequenos Limbombos Dams (TPTC, 2010c).

For flood control rules during the October to March rainy season, ARA-Sul follows a process of estimating climate tendency using SARCOF weather forecast service. An estimation of likely flood impacts is given using a combination of download rainfall information, GIS tools and the Geospatial Stream Flow Model (TPTC, 2010c).

The observed annual discharge for period 1990-2008 from Corumana reservoir is shown in Figure 5-2. This includes dam spillage and releases for hydropower and irrigation.

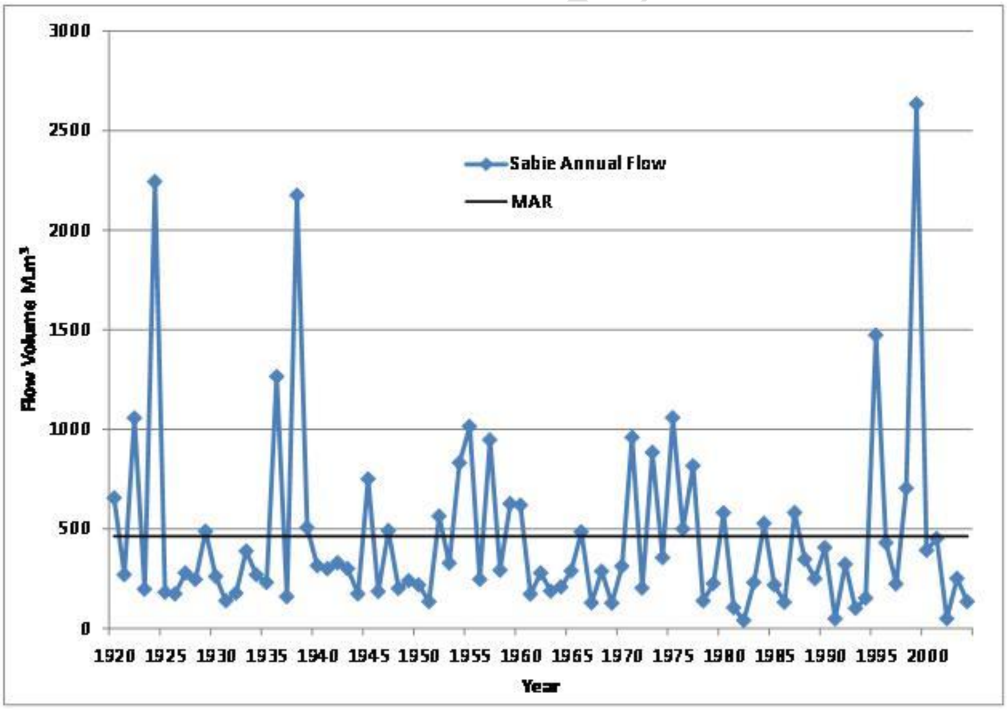


Figure 5-1 Annual flow distribution in Sabíe River

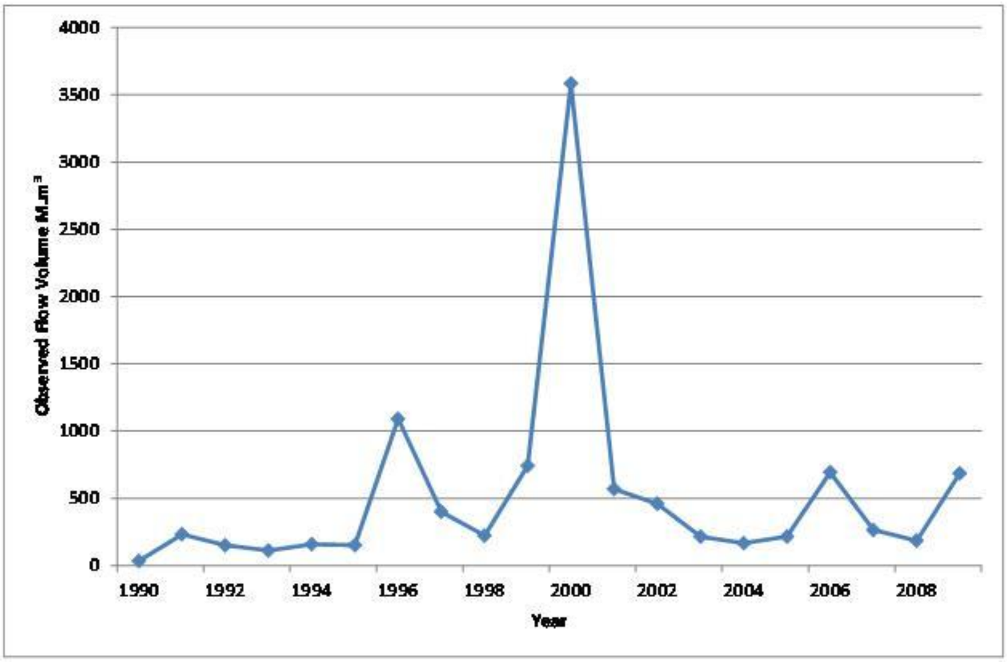


Figure 5-2 Annual observed discharge from Corumana reservoir

The construction of the Corumana Dam has altered the flow regime of the dam by attenuating floods and increased low flows. During low flows months, June-October, the releases from Corumana reservoir are higher than the inflow into it. This is due to releases for hydropower and to supply irrigation users. In future the releases could be higher with a raised FSL.

Under future climates with higher temperatures, the evaporation at the reservoir is expected to be higher with output from downscaled regional climate scenarios indicating higher mean annual precipitation for the intermediate future (± 2046-2065) in the Sabíe River catchment. The increase in rainfall could lead to increased flow into the reservoir overall but less flow at critical times (Lumsden *et al*., 2009). Higher temperatures could also lead to higher demand from downstream irrigators.

The hydrological study is attached as Appendix 2.

5.5 Hydrogeology/groundwater

A baseline study of Hydrogeology/groundwater was carried out including chemical analysis and analysis of isotopes of surface and groundwater. The results of the study are reported in Appendix 3.

Groundwater resources are limited in the area except along fault zones, dyke contact zones and in alluvial valleys. Dykes are present and good groundwater occurrence can be expected at scientific selected drill sites. The water quality in the Karoo formations is variable but is generally acceptable in these formations.

The baseline survey showed high sodium and chloride values for the water in the reservoir and groundwater. Fluoride, sodium, chloride and total dissolved solids (TDS) values in the reservoir and groundwater exceed the Mozambican maximum allowable limits for human use. The surface water sampled in the reservoir is suitable for irrigation. The chemical analysis also indicates unacceptable high salinity and fluoride in the groundwater. The groundwater is not suitable for irrigation.

5.6 Terrestrial ecology

The Terrestrial Ecology Baseline study is attached in Appendix 4.

5.6.1 Landscapes and Vegetation Communities in the project area

The Corumana Dam is situated within the Maputaland Centre of Plant Endemism (MCPE). This area extends north from coastal KwaZulu-Natal (from about Richards Bay) well into southern Mozambique. The MCPE is a focus-point of high plant endemism that supports between 2,500 and 3,000 vascular plant species of which at least 203 taxa are endemic or near-endemic to the centre (Van Wyk, 1996). The Corumana Dam is situated at the northern edge of the core area of the MCPE. These are not critical natural habitats.

Previous vegetation studies in the nearby Parque Nacional do Limpopo (Stahlmans et al., 2004), found that at larger scales, vegetation could not be easily mapped as individual communities, but as landscapes in which vegetation communities are embedded. Fieldwork conducted for this study confirmed that two landscapes found in the Kruger National Park are clearly represented around Corumana reservoir, namely *Sclerocarya birrea* / *Acacia nigrescens* Savanna and Lebombo South. An additional landscape that has been formed through the inundation of the Sabíe River valley is Floodplain Grassland. These are spatially indicated on Figure 5-3. Photos of the different types of vegetation landscapes are presented in Appendix 4.

***Sclerocarya birrea* / *Acacia nigrescens* Savanna Landscape**

This landscape is mostly represented along the northern and southern shores of Corumana reservoir and is characterised by fairly level plains and well-defined drainage lines. The underlying geology is basalt, which weathers into black, brown or red clayey soil. Vegetation structure varies from open to closed tree savanna with a moderate shrub layer and dense grass layer, to low dense thicket on sodic soils. Three vegetation communities are embedded within this landscape: *Sclerocarya birrea – Acacia nigrescens* Open Woodland, *Acacia borleae – Euclea divinorum* Thicket and *Ficus sycomorus – Acacia xanthophloea* Riverine Woodland. This Landscape type will be affected by inundation after increasing the FSL of the dam to either 115 masl or 117 masl.

Lebombo South Landscape

The Lebombo Hills along the Mozambican border with South Africa dominate the physiography of this landscape, with ridges and valleys oriented north-south. The geology is predominantly rhyolite of the Lebombo Group (Karoo Sequence) which produces mostly lithic rhyolitic soils. The vegetation structure is mostly closed woodland with a fairly rich grassy understory. Two vegetation communities / associations are embedded within this landscape around Corumana reservoir, namely *Combretum apiculatum – Sclerocarya birrea* Closed Woodland and

Euphorbia confinalis – Grewia caffra Thicket. At the Sabíe Gorge, where the inlet to the Corumana reservoir is situated (at the border with the Kruger National Park), a further two vegetation communities are embedded in the Lebombo South landscape and are confined to the macro-channel floor of the Sabíe River: *Breonadia salicina – Phragmites mauritianus* Wooded Grassland and *Phyllanthus reticulatus - Bridelia cathartica* Thicket.

Floodplain Grassland Landscape

This landscape is the dominant vegetation belt along the margin of the Corumana reservoir and is the landscape that will be most affected by increasing the FSL of the dam. It is estimated that in a 1 in 1,000 year flood at 120 masl, 570 ha of Floodplain Grassland would be inundated. Three narrow vegetation communities are embedded within the Floodplain Grassland landscape, each occurring at different levels of inundation: *Paspalidium obtusifolium – Cynodon dactylon* Grassland, *Epaltes gariepina – Chenopodium* sp. Herbland and *Sorghum bicolor* Grassland. Most of the Floodplain Grassland landscape will be impacted by inundation to full supply level (117 masl as well as the alternative 115 masl level).

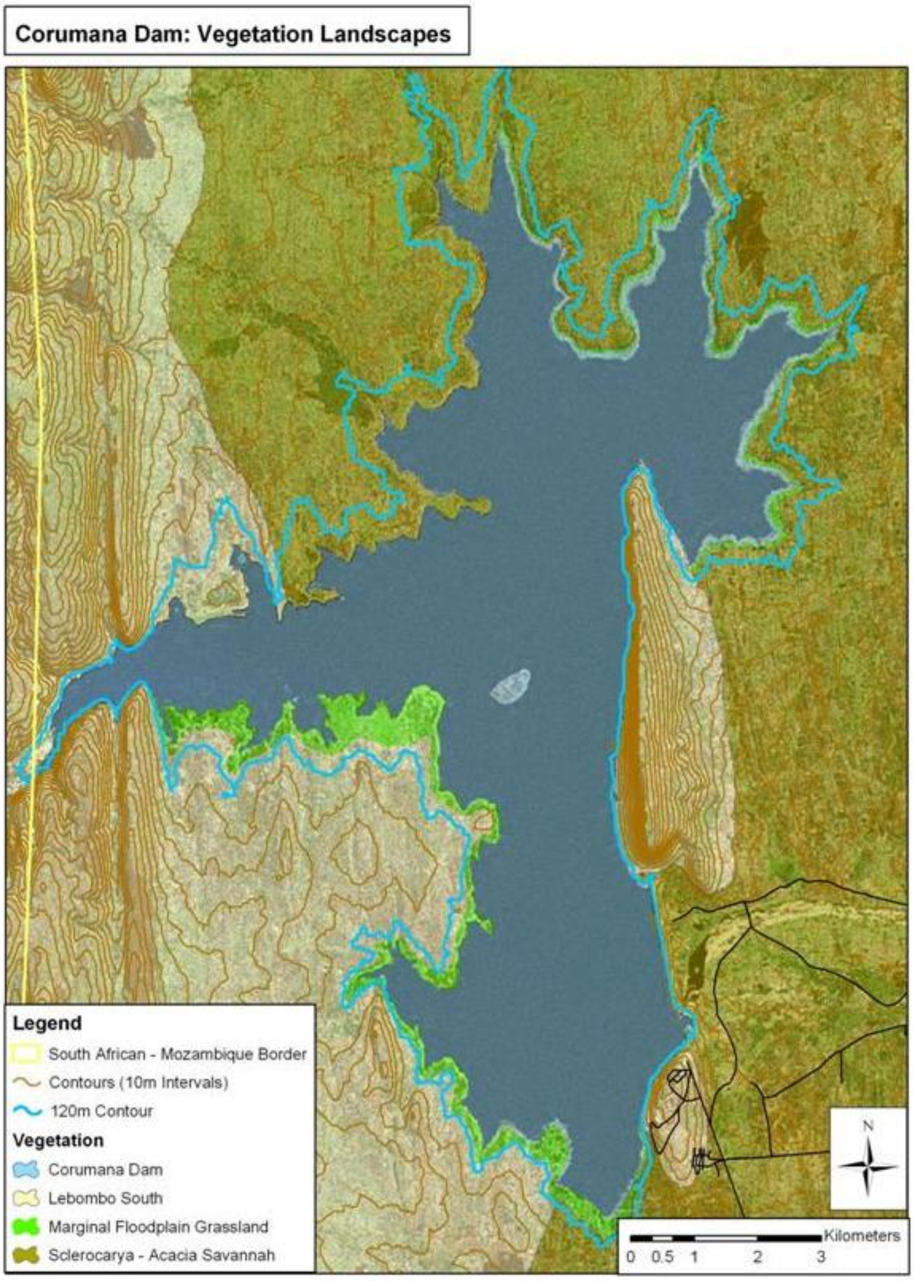


Figure 5-3 Vegetation Landscapes around the Corumana Reservoir.

Threatened Plant Species

The most important landscape for threatened plant species in the study area is Lebombo South. Seven threatened species are likely to be confined to this landscape, while an additional four species are likely to be shared with the plains to the east. However, this landscape is less likely to experience as much inundation as the lower-lying *Sclerocarya birrea* / *Acacia nigrescens* Savanna landscape, which potentially supports three highly threatened species in areas that could be inundated (*Adenium swazicum*, *Ipomoea venosa*, *Turbina longiflora*). Three threatened plant species were confirmed to occur within the project area, but outside of the potential area of inundation: *Triaspis hypericoides* (Vulnerable), *Afzelia quanzensis* (Near Threatened) and *Dalbergia melanoxylon* (Near Threatened).

5.6.2 Bird Fauna in the Project Area

Over 180 bird species have been recorded within the general vicinity of the Corumana Dam (Parker, 1999; Sudlow, 2008; data from the current second South African Bird Atlas Project). The fieldwork carried out during 3-7 January 2011 has increased this total to 200 species. Bird species observed during fieldwork around the dam can be separated into five broad avian assemblages: Woodland, Thicket, Riparian Vegetation, Floodplain Grassland and Open Water. The most important landscape / habitat for threatened birds is *Sclerocarya birrea* / *Acacia nigrescens* Savanna, in which two IUCN Red Data species were confirmed to occur (Bateleur, European Roller both of which are globally categorized as Near Threatened, but neither of which have globally, regionally or nationally significant populations within the future inundation zone).

5.6.3 Mammals, reptiles and amphibians in the Project Area

Most large mammals in southern Mozambique have been exterminated through hunting and those that survive do so in protected areas such as Parque Nacional do Limpopo. Around Corumana reservoir, the only area with populations of large mammals is the Sabie Game Park, a privately run controlled hunting reserve on the north-western shores of the dam. Its legal boundary on this side is the originally intended FSL of the reservoir. This reserve has at present access to approximately 16 km of shoreline of the dam (*Brian Ring pers.comm.*) where large mammals can access grazing and predators can engage in hunting along the floodplain. These mammals include the following globally threatened species: African Elephant, Hippopotamus, White and Black Rhinos, Lion and Leopard. The only mammal listed above that is likely to regularly forage on the grasslands to be inundated increasing the FSL of the dam is Hippopotamus. Around the rest of the Corumana reservoir, the only mammals likely to still occur in the marginal vegetation are rodents, small carnivores and possibly small antelope such as Common Duiker and Steenbok.

Mammal occurrence during the fieldwork was noted through direct observation and indirect evidence (spoor, dung). No dedicated mammal surveys were undertaken, i.e. no trapping or nocturnal surveys. Antelope species were confirmed in the Sabie Game Park (Kudu, Waterbuck, Steenbock), but nowhere along the rest of the reservoir shoreline. Scats of African Clawless Otter were found at several localities close to the water’s edge. The only rodents confirmed to occur during fieldwork were Greater Cane-rat and Tree Squirrel.

The only Red Data reptile species potentially occurring in the study area according to data on the IUCN Redlist website is *Kinixys natalensis* (Natal Hinged Tortoise), which has a status of Near Threatened. This is a terrestrial species unlikely to occur close to the reservoir and is not expected on the floodplain area. Occurrence of this species could not be confirmed during fieldwork.

Reptiles were observed through direct observation only; no trapping exercises were undertaken. Species confirmed to occur during the fieldwork were: Nile Crocodile (IUCN Least Concern), Leopard Tortoise, Water Monitor , (IUCN Least Concern), Black Mamba (IUCN Least Concern), Yellow-throated Plated Lizard, Common Dwarf Gecko, Rainbow Skink (IUCN Least Concern) and Variable Skink. The Leopard Tortoise, Yellow-throated Plated Lizard, Common Dwarf Gecko and Variable Skink are not on the IUCN Red List.

No Red Data amphibians are likely to occur within the study area. Amphibians were observed through direct observation (visual or audible) only; no trapping exercises were undertaken. Species confirmed during the fieldwork were: African River Frog, Flat-backed Toad, Guttural Toad, Painted Reed Frog, Foamnest Frog, Brown-backed Tree Frog, Banded Rubber Frog and Natal Sand Frog. These species are not expected to be affected by the project.

5.6.4 Conservation areas

In South Africa, the Kruger National Park has national protected status and forms part of the border with Mozambique. A limited amount of riparian vegetation is likely to be lost through increasing the FSL of Corumana reservoir to either 115 masl or 117 masl. On the northern side of the reservoir in Mozambique, the privately-owned Sabie Game Park manages about 30,000 ha of untransformed woodland and marginal dam vegetation. The Sabie Game Park does not have any formal protection status in Mozambique and is not a registered hunting coutada (Brian Ring, pers.comm.). The Sabie Game Park is currently focussed solely on hunting safaris, but as numbers of plains game and large predators increase, the objective is to introduce ecotourism. A new game park, the Ingwe Game Park, is being proposed to the south of the reservoir near Jone and Panganine. No major land use changes in KNP or SGP are planned in the near future.

5.7 Aquatic and Riparian ecology

The Aquatic and Riparian Ecology Baseline study is attached in Appendix 5.

Sampling sites for the baseline Study for Aquatic ecology is shown in Figure 5-4.

Figure 5-4 Sampling sites for Baseline study Aquatic ecology. Station 1 is situated in Kruger National Park.

The following surveys were carried out on each of the three stations:

- At station 1 in KNP, South Africa, riverine and riparian vegetation (VEGRAI), aquatic macroinvertebrates (SASS5) and fish fauna was sampled and assessed;
- At station 2 immediately downstream of the dam aquatic macroinvertebrates (SASS5) and fish fauna was sampled and assessed; and
- At station 3 state distance downstream Riverine and Riparian vegetation (VEGRAI) was assessed

5.7.1 The riverine and riparian vegetation

The riverine and riparian vegetation includes the marginal (riverine) and non-marginal zones (riverine elements and riparian vegetation), as employed in the VEGRAI assessment technique. In the VEGRAI assessment for Station 1 (in the upstream of the Corumana reservoir in Sabíe River in Kruger National Park), six woody and 11 non-woody plant taxa were identified for the marginal zone. In the non-marginal zone, 11 woody taxa and one non-woody taxon were identified. The marginal zone was dominated by non-woody taxa including *Phragmites mauritianus* and *Miscanthus junceus*. The non-marginal zone was dominated by *Euclea natalensis angustifolia* and *Kigelia africana*.

Given that station 1 is within a statutory protected area, the impact of surrounding and upstream land use on both the marginal and non-marginal zones was found to be very low to average.

The invasion of the marginal and non-marginal zones by alien plants was found to be low, with the cover below 10%, intensity low and extent average. There is a relatively widespread presence in the marginal zone of *Pistia stratiotes* (Water Lettuce) and *Azolla filiculoides* (Water Fern).

The description for the reference conditions for Station 1 may be given as an open, reed and shrub dominated state. In the absence of the Corumana Dam and no regulation of the water quantity in the upstream environment, it is possible that the reference state would be characterized more by the greater presence of woody vegetation. The marginal and non-marginal vegetation in the region of Station 1 was significantly altered during the 1 in 100 year flood of 2000. Based on a comaprison with observations during own previous field studies in the 1980s and 1990s with the present observations, the habitat has changed from a dense almost closed canopy, to an open one with reduced large woody species. Prior to the flood the vegetation along the banks of the river at Sabíe Gorge could be characterised as a *Ficus sycomorus – Acacia xanthophloea* Riverine Woodland which is a tall closed woodland with *Ficus sycomorus* as a dominating element No adult *Ficus sycomorus* trees are now present at the site.

The VEGRAI value for Station 1 was calculated to be 85%, giving a VEGRAI EC classification of B, which may be described as Largely Natural with few modifications. A small change in habitats and biota has taken place, with ecosystem function essentially unchanged. No protected, red listed, endangered or endemic species were collected (IUCN Red List). All the species collected may be classified as of Least Concern.

In the VEGRAI assessment for Station 3, the non-marginal zone predominated, with a very limited marginal zone on the left bank that was assessed. In the non-marginal zone, six woody taxa and nine non-woody taxa were identified. Woody species included *Acacia xanthophloea, Ficus capreifolia* and *F. sycomorus.* Non-woody species included *Phragmites mauritianus, Sporobolus africanus*, *Paspalum dilatatum* and *P. scrobiculatum*.

The impact of surrounding and upstream land use on both the marginal and non-marginal zones was found to be of average intensity and high extent. The impact on the marginal zone by livestock and subsistence crop farming and rural residential development was estimated as low to average, with respect to vegetation removal.

The invasion of the marginal and non-marginal zones by alien plants was found to be significant, with the cover in the non-marginal zone at 20 - 40%, with average intensity and high extent. Alien species include *Psidium guajava* (guava), *Mangifera indica* (mango) and *Musa acuminata* (banana).

The description for the reference conditions for the marginal zone at Station 3 may be given as a reed and shrub dominated state. The non-marginal zone may be described as being dominated by trees, reeds and shrubs. The present state of the riparian vegetation may be described as a reed and shrub dominated one.

The Level 3 VEGRAI value for Station 3 was calculated to be 55.6%, giving a VEGRAI EC classification of D, which may be described as Largely Modified. A large loss of habitats, biota and basic ecosystem function has occurred. No protected, red listed, endangered or endemic species were collected (IUCN Red List). All the species collected may be classified as of Least Concern.

The condition of the riparian vegetation is certainly not the same all along the river channel downstream of Corumana Dam. The condition, as expressed for Station 3, is as a result of the presence of access routes to the riverine environment and the concomitant influence of anthropogenic activities. The assessment for station 3 indicate the greatest impact to which the riverine and riparian environment has been affected are areas downstream of the Corumana Dam that may be classified within the ambit of the eco-status of C and B.

The environment around the edges of the Corumana reservoir was not included in the VEGRAI assessments. The FSL level of 117 masl will increase the surface area of the reservoir by 23% adding a total of 1,600 ha to the water body. The FSL level of 115 masl will increase the area by 13% adding 926 ha to the water body. The associated loss of riparian vegetation, the existence of which is primarily induced by the presence of the dam embankment, will in time be replaced by riparian vegetation extending over a greater perimeter around the dam. The vegetation around the fringes of the dam included *Epaltes gariepina – Chenopodium* sp herbland closest to the water body, followed by *Paspalidium obtusifolium – Cynodon dactylon* grassland and then *Sorghum bicolor* grassland. There are stands of *Ficus sycomorus – Acacia xanthophloea* woodland in the northern bays of the dam. None of the species stated here have high conservation value (IUCN Red List).

5.7.2 The aquatic macro-invertebrates and water quality

The aquatic macroinvertebrates and water quality was assessed using SASS5 (South African Scoring System Index). The total SASS5 score, number of taxa and ASPT for Station 1 was found to be 206, 35 and 5.9, respectively. The taxa which scored 10 or more on the SASS5 scale of 1 to 15, included the *Heptageniidae* (flat-headed mayflies) (13), *Calopterygidae* (damselflies) (10) and *Pyralidae* (aquatic caterpillars) (12). There were no taxa that dominated the sample given that the estimated abundance for 10 taxa was B (10 to 100 individuals) and for the remaining taxa only one individual or A (2 to 10).

Using the Biological Bands for the Lower Lowveld (Dallas, 2007), the Ecological Category for Station 1 may be defined as A, Unmodified, Natural.

In accordance with the ToR the SASS5 technique was used to assess the aquatic macroinvertebrates. The SASS5 technique involves the determination of the presence of taxa at higher order levels and therefore it is not possible to assess whether protected, red-listed, endangered or endemic species are present. Nearly nine percent of freshwater molluscs in southern Africa are regionally threatened. In the case of the dragonflies and mayflies, the majority of species (approximately 76%) are classed as Least Concern. In the case of freshwater crabs, 94% of the species that could be assigned conservation status were assessed as of Least Concern.

The overall biotope suitability for the biotopes sampled was 71% (SASS5) and the IHAS was 79%. The pH of the water was found to be 6.6 and the conductivity 15 mSm^{-1}. The water was a normal transparent colour, the flow low and turbidity very low. The description of water colour employed for the SASS5 techniques operates with the following coulor descriptions : tea brown, light or dark brown, light or dark green, yellow, grey, milky white, black and transparent. The nature of the Sabíe River channel, from the international border with Mozambique to the gauging weir a short distance downstream from the Lower Sabíe camp in the Kruger National Park, was scanned using Google Earth images, for length and width of reach segment, channel form and the presence of isolated pools and likely pool-riffle sequences. The total distance of 11.312 km was divided into 12 reach segments with channel width varying between 190 and 570 m. Nine of the 12 segments were dominated by anastomising channels and there appeared to be a total of 54 large, isolated pools and 144 areas where run/riffle sequences are likely to be present.

The total SASS5 score, number of taxa and ASPT for Station 2 downstream the Dam was found to be 50, 11 and 4.5, respectively.

Using the Biological Bands for the Lower Lowveld (Dallas, 2007), the Ecological Category for Station 2 may be defined as E, Seriously Modified.

The overall biotope suitability for the biotopes sampled was 54% and the IHAS was 60%. A road bridge crosses over the Sabíe River at the site. The pH of the water was found to be 7.0 and the conductivity 17 mSm^{-1}. The water was a grey colour, the flow low and turbidity very low.

5.7.3 The fish fauna

The number of fish species collected at Station 1 upstream the dam (6 species) was 15% of that potentially expected. The species collected included Smallscale Yellowfish (*Barbus polylepis*), Tigerfish (*Hydrocynus vittatus*), Sharptooth Catfish (*Clarias gariepinus*), Banded Tilapia (*Tilapia sparrmanii*), Redbreast Tilapia (*T. rendalli*) and the River Goby (*Glossogobius callidus*).

The number of fish species collected at Station 2 (7 species) was 15% of that potentially expected, and included the *Labeo cylindricus* (Redeye Labeo), *H. Vittatus* (Tigerfish), *Synodontis zambezensis* (Brown Squeaker), *Aplocheilichthys johnstoni* (Johnston's Topminnow), *T. Sparrmanii* (Banded Tilapia), *Oreochromis mossambicus* (Mozambique Tilapia) and the *G. Callidus* (River Goby). The number of species for the pooled data (combined stations) was 10 species.

Three of the species of fish collected at Stations 1 and 2 migrate during their life history for feeding (*H. vittatus*) and spawning (*L. cylindricus, H. vittatus*, *C. gariepinus*) purposes.

Of the 40 species of fish potentially found at the site, *Anguilla mossambica*, *A. bengalensis labiata*, *A. marmorata*, *Labeo rosae*, *L. ruddi*, *L. congoro* and *L. molybdinus* have a significant requirement at some stage during their life history for migration. All the species collected are classified as of Least Concern by the IUCN red data list (IUCN, 2010), except *O. mossambicus*, which is Near Threatened. The Orange-fringed Large-mouth, Chetia brevis, is listed as Endangered.

The FAII score for the pooled data was 74%, giving and Integrity Class rating of C, Moderately Modified. For the two individual stations, the results were 87%, Class B (Station 1) and 60%, Class C (Station 2).

During the SIA field study the Fishing Associations and the Community Fishing Council informed that there are approximately 400 fishermen involved in the artisanal fishing in the Corumana reservoir at present. 217 fishermen are registered in the Fishing Associations. Fish are, caught using gill nets that are assessed using small boats.

5.8 Conclusion

The environmental impact assessment of the present state of the riparian vegetation, macroinvertebrates and fish fauna in the Sabíe River in the region of the Corumana Dam and reservoir may be described for the upstream environment as largely natural with few modifications and for the downstream environment as moderately to seriously modified, with a loss and change in habitats and biota, with ecosystem function changed.

6 Environmental Impact Assessment and Mitigation Measures

6.1 Introduction

Corumana dam has been in operation since 1989. Therefore, many of the large impacts normally observed as a result of constructing a dam have already taken place. This assessment has therefore focused on new or increased impacts that will result from increasing the operational water level in the reservoir to either 115 or 117 masl, as well as a modelled 1 in 1,000 year return period flood event where the flood level would read 120 masl, controlling the downstream flow and construction of the saddle wall with a fuse plug emergency spillway.

During the *scoping phase*, the following impacts were identified as the most significant that should be addressed in the EIA:

- Positive impacts generated by the Project;
- Inundation of terrestrial habitats surrounding the present reservoir;
- Hydraulic effects in terms of backwater effect (increased inundation) and induced sedimentation upstream of the reservoir resulting from increasing the FSL to either 115 or 117 masl of the reservoir (including effects in the Sabíe River in the Kruger National Park);
- Impacts on aquatic and riparian organisms of backwater effect and induced sedimentation resulting from increasing FSL to either 115 or 117 masl of the reservoir including species of conservation importance or concern upstream and downstream;
- Creation of habitats - lake fish, amphibians, waterfowl and other animals that are associated with lakes in the newly inundated areas of the reservoir following the raise the FSL of the reservoir;
- Impacts on downstream flow and biodiversity and water availability for users;
- Impacts on aquatic and riparian organisms due to effects on downstream flow including species of conservation importance or concern;
- Assessment of risk of development of thermal stratification in the reservoir;

- Construction and operating impacts;
- Increased risk of grounds for waterborne disease; and
- Any loss of physical cultural heritage.

6.2 Impact Classification

Impact matrix

The assessed impacts have been classified with respect to their severity on ecological features and issues. The classifications were carried out according to a procedure applied in South Africa using the following assessment criteria (DEAT 1998):

- The extent of the impact was classified as regional, local or site specific using the criteria shown in Table 6-1;
- The magnitude of the impact was classified as large, medium, low, very low or no impact using the criteria shown in Table 6-1; and
- The duration of the impact was classified as construction period, medium term or long term using the criteria shown in Table 6-1.

These criteria will serve to classify the significance of the impact combining the criteria on extent, magnitude and duration. Additionally, an assessment of the probability of the potential impact actually occurring has been assigned as well as a confidence given to the information available in understanding the impact according to the criteria shown in Table 6-3 and Table 6-4.

Table 6-1 Assessment criteria for the evaluation of impacts (Adapted from DEAT 1998)

Criteria	Category	Description
Extent of impact	Regional	Beyond 10 km of the site boundary
	Local	Within 10 km of the site boundary
	Site specific	On site or within 10 m of linear infrastructure corridor
Magnitude of impact	Large	Natural functions and processes are ***severely*** altered. Sensitive/protected species or habitats severely affected
	Medium	Natural functions and processes are ***notably*** altered. Sensitive/protected species or habitats affected
	Low	Natural functions and processes are ***slightly*** altered. Sensitive/protected species or habitats not affected
	Very Low	Natural functions and processes are ***negligibly*** altered
	No Impact	Natural functions and processes remain ***unaltered***
Duration of impact	Construction period	Up to 5 years
	Medium term	0 -10 years after construction
	Long term	More than 10 years after construction

Table 6-2 Definition of significance ratings (Adapted from DEAT 1998). The criteria for "extent of impact", "magnitude of impact" and duration of impact used for the ratings are shown in Table 6-1.

Significance ratings	Level of criteria required
Large impact	High magnitude with a regional and long term duration
	High magnitude with either regional extent and medium term duration or a local extent and long term duration
Medium impact	Medium magnitude with a regional extent and long term duration
	High magnitude with a local extent and medium term duration
	High magnitude with a regional extent and construction period or a site specific extent and long term duration
Low impact	High magnitude with either a local extent and construction period duration or a site specific extent and medium term duration
	Medium magnitude with any combination of extent and duration except site specific and construction period or regional and long term
	Low magnitude with at regional extent and long term duration
	High magnitude with a site specific extent and construction period duration
	Medium magnitude with a site specific extent and construction period duration
	Low magnitude with any combination of extent and duration except site specific and construction period or regional and long term
Very low impact	Very low magnitude with a regional extent and long term duration
	Low magnitude with a site specific extent and construction period duration
	Very low magnitude with any combination of extent and duration except regional and long term
No impact	Zero magnitude with any combination of extent and duration

Table 6-3 Definition of probability ratings (Adapted from DEAT 1998).

Probability ratings	Criteria
Definite	Estimated greater than 99% chance of the impact occurring
Highly probable	Estimated 80 to 99% chance of the impact occurring
Probable	Estimated 20 to 80 % chance of the impact occurring
Possible	Estimated 1 to 20 % chance of the impact occurring
Unlikely	Estimated less than 1 % chance of the impact occurring

Table 6-4 Definition of confidence ratings (Adapted from DEAT 1998).

Probability ratings	Criteria
Certain	Wealth of information on and sound understanding of the environmental factors potentially influencing the impact
Sure	Reasonable amount of useful information on and relatively sound understanding of the environmental factors potentially influencing the impact
Unsure	Limited useful information on and understanding of the environmental factors potentially influencing this impact.

6.3 Positive Impacts

Increasing the FSL of the Corumana Dam will generate a number of positive effects:

- Additional water will increase the yield from Corumana Dam available to potentially augment water supply for the Greater Maputo Metropolitan Area in the future under future investment projects. The IIMA Agreement states that 87.6 Mm^3/a of water is reserved for Maputo city from the Incomati and Maputo basins, the additional storage in Corumana reservoir would assist in meeting those allocations;

- Improved regulation will increase the reliability of water available for irrigation during low flow periods and allow for limited expansion;

- Although not a direct project related impact, the incremental yield available for augmentation of water supply to the Greater Maputo Metropolitan Area has the potential to reduce the incidences of waterborne diseases and increase the welfare of local people by allowing the expansion of the area covered with water supply system.

- Additional water will be available for downstream irrigators during in seasons of low flow;

- The project will provide conditions for increasing hydropower generation by nearly 4.8 GWh per year in firm energy;

- The new inundated areas in the reservoir will potentially enlarge the existing fishery in the reservoir. It has been estimated that a net increase in the total size of the fishery of up to 2% can be expected; and

- The construction work will create employment opportunities by requiring local and regional labour.

These positive effects of the development is dealt with in more detail in the ESIA's Volume 2 Socioeconomic context (Social Impact Assessment).

The new inundated areas in the reservoir will potentially enlarge the existing fishery in the reservoir.

The SIA field study found that there are approximately 400 fishermen involved in the artisanal fishing in the Corumana reservoir at present. 217 fishermen are registered in the Fishing Associations. Fishing is carried out using gill nets from small boats. Increasing the FSL of the dam to 117 masl will not impact deleteriously on the fishery, on the contrary, it will potentially enlarge the existing fishery.

Reservoir fish yield may be related to the magnitude of drawdown, the mean water depth and electrical conductivity. It appears that annual draw-downs of between 2.5 m and 4.0 m is optimal. The average draw-down for the Corumana Dam appears to be 3.0 m (Lahmeyer International, 2003). In addition, fish yields per unit area may be related to reservoir electrical conductivity, with higher conductivities indicating greater concentrations of nutrients. An increase in mean depth will mean deeper waters will be less suitable for fish production. Electrical conductivity is unlikely to change significantly, but mean depth is expected to increase by 21%, with potential annual fish yield per unit area declining by a slightly smaller percentage. The reservoir surface area, on the other hand, will increase by 23%, and hence the annual reservoir fish yield will increase, by a smaller percentage. The result is that, whilst catch per unit area, and effort, may decrease, total annual reservoir fish yield will increase, leading to a small increase in the potential size of the fishery of two percent.

The most productive fish producing areas are located in shallower waters, mostly where the depth is less than 10 m. An increase in FSL from 111 masl to either 115 masl or 117 masl will increase the extent of the littoral zone of 10 m or less from 32.3 km^2 to 34.4 km^2, or 6%. This implies that the fish production may also increase by around this percentage (Lahmeyer, 2003).

Hence, an increase in mean depth will mean a decrease in total annual potential fish yield per unit area for the dam. The increase in surface area of 23%, however, will result in an increase in suitable habitat of 6%, leading to a net increase in the total size of the fishery of up to 2%.

6.4 Hydrology and Sedimentation

6.4.1 Impact Assessment

The assessment of impacts on hydrology and sedimentation of increasing the FSL of the dam included assessments of:

- Upstream inundation and backwater effects;
- Induced upstream sedimentation;
- Impacts on downstream flow; and
- Impacts on limnology including risk of the development of thermal stratification in the reservoir.

The assessments were based on hydrological modelling using the U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Centre River Analysis System (HEC-RAS) software (version 4.1) and the Reservoir simulation model (RESSIM). Methodologies and detailed results are attached in Appendix 2.

Inundation frequencies
The RESSIM model was used to determine dam levels for Corumana Dam for different full supply levels. Table 6-5 and Figure 6-1 shows the water levels for different full supply levels at Corumana Dam for 85 years of simulated flow data. An FSL of 117 masl would cause inundation of approximately 730 m into South Africa. An FSL of 115 masl would reduce the stretch of inundation to approximately 450 m into South Africa. The inundation would be confined to the river channel. The historical firm yield was used as the target draft and evenly distributed throughout the year. Under this scenario the results show that the dam would only be at full supply level 117 masl for 9.8% of the flow record (Table 6-5) and for a FSL of 115 masl the dam would be full for 10.5% of the flow record.

Table 6-5 The frequency that specified water levels in the dam are exceeded for different FSL scenarios.

	The frequency that specified dam levels are exceeded			
Dam Level (MASL)	FSL at 111 masl (%)	FSL at 113 masl (%)	FSL at 115 masl (%)	FSL at 117 masl (%)
106	82.2	88.6	93.0	95.9
107	74.3	83.2	89.0	93.5
108	66.1	76.7	84.0	89.5
109	55.3	69.6	77.7	85.7
110	45.2	59.1	70.9	79.8
111	28.9	49.1	61.3	72.8
112	0.0	38.3	52.7	64.9
113	0.0	21.0	44.3	55.8
114	0.0	0.0	31.2	47.3
115	0.0	0.0	10.5	38.6
116	0.0	0.0	0.0	22.1
117	0.0	0.0	0.0	9.8

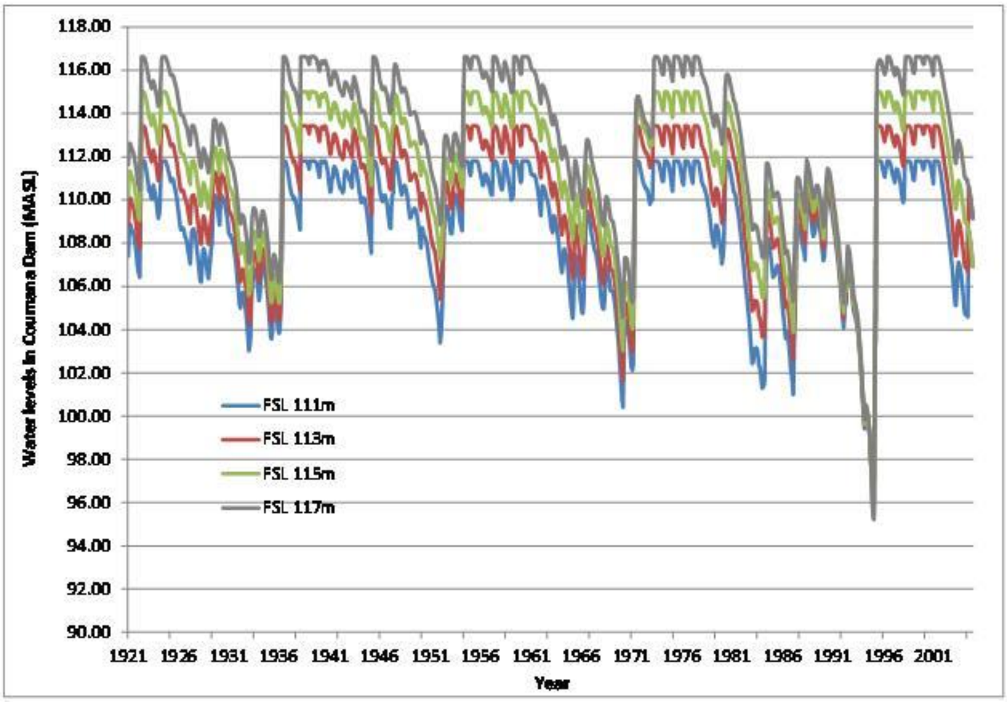


Figure 6-1 The water level in Corumana reservoir using 85 years of simulated inflow data for different FSLs

Assessment of backwater effect

The results of the hydraulic modelling of the backwater effect (upstream inundation in a flood event) of a 1 in 200 year return period flood event and different FSL are shown in Figure 6-2 (the flood in 2000 was representative of a 1 in 100 year return flood).

The results show that at the current FSL of 111 m, the backwater effect extends 690 m into South Africa from the border to Mozambique. With an increased FSL to 117 masl the backwater effect extends approximately 1,195 m into South Africa (marked by the red line) and is confined to the river channel (Figure 6-2). This can be considered a conservative estimate of the backwater effect as in the simulation the dam gates were only opened when the level in the dam reached 119.5 m. The backwater effect for an alternative scenario of a FSL of 115 masl (marked by the green line) extends approximately 1,050 m into South Africa. It should be noted that the backwater analysis carried out was for a worst-case scenario, namely, a 1 in 200 year return period flood with the gates only being opened at 119.5 m to prevent the plug in the saddle embankment from being broken.

Two options to diminish the backwater effect into South Africa are:

- To make pre-releases to draw down the dam before a 1in 200 year or 1 in 100 year flood peak reaches the dam. This would reduce the backwater effect and provide storage for flood attenuation. This measure could lessen the backwater effect of the 117 masl option by up to 385 m. To protect downstream users from pre-releases a warning system would need to be in place. ARA-Sul is in the process of establishing a permanent department to assist with flood prediction and disaster management (TPTC, 2010c). Drawing down the dam before a flood does have implications for the yield of the dam especially if the flood is not as large as expected and the dam does not return back to full supply level – at 117 masl; and

- To operate the dam gates so that input to the dam would equal output. This measure could lessen the backwater effect by up to 290 m with a FSL of 117 masl. The disadvantages would be little attenuation of the flood if the dam was already at 117 masl. However, full supply level of 117 masl would be maintained during the flooding period and would not impact the yield of the dam.

The upstream inundation due to a 1 in 200 year flood is likely to be of a short duration period with a high magnitude, very low frequency resulting in a **Medium Impact.**

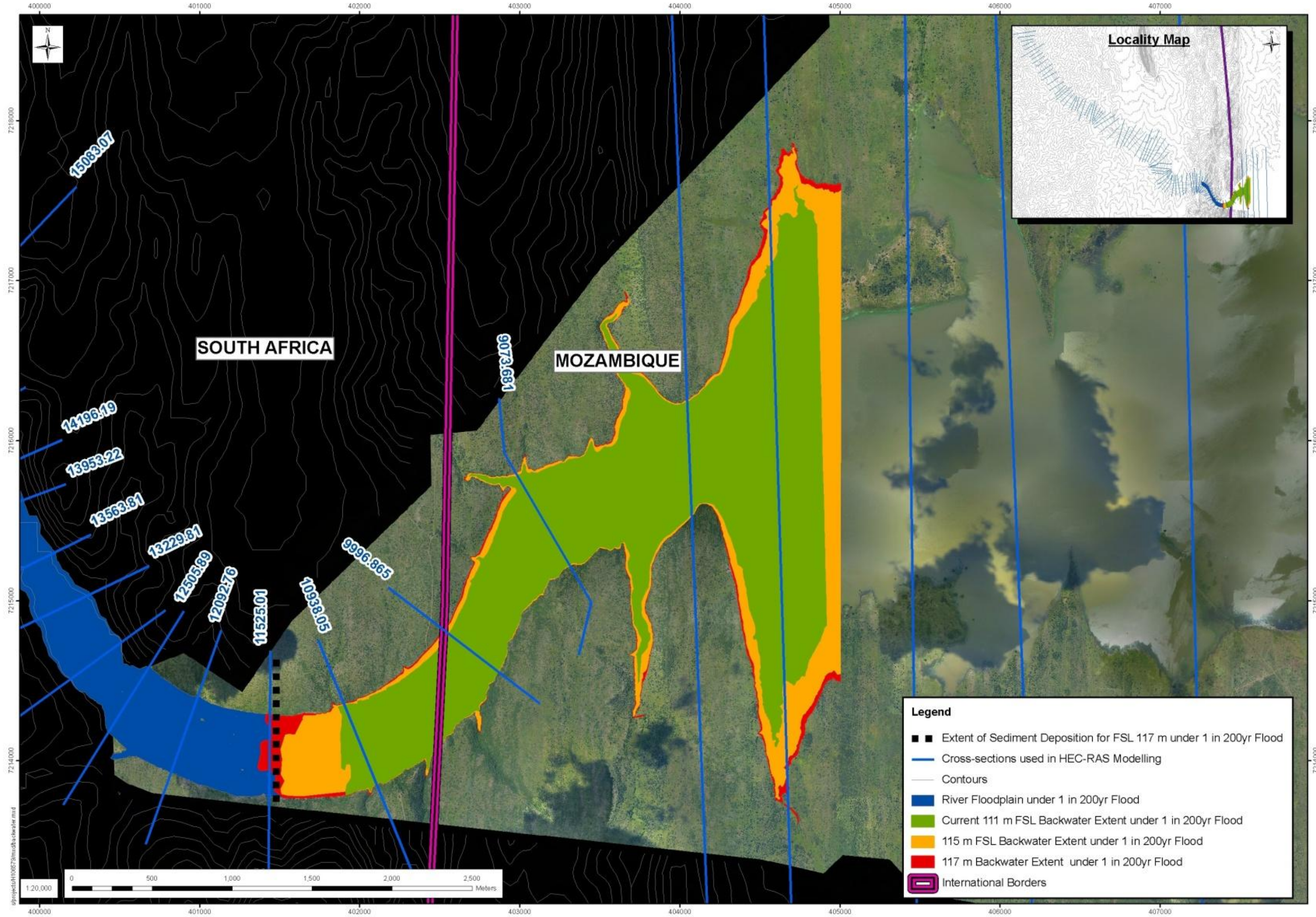


Figure 6-2 Simulated backwater effect and induced sediment deposition extent

Assessment of induced sedimentation upstream the reservoir
The assessment of induced sedimentation using the HEC-RAS model found that for a 1 in 200 year flood the zone of induced sedimentation caused by increasing the FSL to 117 masl would extend from the reservoir to an area 1,080m into South Africa (stipulated line on. Figure 6-2). It should be noted that over the next 50 years, due to sediment build up in the upper part of the dam basin, the extent of sedimentation induced by a FSL of 117 masl may migrate further upstream.

For an alternative scenario of a FSL of 115 masl the extent of induced sedimentation was found to be approximately 935 m into South Africa.

No sediment sampling has been done as part of this report. The most recent sampling was carried out by SWECO (2003) who produced a Final report, Annex II: Sediment Yield Report for Corumana, Macarretane, Massingir and Pequenos Limbombos Dams. Ten bed samples were taken along the old river reach in the Corumana reservoir. The two samples taken near to the entrance to the dam had a high sand content (up to 40%) with the other eight samples further into the dam consisting of at least 50% clay. Unfortunately the Final Report, Annex I: Sediment Yield Report which apparently contains a detailed basin survey was not made available. As a consequence estimates of areal sedimentation cannot be made.

The increased sedimentation can be mitigated by is the use of flushing to control sediment which is a methodology best suited to those dams situated in a valley where the inflow into the reservoir has a straight path to the outlet. Due to the shape of reservoir at Corumana the inflow velocity to the reservoir will dissipate before the outlet so occasional flushing is unlikely to have a major impact on water quality. Therefore, this is not a viable mitigation measure.

The upstream sedimentation induced by a FSL of 117 masl under a 1 in 200 year flood is likely to be of a long duration period, local extent with a high magnitude resulting in a **Medium Impact.** Smaller floods such as 1 in 100 year and 1 in 50 year were investigated and the extent of the induced upstream sedimentation due to the dam was 100m less.

Impacts on downstream flow
The Sabie River has a catchment area of approximately 6,900km^2. However, 90% of the catchment area is in South Africa with only 10% on the Mozambican side of the border. Given increasing demands upstream in South Africa within the Inkomati Water Management Area the catchment is considered to be stressed. Water requirements are estimated to be in excess of the available water resources, especially if the water requirements for Mozambique and the Ecological Reserve in South Africa are taken into account. The result of this at the basin scale is that the Ecological Reserve is often not met and the cross border flows into Mozambique have on occasions been less than specified in various international agreements.

The RESSIM model was used to determine the historical firm yield for Corumana Dam using different full supply levels. The results of these simulations are show in Table 6-1-6 The results show that increasing the FSL of Corumana Dam to 117 masl increases the historical firm yield, reduces the spillage and results in higher evaporative losses. The annual downstream flows from the dam (Yield + Spillage) will reduce by 5.1%. This is considered a **Low Impact**. For the 115 masl alternative option the downstream flow rate is reduced by 3.3%.

Table 6-6 Flow volumes of reservoir operation simulations for Corumana Dam

FSL (masl)	Inflow (Mm^3/annum)	Historical Firm Yield (Mm^3/annum)	Evaporative Loss (Mm^3/annum)	Spill (Mm^3/annum)
111	457.2	234.0	69.4	154.5
113	457.2	239.4	75.5	142.8
115	457.2	244.8	81.8	130.9
117	457.2	250.8	88.6	117.8

A result of the increased storage capacity of an increased FSL would be that smaller floods (i.e. the 1 in 10 year flood) would be absorbed as the long as the dam was below FSL of 117 masl. Beck and Basson (2003) found that for South African conditions the dominant discharge that maintains or shapes the river channel would be consistent with the 1:10-year flood peak. If the 1 in 10 year flood is absorbed by increasing the full supply level this could lead the narrowing of the river channel downstream and an increase in riparian vegetation. The impact on downstream channel morphology is likely to be of a long duration period, regional extent (beyond 10 km of the site boundary) with a medium magnitude resulting in a medium impact.

A reduction in sediment carrying floods could also lead to increased erosion of the river channel immediately downstream of the dam wall. An area that is particularly vulnerable is around the road bridge approximately 2 km downstream of the Corumana spillway. To moderate the impacts to downstream channel morphology environmental releases from the dam should be planned for in the final EMP.

There have been various attempts to define the environmental flow requirements for the lower part of the Incomati River in Mozambique. The present operation of the Corumana Dam since they commenced in 1989 has modified the low flow regime. In general, the flows have been higher during the dry season when compared with the conditions prior to regulation. The present minimum flow is about 6 - 7 m^3/s. This is determined primarily by the irrigation needs downstream of the confluence with the Incomati River and is further utilized for power production.

Because of the operations over the past two decades, the conclusion of the aquatic assessment indicates that the lower part of the Sabíe River is described as moderately to seriously modified, with a loss and change in habitats and biota with a change in ecosystem functions. The consideration of environmental flow releases also needs to consider the estuarine requirements. The direct effect of freshwater in an estuary is to reduce the water salinity and increase nutrient supply (from sediment deposition) for the primary productivity of the estuarine ecosystems, namely mangroves and reed beds. Upstream abstractions have reduced freshwater flows into the estuary and changed the flow regime. This may negatively affect the estuarine ecosystem and consequently the shrimp and fish production in Maputo Bay.

The estuary has an extensive mangrove forest covering approximately 5,000 ha around the mouth area that influences the health of the coastal zone and adjacent marine habitats and protects the coast from erosion provoked by the prevailing easterly winds. The positive relationship between mangrove areas and production of valuable fish and prawns is well documented. A number of commercially important fish, shrimp, crab, and mollusk species use mangroves as nursery grounds (for feeding and shelter) during the juvenile and adult stages of their development. Six species of mangrove occur in the estuary. Mangroves at the estuary have suffered anthropogenic impact and large areas are being harvested for construction, charcoal production, and firewood.

The Joint Inkomati Basin Study recommended a minimum flow from the Inkomati River into the estuary of 5.0 m^3/s, primarily to prevent saltwater intrusion (Consultec *et al*. 2000). This is equivalent to an annual volume of 158 million m^3 and was considered sufficient to maintain the estuarine ecology as long as regulation allowed for floods to reset the system and flush out pollutants according to the annual discharge cycle. Annual distributions of the environmental flow requirements were subsequently estimated under the "National Water Resources Development Plan for the Inkomati River Basin" completed in 2003. It estimated a monthly flow series with an annual environmental flow equivalent too roughly 23% of the MAR (Table 6-7). The Joint Inkomati Basin Study used two different methods to estimate minimum low-flows for the lower part of the Inkomati River, near Manica, for an ecological Category B. The Reserve Desktop Method indicated minimum flows of between 20.73 m^3/s in September, and 57.02 m^3/s in February. The Tennant Method indicated minimum flows of between 23.32 m^3/s in September, and 46.64 m^3/s in February (Consultec *et al*. 2000). These are equivalent to annual volumes of 1,096 and 1,103 million m^3 respectively.

Table 6-7 Monthly distribution of IFR of channel 201 Inkomati River downstream of Corumana Dam

Table 11-10a Monthly distribution of IFR of channel 201 Inkomati River downstream of Corumana Dam

Item	Flow (million m^3)	% MAR
MAR	787.40	
Total IFR	183.57	23.3
Maintenance low flow	119.54	15.2
Drought lowflow	63.11	8.0
Maintenance high flow	64.03	8.1

Monthly Distributions (all figures in million m^3)

Month	Mean	SD	CV	Maintenance low flow	Drought low flow	Maintenance high flow	Maintenance total flow
Oct	20.01	9.05	0.45	6.24	3.42	0.54	6.78
Nov	40.82	29.76	0.73	7.19	3.89	3.06	10.25
Dec	84.50	79.14	0.94	9.39	4.98	8.26	17.64
Jan	131.26	125.97	0.96	12.20	6.37	8.38	20.58
Feb	188.45	256.58	1.36	15.94	8.22	31.37	47.31
Mar	141.26	173.80	1.23	15.60	8.05	8.38	23.99
Apr	66.86	47.57	0.71	13.29	6.91	4.04	17.33
May	34.16	16.78	0.49	10.53	5.54	0.00	10.53
Jun	24.06	6.58	0.27	8.70	4.64	0.00	8.70
Jul	20.52	5.16	0.25	7.48	4.03	0.00	7.48
Aug	18.09	4.51	0.25	6.71	3.65	0.00	6.71
Sep	17.40	6.88	0.40	6.28	3.44	0.00	6.28

Studies in Mozambique to date have been limited by the lack of detailed data available and have been primarily carried out at a low confidence desktop level. The desktop method is based on monthly hydrology and is, therefore, inappropriate for assessing flood requirements, which need daily or sub-daily hydrology. A further limitation to the Joint Inkomati Basin Study is that it is concerned only with low flows. The lower Inkomati is essentially a floodplain system, so a focused study that quantifies environmental flood requirements is required (Palmer, 2010 per com). This also needs to consider the coastal interaction and dynamics to estimate the estuarine impacts. Given the lack of available data this is far beyond the scope of this study and requires a sustained program of long term monitoring with a feedback loop to the operating rules of the Corumana Dam. Recommendations have been included under the EMP to facilitate establishment of such a biomonitoring program and for inclusion in the development of the operating rules during the implementation phase of the project. This will be important as EWRs can impact the yield of the dam.

As the downstream riparian on a shared transboundary waterway, the development and implementation of environmental flows in Mozambique is dependent in large part on the implementation of similar measures upstream. In the case of the Sabíe catchment upstream, the required ecological reserve is defined in South Africa at the inflow of the Sabíe and Sand rivers to the Kruger National Park. The ecological reserve for the Sabíe River is 168 Mm^3 and the Sand River 40.2 Mm^3. On the main stem of the Incomati River, minimum flows at the inflow to Mozambique have been quite small in years with normal rainfall. The low flows are aggravated by the intensive use of water and the many storage dams in South Africa and Swaziland such that this resulted in instances of zero flows at the Ressano Garcia border. As a result, negotiations between the three Governments have resulted in agreement upon a minimum flow of 2 m^3/s.

Further to transboundary collaboration on developing an agreed framework for sustainability and meeting environmental flow requirements, the “Tripartite Interim Agreement for Co-operation on the Protection and Sustainable Utilization of the Incomati and Maputo Watercourses (IIMA)” signed by Mozambique, South Africa and Swaziland in August 2002 includes a minimum flow of 0.6 m^3/s and annual mean of 200 Mm^3/a for the lower Sabíe River that should be maintained to sustain the ecology of the water course. Under the auspices of the Tripartite PRIMA program an Integrated Water Resources Management Plan is being developed for the Incomati River basin. This is based on the strategic principles of the IIMA and, together with the other IAAP projects, will support the establishment of a Comprehensive Agreements that will replace the IIMA.

The IWRM plan is presenting an integrated approach to the protection, development, use and management of the water resources to ensure that the quantity and quality objectives are achieved. The IWRM plan will provide specific emphasis to the “first priority supplies” in the basins (domestic, industrial, livestock, environmental flows) and other water utilization functions on the basins such as afforestation and irrigation (specifically addressed in IIMA), hydropower, recreation and tourism, fishery, wildlife and nature reserves, and other aquatic and terrestrial ecosystems.

The TPTC Inkomati Status Quo Report (2010a) states that Environmental Water Requirements (EWRs) for the Incomati Basin, have been studied in considerable detail within Swaziland (e.g. KOBWA 1998, 2010) and South Africa (e.g. DWA 2003, 2006, 2008). However, it notes that previous assessments of EWRs within Mozambique have been based on desktop methods for the purpose of initial planning and are therefore of low confidence. The TPTC (2010a) has therefore focused on the initial steps needed to assess EWRs within the Mozambican portion of the catchment. The steps taken thus far have been to quantify Ecological Importance and Sensitivity, Social and Cultural Importance, and Present Ecological State for various river reaches within Mozambique.

To determine EWRs for the Sabíe below Corumana Dam the whole of the Inkomati basin in Mozambique would need to be considered including the estuary. The methods employed in establishing EWRs should focus on identifying the size, duration and timing of specific flows and flow patterns that are considered to be the most important for maintaining the abiotic and biotic components of a stretch of river in a particular condition. The TPTC (2010b) has recommended two phases for the establishment EWRs in the lower Inkomati

River. The first phase is to set provisional minimum flows at selected key sites, and to then establish and apply an environmental monitoring programme, in which Key Performance Indicators are monitored, and the provisional minimum flows revised. The purpose of the second phase is to undertake detailed assessments of the EWRs. This second phase would assess the ecological and socio-economic consequences of different operational flow scenarios, and to recommend a flow scenario that optimizes environmental goods and services. Outcomes from the second phase should include a recommended flow scenario and a revised monitoring programme. A study of this nature is likely to take more than six to twelve months as it is required to cover at least one high and low flow season. Ideally it should be integrated in to a long-term biomonitoring program that can feedback in to the ongoing operation of infrastructure within the catchment. the TPTC (2010b) report recommends that a multi-disciplinary team undertake studies in the following subject fields: Hydrodynamics; Water Quality, focusing on Saline Intrusion; Remote sensing and Estuarine Health; Socio Economics; Catchment to Coast (C2C) Decision Support Tool; Sedimentology, and Biodiversity. The EMP includes a recommendation for further elaboration of longer term monitoring to inform the inclusion of environmental flow provisions in the operating rules for the dam.

Assessment of thermal stratification in the reservoir
The limnological assessment found that Corumana reservoir would probably not exhibit strong thermal stratification during the summer months and that the dam would probably exhibit weak thermal stratification during the daytime but it would easily be broken down by light wind mixing or cooling during the evenings. Corumana reservoir would therefore probably not exhibit some of the water quality problems associated with strong thermal stratification such as anoxic bottom water and elevated iron and manganese concentrations as a result of these anoxic conditions. (This is discussed in detail in Appendix 2).

6.4.2 Mitigation measures

The following measures can be employed to mitigate impacts on hydrology of increasing the FSL of the dam:

- To diminish the inundation upstream the dam gates could be operated so that inflow equals outflow during a major flood which would maintain the dam level at either 115 or 117 masl (backwater effect).

- To moderate the impacts to downstream channel morphology environmental releases from the dam should planned for and operationalized.

6.5 Hydrogeology/groundwater

6.5.1 Impact Assessment

The seepage area on the northern end of the embankment is of concern. Increasing the FSL from 111 masl to 115 or 117 masl can increase pressure on the seepage areas and increase flow. A separate Technical Services and Dam Safety assignment being implemented as part of project preparation is assessing the dam safety and detailing the measures needed under the project to support the increased reservoir level.

Risk of increased seepage will be mitigated by the planned remedial works to strengthen the dam and prevent seepage. When the planned remedial work has been carried out **No Impact** is expected.

The other concern from a geohydrological point of view is the saddle wall on the southern side of the dam. Monitoring boreholes will be required to establish background water levels in the downstream area from the saddle wall. This should be carried out by the Engineering design consultant. Seepage through the saddle wall and or pressure on the groundwater levels may impact on agricultural activities and settlements south of the saddle dam.

Table 6-8. Summary of significance and probability of potential impacts.

Process Impacted	Extent of impact	Magnitude of impact	Duration of impact	Significance ratings	Probability ratings	Confidence ratings
Impacts of increased level of water in reservoir on seepage	Local	Medium	Long term	Large impact*	Highly probable	Sure
Hydrogeological effects on saddle wall	Local	Medium	Long term	Low impact	Probable	Unsure

* When remedial work has been carried out, **No Impact** is expected.

6.5.2 Mitigating Measures

Impacts of increased level of water in the reservoir on seepage from the dam

It is planned to strengthen the dam to prevent existing seepage. A geotechnical investigation, drilling and installation of piezometers is being outlined as part of the Technical Services and Dam Safety assignment before the dam completion will be carried out. The seepage paths must be clarified and remediation measures implemented by the borrower and the dam operators before filling of the dam. Recording and evaluation of the impact of the filling on the seepage areas will indicate the extent of the impacts and if the remediation was successful.

Hydrogeological effects on the saddle wall.

The geotechnical investigations will indicate the depth of weathered zone in the area where the saddle wall will be constructed. The construction must assure that no seepage will occur through or underneath the saddle wall. Installation of monitoring piezometer boreholes that can be recorded before, during and after filling will give a valuable indication of the potential impact of the saddle wall should leakage occur. Isotope technique can be used to evaluate possible mixing of dam water leakage and groundwater.

6.6 Terrestrial ecology

6.6.1 Impact Assessment

A. Construction Phase

The construction phase is here considered to be from the start of the construction to the filling up of the dam to the new Full Supply Level. After this point the project is considered to be in Operational Phase, even though the dam is already operational.

i. Loss of Natural Habitat through Inundation

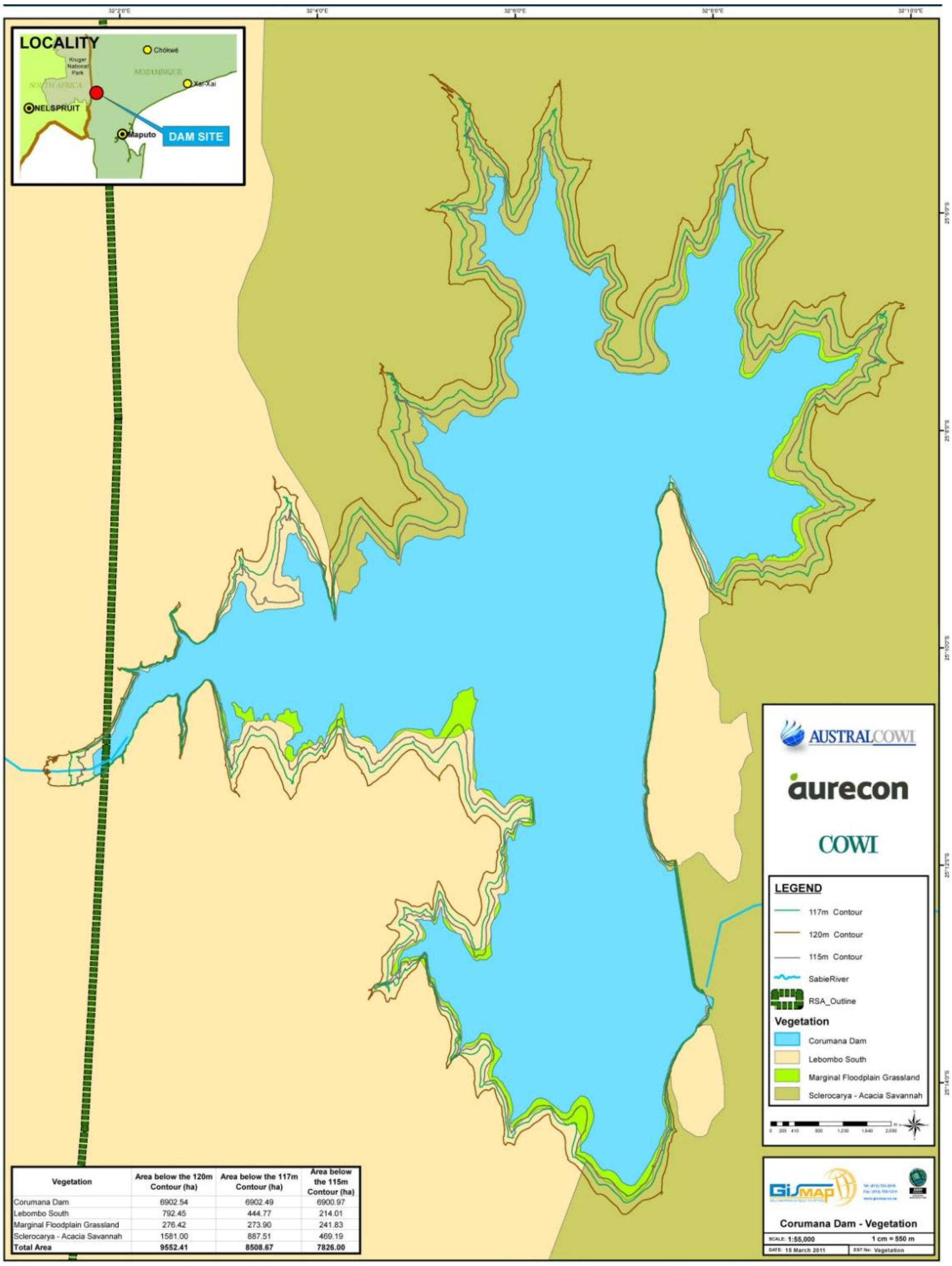
The following areas of natural habitat around the Corumana reservoir will be affected by inundation after raising the Full Supply Level to 117 masl. (Figure 6-3 and Table 6-9):

- 888 ha of *Sclerocarya birrea – Acacia nigrescens* Savanna;
- 445 ha of Lebombo South Landscape; and
- 274 ha Floodplain Grassland

Raising the Full Supply Level to 115 masl will affect a total terrestrial area that is 40 % smaller. The following areas will be affected by inundation (Figure 6-3 and Table 6-9):

- 469 ha of *Sclerocarya birrea – Acacia nigrescens* Savanna;
- 214 ha of Lebombo South Landscape; and
- 242 ha Floodplain Grassland

The hydrological modelling has showed that FSL 115 masl or 117 masl will rarely be obtained (i.e. in only about 10% of the time), so some of the affected area will only be affected part of the time (Table 6-10).



Vegetation	Area below the 120m Contour (ha)	Area below the 117m Contour (ha)	Area below the 115m Contour (ha)
Corumana Dam	6902.54	6902.49	6900.97
Lebombo South	792.45	444.77	214.01
Marginal Floodplain Grassland	276.42	273.90	241.83
Sclerocarya - Acacia Savannah	1581.00	887.51	469.19
Total Area	**9552.41**	**8508.67**	**7826.00**

Figure 6-3 Vegetation Landscapes around Corumana reservoir that will be affected by inundation for a FSL of 117 masl and 115 masl. The 120 masl is also indicated which correspond to the 1 in 1,000 year flood which will activate the planned fuse plug emergency spillway.

Table 6-9. Estimated areas af diffferent vegetation landscapes that will be affected by inundation at FSL 117 masl, FSL 115 masl and the 120 masl which correspond to a 1 in 1,000 year return period flood event which will activate the planned fuse Plug emergency spillway

	Area below the 115 masl contour (ha)	Area below the 117 masl contour (ha)	Area below the 120 masl contour (ha)
Sclerocarya birrea – Acacia nigrescens Savanna	469	888	1581
Lebombo South Landscape	214	445	792
Floodplain Grassland	242	274	276

Table 6-10 The frequency that specified water levels in the dam are exceeded for FSL at 117 m. and 115 m.

Dam Level (MASL)	FSL at 117 masl (%)	FSL at 115 masl (%)
107	93.5	89.0
108	89.5	84.0
109	85.7	77.7
110	79.8	70.9
111	72.8	61.3
112	64.9	52.7
113	55.8	44.3
114	47.3	31.2
115	38.6	10.5
116	22.1	0.0
117	9.8	0.0

Riparian vegetation along the Sabíe River upstream of the dam may be lost. This is a very restricted vegetation type within the study area, better represented in the

Kruger National Park than downstream of Corumana Dam, partly through anthropogenic impacts such as fuel wood collection and overgrazing, as well as different geomorphology of the macro-channel.

Riparian vegetation along a narrow stretch of the river channel extending some 730 m into Kruger National Park in South Africa will be inundated when increasing the FSL to 117 masl. The affected stretch will be reduced to 450 m for the alternative FSL of 115 masl. In case of a 1 in 200 years flood, riparian vegetation will be affected along stretches extending approximately 1,195 metres (for the FSL of 117 masl) and 1,050 metres (for the FSL of 115 masl) into the Kruger National Park.

KNP is a protected conservation area of international significance that supports many species of fauna and flora.

The entire Floodplain Grassland landscape is likely to be lost through inundation.

Grassland is likely to play an important role in the grazing dynamics of the herbivores in Sabie Game Park, particularly as grazing potential decreases in the dry season. This valuable winter grazing will be lost until Floodplain Grassland re-establishes in the future.

This is particularly significant on the north-western shores of the dam, in the Sabie Game Park, where IUCN Red Data mammals potentially use the floodplain habitat for grazing and hunting. However, the loss of Floodplain Grassland will not be permanent, and once the new inundation levels are reached, this vegetation type will begin re-establishing.

The impact of inundation on terrestrial vegetation is considered to have **Medium Impact** (Table 6-11)

ii. Loss of Populations of Species of Conservation Concern

Three threatened plant species potentially occur in the area to be inundated by the raising of the FSL: *Adenium swazicum* (Endangered), *Ipomoea venosa* (Vulnerable) and *Turbina longiflora* (Vulnerable). It is possible that these species were overlooked during fieldwork because of the large areas that had to be covered (study area 15 x 20 km).

This impact is considered to have **Medium Impact** (Table 6-11).

iii. Introduction and spreading of invasive plant species

Construction activities will result in areas of bare soil being exposed, which are vulnerable to colonisation by invasive plant species. A number of potential invasive species are already present in the vicinity of Corumana reservoir, in particular the aggressive invasive alien herb *Parthenium hysterophorus*, and a seed bank is present from which species such as this could easily spread.

An increased surface area of the dam also would result in an increase in the potential area of infestation for four invasive aquatic plants that already occur in the area: Water Lettuce (*Pistia stratiotes*), Water Hyacinth (*Eichhornia crassipes*), Red Water Fern (*Azolla filiculoides*) and Kariba Weed (*Salvinia molesta*).

All four species are currently targeted by alien plant control programmes in the Kruger National Park using biological control methods. These programmes have had much success in the control of *Azolla filiculoides, Pistia stratiotes* and *Salvinia molesta* but mixed success with *Eichhornia crassipes* which should be viewed as the highest potential threat.

Recommendations for suitable mitigation measures to be implemented as part of the project are included as part of the EMP to address the potential problem of invasive plant species (Volume 3 Environmental Management Plan) and as the South African National Parks Board is controlling alien plants in the river systems of Kruger National Park the impact is considered to be a **Low Impact.**

iv. Impacts of construction of the saddle dam and excavation of the emergency spillway

After completion, the footprint of the saddle dam will cover an area of approximately 0.1 km^2 of Floodplain Grassland, which will be permanently lost. In addition, excavation of the emergency spillway will temporarily remove approximately 0.4 km^2 of grassland. After completion of excavation, the grassland will be re-established by invasion of grass species from the surrounding area. However, during and immediately after the excavation the area is subject to erosion especially during rainfall. The eroded material will be discharged to the reservoir and deteriorate the water quality in terms of increased suspended solids.

These impacts are considered to be **Low Impact (**Table 6-11**).**

v. Impacts of saddle dam fuse plug activation

In case of a 1 in 1,000 year flood, at 120 masl, the saddle dam fuse plug activation will cause temporary flooding of areas with mostly *Sclerocarya-Acacia* Savanna south of Corumana reservoir. Figure 6-4 indicate areas with high risk of inundation in case water is not drained off. However, a discharge channel will be constructed to chanellize releases from the emergency spillway to the Sabie River downstream Corumana Dam (Figure 6-5).

This impact is considered to be **Low Impac**t (Table 6-11).

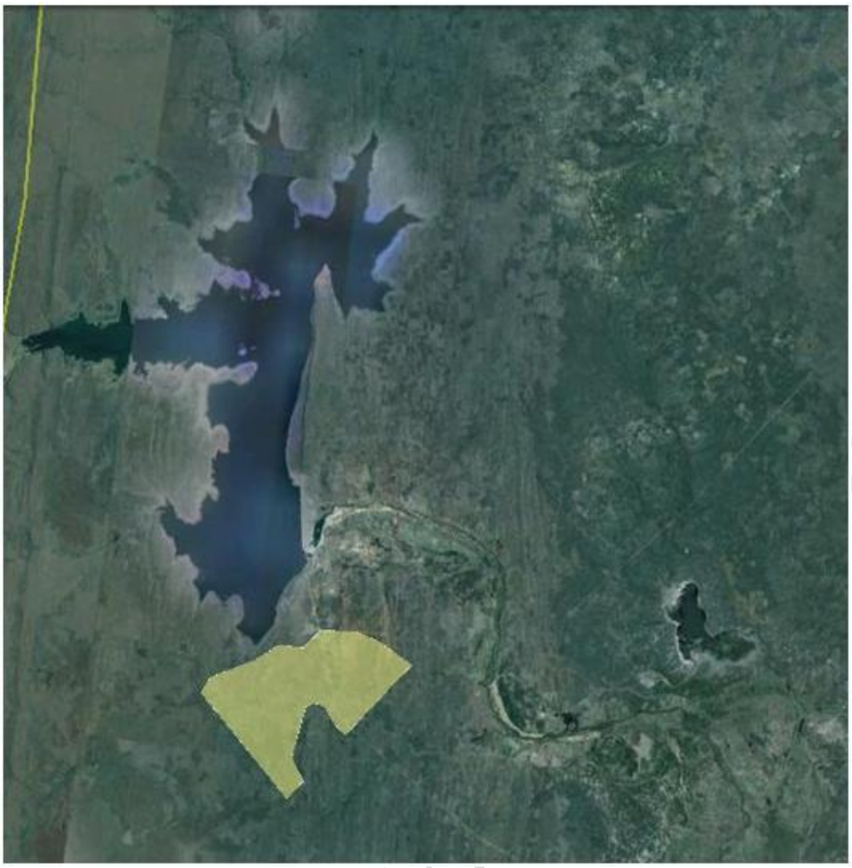


Figure 6-4. Area with a high risk of flooding in case of saddle dam fuse Plug activation in case a channel to drain off the water is not constructed. The área is approximately 1500 ha.

B. Operational Phase

Even though the Corumana Dam is already operational, for the purposes of this project, Operational Phase is considered to be from the completion of the dam to the new Full Supply Level of 115 masl or 117 masl depending on the alternative selected. The ecological impacts during the operational phase are likely to be greater on Riparian Vegetation than Terrestrial Vegetation. The impacts on Riparian Vegetation will be dealt with in Section 6.7, and include loss of riparian vegetation through increased riverbank erosion downstream of the dam wall, reduced recruitment of riparian vegetation downstream of dam because of a modified flood regime, etc.

Table 6-11 Assessment of Impacts on Terrestrial Ecology

Process Impacted	Extent of impact	Magnitude of impact	Duration of impact	Significance ratings	Probability ratings	Confidence ratings
Loss of natural habitat through inundation	Site Specific	High	Long term	Medium Impact	Definite	Certain
Loss of habitat in footprint	Local	Low	Long	Low	Definite	Sure

of saddle dam			term	impact		
Temporary loss of habitat in footprint of emergency spillway and temporary impacts of erosion	Local	Low	Short term	Low impact	Definite	Sure
Inundation of Floodplain Grassland and Sclero-carya-Acacia Savanna in case of saddle dam activa-tion during a 1 in 1000 year flood	Local	Medium	Medium	Low impact	Unlikely	Unsure

6.6.2 Mitigation Measures

Two of the inundated landscapes are well represented outside of the reservoir inundation area (*Sclerocarya birrea - Acacia nigrescens* Savanna and Lebombo South). The Floodplain Grasslandcan be expected to re-establish at a higher level once new inundation levels are reached. The deeply rooted grass *Cynodon dactylum*, in particular, will rapidly colonise the new drawdown zone. The loss of habitats is not considered significant as per the World Bank`s Natural Habitats Policy (OP 4.04). Measures to mitigate inundation of natural habitat is thus not considered necessary.

i. Dedicated threatened plant surveys

The EMP includes provision for further surveys to be undertaken during project implementation in areas where terrestrial vegetation is likely to be flooded. These surveys should focus on locating the potentially occurring threatened species listed in Appendix 3 and should take place at the correct time of the year to locate these species prior to impoundment. The survey team should record locations of all populations with a GPS and the plants should be relocated to suitable representative habitat outside of the full supply level.

ii. Reservoir Management Plan

Proper management of the Corumana reservoir requires a detailed consultative process to reach agreement on an appropriate spatial plan. The reservoir provides important fisheries, the sustainability of which are dependent upon the protection of breeding habitats for fish and water birds.

Sabie Game Park is struggling with poachers who are brought in illegally via the reservoir by local fishermen and it is feared that if the water level rise, poachers will be able to penetrate further into the park and the problem will worsen.The development and implemention of a Reservoir Management Plan as part of the EMP would provide a consultative mechanism to develop appropriate zoning of the reservoir to meet the multiple use objectives that will help address concerns over poaching.

In particular, the EMP should use an inclusive consultative process informed by the long-term monitoring of water quality and habitat transformations as a result of the increased full supply level to zone appropriate use of the reservoir.

This would include controlling entry by boat to the Sabie Game Park and Kruger National Park in order to reduce access for poachers as well as protecting productive fisheries for local fishers and important habitats for breeding purposes.

iii. Invasive aquatic plant management plan

As part of the Reservoir Management Plan specific provisions will be developed and implemented during the project to manage and address the problem of invasion of Corumana reservoir by non-indigenous aquatic plants, in particular the four target species that are already present in small numbers (see Appendix 4). The management plan should include training of local people in the identification and eradication of key species. These trained fieldworkers could then be employed by ARA-Sul as the operator to annually monitor the status and distribution of key invasive aquatic plants on the dam. The details of this are included in the EMP.

iv. Impacts of construction of saddle dam and excavation of emergency spillway

Measures to mitigate erosion from the excavation of the saddle dam are outlined in the EMP.

v. Impacts of activation of fuse plug emergency spillway

A discharge channel will be constructed to channelize releases from the emergency spillway to the Sabíe River downstream Corumana Dam (Figure 6-5).

Figure 6-5 Location of discharge channel that will be constructed to chanellize releases from the emergency spillway to the Sabie downstream Corumana Dam

6.7 Aquatic and Riparian Ecology

6.7.1 Impact Assessment

Potential threats to aquatic and riparian biota

The fact that the Corumana Dam has been in operation since 1989 would imply that any significant threat to the aquatic and riparian biota and habitats, in general, has already occurred and that any new threat will be governed by (1) the inundation of the aquatic environment upstream of the Corumana reservoir in Kruger National Park in South Africa, (2) the inundation of a further areas behind the dam itself and (3) the effect of any change in flow characteristics downstream of the dam. These are specifically dealt with in the following subsections.

Although the longitudinal nature of river systems would suggest that impacts are always considered at the regional scale, the focus here is on general impact immediately above the Corumana Dam, the dam itself and a short distance downstream.

The site-specific impact as identified for the upstream reach of the Sabíe River is considered in the next section, and is not dealt with here.

In the case of the aquatic and riparian vegetation and the aquatic macroinvertebrate fauna, no habitats or species of conservation importance or concern were collected or identified (IUCN Red Data List 2010). Given that the dam has been existence since 1989, it is plausible that there will be no new threat to migrating fish species. The ideal in the case of the design and construction of a new dam would be to include some form of fish ladder. The fact that the dam has been in operation since 1989 and has a height of 45 m makes this implausible.

The magnitude of any potential threat, for example the loss of important biota, is considered low. Impacts associated with the ecology around the newly completed dam can be seen to exist potentially at the medium term level. The significance rating would thus be low impact in general. It is probable that this will be the case and the confidence is rated as sure.

The impact of potential threats to the aquatic flora and fauna and habitats of conservation importance is considered **Low Impact**.

Table 6-12 Assessment of Impact on Aquatic ecology

Process Impacted	Extent of impact	Magnitude of impact	Duration of impact	Significance ratings	Probability ratings	Confidence ratings

Threats to aquatic flora and fauna and habitats of conservation importance or concern, generally	Local	Low	Medium term	Low impact	Probable	Sure

Impacts on aquatic and riparian biota in the Sabíe River upstream of the Corumana reservoir

The riparian vegetation upstream has undergone a significant, natural, change in the recent past, as a consequence of the effects of the 1 in 100 year flood in 2000. The change in state would have been from a tree, shrub and reed state, with high abundance and cover, into the present, more open one state, with fewer large trees.

Inundation at the site will clearly lead to the loss of habitats, especially in the marginal zone. The impact on the non-marginal zone will not be as significant, given that no plants of high conservation value (all those collected may be classified as Least Concern) were observed at the assessed area, and that the area is open with low woody and non-woody abundance and cover.

Riparian vegetation along a narrow stretch of the anastomising river channel extending some 730 m into Kruger National Park in South Africa will be inundated when increasing the FSL to 117 masl. The affected stretch will be reduced to 450 m for the alternative FSL of 115 masl. In case of a 1 in 200 years flood, riparian vegetation will be affected along stretches extending approximately 1,195 metres (for the FSL of 117 masl) and 1,050 metres (for the FSL of 115 masl) into the Kruger National Park.

The inundated area for the 1 in 200 year flood for FSL 117 masl will extend into most of the first reach from the international border, with the equivalent loss of anastomising channel.

Clearly, though, the effect of reduced flow rate will result in sediment deposition and the development of alluvial deposits a short distance further, most likely within the reach at the site, as well as within the succeeding upstream reach. The presence, therefore, of at least a further seven upstream reaches, totalling approximately eight km, within the Northern Lebombo Bushveld, is important.

Although any loss should be avoided, it appears that approximately 1,195 m (most of reach 1) of a total of 7,896 m (reaches 1 to 8 within the Northern Lebombo Bushveld) or 15% of the bedrock anastomising reaches within the Northern Lebombo Bushveld will be potentially transformed. Within this approximately a quarter of the first reach, or 315 m, was already altered.

The aquatic macroinvertebrate fauna reflects an ecological status within the instream environment that may be defined as unmodified and natural, perhaps even reflecting a state close to the pristine one. It is thus important that the status quo be maintained.

As stated for the riparian vegetation, inundation at the site and the concomitant deposition of sediments will lead to the loss of biotopes, especially in the marginal zone, in particular, the stones in current and stones out of current types. In addition, however, as stated for the riparian vegetation, the presence upstream of the site, of approximately 8 km, of potentially unaffected bedrock anastomising channel within the Northern Lebombo Bushveld, is an important consideration in determining the impact that the inundation will have on the conservation of habitats and biota of high value in the region.

The assessment of induced sedimentation for a 1 in 200 year flood the zone of induced sedimentation caused by increasing the FSL to 117 masl would extend 1,080 m into South Africa corresponding to 14 % of the bedrock anastomising reaches within the Northern Lebombo Bushveld that will be potentially affected by sedimentation. For the 115 masl FSL induced sedimentation will take place up to 935 m into South Africa corresponding to 12% of the bedrock anastomising reaches

The FAII yielded an eco-status (B) that may be described as largely natural with few modifications. The only species significantly important with respect to migration from the observed data set is *Hydrocynus vittatus* (Tigerfish). The presence of the Corumana reservoir, however, provides a host of habitats in which the Tigerfish may flourish.

Given that 40 species of fish potentially exist at the station, and of those that were not observed during the survey, seven (17.5%) rely on migration for feeding or spawning. The impact of increasing the FSL of Corumana Dam to 117 masl will not change the status quo with respect to fish migration.

The Orange-fringed Large-mouth, *Chetia brevis*, which potentially exists at the site, is listed as Endangered. It is plausible that the species exists at the site. The species has a relatively narrow distribution, including the Komati-Incomati and coastal lakes of Mozambique and thrives in impoundments. The *Chetia brevis* thrives well in impoundments so impact on this species is expected to be negligible.

The impact of potential threats to the region upstream is considered **Low Impact**.

Table 6-13 Assessment of Impact on Aquatic ecology (upstream)

Process Impacted	Extent of impact	Magnitude of impact	Duration of impact	Significance ratings	Probability ratings	Confidence ratings
Threat to upstream aquatic flora and fauna	Site specific	Medium	Long term	Low impact	Highly Probable	Sure

The pertubation of aquatic habitats and flora and fauna in the new inundated area

The FSL level of 117 masl for Corumana Dam will increase the surface area of the dam from 6,902 ha to 8,509 ha (23%), adding a total of 1,607 ha to the water body surface.

The associated loss of riparian vegetation, the existence of which is primarily induced by the presence of the dam embankment perimeter, will in time be replaced by riparian vegetation extending over a greater distance. The vegetation around the fringes of the dam includes *Epaltes gariepina – Chenopodium* sp herbland closest to the water body, followed by *Paspalidium obtusifolium – Cynodon dactylon* grassland and then *Sorghum bicolor* grassland. There are stands of *Ficus sycomorus – Acacia xanthophloea* woodland in the northern bays of the dam. None of the species stated here have high conservation value.

The addition of nutrients to the main body of water, from decomposing vegetable matter, may result in an increase in primary production and the presence of isolated algal blooms, given that relative depth of the dam is low at 0.36%, the mean hydraulic residence time is three years, the water is moderately clear (Secchi Disk value of 1.5 m) and the mean annual temperature is 24°C. The presence of *Pistia stratiotes* (Water Lettuce) and *Azolla filiculoides* (Water Fern) in the Sabíe River, as well as *Eichhornia crassipes* (Water Hyacinth) further upstream, may exacerbate the potential problem of vegetative blooms in the Corumana reservoir.

The impact of potential threats to the aquatic habitats and flora and fauna in the new inundated area is considered **Low Impact**.

Table -14 Assessment of Impact on Aquatic ecology (newly inundated area)

Process Impacted	Extent of impact	Magnitude of impact	Duration of impact	Significance ratings	Probability ratings	Confidence ratings
Perturbation of aquatic habitats and flora in the newly inundated area	Site specific	Low	Medium term	Low impact	Probable	Sure

Pertubation of the fish fauna in the new inundated area

As stated in section 6.3, the new inundated areas in the reservoir will potentially enlarge the existing fishery in the reservoir.

The only plausible negative impact on the development of the fish fauna in the new inundated area may be the inability of fish populations with a more specialized life history to adjust to the environmental changes that will occur over a period of years.

However, the common artisanal species present in the dam are generalists, and therefore able to better withstand varying environmental conditions, including the Sharptooth Catfish, *Clarias gariepinus*, the Carp, *Cyprinus carpio* and Mozambique Tilapia, *Oreochromis mossambicus*.

The impact on the fish fauna in the new inundated area is considered **Very Low Impact**.

Table 6-15 Assessment of Impact on Fish Fauna

Process Impacted	Extent of impact	Magnitude of impact	Duration of impact	Significance ratings	Probability ratings	Confidence ratings
Perturbation of fish fauna in the newly inundated area	Site specific	Low	Medium term	Very low impact	Probable	Sure

Impacts on aquatic flora and fauna of any changes of downstream flow
Assuming a constant release from the Corumana reservoir throughout the year and using updated inflow hydrological data, results have shown that after increasing the FSL from 111 masl to 115 or 117 masl (with an increase in firm yield, reduction in spillage and higher evaporative loss) will reduce the downstream flows from the dam by 3.3 % or 5.1%, respectively.

This is not likely to be significant enough to affect biota negatively. In addition, the aquatic and riparian environments downstream have been shown to be impacted significantly by anthropogenic activities.

The Level 3 VEGRAI value for Station 3 was calculated to be 55.6%, giving a VEGRAI EC classification of D, which may be described as Largely Modified. A large loss of habitats, biota and basic ecosystem function has occurred. Using the Biological Bands for the Lower Lowveld (Dallas, 2007), the Ecological Category for Station 2 was determined to be E, Seriously Modified, for the macroinvertebrate fauna. The FAII score for Station 2 was found to be 60%, Class C, described as Moderately Modified. There is a lower than expected species richness and presence of most intolerant species.

The impact on aquatic flora and fauna of any changes of downstream flow may be considered as shown below.

Table 6-16 Assessment of Impact on Aquatic ecology (change of downstream flow)

Process Impacted	Extent of impact	Magnitude of impact	Duration of impact	Significance ratings	Probability ratings	Confidence ratings

Impacts on aquatic flora and fauna of change of downstream flow	Regional	Low	Long term	Low impact	Probable	Uncertain

6.7.2 Mitigation Measures

(1) The most important consideration is to create mitigation measures to minimize the effect of the new inundation on the biota upstream of the Corumana Dam. Given the scenario that the FSL is increased from 111 masl to 115 or 117 masl, avoidance of, or compensation for, the loss of habitat and concomitant biota are not likely options. It is proposed that biomonitoring stations be established in appropriate localities in the upstream reach to study and monitor the hydrological, geomorphologic and biotic changes that occur. The proposed biomonitoring programme is described in Volume 3. Environmental Management Plan

(2) Similarly, the influence of the reduced flow downstream of the dam, when the outflow is not being managed otherwise, must be monitored in terms of its influence on (1) the aquatic ecosystems and (2) rural anthropogenic activities.

6.8 Construction impacts

The application of improper construction methodologies and outdated machinery as well as improper handling, storage, use and disposal of construction materials and waste during construction could result in the pollution of soil, groundwater, surface water and air.

At this stage of project preparation, the location and layout of temporary construction sites and storage facilities as well as construction methodologies have not been decided and planned in sufficient detail so that specific assessments of the construction impacts cannot be made. However, in the following section, general possible impacts that have to be mitigated and included in the Environmental Management Plan are outlined.

6.8.1 Impact Assessment

Soil and groundwater pollution

Soils and groundwater may be polluted due to:

- Spillages of fuel, lubrication oils and hydraulic fluids from construction vehicles and machinery and spills from storage areas;
- Improper methodology for mixing of cement and concrete; and
- Disposal of construction wastes from cosntruction sites (packaging, stones and gravel, cement and concrete residue, wood, etc.) or household waste from workers camp.

Surface water pollution
The construction of the saddle wall and the emergency spillway will contribute to a large amount of soil movement around the project site. During rainfall there is a risk of erosion and sediment discharges into the reservoir, which may affect flora and fauna on shallow water in the rerservoir. If other working sites are established close to streams, erosion and discharge of sediment during rainfall may affect habitats and aquatic organisms.

Surface water may also be polluted due to:

- Spillages of fuel, lubrication oils, hydraulic fluids or other hazardous substances from construction vehicles and machinery or spillages from storage areas;
- Discharges from cement batching plants;
- Stormwater run-off;
- Discharge of wastewater from constuction sites or workers camp; and
- Washing of vehicles or equipment.

Air Pollution
During the construction works air quality may be affected by dust emissions and particulates and gaseous emissions from machinery.

Dust emission

Dust emissions may primarily arise from:

- Road use and transportation of materials;
- Exposed soil in working areas and during reservoir clearance;
- Material stockpiles; and
- Quarry operations, aggregate crushing, blasting at the quarry and work sites.

Emissions from machinery

Particulates (other than dust) and gaseous emissions will arise from vehicles, heavy machinery and diesel generators.

Air quality impacts can be a nuisance to workers and surrounding communities. The community most at risk is Chavane Village, which is situated close to the planned saddle wall and emergency spillway.

Noise and vibration
Heavy vehicles and construction machinery and any blasting are the main sources of noise and vibrations. All of these noise emissions will cause disturbances to local households, workers, livestock and wildlife species.

Construction Related Wastes

Inert Construction Wastes

The following types of inert waste are anticipated to be produced from the construction activities: natural materials (soil and rock), contaminated soil and non-hazardous construction wastes and waste derived from the workers camps

Hazardous Construction Wastes

Small quantities of hazardous wastes will arise mainly from the vehicle maintenance activities. Hazardous wastes, which could be generated include: Dust (from vehicles), liquid fuels, lubricants, hydraulic oils, contaminated soil, spillage control materials used to absorb oil and chemical spillages, machine/engine filter cartridges and oily rags, spent filters, contaminated soil.

Quarrries and borrow pits

Reopening the Corumana quarry is only expected to have limited environmental effects, but establishment of any new quarries for rip-rap and borrow pits for clay and fill material for the saddle dam could have significant environmental effects depending on the location and management of the sites. The locations of any new quarries and borrow-pits is, however not known so a specific assessment of impacts of these cannot be made, but possible impacts may include:

- Removal of plant communities and associated fauna, including rare and protected species;
- Filling of the holes with water and eventually a pond or lake comes into being, which may support fish, amphibians, reptiles and birds;
- Impacts on groundwater in terms of blocking the flow if the quarry pit is established so as to intercept the water table or aquifers;
- Impacts on surface waters. The clearing of vegetation, stripping of topsoil and removal of material from borrow pits could cause erosion and discharge of suspended solids to any adjacent surface waters;
- The operation of heavy equipment along access roads and surrounding areas of the borrow pits will lead to compaction of affected areas, thus disturbing the natural state of local soils; and
- Inundated borrow pits could become breeding areas for mosquitoes during the rainy season should they become inundated with water.

6.8.2 Mitigation measures

Key mitigation measures for these potential contruction phase impacts are outlined in the Environmental Management Plan (Cf. Section 7).

6.9 Conclusion

Key impacts and mitigation measures of increasing the dam's FSL to 115 or 117 masl are summarised in the tables below.

Most of the assessed negative impacts were classified as low (12 out of 19). The assessed impacts were distributed on the different classes as follows:

- 5 of the assessed impacts were classified as as Medium Impact;
- 12 of the assessed impacts were classified as Low Impact;
- 1 as Very Low Impact; and
- 1 as No Impact.

The decision as to whether the project should proceed should take into consideration all the environmental, social, economic, technical and political issues.

From the environmental perspective, the associated impacts identified in the EIA can be adequately addressed through the set of proposed mitigation measures outlined in the EIA and the EMP and do not present any barrier to proceeding with project preparation and implementation – although it is important to note that some studies remain to be carried out during the early stages of project implementation.

Table 6-17 Overview of impacts and classification

No	Risk	Impact	Details	Mitigation
1	Backwater effect in Sabíe River (i.e., upstream inundation in a flood event) within the Republic of South Africa as a result of raising the FSL.	Medium	At a FSL of 117 masl the backwater effect is estimated to be 730 m into South Africa. The affected stretch would be 450 m for the alternative FSL of 115 masl. In a -1-in-200 year return period flood at FSL 117 masl, the backwater effect could reach approximately 1,195 m into South Africa and be confined to the river channel. In the same 1-in-200 year return period flood at FSL of 115 masl, the backwater effect could reach 1,050 m into South Africa and be confined to the river channel.	Operating Rules of the dam allow for draw down of the reservoir, particularly during flood conditions, to diminish upstream inundation.
2	Induced sedimentation as a result of raised FSL to 115 or 117 masl.	Medium	In a 1 in 200 year return period flood, the zone of induced sedimentation caused by a FSL of 117 masl could extend 1,080 m into South Africa. In the same 1 in 200 year return period flood at FSL of 115 masl, the zone of induced sedimentation could reach 935 m into South Africa.	Operating rules of the dam allow for draw down of the reservoir, particularly during flood conditions, to diminish upstream inundation.
3	Inundation and loss of terrestrial habitats.	Medium	Increasing the FSL of the reservoir will inundate terrestrial habitats thus leading to a loss surrounding the present reservoir. The following areas of natural habitat around the Corumana reservoir will be affected by inundation after raising the FSL to 117 masl: i) 888 ha of Sclerocarya birrea – Acacia nigrescens Savanna; ii) 445 ha of Lebombo South Landscape; and iii) 274 ha Floodplain Grassland. Raising the FSL to 115 masl would affect a total terrestrial area that is 40% smaller. The following areas of natural habitat around the Corumana reservoir would be affected by inundation after raising the FSL to 115 masl: i) 469 ha of Sclerocarya birrea – Acacia nigrescens Savanna; ii) 214 ha of Lebombo South Landscape; and iii) 242 ha Floodplain Grassland. The hydrological modelling has showed that FSL 115 masl or 117 masl will rarely be obtained (i.e. in only about 10% of the time), so some of the affected area will only be affected part of the time. Riparian vegetation along a narrow stretch of the river channel extending some 730 m into South Africa (where Kruger National Park lies) will be inundated at a FSL of 117 masl. The affected stretch would be 450 m for a FSL of 115 masl.	Floodplain Grassland is expected to re-establish on higher ground along the new reservoir shoreline. The two main terrestrial natural habitat types that would be lost through reservoir inundation (Sclerocarya birrea – Acacia nigrescens Savanna and Lebombo South Landscape) occur extensively in the Kruger National Park, the existing Sabie Game Park, and in the area of the proposed Ingwe Game Park, such that measures to ensure further protection of these habitat types outside the reservoir inundation zone are not considered necessary.
4	Narrowing of the downstream river channel and increase in riverine vegetation as a result of raising the FLS to 115 or 117 masl.	Medium	Increased storage capacity following completion could mean smaller floods (i.e., 1 in 10 year return period flood) would be absorbed. A reduction in sedimentation carrying floods could lead to increased erosion immediately downstream of the dam wall. An area that is particularly vulnerable to erosion is around the road bridge approximately 2 km downstream of the dam.	Environmental water release requirements incorporated into the dam's operating rules Implementation of environmental flow program and monitoring plan
5	Loss of some individuals of three threatened plant species as a	Medium	Three threatened plant species potentially occur in the area to be inundated: Adenium swazicum (Endangered), Ipomoea venosa (Vulnerable) and Turbina longiflora	Intensive survey to locate any invididuals of these threatened plant species within the future inundations zone, followed by relocating

No	Risk	Impact	Details	Mitigation
	result of inundation.		(Vulnerable).	individual plants whenever feasible to suitable, protected habitats.
6	Impact on grazing potential in Sabie Game Park due to inundation of Floodplain Grassland.	Medium	Floodplain Grassland likely plays an important role in the grazing dynamics of herbivores, particularly as grazing potential decreases in the dry season. While re-establishment of grassland is expected to be quite fast there will be a temporary loss in winter grazing until it re-establishes under new operating conditions.	Ensuring adequate Floodplain Grassland along the reservoir shoreline for wildlife and livestock will be among the key technical criteria used in the environmental flow requirements to inform development of the new Operating Rules for the dam.
7	Increase in prevalence rates of waterborne diseases.	Medium	African reservoirs are known for causing significant increases in intestinal and /or urinary bilhariza (aka schistosomiasis) and malaria.	A baseline of these waterborne diseases will be established before the complete inundation of the reservoir; monitoring of these waterborne diseases will be carried out in the years following complete inundation. If required, both types of bilharzia can be easily treated with the drug Praziquantel, while malaria can be effectively controlled through the distribution and use of impregnated mosquito nets.
8	Reduction in annual downstream flow as a result of increased FSL	Low	Increases in the historical firm yield, reduced spillage and higher evaporation losses (yield and spillage) are estimated to decrease downstream flows by approximately 5.1%.	Environmental water release requirements incorporated into Operating Rules. Implementation of environmental water releases and monitoring programs.
9	Invasion of non-native species on bare soil and in dam reservoir.	Low	A number of potential invasive species are present in the vicinity of the reservoir, including Parthenium hysterophorus as an alien herb and seed bank. Increased reservoir area might possibly result in increased infestation of aquatic plants currently present (Water Lettuce Pistia stratiotes; Water Hyacinth Eichhornia crassipes; Red Water Fern Azolla filiculoides; and Kariba Weed Salvinia molesta), particularly if eutrophic conditions develop.	Monitoring measures to be implemented will be specified in the Reservoir Management Plan, including a longer- term contigency plan to be developed with ARA-Sul. Basin wide collaboration through TPTC and upstream with the SANParks biocontrol program, to be put in place. Currently, the South African National Parks Board (SANParks) is controlling alien plants in the river systems of Kruger National Park.
10	Threat to aquatic and riparian biota and habitats as a result of increased FSL.	Low	No habitats or species of conservation importance or concern were collected or identified (IUCN Red List). Since Corumana Dam has been in place and the reservoir has been in operation since 1989, there is no new threat to migrating fish species.	Environmental Monitoring Plan provides for regular biological monitoring in the reservoir and downstream of the Corumana Dam.
11	Negative environmental footprint from construction of the saddle dam with fuse plug emergency spillway.	Low	The saddle dam will cover an area of approximately 0.1km2 (10 ha) of Floodplain Grassland.	Relatively small area of habitat loss with no specific mitigation measures. Habitat is well represented in the project area.
12	Temporary loss of habitat in footprint of emergency spillway and temporary impacts of erosion.	Low	Excavation for the emergency spillway will temporarily remove approximately 0.4 km2 (40 ha) of Floodplain Grassland. During and immediately after, the area is vulnerable to erosion which may lead to increased suspended solids in runoff. In the long term, however, surrounding grass species are likely to re-establish themselves in the exposed area.	Construction and Workers Camp Mangement Plan requires contractors to plan all excavations, topsoil and subsoil storage so as to minimize runoff and erosion. Managed re-vegetation—using native plant species--by the Contractor of this area will assist natural restoration.
13	Inundation of habitats following activation of the fuse plug and	Low	1 in 1,000 year return period flood would activate the fuse plug and channel water through the emergency spillway causing temporary flooding of areas with Floodplain	A channel will be constructed as part of the project to discharge releases from the emergency spillway to Massecate River and into the

No	Risk	Impact	Details	Mitigation
	emergency spillway.		Grassland and Sclerocarya-Acacia Savanna south of Corumana reservoir.	Sabíe River downstream of the Corumana Dam.
14	Backwater effect on riparian vegetation as a result of increased FSL.	Low	Backwater effects and induced sedimentation due to increasing the FSL of the dam will affect riparian vegetation upstream the reservoir during flood events. This area was severely affected as a result of the 1 in 100 year flood in 2000. Impact on the non-marginal zone not considered significant given that all plants collected were classified as Least Concern. No plants of high conservation value were observed at the assessed area.	Environmental Monitoring Plan provides for continued monitoring to allow for long term assessment. The new Operating Rules for the Corumana Dam are expected to minimize the frequency and duration of any backwater flooding within the Kruger National Park.
15	Negative impact on upstream macroinvertebrate fauna as a result of increasing the FSL.	Low	An increased FSL to 115 or 117 masl may induce sedimentation and inundation upstream. However, impact is considered to be low as extent of sedimentation and inundation is expected to be over a small area confined within the existing channel.	Environmental Monitoring Plan includes assessment of macroinvertebrates and how they respond to any long-term negative impacts
16	Negative impact on upstream fish populations due to induced sedimentation at higher FSL	Low	An increased FSL to 115 or 117 masl may induce sedimentation and inundation upstream. However, impact is considered to be low as extent of sedimentation and inundation is expected to be over a small area confined within the existing channel.	Environmental Monitoring Plan includes fish monitoring to assess and respond to any long term negative impacts
17	Negative impact of reduced downstream flows on aquatic and riparian environments and increased erosion as a result of increasing the FSL.	Low	The aquatic and riparian environments downstream the dam have been shown to be impacted significantly by anthropogenic activities. Riparian vegetation described as Largely Modified, macroinvertebrate fauna Seriously Modified and fish fauna as Moderately Modified. The estimated 5.1% reduction in downstream flows at FSL 117 masl is not expected to have a significant negative impact. The impacts on aquatic flora and fauna downstream as a result of increased erosion of the river channel immediately downstream of the dam wall is considered a Low Impact.	Environmental Monitoring Plan provides for downstream assessment of any longer-term changes in aquatic and riparian ecosystems.
18	Construction impacts.	Low	The application of improper construction methodologies and outdated machinery as well as improper handling, storage, use and disposal of construction materials and wastes during construction could result in the pollution of soil, groundwater and air.	Construction and Workers Camp Management Plan, along with the Construction EMP (CEMP) to be prepared and implemented by the Contractor, outlines necessary measures to manage and mitigate negative construction impacts.
19	Negative impact on ability of fish populations to adjust as a result of increasing FSL.	Very Low	Increasing the FSL of the reservoir will most likely enlarge the existing fishery in the reservoir (estimated net increase of total size of fishery is expected to increase by 2%). The common artisanal species present in the reservoir are environmental generalists (Sharptooth Catfish Clarias gariepinus; Common Carp Cyprinus carpio; and Mozambique Tilapia Oreochromis mossambicus). Although the reservoir will expand in area, it is unlikely to undergo changes that would signficantly harm existing fish populations, including of the species with more specialized ecological requirements.	Implementation of the Fisheries Program as part of the Reservoir Management Plan includes includes regular monitoring, improved zoning to protect fish breeding habitats, and improved management.
20	Increased seepage from the dam embankment.	No	Seepage from the dam has been observed on the downstream side of the embankment. Increasing the FSL to 117 masl could increase the pressure on the seepage area and increase flow. However, the project will reduce this impact to none through the dam safety assessment and design contract for the dam works to be financed by the project.	Geotechnical investigations carried out as part of Dam Safety Audit during project preparation. Remedial measures to be financed under project implementation Dam safety Panel of Experts appointed to advise on safety aspects

No	Risk	Impact	Details	Mitigation
21	Loss of physical cultural heritage	-	The only sites with cultural and historical value around the Corumana Dam are the Mahungo and Malengane mounts where massacres occurred during the war of 1976-1992. Family graves are considered sacred places.	Additional survey and salvage of archeological items and fossils as part of the Inundation Preparation Plan Construction and Workers Camp Mangement Plan includes chance finds procedures for archaeological relics, fossils, or other physical cultural resources that might be uncovered during construction. Resettlement Action Plan provides for addressing family graves

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APPENDIX 1.

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APPENDIX 2

Hydrological study

1. Introduction

The Completion of Corumana Dam forms part of the Government of the Republic of Mozambique's Directorate of Water (DNA) National Water Resources Development Project. The dam will be completed by the installation of spillway gates and a saddle dam with a fuse plug emergency spillway. The installation of spillway gates will raise the full supply level (FSL) of the dam from 111 masl to 117 masl. The increased storage capacity of the dam will be used to augment the Maputo water supply, generate more electricity and provide water for irrigation.

As part of the Environmental Impact Assessment (EIA) Study of increasing the FSL of Corumana Dam, this report addresses the potential hydrological impacts of the dam on the present hydrological regime of the Sabíe River at the dam site. The findings of the report will be used to inform the Environmental Management Plan (EMP), to be produced at the conclusion of the EIA Study.

The hydrological analysis essentially entailed two key tasks viz.:

- an assessment of the present hydrological characteristics of the Sabíe River at the location of the dam

- an assessment of the potential impact of the proposed increase in FSL on the existing hydrological regime in the Sabíe River

1.1. Current hydrological situation

A number of hydrological studies have previously been undertaken in the Sabíe River Basin. These include:

- Department of Water Affairs, (1990). Sabíe River Catchment, Volumes 1,3,4,6,7,8,9 of 10. Report No. P.X300/00/0490.

- WRC, (1994). Surface water resources of South Africa. Volume VI, Appendices. Report No. 298/6.1/94.

- Chunnet, Fourie and Partners and Consultec, (1995). Joint Inkomati Basin Study. Volumes 1 to 7.

- DWAF (2009). Inkomati Water Availability Assessment Study: Hydrology of the Komati Catchment. Report No. PWMA 05/X22/00/1408.

- Lahmeyer International with Consultec and Austral (2003) extended the hydrology record of the Joint Inkomati Basin Study in Final Feasibility Study Report: Raising the Full Supply Level of Corumana Dam.

The hydrological analyses which were undertaken as part of this study were primarily based on flow data obtained from the Inkomati Water Availability Assessment Study or IWAAS (DWAF, 2009). The hydrology and yield models set up as part of the IWAAS provide much more detail than was available in previous models of the Inkomati Water Management Area, with catchment delineation at sub-quaternary scale. Table 1 summarises the key hydrological indices for the Corumana Dam catchment. According to the IWAAS information the MAR for the total Sabíe catchment decreased by between 10 % and 13 % when compared with previous studies for the same period.

Table 1: Key hydrological indices: Corumana Dam catchment

Catchment area	7048 km^2
Catchment Mean Annual Precipitation (MAP)	773 mm
Mean Annual Evaporation (MAE) (Quaternary Catchment X33D)	1453 mm
Naturalised Mean Annual Runoff (MAR)	674.5 Mm3 (WR 2005)

Figure 1 shows the annual flow volumes in the Sabíe River, based on developed simulated monthly flow sequences, for the period 1920 to 2004. The Figure shows that the annual flow volumes are highly variable with some years characterised by very low flows, while other years display runoff volumes equivalent to up to 6 times the MAR.

Figure 2 displays the seasonal flow distribution in the Sabíe River, based on simulated monthly flow sequences for the period 1920 to 2004. The Figure shows that the majority of flow occurs during the summer rainfall season (Nov. to Apr.) with over 80% of flow occurring from December to April.

The regional authority Administração Regional de Aguas do Sul (ARA-Sul) is responsible for the operation and maintenance of Corumana Dam. The Direcção Nacional de Àguas (DNA) has the overall responsibility for the management of the lower Incomati basin situated in Mozambique (TPTC, 2010c).

The releases from Corumana Dam are currently being managed based on Basin Plans, which comprise of yearly user plans submitted by the users to ARA-Sul. These plans form the basis of the Dam Discharge Plan which follows the principles of the recent study in 2010 by Consultec in Association with SWECO on Operating Rules of Corumana, Massingir and Pequenos Limbombos Dams (TPTC, 2010c).

For flood control rules during the October to March rainy season, ARA-Sul follows a process of estimating climate tendency using SARCOF weather forecast service. An estimation of likely flood impacts is given using a combination of download rainfall information, GIS tools and the Geospatial Stream Flow Model (TPTC, 2010c).

The observed annual discharge for period 1990-2008 from Corumana reservoir is shown in figure 3 this includes dam spillage and releases for hydropower and irrigation.

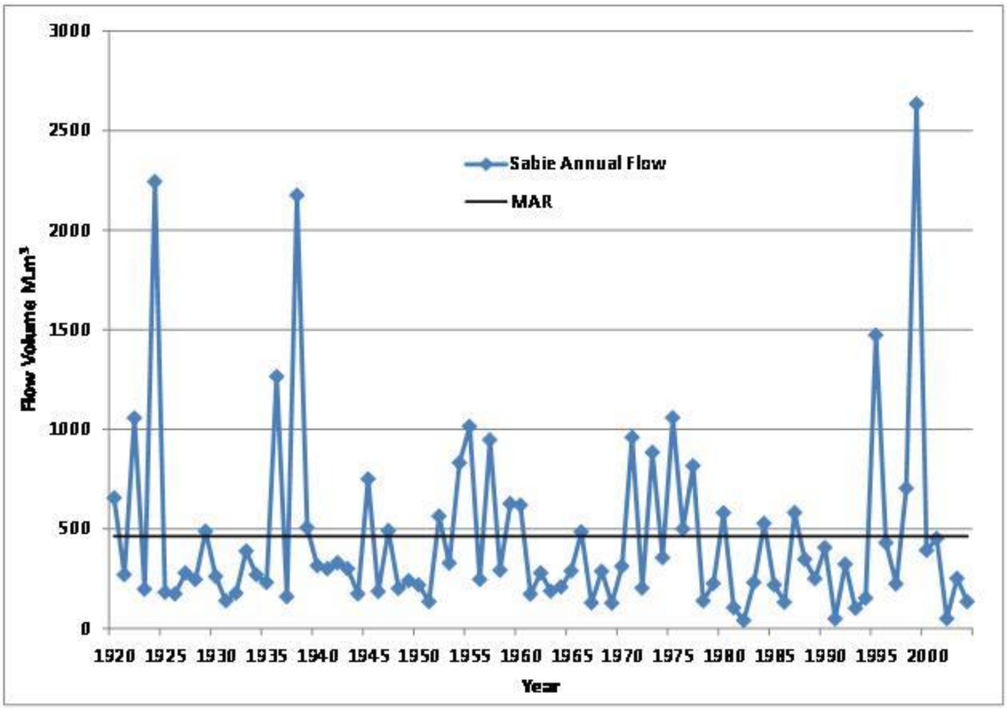

Figure 1: Annual flow distribution in Sabíe River

Monthly flow duration curves (flow volume vs. time exceeded) for individual months at the Corumana reservoir inlet on the Sabíe River are shown in Figure 4. These are based on a simulated monthly flow sequence from the IWAAS (DWAF, 2009). The flow duration curves show the percentage of time that certain values of monthly discharge were exceeded and give an indication to the long term yield of a river. Low flows occur from May to October and the flat curves indicate that floods are uncommon during these months. The steep curves from November to April indicate frequent floods and high variability of flows.

The construction of the Corumana dam has altered the flow regime of the dam by attenuating floods and increased low flows. During low flows months, June-October, the releases from Corumana dam are higher than the inflow into it. This is due to releases for hydropower and to supply irrigation users. In the future, the flow into Corumana Dam could increase as environmental water requirements are met in the upper catchment.

Under future climates with higher temperatures, the evaporation at the dam is expected to be higher with output from downscaled regional climate scenarios indicating higher mean annual precipitation for the intermediate future (± 2046-2065) in the Sabíe catchment. The increase in rainfall could lead to increased flow into the dam overall but less flow at critical times (Lumsden *et al*., 2009). Higher temperatures will lead to higher demand from irrigators.

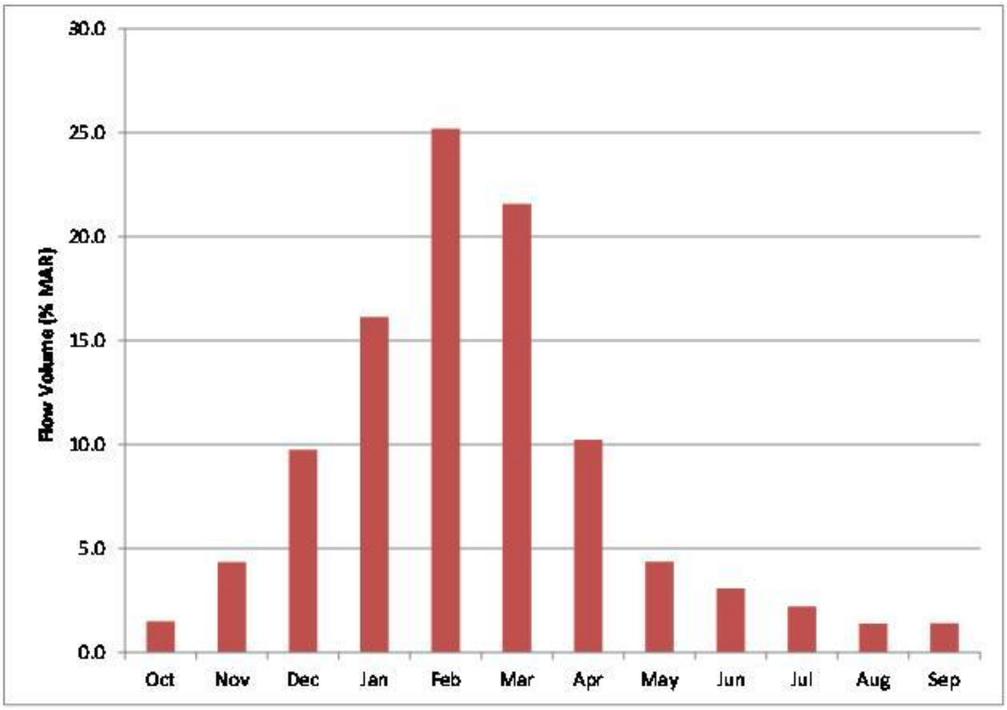

Figure 2: Monthly flow distribution in Sabíe River

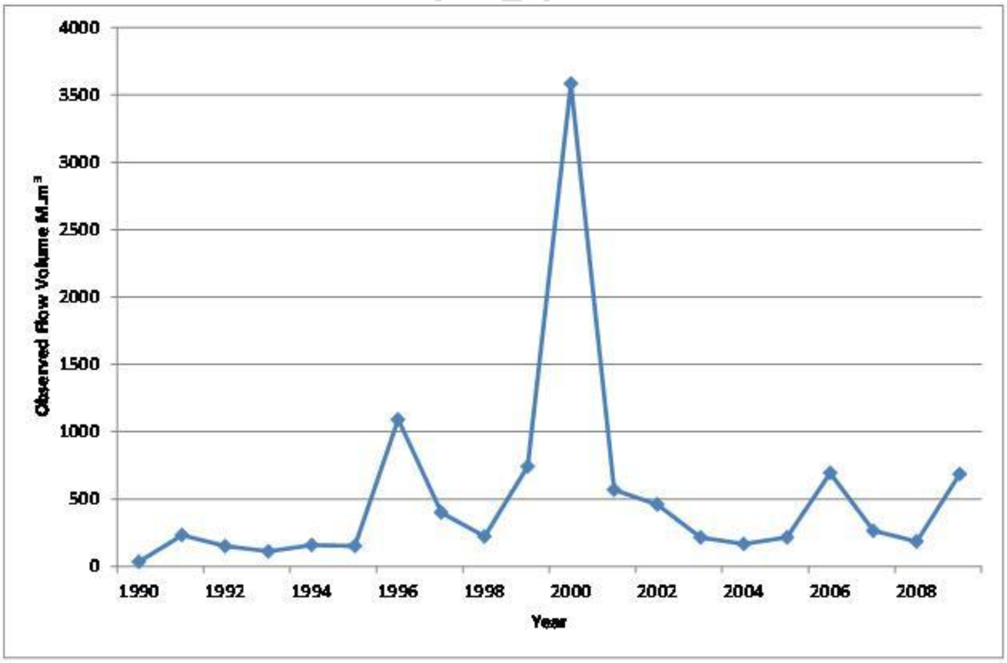

Figure 3: Annual observed discharge from Corumana reservoir

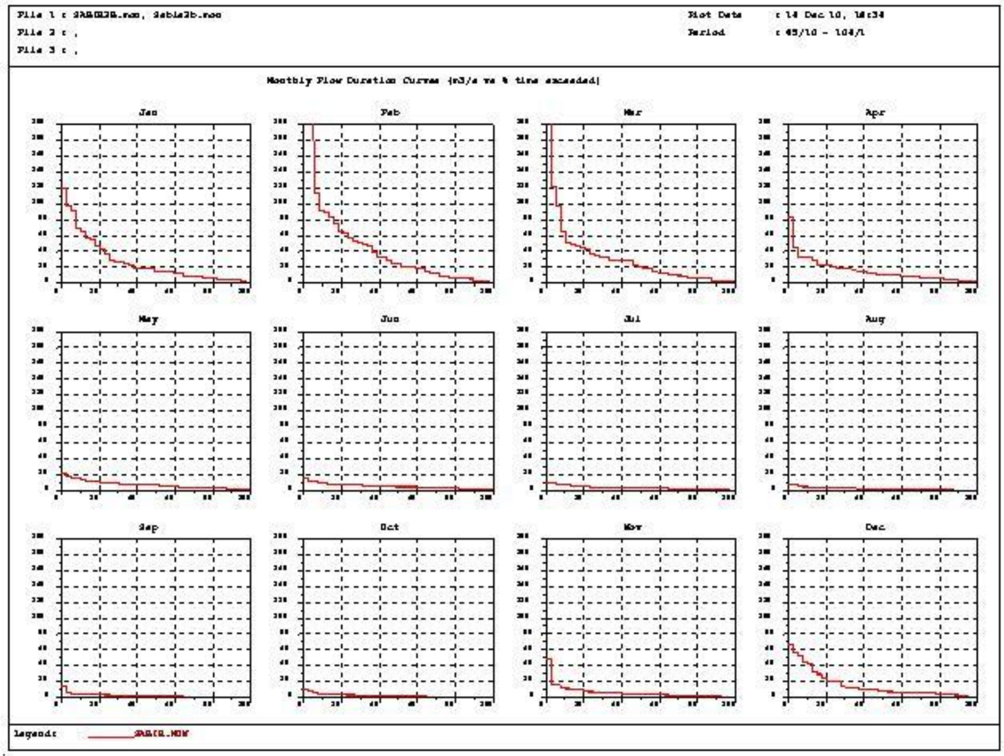

Figure 4: Sabíe River monthly flow duration curves for individual months at Corumana reservoir inlet

2. Materials and methods

2.1. Hydraulic modelling to determine the backwater effect and extent of induced sedimentation

The U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Centre River Analysis System (HEC-RAS) software (version 4.1) (USACE, 2008), was used for the determination of both floodlines and the backwater effect (upstream inundation) due to an incoming hydrograph corresponding to a 1 in 200 year inflow. To ascertain the floodlines upstream of the dam basin, a hydrodynamic model with simplified cross-sections representing the geometry of the dam basin i.e. that matched the stage capacity curve of the dam, was prepared. The flood peaks and associated hydrographs used were from the Lahmeyer International 2003 'Feasibility Study on Raising the Full Supply Level of Corumana Dam'.

The HEC-RAS model requires the definition of boundary conditions, the estimation of friction coefficients, topographic data and relevant information on major hydraulic structures in order to perform hydraulic calculations. For the purpose of this study, inflow flood hydrographs were used to represent upstream boundary conditions and normal depth was used as downstream boundary condition. The Manning values depended on the type of bed material, extent of in-channel vegetation and density of vegetal cover on the floodplain. Estimates of Manning roughness values (n) of 0.03 were assigned to the river channel and flood plain.

To accommodate transitional losses due to river bends, Manning values at bend locations were increased to 0.04.

The land surface (topographic) data requirements in HEC-RAS include geometric data representing the river centreline as well as channel and floodplain cross-sectional data. The topographic survey information from a LIDAR survey, which was made available by Southern Mapping, were used for the extraction of geometric information with the aid of HEC-GeoRAS (USACE, 2000) for the configuration of the Sabíe River model. HEC-GeoRAS is a pre- and post-processing GIS software package that runs in conjunction with Arc GIS software. In addition, the following GIS tools were used to transform the topographic data into the required HEC-GeoRAS format:

- ArcGIS 3D Analyst
- 3D-River Centreline Interpolator (developed by Aurecon)

ArcGIS 3D Analyst in conjunction with the 3D River Centreline interpolating tool developed by Aurecon, were used to develop a triangulated irregular network (TIN) topographic model from the available topographic data. The 3D-River Centreline interpolating tool works by intersecting the polyline that represents the river centreline with the contours and assigns elevation values of intersected contours to the polyline. The tool then linearly interpolates elevations between the intersected contours and assigns these values at the river centreline vertices, which are spaced at specified intervals between the intersected contours. The resulting river centreline is a 3D-Polyline with approximate river bed elevations. The TIN topographic model was then developed using ArcGIS 3D analyst with the contours specified as 'soft' break lines and the river centreline (3D-Polyline) as the 'hard' break line. The need for incorporating a 3D river centreline in the generation of the TIN, is necessitated by the fact that a TIN produced by contours only, would result in a stepped river bed rather than a gently sloping river bed profile. Although the 3D-Polyline Interpolator assumes a linear slope of the riverbed between the intersected contours, which may not be physically correct, in view of the resolution of the available terrain data it is deemed to be an acceptable assumption.

Once the TIN has been successfully created, HEC-GeoRAS was used to prepare the HEC-RAS geometric import file. In addition to the land surface TIN, the preparation of the HEC-RAS GIS import file requires four line coverage representing the Main Channel Invert Coverage, Cross-Section Cut Line Coverage, Main Channel Banks Coverage and Flow Path Coverage. These are detailed below:

i) Main Channel Invert Coverage

The Main Channel Invert Coverage, which establishes the planimetric connectivity of the river network system and is represented by an arc, was digitised based on the available maps and imagery.

ii) Cross-Section Cut Line Coverage

The Cross-section Cut Line Coverage defines the location of the cross-section and the expanse of the floodplain, and is used by the HEC-GeoRAS software to extract cross-section station-elevation data. The cross-sections were orientated facing downstream, stationed from left to right and located to address the following:

- Representative locations – Each cross-section was located such that it represents the reach for half the distance to the adjacent section. This enables HEC-RAS to calculate friction losses using a measure of average friction slope and a distance weighted reach length between two cross-sections. In general, the cross-sections were located at points that represent the average geometry of the stream reach in terms of shape and slope.

- Abrupt changes – Cross-sections were located where there were abrupt and significant changes in the channel and/or floodplain geometry and land coverage.

- The HEC-RAS zero station value is located 1215 m below the Corumana Dam wall.

iii) Main Channel Banks Coverage

The Main Channel Banks Coverage delineates the cross-section into 'main channel' and 'overbank' areas. Since the 10 m contours initially provided limited detail to sufficiently represent the main river bed and banks, the placement of the bank coverage was arbitrary. Arbitrarily selected bank coverage is warranted because of the simplified equally distributed Manning's roughness which is assumed over the cross section. The detailed topographical survey contributes to more detailed coverage estimates.

iv) Flow Path Coverage

The Flow Path Coverage represents the paths of water flow along the main channel and the overbank areas respectively. HEC-GeoRAS intersects the flow path with the cross-section cut lines to determine the reach lengths between cross-sections.

The detailed configuration for Corumana dam and its associated upstream reach is shown in Figure 5.

According to the 'Feasibility Study on Raising the Full Supply Level of Corumana Dam' the crest level of the earth plug in the emergency spillway was set at 120 masl. This was set as high as possible to allow for the breaking of the plug only under a 1 in 1,000 year flood event. Therefore in the HEC-RAS model all the gates including the bottom outlet were set to open at 119.5m so that the 1-in-200 year design flood did not break the plug in the proposed emergency spillway.

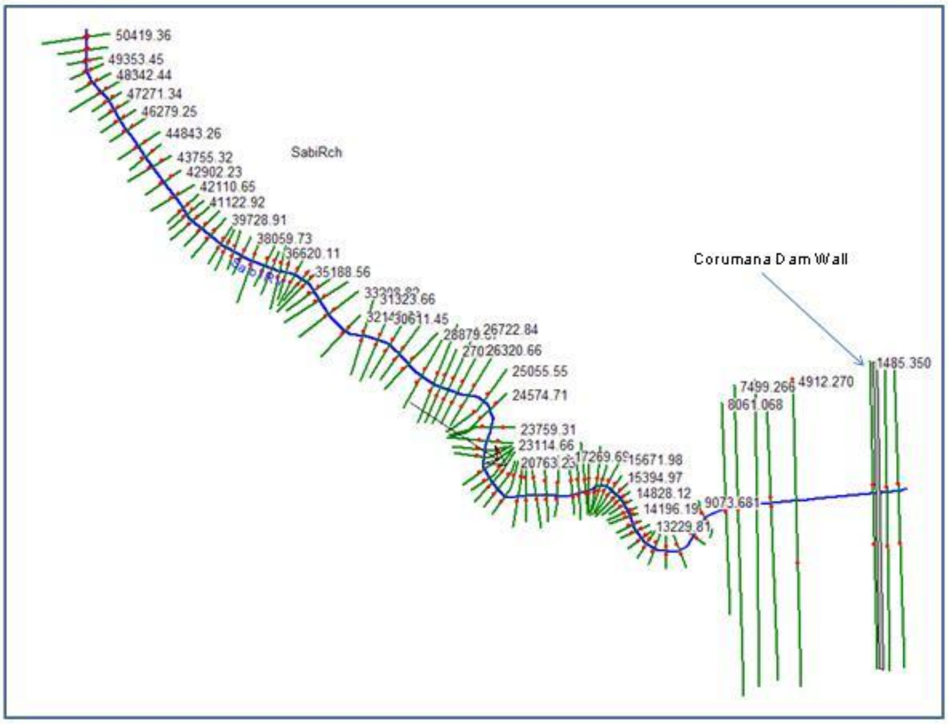

Figure 5: Corumana Dam and Upstream Reach Model Configuration

Figure 6 shows the backwater curve analysis concept for the determination of floodlines and backwater extent in the Sabíe River reach. Point A is the intersection of the pre-dam and existing dam water surface level for the 1 in 200 year flood. Point A is then projected to ground level (marked by a yellow cross) and this marks the end of influence of the dam. Point B in is the intersection of the pre-dam and dam water surface level of the proposed FSL (117 masl) for the 1 in 200 year flood. Point B is then projected to ground level (marked by a red cross) and this marks the end of influence of the dam.

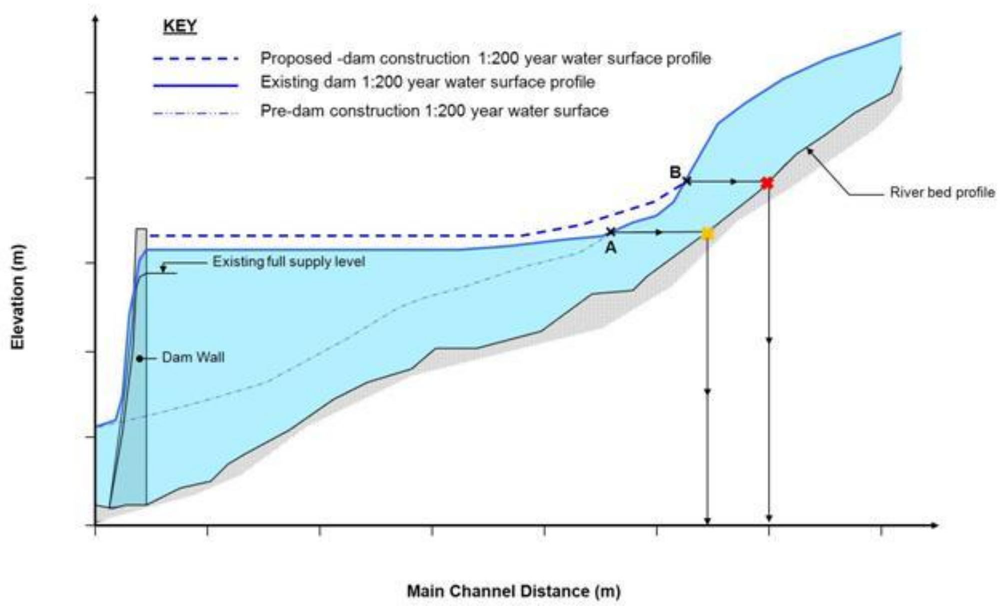

Figure 6 Backwater curve analysis concept (Sabíe River Reach)

2.2. Simulation of fluctuations in dam levels

The RESSIM reservoir simulation model (Middleton et al., 1981) can be used to simulate the fluctuations of reservoir storage state. The change in storage can be used to ascertain the historical firm yield of the reservoir. The model requires a monthly flow record, in this simulation the simulated flow from the IWAAS study was used, monthly rainfall and evaporation as well as information regarding the reservoir characteristics. An annual S-pan evaporation figure for the South African Quaternary Catchment X33D was used (WR2005). Monthly evaporation percentages for evaporation zone 5A were applied to produce monthly evaporation figures. The monthly figures were then multiplied by pan factors for open water evaporation for use with Symons Pan Data. The gross monthly evaporation figures used in the RESSIM model are shown in Table 2.

Table 2: Monthly evaporation values used in the RESSIM model

Average monthly gross evaporation (mm)											
Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept
112	113	130	138	124	121	92	79	64	67	83	101

2.3. Limnological Assessment

The purpose of this section is to briefly describe the possible physical limnological characteristics of Corumana Dam after installation of the gates. When full, the Corumana reservoir has a main water body running roughly along the north-south axis with a side running roughly in an East-West direction along the Sabíe River inflow. The reservoir will have a very convoluted shoreline as a result of the terrain it has been constructed in.

Reservoirs exhibit distinct longitudinal gradients. Typically, three zones can be distinguished along the longitudinal axis of a reservoir. This is probably the case with Corumana reservoir.

- The riverine zone is almost a lotic environment (flowing water environment). It is characterised by higher flows, shorter water retention times, and higher levels of nutrients, suspended sediment and light extinction than the downstream sections of the reservoir.

- The transition zone is characterised by decreasing flow velocities, increased water residence times, sedimentation of silt and clay particles, and increased light penetration. The transition zone is often associated with a plunge point. This is the position in a reservoir where, due to density differences, the inflowing waters may enter the lacustrine zone at intermediate depths. Algal production is generally higher in the transition zone because of higher nutrient availability and a favourable underwater light climate.

- The lacustrine zone occurs in the main basin, nearest to the dam wall. It usually has a longer water residence time, lower concentrations of suspended material, increased light penetration and transparency. Algal growth is generally limited by the availability of nutrients.

In the case of Corumana Dam, the riverine and transition zones are probably limited to the Sabíe River arm of the dam with the main water body representing the lacustrine (standing water) zone.

A number of limnological characteristics of a reservoir can be inferred from its morphometric characteristics (Hutchinson, 1957, Wetzel, 1975). A summary of the limnological characteristics of Corumana reservoir is shown in Table 3

The mean and the maximum water depth influence stratification, and the proportion of water in which biological activities such as algal growth can take place (the photic zone). The photic zone is the area of a dam that has sufficient light to support photosynthesis. Deep reservoirs are less able to support plant growth than shallow reservoirs because less of their overall volume is in the photic zone. Shallow reservoirs have proportionally larger volumes within the photic zone that can support healthy plant growth. Although the maximum depth of Corumana Dam (Table 3) is 39 m, the mean depth is about 15 m indicating that the dam is relatively shallow with a large volume of water that can support primary productivity.

Table 3 Limnological characteristics of Corumana reservoir calculated according to Hutchinson (1957) and Wetzel (1975)

Characteristics	Unit	Corumana reservoir
Reservoir characteristics		
Full Supply Level (FSL)	m	117
Deepest level at dam wall	m	78
Area (at FSL)	km^2	91
Volume (at FSL)	Mm^3	1375
Depth characteristics		
Maximum depth	m	39
Mean depth	m	15.1
Depth ratio		0.39
Relative depth	%	0.36
Development of volume		1.16
Wind mixing characteristics		
Longest fetch (N-S axis)	km	16
Wind mixed epilimnion (WME)	m	16
Potential maximum WME	m	20.80
Potential wave height	cm	133
Longest fetch (W-E axis at dam wall)	km	4.1
Wind mixed epilimnion (WME)	m	8.1
Potential maximum WME	km	10.53

Potential wave height	cm	67

The development of volume expresses the form of the reservoir basin and is defined as the ratio of the volume of a reservoir to that of a cone of basal area, equal to the area of a reservoir and height, equal to the maximum depth.

Corumana reservoir has a development of volume value of 1.16 (Table 3) confirming that the reservoir is relatively shallow.

The relative depth is an expression of the maximum depth as a percentage of the mean diameter. Most lakes have a relative depth of less than 2% while deep lakes with a small surface area have a relative depth of greater than 4%. Corumana reservoir has a relative depth of 0.36% (Table A1.3) and therefore has more in common with shallow lakes or reservoirs than deep lakes or reservoirs.

3. Results

3.1. Impact of inundation and backwater effect

The RESSIM model was used to determine dam levels for Corumana Dam for different full supply levels. RESSIM gives a monthly storage capacity as output that was converted to a level (masl) using the stage-area-storage data from the Final Feasibility Study Report: Raising the Full Supply Level of Corumana Dam (Lahmeyer International, 2003). Figure 7 shows the water levels for different full supply levels at Corumana Dam for 85 years of simulated flow data. The historical firm yield was used as the target draft and evenly distributed throughout the year. Under this scenario the results show that dam would only be at full supply level for approximately 10% of the flow record (Table 4). From a hydrological perspective the impact of dam inundation would be long term, with a high magnitude resulting in a large impact. The inundation for a FSL of 117 masl would extend approximately 730 m into South Africa. An FSL of 115 masl would reduce the stretch which will be inundated to approximately 450 m into South Africa.

Table 4. The frequency that specified water levels in the dam are exceeded for different FSL scenarios.

	The frequency that specified dam levels are exceeded			
Dam Level (MASL)	FSL at 111 masl (%)	FSL at 113 masl (%)	FSL at 115 masl (%)	FSL at 117 masl (%)
106	82.2	88.6	93.0	95.9
107	74.3	83.2	89.0	93.5
108	66.1	76.7	84.0	89.5
109	55.3	69.6	77.7	85.7
110	45.2	59.1	70.9	79.8
111	28.9	49.1	61.3	72.8
112	0.0	38.3	52.7	64.9
113	0.0	21.0	44.3	55.8
114	0.0	0.0	31.2	47.3
115	0.0	0.0	10.5	38.6
116	0.0	0.0	0.0	22.1
117	0.0	0.0	0.0	9.8

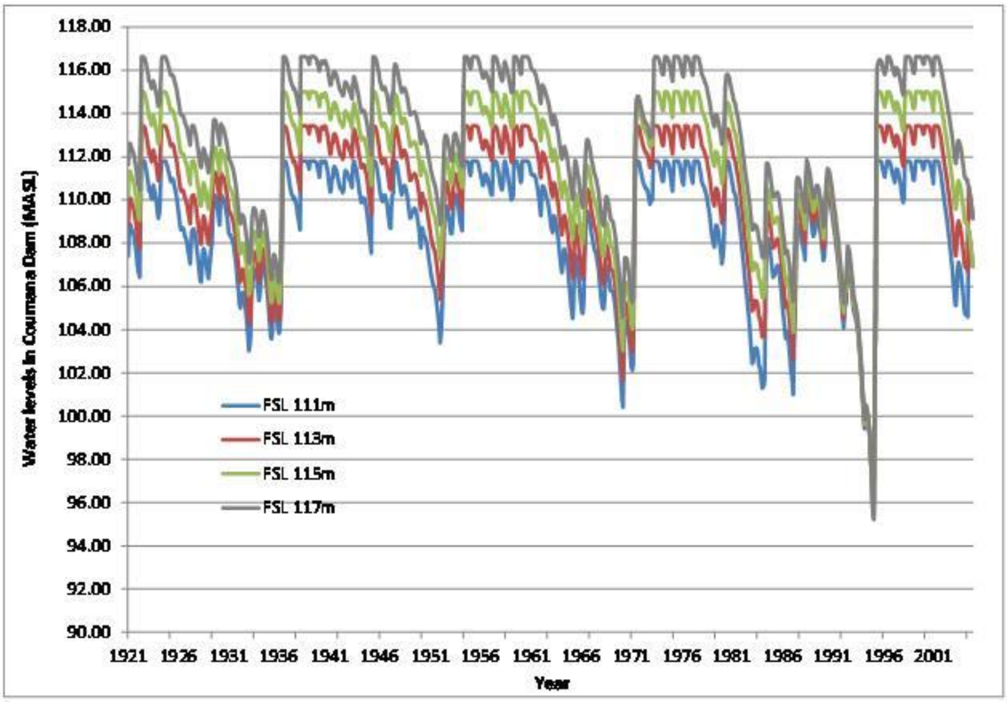

Figure 7: The water level in Corumana reservoir using 85 years of simulated inflow data for different FSLs

The results of the hydraulic modelling of the backwater effect, during a 1 in 200 year return flood event are shown in Figure 8. The results show that at the current FSL of 111 masl, the backwater effect extends 690 m into from the border of Mozambique and South Africa. With a raised FSL of 117 masl the backwater effect extends approximately 1,195 m into South Africa and is confined to the river channel. The backwater effect for an alternative scenario of a FSL of 115 masl extends approximately 1,050 m into South Africa. The upstream inundation due to a 1 in 200 year flood is likely to be of a short duration period with a high magnitude resulting in a medium impact.

It should be noted that the backwater analysis carried out was for a worst-case scenario, namely, a 1 in 200 year flood with the gates only being opened at 119.5 m to prevent the plug in the saddle embankment from being broken. Two options to diminish the backwater effect into South Africa are:

- To make pre-releases to draw down the dam before a 1 in 200 year or 1 in 100 year flood peak reaches the dam. This would reduce the backwater effect and provide storage for flood attenuation. This measure could lessen the backwater effect of the 117 masl option by up to 385 m. To protect downstream users from pre-releases a warning system would need to be in place. ARA-Sul is in the process of establishing a permanent department to assist with flood prediction and disaster management (TPTC, 2010c). Drawing down the dam before a flood does have implications for the yield of the dam especially if the flood is not as large as expected and the dam does not return back to full supply level – at 117 masl.

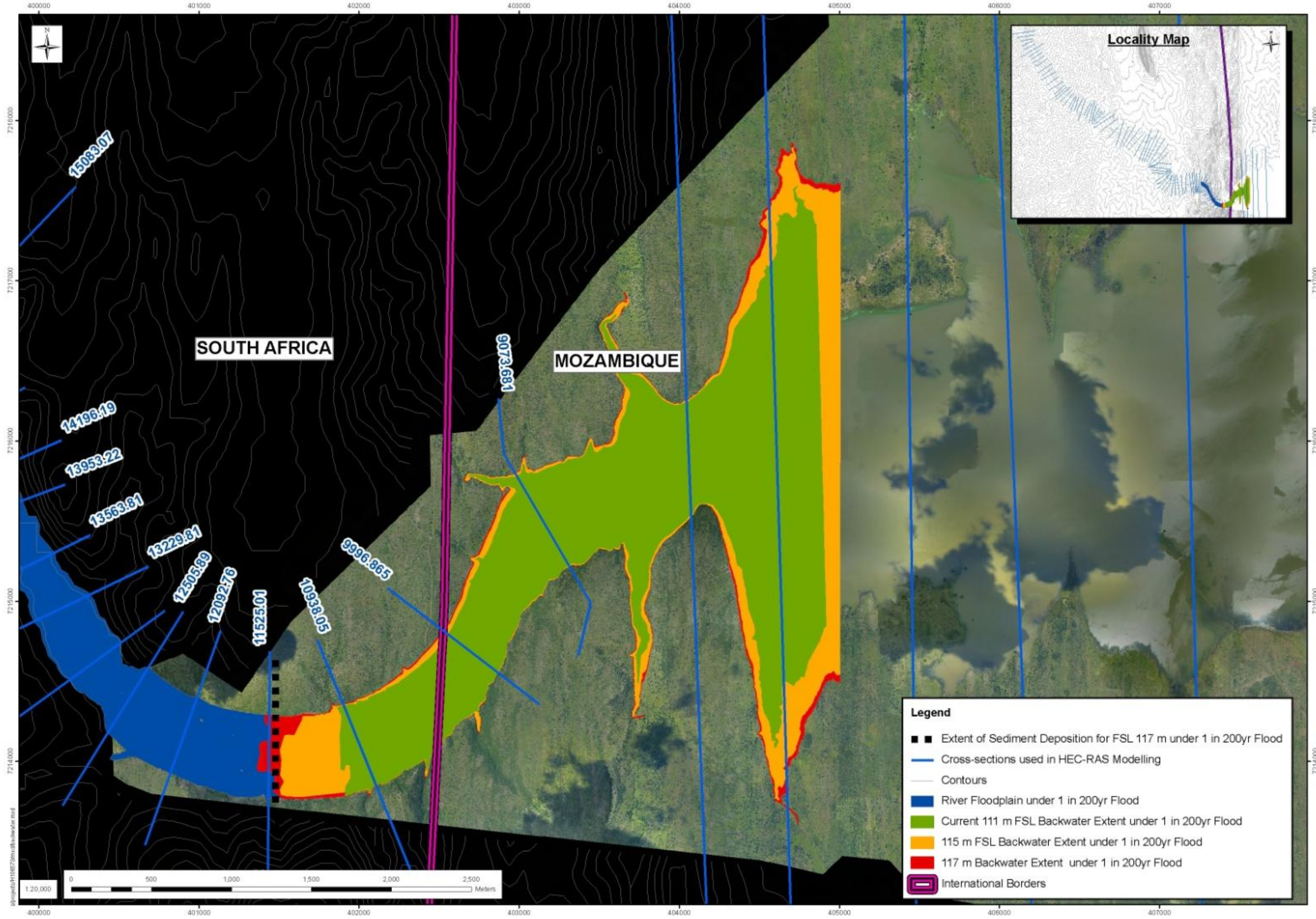

Figure 8: Simulated backwater effect and induced sediment deposition extent

3.2 Impacts on sedimentation

The SWECO 2003 Sedimentation Study of Corumana Dam reports that the long-term sediment yields using Rooseboom et al. (1992) methodology is estimated to be 310 t/km^2/a. Rooseboom et al. 1992 produced a mean sediment yield map of South Africa using data on sediment accumulation in reservoirs and sediment loads in rivers. From this map and associated soil erodibility maps, an estimate of the average for any given area can be made. The Water Research Commission publication, Surface Water Resources of South Africa, 1990 (WR90), presents estimates of the mean sediment yield for Quaternary Catchments calculated from the sediment yield and soil erodibility maps. Rooseboom et al. 1992 also carried out statistical analyses of the recorded sediment yield data to obtain an indication of the confidence with which the sediment yield could be estimated for the various regions of South Africa. From these analyses he derived sets of curves which give multiples by which the estimated mean sediment yields should be multiplied to change the confidence level from the 50% confidence of the mean yields. The sediment yields are expressed as the volume of sediment that would be produced by the catchment over a specified period at an assumed density of 1,350 kg/m3 which according to Rooseboom (1980) is an acceptable average for a fifty year old silt deposit in reservoirs under South African conditions.

According to the SWECO reservoir basin survey of Corumana Dam in 2002 there was a reduction in total storage capacity of 4.5% from 878.8Mm3 to 838.7Mm^3 over a 13 year period. Predicted storage capacity of Corumana reservoir and under full supply levels of 111 masl and 117 masl are shown in Table 4.

Table 4: Predicted future storage capacities of Corumana reservoir (SWECO 2003)

	Present Full Supply Level 111 masl (M.m^3)	Full Supply Level 117 masl (M.m^3)
Present	839	1334
2025	811	1307
2050	796	1292

The SWECO 2003 Sedimentation Study of Corumana Dam found the results from the reservoir basin study 2002 and those from the Rooseboom methodology to be in agreement while the results from using a sediment rating curve based on reservoir inflow to substantially underestimate the sediment yield.

To investigate potential induced sedimentation, due to increasing the FSL, in the upper reaches of the dam an unsteady state flow simulation was performed using the HEC-RAS model configuration in Figure 5. Inflow hydrographs for the 1 in 200 year return period were simulated. The transport capacity of a stream is sensitive to flow velocity and consequently a decrease in flow velocity, which will also result in a decrease in stream power, will cause a reduction in sediment transport and subsequent deposition of sediment. Stream Power is a product of velocity and shear stress (Yang, 1984).

Stream power has been used in relation to sediment transport and bedload (Allan, 1977) by comparing the power needed to transport the sediment along a particular reach with the power actually available (Goudie, 2004). In this study the stream power was compared in the river reach that approaches Corumana Dam at each HEC-RAS cross-section when the FSL is at 111 masl and 117 masl.

Due to the backwater effect there will be a relative reduction in stream power between the two scenarios for some distance to a point where they are equal. The zone in which the 117 masl scenario's stream power is less than the 111 masl scenarios is the area where induced sedimentation is likely to occur. The extent upstream to which induced sedimentation could be expected is marked by the black dotted line in Figure 8. This equates to 1,080 m into South Africa. For an alternative scenario of a FSL of 115 masl the extent of induced sedimentation was found to be approximately 935 m into South Africa. It should be noted that over the next 50 years, due to sediment build up in the upper part of the dam basin, sedimentation may migrate further upstream.

No sediment sampling has been done as part of this report. The most recent sampling was carried out by SWECO (2003) who produced a Final report, Annex II: Sediment Yield Report for Corumana, Macarretane, Massingir and Pequenos Limbombos Dams. Ten bed samples were taken along the old river reach in the Corumana reservoir. The two samples taken near to the entrance to the dam had a high sand content (up to 40%) with the other eight samples further into the dam consisting of at least 50% clay. Unfortunately the Final Report, Annex I: Sediment Yield Report which apparently contains a detailed basin survey was not made available. As a consequence estimates of areal sedimentation cannot be made.

The upstream sedimentation due to a 1 in 200 year flood is likely to be of a long duration period, local extent with a high magnitude resulting in a medium impact A mitigating factor for the reduction of sedimentation would be improved land use practice particularly in the areas of the catchment upstream of the Kruger National Park where land use practices have led to erosion of both river banks and adjacent areas. The catchment management practices would need to be those that prevent erosion and sediment runoff. An example of this would be to restore the riparian vegetation so it acts as a buffer. It is recommended that such management practices explored through cooperation under the Tripartite Permanent Technical Committee (TPTC) between Mozambique, South Africa and Swaziland.

Using flushing to control sediment is best suited to those dams situated in a valley where the inflow into the reservoir has a straight path to the outlet. Due to the shape of reservoir at Corumana, the inflow velocity to the reservoir will dissipate before the outlet so occasional flushing is unlikely to have a major impact on water quality.

3.3 Impact on downstream flow

The RESSIM model was used to determine the historical firm yield for Corumana Dam using different full supply levels. A constant release was assumed throughout the year. This was to enable comparison with the Lahmeyer International 2003 feasibility report as updated inflow hydrology was used in the simulation. The results of these simulations are show in Table 5.

Table 5: Flow volumes of reservoir operation simulations for Corumana Dam

FSL (masl)	Inflow ($M.m^3$/annum)	Historical Firm Yield ($M.m^3$/annum)	Evaporative Loss ($M.m^3$/annum)	Spill ($M.m^3$/annum)
111	457.2	234.0	69.4	154.5
113	457.2	239.4	75.5	142.8
115	457.2	244.8	81.8	130.9
117	457.2	250.8	88.6	117.8

The results in Table 5 show that increasing the FSL of Corumana Dam to 117 masl increases the historical firm yield reduces the spillage and results in higher evaporative losses. The annual downstream flows from the dam with a FSL of 117 masl (yield and spillage) reduce by 5.1% with a FSL of 115 masl the flows are reduced by 3.3%.

A comparison with the firm yield from the Lahmeyer International 2003 feasibility report (Table 6) reveals a 22% reduction in firm yield to this study. A reduction in firm yield was to be expected as the MAR inflow used in this study was 18% lower than in the previous study.

Table 6: Comparison of MAR and historical firm yield for Corumana Dam

	This study	Lahmeyer (2003)
MAR as inflow (M.m^3/annum)	457.2	556.3
Historical firm yield (M.m^3/annum) FSL 111 masl	234.0	299.8
Historical firm yield (M.m^3/annum) FSL 117 masl	250.8	321.9

A result of the increased storage capacity of a raised FSL would be that smaller floods (i.e. the 1 in 10 year flood) would be absorbed as the long as the dam was below FS of 117 masl. Beck and Basson (2003) found that for South African conditions the dominant discharge that maintains or shapes the river channel would be consistent with the 1:10-year flood peak. If the 1 in 10 year flood is absorbed by increasing the full supply level this could lead the narrowing of the river channel downstream and an increase in riparian vegetation. The impact on downstream channel morphology is likely to be of a long duration period, regional extent (beyond 10 km of the site boundary) with a medium magnitude resulting in a medium impact.

A reduction in sediment carrying floods could also lead to increased erosion of the river channel immediately downstream of the dam wall. An area that is particularly vulnerable is around the road bridge approximately 2 km downstream of the Corumana spillway. To moderate the impacts to downstream channel morphology environmental releases from the dam should be made.

The TPTC Inkomati Status Quo Report (2010a) states that Environmental Water Requirements (EWRs) for the Incomati Basin, have been studied in considerable detail within Swaziland (e.g. KOBWA 1998, 2010), and South Africa (e.g. DWA 2003, 2006, 2008). Previous assessments of EWRs within Mozambique, have been based on desktop methods, for the purpose of initial planning, so the results are of low confidence.

Other environmental water requirement work in Mozambique has looked at the Inkomati basin as a whole particularly in regard to minimum flows into the estuary to limit salt intrusion.The Joint Inkomati Basin Study recommended a minimum flow from the Inkomati River into the estuary of 5.0 m^3/s (Consultec *et al*. 2000). This is equivalent to an annual volume of 158 million m^3.

The Joint Inkomati Basin Study used two different methods to estimate minimum low-flows for the lower part of the Inkomati River, near Manica, for an ecological Category B. The Reserve Desktop Method indicated minimum flows of between 20.73 m^3/s in September, and 57.02 m^3/s in February. The Tennant Method indicated minimum flows of between 23.32 m^3/s in September, and

46.64 m^3/s in February (Consultec *et al*. 2000). These are equivalent to annual volumes of 1,096 and 1,103 million m^3 respectively. A limitation to the Joint Inkomati basin Study work is that it is concerned with low flows.

The desktop method is based on monthly hydrology and is, therefore, inappropriate for assessing flood requirements, which need daily or sub-daily hydrology. The lower Inkomati is essentially a floodplain system, so a focused study that quantifies environmental flood requirements is required (Palmer, 2010 per com). This should be carried out during the detailed design phase as EWRs can impact the yield of the dam.

TPTC (2010a) focused on the initial steps needed to assess EWRs within the Mozambican portion of the catchment. The steps taken in this study were to quantify Ecological Importance and Sensitivity, Social and Cultural Importance, and Present Ecological State for various river reaches within Mozambique. The assessment was based on a reconnaissance-level study only.

To determine EWRs for the Sabíe below Corumana Dam the whole of the Inkomati basin in Mozambique would need to be considered including the estuary. The methods employed in establishing EWRs should focus on identifying the size, duration and timing of specific flows and flow patterns that are considered to be the most important for maintaining the abiotic and biotic components of a stretch of river in a particular condition. TPTC (2010b) recommended two phases for the establishment EWRs in the lower Inkomati: The first is to set provisional minimum flows at selected key sites, and to then establish and apply an environmental monitoring programme, in which Key Performance Indicators are monitored, and the provisional minimum flows revised. The purpose of the second phase is to undertake detailed assessments of the EWRs. This second phase would assess the ecological and socio-economic consequences of different operational flow scenarios, and to recommend a flow scenario that optimizes environmental goods and services. Outcomes from the second phase should include a recommended flow scenario and a revised monitoring programme. A study of this nature is likely to take at least six months so that the high and low flow seasons can be investigated and the TPTC (2010b) report recommends that a multi-disciplinary team undertake studies in the following subject fields: Hydrodynamics; Water Quality, focusing on Saline Intrusion; Remote sensing and Estuarine Health; Socio Economics; C2C Decision Support Tool; Sedimentology, and Biodiversity.

3.4 Impacts on Limnology

The longest open-water fetch would be along the North-South axis of the main basin and is about 16 km long. It is calculated that a light to moderate wind would result in a wind mixed epilimnion depth of about 16 m. A strong wind may result in a maximum wind mixed epilimnion depth of 20.8 m. The wind mixed epilimnion depth is greater than the mean depth indicating that Corumana reservoir would probably not exhibit strong thermal stratification during the summer months. The East-West axis wind fetch at the dam wall is about 4.1km. It is calculated that a light to moderate wind would result in a wind mixed epilimnion depth of about 8.1 m. A strong wind may result in a maximum wind mixed epilimnion depth of 10.5 m.

Over the distance of 16 km, wave heights of up to 133 cm could be generated under strong wind conditions. Over the distance of 4.1 km, wave heights of up to 67 cm could be generated under strong wind conditions. This could lead to erosion and armouring of the shoreline on the downwind shore due to wave action. However, the majority of the coastline is a gently sloping lakebed so most of the power of the wave will dissipate before it hits the shore. The areas that could be considered at risk from benching are those areas that have a shorter reach. In addition, there is no evidence of erosion currently in these areas. Therefore, mitigating measures are not considered necessary.

With a mean annual runoff and 457 Mm^3 and a volume of 1,375 Mm^3, the completed Corumana reservoir will have a mean hydraulic residence time of 3 years. This means that there is sufficient time for the establishment of a healthy aquatic ecosystem and that most of the nutrients would be converted into biomass (algae and other aquatic plants) rather than being flushed from the system as would be the case with a reservoir with a short water residence time.

Summer thermal stratification refers to the process in which several horizontal water layers of different density may form in a deep reservoir. During summer stratification, the bottom water (hypolimnion) is cool, high in nutrients, low in light, low in productivity, and low in dissolved oxygen. The top water (epilimnion) is warm, higher in dissolved oxygen, light, and production, but lower in nutrients because it is assimilated by algae. The sharp boundary between the two layers is called the thermocline and the metalimnion exists in this area.

However, due to the shallow mean depth, a wind-mixed epilimnion depth that is similar to the mean depth, and relatively high winter and summer temperatures, Corumana reservoir would probably not exhibit strong thermal stratification during the summer months. Corumana reservoir would probably be classified as a polimitic reservoir. The reservoir would probably exhibit weak thermal stratification during the daytime but it would easily be broken down by light wind mixing or cooling during the evenings. Corumana reservoir would probably not exhibit some of the water quality problems associated with strong thermal stratification such as anoxic bottom water and elevated iron and manganese concentrations as a result of these anoxic conditions.

A first order estimate was made of the surface water temperature in Corumana reservoir using an equation developed by Walmsley and Van Schalkwyk (1984) which relates temperature for South African reservoirs to altitude, latitude and water clarity (Secchi disk depth). It was assumed that the water would be moderately clear and that the Secchi disk depth would be about 1.5m. It was estimated that the average surface water temperature in Corumana reservoir would be about 24 °C. The maximum summer water temperature could be as high as 32 °C and the minimum winter temperature could be as low as 19 °C.

4. Conclusion

The results of this study provide a quantification of the hydrological impacts of flow curtailment as a result of the proposed increase in the full supply level of Corumana Dam. Using hydrology from the IWAAS (DWAF, 2009) as input into the reservoir model RESSIM the historical firm yield was found to be lower than in previous studies. This was an expected result as the simulated MAR input was 17% lower than in the 2003 study.

The limnological assessment found that Corumana reservoir would probably not exhibit strong thermal stratification during the summer months and that the dam would probably exhibit weak thermal stratification during the daytime but it would easily be broken down by light wind mixing or cooling during the evenings.

The assessment of induced sedimentation using the HEC-RAS model found that for a 1 in 200 year flood the extent of the zone of induced sedimentation cause by increasing the FSL would be 1,080 m into South Africa. It is possible that in future years the extent of sedimentation could migrate further upstream. A mitigating factor for the reduction of sedimentation would be improved land use practice particularly in the areas of the catchment upstream of the Kruger National Park where land use practices have led to erosion of the river banks and adjacent areas.

The results of the hydraulic modelling of the backwater effect (upstream inundation in a flood event), during a 1 in 200 year return period flood event show that at a FSL of 111 masl the area of influence extends to the South African border and with a raised FSL of 117 masl the area of influence of the backwater effect extends approximately 1,195 m into South Africa. The backwater effect at this point is confined to the river channel. This can be considered a conservative estimate of the backwater effect as in the simulation the dam gates were only opened when the level in the dam reached 119.5 masl. To diminish the inundation upstream the dam gates could be operated so that inflow equals outflow during a major flood which would maintain the dam level at 117 masl during the flooding period.

A result of the increased storage capacity of a raised FSL would be that smaller floods (i.e. the 1 in 10 year flood) would be absorbed as the long as the dam was below FSL. If the 1 in 10 year flood is absorbed by increasing the full supply level this could lead the narrowing of the river channel downstream and an increase in riparian vegetation. To moderate the impacts to downstream channel morphology environmental releases from the dam should be made.

Positive impacts of the raised FSL would be additional water being available for downstream irrigators during in seasons of low flow. The IIMA Agreement states that 87.6 Mm^3/a of water is reserved for Maputo city from the Incomati and Maputo basins, the additional storage in Corumana reservoir would assist in meeting those allocations.

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ANNEXURE A

SIMULATED MONTHLY FLOW SEQUENCE IN SABÍE RIVER AT LOCATION OF CORUMANA DAM (IWAAS: DWAF, 2009)

FILE : c:\Convert\Sabie2.nsi

UNITS : MCM

Sabíe to Corumana

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1920	28.94	36.10	34.24	29.06	45.88	236.70	150.98	35.32	23.81	15.99	9.88	8.86
1921	11.34	72.91	69.54	25.22	15.02	22.93	17.78	10.69	9.44	6.22	4.86	3.35
1922	5.01	17.87	17.79	234.27	437.24	234.80	48.06	25.52	16.25	10.51	6.00	4.32
1923	2.31	3.02	27.64	19.98	8.61	62.62	37.08	13.46	8.39	5.51	4.30	3.84
1924	3.42	36.75	50.22	128.69	152.05	1161.68	575.30	49.86	32.95	22.90	13.88	16.12
1925	12.79	14.73	11.33	17.46	29.79	34.57	19.07	11.77	7.52	10.40	5.98	6.17
1926	2.29	4.95	6.42	13.68	27.89	31.92	21.46	12.53	9.08	21.85	13.00	8.71
1927	12.88	11.88	9.55	79.73	61.17	33.02	27.06	16.06	10.38	7.83	4.88	3.54
1928	1.77	2.45	10.92	21.96	49.40	70.89	40.91	16.50	12.76	7.82	5.16	5.21
1929	18.32	53.08	49.05	48.95	45.47	106.28	82.22	34.02	21.90	14.27	8.10	6.02
1930	1.74	2.92	87.63	63.00	19.55	24.11	21.96	10.43	8.30	11.67	5.28	4.56
1931	2.70	17.50	27.18	20.90	19.94	18.22	11.72	8.53	6.02	3.47	0.83	1.16
1932	0.76	4.57	18.23	45.05	39.07	26.37	18.91	10.14	6.68	4.52	1.66	1.44
1933	0.82	31.99	42.25	89.72	76.25	48.82	35.22	22.65	17.99	10.76	6.01	5.70
1934	4.28	33.73	56.17	54.90	44.18	28.52	17.97	10.92	7.95	5.54	2.68	2.33
1935	0.82	0.65	2.15	20.76	35.33	64.55	43.20	21.32	15.05	10.94	5.96	10.43
1936	15.92	31.66	63.15	156.67	590.59	277.90	50.40	29.74	20.00	12.90	8.46	7.74
1937	4.30	4.32	12.80	19.03	20.89	14.36	32.27	17.80	11.34	7.85	4.56	9.99

1938	9.98	9.31	453.08	281.34	720.78	474.50	101.78	37.52	25.91	25.48	16.72	18.61
1939	12.84	114.04	127.03	60.18	33.91	42.21	34.15	21.85	23.46	14.76	10.26	11.53
1940	8.22	54.57	60.20	34.34	23.69	25.02	46.71	28.14	14.45	9.64	5.60	4.37
1941	2.60	2.97	33.05	66.31	33.22	60.73	33.54	17.57	19.13	11.79	8.35	10.09
1942	9.60	20.26	24.73	23.42	19.66	37.99	74.81	43.01	20.17	19.27	17.47	19.27
1943	14.07	24.12	14.40	17.67	103.92	70.92	21.01	11.21	9.58	5.76	3.24	3.29
1944	8.92	9.99	8.30	33.91	34.53	29.27	21.85	11.73	7.75	4.47	1.60	1.12
1945	3.73	3.15	3.05	304.33	277.34	83.37	30.94	18.30	12.02	7.50	3.99	2.50
1946	1.26	9.19	13.42	19.30	36.31	38.43	26.44	14.61	12.03	7.39	3.84	3.43
1947	3.62	22.55	92.54	67.15	34.88	127.61	82.23	24.37	15.66	9.85	5.21	5.10
1948	5.96	7.88	8.25	36.08	45.25	33.94	22.21	15.46	10.93	7.26	3.96	3.84
1949	1.38	28.20	35.60	34.04	31.10	34.66	25.01	18.21	12.72	8.59	5.81	4.77
1950	1.96	3.34	63.09	47.67	10.68	16.51	23.19	17.72	10.75	7.52	8.81	7.36
1951	11.09	9.05	14.81	15.66	16.36	23.19	15.50	9.04	7.23	6.72	3.62	2.15
1952	2.03	37.52	64.42	66.48	141.26	123.76	55.95	28.68	18.95	11.93	6.92	6.14
1953	3.65	14.14	27.01	64.28	84.27	50.04	31.57	19.87	13.32	8.01	5.96	4.70
1954	3.76	15.78	13.36	167.34	246.54	196.28	86.90	37.80	27.39	18.13	10.50	7.44
1955	11.54	40.15	74.25	50.70	372.29	286.24	75.43	33.55	26.35	18.56	11.91	13.73
1956	10.45	9.13	14.87	16.10	32.65	50.90	37.34	22.35	15.51	14.35	11.37	11.37
1957	13.76	14.77	25.66	499.20	269.61	37.83	32.22	19.13	13.42	8.54	4.81	7.79
1958	6.32	14.43	24.35	45.38	99.74	55.12	17.06	10.65	6.69	5.82	2.68	4.16
1959	3.88	10.86	35.26	31.91	270.34	162.99	43.56	26.33	17.25	10.44	6.88	7.29
1960	4.04	35.76	141.47	97.26	70.94	92.61	62.13	31.27	30.90	22.54	16.46	13.49
1961	10.30	15.03	26.24	27.63	31.27	20.84	16.21	9.67	6.98	4.32	2.16	1.13
1962	0.88	79.51	72.98	25.86	22.42	16.55	15.33	9.52	13.37	12.05	6.08	4.28

1963	3.12	12.55	16.65	56.18	47.91	17.76	13.42	7.82	5.80	3.30	1.11	0.84
1964	5.71	7.26	38.78	64.09	37.60	20.93	14.52	7.65	5.22	2.93	0.93	2.25
1965	1.02	11.82	10.20	49.56	113.25	63.49	16.36	8.75	6.42	3.85	2.10	2.16
1966	5.86	7.70	23.08	49.32	119.63	74.73	87.55	58.03	24.83	16.34	10.17	7.17
1967	6.46	9.67	14.78	13.58	15.22	18.03	17.67	10.60	9.37	6.12	3.68	2.56
1968	1.73	12.53	16.57	24.23	48.55	75.71	51.03	22.41	14.94	9.81	5.05	5.01
1969	24.85	22.49	26.75	14.87	13.67	7.85	5.18	3.04	3.97	2.55	0.85	0.80
1970	0.69	5.23	14.02	113.18	79.76	27.86	24.32	16.30	12.22	8.19	4.59	5.72
1971	7.39	15.55	34.02	176.71	228.87	263.35	119.11	43.57	29.54	20.08	12.06	8.83
1972	11.52	14.91	11.52	20.05	21.45	16.74	28.78	17.74	11.39	7.88	5.10	34.68
1973	27.77	29.44	177.37	259.46	180.46	77.70	46.30	28.76	19.64	18.42	10.08	9.01
1974	7.25	13.64	26.33	70.11	93.35	55.53	27.94	21.45	16.06	10.42	6.49	5.76
1975	3.27	4.13	84.91	322.59	286.93	173.52	86.50	37.64	24.92	16.31	10.05	7.27
1976	5.53	10.39	19.27	70.05	130.67	124.94	61.65	27.42	18.07	10.70	7.55	13.49
1977	9.10	11.82	66.39	247.37	202.29	136.99	74.04	26.79	17.66	11.58	6.95	5.54
1978	6.50	18.65	19.98	23.43	14.96	19.81	12.18	7.70	5.55	4.12	2.81	2.52
1979	3.36	12.26	17.83	18.69	62.62	52.41	23.43	13.29	8.20	4.78	3.58	4.88
1980	3.67	42.38	53.97	126.04	158.62	91.01	38.32	25.06	16.38	10.05	7.17	7.90
1981	7.95	9.19	9.54	25.27	16.47	7.69	10.29	6.51	4.48	3.65	1.44	1.43
1982	1.17	2.76	2.95	4.02	3.62	6.64	7.11	5.35	3.47	1.67	0.63	0.60
1983	1.90	26.40	34.71	37.56	21.64	28.85	20.07	9.98	7.25	19.56	12.62	10.91
1984	10.93	25.39	26.71	36.56	216.35	133.39	28.76	19.52	12.76	8.43	5.04	4.32
1985	6.95	8.31	28.57	32.41	36.02	26.03	34.12	19.27	12.01	7.04	4.21	3.50
1986	3.30	4.10	8.17	10.01	8.39	35.79	25.65	9.22	6.34	3.53	3.59	12.94
1987	8.94	7.67	113.79	77.59	143.05	116.54	42.66	23.81	18.72	11.63	9.04	8.45

1988	16.92	12.11	15.02	9.98	152.16	87.41	17.54	10.37	11.50	7.02	4.36	2.79
1989	5.43	16.42	33.17	38.40	47.84	39.41	26.69	16.04	10.78	7.48	4.45	2.99
1990	3.66	4.87	36.87	97.22	79.32	75.03	47.88	21.69	18.09	10.13	6.12	4.73
1991	2.70	6.11	8.47	9.86	7.38	4.74	4.78	2.11	1.39	0.22	0.21	0.20
1992	0.18	3.63	56.66	39.96	29.20	86.63	61.42	18.45	12.31	7.16	4.28	3.00
1993	2.50	5.85	16.99	19.95	17.48	16.08	10.42	5.43	3.39	1.36	0.34	0.54
1994	4.08	3.12	9.45	41.75	28.44	18.04	18.76	11.61	7.84	4.53	2.98	1.41
1995	1.54	17.50	150.08	186.59	614.38	323.74	52.26	41.75	30.02	23.90	18.59	12.60
1996	11.40	11.55	18.75	49.43	48.53	122.80	84.23	28.75	20.12	13.58	8.15	12.32
1997	13.25	17.33	15.66	59.48	46.38	24.24	18.15	10.23	7.10	5.62	2.53	3.72
1998	12.97	40.81	142.55	145.62	125.28	98.56	58.53	29.50	20.39	13.34	8.86	7.42
1999	5.92	24.72	55.59	154.71	1186.48	846.86	213.66	47.99	38.59	27.28	17.36	15.46
2000	12.86	34.17	78.85	50.97	71.50	51.21	32.79	20.35	15.53	11.24	7.28	5.45
2001	7.36	125.70	119.25	66.31	48.16	31.89	21.71	11.37	8.65	5.71	3.26	2.37
2002	4.87	4.06	8.24	7.89	7.10	6.21	4.40	1.63	2.99	1.04	0.29	0.46
2003	0.38	1.41	1.04	24.72	62.26	76.10	39.09	17.27	11.79	8.71	4.63	3.80
2004	2.41	6.45	15.01	31.57	22.41	15.85	14.60	9.73	7.07	4.59	2.07	2.42

ANNEXURE B

HEC-RAS OUTPUT FOR THE SABÍE RIVER UPSTREAM OF CORUMANA DAM FOR THE 1 IN 200 YEAR FLOOD

HEC-RAS Output Corumana Dam FSL 111 masl 1 in 200 year flood				
HEC-RAS Station	Max Flow (m^3/s)	W.S. Elev (masl)	Average Veloc-ity (m/s)	Stream Power (N/m s)
16514.69	3090.02	143.52	1.98	47.3
16183.9	3089.96	142.92	2.63	117.5
15959.77	3089.94	142.51	2.68	123.3
15671.98	3089.9	142.14	2.35	80.8
15394.97	3089.88	141.68	2.36	143.7
15083.07	3089.84	140.94	2.5	170.1
14828.12	3089.82	140.54	2.21	100.6
14531.36	3089.81	139.25	3.77	576.7
14196.19	3089.8	137.7	3.55	481.6
13953.22	3089.8	135.81	4.79	1212.7
13563.81	3089.79	133.42	2.95	270.5
13229.81	3089.77	132.61	2.48	163.6
12830.47	3089.75	131.71	2.5	169.9
12505.89	3089.73	130.88	2.52	159.8
12092.76	3089.69	129.93	2.52	149.4
11525.01	3089.67	127.62	3.99	715.9
10938.05	3089.65	124.14	2.78	129.7
9996.865	3089.62	121.81	3.63	256.9
9073.681	3089.57	119.32	2.8	122.6
8061.068	2969.41	116.75	3.45	238.6
7499.266	1952.62	115	0.25	0.1
6661.069	1949.8	115	0.17	0.0
6023.782	1949.62	114.99	0.15	0.0
4912.27	1943.51	115	0.02	0.0
1485.35	1938.1	115	0.02	0.0
1215.541	Inl Struct			

HEC-RAS Output Corumana Dam FSL 117 masl 1 in 200 year flood				
HEC-RAS Station	Max Flow (m^3/s)	W.S. Elev (masl)	Average Ve-locity (m/s)	Stream Power (N/m s)
16514.69	3090.11	143.52	1.98	47.3
16183.9	3090.08	142.92	2.63	117.5
15959.77	3090.04	142.51	2.68	123.3
15671.98	3090.01	142.14	2.35	80.8
15394.97	3089.99	141.68	2.36	143.7
15083.07	3089.95	140.94	2.5	170.1
14828.12	3089.93	140.54	2.21	100.6
14531.36	3089.92	139.25	3.77	576.8
14196.19	3089.91	137.7	3.55	481.6
13953.22	3089.9	135.81	4.79	1212.4
13563.81	3089.9	133.42	2.95	270.5
13229.81	3089.88	132.61	2.48	163.6
12830.47	3089.85	131.71	2.5	169.9
12505.89	3089.83	130.88	2.52	159.8
12092.76	3089.79	129.93	2.52	149.4
11525.01	3089.76	127.62	3.99	715.9
10938.05	3089.75	124.14	2.78	129.8
9996.865	3089.73	121.82	3.63	256.1
9073.681	3087.22	119.93	2.21	53.0
8061.068	1490.01	119.48	0.76	1.9
7499.266	2917.97	119.53	0.17	0.0
6661.069	2903.63	119.53	0.14	0.0
6023.782	2884.54	119.53	0.13	0.0
4912.27	2658.67	119.52	0.02	0.0
1485.35	2309.41	119.5	0.02	0.0
1215.541	Inl Struct			

ANNEXURE C

SIMULATION OF RESERVOIR PERFORMANCE FOR CORUMANA DAM, FULL SUPPLY LEVEL 111 MASL, HISTORICAL FIRM YIELD AS TARGET DRAFT (RESSIM MODEL)

SIMULATION OF RESERVOIR PERFORMANCE AT Corumana Dam FSL 111 masl Units M.m^3

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YEAR	MONTH	INFLOW	DRAFT	SHORTFALL	EVAPORATION	SPILLAGE	STORAGE
1921	10	11.34	19.50	0.00	5.98	0.00	571.86
1921	11	72.91	19.50	0.00	5.55	0.00	619.72
1921	12	69.54	19.50	0.00	6.73	0.00	663.03
1921	1	25.22	19.50	0.00	8.01	0.00	660.75
1921	2	15.02	19.50	0.00	7.25	0.00	649.01
1921	3	22.93	19.50	0.00	6.74	0.00	645.70
1921	4	17.78	19.50	0.00	5.22	0.00	638.76
1921	5	10.69	19.50	0.00	4.48	0.00	625.46
1921	6	9.44	19.50	0.00	3.49	0.00	611.91
1921	7	6.22	19.50	0.00	3.77	0.00	594.86
1921	8	4.86	19.50	0.00	4.45	0.00	575.77
1921	9	3.35	19.50	0.00	5.44	0.00	554.18
1922	10	5.01	19.50	0.00	5.77	0.00	533.92
1922	11	17.87	19.50	0.00	5.50	0.00	526.79
1922	12	17.79	19.50	0.00	6.59	0.00	518.49
1922	1	234.27	19.50	0.00	5.91	0.00	727.35
1922	2	437.24	19.50	0.00	6.90	258.19	880.00
1922	3	234.80	19.50	0.00	8.07	207.23	880.00
1922	4	48.06	19.50	0.00	6.20	22.36	880.00
1922	5	25.52	19.50	0.00	5.53	0.49	880.00
1922	6	16.25	19.50	0.00	4.49	0.00	872.26
1922	7	10.51	19.50	0.00	4.61	0.00	858.66
1922	8	6.00	19.50	0.00	5.73	0.00	839.43
1922	9	4.32	19.50	0.00	6.87	0.00	817.38
1923	10	2.31	19.50	0.00	7.45	0.00	792.74
1923	11	3.02	19.50	0.00	7.29	0.00	768.97
1923	12	27.64	19.50	0.00	7.72	0.00	769.39
1923	1	19.98	19.50	0.00	8.71	0.00	761.16
1923	2	8.61	19.50	0.00	7.71	0.00	742.57
1923	3	62.62	19.50	0.00	6.86	0.00	778.83
1923	4	37.08	19.50	0.00	5.97	0.00	790.44
1923	5	13.46	19.50	0.00	5.02	0.00	779.38
1923	6	8.39	19.50	0.00	4.17	0.00	764.10
1923	7	5.51	19.50	0.00	4.31	0.00	745.79
1923	8	4.30	19.50	0.00	5.22	0.00	725.37
1923	9	3.84	19.50	0.00	6.17	0.00	703.54

1924	10	3.42	19.50	0.00	6.67	0.00	680.79
1924	11	36.75	19.50	0.00	6.08	0.00	691.97
1924	12	50.22	19.50	0.00	7.30	0.00	715.38
1924	1	128.69	19.50	0.00	7.54	0.00	817.04
1924	2	152.05	19.50	0.00	7.41	62.17	880.00
1924	3	1161.68	19.50	0.00	6.75	1135.43	880.00
1924	4	575.30	19.50	0.00	6.16	549.64	880.00
1924	5	49.86	19.50	0.00	5.44	24.92	880.00
1924	6	32.95	19.50	0.00	4.48	8.97	880.00
1924	7	22.90	19.50	0.00	4.69	0.00	878.71
1924	8	13.88	19.50	0.00	5.81	0.00	867.28
1924	9	16.12	19.50	0.00	6.77	0.00	857.13
1925	10	12.79	19.50	0.00	7.56	0.00	842.86
1925	11	14.73	19.50	0.00	7.55	0.00	830.54
1925	12	11.33	19.50	0.00	8.71	0.00	813.66
1925	1	17.46	19.50	0.00	8.68	0.00	802.94
1925	2	29.79	19.50	0.00	7.66	0.00	805.58
1925	3	34.57	19.50	0.00	7.58	0.00	813.07
1925	4	19.07	19.50	0.00	6.12	0.00	806.52
1925	5	11.77	19.50	0.00	5.08	0.00	793.70
1925	6	7.52	19.50	0.00	4.21	0.00	777.51
1925	7	10.40	19.50	0.00	4.24	0.00	764.17
1925	8	5.98	19.50	0.00	5.34	0.00	745.30
1925	9	6.17	19.50	0.00	6.27	0.00	725.71
1926	10	2.29	19.50	0.00	6.97	0.00	701.53
1926	11	4.95	19.50	0.00	6.63	0.00	680.35
1926	12	6.42	19.50	0.00	7.62	0.00	659.65
1926	1	13.68	19.50	0.00	7.85	0.00	645.99
1926	2	27.89	19.50	0.00	6.99	0.00	647.39
1926	3	31.92	19.50	0.00	6.92	0.00	652.89
1926	4	21.46	19.50	0.00	5.32	0.00	649.53
1926	5	12.53	19.50	0.00	4.61	0.00	637.95
1926	6	9.08	19.50	0.00	3.69	0.00	623.83
1926	7	21.85	19.50	0.00	3.64	0.00	622.54
1926	8	13.00	19.50	0.00	4.69	0.00	611.36
1926	9	8.71	19.50	0.00	5.65	0.00	594.91
1927	10	12.88	19.50	0.00	5.82	0.00	582.47
1927	11	11.88	19.50	0.00	6.12	0.00	568.74
1927	12	9.55	19.50	0.00	6.89	0.00	551.89
1927	1	79.73	19.50	0.00	6.61	0.00	605.51
1927	2	61.17	19.50	0.00	6.77	0.00	640.41
1927	3	33.02	19.50	0.00	6.85	0.00	647.08
1927	4	27.06	19.50	0.00	5.17	0.00	649.47
1927	5	16.06	19.50	0.00	4.61	0.00	641.42
1927	6	10.38	19.50	0.00	3.71	0.00	628.59
1927	7	7.83	19.50	0.00	3.81	0.00	613.11
1927	8	4.88	19.50	0.00	4.67	0.00	593.82
1927	9	3.54	19.50	0.00	5.54	0.00	572.32
1928	10	1.77	19.50	0.00	5.87	0.00	548.72
1928	11	2.45	19.50	0.00	5.79	0.00	525.88

1928	12	10.92	19.50	0.00	6.51	0.00	510.79
1928	1	21.96	19.50	0.00	6.62	0.00	506.63
1928	2	49.40	19.50	0.00	5.89	0.00	530.64
1928	3	70.89	19.50	0.00	5.93	0.00	576.10
1928	4	40.91	19.50	0.00	4.97	0.00	592.54
1928	5	16.50	19.50	0.00	4.36	0.00	585.18
1928	6	12.76	19.50	0.00	3.48	0.00	574.95
1928	7	7.82	19.50	0.00	3.63	0.00	559.64
1928	8	5.16	19.50	0.00	4.43	0.00	540.87
1928	9	5.21	19.50	0.00	5.20	0.00	521.39
1929	10	18.32	19.50	0.00	5.41	0.00	514.79
1929	11	53.08	19.50	0.00	5.26	0.00	543.12
1929	12	49.05	19.50	0.00	6.51	0.00	566.16
1929	1	48.95	19.50	0.00	7.20	0.00	588.40
1929	2	45.47	19.50	0.00	6.53	0.00	607.84
1929	3	106.28	19.50	0.00	5.93	0.00	688.69
1929	4	82.22	19.50	0.00	5.49	0.00	745.92
1929	5	34.02	19.50	0.00	4.95	0.00	755.49
1929	6	21.90	19.50	0.00	4.07	0.00	753.82
1929	7	14.27	19.50	0.00	4.24	0.00	744.35
1929	8	8.10	19.50	0.00	5.26	0.00	727.69
1929	9	6.02	19.50	0.00	6.25	0.00	707.95
1930	10	1.74	19.50	0.00	6.85	0.00	683.35
1930	11	2.92	19.50	0.00	6.62	0.00	660.15
1930	12	87.63	19.50	0.00	6.80	0.00	721.48
1930	1	63.00	19.50	0.00	8.16	0.00	756.82
1930	2	19.55	19.50	0.00	7.51	0.00	749.37
1930	3	24.11	19.50	0.00	7.41	0.00	746.57
1930	4	21.96	19.50	0.00	5.68	0.00	743.35
1930	5	10.43	19.50	0.00	5.00	0.00	729.28
1930	6	8.30	19.50	0.00	4.00	0.00	714.07
1930	7	11.67	19.50	0.00	3.93	0.00	702.31
1930	8	5.28	19.50	0.00	5.08	0.00	683.01
1930	9	4.56	19.50	0.00	6.02	0.00	662.05
1931	10	2.70	19.50	0.00	6.45	0.00	638.80
1931	11	17.50	19.50	0.00	6.32	0.00	630.48
1931	12	27.18	19.50	0.00	7.21	0.00	630.95
1931	1	20.90	19.50	0.00	7.73	0.00	624.62
1931	2	19.94	19.50	0.00	6.83	0.00	618.23
1931	3	18.22	19.50	0.00	6.42	0.00	610.53
1931	4	11.72	19.50	0.00	5.03	0.00	597.72
1931	5	8.53	19.50	0.00	4.32	0.00	582.43
1931	6	6.02	19.50	0.00	3.44	0.00	565.51
1931	7	3.47	19.50	0.00	3.60	0.00	545.88
1931	8	0.83	19.50	0.00	4.37	0.00	522.84
1931	9	1.16	19.50	0.00	5.13	0.00	499.37
1932	10	0.76	19.50	0.00	5.48	0.00	475.15
1932	11	4.57	19.50	0.00	5.36	0.00	454.86
1932	12	18.23	19.50	0.00	5.74	0.00	447.85
1932	1	45.05	19.50	0.00	5.94	0.00	467.47

1932	2	39.07	19.50	0.00	5.75	0.00	481.29
1932	3	26.37	19.50	0.00	5.60	0.00	482.55
1932	4	18.91	19.50	0.00	4.44	0.00	477.52
1932	5	10.14	19.50	0.00	3.84	0.00	464.33
1932	6	6.68	19.50	0.00	3.06	0.00	448.45
1932	7	4.52	19.50	0.00	3.11	0.00	430.36
1932	8	1.66	19.50	0.00	3.79	0.00	408.74
1932	9	1.44	19.50	0.00	4.45	0.00	386.23
1933	10	0.82	19.50	0.00	4.67	0.00	362.88
1933	11	31.99	19.50	0.00	4.24	0.00	371.13
1933	12	42.25	19.50	0.00	5.22	0.00	388.66
1933	1	89.72	19.50	0.00	5.42	0.00	453.46
1933	2	76.25	19.50	0.00	5.74	0.00	504.47
1933	3	48.82	19.50	0.00	5.69	0.00	528.10
1933	4	35.22	19.50	0.00	4.67	0.00	539.16
1933	5	22.65	19.50	0.00	4.06	0.00	538.25
1933	6	17.99	19.50	0.00	3.26	0.00	533.47
1933	7	10.76	19.50	0.00	3.45	0.00	521.28
1933	8	6.01	19.50	0.00	4.25	0.00	503.55
1933	9	5.70	19.50	0.00	4.93	0.00	484.82
1934	10	4.28	19.50	0.00	5.38	0.00	464.21
1934	11	33.73	19.50	0.00	5.07	0.00	473.37
1934	12	56.17	19.50	0.00	5.83	0.00	504.20
1934	1	54.90	19.50	0.00	6.75	0.00	532.85
1934	2	44.18	19.50	0.00	6.09	0.00	551.44
1934	3	28.52	19.50	0.00	6.32	0.00	554.14
1934	4	17.97	19.50	0.00	4.81	0.00	547.80
1934	5	10.92	19.50	0.00	4.00	0.00	535.22
1934	6	7.95	19.50	0.00	3.23	0.00	520.44
1934	7	5.54	19.50	0.00	3.42	0.00	503.07
1934	8	2.68	19.50	0.00	4.16	0.00	482.09
1934	9	2.33	19.50	0.00	4.87	0.00	460.04
1935	10	0.82	19.50	0.00	5.26	0.00	436.10
1935	11	0.65	19.50	0.00	5.05	0.00	412.20
1935	12	2.15	19.50	0.00	5.61	0.00	389.25
1935	1	20.76	19.50	0.00	5.45	0.00	385.06
1935	2	35.33	19.50	0.00	5.12	0.00	395.78
1935	3	64.55	19.50	0.00	4.81	0.00	436.02
1935	4	43.20	19.50	0.00	4.13	0.00	455.59
1935	5	21.32	19.50	0.00	3.57	0.00	453.84
1935	6	15.05	19.50	0.00	3.00	0.00	446.38
1935	7	10.94	19.50	0.00	3.10	0.00	434.73
1935	8	5.96	19.50	0.00	3.79	0.00	417.40
1935	9	10.43	19.50	0.00	4.29	0.00	404.04
1936	10	15.92	19.50	0.00	4.68	0.00	395.78
1936	11	31.66	19.50	0.00	4.32	0.00	403.62
1936	12	63.15	19.50	0.00	5.42	0.00	441.85
1936	1	156.67	19.50	0.00	5.78	0.00	573.24
1936	2	590.59	19.50	0.00	5.18	259.15	880.00
1936	3	277.90	19.50	0.00	8.10	250.30	880.00

1936	4	50.40	19.50	0.00	6.37	24.53	880.00
1936	5	29.74	19.50	0.00	5.49	4.75	880.00
1936	6	20.00	19.50	0.00	4.49	0.00	876.01
1936	7	12.90	19.50	0.00	4.68	0.00	864.74
1936	8	8.46	19.50	0.00	5.75	0.00	847.95
1936	9	7.74	19.50	0.00	6.84	0.00	829.35
1937	10	4.30	19.50	0.00	7.47	0.00	806.68
1937	11	4.32	19.50	0.00	7.28	0.00	784.22
1937	12	12.80	19.50	0.00	8.22	0.00	769.31
1937	1	19.03	19.50	0.00	8.47	0.00	760.36
1937	2	20.89	19.50	0.00	7.74	0.00	754.02
1937	3	14.36	19.50	0.00	7.48	0.00	741.40
1937	4	32.27	19.50	0.00	5.15	0.00	749.02
1937	5	17.80	19.50	0.00	5.00	0.00	742.31
1937	6	11.34	19.50	0.00	4.02	0.00	730.14
1937	7	7.85	19.50	0.00	4.08	0.00	714.41
1937	8	4.56	19.50	0.00	5.08	0.00	694.39
1937	9	9.99	19.50	0.00	5.84	0.00	679.04
1938	10	9.98	19.50	0.00	6.55	0.00	662.97
1938	11	9.31	19.50	0.00	6.40	0.00	646.38
1938	12	453.08	19.50	0.00	6.53	193.43	880.00
1938	1	281.34	19.50	0.00	9.05	252.79	880.00
1938	2	720.78	19.50	0.00	7.35	693.93	880.00
1938	3	474.50	19.50	0.00	8.09	446.91	880.00
1938	4	101.78	19.50	0.00	6.18	76.10	880.00
1938	5	37.52	19.50	0.00	5.51	12.51	880.00
1938	6	25.91	19.50	0.00	4.48	1.93	880.00
1938	7	25.48	19.50	0.00	4.58	1.40	880.00
1938	8	16.72	19.50	0.00	5.81	0.00	871.41
1938	9	18.61	19.50	0.00	6.83	0.00	863.69
1939	10	12.84	19.50	0.00	7.61	0.00	849.42
1939	11	114.04	19.50	0.00	7.31	56.65	880.00
1939	12	127.03	19.50	0.00	8.45	99.08	880.00
1939	1	60.18	19.50	0.00	9.41	31.27	880.00
1939	2	33.91	19.50	0.00	8.46	5.95	880.00
1939	3	42.21	19.50	0.00	7.99	14.72	880.00
1939	4	34.15	19.50	0.00	6.00	8.65	880.00
1939	5	21.85	19.50	0.00	5.22	0.00	877.13
1939	6	23.46	19.50	0.00	4.12	0.00	876.97
1939	7	14.76	19.50	0.00	4.69	0.00	867.54
1939	8	10.26	19.50	0.00	5.75	0.00	852.55
1939	9	11.53	19.50	0.00	6.84	0.00	837.74
1940	10	8.22	19.50	0.00	7.50	0.00	818.96
1940	11	54.57	19.50	0.00	6.50	0.00	847.53
1940	12	60.20	19.50	0.00	8.45	0.00	879.78
1940	1	34.34	19.50	0.00	9.40	5.23	880.00
1940	2	23.69	19.50	0.00	8.60	0.00	875.59
1940	3	25.02	19.50	0.00	8.21	0.00	872.90
1940	4	46.71	19.50	0.00	5.96	14.14	880.00
1940	5	28.14	19.50	0.00	5.54	3.10	880.00

1940	6	14.45	19.50	0.00	4.49	0.00	870.46
1940	7	9.64	19.50	0.00	4.60	0.00	856.00
1940	8	5.60	19.50	0.00	5.72	0.00	836.38
1940	9	4.37	19.50	0.00	6.86	0.00	814.39
1941	10	2.60	19.50	0.00	7.15	0.00	790.34
1941	11	2.97	19.50	0.00	7.11	0.00	766.70
1941	12	33.05	19.50	0.00	7.51	0.00	772.74
1941	1	66.31	19.50	0.00	7.97	0.00	811.58
1941	2	33.22	19.50	0.00	8.03	0.00	817.27
1941	3	60.73	19.50	0.00	7.33	0.00	851.17
1941	4	33.54	19.50	0.00	6.24	0.00	858.98
1941	5	17.57	19.50	0.00	5.30	0.00	851.75
1941	6	19.13	19.50	0.00	4.25	0.00	847.13
1941	7	11.79	19.50	0.00	4.59	0.00	834.83
1941	8	8.35	19.50	0.00	5.59	0.00	818.09
1941	9	10.09	19.50	0.00	6.54	0.00	802.14
1942	10	9.60	19.50	0.00	7.29	0.00	784.94
1942	11	20.26	19.50	0.00	6.82	0.00	778.88
1942	12	24.73	19.50	0.00	7.95	0.00	776.16
1942	1	23.42	19.50	0.00	8.70	0.00	771.37
1942	2	19.66	19.50	0.00	7.85	0.00	763.69
1942	3	37.99	19.50	0.00	7.29	0.00	774.89
1942	4	74.81	19.50	0.00	4.69	0.00	825.51
1942	5	43.01	19.50	0.00	5.28	0.00	843.73
1942	6	20.17	19.50	0.00	4.37	0.00	840.03
1942	7	19.27	19.50	0.00	4.36	0.00	835.44
1942	8	17.47	19.50	0.00	5.51	0.00	827.90
1942	9	19.27	19.50	0.00	6.70	0.00	820.97
1943	10	14.07	19.50	0.00	7.37	0.00	808.17
1943	11	24.12	19.50	0.00	6.58	0.00	806.21
1943	12	14.40	19.50	0.00	8.46	0.00	792.65
1943	1	17.67	19.50	0.00	8.65	0.00	782.17
1943	2	103.92	19.50	0.00	7.26	0.00	859.33
1943	3	70.92	19.50	0.00	8.18	22.57	880.00
1943	4	21.01	19.50	0.00	6.31	0.00	875.20
1943	5	11.21	19.50	0.00	5.49	0.00	861.42
1943	6	9.58	19.50	0.00	4.36	0.00	847.13
1943	7	5.76	19.50	0.00	4.59	0.00	828.80
1943	8	3.24	19.50	0.00	5.61	0.00	806.93
1943	9	3.29	19.50	0.00	6.68	0.00	784.04
1944	10	8.92	19.50	0.00	7.20	0.00	766.27
1944	11	9.99	19.50	0.00	6.98	0.00	749.78
1944	12	8.30	19.50	0.00	8.12	0.00	730.46
1944	1	33.91	19.50	0.00	7.85	0.00	737.03
1944	2	34.53	19.50	0.00	7.34	0.00	744.71
1944	3	29.27	19.50	0.00	7.33	0.00	747.15
1944	4	21.85	19.50	0.00	5.80	0.00	743.70
1944	5	11.73	19.50	0.00	4.94	0.00	731.00
1944	6	7.75	19.50	0.00	4.01	0.00	715.23
1944	7	4.47	19.50	0.00	4.11	0.00	696.09

1944	8	1.60	19.50	0.00	5.05	0.00	673.14
1944	9	1.12	19.50	0.00	6.01	0.00	648.75
1945	10	3.73	19.50	0.00	6.31	0.00	626.67
1945	11	3.15	19.50	0.00	6.22	0.00	604.10
1945	12	3.05	19.50	0.00	7.24	0.00	580.41
1945	1	304.33	19.50	0.00	6.48	0.00	858.75
1945	2	277.34	19.50	0.00	7.03	229.56	880.00
1945	3	83.37	19.50	0.00	8.29	55.58	880.00
1945	4	30.94	19.50	0.00	6.39	5.05	880.00
1945	5	18.30	19.50	0.00	5.53	0.00	873.27
1945	6	12.02	19.50	0.00	4.47	0.00	861.32
1945	7	7.50	19.50	0.00	4.64	0.00	844.68
1945	8	3.99	19.50	0.00	5.67	0.00	823.50
1945	9	2.50	19.50	0.00	6.80	0.00	799.70
1946	10	1.26	19.50	0.00	7.34	0.00	774.12
1946	11	9.19	19.50	0.00	6.95	0.00	756.86
1946	12	13.42	19.50	0.00	7.98	0.00	742.80
1946	1	19.30	19.50	0.00	8.40	0.00	734.20
1946	2	36.31	19.50	0.00	7.50	0.00	743.51
1946	3	38.43	19.50	0.00	7.22	0.00	755.23
1946	4	26.44	19.50	0.00	5.75	0.00	756.42
1946	5	14.61	19.50	0.00	5.03	0.00	746.50
1946	6	12.03	19.50	0.00	4.01	0.00	735.01
1946	7	7.39	19.50	0.00	4.18	0.00	718.72
1946	8	3.84	19.50	0.00	5.15	0.00	697.91
1946	9	3.43	19.50	0.00	6.05	0.00	675.79
1947	10	3.62	19.50	0.00	6.47	0.00	653.44
1947	11	22.55	19.50	0.00	5.96	0.00	650.53
1947	12	92.54	19.50	0.00	7.18	0.00	716.39
1947	1	67.15	19.50	0.00	8.24	0.00	755.80
1947	2	34.88	19.50	0.00	7.53	0.00	763.64
1947	3	127.61	19.50	0.00	6.60	0.00	865.15
1947	4	82.23	19.50	0.00	6.29	41.59	880.00
1947	5	24.37	19.50	0.00	5.54	0.00	879.33
1947	6	15.66	19.50	0.00	4.48	0.00	871.01
1947	7	9.85	19.50	0.00	4.61	0.00	856.75
1947	8	5.21	19.50	0.00	5.73	0.00	836.73
1947	9	5.10	19.50	0.00	6.80	0.00	815.53
1948	10	5.96	19.50	0.00	7.26	0.00	794.73
1948	11	7.88	19.50	0.00	7.20	0.00	775.91
1948	12	8.25	19.50	0.00	8.25	0.00	756.41
1948	1	36.08	19.50	0.00	8.07	0.00	764.93
1948	2	45.25	19.50	0.00	7.56	0.00	783.11
1948	3	33.94	19.50	0.00	7.63	0.00	789.92
1948	4	22.21	19.50	0.00	5.83	0.00	786.80
1948	5	15.46	19.50	0.00	5.01	0.00	777.76
1948	6	10.93	19.50	0.00	4.04	0.00	765.15
1948	7	7.26	19.50	0.00	4.26	0.00	748.65
1948	8	3.96	19.50	0.00	5.27	0.00	727.84
1948	9	3.84	19.50	0.00	6.17	0.00	706.01

1949	10	1.38	19.50	0.00	6.84	0.00	681.05
1949	11	28.20	19.50	0.00	6.16	0.00	683.59
1949	12	35.60	19.50	0.00	7.02	0.00	692.68
1949	1	34.04	19.50	0.00	8.05	0.00	699.17
1949	2	31.10	19.50	0.00	6.95	0.00	703.81
1949	3	34.66	19.50	0.00	6.90	0.00	712.07
1949	4	25.01	19.50	0.00	5.50	0.00	712.08
1949	5	18.21	19.50	0.00	4.83	0.00	705.96
1949	6	12.72	19.50	0.00	3.88	0.00	695.30
1949	7	8.59	19.50	0.00	4.04	0.00	680.35
1949	8	5.81	19.50	0.00	4.98	0.00	661.69
1949	9	4.77	19.50	0.00	5.96	0.00	641.00
1950	10	1.96	19.50	0.00	6.44	0.00	617.02
1950	11	3.34	19.50	0.00	6.20	0.00	594.66
1950	12	63.09	19.50	0.00	6.25	0.00	632.00
1950	1	47.67	19.50	0.00	7.82	0.00	652.35
1950	2	10.68	19.50	0.00	7.18	0.00	636.35
1950	3	16.51	19.50	0.00	6.67	0.00	626.69
1950	4	23.19	19.50	0.00	4.94	0.00	625.44
1950	5	17.72	19.50	0.00	4.34	0.00	619.32
1950	6	10.75	19.50	0.00	3.63	0.00	606.94
1950	7	7.52	19.50	0.00	3.74	0.00	591.22
1950	8	8.81	19.50	0.00	4.39	0.00	576.13
1950	9	7.36	19.50	0.00	5.43	0.00	558.57
1951	10	11.09	19.50	0.00	5.70	0.00	544.46
1951	11	9.05	19.50	0.00	5.64	0.00	528.37
1951	12	14.81	19.50	0.00	6.42	0.00	517.26
1951	1	15.66	19.50	0.00	6.52	0.00	506.90
1951	2	16.36	19.50	0.00	5.93	0.00	497.83
1951	3	23.19	19.50	0.00	5.84	0.00	495.69
1951	4	15.50	19.50	0.00	4.52	0.00	487.17
1951	5	9.04	19.50	0.00	3.83	0.00	472.88
1951	6	7.23	19.50	0.00	3.01	0.00	457.60
1951	7	6.72	19.50	0.00	3.11	0.00	441.70
1951	8	3.62	19.50	0.00	3.84	0.00	421.98
1951	9	2.15	19.50	0.00	4.55	0.00	400.08
1952	10	2.03	19.50	0.00	4.80	0.00	377.81
1952	11	37.52	19.50	0.00	4.24	0.00	391.59
1952	12	64.42	19.50	0.00	5.34	0.00	431.17
1952	1	66.48	19.50	0.00	5.76	0.00	472.38
1952	2	141.26	19.50	0.00	5.62	0.00	588.53
1952	3	123.76	19.50	0.00	6.56	0.00	686.23
1952	4	55.95	19.50	0.00	5.25	0.00	717.42
1952	5	28.68	19.50	0.00	4.88	0.00	721.72
1952	6	18.95	19.50	0.00	3.98	0.00	717.19
1952	7	11.93	19.50	0.00	4.14	0.00	705.48
1952	8	6.92	19.50	0.00	5.09	0.00	687.81
1952	9	6.14	19.50	0.00	5.97	0.00	668.48
1953	10	3.65	19.50	0.00	6.49	0.00	646.14
1953	11	14.14	19.50	0.00	6.05	0.00	634.73

1953	12	27.01	19.50	0.00	7.35	0.00	634.88
1953	1	64.28	19.50	0.00	7.83	0.00	671.83
1953	2	84.27	19.50	0.00	6.81	0.00	729.79
1953	3	50.04	19.50	0.00	7.37	0.00	752.96
1953	4	31.57	19.50	0.00	5.71	0.00	759.32
1953	5	19.87	19.50	0.00	4.99	0.00	754.69
1953	6	13.32	19.50	0.00	4.08	0.00	744.43
1953	7	8.01	19.50	0.00	4.25	0.00	728.69
1953	8	5.96	19.50	0.00	5.13	0.00	710.03
1953	9	4.70	19.50	0.00	5.92	0.00	689.31
1954	10	3.76	19.50	0.00	6.68	0.00	666.89
1954	11	15.78	19.50	0.00	6.07	0.00	657.10
1954	12	13.36	19.50	0.00	7.43	0.00	643.54
1954	1	167.34	19.50	0.00	7.27	0.00	784.11
1954	2	246.54	19.50	0.00	7.57	123.58	880.00
1954	3	196.28	19.50	0.00	8.12	168.66	880.00
1954	4	86.90	19.50	0.00	6.25	61.15	880.00
1954	5	37.80	19.50	0.00	5.46	12.84	880.00
1954	6	27.39	19.50	0.00	4.43	3.46	880.00
1954	7	18.13	19.50	0.00	4.69	0.00	873.94
1954	8	10.50	19.50	0.00	5.79	0.00	859.15
1954	9	7.44	19.50	0.00	6.98	0.00	840.11
1955	10	11.54	19.50	0.00	7.24	0.00	824.90
1955	11	40.15	19.50	0.00	6.88	0.00	838.68
1955	12	74.25	19.50	0.00	8.30	5.13	880.00
1955	1	50.70	19.50	0.00	9.46	21.74	880.00
1955	2	372.29	19.50	0.00	7.51	345.28	880.00
1955	3	286.24	19.50	0.00	8.28	258.46	880.00
1955	4	75.43	19.50	0.00	6.45	49.48	880.00
1955	5	33.55	19.50	0.00	5.33	8.72	880.00
1955	6	26.35	19.50	0.00	4.43	2.42	880.00
1955	7	18.56	19.50	0.00	4.69	0.00	874.37
1955	8	11.91	19.50	0.00	5.80	0.00	860.98
1955	9	13.73	19.50	0.00	6.69	0.00	848.52
1956	10	10.45	19.50	0.00	7.62	0.00	831.85
1956	11	9.13	19.50	0.00	7.44	0.00	814.05
1956	12	14.87	19.50	0.00	8.31	0.00	801.10
1956	1	16.10	19.50	0.00	8.80	0.00	788.90
1956	2	32.65	19.50	0.00	7.73	0.00	794.32
1956	3	50.90	19.50	0.00	7.47	0.00	818.25
1956	4	37.34	19.50	0.00	5.91	0.00	830.19
1956	5	22.35	19.50	0.00	5.33	0.00	827.70
1956	6	15.51	19.50	0.00	4.29	0.00	819.43
1956	7	14.35	19.50	0.00	4.32	0.00	809.96
1956	8	11.37	19.50	0.00	5.45	0.00	796.37
1956	9	11.37	19.50	0.00	6.44	0.00	781.80
1957	10	13.76	19.50	0.00	7.03	0.00	769.03
1957	11	14.77	19.50	0.00	7.17	0.00	757.14
1957	12	25.66	19.50	0.00	7.96	0.00	755.33
1957	1	499.20	19.50	0.00	7.78	347.25	880.00

1957	2	269.61	19.50	0.00	8.44	241.67	880.00
1957	3	37.83	19.50	0.00	8.33	10.00	880.00
1957	4	32.22	19.50	0.00	6.29	6.43	880.00
1957	5	19.13	19.50	0.00	5.53	0.00	874.10
1957	6	13.42	19.50	0.00	4.43	0.00	863.59
1957	7	8.54	19.50	0.00	4.64	0.00	847.99
1957	8	4.81	19.50	0.00	5.69	0.00	827.61
1957	9	7.79	19.50	0.00	6.60	0.00	809.30
1958	10	6.32	19.50	0.00	7.35	0.00	788.78
1958	11	14.43	19.50	0.00	7.03	0.00	776.68
1958	12	24.35	19.50	0.00	7.68	0.00	773.85
1958	1	45.38	19.50	0.00	8.44	0.00	791.29
1958	2	99.74	19.50	0.00	7.78	0.00	863.75
1958	3	55.12	19.50	0.00	8.23	11.14	880.00
1958	4	17.06	19.50	0.00	6.39	0.00	871.17
1958	5	10.65	19.50	0.00	5.15	0.00	857.17
1958	6	6.69	19.50	0.00	4.37	0.00	839.99
1958	7	5.82	19.50	0.00	4.47	0.00	821.84
1958	8	2.68	19.50	0.00	5.56	0.00	799.46
1958	9	4.16	19.50	0.00	6.36	0.00	777.75
1959	10	3.88	19.50	0.00	7.13	0.00	755.00
1959	11	10.86	19.50	0.00	6.99	0.00	739.37
1959	12	35.26	19.50	0.00	7.91	0.00	747.22
1959	1	31.91	19.50	0.00	8.58	0.00	751.05
1959	2	270.34	19.50	0.00	6.85	115.03	880.00
1959	3	162.99	19.50	0.00	8.35	135.14	880.00
1959	4	43.56	19.50	0.00	5.95	18.11	880.00
1959	5	26.33	19.50	0.00	5.45	1.38	880.00
1959	6	17.25	19.50	0.00	4.46	0.00	873.29
1959	7	10.44	19.50	0.00	4.67	0.00	859.56
1959	8	6.88	19.50	0.00	5.67	0.00	841.27
1959	9	7.29	19.50	0.00	6.70	0.00	822.36
1960	10	4.04	19.50	0.00	7.47	0.00	799.43
1960	11	35.76	19.50	0.00	7.00	0.00	808.69
1960	12	141.47	19.50	0.00	7.72	42.94	880.00
1960	1	97.26	19.50	0.00	9.55	68.21	880.00
1960	2	70.94	19.50	0.00	7.94	43.50	880.00
1960	3	92.61	19.50	0.00	8.16	64.95	880.00
1960	4	62.13	19.50	0.00	6.35	36.28	880.00
1960	5	31.27	19.50	0.00	5.46	6.31	880.00
1960	6	30.90	19.50	0.00	4.06	7.34	880.00
1960	7	22.54	19.50	0.00	4.63	0.00	878.41
1960	8	16.46	19.50	0.00	5.72	0.00	869.65
1960	9	13.49	19.50	0.00	6.84	0.00	856.80
1961	10	10.30	19.50	0.00	7.47	0.00	840.13
1961	11	15.03	19.50	0.00	7.50	0.00	828.16
1961	12	26.24	19.50	0.00	8.44	0.00	826.46
1961	1	27.63	19.50	0.00	8.97	0.00	825.62
1961	2	31.27	19.50	0.00	8.22	0.00	829.18
1961	3	20.84	19.50	0.00	7.95	0.00	822.57

1961	4	16.21	19.50	0.00	6.08	0.00	813.20
1961	5	9.67	19.50	0.00	5.26	0.00	798.11
1961	6	6.98	19.50	0.00	4.23	0.00	781.36
1961	7	4.32	19.50	0.00	4.36	0.00	761.82
1961	8	2.16	19.50	0.00	5.22	0.00	739.26
1961	9	1.13	19.50	0.00	6.38	0.00	714.51
1962	10	0.88	19.50	0.00	6.79	0.00	689.10
1962	11	79.51	19.50	0.00	6.20	0.00	742.91
1962	12	72.98	19.50	0.00	7.75	0.00	788.64
1962	1	25.86	19.50	0.00	8.75	0.00	786.25
1962	2	22.42	19.50	0.00	7.74	0.00	781.42
1962	3	16.55	19.50	0.00	7.64	0.00	770.83
1962	4	15.33	19.50	0.00	5.69	0.00	760.97
1962	5	9.52	19.50	0.00	4.98	0.00	746.01
1962	6	13.37	19.50	0.00	3.73	0.00	736.14
1962	7	12.05	19.50	0.00	4.02	0.00	724.67
1962	8	6.08	19.50	0.00	5.18	0.00	706.07
1962	9	4.28	19.50	0.00	6.20	0.00	684.65
1963	10	3.12	19.50	0.00	6.64	0.00	661.63
1963	11	12.55	19.50	0.00	6.52	0.00	648.16
1963	12	16.65	19.50	0.00	7.40	0.00	637.91
1963	1	56.18	19.50	0.00	7.49	0.00	667.10
1963	2	47.91	19.50	0.00	6.89	0.00	688.62
1963	3	17.76	19.50	0.00	7.24	0.00	679.64
1963	4	13.42	19.50	0.00	5.34	0.00	668.22
1963	5	7.82	19.50	0.00	4.66	0.00	651.88
1963	6	5.80	19.50	0.00	3.72	0.00	634.46
1963	7	3.30	19.50	0.00	3.86	0.00	614.40
1963	8	1.11	19.50	0.00	4.68	0.00	591.33
1963	9	0.84	19.50	0.00	5.56	0.00	567.11
1964	10	5.71	19.50	0.00	5.56	0.00	547.76
1964	11	7.26	19.50	0.00	5.84	0.00	529.68
1964	12	38.78	19.50	0.00	6.31	0.00	542.65
1964	1	64.09	19.50	0.00	6.94	0.00	580.30
1964	2	37.60	19.50	0.00	6.62	0.00	591.78
1964	3	20.93	19.50	0.00	6.56	0.00	586.65
1964	4	14.52	19.50	0.00	4.93	0.00	576.74
1964	5	7.65	19.50	0.00	4.30	0.00	560.60
1964	6	5.22	19.50	0.00	3.41	0.00	542.90
1964	7	2.93	19.50	0.00	3.51	0.00	522.82
1964	8	0.93	19.50	0.00	4.23	0.00	500.03
1964	9	2.25	19.50	0.00	4.93	0.00	477.85
1965	10	1.02	19.50	0.00	5.30	0.00	454.07
1965	11	11.82	19.50	0.00	5.11	0.00	441.28
1965	12	10.20	19.50	0.00	5.94	0.00	426.05
1965	1	49.56	19.50	0.00	5.52	0.00	450.59
1965	2	113.25	19.50	0.00	5.49	0.00	538.85
1965	3	63.49	19.50	0.00	6.24	0.00	576.61
1965	4	16.36	19.50	0.00	4.95	0.00	568.52
1965	5	8.75	19.50	0.00	4.20	0.00	553.57

1965	6	6.42	19.50	0.00	3.34	0.00	537.14
1965	7	3.85	19.50	0.00	3.49	0.00	518.00
1965	8	2.10	19.50	0.00	4.19	0.00	496.41
1965	9	2.16	19.50	0.00	4.98	0.00	474.09
1966	10	5.86	19.50	0.00	5.19	0.00	455.26
1966	11	7.70	19.50	0.00	5.14	0.00	438.32
1966	12	23.08	19.50	0.00	5.73	0.00	436.17
1966	1	49.32	19.50	0.00	6.07	0.00	459.92
1966	2	119.63	19.50	0.00	4.95	0.00	555.10
1966	3	74.73	19.50	0.00	5.93	0.00	604.40
1966	4	87.55	19.50	0.00	4.92	0.00	667.53
1966	5	58.03	19.50	0.00	4.67	0.00	701.39
1966	6	24.83	19.50	0.00	3.77	0.00	702.95
1966	7	16.34	19.50	0.00	4.07	0.00	695.72
1966	8	10.17	19.50	0.00	5.03	0.00	681.36
1966	9	7.17	19.50	0.00	6.07	0.00	662.96
1967	10	6.46	19.50	0.00	6.40	0.00	643.52
1967	11	9.67	19.50	0.00	6.37	0.00	627.31
1967	12	14.78	19.50	0.00	7.27	0.00	615.33
1967	1	13.58	19.50	0.00	7.55	0.00	601.86
1967	2	15.22	19.50	0.00	6.47	0.00	591.11
1967	3	18.03	19.50	0.00	6.32	0.00	583.32
1967	4	17.67	19.50	0.00	4.83	0.00	576.65
1967	5	10.60	19.50	0.00	4.27	0.00	563.49
1967	6	9.37	19.50	0.00	3.34	0.00	550.01
1967	7	6.12	19.50	0.00	3.51	0.00	533.12
1967	8	3.68	19.50	0.00	4.28	0.00	513.02
1967	9	2.56	19.50	0.00	5.11	0.00	490.97
1968	10	1.73	19.50	0.00	5.47	0.00	467.73
1968	11	12.53	19.50	0.00	5.11	0.00	455.65
1968	12	16.57	19.50	0.00	5.87	0.00	446.85
1968	1	24.23	19.50	0.00	6.25	0.00	445.32
1968	2	48.55	19.50	0.00	5.52	0.00	468.85
1968	3	75.71	19.50	0.00	5.41	0.00	519.65
1968	4	51.03	19.50	0.00	4.52	0.00	546.66
1968	5	22.41	19.50	0.00	4.13	0.00	545.44
1968	6	14.94	19.50	0.00	3.34	0.00	537.54
1968	7	9.81	19.50	0.00	3.42	0.00	524.43
1968	8	5.05	19.50	0.00	4.26	0.00	505.72
1968	9	5.01	19.50	0.00	4.88	0.00	486.36
1969	10	24.85	19.50	0.00	4.95	0.00	486.76
1969	11	22.49	19.50	0.00	5.43	0.00	484.32
1969	12	26.75	19.50	0.00	5.96	0.00	485.61
1969	1	14.87	19.50	0.00	6.64	0.00	474.34
1969	2	13.67	19.50	0.00	5.84	0.00	462.68
1969	3	7.85	19.50	0.00	5.64	0.00	445.38
1969	4	5.18	19.50	0.00	4.26	0.00	426.80
1969	5	3.04	19.50	0.00	3.57	0.00	406.77
1969	6	3.97	19.50	0.00	2.76	0.00	388.47
1969	7	2.55	19.50	0.00	2.86	0.00	368.66

1969	8	0.85	19.50	0.00	3.45	0.00	346.56
1969	9	0.80	19.50	0.00	4.01	0.00	323.85
1970	10	0.69	19.50	0.00	4.23	0.00	300.81
1970	11	5.23	19.50	0.00	3.97	0.00	282.57
1970	12	14.02	19.50	0.00	4.38	0.00	272.71
1970	1	113.18	19.50	0.00	4.48	0.00	361.90
1970	2	79.76	19.50	0.00	4.91	0.00	417.25
1970	3	27.86	19.50	0.00	4.99	0.00	420.62
1970	4	24.32	19.50	0.00	4.00	0.00	421.45
1970	5	16.30	19.50	0.00	3.50	0.00	414.74
1970	6	12.22	19.50	0.00	2.81	0.00	404.65
1970	7	8.19	19.50	0.00	2.94	0.00	390.41
1970	8	4.59	19.50	0.00	3.56	0.00	371.93
1970	9	5.72	19.50	0.00	4.16	0.00	353.99
1971	10	7.39	19.50	0.00	4.28	0.00	337.61
1971	11	15.55	19.50	0.00	4.20	0.00	329.45
1971	12	34.02	19.50	0.00	4.71	0.00	339.27
1971	1	176.71	19.50	0.00	4.86	0.00	491.62
1971	2	228.87	19.50	0.00	5.67	0.00	695.32
1971	3	263.35	19.50	0.00	6.61	52.56	880.00
1971	4	119.11	19.50	0.00	6.28	93.33	880.00
1971	5	43.57	19.50	0.00	5.14	18.93	880.00
1971	6	29.54	19.50	0.00	4.49	5.55	880.00
1971	7	20.08	19.50	0.00	4.69	0.00	875.89
1971	8	12.06	19.50	0.00	5.80	0.00	862.65
1971	9	8.83	19.50	0.00	6.99	0.00	844.99
1972	10	11.52	19.50	0.00	7.44	0.00	829.56
1972	11	14.91	19.50	0.00	7.52	0.00	817.45
1972	12	11.52	19.50	0.00	8.42	0.00	801.05
1972	1	20.05	19.50	0.00	8.81	0.00	792.79
1972	2	21.45	19.50	0.00	7.89	0.00	786.84
1972	3	16.74	19.50	0.00	7.76	0.00	776.33
1972	4	28.78	19.50	0.00	5.57	0.00	780.04
1972	5	17.74	19.50	0.00	5.13	0.00	773.15
1972	6	11.39	19.50	0.00	4.13	0.00	760.91
1972	7	7.88	19.50	0.00	4.30	0.00	744.99
1972	8	5.10	19.50	0.00	5.21	0.00	725.37
1972	9	34.68	19.50	0.00	5.50	0.00	735.06
1973	10	27.77	19.50	0.00	6.68	0.00	736.65
1973	11	29.44	19.50	0.00	6.79	0.00	739.80
1973	12	177.37	19.50	0.00	7.33	10.35	880.00
1973	1	259.46	19.50	0.00	9.01	230.95	880.00
1973	2	180.46	19.50	0.00	8.20	152.76	880.00
1973	3	77.70	19.50	0.00	8.18	50.02	880.00
1973	4	46.30	19.50	0.00	6.09	20.71	880.00
1973	5	28.76	19.50	0.00	5.50	3.76	880.00
1973	6	19.64	19.50	0.00	4.49	0.00	875.65
1973	7	18.42	19.50	0.00	4.54	0.00	870.03
1973	8	10.08	19.50	0.00	5.76	0.00	854.85
1973	9	9.01	19.50	0.00	6.89	0.00	837.48

1974	10	7.25	19.50	0.00	7.54	0.00	817.69
1974	11	13.64	19.50	0.00	7.08	0.00	804.75
1974	12	26.33	19.50	0.00	8.24	0.00	803.34
1974	1	70.11	19.50	0.00	8.37	0.00	845.58
1974	2	93.35	19.50	0.00	7.87	31.57	880.00
1974	3	55.53	19.50	0.00	8.19	27.84	880.00
1974	4	27.94	19.50	0.00	6.36	2.08	880.00
1974	5	21.45	19.50	0.00	5.20	0.00	876.75
1974	6	16.06	19.50	0.00	4.42	0.00	868.90
1974	7	10.42	19.50	0.00	4.66	0.00	855.16
1974	8	6.49	19.50	0.00	5.71	0.00	836.44
1974	9	5.76	19.50	0.00	6.81	0.00	815.89
1975	10	3.27	19.50	0.00	7.47	0.00	792.19
1975	11	4.13	19.50	0.00	7.25	0.00	769.57
1975	12	84.91	19.50	0.00	7.27	0.00	827.71
1975	1	322.59	19.50	0.00	8.23	242.57	880.00
1975	2	286.93	19.50	0.00	7.93	259.50	880.00
1975	3	173.52	19.50	0.00	8.15	145.87	880.00
1975	4	86.50	19.50	0.00	6.33	60.67	880.00
1975	5	37.64	19.50	0.00	5.44	12.70	880.00
1975	6	24.92	19.50	0.00	4.48	0.94	880.00
1975	7	16.31	19.50	0.00	4.70	0.00	872.11
1975	8	10.05	19.50	0.00	5.79	0.00	856.88
1975	9	7.27	19.50	0.00	6.92	0.00	837.72
1976	10	5.53	19.50	0.00	7.45	0.00	816.30
1976	11	10.39	19.50	0.00	7.11	0.00	800.08
1976	12	19.27	19.50	0.00	8.24	0.00	791.61
1976	1	70.05	19.50	0.00	8.61	0.00	833.55
1976	2	130.67	19.50	0.00	6.99	57.73	880.00
1976	3	124.94	19.50	0.00	7.89	97.55	880.00
1976	4	61.65	19.50	0.00	6.43	35.72	880.00
1976	5	27.42	19.50	0.00	5.53	2.39	880.00
1976	6	18.07	19.50	0.00	4.49	0.00	874.08
1976	7	10.70	19.50	0.00	4.68	0.00	860.60
1976	8	7.55	19.50	0.00	5.69	0.00	842.96
1976	9	13.49	19.50	0.00	6.56	0.00	830.39
1977	10	9.10	19.50	0.00	7.54	0.00	812.45
1977	11	11.82	19.50	0.00	7.37	0.00	797.41
1977	12	66.39	19.50	0.00	8.13	0.00	836.16
1977	1	247.37	19.50	0.00	8.25	175.79	880.00
1977	2	202.29	19.50	0.00	7.61	175.18	880.00
1977	3	136.99	19.50	0.00	7.84	109.65	880.00
1977	4	74.04	19.50	0.00	6.13	48.41	880.00
1977	5	26.79	19.50	0.00	5.51	1.78	880.00
1977	6	17.66	19.50	0.00	4.49	0.00	873.67
1977	7	11.58	19.50	0.00	4.59	0.00	861.16
1977	8	6.95	19.50	0.00	5.74	0.00	842.87
1977	9	5.54	19.50	0.00	6.89	0.00	822.02
1978	10	6.50	19.50	0.00	7.30	0.00	801.72
1978	11	18.65	19.50	0.00	6.92	0.00	793.95

1978	12	19.98	19.50	0.00	8.16	0.00	786.27
1978	1	23.43	19.50	0.00	8.50	0.00	781.69
1978	2	14.96	19.50	0.00	7.90	0.00	769.25
1978	3	19.81	19.50	0.00	7.55	0.00	762.01
1978	4	12.18	19.50	0.00	5.73	0.00	748.96
1978	5	7.70	19.50	0.00	4.99	0.00	732.17
1978	6	5.55	19.50	0.00	4.01	0.00	714.21
1978	7	4.12	19.50	0.00	4.13	0.00	694.70
1978	8	2.81	19.50	0.00	5.02	0.00	672.99
1978	9	2.52	19.50	0.00	6.00	0.00	650.01
1979	10	3.36	19.50	0.00	6.30	0.00	627.57
1979	11	12.26	19.50	0.00	6.25	0.00	614.08
1979	12	17.83	19.50	0.00	6.98	0.00	605.42
1979	1	18.69	19.50	0.00	7.42	0.00	597.19
1979	2	62.62	19.50	0.00	6.30	0.00	634.01
1979	3	52.41	19.50	0.00	6.82	0.00	660.10
1979	4	23.43	19.50	0.00	5.33	0.00	658.70
1979	5	13.29	19.50	0.00	4.61	0.00	647.88
1979	6	8.20	19.50	0.00	3.73	0.00	632.85
1979	7	4.78	19.50	0.00	3.85	0.00	614.28
1979	8	3.58	19.50	0.00	4.58	0.00	593.77
1979	9	4.88	19.50	0.00	5.35	0.00	573.80
1980	10	3.67	19.50	0.00	5.96	0.00	552.01
1980	11	42.38	19.50	0.00	5.49	0.00	569.40
1980	12	53.97	19.50	0.00	6.57	0.00	597.30
1980	1	126.04	19.50	0.00	7.05	0.00	696.79
1980	2	158.62	19.50	0.00	7.06	0.00	828.86
1980	3	91.01	19.50	0.00	7.71	12.65	880.00
1980	4	38.32	19.50	0.00	6.37	12.45	880.00
1980	5	25.06	19.50	0.00	5.36	0.20	880.00
1980	6	16.38	19.50	0.00	4.48	0.00	872.40
1980	7	10.05	19.50	0.00	4.67	0.00	858.28
1980	8	7.17	19.50	0.00	5.63	0.00	840.31
1980	9	7.90	19.50	0.00	6.59	0.00	822.12
1981	10	7.95	19.50	0.00	7.16	0.00	803.41
1981	11	9.19	19.50	0.00	7.15	0.00	785.95
1981	12	9.54	19.50	0.00	8.33	0.00	767.66
1981	1	25.27	19.50	0.00	8.04	0.00	765.39
1981	2	16.47	19.50	0.00	7.92	0.00	754.44
1981	3	7.69	19.50	0.00	7.66	0.00	734.97
1981	4	10.29	19.50	0.00	5.51	0.00	720.25
1981	5	6.51	19.50	0.00	4.83	0.00	702.44
1981	6	4.48	19.50	0.00	3.92	0.00	683.50
1981	7	3.65	19.50	0.00	4.02	0.00	663.63
1981	8	1.44	19.50	0.00	4.86	0.00	640.71
1981	9	1.43	19.50	0.00	5.80	0.00	616.84
1982	10	1.17	19.50	0.00	6.27	0.00	592.24
1982	11	2.76	19.50	0.00	6.19	0.00	569.31
1982	12	2.95	19.50	0.00	6.76	0.00	546.00
1982	1	4.02	19.50	0.00	7.03	0.00	523.50

1982	2	3.62	19.50	0.00	6.24	0.00	501.38
1982	3	6.64	19.50	0.00	5.82	0.00	482.70
1982	4	7.11	19.50	0.00	4.40	0.00	465.91
1982	5	5.35	19.50	0.00	3.55	0.00	448.21
1982	6	3.47	19.50	0.00	2.92	0.00	429.25
1982	7	1.67	19.50	0.00	3.05	0.00	408.38
1982	8	0.63	19.50	0.00	3.59	0.00	385.92
1982	9	0.60	19.50	0.00	4.31	0.00	362.71
1983	10	1.90	19.50	0.00	4.46	0.00	340.64
1983	11	26.40	19.50	0.00	4.22	0.00	343.32
1983	12	34.71	19.50	0.00	4.77	0.00	353.76
1983	1	37.56	19.50	0.00	4.90	0.00	366.92
1983	2	21.64	19.50	0.00	4.93	0.00	364.13
1983	3	28.85	19.50	0.00	4.75	0.00	368.73
1983	4	20.07	19.50	0.00	3.73	0.00	365.57
1983	5	9.98	19.50	0.00	3.26	0.00	352.79
1983	6	7.25	19.50	0.00	2.58	0.00	337.96
1983	7	19.56	19.50	0.00	2.23	0.00	335.80
1983	8	12.62	19.50	0.00	3.26	0.00	325.66
1983	9	10.91	19.50	0.00	3.79	0.00	313.28
1984	10	10.93	19.50	0.00	4.04	0.00	300.67
1984	11	25.39	19.50	0.00	3.88	0.00	302.68
1984	12	26.71	19.50	0.00	4.63	0.00	305.26
1984	1	36.56	19.50	0.00	4.73	0.00	317.60
1984	2	216.35	19.50	0.00	4.01	0.00	510.43
1984	3	133.39	19.50	0.00	5.95	0.00	618.37
1984	4	28.76	19.50	0.00	5.00	0.00	622.63
1984	5	19.52	19.50	0.00	4.43	0.00	618.22
1984	6	12.76	19.50	0.00	3.61	0.00	607.87
1984	7	8.43	19.50	0.00	3.75	0.00	593.05
1984	8	5.04	19.50	0.00	4.59	0.00	574.00
1984	9	4.32	19.50	0.00	5.41	0.00	553.41
1985	10	6.95	19.50	0.00	5.63	0.00	535.23
1985	11	8.31	19.50	0.00	5.63	0.00	518.41
1985	12	28.57	19.50	0.00	6.50	0.00	520.99
1985	1	32.41	19.50	0.00	6.86	0.00	527.04
1985	2	36.02	19.50	0.00	6.03	0.00	537.53
1985	3	26.03	19.50	0.00	6.13	0.00	537.93
1985	4	34.12	19.50	0.00	4.36	0.00	548.19
1985	5	19.27	19.50	0.00	4.15	0.00	543.80
1985	6	12.01	19.50	0.00	3.34	0.00	532.98
1985	7	7.04	19.50	0.00	3.48	0.00	517.04
1985	8	4.21	19.50	0.00	4.19	0.00	497.56
1985	9	3.50	19.50	0.00	4.99	0.00	476.58
1986	10	3.30	19.50	0.00	5.30	0.00	455.07
1986	11	4.10	19.50	0.00	5.21	0.00	434.46
1986	12	8.17	19.50	0.00	5.57	0.00	417.56
1986	1	10.01	19.50	0.00	5.72	0.00	402.35
1986	2	8.39	19.50	0.00	5.34	0.00	385.90
1986	3	35.79	19.50	0.00	4.86	0.00	397.33

1986	4	25.65	19.50	0.00	3.96	0.00	399.52
1986	5	9.22	19.50	0.00	3.43	0.00	385.81
1986	6	6.34	19.50	0.00	2.69	0.00	369.97
1986	7	3.53	19.50	0.00	2.79	0.00	351.21
1986	8	3.59	19.50	0.00	3.21	0.00	332.08
1986	9	12.94	19.50	0.00	3.69	0.00	321.83
1987	10	8.94	19.50	0.00	4.14	0.00	307.13
1987	11	7.67	19.50	0.00	4.18	0.00	291.12
1987	12	113.79	19.50	0.00	4.22	0.00	381.20
1987	1	77.59	19.50	0.00	5.70	0.00	433.59
1987	2	143.05	19.50	0.00	5.26	0.00	551.88
1987	3	116.54	19.50	0.00	6.05	0.00	642.86
1987	4	42.66	19.50	0.00	5.15	0.00	660.87
1987	5	23.81	19.50	0.00	4.61	0.00	660.58
1987	6	18.72	19.50	0.00	3.72	0.00	656.08
1987	7	11.63	19.50	0.00	3.91	0.00	644.29
1987	8	9.04	19.50	0.00	4.78	0.00	629.05
1987	9	8.45	19.50	0.00	5.72	0.00	612.28
1988	10	16.92	19.50	0.00	5.97	0.00	603.73
1988	11	12.11	19.50	0.00	6.21	0.00	590.13
1988	12	15.02	19.50	0.00	6.69	0.00	578.96
1988	1	9.98	19.50	0.00	7.42	0.00	562.02
1988	2	152.16	19.50	0.00	5.62	0.00	689.06
1988	3	87.41	19.50	0.00	7.08	0.00	749.90
1988	4	17.54	19.50	0.00	5.79	0.00	742.15
1988	5	10.37	19.50	0.00	4.95	0.00	728.06
1988	6	11.50	19.50	0.00	3.80	0.00	716.27
1988	7	7.02	19.50	0.00	4.15	0.00	699.64
1988	8	4.36	19.50	0.00	5.06	0.00	679.44
1988	9	2.79	19.50	0.00	6.06	0.00	656.67
1989	10	5.43	19.50	0.00	6.34	0.00	636.26
1989	11	16.42	19.50	0.00	5.95	0.00	627.24
1989	12	33.17	19.50	0.00	6.90	0.00	634.01
1989	1	38.40	19.50	0.00	7.45	0.00	645.46
1989	2	47.84	19.50	0.00	6.94	0.00	666.86
1989	3	39.41	19.50	0.00	6.81	0.00	679.96
1989	4	26.69	19.50	0.00	5.35	0.00	681.79
1989	5	16.04	19.50	0.00	4.75	0.00	673.59
1989	6	10.78	19.50	0.00	3.82	0.00	661.05
1989	7	7.48	19.50	0.00	3.95	0.00	645.08
1989	8	4.45	19.50	0.00	4.80	0.00	625.23
1989	9	2.99	19.50	0.00	5.77	0.00	602.95
1990	10	3.66	19.50	0.00	5.97	0.00	581.15
1990	11	4.87	19.50	0.00	6.09	0.00	560.42
1990	12	36.87	19.50	0.00	6.39	0.00	571.40
1990	1	97.22	19.50	0.00	7.22	0.00	641.90
1990	2	79.32	19.50	0.00	6.95	0.00	694.77
1990	3	75.03	19.50	0.00	7.06	0.00	743.24
1990	4	47.88	19.50	0.00	5.77	0.00	765.85
1990	5	21.69	19.50	0.00	5.07	0.00	762.97

1990	6	18.09	19.50	0.00	3.94	0.00	757.62
1990	7	10.13	19.50	0.00	4.29	0.00	743.96
1990	8	6.12	19.50	0.00	5.26	0.00	725.32
1990	9	4.73	19.50	0.00	6.27	0.00	704.28
1991	10	2.70	19.50	0.00	6.85	0.00	680.64
1991	11	6.11	19.50	0.00	6.36	0.00	660.89
1991	12	8.47	19.50	0.00	7.39	0.00	642.46
1991	1	9.86	19.50	0.00	7.81	0.00	625.02
1991	2	7.38	19.50	0.00	6.93	0.00	605.97
1991	3	4.74	19.50	0.00	6.63	0.00	584.58
1991	4	4.78	19.50	0.00	4.96	0.00	564.90
1991	5	2.11	19.50	0.00	4.23	0.00	543.28
1991	6	1.39	19.50	0.00	3.34	0.00	521.82
1991	7	0.22	19.50	0.00	3.43	0.00	499.11
1991	8	0.21	19.50	0.00	4.13	0.00	475.69
1991	9	0.20	19.50	0.00	4.89	0.00	451.50
1992	10	0.18	19.50	0.00	5.16	0.00	427.02
1992	11	3.63	19.50	0.00	4.77	0.00	406.38
1992	12	56.66	19.50	0.00	4.94	0.00	438.59
1992	1	39.96	19.50	0.00	6.04	0.00	453.01
1992	2	29.20	19.50	0.00	5.53	0.00	457.18
1992	3	86.63	19.50	0.00	5.25	0.00	519.06
1992	4	61.42	19.50	0.00	4.58	0.00	556.40
1992	5	18.45	19.50	0.00	4.18	0.00	551.17
1992	6	12.31	19.50	0.00	3.35	0.00	540.64
1992	7	7.16	19.50	0.00	3.50	0.00	524.80
1992	8	4.28	19.50	0.00	4.19	0.00	505.39
1992	9	3.00	19.50	0.00	5.06	0.00	483.82
1993	10	2.50	19.50	0.00	5.43	0.00	461.39
1993	11	5.85	19.50	0.00	5.23	0.00	442.51
1993	12	16.99	19.50	0.00	5.73	0.00	434.27
1993	1	19.95	19.50	0.00	6.04	0.00	428.68
1993	2	17.48	19.50	0.00	5.52	0.00	421.13
1993	3	16.08	19.50	0.00	5.16	0.00	412.55
1993	4	10.42	19.50	0.00	4.02	0.00	399.45
1993	5	5.43	19.50	0.00	3.41	0.00	381.97
1993	6	3.39	19.50	0.00	2.71	0.00	363.15
1993	7	1.36	19.50	0.00	2.75	0.00	342.26
1993	8	0.34	19.50	0.00	3.29	0.00	319.81
1993	9	0.54	19.50	0.00	3.81	0.00	297.04
1994	10	4.08	19.50	0.00	3.90	0.00	277.72
1994	11	3.12	19.50	0.00	3.76	0.00	257.58
1994	12	9.45	19.50	0.00	4.06	0.00	243.47
1994	1	41.75	19.50	0.00	3.90	0.00	261.82
1994	2	28.44	19.50	0.00	4.05	0.00	266.71
1994	3	18.04	19.50	0.00	4.05	0.00	261.19
1994	4	18.76	19.50	0.00	2.93	0.00	257.53
1994	5	11.61	19.50	0.00	2.59	0.00	247.04
1994	6	7.84	19.50	0.00	2.09	0.00	233.29
1994	7	4.53	19.50	0.00	2.12	0.00	216.20

1994	8	2.98	19.50	0.00	2.44	0.00	197.24
1994	9	1.41	19.50	0.00	2.88	0.00	176.27
1995	10	1.54	19.50	0.00	2.83	0.00	155.48
1995	11	17.50	19.50	0.00	2.63	0.00	150.84
1995	12	150.08	19.50	0.00	2.93	0.00	278.50
1995	1	186.59	19.50	0.00	4.45	0.00	441.14
1995	2	614.38	19.50	0.00	5.07	150.94	880.00
1995	3	323.74	19.50	0.00	8.16	296.08	880.00
1995	4	52.26	19.50	0.00	6.24	26.52	880.00
1995	5	41.75	19.50	0.00	5.34	16.91	880.00
1995	6	30.02	19.50	0.00	4.46	6.06	880.00
1995	7	23.90	19.50	0.00	4.64	0.00	879.76
1995	8	18.59	19.50	0.00	5.67	0.00	873.18
1995	9	12.60	19.50	0.00	7.03	0.00	859.24
1996	10	11.40	19.50	0.00	7.55	0.00	843.59
1996	11	11.55	19.50	0.00	7.46	0.00	828.18
1996	12	18.75	19.50	0.00	8.50	0.00	818.93
1996	1	49.43	19.50	0.00	8.40	0.00	840.47
1996	2	48.53	19.50	0.00	8.33	0.00	861.17
1996	3	122.80	19.50	0.00	7.79	76.68	880.00
1996	4	84.23	19.50	0.00	6.13	58.60	880.00
1996	5	28.75	19.50	0.00	5.51	3.74	880.00
1996	6	20.12	19.50	0.00	4.47	0.00	876.15
1996	7	13.58	19.50	0.00	4.59	0.00	865.64
1996	8	8.15	19.50	0.00	5.68	0.00	848.61
1996	9	12.32	19.50	0.00	6.73	0.00	834.70
1997	10	13.25	19.50	0.00	7.36	0.00	821.10
1997	11	17.33	19.50	0.00	7.15	0.00	811.78
1997	12	15.66	19.50	0.00	8.08	0.00	799.85
1997	1	59.48	19.50	0.00	8.26	0.00	831.57
1997	2	46.38	19.50	0.00	8.30	0.00	850.15
1997	3	24.24	19.50	0.00	8.22	0.00	846.66
1997	4	18.15	19.50	0.00	6.23	0.00	839.08
1997	5	10.23	19.50	0.00	5.38	0.00	824.43
1997	6	7.10	19.50	0.00	4.31	0.00	807.72
1997	7	5.62	19.50	0.00	4.44	0.00	789.40
1997	8	2.53	19.50	0.00	5.44	0.00	766.99
1997	9	3.72	19.50	0.00	6.43	0.00	744.78
1998	10	12.97	19.50	0.00	6.67	0.00	731.58
1998	11	40.81	19.50	0.00	6.11	0.00	746.79
1998	12	142.55	19.50	0.00	7.15	0.00	862.68
1998	1	145.62	19.50	0.00	9.22	99.58	880.00
1998	2	125.28	19.50	0.00	7.68	98.10	880.00
1998	3	98.56	19.50	0.00	7.98	71.08	880.00
1998	4	58.53	19.50	0.00	6.15	32.88	880.00
1998	5	29.50	19.50	0.00	5.38	4.62	880.00
1998	6	20.39	19.50	0.00	4.47	0.00	876.42
1998	7	13.34	19.50	0.00	4.66	0.00	865.60
1998	8	8.86	19.50	0.00	5.68	0.00	849.28
1998	9	7.42	19.50	0.00	6.80	0.00	830.39

1999	10	5.92	19.50	0.00	7.38	0.00	809.44
1999	11	24.72	19.50	0.00	6.70	0.00	807.96
1999	12	55.59	19.50	0.00	8.07	0.00	835.98
1999	1	154.71	19.50	0.00	8.54	82.65	880.00
1999	2	1186.48	19.50	0.00	6.44	1160.54	880.00
1999	3	846.86	19.50	0.00	7.19	820.17	880.00
1999	4	213.66	19.50	0.00	6.22	187.94	880.00
1999	5	47.99	19.50	0.00	5.47	23.02	880.00
1999	6	38.59	19.50	0.00	4.41	14.68	880.00
1999	7	27.28	19.50	0.00	4.68	3.10	880.00
1999	8	17.36	19.50	0.00	5.82	0.00	872.04
1999	9	15.46	19.50	0.00	6.85	0.00	861.15
2000	10	12.86	19.50	0.00	7.64	0.00	846.86
2000	11	34.17	19.50	0.00	6.82	0.00	854.72
2000	12	78.85	19.50	0.00	8.69	25.38	880.00
2000	1	50.97	19.50	0.00	9.41	22.06	880.00
2000	2	71.50	19.50	0.00	7.67	44.33	880.00
2000	3	51.21	19.50	0.00	8.02	23.69	880.00
2000	4	32.79	19.50	0.00	6.13	7.16	880.00
2000	5	20.35	19.50	0.00	5.46	0.00	875.39
2000	6	15.53	19.50	0.00	4.47	0.00	866.95
2000	7	11.24	19.50	0.00	4.63	0.00	854.06
2000	8	7.28	19.50	0.00	5.71	0.00	836.13
2000	9	5.45	19.50	0.00	6.87	0.00	815.21
2001	10	7.36	19.50	0.00	7.29	0.00	795.78
2001	11	125.70	19.50	0.00	6.19	15.79	880.00
2001	12	119.25	19.50	0.00	8.49	91.26	880.00
2001	1	66.31	19.50	0.00	9.32	37.49	880.00
2001	2	48.16	19.50	0.00	8.61	20.05	880.00
2001	3	31.89	19.50	0.00	8.24	4.15	880.00
2001	4	21.71	19.50	0.00	6.37	0.00	875.84
2001	5	11.37	19.50	0.00	5.52	0.00	862.19
2001	6	8.65	19.50	0.00	4.41	0.00	846.92
2001	7	5.71	19.50	0.00	4.59	0.00	828.55
2001	8	3.26	19.50	0.00	5.61	0.00	806.70
2001	9	2.37	19.50	0.00	6.69	0.00	782.87
2002	10	4.87	19.50	0.00	7.08	0.00	761.17
2002	11	4.06	19.50	0.00	7.08	0.00	738.64
2002	12	8.24	19.50	0.00	7.94	0.00	719.45
2002	1	7.89	19.50	0.00	8.42	0.00	699.42
2002	2	7.10	19.50	0.00	7.34	0.00	679.68
2002	3	6.21	19.50	0.00	7.07	0.00	659.32
2002	4	4.40	19.50	0.00	5.21	0.00	639.01
2002	5	1.63	19.50	0.00	4.52	0.00	616.63
2002	6	2.99	19.50	0.00	3.48	0.00	596.63
2002	7	1.04	19.50	0.00	3.71	0.00	574.46
2002	8	0.29	19.50	0.00	4.49	0.00	550.76
2002	9	0.46	19.50	0.00	5.25	0.00	526.48
2003	10	0.38	19.50	0.00	5.66	0.00	501.69
2003	11	1.41	19.50	0.00	5.37	0.00	478.24

2003	12	1.04	19.50	0.00	6.25	0.00	453.53
2003	1	24.72	19.50	0.00	5.76	0.00	452.99
2003	2	62.26	19.50	0.00	5.28	0.00	490.47
2003	3	76.10	19.50	0.00	5.48	0.00	541.59
2003	4	39.09	19.50	0.00	4.65	0.00	556.54
2003	5	17.27	19.50	0.00	4.20	0.00	550.10
2003	6	11.79	19.50	0.00	3.31	0.00	539.08
2003	7	8.71	19.50	0.00	3.41	0.00	524.87
2003	8	4.63	19.50	0.00	4.22	0.00	505.78
2003	9	3.80	19.50	0.00	5.01	0.00	485.08
2004	10	2.41	19.50	0.00	5.41	0.00	462.58
2004	11	6.45	19.50	0.00	5.09	0.00	444.44
2004	12	15.01	19.50	0.00	5.94	0.00	434.01
2004	1	31.57	19.50	0.00	5.83	0.00	440.25
2004	2	22.41	19.50	0.00	5.55	0.00	437.60
2004	3	15.85	19.50	0.00	5.33	0.00	428.63
2004	4	14.60	19.50	0.00	4.12	0.00	419.60
2004	5	9.73	19.50	0.00	3.46	0.00	406.37
2004	6	7.07	19.50	0.00	2.82	0.00	391.12
2004	7	4.59	19.50	0.00	2.88	0.00	373.33
2004	8	2.07	19.50	0.00	3.48	0.00	352.42
2004	9	2.42	19.50	0.00	4.09	0.00	331.26

ANNEXURE D

SIMULATION OF RESERVOIR PERFORMANCE FOR CORUMANA DAM, FULL SUPPLY LEVEL 117 MASL, HISTORICAL FIRM YIELD AS TARGET DRAFT (RESSIM MODEL)

SIMULATION OF RESERVOIR PERFORMANCE AT Corumana Dam FSL 117 masl Units $M.m^3$

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YEAR	MONTH	INFLOW	DRAFT	SHORTFALL	EVAPORATION	SPILLAGE	STORAGE
1921	10	11.34	20.90	0.00	7.65	0.00	865.79
1921	11	72.91	20.90	0.00	7.12	0.00	910.68
1921	12	69.54	20.90	0.00	8.48	0.00	950.84
1921	1	25.22	20.90	0.00	9.94	0.00	945.22
1921	2	15.02	20.90	0.00	9.00	0.00	930.34
1921	3	22.93	20.90	0.00	8.37	0.00	924.00
1921	4	17.78	20.90	0.00	6.48	0.00	914.40
1921	5	10.69	20.90	0.00	5.56	0.00	898.63
1921	6	9.44	20.90	0.00	4.34	0.00	882.83
1921	7	6.22	20.90	0.00	4.70	0.00	863.44
1921	8	4.86	20.90	0.00	5.57	0.00	841.84
1921	9	3.35	20.90	0.00	6.83	0.00	817.45
1922	10	5.01	20.90	0.00	7.29	0.00	794.27
1922	11	17.87	20.90	0.00	6.98	0.00	784.26
1922	12	17.79	20.90	0.00	8.37	0.00	772.78
1922	1	234.27	20.90	0.00	7.52	0.00	978.64
1922	2	437.24	20.90	0.00	8.25	11.73	1375.00
1922	3	234.80	20.90	0.00	10.55	203.35	1375.00
1922	4	48.06	20.90	0.00	8.10	19.06	1375.00
1922	5	25.52	20.90	0.00	7.23	0.00	1372.39
1922	6	16.25	20.90	0.00	5.86	0.00	1361.87
1922	7	10.51	20.90	0.00	6.02	0.00	1345.46
1922	8	6.00	20.90	0.00	7.51	0.00	1323.05
1922	9	4.32	20.90	0.00	9.03	0.00	1297.44
1923	10	2.31	20.90	0.00	9.84	0.00	1269.01
1923	11	3.02	20.90	0.00	9.67	0.00	1241.46
1923	12	27.64	20.90	0.00	10.30	0.00	1237.90
1923	1	19.98	20.90	0.00	11.59	0.00	1225.40
1923	2	8.61	20.90	0.00	10.26	0.00	1202.85
1923	3	62.62	20.90	0.00	9.17	0.00	1235.40
1923	4	37.08	20.90	0.00	7.87	0.00	1243.71
1923	5	13.46	20.90	0.00	6.59	0.00	1229.68
1923	6	8.39	20.90	0.00	5.49	0.00	1211.68
1923	7	5.51	20.90	0.00	5.69	0.00	1190.60
1923	8	4.30	20.90	0.00	6.92	0.00	1167.08
1923	9	3.84	20.90	0.00	8.22	0.00	1141.81

1924	10	3.42	20.90	0.00	8.92	0.00	1115.41
1924	11	36.75	20.90	0.00	8.17	0.00	1123.08
1924	12	50.22	20.90	0.00	9.77	0.00	1142.63
1924	1	128.69	20.90	0.00	9.99	0.00	1240.44
1924	2	152.05	20.90	0.00	9.53	0.00	1362.06
1924	3	1161.68	20.90	0.00	8.77	1119.07	1375.00
1924	4	575.30	20.90	0.00	8.05	546.35	1375.00
1924	5	49.86	20.90	0.00	7.12	21.84	1375.00
1924	6	32.95	20.90	0.00	5.86	6.19	1375.00
1924	7	22.90	20.90	0.00	6.13	0.00	1370.87
1924	8	13.88	20.90	0.00	7.60	0.00	1356.26
1924	9	16.12	20.90	0.00	8.85	0.00	1342.62
1925	10	12.79	20.90	0.00	9.90	0.00	1324.61
1925	11	14.73	20.90	0.00	9.91	0.00	1308.53
1925	12	11.33	20.90	0.00	11.45	0.00	1287.52
1925	1	17.46	20.90	0.00	11.43	0.00	1272.64
1925	2	29.79	20.90	0.00	10.10	0.00	1271.44
1925	3	34.57	20.90	0.00	9.97	0.00	1275.14
1925	4	19.07	20.90	0.00	8.02	0.00	1265.29
1925	5	11.77	20.90	0.00	6.67	0.00	1249.49
1925	6	7.52	20.90	0.00	5.54	0.00	1230.57
1925	7	10.40	20.90	0.00	5.59	0.00	1214.48
1925	8	5.98	20.90	0.00	7.06	0.00	1192.50
1925	9	6.17	20.90	0.00	8.31	0.00	1169.46
1926	10	2.29	20.90	0.00	9.29	0.00	1141.57
1926	11	4.95	20.90	0.00	8.88	0.00	1116.74
1926	12	6.42	20.90	0.00	10.26	0.00	1092.00
1926	1	13.68	20.90	0.00	10.62	0.00	1074.16
1926	2	27.89	20.90	0.00	9.48	0.00	1071.66
1926	3	31.92	20.90	0.00	9.37	0.00	1073.31
1926	4	21.46	20.90	0.00	7.17	0.00	1066.70
1926	5	12.53	20.90	0.00	6.22	0.00	1052.11
1926	6	9.08	20.90	0.00	4.99	0.00	1035.31
1926	7	21.85	20.90	0.00	4.93	0.00	1031.32
1926	8	13.00	20.90	0.00	6.35	0.00	1017.07
1926	9	8.71	20.90	0.00	7.68	0.00	997.21
1927	10	12.88	20.90	0.00	7.94	0.00	981.25
1927	11	11.88	20.90	0.00	8.37	0.00	963.86
1927	12	9.55	20.90	0.00	9.47	0.00	943.04
1927	1	79.73	20.90	0.00	9.13	0.00	992.74
1927	2	61.17	20.90	0.00	9.11	0.00	1023.91
1927	3	33.02	20.90	0.00	9.08	0.00	1026.95
1927	4	27.06	20.90	0.00	6.83	0.00	1026.28
1927	5	16.06	20.90	0.00	6.07	0.00	1015.37
1927	6	10.38	20.90	0.00	4.89	0.00	999.96
1927	7	7.83	20.90	0.00	5.03	0.00	981.86
1927	8	4.88	20.90	0.00	6.20	0.00	959.64
1927	9	3.54	20.90	0.00	7.39	0.00	934.89
1928	10	1.77	20.90	0.00	7.89	0.00	907.87
1928	11	2.45	20.90	0.00	7.83	0.00	881.59

1928	12	10.92	20.90	0.00	8.88	0.00	862.72
1928	1	21.96	20.90	0.00	9.07	0.00	854.72
1928	2	49.40	20.90	0.00	8.07	0.00	875.15
1928	3	70.89	20.90	0.00	8.01	0.00	917.13
1928	4	40.91	20.90	0.00	6.58	0.00	930.56
1928	5	16.50	20.90	0.00	5.72	0.00	920.44
1928	6	12.76	20.90	0.00	4.57	0.00	907.73
1928	7	7.82	20.90	0.00	4.78	0.00	889.87
1928	8	5.16	20.90	0.00	5.85	0.00	868.28
1928	9	5.21	20.90	0.00	6.91	0.00	845.68
1929	10	18.32	20.90	0.00	7.24	0.00	835.86
1929	11	53.08	20.90	0.00	7.04	0.00	861.01
1929	12	49.05	20.90	0.00	8.59	0.00	880.57
1929	1	48.95	20.90	0.00	9.39	0.00	899.23
1929	2	45.47	20.90	0.00	8.43	0.00	915.37
1929	3	106.28	20.90	0.00	7.58	0.00	993.17
1929	4	82.22	20.90	0.00	6.84	0.00	1047.65
1929	5	34.02	20.90	0.00	6.08	0.00	1054.69
1929	6	21.90	20.90	0.00	4.97	0.00	1050.72
1929	7	14.27	20.90	0.00	5.18	0.00	1038.91
1929	8	8.10	20.90	0.00	6.42	0.00	1019.68
1929	9	6.02	20.90	0.00	7.66	0.00	997.14
1930	10	1.74	20.90	0.00	8.41	0.00	969.57
1930	11	2.92	20.90	0.00	8.17	0.00	943.42
1930	12	87.63	20.90	0.00	8.42	0.00	1001.73
1930	1	63.00	20.90	0.00	9.94	0.00	1033.89
1930	2	19.55	20.90	0.00	9.06	0.00	1023.49
1930	3	24.11	20.90	0.00	8.93	0.00	1017.76
1930	4	21.96	20.90	0.00	6.84	0.00	1011.99
1930	5	10.43	20.90	0.00	6.02	0.00	995.49
1930	6	8.30	20.90	0.00	4.83	0.00	978.06
1930	7	11.67	20.90	0.00	4.75	0.00	964.09
1930	8	5.28	20.90	0.00	6.15	0.00	942.32
1930	9	4.56	20.90	0.00	7.31	0.00	918.67
1931	10	2.70	20.90	0.00	7.85	0.00	892.62
1931	11	17.50	20.90	0.00	7.73	0.00	881.49
1931	12	27.18	20.90	0.00	8.82	0.00	878.95
1931	1	20.90	20.90	0.00	9.43	0.00	869.52
1931	2	19.94	20.90	0.00	8.33	0.00	860.23
1931	3	18.22	20.90	0.00	7.83	0.00	849.72
1931	4	11.72	20.90	0.00	6.14	0.00	834.40
1931	5	8.53	20.90	0.00	5.28	0.00	816.75
1931	6	6.02	20.90	0.00	4.22	0.00	797.65
1931	7	3.47	20.90	0.00	4.43	0.00	775.80
1931	8	0.83	20.90	0.00	5.39	0.00	750.33
1931	9	1.16	20.90	0.00	6.37	0.00	724.22
1932	10	0.76	20.90	0.00	6.86	0.00	697.22
1932	11	4.57	20.90	0.00	6.75	0.00	674.15
1932	12	18.23	20.90	0.00	7.27	0.00	664.21
1932	1	45.05	20.90	0.00	7.52	0.00	680.84

1932	2	39.07	20.90	0.00	7.21	0.00	691.80
1932	3	26.37	20.90	0.00	6.97	0.00	690.30
1932	4	18.91	20.90	0.00	5.50	0.00	682.80
1932	5	10.14	20.90	0.00	4.76	0.00	667.29
1932	6	6.68	20.90	0.00	3.80	0.00	649.27
1932	7	4.52	20.90	0.00	3.88	0.00	629.01
1932	8	1.66	20.90	0.00	4.76	0.00	605.01
1932	9	1.44	20.90	0.00	5.63	0.00	579.92
1933	10	0.82	20.90	0.00	5.96	0.00	553.88
1933	11	31.99	20.90	0.00	5.47	0.00	559.50
1933	12	42.25	20.90	0.00	6.68	0.00	574.17
1933	1	89.72	20.90	0.00	6.85	0.00	636.14
1933	2	76.25	20.90	0.00	7.03	0.00	684.45
1933	3	48.82	20.90	0.00	6.83	0.00	705.54
1933	4	35.22	20.90	0.00	5.55	0.00	714.31
1933	5	22.65	20.90	0.00	4.81	0.00	711.25
1933	6	17.99	20.90	0.00	3.86	0.00	704.48
1933	7	10.76	20.90	0.00	4.08	0.00	690.26
1933	8	6.01	20.90	0.00	5.03	0.00	670.35
1933	9	5.70	20.90	0.00	5.86	0.00	649.29
1934	10	4.28	20.90	0.00	6.42	0.00	626.25
1934	11	33.73	20.90	0.00	6.07	0.00	633.01
1934	12	56.17	20.90	0.00	6.95	0.00	661.33
1934	1	54.90	20.90	0.00	7.95	0.00	687.39
1934	2	44.18	20.90	0.00	7.10	0.00	703.57
1934	3	28.52	20.90	0.00	7.32	0.00	703.87
1934	4	17.97	20.90	0.00	5.55	0.00	695.39
1934	5	10.92	20.90	0.00	4.62	0.00	680.79
1934	6	7.95	20.90	0.00	3.73	0.00	664.11
1934	7	5.54	20.90	0.00	3.96	0.00	644.79
1934	8	2.68	20.90	0.00	4.83	0.00	621.75
1934	9	2.33	20.90	0.00	5.68	0.00	597.50
1935	10	0.82	20.90	0.00	6.16	0.00	571.26
1935	11	0.65	20.90	0.00	5.94	0.00	545.07
1935	12	2.15	20.90	0.00	6.63	0.00	519.69
1935	1	20.76	20.90	0.00	6.48	0.00	513.07
1935	2	35.33	20.90	0.00	6.08	0.00	521.42
1935	3	64.55	20.90	0.00	5.67	0.00	559.40
1935	4	43.20	20.90	0.00	4.79	0.00	576.91
1935	5	21.32	20.90	0.00	4.12	0.00	573.21
1935	6	15.05	20.90	0.00	3.46	0.00	563.90
1935	7	10.94	20.90	0.00	3.56	0.00	550.38
1935	8	5.96	20.90	0.00	4.36	0.00	531.08
1935	9	10.43	20.90	0.00	4.96	0.00	515.65
1936	10	15.92	20.90	0.00	5.42	0.00	505.25
1936	11	31.66	20.90	0.00	5.00	0.00	511.01
1936	12	63.15	20.90	0.00	6.25	0.00	547.01
1936	1	156.67	20.90	0.00	6.58	0.00	676.20
1936	2	590.59	20.90	0.00	5.72	0.00	1240.17
1936	3	277.90	20.90	0.00	9.95	112.22	1375.00

1936	4	50.40	20.90	0.00	8.33	21.17	1375.00
1936	5	29.74	20.90	0.00	7.18	1.66	1375.00
1936	6	20.00	20.90	0.00	5.87	0.00	1368.23
1936	7	12.90	20.90	0.00	6.11	0.00	1354.12
1936	8	8.46	20.90	0.00	7.53	0.00	1334.15
1936	9	7.74	20.90	0.00	8.98	0.00	1312.01
1937	10	4.30	20.90	0.00	9.84	0.00	1285.57
1937	11	4.32	20.90	0.00	9.63	0.00	1259.36
1937	12	12.80	20.90	0.00	10.92	0.00	1240.34
1937	1	19.03	20.90	0.00	11.29	0.00	1227.18
1937	2	20.89	20.90	0.00	10.32	0.00	1216.85
1937	3	14.36	20.90	0.00	9.97	0.00	1200.34
1937	4	32.27	20.90	0.00	6.88	0.00	1204.83
1937	5	17.80	20.90	0.00	6.66	0.00	1195.08
1937	6	11.34	20.90	0.00	5.35	0.00	1180.17
1937	7	7.85	20.90	0.00	5.44	0.00	1161.68
1937	8	4.56	20.90	0.00	6.80	0.00	1138.53
1937	9	9.99	20.90	0.00	7.86	0.00	1119.76
1938	10	9.98	20.90	0.00	8.84	0.00	1100.00
1938	11	9.31	20.90	0.00	8.68	0.00	1079.73
1938	12	453.08	20.90	0.00	8.88	128.02	1375.00
1938	1	281.34	20.90	0.00	11.83	248.61	1375.00
1938	2	720.78	20.90	0.00	9.60	690.28	1375.00
1938	3	474.50	20.90	0.00	10.57	443.03	1375.00
1938	4	101.78	20.90	0.00	8.08	72.80	1375.00
1938	5	37.52	20.90	0.00	7.21	9.41	1375.00
1938	6	25.91	20.90	0.00	5.85	0.00	1374.16
1938	7	25.48	20.90	0.00	5.98	0.00	1372.75
1938	8	16.72	20.90	0.00	7.59	0.00	1360.98
1938	9	18.61	20.90	0.00	8.93	0.00	1349.76
1939	10	12.84	20.90	0.00	9.95	0.00	1331.75
1939	11	114.04	20.90	0.00	9.58	40.31	1375.00
1939	12	127.03	20.90	0.00	11.04	95.09	1375.00
1939	1	60.18	20.90	0.00	12.31	26.97	1375.00
1939	2	33.91	20.90	0.00	11.06	1.95	1375.00
1939	3	42.21	20.90	0.00	10.45	10.86	1375.00
1939	4	34.15	20.90	0.00	7.85	5.40	1375.00
1939	5	21.85	20.90	0.00	6.82	0.00	1369.13
1939	6	23.46	20.90	0.00	5.39	0.00	1366.30
1939	7	14.76	20.90	0.00	6.12	0.00	1354.04
1939	8	10.26	20.90	0.00	7.51	0.00	1335.89
1939	9	11.53	20.90	0.00	8.96	0.00	1317.56
1940	10	8.22	20.90	0.00	9.85	0.00	1295.03
1940	11	54.57	20.90	0.00	8.56	0.00	1320.14
1940	12	60.20	20.90	0.00	11.02	0.00	1348.41
1940	1	34.34	20.90	0.00	12.15	0.00	1349.71
1940	2	23.69	20.90	0.00	11.12	0.00	1341.38
1940	3	25.02	20.90	0.00	10.61	0.00	1334.88
1940	4	46.71	20.90	0.00	7.70	0.00	1353.00
1940	5	28.14	20.90	0.00	7.17	0.00	1353.06

1940	6	14.45	20.90	0.00	5.81	0.00	1340.80
1940	7	9.64	20.90	0.00	5.97	0.00	1323.57
1940	8	5.60	20.90	0.00	7.43	0.00	1300.84
1940	9	4.37	20.90	0.00	8.95	0.00	1275.36
1941	10	2.60	20.90	0.00	9.36	0.00	1247.70
1941	11	2.97	20.90	0.00	9.35	0.00	1220.42
1941	12	33.05	20.90	0.00	9.93	0.00	1222.64
1941	1	66.31	20.90	0.00	10.50	0.00	1257.55
1941	2	33.22	20.90	0.00	10.44	0.00	1259.42
1941	3	60.73	20.90	0.00	9.50	0.00	1289.75
1941	4	33.54	20.90	0.00	8.01	0.00	1294.38
1941	5	17.57	20.90	0.00	6.78	0.00	1284.28
1941	6	19.13	20.90	0.00	5.44	0.00	1277.07
1941	7	11.79	20.90	0.00	5.87	0.00	1262.08
1941	8	8.35	20.90	0.00	7.17	0.00	1242.36
1941	9	10.09	20.90	0.00	8.41	0.00	1223.15
1942	10	9.60	20.90	0.00	9.40	0.00	1202.45
1942	11	20.26	20.90	0.00	8.82	0.00	1192.99
1942	12	24.73	20.90	0.00	10.28	0.00	1186.54
1942	1	23.42	20.90	0.00	11.23	0.00	1177.83
1942	2	19.66	20.90	0.00	10.12	0.00	1166.47
1942	3	37.99	20.90	0.00	9.40	0.00	1174.16
1942	4	74.81	20.90	0.00	6.02	0.00	1222.05
1942	5	43.01	20.90	0.00	6.69	0.00	1237.47
1942	6	20.17	20.90	0.00	5.50	0.00	1231.24
1942	7	19.27	20.90	0.00	5.49	0.00	1224.12
1942	8	17.47	20.90	0.00	6.93	0.00	1213.76
1942	9	19.27	20.90	0.00	8.44	0.00	1203.69
1943	10	14.07	20.90	0.00	9.28	0.00	1187.59
1943	11	24.12	20.90	0.00	8.29	0.00	1182.52
1943	12	14.40	20.90	0.00	10.65	0.00	1165.37
1943	1	17.67	20.90	0.00	10.90	0.00	1151.23
1943	2	103.92	20.90	0.00	9.16	0.00	1225.09
1943	3	70.92	20.90	0.00	10.12	0.00	1264.99
1943	4	21.01	20.90	0.00	7.85	0.00	1257.25
1943	5	11.21	20.90	0.00	6.82	0.00	1240.74
1943	6	9.58	20.90	0.00	5.43	0.00	1223.98
1943	7	5.76	20.90	0.00	5.73	0.00	1203.11
1943	8	3.24	20.90	0.00	7.02	0.00	1178.43
1943	9	3.29	20.90	0.00	8.38	0.00	1152.44
1944	10	8.92	20.90	0.00	9.07	0.00	1131.39
1944	11	9.99	20.90	0.00	8.82	0.00	1111.66
1944	12	8.30	20.90	0.00	10.28	0.00	1088.78
1944	1	33.91	20.90	0.00	9.98	0.00	1091.81
1944	2	34.53	20.90	0.00	9.30	0.00	1096.14
1944	3	29.27	20.90	0.00	9.25	0.00	1095.27
1944	4	21.85	20.90	0.00	7.30	0.00	1088.92
1944	5	11.73	20.90	0.00	6.21	0.00	1073.54
1944	6	7.75	20.90	0.00	5.06	0.00	1055.33
1944	7	4.47	20.90	0.00	5.20	0.00	1033.70

1944	8	1.60	20.90	0.00	6.40	0.00	1008.00
1944	9	1.12	20.90	0.00	7.66	0.00	980.56
1945	10	3.73	20.90	0.00	8.09	0.00	955.30
1945	11	3.15	20.90	0.00	8.02	0.00	929.53
1945	12	3.05	20.90	0.00	9.38	0.00	902.30
1945	1	304.33	20.90	0.00	8.45	0.00	1177.28
1945	2	277.34	20.90	0.00	8.50	50.22	1375.00
1945	3	83.37	20.90	0.00	10.84	51.63	1375.00
1945	4	30.94	20.90	0.00	8.36	1.68	1375.00
1945	5	18.30	20.90	0.00	7.24	0.00	1365.16
1945	6	12.02	20.90	0.00	5.84	0.00	1350.44
1945	7	7.50	20.90	0.00	6.08	0.00	1330.97
1945	8	3.99	20.90	0.00	7.45	0.00	1306.60
1945	9	2.50	20.90	0.00	8.97	0.00	1279.23
1946	10	1.26	20.90	0.00	9.74	0.00	1249.85
1946	11	9.19	20.90	0.00	9.26	0.00	1228.88
1946	12	13.42	20.90	0.00	10.68	0.00	1210.71
1946	1	19.30	20.90	0.00	11.26	0.00	1197.85
1946	2	36.31	20.90	0.00	10.06	0.00	1203.20
1946	3	38.43	20.90	0.00	9.64	0.00	1211.09
1946	4	26.44	20.90	0.00	7.63	0.00	1208.99
1946	5	14.61	20.90	0.00	6.67	0.00	1196.03
1946	6	12.03	20.90	0.00	5.33	0.00	1181.83
1946	7	7.39	20.90	0.00	5.56	0.00	1162.77
1946	8	3.84	20.90	0.00	6.88	0.00	1138.83
1946	9	3.43	20.90	0.00	8.12	0.00	1113.24
1947	10	3.62	20.90	0.00	8.74	0.00	1087.22
1947	11	22.55	20.90	0.00	8.10	0.00	1080.78
1947	12	92.54	20.90	0.00	9.74	0.00	1142.68
1947	1	67.15	20.90	0.00	10.92	0.00	1178.01
1947	2	34.88	20.90	0.00	9.83	0.00	1182.16
1947	3	127.61	20.90	0.00	8.59	0.00	1280.28
1947	4	82.23	20.90	0.00	7.96	0.00	1333.66
1947	5	24.37	20.90	0.00	7.11	0.00	1330.02
1947	6	15.66	20.90	0.00	5.75	0.00	1319.03
1947	7	9.85	20.90	0.00	5.92	0.00	1302.06
1947	8	5.21	20.90	0.00	7.36	0.00	1279.00
1947	9	5.10	20.90	0.00	8.78	0.00	1254.43
1948	10	5.96	20.90	0.00	9.40	0.00	1230.09
1948	11	7.88	20.90	0.00	9.36	0.00	1207.70
1948	12	8.25	20.90	0.00	10.76	0.00	1184.29
1948	1	36.08	20.90	0.00	10.56	0.00	1188.91
1948	2	45.25	20.90	0.00	9.86	0.00	1203.40
1948	3	33.94	20.90	0.00	9.88	0.00	1206.56
1948	4	22.21	20.90	0.00	7.52	0.00	1200.36
1948	5	15.46	20.90	0.00	6.45	0.00	1188.46
1948	6	10.93	20.90	0.00	5.21	0.00	1173.28
1948	7	7.26	20.90	0.00	5.50	0.00	1154.14
1948	8	3.96	20.90	0.00	6.84	0.00	1130.36
1948	9	3.84	20.90	0.00	8.04	0.00	1105.26

1949	10	1.38	20.90	0.00	8.95	0.00	1076.79
1949	11	28.20	20.90	0.00	8.11	0.00	1075.98
1949	12	35.60	20.90	0.00	9.22	0.00	1081.46
1949	1	34.04	20.90	0.00	10.52	0.00	1084.08
1949	2	31.10	20.90	0.00	9.05	0.00	1085.23
1949	3	34.66	20.90	0.00	8.95	0.00	1090.04
1949	4	25.01	20.90	0.00	7.11	0.00	1087.04
1949	5	18.21	20.90	0.00	6.22	0.00	1078.13
1949	6	12.72	20.90	0.00	5.01	0.00	1064.94
1949	7	8.59	20.90	0.00	5.22	0.00	1047.41
1949	8	5.81	20.90	0.00	6.45	0.00	1025.87
1949	9	4.77	20.90	0.00	7.76	0.00	1001.99
1950	10	1.96	20.90	0.00	8.42	0.00	974.62
1950	11	3.34	20.90	0.00	8.16	0.00	948.90
1950	12	63.09	20.90	0.00	8.28	0.00	982.82
1950	1	47.67	20.90	0.00	10.20	0.00	999.39
1950	2	10.68	20.90	0.00	9.27	0.00	979.90
1950	3	16.51	20.90	0.00	8.64	0.00	966.86
1950	4	23.19	20.90	0.00	6.41	0.00	962.75
1950	5	17.72	20.90	0.00	5.63	0.00	953.94
1950	6	10.75	20.90	0.00	4.71	0.00	939.08
1950	7	7.52	20.90	0.00	4.87	0.00	920.84
1950	8	8.81	20.90	0.00	5.74	0.00	903.01
1950	9	7.36	20.90	0.00	7.11	0.00	882.36
1951	10	11.09	20.90	0.00	7.50	0.00	865.06
1951	11	9.05	20.90	0.00	7.45	0.00	845.76
1951	12	14.81	20.90	0.00	8.52	0.00	831.15
1951	1	15.66	20.90	0.00	8.67	0.00	817.24
1951	2	16.36	20.90	0.00	7.90	0.00	804.80
1951	3	23.19	20.90	0.00	7.79	0.00	799.30
1951	4	15.50	20.90	0.00	6.02	0.00	787.88
1951	5	9.04	20.90	0.00	5.12	0.00	770.90
1951	6	7.23	20.90	0.00	4.04	0.00	753.19
1951	7	6.72	20.90	0.00	4.20	0.00	734.81
1951	8	3.62	20.90	0.00	5.21	0.00	712.32
1951	9	2.15	20.90	0.00	6.24	0.00	687.33
1952	10	2.03	20.90	0.00	6.65	0.00	661.81
1952	11	37.52	20.90	0.00	5.93	0.00	672.50
1952	12	64.42	20.90	0.00	7.40	0.00	708.62
1952	1	66.48	20.90	0.00	7.77	0.00	746.43
1952	2	141.26	20.90	0.00	7.39	0.00	859.40
1952	3	123.76	20.90	0.00	8.24	0.00	954.02
1952	4	55.95	20.90	0.00	6.40	0.00	982.67
1952	5	28.68	20.90	0.00	5.89	0.00	984.55
1952	6	18.95	20.90	0.00	4.80	0.00	977.80
1952	7	11.93	20.90	0.00	4.99	0.00	963.85
1952	8	6.92	20.90	0.00	6.14	0.00	943.72
1952	9	6.14	20.90	0.00	7.21	0.00	921.75
1953	10	3.65	20.90	0.00	7.88	0.00	896.62
1953	11	14.14	20.90	0.00	7.37	0.00	882.49

1953	12	27.01	20.90	0.00	8.96	0.00	879.64
1953	1	64.28	20.90	0.00	9.53	0.00	913.49
1953	2	84.27	20.90	0.00	8.20	0.00	968.66
1953	3	50.04	20.90	0.00	8.74	0.00	989.07
1953	4	31.57	20.90	0.00	6.73	0.00	993.01
1953	5	19.87	20.90	0.00	5.87	0.00	986.11
1953	6	13.32	20.90	0.00	4.79	0.00	973.74
1953	7	8.01	20.90	0.00	4.99	0.00	955.86
1953	8	5.96	20.90	0.00	6.03	0.00	934.88
1953	9	4.70	20.90	0.00	6.98	0.00	911.70
1954	10	3.76	20.90	0.00	7.90	0.00	886.66
1954	11	15.78	20.90	0.00	7.21	0.00	874.34
1954	12	13.36	20.90	0.00	8.82	0.00	857.98
1954	1	167.34	20.90	0.00	8.64	0.00	995.78
1954	2	246.54	20.90	0.00	8.74	0.00	1212.68
1954	3	196.28	20.90	0.00	9.85	3.21	1375.00
1954	4	86.90	20.90	0.00	8.17	57.83	1375.00
1954	5	37.80	20.90	0.00	7.13	9.77	1375.00
1954	6	27.39	20.90	0.00	5.80	0.69	1375.00
1954	7	18.13	20.90	0.00	6.13	0.00	1366.10
1954	8	10.50	20.90	0.00	7.58	0.00	1348.12
1954	9	7.44	20.90	0.00	9.15	0.00	1325.51
1955	10	11.54	20.90	0.00	9.52	0.00	1306.62
1955	11	40.15	20.90	0.00	9.07	0.00	1316.81
1955	12	74.25	20.90	0.00	10.88	0.00	1359.27
1955	1	50.70	20.90	0.00	12.28	1.79	1375.00
1955	2	372.29	20.90	0.00	9.82	341.57	1375.00
1955	3	286.24	20.90	0.00	10.83	254.51	1375.00
1955	4	75.43	20.90	0.00	8.43	46.10	1375.00
1955	5	33.55	20.90	0.00	6.96	5.69	1375.00
1955	6	26.35	20.90	0.00	5.79	0.00	1374.66
1955	7	18.56	20.90	0.00	6.14	0.00	1366.18
1955	8	11.91	20.90	0.00	7.58	0.00	1349.61
1955	9	13.73	20.90	0.00	8.76	0.00	1333.68
1956	10	10.45	20.90	0.00	10.00	0.00	1313.24
1956	11	9.13	20.90	0.00	9.78	0.00	1291.68
1956	12	14.87	20.90	0.00	10.97	0.00	1274.68
1956	1	16.10	20.90	0.00	11.64	0.00	1258.24
1956	2	32.65	20.90	0.00	10.24	0.00	1259.75
1956	3	50.90	20.90	0.00	9.85	0.00	1279.90
1956	4	37.34	20.90	0.00	7.73	0.00	1288.61
1956	5	22.35	20.90	0.00	6.94	0.00	1283.12
1956	6	15.51	20.90	0.00	5.58	0.00	1272.15
1956	7	14.35	20.90	0.00	5.62	0.00	1259.98
1956	8	11.37	20.90	0.00	7.11	0.00	1243.33
1956	9	11.37	20.90	0.00	8.42	0.00	1225.38
1957	10	13.76	20.90	0.00	9.21	0.00	1209.03
1957	11	14.77	20.90	0.00	9.41	0.00	1193.50
1957	12	25.66	20.90	0.00	10.47	0.00	1187.79
1957	1	499.20	20.90	0.00	10.21	280.88	1375.00

1957	2	269.61	20.90	0.00	11.03	237.68	1375.00
1957	3	37.83	20.90	0.00	10.89	6.04	1375.00
1957	4	32.22	20.90	0.00	8.23	3.09	1375.00
1957	5	19.13	20.90	0.00	7.23	0.00	1366.00
1957	6	13.42	20.90	0.00	5.80	0.00	1352.72
1957	7	8.54	20.90	0.00	6.08	0.00	1334.29
1957	8	4.81	20.90	0.00	7.47	0.00	1310.73
1957	9	7.79	20.90	0.00	8.70	0.00	1288.92
1958	10	6.32	20.90	0.00	9.72	0.00	1264.62
1958	11	14.43	20.90	0.00	9.33	0.00	1248.82
1958	12	24.35	20.90	0.00	10.21	0.00	1242.06
1958	1	45.38	20.90	0.00	11.22	0.00	1255.32
1958	2	99.74	20.90	0.00	10.27	0.00	1323.89
1958	3	55.12	20.90	0.00	10.64	0.00	1347.47
1958	4	17.06	20.90	0.00	8.25	0.00	1335.38
1958	5	10.65	20.90	0.00	6.65	0.00	1318.47
1958	6	6.69	20.90	0.00	5.67	0.00	1298.60
1958	7	5.82	20.90	0.00	5.81	0.00	1277.71
1958	8	2.68	20.90	0.00	7.25	0.00	1252.24
1958	9	4.16	20.90	0.00	8.33	0.00	1227.16
1959	10	3.88	20.90	0.00	9.38	0.00	1200.76
1959	11	10.86	20.90	0.00	9.24	0.00	1181.48
1959	12	35.26	20.90	0.00	10.48	0.00	1185.36
1959	1	31.91	20.90	0.00	11.33	0.00	1185.04
1959	2	270.34	20.90	0.00	9.02	50.47	1375.00
1959	3	162.99	20.90	0.00	10.92	131.17	1375.00
1959	4	43.56	20.90	0.00	7.78	14.88	1375.00
1959	5	26.33	20.90	0.00	7.13	0.00	1373.30
1959	6	17.25	20.90	0.00	5.83	0.00	1363.83
1959	7	10.44	20.90	0.00	6.11	0.00	1347.26
1959	8	6.88	20.90	0.00	7.43	0.00	1325.81
1959	9	7.29	20.90	0.00	8.81	0.00	1303.39
1960	10	4.04	20.90	0.00	9.85	0.00	1276.68
1960	11	35.76	20.90	0.00	9.28	0.00	1282.26
1960	12	141.47	20.90	0.00	10.18	17.65	1375.00
1960	1	97.26	20.90	0.00	12.49	63.87	1375.00
1960	2	70.94	20.90	0.00	10.38	39.66	1375.00
1960	3	92.61	20.90	0.00	10.67	61.04	1375.00
1960	4	62.13	20.90	0.00	8.30	32.93	1375.00
1960	5	31.27	20.90	0.00	7.14	3.23	1375.00
1960	6	30.90	20.90	0.00	5.31	4.69	1375.00
1960	7	22.54	20.90	0.00	6.06	0.00	1370.58
1960	8	16.46	20.90	0.00	7.47	0.00	1358.67
1960	9	13.49	20.90	0.00	8.94	0.00	1342.32
1961	10	10.30	20.90	0.00	9.78	0.00	1321.93
1961	11	15.03	20.90	0.00	9.85	0.00	1306.21
1961	12	26.24	20.90	0.00	11.10	0.00	1300.45
1961	1	27.63	20.90	0.00	11.77	0.00	1295.41
1961	2	31.27	20.90	0.00	10.77	0.00	1295.01
1961	3	20.84	20.90	0.00	10.39	0.00	1284.56

1961	4	16.21	20.90	0.00	7.95	0.00	1271.92
1961	5	9.67	20.90	0.00	6.88	0.00	1253.81
1961	6	6.98	20.90	0.00	5.55	0.00	1234.34
1961	7	4.32	20.90	0.00	5.74	0.00	1212.02
1961	8	2.16	20.90	0.00	6.90	0.00	1186.38
1961	9	1.13	20.90	0.00	8.47	0.00	1158.14
1962	10	0.88	20.90	0.00	9.07	0.00	1129.04
1962	11	79.51	20.90	0.00	8.35	0.00	1179.31
1962	12	72.98	20.90	0.00	10.23	0.00	1221.16
1962	1	25.86	20.90	0.00	11.38	0.00	1214.73
1962	2	22.42	20.90	0.00	10.06	0.00	1206.20
1962	3	16.55	20.90	0.00	9.92	0.00	1191.92
1962	4	15.33	20.90	0.00	7.40	0.00	1178.96
1962	5	9.52	20.90	0.00	6.48	0.00	1161.09
1962	6	13.37	20.90	0.00	4.87	0.00	1148.70
1962	7	12.05	20.90	0.00	5.26	0.00	1134.59
1962	8	6.08	20.90	0.00	6.78	0.00	1112.99
1962	9	4.28	20.90	0.00	8.15	0.00	1088.22
1963	10	3.12	20.90	0.00	8.78	0.00	1061.66
1963	11	12.55	20.90	0.00	8.66	0.00	1044.65
1963	12	16.65	20.90	0.00	9.86	0.00	1030.54
1963	1	56.18	20.90	0.00	9.99	0.00	1055.83
1963	2	47.91	20.90	0.00	9.08	0.00	1073.76
1963	3	17.76	20.90	0.00	9.46	0.00	1061.17
1963	4	13.42	20.90	0.00	6.98	0.00	1046.71
1963	5	7.82	20.90	0.00	6.11	0.00	1027.52
1963	6	5.80	20.90	0.00	4.89	0.00	1007.53
1963	7	3.30	20.90	0.00	5.10	0.00	984.83
1963	8	1.11	20.90	0.00	6.21	0.00	958.83
1963	9	0.84	20.90	0.00	7.44	0.00	931.33
1964	10	5.71	20.90	0.00	7.49	0.00	908.65
1964	11	7.26	20.90	0.00	7.91	0.00	887.10
1964	12	38.78	20.90	0.00	8.60	0.00	896.38
1964	1	64.09	20.90	0.00	9.39	0.00	930.18
1964	2	37.60	20.90	0.00	8.79	0.00	938.10
1964	3	20.93	20.90	0.00	8.65	0.00	929.48
1964	4	14.52	20.90	0.00	6.50	0.00	916.60
1964	5	7.65	20.90	0.00	5.68	0.00	897.67
1964	6	5.22	20.90	0.00	4.53	0.00	877.46
1964	7	2.93	20.90	0.00	4.68	0.00	854.81
1964	8	0.93	20.90	0.00	5.68	0.00	829.16
1964	9	2.25	20.90	0.00	6.67	0.00	803.83
1965	10	1.02	20.90	0.00	7.25	0.00	776.70
1965	11	11.82	20.90	0.00	7.05	0.00	760.58
1965	12	10.20	20.90	0.00	8.24	0.00	741.64
1965	1	49.56	20.90	0.00	7.70	0.00	762.60
1965	2	113.25	20.90	0.00	7.53	0.00	847.42
1965	3	63.49	20.90	0.00	8.19	0.00	881.83
1965	4	16.36	20.90	0.00	6.38	0.00	870.90
1965	5	8.75	20.90	0.00	5.43	0.00	853.32

1965	6	6.42	20.90	0.00	4.34	0.00	834.50
1965	7	3.85	20.90	0.00	4.55	0.00	812.90
1965	8	2.10	20.90	0.00	5.50	0.00	788.61
1965	9	2.16	20.90	0.00	6.58	0.00	763.29
1966	10	5.86	20.90	0.00	6.91	0.00	741.34
1966	11	7.70	20.90	0.00	6.90	0.00	721.24
1966	12	23.08	20.90	0.00	7.73	0.00	715.70
1966	1	49.32	20.90	0.00	8.17	0.00	735.94
1966	2	119.63	20.90	0.00	6.57	0.00	828.10
1966	3	74.73	20.90	0.00	7.54	0.00	874.39
1966	4	87.55	20.90	0.00	6.14	0.00	934.91
1966	5	58.03	20.90	0.00	5.71	0.00	966.32
1966	6	24.83	20.90	0.00	4.57	0.00	965.68
1966	7	16.34	20.90	0.00	4.93	0.00	956.19
1966	8	10.17	20.90	0.00	6.08	0.00	939.37
1966	9	7.17	20.90	0.00	7.36	0.00	918.28
1967	10	6.46	20.90	0.00	7.79	0.00	896.05
1967	11	9.67	20.90	0.00	7.78	0.00	877.05
1967	12	14.78	20.90	0.00	8.89	0.00	862.04
1967	1	13.58	20.90	0.00	9.25	0.00	845.47
1967	2	15.22	20.90	0.00	7.94	0.00	831.85
1967	3	18.03	20.90	0.00	7.76	0.00	821.22
1967	4	17.67	20.90	0.00	5.94	0.00	812.06
1967	5	10.60	20.90	0.00	5.24	0.00	796.52
1967	6	9.37	20.90	0.00	4.12	0.00	780.87
1967	7	6.12	20.90	0.00	4.33	0.00	761.75
1967	8	3.68	20.90	0.00	5.30	0.00	739.23
1967	9	2.56	20.90	0.00	6.36	0.00	714.53
1968	10	1.73	20.90	0.00	6.86	0.00	688.50
1968	11	12.53	20.90	0.00	6.44	0.00	673.69
1968	12	16.57	20.90	0.00	7.43	0.00	661.93
1968	1	24.23	20.90	0.00	7.92	0.00	657.34
1968	2	48.55	20.90	0.00	6.97	0.00	678.01
1968	3	75.71	20.90	0.00	6.75	0.00	726.07
1968	4	51.03	20.90	0.00	5.53	0.00	750.66
1968	5	22.41	20.90	0.00	4.99	0.00	747.18
1968	6	14.94	20.90	0.00	4.03	0.00	737.19
1968	7	9.81	20.90	0.00	4.14	0.00	721.96
1968	8	5.05	20.90	0.00	5.16	0.00	700.95
1968	9	5.01	20.90	0.00	5.94	0.00	679.13
1969	10	24.85	20.90	0.00	6.04	0.00	677.03
1969	11	22.49	20.90	0.00	6.62	0.00	672.01
1969	12	26.75	20.90	0.00	7.26	0.00	670.60
1969	1	14.87	20.90	0.00	8.06	0.00	656.51
1969	2	13.67	20.90	0.00	7.10	0.00	642.18
1969	3	7.85	20.90	0.00	6.87	0.00	622.26
1969	4	5.18	20.90	0.00	5.21	0.00	601.32
1969	5	3.04	20.90	0.00	4.39	0.00	579.08
1969	6	3.97	20.90	0.00	3.42	0.00	558.73
1969	7	2.55	20.90	0.00	3.56	0.00	536.82

1969	8	0.85	20.90	0.00	4.32	0.00	512.44
1969	9	0.80	20.90	0.00	5.08	0.00	487.27
1970	10	0.69	20.90	0.00	5.40	0.00	461.66
1970	11	5.23	20.90	0.00	5.14	0.00	440.85
1970	12	14.02	20.90	0.00	5.73	0.00	428.24
1970	1	113.18	20.90	0.00	5.88	0.00	514.64
1970	2	79.76	20.90	0.00	6.06	0.00	567.43
1970	3	27.86	20.90	0.00	6.00	0.00	568.39
1970	4	24.32	20.90	0.00	4.79	0.00	567.02
1970	5	16.30	20.90	0.00	4.19	0.00	558.24
1970	6	12.22	20.90	0.00	3.36	0.00	546.20
1970	7	8.19	20.90	0.00	3.52	0.00	529.97
1970	8	4.59	20.90	0.00	4.28	0.00	509.38
1970	9	5.72	20.90	0.00	5.02	0.00	489.17
1971	10	7.39	20.90	0.00	5.19	0.00	470.47
1971	11	15.55	20.90	0.00	5.13	0.00	459.99
1971	12	34.02	20.90	0.00	5.75	0.00	467.36
1971	1	176.71	20.90	0.00	5.89	0.00	617.28
1971	2	228.87	20.90	0.00	6.50	0.00	818.75
1971	3	263.35	20.90	0.00	7.30	0.00	1053.90
1971	4	119.11	20.90	0.00	7.00	0.00	1145.12
1971	5	43.57	20.90	0.00	6.02	0.00	1161.77
1971	6	29.54	20.90	0.00	5.30	0.00	1165.10
1971	7	20.08	20.90	0.00	5.55	0.00	1158.73
1971	8	12.06	20.90	0.00	6.86	0.00	1143.03
1971	9	8.83	20.90	0.00	8.28	0.00	1122.68
1972	10	11.52	20.90	0.00	8.83	0.00	1104.47
1972	11	14.91	20.90	0.00	8.94	0.00	1089.54
1972	12	11.52	20.90	0.00	10.01	0.00	1070.15
1972	1	20.05	20.90	0.00	10.48	0.00	1058.82
1972	2	21.45	20.90	0.00	9.39	0.00	1049.98
1972	3	16.74	20.90	0.00	9.22	0.00	1036.59
1972	4	28.78	20.90	0.00	6.63	0.00	1037.85
1972	5	17.74	20.90	0.00	6.09	0.00	1028.60
1972	6	11.39	20.90	0.00	4.90	0.00	1014.18
1972	7	7.88	20.90	0.00	5.11	0.00	996.05
1972	8	5.10	20.90	0.00	6.21	0.00	974.04
1972	9	34.68	20.90	0.00	6.56	0.00	981.26
1973	10	27.77	20.90	0.00	7.94	0.00	980.19
1973	11	29.44	20.90	0.00	8.06	0.00	980.67
1973	12	177.37	20.90	0.00	8.68	0.00	1128.46
1973	1	259.46	20.90	0.00	10.46	0.00	1356.56
1973	2	180.46	20.90	0.00	10.63	130.49	1375.00
1973	3	77.70	20.90	0.00	10.69	46.11	1375.00
1973	4	46.30	20.90	0.00	7.96	17.44	1375.00
1973	5	28.76	20.90	0.00	7.19	0.67	1375.00
1973	6	19.64	20.90	0.00	5.87	0.00	1367.87
1973	7	18.42	20.90	0.00	5.94	0.00	1359.45
1973	8	10.08	20.90	0.00	7.53	0.00	1341.10
1973	9	9.01	20.90	0.00	9.03	0.00	1320.19

1974	10	7.25	20.90	0.00	9.91	0.00	1296.63
1974	11	13.64	20.90	0.00	9.34	0.00	1280.03
1974	12	26.33	20.90	0.00	10.89	0.00	1274.57
1974	1	70.11	20.90	0.00	11.05	0.00	1312.74
1974	2	93.35	20.90	0.00	10.25	0.00	1374.94
1974	3	55.53	20.90	0.00	10.71	23.86	1375.00
1974	4	27.94	20.90	0.00	8.32	0.00	1373.72
1974	5	21.45	20.90	0.00	6.79	0.00	1367.48
1974	6	16.06	20.90	0.00	5.77	0.00	1356.88
1974	7	10.42	20.90	0.00	6.09	0.00	1340.30
1974	8	6.49	20.90	0.00	7.47	0.00	1318.42
1974	9	5.76	20.90	0.00	8.95	0.00	1294.33
1975	10	3.27	20.90	0.00	9.86	0.00	1266.83
1975	11	4.13	20.90	0.00	9.61	0.00	1240.45
1975	12	84.91	20.90	0.00	9.69	0.00	1294.78
1975	1	322.59	20.90	0.00	10.76	210.70	1375.00
1975	2	286.93	20.90	0.00	10.37	255.66	1375.00
1975	3	173.52	20.90	0.00	10.66	141.96	1375.00
1975	4	86.50	20.90	0.00	8.27	57.33	1375.00
1975	5	37.64	20.90	0.00	7.11	9.63	1375.00
1975	6	24.92	20.90	0.00	5.85	0.00	1373.17
1975	7	16.31	20.90	0.00	6.14	0.00	1362.44
1975	8	10.05	20.90	0.00	7.57	0.00	1344.02
1975	9	7.27	20.90	0.00	9.07	0.00	1321.32
1976	10	5.53	20.90	0.00	9.80	0.00	1296.15
1976	11	10.39	20.90	0.00	9.39	0.00	1276.25
1976	12	19.27	20.90	0.00	10.91	0.00	1263.71
1976	1	70.05	20.90	0.00	11.41	0.00	1301.45
1976	2	130.67	20.90	0.00	9.13	27.09	1375.00
1976	3	124.94	20.90	0.00	10.32	93.72	1375.00
1976	4	61.65	20.90	0.00	8.40	32.35	1375.00
1976	5	27.42	20.90	0.00	7.23	0.00	1374.29
1976	6	18.07	20.90	0.00	5.87	0.00	1365.59
1976	7	10.70	20.90	0.00	6.12	0.00	1349.27
1976	8	7.55	20.90	0.00	7.46	0.00	1328.47
1976	9	13.49	20.90	0.00	8.63	0.00	1312.43
1977	10	9.10	20.90	0.00	9.92	0.00	1290.71
1977	11	11.82	20.90	0.00	9.73	0.00	1271.90
1977	12	66.39	20.90	0.00	10.77	0.00	1306.62
1977	1	247.37	20.90	0.00	10.79	147.30	1375.00
1977	2	202.29	20.90	0.00	9.95	171.44	1375.00
1977	3	136.99	20.90	0.00	10.25	105.84	1375.00
1977	4	74.04	20.90	0.00	8.02	45.12	1375.00
1977	5	26.79	20.90	0.00	7.21	0.00	1373.68
1977	6	17.66	20.90	0.00	5.86	0.00	1364.58
1977	7	11.58	20.90	0.00	6.01	0.00	1349.26
1977	8	6.95	20.90	0.00	7.52	0.00	1327.79
1977	9	5.54	20.90	0.00	9.05	0.00	1303.38
1978	10	6.50	20.90	0.00	9.63	0.00	1279.34
1978	11	18.65	20.90	0.00	9.17	0.00	1267.93

1978	12	19.98	20.90	0.00	10.81	0.00	1256.19
1978	1	23.43	20.90	0.00	11.27	0.00	1247.46
1978	2	14.96	20.90	0.00	10.46	0.00	1231.05
1978	3	19.81	20.90	0.00	10.01	0.00	1219.95
1978	4	12.18	20.90	0.00	7.61	0.00	1203.62
1978	5	7.70	20.90	0.00	6.64	0.00	1183.78
1978	6	5.55	20.90	0.00	5.35	0.00	1163.08
1978	7	4.12	20.90	0.00	5.54	0.00	1140.76
1978	8	2.81	20.90	0.00	6.76	0.00	1115.91
1978	9	2.52	20.90	0.00	8.13	0.00	1089.40
1979	10	3.36	20.90	0.00	8.59	0.00	1063.27
1979	11	12.26	20.90	0.00	8.59	0.00	1046.04
1979	12	17.83	20.90	0.00	9.62	0.00	1033.36
1979	1	18.69	20.90	0.00	10.23	0.00	1020.92
1979	2	62.62	20.90	0.00	8.70	0.00	1053.94
1979	3	52.41	20.90	0.00	9.26	0.00	1076.19
1979	4	23.43	20.90	0.00	7.15	0.00	1071.57
1979	5	13.29	20.90	0.00	6.17	0.00	1057.79
1979	6	8.20	20.90	0.00	5.01	0.00	1040.07
1979	7	4.78	20.90	0.00	5.19	0.00	1018.76
1979	8	3.58	20.90	0.00	6.21	0.00	995.23
1979	9	4.88	20.90	0.00	7.30	0.00	971.90
1980	10	3.67	20.90	0.00	8.18	0.00	946.50
1980	11	42.38	20.90	0.00	7.59	0.00	960.39
1980	12	53.97	20.90	0.00	9.00	0.00	984.46
1980	1	126.04	20.90	0.00	9.52	0.00	1080.08
1980	2	158.62	20.90	0.00	9.18	0.00	1208.62
1980	3	91.01	20.90	0.00	9.68	0.00	1269.05
1980	4	38.32	20.90	0.00	7.93	0.00	1278.54
1980	5	25.06	20.90	0.00	6.70	0.00	1276.00
1980	6	16.38	20.90	0.00	5.61	0.00	1265.87
1980	7	10.05	20.90	0.00	5.84	0.00	1249.18
1980	8	7.17	20.90	0.00	7.06	0.00	1228.39
1980	9	7.90	20.90	0.00	8.29	0.00	1207.11
1981	10	7.95	20.90	0.00	9.02	0.00	1185.13
1981	11	9.19	20.90	0.00	9.03	0.00	1164.40
1981	12	9.54	20.90	0.00	10.55	0.00	1142.48
1981	1	25.27	20.90	0.00	10.20	0.00	1136.65
1981	2	16.47	20.90	0.00	10.04	0.00	1122.18
1981	3	7.69	20.90	0.00	9.73	0.00	1099.24
1981	4	10.29	20.90	0.00	7.02	0.00	1081.61
1981	5	6.51	20.90	0.00	6.16	0.00	1061.06
1981	6	4.48	20.90	0.00	5.02	0.00	1039.62
1981	7	3.65	20.90	0.00	5.17	0.00	1017.20
1981	8	1.44	20.90	0.00	6.29	0.00	991.46
1981	9	1.43	20.90	0.00	7.54	0.00	964.45
1982	10	1.17	20.90	0.00	8.20	0.00	936.51
1982	11	2.76	20.90	0.00	8.15	0.00	910.23
1982	12	2.95	20.90	0.00	8.97	0.00	883.31
1982	1	4.02	20.90	0.00	9.38	0.00	857.05

1982	2	3.62	20.90	0.00	8.39	0.00	831.38
1982	3	6.64	20.90	0.00	7.88	0.00	809.24
1982	4	7.11	20.90	0.00	6.00	0.00	789.44
1982	5	5.35	20.90	0.00	4.87	0.00	769.02
1982	6	3.47	20.90	0.00	4.04	0.00	747.54
1982	7	1.67	20.90	0.00	4.25	0.00	724.06
1982	8	0.63	20.90	0.00	5.06	0.00	698.73
1982	9	0.60	20.90	0.00	6.16	0.00	672.27
1983	10	1.90	20.90	0.00	6.47	0.00	646.80
1983	11	26.40	20.90	0.00	6.20	0.00	646.10
1983	12	34.71	20.90	0.00	6.98	0.00	652.93
1983	1	37.56	20.90	0.00	7.08	0.00	662.51
1983	2	21.64	20.90	0.00	7.03	0.00	656.22
1983	3	28.85	20.90	0.00	6.77	0.00	657.39
1983	4	20.07	20.90	0.00	5.28	0.00	651.28
1983	5	9.98	20.90	0.00	4.61	0.00	635.75
1983	6	7.25	20.90	0.00	3.67	0.00	618.43
1983	7	19.56	20.90	0.00	3.20	0.00	613.89
1983	8	12.62	20.90	0.00	4.68	0.00	600.93
1983	9	10.91	20.90	0.00	5.47	0.00	585.47
1984	10	10.93	20.90	0.00	5.88	0.00	569.61
1984	11	25.39	20.90	0.00	5.69	0.00	568.41
1984	12	26.71	20.90	0.00	6.76	0.00	567.46
1984	1	36.56	20.90	0.00	6.86	0.00	576.26
1984	2	216.35	20.90	0.00	5.74	0.00	765.96
1984	3	133.39	20.90	0.00	7.59	0.00	870.86
1984	4	28.76	20.90	0.00	6.14	0.00	872.58
1984	5	19.52	20.90	0.00	5.43	0.00	865.77
1984	6	12.76	20.90	0.00	4.42	0.00	853.21
1984	7	8.43	20.90	0.00	4.60	0.00	836.14
1984	8	5.04	20.90	0.00	5.64	0.00	814.64
1984	9	4.32	20.90	0.00	6.68	0.00	791.38
1985	10	6.95	20.90	0.00	6.98	0.00	770.45
1985	11	8.31	20.90	0.00	7.00	0.00	750.86
1985	12	28.57	20.90	0.00	8.12	0.00	750.41
1985	1	32.41	20.90	0.00	8.54	0.00	753.38
1985	2	36.02	20.90	0.00	7.47	0.00	761.03
1985	3	26.03	20.90	0.00	7.55	0.00	758.61
1985	4	34.12	20.90	0.00	5.37	0.00	766.46
1985	5	19.27	20.90	0.00	5.08	0.00	759.75
1985	6	12.01	20.90	0.00	4.08	0.00	746.78
1985	7	7.04	20.90	0.00	4.26	0.00	728.67
1985	8	4.21	20.90	0.00	5.15	0.00	706.83
1985	9	3.50	20.90	0.00	6.16	0.00	683.27
1986	10	3.30	20.90	0.00	6.58	0.00	659.09
1986	11	4.10	20.90	0.00	6.51	0.00	635.78
1986	12	8.17	20.90	0.00	7.00	0.00	616.04
1986	1	10.01	20.90	0.00	7.23	0.00	597.93
1986	2	8.39	20.90	0.00	6.78	0.00	578.64
1986	3	35.79	20.90	0.00	6.20	0.00	587.33

1986	4	25.65	20.90	0.00	5.01	0.00	587.07
1986	5	9.22	20.90	0.00	4.32	0.00	571.07
1986	6	6.34	20.90	0.00	3.40	0.00	553.11
1986	7	3.53	20.90	0.00	3.55	0.00	532.19
1986	8	3.59	20.90	0.00	4.12	0.00	510.75
1986	9	12.94	20.90	0.00	4.78	0.00	498.01
1987	10	8.94	20.90	0.00	5.38	0.00	480.67
1987	11	7.67	20.90	0.00	5.47	0.00	461.97
1987	12	113.79	20.90	0.00	5.56	0.00	549.29
1987	1	77.59	20.90	0.00	7.09	0.00	598.89
1987	2	143.05	20.90	0.00	6.39	0.00	714.65
1987	3	116.54	20.90	0.00	7.07	0.00	803.22
1987	4	42.66	20.90	0.00	5.89	0.00	819.09
1987	5	23.81	20.90	0.00	5.24	0.00	816.76
1987	6	18.72	20.90	0.00	4.23	0.00	810.35
1987	7	11.63	20.90	0.00	4.44	0.00	796.64
1987	8	9.04	20.90	0.00	5.43	0.00	779.35
1987	9	8.45	20.90	0.00	6.51	0.00	760.39
1988	10	16.92	20.90	0.00	6.80	0.00	749.61
1988	11	12.11	20.90	0.00	7.07	0.00	733.75
1988	12	15.02	20.90	0.00	7.63	0.00	720.24
1988	1	9.98	20.90	0.00	8.46	0.00	700.87
1988	2	152.16	20.90	0.00	6.42	0.00	825.71
1988	3	87.41	20.90	0.00	7.89	0.00	884.33
1988	4	17.54	20.90	0.00	6.39	0.00	874.57
1988	5	10.37	20.90	0.00	5.47	0.00	858.58
1988	6	11.50	20.90	0.00	4.19	0.00	844.99
1988	7	7.02	20.90	0.00	4.58	0.00	826.52
1988	8	4.36	20.90	0.00	5.59	0.00	804.39
1988	9	2.79	20.90	0.00	6.70	0.00	779.58
1989	10	5.43	20.90	0.00	7.03	0.00	757.08
1989	11	16.42	20.90	0.00	6.60	0.00	746.00
1989	12	33.17	20.90	0.00	7.66	0.00	750.61
1989	1	38.40	20.90	0.00	8.24	0.00	759.87
1989	2	47.84	20.90	0.00	7.66	0.00	779.15
1989	3	39.41	20.90	0.00	7.47	0.00	790.18
1989	4	26.69	20.90	0.00	5.86	0.00	790.11
1989	5	16.04	20.90	0.00	5.19	0.00	780.07
1989	6	10.78	20.90	0.00	4.17	0.00	765.78
1989	7	7.48	20.90	0.00	4.32	0.00	748.04
1989	8	4.45	20.90	0.00	5.25	0.00	726.34
1989	9	2.99	20.90	0.00	6.31	0.00	702.12
1990	10	3.66	20.90	0.00	6.54	0.00	678.35
1990	11	4.87	20.90	0.00	6.68	0.00	655.63
1990	12	36.87	20.90	0.00	7.03	0.00	664.57
1990	1	97.22	20.90	0.00	7.91	0.00	732.99
1990	2	79.32	20.90	0.00	7.53	0.00	783.88
1990	3	75.03	20.90	0.00	7.59	0.00	830.42
1990	4	47.88	20.90	0.00	6.17	0.00	851.23
1990	5	21.69	20.90	0.00	5.40	0.00	846.62

1990	6	18.09	20.90	0.00	4.19	0.00	839.62
1990	7	10.13	20.90	0.00	4.57	0.00	824.28
1990	8	6.12	20.90	0.00	5.59	0.00	803.91
1990	9	4.73	20.90	0.00	6.67	0.00	781.07
1991	10	2.70	20.90	0.00	7.29	0.00	755.59
1991	11	6.11	20.90	0.00	6.77	0.00	734.02
1991	12	8.47	20.90	0.00	7.88	0.00	713.72
1991	1	9.86	20.90	0.00	8.31	0.00	694.36
1991	2	7.38	20.90	0.00	7.38	0.00	673.46
1991	3	4.74	20.90	0.00	7.06	0.00	650.24
1991	4	4.78	20.90	0.00	5.29	0.00	628.83
1991	5	2.11	20.90	0.00	4.52	0.00	605.53
1991	6	1.39	20.90	0.00	3.57	0.00	582.45
1991	7	0.22	20.90	0.00	3.66	0.00	558.10
1991	8	0.21	20.90	0.00	4.42	0.00	532.99
1991	9	0.20	20.90	0.00	5.24	0.00	507.06
1992	10	0.18	20.90	0.00	5.53	0.00	480.81
1992	11	3.63	20.90	0.00	5.13	0.00	458.41
1992	12	56.66	20.90	0.00	5.32	0.00	488.85
1992	1	39.96	20.90	0.00	6.45	0.00	501.46
1992	2	29.20	20.90	0.00	5.88	0.00	503.88
1992	3	86.63	20.90	0.00	5.56	0.00	564.05
1992	4	61.42	20.90	0.00	4.82	0.00	599.75
1992	5	18.45	20.90	0.00	4.37	0.00	592.93
1992	6	12.31	20.90	0.00	3.50	0.00	580.85
1992	7	7.16	20.90	0.00	3.65	0.00	563.46
1992	8	4.28	20.90	0.00	4.38	0.00	542.46
1992	9	3.00	20.90	0.00	5.28	0.00	519.28
1993	10	2.50	20.90	0.00	5.67	0.00	495.21
1993	11	5.85	20.90	0.00	5.46	0.00	474.70
1993	12	16.99	20.90	0.00	5.98	0.00	464.81
1993	1	19.95	20.90	0.00	6.29	0.00	457.57
1993	2	17.48	20.90	0.00	5.75	0.00	448.40
1993	3	16.08	20.90	0.00	5.36	0.00	438.23
1993	4	10.42	20.90	0.00	4.17	0.00	423.58
1993	5	5.43	20.90	0.00	3.53	0.00	404.58
1993	6	3.39	20.90	0.00	2.81	0.00	384.26
1993	7	1.36	20.90	0.00	2.85	0.00	361.87
1993	8	0.34	20.90	0.00	3.40	0.00	337.91
1993	9	0.54	20.90	0.00	3.93	0.00	313.61
1994	10	4.08	20.90	0.00	4.03	0.00	292.76
1994	11	3.12	20.90	0.00	3.88	0.00	271.10
1994	12	9.45	20.90	0.00	4.19	0.00	255.47
1994	1	41.75	20.90	0.00	4.02	0.00	272.30
1994	2	28.44	20.90	0.00	4.15	0.00	275.69
1994	3	18.04	20.90	0.00	4.13	0.00	268.70
1994	4	18.76	20.90	0.00	2.98	0.00	263.58
1994	5	11.61	20.90	0.00	2.63	0.00	251.66
1994	6	7.84	20.90	0.00	2.11	0.00	236.48
1994	7	4.53	20.90	0.00	2.13	0.00	217.98

1994	8	2.98	20.90	0.00	2.45	0.00	197.61
1994	9	1.41	20.90	0.00	2.88	0.00	175.23
1995	10	1.54	20.90	0.00	2.82	0.00	153.05
1995	11	17.50	20.90	0.00	2.61	0.00	147.04
1995	12	150.08	20.90	0.00	2.88	0.00	273.34
1995	1	186.59	20.90	0.00	4.40	0.00	434.62
1995	2	614.38	20.90	0.00	5.03	0.00	1023.08
1995	3	323.74	20.90	0.00	8.94	0.00	1316.98
1995	4	52.26	20.90	0.00	7.96	0.00	1340.38
1995	5	41.75	20.90	0.00	6.88	0.00	1354.35
1995	6	30.02	20.90	0.00	5.78	0.00	1357.69
1995	7	23.90	20.90	0.00	6.02	0.00	1354.67
1995	8	18.59	20.90	0.00	7.35	0.00	1345.01
1995	9	12.60	20.90	0.00	9.12	0.00	1327.59
1996	10	11.40	20.90	0.00	9.81	0.00	1308.28
1996	11	11.55	20.90	0.00	9.71	0.00	1289.22
1996	12	18.75	20.90	0.00	11.09	0.00	1275.98
1996	1	49.43	20.90	0.00	10.96	0.00	1293.55
1996	2	48.53	20.90	0.00	10.79	0.00	1310.39
1996	3	122.80	20.90	0.00	10.03	27.26	1375.00
1996	4	84.23	20.90	0.00	8.02	55.31	1375.00
1996	5	28.75	20.90	0.00	7.20	0.65	1375.00
1996	6	20.12	20.90	0.00	5.84	0.00	1368.38
1996	7	13.58	20.90	0.00	6.00	0.00	1355.06
1996	8	8.15	20.90	0.00	7.44	0.00	1334.87
1996	9	12.32	20.90	0.00	8.83	0.00	1317.46
1997	10	13.25	20.90	0.00	9.68	0.00	1300.13
1997	11	17.33	20.90	0.00	9.43	0.00	1287.13
1997	12	15.66	20.90	0.00	10.66	0.00	1271.23
1997	1	59.48	20.90	0.00	10.91	0.00	1298.90
1997	2	46.38	20.90	0.00	10.86	0.00	1313.52
1997	3	24.24	20.90	0.00	10.68	0.00	1306.18
1997	4	18.15	20.90	0.00	8.09	0.00	1295.34
1997	5	10.23	20.90	0.00	6.98	0.00	1277.69
1997	6	7.10	20.90	0.00	5.61	0.00	1258.27
1997	7	5.62	20.90	0.00	5.79	0.00	1237.20
1997	8	2.53	20.90	0.00	7.13	0.00	1211.70
1997	9	3.72	20.90	0.00	8.46	0.00	1186.06
1998	10	12.97	20.90	0.00	8.82	0.00	1169.31
1998	11	40.81	20.90	0.00	8.10	0.00	1181.13
1998	12	142.55	20.90	0.00	9.42	0.00	1293.36
1998	1	145.62	20.90	0.00	11.76	31.32	1375.00
1998	2	125.28	20.90	0.00	10.05	94.33	1375.00
1998	3	98.56	20.90	0.00	10.43	67.23	1375.00
1998	4	58.53	20.90	0.00	8.04	29.59	1375.00
1998	5	29.50	20.90	0.00	7.04	1.56	1375.00
1998	6	20.39	20.90	0.00	5.85	0.00	1368.64
1998	7	13.34	20.90	0.00	6.09	0.00	1354.99
1998	8	8.86	20.90	0.00	7.44	0.00	1335.51
1998	9	7.42	20.90	0.00	8.93	0.00	1313.10

1999	10	5.92	20.90	0.00	9.71	0.00	1288.41
1999	11	24.72	20.90	0.00	8.86	0.00	1283.37
1999	12	55.59	20.90	0.00	10.65	0.00	1307.41
1999	1	154.71	20.90	0.00	11.17	55.05	1375.00
1999	2	1186.48	20.90	0.00	8.43	1157.15	1375.00
1999	3	846.86	20.90	0.00	9.40	816.56	1375.00
1999	4	213.66	20.90	0.00	8.13	184.63	1375.00
1999	5	47.99	20.90	0.00	7.16	19.93	1375.00
1999	6	38.59	20.90	0.00	5.77	11.92	1375.00
1999	7	27.28	20.90	0.00	6.12	0.26	1375.00
1999	8	17.36	20.90	0.00	7.61	0.00	1363.85
1999	9	15.46	20.90	0.00	8.97	0.00	1349.44
2000	10	12.86	20.90	0.00	10.01	0.00	1331.39
2000	11	34.17	20.90	0.00	8.95	0.00	1335.71
2000	12	78.85	20.90	0.00	11.36	7.31	1375.00
2000	1	50.97	20.90	0.00	12.30	17.77	1375.00
2000	2	71.50	20.90	0.00	10.03	40.57	1375.00
2000	3	51.21	20.90	0.00	10.48	19.83	1375.00
2000	4	32.79	20.90	0.00	8.02	3.87	1375.00
2000	5	20.35	20.90	0.00	7.14	0.00	1367.31
2000	6	15.53	20.90	0.00	5.84	0.00	1356.10
2000	7	11.24	20.90	0.00	6.06	0.00	1340.38
2000	8	7.28	20.90	0.00	7.49	0.00	1319.27
2000	9	5.45	20.90	0.00	9.03	0.00	1294.79
2001	10	7.36	20.90	0.00	9.63	0.00	1271.61
2001	11	125.70	20.90	0.00	8.20	0.00	1368.22
2001	12	119.25	20.90	0.00	11.07	80.50	1375.00
2001	1	66.31	20.90	0.00	12.19	33.22	1375.00
2001	2	48.16	20.90	0.00	11.26	16.00	1375.00
2001	3	31.89	20.90	0.00	10.78	0.21	1375.00
2001	4	21.71	20.90	0.00	8.33	0.00	1367.48
2001	5	11.37	20.90	0.00	7.22	0.00	1350.73
2001	6	8.65	20.90	0.00	5.78	0.00	1332.70
2001	7	5.71	20.90	0.00	6.02	0.00	1311.49
2001	8	3.26	20.90	0.00	7.39	0.00	1286.46
2001	9	2.37	20.90	0.00	8.86	0.00	1259.07
2002	10	4.87	20.90	0.00	9.42	0.00	1233.62
2002	11	4.06	20.90	0.00	9.47	0.00	1207.31
2002	12	8.24	20.90	0.00	10.66	0.00	1183.99
2002	1	7.89	20.90	0.00	11.36	0.00	1159.62
2002	2	7.10	20.90	0.00	9.94	0.00	1135.87
2002	3	6.21	20.90	0.00	9.62	0.00	1111.56
2002	4	4.40	20.90	0.00	7.13	0.00	1087.93
2002	5	1.63	20.90	0.00	6.22	0.00	1062.44
2002	6	2.99	20.90	0.00	4.83	0.00	1039.71
2002	7	1.04	20.90	0.00	5.18	0.00	1014.66
2002	8	0.29	20.90	0.00	6.32	0.00	987.74
2002	9	0.46	20.90	0.00	7.45	0.00	959.84
2003	10	0.38	20.90	0.00	8.12	0.00	931.20
2003	11	1.41	20.90	0.00	7.78	0.00	903.92

2003	12	1.04	20.90	0.00	9.16	0.00	874.90
2003	1	24.72	20.90	0.00	8.55	0.00	870.17
2003	2	62.26	20.90	0.00	7.81	0.00	903.72
2003	3	76.10	20.90	0.00	7.91	0.00	951.01
2003	4	39.09	20.90	0.00	6.52	0.00	962.68
2003	5	17.27	20.90	0.00	5.84	0.00	953.21
2003	6	11.79	20.90	0.00	4.61	0.00	939.49
2003	7	8.71	20.90	0.00	4.77	0.00	922.53
2003	8	4.63	20.90	0.00	5.93	0.00	900.33
2003	9	3.80	20.90	0.00	7.08	0.00	876.16
2004	10	2.41	20.90	0.00	7.71	0.00	849.95
2004	11	6.45	20.90	0.00	7.34	0.00	828.17
2004	12	15.01	20.90	0.00	8.64	0.00	813.64
2004	1	31.57	20.90	0.00	8.51	0.00	815.80
2004	2	22.41	20.90	0.00	8.04	0.00	809.27
2004	3	15.85	20.90	0.00	7.71	0.00	796.51
2004	4	14.60	20.90	0.00	5.98	0.00	784.23
2004	5	9.73	20.90	0.00	5.04	0.00	768.01
2004	6	7.07	20.90	0.00	4.13	0.00	750.05
2004	7	4.59	20.90	0.00	4.26	0.00	729.48
2004	8	2.07	20.90	0.00	5.20	0.00	705.45
2004	9	2.42	20.90	0.00	6.20	0.00	680.77

APPENDIX 3

Baseline study. Hydrogeology

1. Introduction

A hydrogeological baseline study was carried out. The study included:

- Review of existing reports and information
- Water sampling and chemical analysis of samples

2. Materials and methods

Existing reports

All existing reports and information available regarding the dam were obtained and studied to familiarise ourselves with the geological and hydrogeological environment at the dam site. No hydrogeological study was done at the dam site during the feasibility or design stage. The hydrogeology of the area was studied on the 1:1 000 000 scale Hydrogeological Map of Mozambique.

Site visit and water sampling

The desk study was followed by a site visit on 22 October 2010, during which the dam and surrounding area was visited to observe any areas that can potentially be impacted increasing the reservoir level. During the site visit the seepage area on the northern end of the embankment was visited (Photo 1). Sites were selected where samples for chemical and isotope analysis should be taken. Isotope samples were taken during the first visit to the site. No boreholes in the vicinity of the site were available for sampling.

Samples were taken for isotope and chemical analysis and their coordinates are shown in Table 1. The locality of the sampling points is shown on Figure 1.

At the time the isotope samples were taken the borehole data was not available and they were not sampled for isotopes. The samples taken for chemical analysis were submitted to Clean Stream Scientific Services (Pty) Ltd, certified analytical chemical laboratory in Pretoria.

Photo 1: Seepage at the northern end of the dam wall.

Table 1. Sampling sites at the Corumana Dam area.

Site		Position	
C-Dam	At the Dam site	S25.21962	E32.13268
C01	Seepage sampled	S25.20393	E32.12968
RG1	Sampled at the Bridge (isotope sample C04)	S25.205367	E32.14333
C03	No sample	S25.20805	E32.13072
BH 0370	Sample container broken at arrival to lab. Therefore no analysis	S25.30253	E32.21033
BH 012	Sample container broken at arrival to lab. Therefore no analysis	S25.32123	E32.25427
BH 14-02	Sampled from hand pump, not possible to measure SWL	S25.32155	E32.25127

The Stable Isotopes Oxygen-18 and Deuterium that were employed in this study are the nonradioactive (or "stable") isotopes 18O and 2H. They label the water molecule itself and the concentration of these isotopes can only be changed by physical processes such as evaporation and can therefore be used as a detector of evaporated dam or surface water in the monitoring boreholes. Together with the information obtained from the chemical analysis, the isotope data can assist in:

- Determining the origins of different water bodies;
- Provide an estimate of the degree of mixing;
- Determining the location of water recharge; and
- Determining the dynamics of the groundwater regime.

The isotope samples were submitted to I Temba LABS, an International Atomic Energy Agency (IAEA) certified laboratory in Johannesburg for analysis.

Borehole data

Borehole data was received from ARA-Sul after the site visit. The data was evaluated for sampling and recording. Based on the data, field work to sample water and boreholes for chemical analysis was done on the 18th October 2010. This data is necessary to serve as background information to the project.

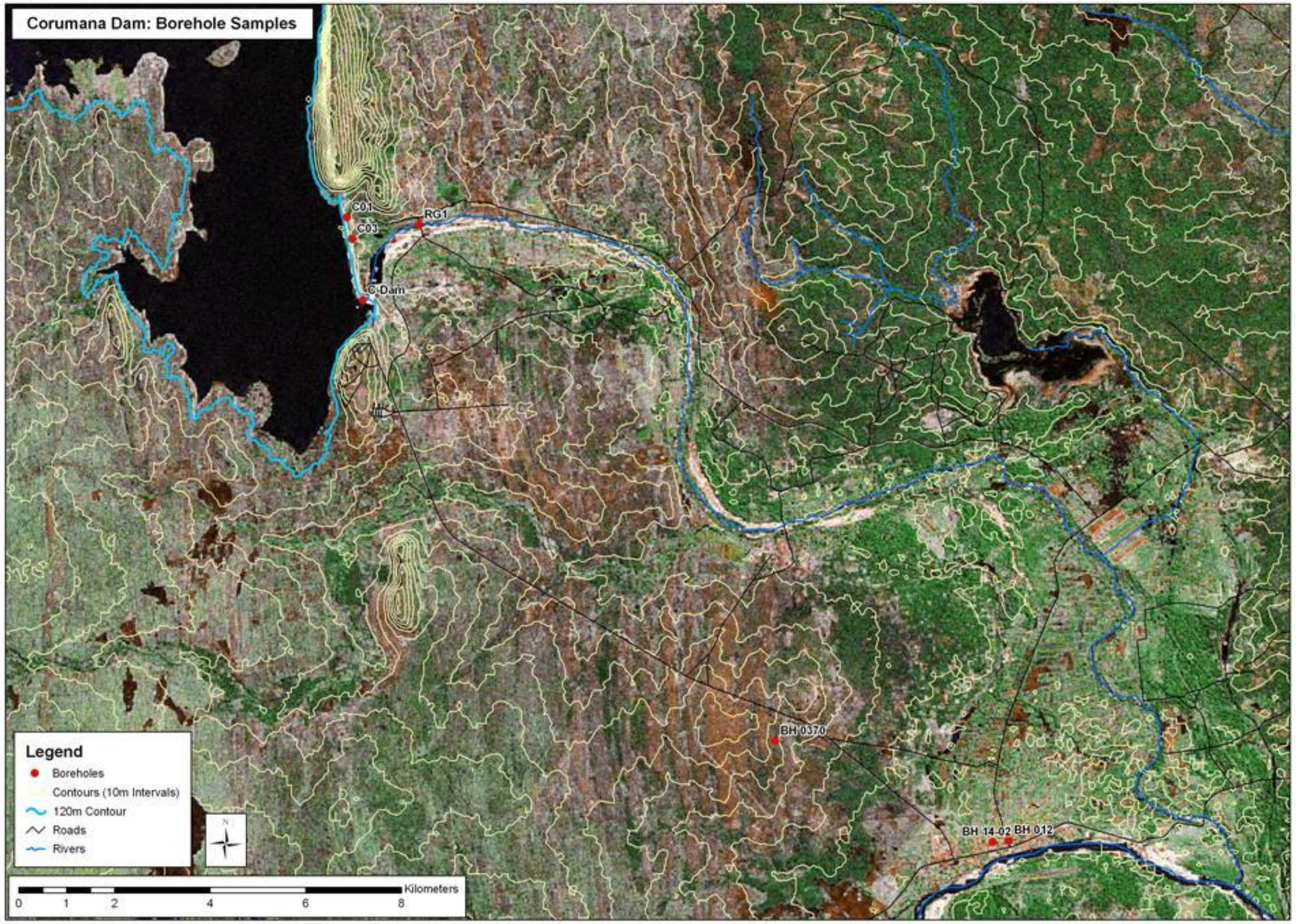

Figure 1. Location of sampling sites

3. Results

3.1. Hydrogeological Map

The 1:1 000 000 scale Hydrogeological Map of Mozambique showed that the site is underlain by rocks of the extrusive rhyolite and granophyre formations of the Lebombo Group, Sequence Karoo, hosting inter-granular and fissured aquifers with low permeability. Groundwater resources are limited in the area except along fault zones, dyke contact zones and in alluvial valleys. Dykes are present and good groundwater occurrence can be expected at scientific selected drill sites. The water quality in the Karoo formations is variable but is generally acceptable in these formations.

3.2. Chemistry

The results of the chemical analyses of samples are shown in Table 2 where it is compared with Mozambican Water Guidelines for Human Use (LNHAA, 1997).

High chloride and sodium values are shown for the samples taken at the dam site, seepage area and the downstream bridge. The groundwater sample taken at the borehole also shows a high sodium and chloride value. The borehole shows unacceptable high fluoride value. The fluoride value exceeds the maximum allowable limit according to the Mozambican Water Guidelines for Human Use). Concentrations of sodium, chloride and TDS also exceed the maximum allowable limits. The results were plotted on the Piper diagram to look at the chemical character of the samples. The Piper diagram is shown in Figure 2. All the samples fall into the sodium chloride field as expected.

The high sodium and EC values could impact on the suitability for irrigation and the values were therefore evaluated by plotting the Sodium Adsorption Ratios for the different samples. The results are shown in Figure 3 and compared with the guidelines (MICOA 2004) in Table 3. The samples collected in the reservoir are good for irrigation but the groundwater is not good for irrigation.

Table 2. Results of chemical analyses of samples. Compared to Mozambique Standards for drinking water.

Parameter	Sample Nr.				
	BH14-02	CO1	C-DAM	RG1	Mozambique maximum allowable limit for human Consumption
Ca	18.11	64.19	15.91	14.74	
Mg	30.68	27.67	27.99	21.59	
Na	616.82	202.49	201.40	157.59	200
K	7.99	12.615	9.35	7.26	
Mn	0.033	0.012	0.005	0.005	0.1
Fe	0.025	0.019	0.065	0.043	0.3
F	2.11	0.22	0.19	<0.183	1.5
NH_4-N	<0.015	<0.015	<0.015	<0.015	
NO_3-N	2.53	0.10	0.68	0.16	50
Total Hardness	172	274	155	126	500
Al	<0.006	<0.006	0.056	0.029	0.2
PO_4-P	0.52	0.92	0.047	0.044	
Cl	608.00	312.00	336.00	249.40	250
SO_4	105.82	48.77	46.76	37.53	250
TDS (mg/l)	1688.00	780.00	671.00	522.00	1000
M-Alk ($CaCO_3$)	496.40	186.60	53.80	55.50	-
pH	8.14	7.80	7.96	7.80	6.5-8.5
EC (mS/m)	255.50	58.80	21.44	19.76	

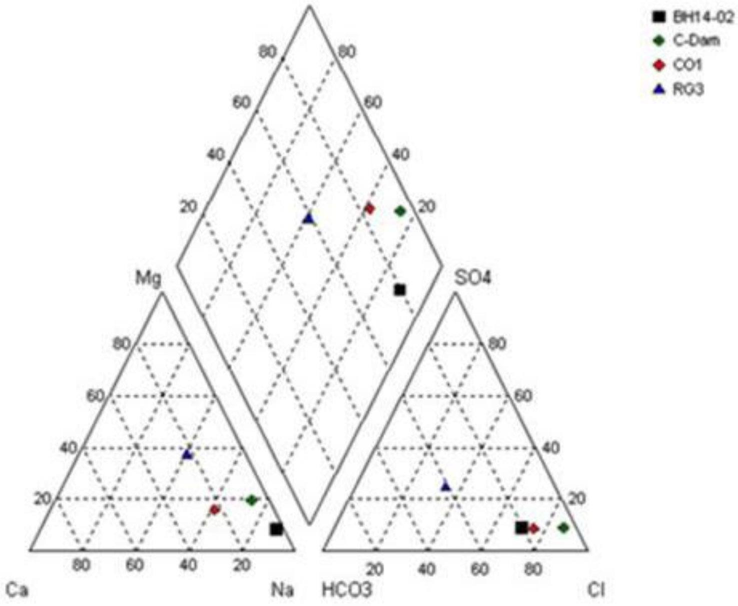

Figure 2. Piper diagram for samples taken at Corumana Dam site.

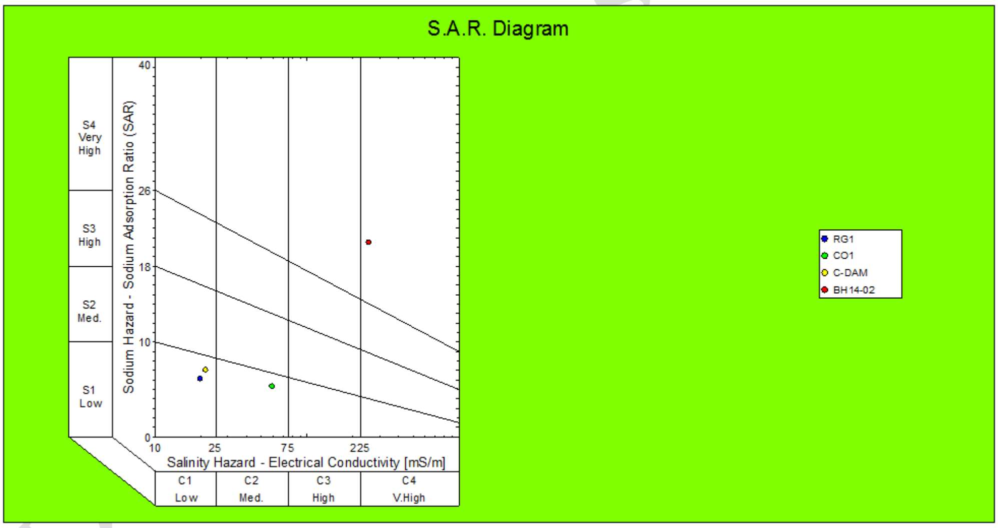

Figure 3. Sodium Adsorption Ratios (SAR) for samples collected at the Corumana site.

Table 3. Sodium Adsorption Ratio (SAR). MICOA (2004)

Max	Min	Classification	Quality	Comments
0	10	Low	Good	Ready for irrigation, no restrictions
11	18	Medium	Moderate	Problematic on soils with fine texture, with low flow rates, except if the soil contain gypsum. Water can be used in soil with thick texture or organic soil with good permeability
19	26	High	Bad	Problematic in most soils. Irrigation possible in soils that contain gypsum
>26		Very high	Very Bad	Not good for irrigation

3.3. Stable Isotope Analysis

The results of the isotope analysis are shown in Table 4 and plotted to show their locality in relation to the Global Meteoric Water Line (GMWL) in Figure 4. Groundwater samples normally fall on the line which represents the global line for deuterium and oxygen- 18 in rainfall samples. The samples all group off the GMWL which indicate increase in heavier isotopes and therefore evaporation in the samples.

Table 4. Isotope analysis results for Corumana samples.

Laboratory number	Sample Identification	dD ($^{o}/_{oo}$)	D18O ($^{o}/_{oo}$)
AFR 501	CO 1 Dam	-0.7	-0.5
AFR 502	CO 2 Seepage	- 2.7	-1
AFR 503	CO 3 Seepage	.-2.1	-0.91
AFR 504	CO 4 Bridge	-0.7	-0.8

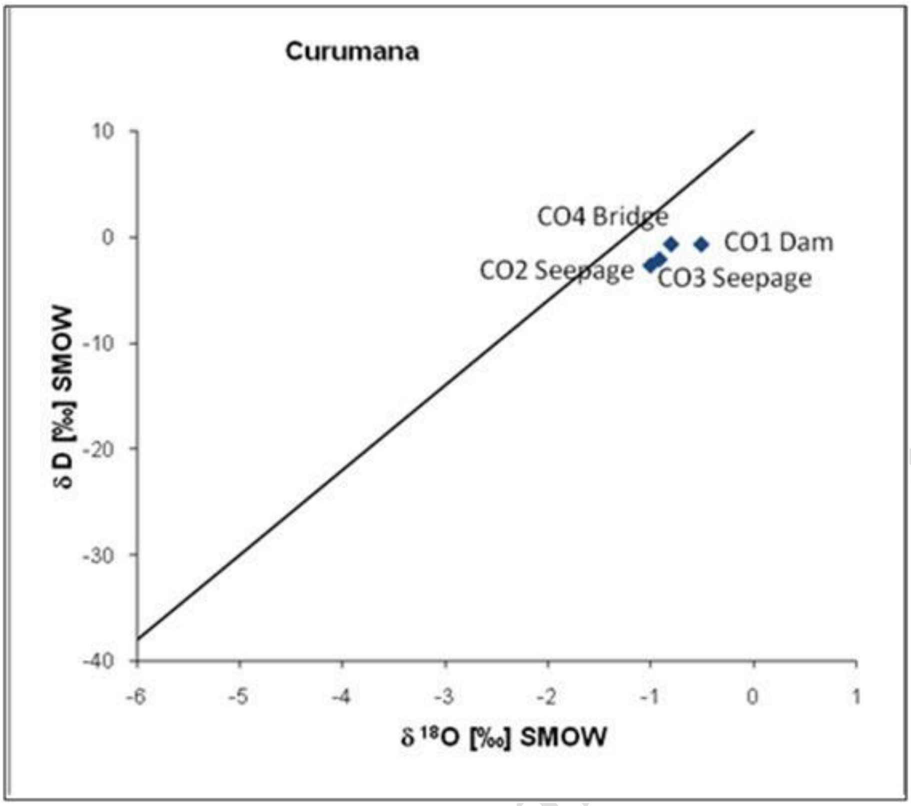

Figure 4. Deuterium vs. Oxygen-18 in relation to the GMWL.

4 Discussion and conclusion

The chemical analyses showed high sodium and chloride values for the dam and groundwater. The report by Consultec and BKS ACRES (2001) showed that the maximum chloride recorded at Corumana is only 74.82 compared to the 201.4 recorded during this study. They did mention in 2001 that there is a temporal trend for EC values to increase gradually with time at most stations in the Incomati River which is an indication that the river is becoming more polluted. The water quality of surface water samples collected at the dam site is still good for irrigation

The completion of the dam, as indicated in the feasibility report by Lahmeyer International in Ass, with Consultec and Austral (2003), could possibly in future make water available for the villages that presently rely on groundwater. The chemical analysis indicates unacceptable high salinity and fluoride in the groundwater. Should water supply from the reservoir possibly in future replace the groundwater to the villages, then the groundwater can still be used for water supply to goats and cattle but not for gardening.

5. References

Geological Map of Mozambique, 1:1 000 000 Scale. Ministry of Mineral Resources and Energy. National Directorate for Geology. 2004

Hydrogeological Map of Mozambique, 1:1000 000 Scale. Ministry of Ministry of Construction and Water, National Directorate for Water Affairs. 1987

Laboratório Nacional de Higiene dos Alimentos e Água. Ministério da Saúde. República de Moçambique. Métodos de Análise de Água, 1997. Lahmeyer International in Ass, with Consultec and Austral (2003) Raising of the Full Supply Level of Corumana Dam – Final Feasibility Study Report. March 2003.

MICOA (2004) Regulamento sobre os padrões de qualidade Ambiental e de Emissão de Efluentes. Decreto nº 18/2004, de 2 de Junho.

Consultec and BKS ACRES (2001) Joint Inkomati Basin Study – Appendix 14: Groundwater. December 2001.

Sweco, Consultec, Impacto and BKS ACRES : Water Resources Development Plan for Inkomati River Basin.

South African National Standards: Drinking Water, SANS 241:2006 Edition 6.1. Published by Standards South Africa.

ANNEXURE A

CLEAN STREAM
Scientific Services (Pty.) Ltd.

489 Jacqueline Drive, Garsfontein, Pretoria, 0042
P.O. Box 905008, Garsfontein, 0042
Tel (012) 348 2813/4, **Fax** 012 348 8575

Specialists in environmental monitoring

Test Report

Page: 1 of 2

Client: Aurecon
Address: 1040 Burnett Street, Hatfield, 0083
Report No: 4298 **Project:** Aurecon

Date of certificate: 29 Nov 2010
Date accepted: 22 Nov 2010
Date completed: 29 Nov 2010

Lab no:			48501	48502	48503	48504	48505	48506	48507
Date sampled:			22 Nov 2010	22 Nov 2010	22 Nov 2010	22 Nov 2010	22 Nov 2010	22 Nov 2010	22 Nov 2010
Sample type:			Water	Water	Water	Water	Water	Water	Water
Locality description			BH14-02	C01	C-DAM	RG1	RG3	RGBH	RGSC1
Analyses:		**Method**							
A	pH	CSM 05	8.14	7.80	7.96	7.80	8.26	7.52	7.57
A	Electrical conductivity (EC) mS/m	CSM 05	255.50	58.80	21.44	19.76	36.65	294.70	292.00
A	Total dissolved solids (TDS) mg/l	CSM 06	1688	780	671	522	175	1280	1208
A	Total alkalinity mg/l	CSM 01	496.4	186.6	53.8	55.5	94.4	350.0	294.3
A	Chloride (Cl) mg/l	CSM 01	608.0	312.0	336.6	249.4	27.9	463.4	533.2
A	Sulphate (SO4) mg/l	CSM 01	105.82	48.77	46.76	37.53	26.84	70.91	30.08
A	Nitrate (NO3) mg/l as N	CSM 01	2.530	0.097	0.678	0.157	0.606	46.854	6.379
A	Ammonium(NH4) mg/l as N	CSM 01	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015
A	Orthophosphate (PO4) mg/l as P	CSM 01	0.520	0.092	0.047	0.044	0.059	0.029	<0.025
A	Fluoride (F) mg/l	CSM 11	2.105	0.218	0.190	<0.183	0.279	2.028	1.258
A	Nitrite (NO2) mg/l as N	CSM 01	0.176	0.162	0.163	0.156	0.167	0.155	0.155
A	Calcium (Ca) mg/l	CSM 02	18.112	64.193	15.909	14.739	14.794	102.130	134.057
A	Magnesium (Mg) mg/l	CSM 02	30.682	27.669	27.992	21.594	14.993	79.939	82.803
A	Sodium (Na) mg/l	CSM 02	616.82	202.49	201.40	157.59	31.05	306.36	244.57
A	Potassium (K) mg/l	CSM 02	7.987	12.615	9.349	7.264	2.286	0.362	0.417
A	Aluminium (Al) mg/l	CSM 02	<0.006	<0.006	0.056	0.029	<0.006	<0.006	<0.006
A	Iron (Fe) mg/l	CSM 02	0.025	0.019	0.065	0.043	0.030	0.021	0.029
A	Manganese (Mn) mg/l	CSM 02	0.033	0.012	0.005	0.005	0.006	0.006	0.012
A	Total hardness mg/l	CSM 06	172	274	155	126	99	584	676

A = Accredited (Included in the SANAS Schedule of Accreditation); N = Not accredited (Excluded from the SANAS Schedule of Accreditation)
OSD = Outsourced; S = Sub-contracted; NR = Not requested; RTF = Results to follow; TNTC = To numerous to count; ND = Not detected
NATD = Not able to determine

sanas Testing Laboratory T0374

Report checked by: na

CLEAN STREAM
Scientific Services (Pty.) Ltd.

489 Jacqueline Drive, Garsfontein, Pretoria, 0042
P.O. Box 905008, Garsfontein, 0042
Tel (012) 348 2813/4, **Fax** 012 348 8575

Specialists in environmental monitoring

Test Report

Client: Aurecon
Address: 1040 Burnett Street, Hatfield, 0083
Report No: 4298 **Project:** Aurecon

Date of certificate: 29 Nov 2010
Date accepted: 22 Nov 2010
Date completed: 29 Nov 2010

Lab no:			48508
Date sampled:			22 Nov 2010
Sample type:			Water
Locality description			RGSC2
Analyses:		**Method**	
A	pH	CSM 05	7.54
A	Electrical conductivity (EC) mS/m	CSM 05	192.10
A	Total dissolved solids (TDS) mg/l	CSM 06	780
A	Total alkalinity mg/l	CSM 01	293.4
A	Chloride (Cl) mg/l	CSM 01	247.8
A	Sulphate (SO4) mg/l	CSM 01	43.99
A	Nitrate (NO3) mg/l as N	CSM 01	9.856
A	Ammonium(NH4) mg/l as N	CSM 01	<0.015
A	Orthophosphate (PO4) mg/l as P	CSM 01	0.028
A	Fluoride (F) mg/l	CSM 11	1.459
A	Nitrite (NO2) mg/l as N	CSM 01	0.189
A	Calcium (Ca) mg/l	CSM 02	95.865
A	Magnesium (Mg) mg/l	CSM 02	54.460
A	Sodium (Na) mg/l	CSM 02	151.14
A	Potassium (K) mg/l	CSM 02	0.494
A	Aluminium (Al) mg/l	CSM 02	<0.006
A	Iron (Fe) mg/l	CSM 02	0.020
A	Manganese (Mn) mg/l	CSM 02	0.014
A	Total hardness mg/l	CSM 06	464

A = Accredited (Included in the SANAS Schedule of Accreditation); N = Not accredited (Excluded from the SANAS Schedule of Accreditation)
OSD = Outsourced; S = Sub-contracted; NR = Not requested; RTF = Results to follow; TNTC = To numerous to count; ND = Not detected
NATD = Not able to determine

sanas Testing Laboratory
T0374

Report checked by: na

ANNEXURE B

National Research Foundation | iThemba LABS Laboratory for Accelerator Based Sciences

Environmental Isotope Laboratory

Postal address: Private Bag 11, Wits, 2050, South Africa.
Physical Address: Empire Road (between Jan Smuts Avenue and Yale Road)
Tel ++27 11 351 7000/1 (switchboard/secretary), Fax ++27 11 351 7053

Report
Reference: AFR015

Date: 15th November 2010

Stable Isotope Analysis on fourteen (14) water samples

submitted by Mr. Mannie Levin
Aurecon
Mozambique Dam Sites

M.J. Butler, O.H.T. Malinga, M.J. Mabitsela

confidential

1. General

Fourteen water samples were submitted by Mr. M. Levin of Aurecon for D/H ($^2H/^1H$) and $^{18}O/^{16}O$ analysis. The samples were received on the 2nd of November 2010.

2. Stable Isotope Analysis

Water D/H ($^2H/^1H$) and $^{18}O/^{16}O$ ratios were analysed in the laboratory of the Environmental Isotope Group (EIG) of iThemba Laboratories, Gauteng. The equipment used for stable isotope analysis consists of a PDZ Europa GEO 20-20 gas mass–spectrometer connected to peripheral sample preparation devices. A PDZ water equilibration system (WES), working in dual inlet mode is employed for hydrogen and oxygen isotope analysis of water. Equilibration time for the water sample with hydrogen is about one hour and CO_2 is equilibrated with a water sample in about eight hours. Laboratory standards, calibrated against international reference materials, are analysed with each batch of samples. The analytical precision is estimated at 0.1‰ for O and 0.5‰ for H.

Analytical results are presented in the common delta-notation:

$$\delta^{18}O(‰) = \left[\frac{(^{18}O/^{16}O)_{sample}}{(^{18}O/^{16}O)_{standard}} - 1 \right] \times 1000$$

which applies to D/H ($^2H/^1H$), accordingly. These delta values are expressed as per mil deviation relative to a known standard, in this case standard mean ocean water (SMOW) for $\delta^{18}O$ and δD.

3. Results

The analytical results are presented in Tables 1 and 2 and partially illustrated in Figure 1.

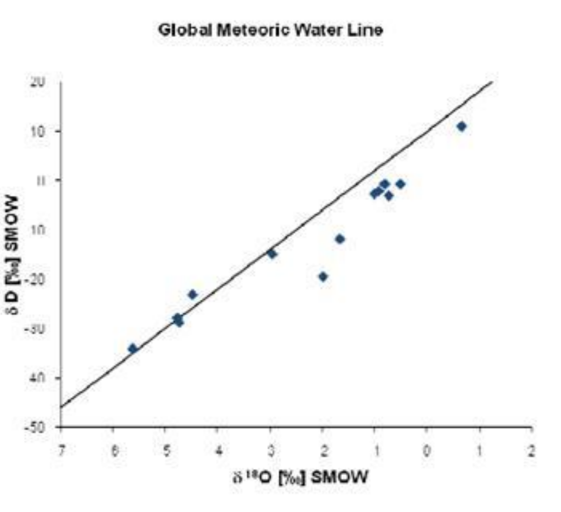

Figure 1: Stable isotope data relative to Global Meteoric Water Line (Craig, 1961).

The stable isotope analyses for the sample data could be well reproduced within the expected analytical error limits. Figure 1 shows the data in a $\delta^{18}O$ vs. δD space relative to the Global Meteoric Water Line (GMWL, Craig, 1961). The sample plots on the GMWL.

4. References

Craig, H. (1961). Isotopic variations in meteoric waters. *Science*, **133**, 1702–1703.

Table 1: Analytical Results

		Deuterium	Oxygen-18
Lab No	Field Name	δD‰ SMOW	$\delta^{18}O$‰ SMOW
AFR 498	RG2	-3.0	-0.72
AFR 499	RGBH	-14.9	-2.95
AFR 500	RGSC	-19.4	-1.98
AFR 501	CO1 Dam	-0.7	-0.50
AFR 502	CO2 Seepage	-2.7	-1.00
AFR 503	CO3 Seepage	-2.1	-0.91
AFR 504	CO4 Bridge	-0.7	-0.80
AFR 505	MHC1	-11.8	-1.66
AFR 506	MHC2	-28.8	-4.72
AFR 507	MHC3	-34.1	-5.61
AFR 508	GGD1 River	-23.1	-4.47
AFR 509	GGD2 Rain	+11.1	+0.67
AFR 510	GGD3 Borehole	-27.9	-4.76
AFR 511	GGD4 Borehole	-27.9	-4.75

Table 2: Stable isotope aliquot determinations

		Deuterium			Oxygen-18		
Lab No.	Field Name:	analysis	Batch	δD‰ SMOW	analysis	Batch	$\delta^{18}O$‰ SMOW
AFR 498	RG2	a	2010/11/05	-2.9	a	2010/11/09	-0.74
		b		-3.2	b		-0.71
			avg.:	**-3.0**		**avg.:**	**-0.72**
			diff.:	*0.2*		*diff.:*	*0.03*
AFR 499	RGBH	a	2010/11/05	-15.1	a	2010/11/12	-2.96
		b		-14.7	b		-2.93
			avg.:	**-14.9**		**avg.:**	**-2.95**
			diff.:	*0.4*		*diff.:*	*0.03*
AFR 500	RGSC	a	2010/11/05	-19.6	a	2010/11/09	-1.97
		b		-19.2	b		-1.98
			avg.:	**-19.4**		**avg.:**	**-1.98**
			diff.:	*0.4*		*diff.:*	*0.01*
AFR 501	CO1 Dam	a	2010/11/05	-0.7	a	2010/11/09	-0.50
		b	2010/11/10	-0.6	b	2010/11/12	-0.50
			avg.:	**-0.7**		**avg.:**	**-0.50**
			diff.:	*0.1*		*diff.:*	*0.00*
AFR 502	CO2 Seepage	a	2010/11/05	-2.6	a	2010/11/09	-1.01
		b		-2.7	b		-0.99
			avg.:	**-2.7**		**avg.:**	**-1.00**
			diff.:	*0.1*		*diff.:*	*0.02*
AFR 503	CO3 Seepage	a	2010/11/05	-2.3	a	2010/11/09	-0.95
		b		-1.9	b		-0.88
			avg.:	**-2.1**		**avg.:**	**-0.91**
			diff.:	*0.4*		*diff.:*	*0.07*
AFR 504	CO4 Bridge	a	2010/11/05	-0.6	a	2010/11/09	-0.80
		b		-0.7	b		-0.81
			avg.:	**-0.7**		**avg.:**	**-0.80**
			diff.:	*0.1*		*diff.:*	*0.01*

AFR 505	MHC1	a	2010/11/05	-11.8	a	2010/11/09	-1.65
		b		-11.9	b		-1.67
			avg.:	**-11.8**		**avg.:**	**-1.66**
			diff.:	*0.2*		*diff.:*	*0.02*
AFR 506	MHC2	a	2010/11/05	-28.5	a	2010/11/09	-4.72
		b		-29.0	b		-4.72
			avg.:	**-28.8**		**avg.:**	**-4.72**
			diff.:	*0.5*		*diff.:*	*0.00*
AFR 507	MHC3	a	2010/11/05	-34.0	a	2010/11/12	-5.56
		b		-34.2	b		-5.66
			avg.:	**-34.1**		**avg.:**	**-5.61**
			diff.:	*0.3*		*diff.:*	*0.11*
AFR 508	GGD1 River	a	2010/11/05	-23.1	a	2010/11/09	-4.44
		b		-23.1	b		-4.50
			avg.:	**-23.1**		**avg.:**	**-4.47**
			diff.:	*0.0*		*diff.:*	*0.06*
AFR 509	GGD2 Rain	a	2010/11/05	11.3	a	2010/11/09	0.62
		b		10.8	b		0.72
			avg.:	**11.1**		**avg.:**	**0.67**
			diff.:	*0.5*		*diff.:*	*0.10*
AFR 510	GGD3 Borehole	a	2010/11/05	-27.7	a	2010/11/09	-4.77
		b		-28.0	b		-4.75
			avg.:	**-27.9**		**avg.:**	**-4.76**
			diff.:	*0.2*		*diff.:*	*0.03*
AFR 511	GGD4 Borehole	a	2010/11/05	-27.9	a	2010/11/09	-4.82
		b		-27.9	b		-4.68
			avg.:	**-27.9**		**avg.:**	**-4.75**
			diff.:	*0.0*		*diff.:*	*0.13*

APPENDIX 4

Baseline study. Terrestrial Ecology

1. Introduction

1.1. Background

ECOREX Consulting Ecologists CC was approached by Austral COWI to provide technical input on terrestrial ecology for an Environmental Impact Assessment (EIA) and a Social Impact Assessment (SIA) for the completion of Corumana Dam. Austral COWI is conducting the EIA and SIA on behalf of Direcçao Nacional de Águas, Maputo (Mozambique) and the project forms part of the National Water Re-sources Development Program 1 (DNA file number NWRDP/07/Cons/2007). This report is based on a review of available data and a rapid assessment field survey undertaken by ECOREX in December 2010.

1.1. Scope of Work

The tasks for this report were:

i) Carry out baseline survey of terrestrial ecology including:

- Mapping of habitat and land use distribution in the project area. The vegetation shall be subdivided in habitat types. The future inundated area behind the dam shall be mapped in detail using field studies, aerial analysis and use of GPS and GIS.

- For each vegetation type a number of common and dominant plant species shall be noted together with unusual and rare species if en-countered. A photo will accompany each description of vegetation type in the report.

- A comprehensive list of bird species encountered in each vegetation type shall be prepared. In order to make the lists understood by layman each species shall be annotated with data on how common the species is and its habitat requirements. Occurrence of endangered, endemic or other unusual species shall be noted.

- Studies on mammals, amphibians, reptiles and other species groups shall be carried out by direct observation, observation of tracks and by enquiring the local people on the occurrence on larger species of mammals. Occurrence of endangered, endemic or other unusual species shall be noted.

- The possible occurrence of endangered plants and animals shall be scrutinised by studies on the habitat requirements and known distribution.

ii) Assessment of impacts on terrestrial ecology including where relevant:

- Inundation of the natural habitats that existed before the dam's construction and derived impacts on wildlife (including impacts on red listed and protected species and area). The incremental land area (hectares) upstream of the dam wall or weir that would be inundated as a result of the project shall be quantified. It shall be indicated whether such inundation would be more or less permanent, frequent for long periods (due to fluctuating reservoir levels), or occasional for brief periods. The land areas to be inundated should be classified, according to whether they are (i) original (pre-dam) natural habitats (riverine forest, bushveld, etc.); (ii) modified habitats with natural vegetation that have emerged in response to previously installed infrastructure (specifically in the case of the Corumana Dam, reservoir-edge grasslands or mudflats); or (iii) agricultural, densely settled, or other previously converted lands where natural vegetation is mostly absent.

- Fragmentation of ecosystems as a result of inundation.
- Disruption of migratory patterns of wildlife by dam construction and associated developments.

iii) Propose mitigating measures

iv) Prepare inputs to Environmental Management Plan

2. Materials and methods

2.1. Desktop study

2.1.1. Mapping of habitat and land use distribution

Since no high resolution aerial imagery was provided, Google Earth™ satellite imagery was used to delineate vegetation community boundaries based on visible structural differences in woody canopy cover and landscape position.

2.1.2. Potential occurrence of threatened flora and fauna

A list of potentially occurring threatened plants was compiled using the SABONET Mozambique Red Data Plant List (Golding, 2002) for national Red Data status and the IUCN Red List (www.iucnredlist.org) for international Red Data status (Table 1). No national conservation status assessments have been made for mammals, birds, reptiles and amphibians, and thus the IUCN Red List was the only source of conservation assessments for Mozambique fauna. This is probably adequate for well-assessed groups such as birds, but small mammals, reptiles and amphibians are likely to be underrepresented. Conservation assessments made in adjacent countries such as South Africa are not relevant since those countries may have different threats driving their conservation assessments that are not necessarily relevant to Mozambique, e.g. high levels of transformation of grassland through irrigated cropland agriculture.

Likelihood of occurrence of each potentially occurring threatened plant and animal was assessed on the basis of known habitat requirements and proximity to confirmed distribution records.

2.2. Fieldwork

2.2.1. Mapping of habitat and land use distribution

The boundaries of vegetation communities identified during the desktop phase were verified through quantitative and qualitative field observations and use of GPS.

2.2.2. Description of Vegetation Communities

Plant communities were described according to vegetation structure (using the classification of Edwards, 1983) and dominant plant species. Dominance was determined through analysis of canopy cover and frequency of occurrence of plant species within 10 x 10 m quadrants using cover-abundance values as described by Kent & Coker (1995). Photographs of each quadrant were taken in order to accompany vegetation descriptions. Environmental variables recorded at each quadrant were position in landscape, soil texture and elevation. Any threatened plant species encountered within quadrants and along the route between quadrants were photographed and the location recorded on a Garmin GPS Map 60CSx.

2.2.3. Description of Faunal Assemblages

Birds were surveyed by walking slowly along transects through each vegetation community using Swarovski 10x42 EL binoculars. Identification was made visually and audibly based on knowledge of each species calls. A comprehensive list of bird species recorded in each vegetation type was pre-pared, including notes of frequency of encounters, habitat usage and national status. Locations of any threatened, locally rare or endemic species were recorded on a GPS.

Mammals, reptiles and amphibians were recorded incidentally while surveying birds and vegetation. Observations were either direct (visual, audibly), indirect (dung, tracks) and through conversations with local people. Occurrence of any threatened or endemic species was noted and the location recorded on a GPS.

3. Results

3.1. Flora

3.1.1. Regional Context

The Corumana Dam is situated within the Tongaland-Pondoland Regional Mosaic of White (1983), an area of high floral diversity confined to coastal south-east Africa. The Maputaland Centre of Plant Endemism (MCPE) is a focus-point of high plant endemism within this regional mosaic that supports between 2,500 and 3,000 vascular plant species of which at least 203 taxa are endemic or near-endemic to the centre (Van Wyk, 1996). The Corumana Dam is situated at the northern edge of the core area of the MCPE, the boundaries of which are the Incomati-Limpopo River in the north (although possibly as far north as the Save River), Lebombo Hills in the west and Indian Ocean in the east.

Two vegetation types described by Wild & Barbosa (1967) for the general vicinity of Corumana reservoir:

i. *Acacia* spp. Tree or Shrub Savannah

This vegetation type occurs mostly on saline soils with clayey zones, or more locally on sandy soils, but in either case soils are usually of a calcareous nature. Some prominent trees are various *Acacia species*, *Sclerocarya birrea* subsp. *cafra*, *Albizia versicolor*, *Terminalia sericea*, *Peltophorum africanum* and *Afzelia quanzensis*. *Spirostachys africana*, *Albizia anthelmintica* and *Albizia petersiana* are more prominent on less permeable soils. In lower-lying areas, extensive grasslands develop with dominant grasses including *Panicum coloratum*, *Urochloa mossambicensis*, *Bothriochloa insculpta*, *Setaria incrassata* and *Eragrostis* species. Scattered trees include *Acacia nilotica*, *Acacia nigrescens*, *Combretum imberbe* and *Combretum hereroense*. A dif-ferment community develops along deep alluvial soils and is dominated by large trees such as *Diospyros mespiliformis*, *Faidherbia albida*, *Combretum imberbe*, *Philenoptera violacea*, *Trichilia emetica* and *Xanthocercis zambesiaca*. This vegetation type often intergrades with the next.

ii. *Themeda-Turbina* Lowland Grassland

Two distinct communities are represented within this vegetation type: grass-land with scattered trees and shrubs, and true grassland with very few trees and shrubs. Themeda triandra is the dominant grass in both communities and other common grasses are *Urochloa mossambicensis*, *Aristida congesta* subsp. *barbicollis*, *Eragrostis superba*, *Bothriochloa insculpta* and *Heteropogon contortus*. Scattered trees and shrubs include *Acacia nigrescens*, *Philenoptera violacea*, *Acacia* species, *Combretum imberbe*, *Ziziphus mucronata* and *Sclerocarya birrea* subsp. *cafra*.

However, fieldwork revealed that neither of the above vegetation types were clearly present in the Corumana Dam area, and the vegetation dynamics are more easily understood if viewing vegetation from a landscape context.

3.1.2. Landscape Context

The plant communities and landscapes of the Parque Nacional do Limpopo (PNL), to the north of the study area, have been described by Stahlmans et al. (2004). The authors found that at larger scales, vegetation could not be easily mapped as individual communities, but as landscapes in which vegetation communities are imbedded. In other words, landscapes are explicit and mapped as such, while vegetation communities / associations are implicit and are embedded within these landscapes. This same approach has been taken in this study. While many of the plant communities and landscapes described Parque Nacional do Limpopo are not relevant to the Corumana Dam area, the authors found a strong correlation in that study with adjacent landscapes in the Kruger National Park as described by Gertenbach (1983). Fieldwork conducted by ECOREX in this study confirmed that two landscapes from the Kruger National Park are clearly represented around Corumana reservoir, namely *Sclerocarya birrea* / *Acacia nigres-*

cens Savannah and Lebombo South. An additional landscape that has been formed through the inundation of the Sabíe River valley is Floodplain Grassland. These are spatially indicated in Figure 1.

i. *Sclerocarya birrea* / *Acacia nigrescens* Savannah Landscape

This landscape is mostly represented along the northern and southern shores of Corumana reservoir and is characterised by fairly level plains and well-defined drainage lines. The underlying geology is basalt, which weathers into black, brown or red clayey soil. Vegetation structure varies from open to closed tree savannah with a moderate shrub layer and dense grass layer, to low dense thicket on sodic soils. Three vegetation communities are embedded within this landscape: *Sclerocarya birrea – Acacia nigrescens* Open Woodland, *Acacia borleae – Euclea divinorum* Thicket and *Ficus sycomorus – Acacia xanthophloea* Riverine Woodland.

o *Sclerocarya birrea – Acacia nigrescens* Open Woodland (Figure1)

This vegetation association is characterised by a fairly open canopy and dense grass understory. It is found on slightly elevated plains where reddish to brown clay loams predominate, but not in areas that experience temporary inundation. Dominant trees are *Sclerocarya birrea* subsp. *cafra* and *Acacia nigrescens*, while other common trees are *Combretum hereroense*, *Combretum imberbe*, *Albizia harveyi* and *Acacia gerrardii*. *Dichrostachys cinerea* subsp. *africana*, *Gymnosporia senegalensis*, *Grewia bicolor* and *Ehretia amoena* are common shrubs. Common grasses are *Panicum coloratum*, *Setaria sphacelata*, *Cenchrus ciliaris*, *Themeda triandra*, *Pogonarthria squarrosa* and *Schmidtia pappophoroides*.

o *Acacia borleae – Euclea divinorum* Thicket

These thickets are found on deep black clays, usually in depressions. The largest thickets were found on the northern shores of the dam. The low shrubs *Acacia borleae* and *Euclea divinorum* are dominant and diagnostic, while other common shrubs are *Cordia sinensis*, *Gymnosporia senegalensis* and *Maerua parvifolia*. Grasses include *Eragrostis* cf. *heteromera* and *Sporobolus* spp.

o *Ficus sycomorus – Acacia xanthophloea* Riverine Woodland (Figure 2)

Vegetation along the banks of streams and rivers is tall closed woodland dominated by *Ficus sycomorus*, *Acacia xanthophloea*, *Philenoptera violacea*, *Diospyros mespiliformis*, *Trichilia emetic* and *Acacia robusta* subsp. clavigera. Common shrubs are *Gymnosporia senegalensis*, *Euclea natalensis*, *Abutilon angulatum* and *Pluchea dioscoridis*. This association is well represented below the Corumana Dam wall (Figure 2), and is possibly represented along some of the streams entering the dam in the north-west. A similar riparian vegetation association was apparently represented in the Sabíe Gorge at the Kruger National Park boundary, but was destroyed during the February 2000 floods. No adult *Ficus sycomorus* trees are now present at the site and it is now represented by various riparian vegetation associations that are embedded in the Lebombo South landscape type (see below).

Approximately 1,581 ha of the S*clerocarya birrea* / *Acacia nigrescens* Savannah landscape could potentially to be lost around the reservoir at the 1 in 1,000 year flood event of 120 masl if mitigation measures are pursued.

Figure 1. ***Sclerocarya birrea – Acacia nigrescens*** **Open Woodland**

Figure 2. ***Ficus sycomorus – Acacia xanthophloea*** **Riverine Woodland**

ii. Lebombo South Landscape

The Lebombo Hills along the South Africa – Mozambique border dominate the physiography of this landscape, with ridges and valleys orientated north-south. The geology is predominantly rhyolite of the Lebombo Group (Karoo Sequence) which produces mostly lithic rhyolitic soils. The vegetation structure is mostly closed woodland with a fairly rich grassy understory. Two vegetation communities / associations are embedded within this landscape around Corumana reservoir, namely Combretum apiculatum – Sclerocarya birrea Closed Woodland and Euphorbia confinalis – Grewia caffra Thicket. At the Sabíe Gorge, where the Corumana reservoir will push into the Kruger National Park, a further two vegetation communities are embedded in the Lebombo South land-scope and are confined to the macro-channel floor of the Sabíe River: *Breonadia salicina* – P*hragmites mauritianus* Wooded Grassland and *Phyllanthus reticulatus - Bridelia cathartica* Thicket.

o *Combretum apiculatum – Sclerocarya birrea* Closed Woodland (Figure 3)

This woodland association is widespread across the Lebombo Hills and is the dominant terrestrial vegetation cover west of Corumana reservoir. Soils are generally fairly shallow and stony. Broad-leaved trees dominate, particularly *Combretum apiculatum* and *Sclerocarya birrea* subsp. *cafra*, while other common trees and shrubs are *Cassia abbreviata*, *Ozoroa engleri*, *Peltophorum africanum*, *Mundulea sericea*, *Pappea capensis, Aloe marlothii, Aloe spicata, Acacia exuvialis*, *Rhoicissus schlechteri*, *Flueggea virosa* and *Dichrostachys cinerea* subsp. *nyassana*. Forbs are generally diverse and include species such as *Ceratotheca triloba*, *Commelina erecta, Syncolostemon* spp., *Emilia transvaalensis*, *Leucas sexdentata* and *Rhynchosia totta*. It is unlikely that much of this vegetation community will be inundated as it is mostly restricted to slopes and crest of the Lebombos, but limited areas along the western shores may be affected.

o *Euphorbia confinalis – Grewia caffra* Thicket (Figure 4)

This is a very distinct vegetation community associated with very steep slopes (e.g. at the Sabíe Gorge, the ridge south of the dam wall) or on rhyolite outcrops in the south and west of the study area. The endemic succulent, *Euphorbia confinalis*, is diagnostic for this community and often occurs in dense groves. Other common canopy trees are *Ptaeroxylon obliquum*, *Terminalia phanerophlebia*, *Sclerocarya birrea* subsp. *caffra*, *Euphorbia cooperi*, *Ficus abutilifolia*, *Berchemia zeyheri, Siderozylon inerme*, *Manilkara mochisia* and *Sterculia rogersii.* Shrubs include *Grewia caffra*, *Pouzolzia mixta*, *Phyllanthus reticulatus*, *Bridelia cathartica*, *Barleria elegans*, *Hibiscus calyphyllus* and *Azima tetracanth*a. Common climbers are *Cissus rotundifolius*, *Momordica balsamina* and *Pristimera longipetiolata*. A few areas of this community are likely to be affected by inundation in the Sabíe Gorge (southern shore) and the western shores of the Corumana reservoir.

Figure 3. ***Combretum apiculatum* – *Sclerocarya birrea*** **Open Woodland**

Figure 4. ***Euphorbia confinalis* – *Grewia caffra*** **Thicket**

The two riparian vegetation communities confined to the macrochannel floor upstream of the Corumana reservoir are:

o ***Breonadia salicina – Phragmites mauritianus*** **Wooded Grassland (Figure 5)**

This is the dominant vegetation community in the braided rocky channels and sandbanks of the Sabíe River upstream of Corumana reservoir. It corresponds to the “*Phragmites mauritianus* reed vegetation” vegetation type of van Coller et al. (1997). *Breonadia salicina* is not present in sufficient numbers to be representative of “*Breonadia salicina* closed evergreen woodland” of Van Coller et al. (1997). *Phragmites australis* is noticeably dominant throughout, with scattered *Breonadia salicina* trees prominent on emergent rocks where seedlings have managed to establish themselves. Scattered shrubs include *Pluchea dioscoridis* and *Nuxia oppositifolia*, while *Mikhania capensis* is a common climber in the reeds.

o ***Phyllanthus reticulatus - Bridelia cathartica*** **Thicket (Figure 6)**

This is a rather narrow community occurring on small islands in the braided channel. Vegetation structure is Low Thicket (sensu Edwards, 1983) and is dominated by woody shrubs and small trees. This community corresponds to the “*Phyllanthus reticulatus* shrub vegetation” vegetation type of Van Coller et al. (1997). *Phyllanthus reticulatus* and *Bridelia cathartica* are dominant, while common woody species are *Grewia caffra*, *Nuxia oppositifolia*, *Antidesma venosum* and *Euclea natalensis* subsp. *angustifolia*. *Syzygium guineense* is diagnostic for this community, although it is not common within the area of inundation.

Figure 5. ***Breonadia salicina – Phragmites mauritianus*** **Wooded Grassland**

Figure 6. ***Phyllanthus reticulatus – Bridelia cathartica*** **Thicket**

The Lebombo South landscape is unlikely to experience the same levels of inundation as the *Sclerocarya birrea – Acacia nigrescens* Savannah landscape, and approximately 792 ha could potentially to be lost around the reservoir at the 1 in 1,000 year flood event of 120 masl if mitigation measures are pursued.

iii. Floodplain Grassland

This landscape is the dominant vegetation belt along the margin of the Corumana reservoir and is the landscape that will be most affected by increasing the FSL of the dam. Most, if not all of this landscape is likely to be lost. Three narrow vegetation communities are embedded within the Floodplain Grass-land landscape, each occurring at different levels of inundation:

o *Paspalidium obtusifolium – Cynodon dactylon* Grassland (Figure 7)

This community is confined to the water's edge and is partly inundated or at least inundated for a significant part of the year. The grasses *Paspalidium obtusifolium* and *Cynodon dactylon* are dominant, with *Paspalidium* often forming floating mats. Other common and diagnostic grasses are *Eriochloa meyeriana* and *Eragrostis* cf. *heteromera*. Several Cyperaceae species are present in this community and the small wetland herb *Phyla nodiflora*.

o *Epaltes gariepina – Chenopodium* sp. Herbland (Figure 8)

This community occurs at slightly more elevated ground than the previous community, but is subject to periodic inundation. It is noticeably distinct be-cause of the dominance by herbaceous plants and lower proportion of grasses. *Epaltes gariepina* and a *Chenopodium* species are dominant and diagnostic. The invasive exotic herb *Parthenium hysterophorus* is very common in places.

o *Sorghum bicolor* Grassland (Figure 9)

This grassland community is particularly common along inlets of the dam and occurs on soils that are only temporarily inundated during flooding. Terrestrial grasses are most prominent, with the tall grass *Sorghum bicolor* dominating throughout. *Urochloa mossambicensis*, *Setaria incrassata*, *Eragrostis* cf. *heteromera* and *Eriochloa meyeriana* are less common grasses. The invasive exotic herb *Parthenium hysterophorus* is common in places, as well as *Nidorella* cf. *auriculata* and a *Chenopodium* species.

Figure 7. *Paspalidium obtusifolium – Cynodon dactylon* Grassland

Figure 8. ***Epaltes gariepina – Chenopodium*** **sp. Herbland**

Figure 9. ***Sorghum bicolor*** **Grassland**

3.1.3. Cultivation

Scattered cultivated fields are found around the dam, although less so close to the margin where land is prone to inundation. The eastern shores have a higher proportion of cultivated fields. Maize was the most frequently encountered crop during the fieldwork. This land-use is most prevalent in the *Sclerocarya birrea – Acacia nigrescens* Savannah landscape, where soils are deeper and more fertile.

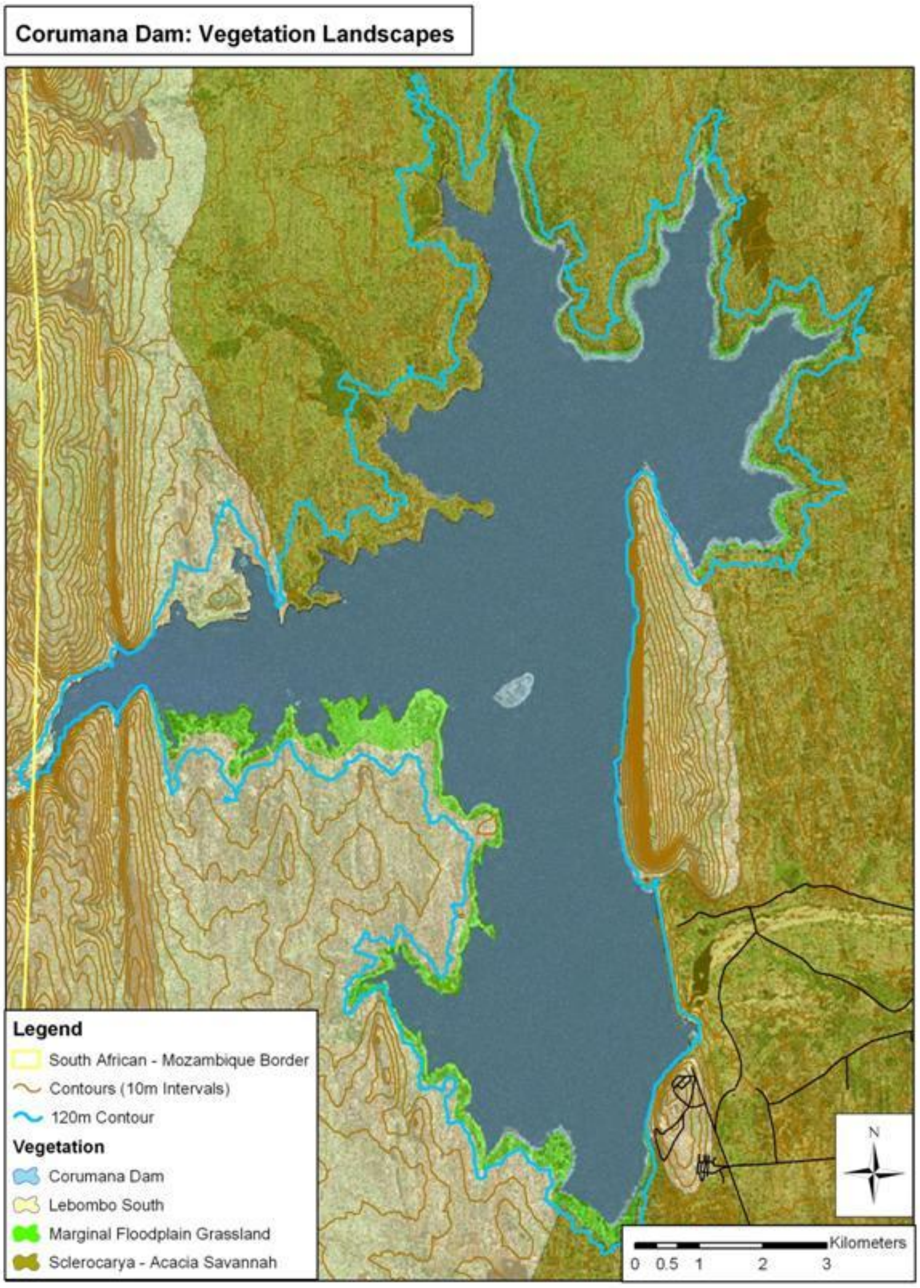

Figure 3-10. Landscape types represented around Corumana reservoir

3.1.4. Conservation-important Plant Species

Four tree species occurring within the study area are included in the IUCN global Red List of threatened species, and an additional 15 species have been allocated national Red Data status (Table 1).

Eleven species have a High likelihood of occurrence in the vicinity of Corumana reservoir because of presence of much suitable habitat and proximity to confirmed distribution records (Table 1). The most threatened of these is *Cyphostemma barbosae*, which has a national status of **Endangered**. This species has been collected in the Lebombos near Ressano Garcia and could thus occur in similar habitat in the Sabíe Gorge where the dam will push back into Kruger National Park. However, it is unlikely to be impacted as it does not occur in riparian vegetation (Wild & Drummond, 1966). Two other species with a High likelihood of occurring have a significant threat status of **Vulnerable**. One of these, *Triaspis hypericoides* subsp. *canescens*, is confined to the Lebombo Hills and was confirmed in the study area during fieldwork, although much higher than the area of inundation and is thus unlikely to be impacted. The other species, *Englerina schlechteri*, occurs as a parasitic plant on *Strychnos* trees in open wooded grassland to the east of the Lebombos. Three of the eleven High likelihood species have a lower threat status of **Near Threatened** (*Afzelia quanzensis*, *Dalbergia melanoxylon* and *Pterocarpus angolensis*), all of which are valuable timber species that are declining because of illegal and unsustainable felling in Mozambique. *Aphelia quanzensis* was con-firmed to occur in *Euphorbia confinalis – Grewia caffra* Thicket in the study area along the Lebombo Hills, but outside of the area of inundation, while *Dalbergia melanoxylon* was confirmed at a number of localities in both landscape types along the northern and western shores of the dam, well above the inundation area.

The remaining five species have been classified as **Data Deficient,** meaning that insufficient data are present in order to confidently assign threat status to these species. Two of these are common species in South Africa, but are likely to be confined to the Lebombos in Mozambique (*Euphorbia clavigera*, *Pavetta catophylla*). Two other species occur on the plains east of the Lebombos but do not occur in neighbouring South Africa (*Maerua brunnescens*, *Polygala torrei*). None of these were located during fieldwork.

Five threatened species have a **Moderate** likelihood of occurring because of some suitable habitat present in the vicinity of Corumana reservoir, although none of these species were confirmed during fieldwork (Table 1). The most threatened of these is *Adenium swazicum*, which has been assigned a threat status of **Endangered**, although in South Africa, where the bulk of its distribution lies, it is classified as Critically Endangered and is almost confined to protected areas. Three other species have been classified as **Vulnerable,** two of which are easily overlooked creepers (*Ipomoea venosa* var. *obtusifolia*, *Turbina longiflora*) and one is a spiny shrub occurring in riverine thickets in the Lebombo Hills *(Caesalpinia rostrata*). The remaining moderate likelihood species (*Brachylaena huillensis*) has a global threat status of Near Threatened and is most likely to be found in woodland on the Lebombos.

The remaining three potentially occurring threatened species are forest or thicket plants that have a **Low** likelihood of occurring because the very limited presence of such habitats in the study area. The most threatened of these is *Warburgia salutaris*, which has a global threat status of **Endangered**. This species is highly sought after for traditional medicine markets and has become locally extinct in many areas in South Africa. The other two species have national threat status of Vulnerable (*Duvernoia aconitiflora*, *Adenopodia schlechteri*).

The most important landscape for threatened plants in the study area is Lebombo South. Seven threatened species are likely to be confined to this landscape, while an additional four species are likely to be shared with the plains to the east. However, this landscape is less likely to experience as much inundation as the lower-lying *Sclerocarya birrea – Acacia nigrescens* Savannah landscape, which potentially supports three highly threatened species in areas that could be inundated (*Adenium swazicum*, *Ipomoea venosa*, *Turbina longiflora*).

Table 1. Red Data Plants potentially occurring in the vicinity of Corumana reservoir.

Species	Family	Red Data	Habitat	Flowering Time	Likelihood	Reason
Crossandra fruticulosa	Acanthaceae	[DD]	*Acacia* bushland and grassland on alluvial plains, riverbanks; up to 175 m elevation	Sep-Mar	High	Specimens from Lebombos at Goba and Komatipoort
Duvernoia aconitiflora	Acanthaceae	[VU]	Forest margins, sometimes along rivers	Mar-May	Low	Limited habitat present in study area
Adenium swazicum	Apocynaceae	[EN]	Open woodland on sandy, brack-ish soil	Jan	Moderate	Specimen from between Magude and Chobela
Brachylaena huillensis	Asteraceae	NT	Semi-deciduous forest or thicket	Nov-Dec	Moderate	Suitable habitat present in study area
Warburgia salutaris	Canellaceae	EN	Forest or thicket	Apr-May	Low	Limited habitat present in study area
Maerua brunnescens	Capparaceae	[DD]	Low altitude dry woodland, often with Acacia, sometimes on termi-taria	Oct-Nov	High	Specimen from Sabíe town
Ipomoea venosa var. obtusi-folia	Convolvulaceae	[VU]	Bushland, sandy riverbanks	January	Moderate	Suitable habitat present in study area
Turbina longiflora	Convolvulaceae	[VU]	Woodland on sandy soil; up to 310 m elevation	Mar-Apr	Moderate	Suitable habitat present in study area
Euphorbia clavigera	Euphorbiaceae	[DD]	Rocky places on Lebombo Mts	Dec	High	Type from Ressano Garcia
Adenopodia schlechteri	Fabaceae	[VU]	Thickets	Dec-Jan	Low	Limited habitat present in study

						area
Afzelia quanzensis	Fabaceae	[NT]	Dry forest, woodland, scrub forest	Sep-Oct	Confirmed	Known from Lebombo Hills in Kruger National Park
Caesalpinia rostrata	Fabaceae	[VU]	Riverine thicket, closed woodland on flats	Nov-Jan	Moderate	Specimens from along Crocodile River in gorge through Lebombos at Komatipoort
Dalbergia melanoxylon	Fabaceae	NT	Woodland and thickets	Oct-Dec	Confirmed	Known from Lebombo Hills in Kruger National Park
Pterocarpus angolensis	Fabaceae	NT	Deciduous woodland and wooded grassland, on sandy soils and granite outcrops	Sep-Oct	High	Known from Lebombo Hills in Kruger National Park
Englerina schlechteri	Loranthaceae	[VU]	Wooded grassland; parasitic on *Strychnos* spp.	Jan-Feb	High	Specimens from Moamba area
Triaspis hypericoides subsp. canescens	Malpighiaceae	[VU]	Woodland on Lebombo Hills	Dec	Confirmed	Type from Ressano Garcia
Polygala torrei	Polygalaceae	[DD]	In pasture grass in dry open bush	Dec	High	Specimen from near Moamba
Pavetta catophylla	Rubiaceae	[DD]	Dry deciduous woodland and thicket	Oct-Nov	High	Known from Lebombo Hills in Kruger National Park
Cyphostemma barbosae	Vitaceae	[EN]	Dry stony places in open woodland	Sep	High	Specimen from Ressano Garcia

Red Data Categories:	
EN = Endangered	DD = Data Deficient
VU = Vulnerable	[ ] = national RD status, not reflected on international IUCN Red List
NT = Near Threatened	

3.2. Vertebrate fauna

3.2.1. Birds

Over 180 bird species have been recorded within the general vicinity of the Corumana reservoir (Parker, 1999; Sudlow, 2008; data from the current second South African Bird Atlas Project). The fieldwork carried out during this study has increased this total to 200 species. Bird species observed during fieldwork around the dam can be separated into five broad avian assemblages:

i. Woodland

This is the most species-rich bird assemblage in the study area, sup-porting at least 84 species (Annexure 2). Greatest affinity in species composition is with the Riparian Vegetation assemblage, with which it shares 29 species (34.5%), fol-lowed by Floodplain Grassland with which it shares 9 species (11%) and Thicket, with which it shares 8 species (9.5%). Forty-seven species (56%) are confined to this as-assemblage. Two globally threatened birds were confirmed to occur in this assemblage, namely Bateleur and European Roller, both of which are classified as near Threatened. Most frequently encountered species in this assemblage were Laughing Dove (100%), Dark-capped Bulbul (100%), Rattling Cisticola (100%), Sabota Lark (100%), Red-backed Shrike (80%), Blue Waxbill (80%), White-bellied Sunbird (80%), White-browed Scrub-Robin (80%), Crested Francolin (60%), Namaqua Dove (60%), Fork-tailed Drongo (60%), Swainson’s Spurfowl (40%), Brown-crowned Tchagra (40%) and Yellow-fronted Canary (40%).

ii. Thicket

This assemblage is confined to relatively small, narrow and / or fragmented thickets, and comprises only 15 species (Annexure 2). The most similar assem-blage is Woodland, with which it shares 8 species (53%). Two species (13%) are confined to this assemblage: Gorgeous Bush Shrike and Terrestrial Brownbul. No globally threatened birds were confirmed to occur. This assemblage was not sampled enough to determine frequency of occurrence of constituent birds spe-cies, but apparently common species were Gorgeous Bush Shrike, Black-backed Puffback, Green-backed Camaroptera and Dark-capped Bulbul.

iii. Riparian Vegetation

This assemblage is best represented along the Sabíe River between the upper reaches of Corumana reservoir and the Kruger National Park. It contains numer-ous aquatic species that use the riparian vegetation for resting or breeding in. Sixty species were recorded in this assemblage (Annexure 3-3), of which 29 spe-cies (48%) are shared with the Woodland assemblage and 24 species (40%) with the Floodplain Grassland assemblage. Seven species (12%) were only recorded in Riparian Vegetation. This assemblage was not sampled enough to determine frequency of occurrence of constituent birds species, but apparently common species were Tawny-flanked Prinia, Red-faced Cisticola, Southern Red Bishop, Red-billed Quelea, Three-banded Plover, Blacksmith Lapwing, Egyptian Goose, Grey Heron, African Pied Wagtail, Diederik Cuckoo, Lesser Masked Weaver, Pied Kingfisher and Wire-tailed Swallow.

iv. Floodplain Grassland

While being a narrow and fluctuating habitat, Floodplain Grassland does occur along the entire dam shoreline, thus representing a significant area (approximately 570 ha) within which this assemblage occurs. Habitat comprises tall to short, flooded grassland. Forty-one species were recorded in Floodplain Grassland during fieldwork (Annexure 2), of which 24 species (58.5%) are shared with Riparian Vegetation and 14 species (34%) also occur in the Open Water as-assemblage. Thirteen species were only recorded in Floodplain Grass-land, the most significant of which is Great White Pelican, although this species is not considered threatened. The most frequently en-countered species were Red-billed Quelea, Three-banded Plover, White-faced Duck, Spur-winged Goose, European Bee-eater.

v. Open Water

Only sixteen species were recorded in this assemblage (Annexure 2), of which seven are aerial insectivores that will hunt insects over open water. Waterfowl were only seen in low numbers, the most frequently encountered being White-faced Duck, Egyptian Goose and Spur-winged Goose. The most frequently encountered aerial insectivores over the dam were Barn Swallow and European Bee-eater.

The most important landscape / habitat for threatened birds is *Sclerocarya birrea – Acacia nigrescens* Savannah, which is likely to be negligibly impacted by increasing the FSL of the Corumana reservoir.

3.2.2. Mammals

Most large mammals in southern Mozambique have been exterminated through hunting and those that survive do so in protected areas such as Parque Nacional do Limpopo. Around Corumana reservoir, the only area with populations of large mammals is the Sabie Game Park, a privately run hunting reserve on the north-western shores of the dam. This reserve has approximately 16 km of shoreline of the dam (Brian Ring pers.comm.) where large mammals can access grazing and predators can engage in hunting along the floodplain. These mammals include the following globally threatened species:

- African Elephant (*Loxodonta africana*) – Vulnerable
- White Rhinoceros (*Ceratotherium simum*) – Near Threatened
- Black Rhinoceros (*Diceros bicornis*) – Critically Endangered
- Hippopotamus (*Hippopotamus amphibious*) - Vulnerable

- Lion (*Panthera leo*) – Vulnerable
- Leopard (*Panthera pardus*) – Near Threatened

The only mammal listed above that is likely to regularly forage on the grasslands to be inundated by increasing the FSL for the dam is Hippopotamus.

Around the rest of the Corumana reservoir, the only mammals likely to still occur in the marginal vegetation are rodents, particularly Greater Cane-rat, Angoni Vlei Rat, Cape Porcupine and Tree Squirrel, and small carnivores such as Slender Mongoose, Water Mongoose, African Civet, Honey Badger, Black-backed Jackal and Large-spotted Genet. Scats of African Clawless Otter were found at several localities close to the water's edge. Small antelope that may still occur along the dam outside of Sabie Game Park but could not be confirmed are Common Duiker and Steenbok.

3.2.3. Reptiles & Amphibians

The Kruger National Park, to the west of Corumana reservoir, has remarkably rich herpetofauna, with over 100 species confirmed to occur within the park boundaries (Pienaar, 1966). While such a rich herpetofauna is certainly likely to be represented across the border in Mozambique, it is likely to be lower in species richness because of less variety of habitat types east of the Lebombos, and even fewer species are likely to be impacted by the inundation caused by increasing the FSL of Corumana Dam.

The reptiles of the Corumana reservoir area fall within the East African coastal mosaic (Broadley, 1997). None of the species endemic to this zoogeographical region were confirmed to occur during fieldwork, but dedicated reptile surveys that include trapping are likely to add some endemics to the list.

The only Red Data reptile species potentially occurring in the study area according to data on the IUCN Redlist website is Natal Hinged Tortoise (*Kinixys natalensis*), which has a status of Near Threatened. This is a terrestrial species unlikely to occur close to the dam and is not expected on the floodplain area.

Species confirmed to occur during fieldwork were *Dendroaspis polylepis* (once in thickets at the dam wall), *Trachylepis margaritifer* (common on rocks in the Lebombos and in Sabíe Gorge), *Trachylepis varius* (common through-out), *Gerrhosaurus validus* (rocks in Sabíe Gorge), *Gerrhosaurus flavigularis* (seen several times in open woodland) and *Varanus niloticus* (Corumana reservoir, Sabíe Gorge).

The Mozambique / Maputaland coastal plain is characterised by high amphibian species richness and falls within the Eastern Escarpment / Coastal District of the Eastern Sub-region as described by Minter et al. (2004). Species characterising this zoogeographical district that were confirmed during fieldwork were *Tomopterna natalensis*, *Afrana angolensis*, *Phrynobatrachus natalensis*, *Hyperolius pusillus*, *Chiromantis xerampelina* and *Bufo gutturalis*.

No Red Data amphibians are likely to occur within the study area.

3.3. Present Ecological State

The Present Ecological State (PES) of the terrestrial vegetation communities was ranked according to:

- o Similarity to original state,
- o Potential to support high biodiversity,
- o Potential to support threatened species, and
- o Functional value.

The results are presented in Table 2. The landscape with the highest PES is the *Sclerocarya birrea – Acacia nigrescens* Savannah that is present within the Sabie Game Park, which is considered Unimpaired. The same landscape outside of the Sabie Game Park is considered to be Moderately Impaired where no cultivation is present or Severely Impaired where cultivation is embedded in the landscape. The Floodplain Grassland landscape, which is likely to be the most impacted landscape, is Moderately Impaired because of the prevalence of invasive alien weeds. Lebombo South landscape, which will only be negligibly impacted through increasing of the FSL of the dam, is Slightly Impaired, particularly along the western shores south of Sabíe River inlet.

Table 2. Present Ecological State of Landscapes represented around Corumana reservoir

Landscape	Original State	Potential for High Biodiversity	Potential for Threatened Species	Functional Value	Present Ecological State
Sclerocarya – *Acacia* Savannah (Sabie Game Park)	High	High	High	High	Unimpaired
Sclerocarya – *Acacia* Savannah (Rest of Dam)	Medium	Medium	Low	Medium	Moderately Impaired
Lebombo South	Medium	High	High	High	Slightly Impaired
Floodplain Grassland	Medium	Medium	Medium	High	Moderately Impaired

4. Discussion and conclusion

The position of the Corumana reservoir in relation to Kruger National Park to the west results in two landscapes found in the Kruger National Park being represented around the dam, namely *Sclerocarya birrea – Acacia nigrescens* Savannah on basalt and Lebombo South on rhyolite. In addition, the inundation of the Sabíe River valley when the dam was built has resulted in an additional landscape being formed, namely Floodplain Grassland.

The two terrestrial landscapes are well represented and protected in Kruger National Park, but are not represented in the nearby Parque Nacional do Limpopo (Stahlmans et al., 2004), the only protected area in Mozambique likely to support these landscapes. Thus, both landscapes can be considered unprotected in Mozambique. Both landscapes are however conserved in the privately owned Sabie Game Park. The Floodplain Grassland landscape is essentially an artificial one, having been formed through the dam construction. This is the landscape most likely to be impacted and will most likely be entirely lost through inundation. However, as new areas of savannah are flooded, the woody vegetation that is not able to withstand prolonged water-logged soils will die and slowly the Floodplain Grassland is likely to return.

The landscape most likely to support conservation-important plants is Lebombo South. Three Red Data species were confirmed to occur in this landscape during fieldwork: *Triaspis hypericoides* (Vulnerable), *Afzelia quanzensis* (Near Threatened) and *Dalbergia melanoxylon* (Near Threatened). None of these were in or near to the proposed new full supply level of the dam. One species, *Dalbergia melanoxylon*, was confirmed at several localities in the *Sclerocarya birrea – Acacia nigrescens* Savannah landscape, always above an elevation of 140 masl. The Lebombo South landscape is less likely to experience as much inundation as the lower-lying *Sclerocarya birrea – Acacia nigrescens* Savannah landscape, which potentially supports three highly threatened species in areas that could be inundated (*Adenium swazicum*, *Ipomoea venosa*, *Turbina longiflora*).

In contrast, the landscape most important for birds is *Sclerocarya birrea – Acacia nigrescens* Savannah. Two Red Data species, Bateleur (Vulnerable) and European Roller (Near Threatened), were confirmed and the roller was found to be fairly common in this landscape. While no threatened birds were reported from Floodplain Grassland, habitat is suitable as overwintering habitat for Great Snipe (Near Threatened).

The most important landscape for mammals is *Sclerocarya birrea – Acacia nigrescens* Savannah that is present in the Sabie Game Park. Suitable foraging habitat is present for Hippopotamus, African Elephant, and both White and Black Rhinoceros, all of which are threatened. Several antelope species graze along the dam shoreline and this is thus hunting habitat for two threatened carnivores, namely Lion and Leopard.

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Annexures

Annexure 1. Checklist of plants recorded in the study area during fieldwork

Species	Family	Growth Form	Red Data	Endemic	Landscape Types		
					Floodplain Grassland	Lebombo South	*Sclerocarya - Acacia* Savannah
Barleria elegans	ACANTHACEAE	Dwarf shrub				x	x
Justicia flava	ACANTHACEAE	Herb				x	x
Hermbstaedtia odorata var. odorata	AMARANTHACEAE	Herb			x		
Kyphocarpa angustifolia	AMARANTHACEAE	Herb					x
Pupalia lappacea var. lappacea	AMARANTHACEAE	Herb				x	
Lannea schweinfurthii var. stuhlmannii	ANACARDIACEAE	Tree					x
Ozoroa engleri	ANACARDIACEAE	Tree				x	
Sclerocarya birrea subsp. cafra	ANACARDIACEAE	Tree				x	x
Searsia gueinzii	ANACARDIACEAE	Shrub				x	x
Sarcostemma viminale	APOCYNACEAE	Succulent				x	
Stapelia gigantea	APOCYNACEAE	Succulent				x	
Pistia stratiotes *	ARACEAE	Aquatic herb			x		
Stylochaeton natalensis	ARACEAE	Geophyte				x	
Asparagus angusticladus	ASPARAGACEAE	Climber				x	
Asparagus cooperi	ASPARAGACEAE	Herb				x	x
Asparagus suaveolens	ASPARAGACEAE	Herb				x	
Aloe chabaudii	ASPHODELACEAE	Succulent				x	
Aloe marlothii	ASPHODELACEAE	Succulent				x	
Aloe spicata	ASPHODELACEAE	Succulent				x	
Aspilia cf. natalensis	ASTERACEAE	Herb				x	
Epaltes gariepina	ASTERACEAE	Herb			x		
Mikhania capensis	ASTERACEAE	Climber				x	
Nidorella cf. auriculata	ASTERACEAE	Herb			x		
Parthenium hysterophorus *	ASTERACEAE	Herb			x		x
Pluchea dioscoridis	ASTERACEAE	Herb				x	
Schkuhria pinnata *	ASTERACEAE	Herb			x		x
Tridax procumbens *	ASTERACEAE	Herb			x	x	x
Ageratum conyzoides *	ASTERACEAE	Herb				x	
Cordia sinensis	BORAGINACEAE	Shrub				x	x
Ehretia amoena	BORAGINACEAE	Shrub				x	x
Ehretia rigida	BORAGINACEAE	Shrub				x	

Heliotropium nelsonii	BORAGINACEAE	Herb			x		x
Nuxia oppositifolia	BUDDLEJACEAE	Tree				x	
Commiphora mollis	BURSERACEAE	Tree				x	
Commiphora pyracanthoides	BURSERACEAE	Shrub				x	
Opuntia ficus-indica *	CACTACEAE	Succulent					x
Cleome angustifolia	CAPPARACEAE	Herb			x	x	x
Maerua parvifolia	CAPPARACEAE	Shrub				x	x
Thilachium africanum	CAPPARACEAE	Shrub				x	
Gymnosporia senegalensis	CELASTRACEAE	Shrub				x	x
Pristimera longipetiolata	CELASTRACEAE	Climber				x	
Chenopodium sp.	CHENOPODIACEAE	Herb			x		
Garcinia livingstonei	CLUSIACEAE	Tree				x	x
Combretum apiculatum subsp. apiculatum	COMBRETACEAE	Tree				x	
Combretum hereroense	COMBRETACEAE	Tree				x	x
Combretum imberbe	COMBRETACEAE	Tree					x
Combretum microphyllum	COMBRETACEAE	Tree				x	x
Combretum mossambicensis	COMBRETACEAE	Shrub				x	x
Terminalia phanerophlebia	COMBRETACEAE	Tree				x	
Terminalia prunioides	COMBRETACEAE	Tree					x
Commelina erecta	COMMELINACEAE	Herb			x	x	x
Ipomoea plebeia subsp. africana	CONVOLVULACEAE	Creeper					x
Seddera suffruticosa	CONVOLVULACEAE	Creeper			x		
Kalanchoe brachyloba	CRASSULACEAE	Succulent				x	
Kalanchoe rotundifolia	CRASSULACEAE	Succulent				x	
Coccinia rehmannii	CUCURBITACEAE	Climber					x
Momordica balsamina	CUCURBITACEAE	Creeper				x	
Cyperus articulatus	CYPERACEAE	Sedge			x		
Cyperus denudatus var. denudatus	CYPERACEAE	Sedge				x	
Cyperus difformis	CYPERACEAE	Sedge			x		
Cyperus dives	CYPERACEAE	Sedge				x	
Mariscus sp.	CYPERACEAE	Sedge				x	
Pycreus polystachyos var. polystachyos	CYPERACEAE	Sedge			x	x	
Sansevieriea hyacinthoides	DRACAENACEAE	Geophyte				x	
Diospyros mespiliformis	EBENACEAE	Tree				x	x
Euclea divinorum	EBENACEAE	Shrub					x
Euclea natalensis subsp. angustifolia	EBENACEAE	Shrub				x	

Euphorbia confinalis	EUPHORBIACEAE	Tree				x	
Euphorbia cooperi	EUPHORBIACEAE	Tree				x	
Jatropha variifolia	EUPHORBIACEAE	Herb				x	
Ricinus communis *	EUPHORBIACEAE	Shrub					x
Spirostachys africana	EUPHORBIACEAE	Tree					x
Acacia borleae	FABACEAE	Shrub					x
Acacia exuvialis	FABACEAE	Tree				x	
Acacia gerrardii subsp. gerrardii	FABACEAE	Tree					x
Acacia grandicornuta	FABACEAE	Tree				x	x
Acacia nigrescens	FABACEAE	Tree					x
Acacia nilotica subsp. kraussiana	FABACEAE	Tree					x
Acacia swazica	FABACEAE	Shrub				x	x
Acacia tortilis subsp. heteracantha	FABACEAE	Tree					x
Acacia xanthophloea	FABACEAE	Tree			x		x
Afzelia quanzensis	FABACEAE	Tree	NT			x	
Albizia harveyi	FABACEAE	Tree				x	x
Clitoria ternatea *	FABACEAE	Climber				x	
Crotalaria sp.	FABACEAE	Shrub				x	
Dalbergia melanoxylon	FABACEAE	Tree	NT			x	x
Dichrostachys cinerea subsp. africana	FABACEAE	Shrub				x	x
Indigofera cf. subcorymbosa	FABACEAE	Herb				x	
Indigofera schimperi var. schimperi	FABACEAE	Herb					x
Mundulea sericea	FABACEAE	Shrub				x	
Ormocarpum trichocarpum	FABACEAE	Shrub				x	
Peltophorum africanum	FABACEAE	Tree				x	
Philenoptera violacea	FABACEAE	Tree			x		x
Pterocarpus rotundifolius subsp. rotundifolius	FABACEAE	Tree				x	
Rhynchosia albissima	FABACEAE	Dwarf shrub					x
Rhynchosia totta	FABACEAE	Creeper				x	
Schotia brachypetala	FABACEAE	Tree				x	
Senna italica	FABACEAE	Dwarf shrub			x		x
Sesbania sesban subsp. sesban	FABACEAE	Shrub				x	
Tephrosia cf. elongata	FABACEAE	Herb				x	
Tephrosia purpurea subsp. leptostachya	FABACEAE	Dwarf shrub				x	
Zornia capensis	FABACEAE	Herb				x	
Dipcadi sp.	HYACINTHACEAE	Geophyte				x	

Drimia delagoensis	HYACINTHACEAE	Geophyte				x	
Drimiopsis burkei subsp. burkei	HYACINTHACEAE	Geophyte				x	
Ledebouria floribunda	HYACINTHACEAE	Geophyte				x	
Clerodendrum ternatum	LAMIACEAE	Dwarf shrub				x	
Leucas sexdentata	LAMIACEAE	Herb					x
Ocimum gratissimum subsp. gratissimum	LAMIACEAE	Dwarf shrub			x		x
Syncolostemon sp.	LAMIACEAE	Dwarf shrub				x	
Vitex harveyana	LAMIACEAE	Shrub				x	
Abutilon angulatum	MALVACEAE	Dwarf shrub			x		x
Abutilon guineense	MALVACEAE	Dwarf shrub				x	
Corchorus aspleniifolius	MALVACEAE	Herb			x		
Corchorus sp.	MALVACEAE	Dwarf shrub				x	
Gossypium herbaceum	MALVACEAE	Shrub					x
Grewia bicolor	MALVACEAE	Shrub				x	x
Grewia caffra	MALVACEAE	Shrub				x	
Grewia hexamita	MALVACEAE	Shrub				x	
Grewia monticola	MALVACEAE	Shrub				x	
Grewia villosa	MALVACEAE	Shrub				x	x
Hibiscus calyphyllus	MALVACEAE	Dwarf shrub				x	x
Hibiscus micranthus var. micranthus	MALVACEAE	Dwarf shrub				x	x
Hibiscus vitifolius subsp. vulgaris	MALVACEAE	Dwarf shrub				x	
Melhania sp.	MALVACEAE	Dwarf shrub					x
Sterculia rogersii	MALVACEAE	Tree				x	
Waltheria indica	MALVACEAE	Dwarf shrub			x		x
Triaspis hypericoides	MALPIGHIACEAE	Shrub	VU	x		x	
Glinus oppositifolius var. oppositifolius	MOLLUGINACEAE	Herb			x		
Ficus abutilifolia	MORACEAE	Tree				x	
Ficus sycomorus	MORACEAE	Tree					x
Maclura africana	MORACEAE	Shrub				x	
Syzygium guineense	MYRTACEAE	Tree				x	
*Boerhavia diffusa **	NYCTAGINACEAE	Herb					x
Ochna inermis	OCHNACEAE	Dwarf shrub				x	
Ochna natalitia	OCHNACEAE	Shrub				x	
Ximenia americana	OLACACEAE	Shrub				x	
Ximenia caffra var. caffra	OLACACEAE	Shrub				x	x
Jasminum flumineense	OLEACEAE	Climber				x	x

Ludwigia octovalvis	ONAGRACEAE	Shrub				x	x
Ludwigia stolonifera	ONAGRACEAE	Aquatic herb				x	
*Argemone mexicana **	PAPAVERACEAE	Herb			x		
Ceratotheca triloba	PEDALIACEAE	Herb			x	x	x
Sesamum alatum	PEDALIACEAE	Herb				x	
Antidesma venosum	PHYLLANTHACEAE	Tree				x	
Bridelia cathartica subsp. cathartica	PHYLLANTHACEAE	Shrub				x	x
Flueggea virosa	PHYLLANTHACEAE	Shrub				x	x
Phyllanthus maderaspatensis	PHYLLANTHACEAE	Dwarf shrub			x		
Phyllanthus reticulatus var. reticulatus	PHYLLANTHACEAE	Shrub				x	x
Andropogon gayanus	POACEAE	Grass				x	
Aristida congesta subsp. barbicollis	POACEAE	Grass					x
Bothriochloa insculpta	POACEAE	Grass				x	x
Brachiaria nigropedata	POACEAE	Grass			x		
Brachiaria xantholeuca	POACEAE	Grass				x	
Cenchrus ciliaris	POACEAE	Grass					x
Chloris virgata	POACEAE	Grass			x		x
Cynodon dactylon	POACEAE	Grass			x		
Dactyloctenium giganteum	POACEAE	Grass				x	x
Digitaria eriantha Steud.	POACEAE	Grass					x
Echinochloa colona	POACEAE	Grass			x		
Enneapogon cenchroides	POACEAE	Grass				x	
Eragrostis curvula	POACEAE	Grass				x	
Eragrostis cf. heteromera	POACEAE	Grass			x		
Eragrostis sp.	POACEAE	Grass					x
Eragrostis superba	POACEAE	Grass				x	x
Eriochloa meyeriana subsp. meyeriana	POACEAE	Grass			x		
Fingerhuthia africana	POACEAE	Grass					x
Heteropogon contortus	POACEAE	Grass				x	x
Hyperthelia dissoluta	POACEAE	Grass					x
Melinis repens	POACEAE	Grass				x	x
Miscanthus junceus	POACEAE	Grass				x	
Panicum coloratum var. coloratum	POACEAE	Grass					x
Panicum deustum	POACEAE	Grass					x
Panicum maximum	POACEAE	Grass				x	x
Paspalidium obtusifolium	POACEAE	Grass			x		

Phragmites mauritianus	POACEAE	Grass			x	x	x
Pogonarthria squarrosa	POACEAE	Grass				x	x
Schizachyrium sanguineum	POACEAE	Grass				x	
Schmidtia pappophoroides	POACEAE	Grass					x
Setaria incrassata	POACEAE	Grass			x		
Setaria sphacelata	POACEAE	Grass					x
Sorghum bicolor subsp. arundinaceum	POACEAE	Grass					
Themeda triandra	POACEAE	Grass				x	x
Tragus berteronianus	POACEAE	Grass			x	x	x
Urochloa mosambicensis	POACEAE	Grass			x	x	x
Polygala uncinata	POLYGALACEAE	Herb				x	
Ptaeroxylon obliquum	PTAEROXYLACEAE	Tree				x	
Berchemia zeyheri	RHAMNACEAE	Tree				x	
Ziziphus mucronata	RHAMNACEAE	Tree					x
Breonadia salicina	RUBIACEAE	Tree				x	
Coddia rudis	RUBIACEAE	Shrub				x	
Vangueria infausta	RUBIACEAE	Shrub					x
Azima tetracantha	SALVADORACEAE	Shrub				x	
Deinbollia oblongifolia	SAPINDACEAE	Shrub				x	
Pappea capensis	SAPINDACEAE	Tree				x	
Manilkara mochisia	SAPOTACEAE	Tree				x	
Sideroxylon inerme	SAPOTACEAE	Tree				x	
Cheilanthes viridis var. glauca	SINOPTERIDACEAE	Fern				x	
Pellaea calomelanos var. calomelanos	SINOPTERIDACEAE	Fern				x	
Solanum kwebense	SOLANACEAE	Shrub				x	
Solanum lichtensteinii	SOLANACEAE	Dwarf shrub					x
Solanum panduriforme	SOLANACEAE	Dwarf shrub				x	
Strychnos madagascariensis	STRYCHNACEAE	Tree				x	
Pouzolzia mixta	URTICACEAE	Shrub				x	
Xerophyta retinervis	VELLOZIACEAE	Dwarf shrub				x	
Chascanum latifolium	VERBENACEAE	Herb				x	x
Lantana rugosa	VERBENACEAE	Dwarf shrub				x	
Lippia javanica	VERBENACEAE	Dwarf shrub				x	x
Phyla nodiflora	VERBENACEAE	Herb			x		
Cissus cactiformis	VITACEAE	Climber				x	x
Cissus cornifolia	VITACEAE	Climber					x

Cissus rotundifolia	VITACEAE	Climber				x	
Rhoicissus schlechteri	VITACEAE	Climber				x	
Rhoicissus tridentata	VITACEAE	Shrub				x	
Tribulus terrestris	ZYGOPHYLLACEAE	Creeper			x		x
Azolla filicoides *	AZOLLACEAE	Aquatic fern			x	x	
TOTAL		216	3	1	40	148	94

Annexure 2. Checklist of birds recorded in the study area during fieldwork

Common Name	Scientific Name	Red Data	Endemic	Mozambique Status	Fieldwork				
					Riparian Vegetation	Floodplain Grassland	Thicket	Woodland	Open Water
African Darter	*Anhinga rufa*			Uncommon resident	x	x			x
African Fish Eagle	*Haliaeetus vocifer*			Uncommon resident	x	x			x
African Hoopoe	*Upupa africana*			Common resident				x	
African Jacana	*Actophilornis africanus*			Common resident		x			
African Mourning Dove	*Streptopelia decipiens*			Common resident				x	
African Openbill	*Anastomus lamelligerus*			Common resident		x			
African Palm Swift	*Cypsiurus parvus*			Common resident	x			x	
African Paradise Flycatcher	*Terpsiphone viridis*			Common resident				x	
African Pied Wagtail	*Motacilla aguimp*			Uncommon resident	x	x			
African Pipit	*Anthus cinnamomeus*			Common resident		x		x	
Arrow-marked Babbler	*Turdoides jardineii*			Common resident				x	
Barn Swallow	*Hirundo rustica*			Very common non-breeding migrant	x	x		x	x
Bateleur	*Terathopius ecaudatus*	VU		Common resident				x	
Black Crake	*Amaurornis flavirostra*			Common resident		x			
Black Cuckoo	*Cuculus clamosus*			Common breeding mi-grant				x	
Black-backed Puffback	*Dryoscopus cubla*			Very common resident			x	x	
Black-bellied Bustard	*Eupodotis melanogaster*			Uncommon resident				x	
Black-chested Snake-Eagle	*Circaetus pectoralis*			Uncommon resident				x	
Black-collared Barbet	*Lybius torquatus*			Common resident				x	
Black-crowned Tchagra	*Tchagra senegala*			Very common resident				x	
Black-headed Heron	*Ardea melanocephala*			Common resident		x			
Black-shouldered Kite	*Elanus caeruleus*			Common resident				x	
Blacksmith Lapwing	*Vanellus armatus*			Common resident	x	x			
Blue-cheeked Bee-eater	*Merops persicus*			Common non-breeding migrant		x		x	x
Blue Waxbill	*Uraeginthus angolensis*			Very common resident				x	

Brown Snake Eagle	*Circaetus cinereus*			Uncommon resident	x			x	
Brown-crowned Tchagra	*Tchagra australis*			Very common resident				x	
Brown-headed Parrot	*Poicephalus cryptoxanthus*			Very common resident				x	
Brown-hooded Kingfisher	*Halcyon albiventris*			Uncommon resident				x	
Brubru	*Nilaus afer*			Common resident				x	
Burchell's Coucal	*Centropus burchellii*			Common resident	x	x		x	
Cape Turtle Dove	*Streptopelia capicola*			Very common resident				x	
Cattle Egret	*Bubulcus ibis*			Common resident		x			
Cinnamon-breasted Rock Bun-ting	*Emberiza tahapisi*			Uncommon resident				x	
Common Fiscal	*Lanius collaris*			Uncommon resident				x	
Common Sandpiper	*Actitis hypoleucos*			Common non-breeding migrant		x			
Common Scimitarbill	*Rhinopomastus cyanomelas*			Common resident				x	
Common Waxbill	*Estrilda astrild*			Uncommon resident		x			
Crested Barbet	*Trachyphonus vaillantii*			Common resident	x			x	
Crested Francolin	*Francolinus sephaena*			Very common resident				x	
Crowned Lapwing	*Vanellus coronatus*			Common resident				x	
Dark-capped Bulbul	*Pycnonotus barbatus*			Very common resident	x		x	x	
Diederik Cuckoo	*Chrysococcyx caprius*			Common breeding mi-grant	x	x		x	
Long-tailed Paradise Whydah	*Vidua paradisea*			Uncommon resident				x	
Egyptian Goose	*Alopochen aegyptiacus*			Uncommon resident	x	x			x
Emerald-spotted Wood Dove	*Turtur chalcospilos*			Very common resident	x			x	
European Bee-eater	*Merops apiaster*			Common non-breeding migrant	x	x		x	x
European Roller	*Coracias garrulus*	NT		Common non-breeding migrant				x	
Fan-tailed Widowbird	*Euplectes axillaris*			Common resident		x			
Fork-tailed Drongo	*Dicrurus adsimilis*			Very common resident	x			x	
Giant Kingfisher	*Megaceryle maxima*			Uncommon resident	x				x
Glossy Starling	*Lamprotornis nitens*			Common resident	x			x	
Golden-breasted Bunting	*Emberiza flaviventris*			Common resident				x	
Goliath Heron	*Ardea goliath*			Uncommon resident	x				
Gorgeous Bush Shrike	*Telephorus quadricolor*			Common resident			x		

Great White Pelican	*Pelecanus onocrotalus*			Common non-breeding visitor		x			x
Green-backed Camaroptera	*Camaroptera brachyura*			Very common resident	x		x		
Green-backed Heron	*Butorides striata*			Common resident	x	x			
Grey Go-away Bird	*Corythaixoides concolor*			Common resident				x	
Grey Heron	*Ardea cinerea*			Common resident	x	x			
Hadeda Ibis	*Bostrychia hagedash*			Common resident	x	x			
Hamerkop	*Scopus umbretta*			Common resident	x				
Harlequin Quail	*Coturnix delegorguei*			Uncommon breeding migrant				x	
House Sparrow	*Passer domesticus*			Common resident				x	
Jameson's Firefinch	*Lagonosticta rhodopareia*			Uncommon resident			x	x	
Kittlitz's Plover	*Charadrius pecuarius*			Common resident		x			
Klaas's Cuckoo	*Chrysococcyx klaas*			Uncommon breeding migrant				x	
Kurrichane Buttonquail	*Turnix sylvatica*			Common resident				x	
Laughing Dove	*Streptopelia senegalensis*			Common resident	x			x	
Lesser Grey Shrike	*Lanius minor*			Uncommon non-breeding migrant				x	
Lesser Masked Weaver	*Ploceus intermedius*			Uncommon resident	x			x	
Lesser Spotted Eagle	*Aquila pomarina*			Uncommon non-breeding migrant				x	
Lesser Striped Swallow	*Hirundo abyssinica*			Uncommon resident	x	x		x	x
Lilac-breasted Roller	*Coracius caudata*			Common resident					
Little Bee-eater	*Merops pusillus*			Common resident	x			x	
Little Egret	*Egretta garzetta*			Common resident	x				
Little Swift	*Apus affinis*			Common resident	x				x
Long-billed Crombec	*Sylvietta rufescens*			Common resident				x	
Magpie Shrike	*Corvinella melanoleuca*			Uncommon resident				x	
Malachite Kingfisher	*Alcedo cristata*			Common resident	x	x			
Marabou Stork	*Leptoptilos crumeniferus*			Rare resident	x				
Mocking Chat	*Thamnolaea cinnamomeiventris*			Uncommon resident				x	
Namaqua Dove	*Oena capensis*			Common resident				x	
Natal Spurfowl	*Pternistes natalensis*			Uncommon resident	x		x	x	
Orange-breasted Bush-Shrike	*Telephorus sulfureopectus*			Common resident	x		x	x	
Pied Crow	*Corvus albus*			Common resident				x	

Pied Kingfisher	*Ceryle rudis*			Common resident	x	x			x
Pin-tailed Whydah	*Vidua macroura*			Uncommon resident	x			x	
Purple Heron	*Ardea purpurea*			Common resident	x	x			
Rattling Cisticola	*Cisticola chiniana*			Very common resident	x			x	
Red-backed Shrike	*Lanius collurio*			Common non-breeding migrant				x	
Red-billed Firefinch	*Lagonosticta senegala*			Uncommon resident				x	
Red-billed Oxpecker	*Buphagus erythrorhynchus*			Uncommon resident				x	
Red-billed Quelea	*Quelea quelea*			Very common resident				x	
Red-eyed Dove	*Streptopelia semitorquata*			Very common resident	x				
Red-faced Cisticola	*Cisticola erythrops*			Common resident	x			x	
Red-faced Mousebird	*Urocolius indicus*			Common resident	x				
Reed Cormorant	*Phalacrocorax africanus*			Common resident	x	x			x
Rufous-naped Lark	*Mirafra africana*			Common resident				x	
Rufous-winged Cisticola	*Cisticola galactotes*			Common resident		x			
Sabota Lark	*Mirafra sabota*			Common resident				x	
Sombre Greenbul	*Andropadus importunus*			Very common resident	x		x		
Southern Boubou	*Laniarius ferrugineus*			Very common resident	x		x		
Southern Carmine Bee-eater	*Merops nubicoides*			Uncommon non-breeding migrant				x	x
Southern Grey-headed Sparrow	*Passer diffusus*			Common resident	x			x	
Southern Red Bishop	*Euplectes orix*			Common resident	x	x			
Southern White-crowned Shrike	*Eurocephalus anguitimens*			Uncommon resident				x	
Southern Yellow-billed Hornbill	*Tockus leucomelas*			Common resident				x	
Speckled Mousebird	*Colius striatus*			Common resident			x	x	
Spectacled Weaver	*Ploceus ocularis*			Common resident	x		x	x	
Spur-winged Goose	*Plectropterus gambensis*			Common resident		x			x
Swainson's Spurfowl	*Francolinus swainsonii*			Uncommon resident				x	
Tawny-flanked Prinia	*Prinia subflava*			Common resident	x	x		x	
Terrestrial Brownbul	*Phyllastrephus terrestris*			Common resident			x		
Three-banded Plover	*Charadrius tricollaris*			Common resident	x	x			
Violet-backed Starling	*Cinnyricinclus leucogaster*			Common breeding mi-grant	x			x	
Water Thick-knee	*Burhinus vermiculatus*			Uncommon resident	x				
White-bellied Sunbird	*Cinnyris talatala*			Very common resident	x			x	
White-breasted Cormorant	*Phalacrocorax lucidus*			Common resident		x			

White-browed Robin-Chat	*Cossypha heuglini*			Uncommon resident	x		x		
White-browed Scrub-Robin	*Erythropygia leucophrys*			Very common resident				x	
White-faced Duck	*Dendrocygna viduata*			Common resident	x	x			x
White-fronted Bee-eater	*Merops bullockoides*			Uncommon resident	x				
White-throated Robin-Chat	*Cossypha humeralis*			Common resident			x	x	
White-winged Widowbird	*Euplectes albonotatus*			Uncommon resident	x	x			
Wire-tailed Swallow	*Hirundo smithii*			Uncommon resident	x	x		x	x
Wood Sandpiper	*Tringa glareola*			Common non-breeding migrant	x	x			
Woodland Kingfisher	*Halcyon senegalensis*			Uncommon breeding migrant	x			x	
Yellow-billed Kite	*Milvus migrans*			Common non-breeding migrant	x			x	
Yellow-breasted Apalis	*Apalis flavida*			Common resident			x	x	
Yellow-fronted Canary	*Serinus mozambicus*			Common resident	x			x	
Yellow-throated Longclaw	*Macronyx croceus*			Common resident		x			
Zebra Waxbill	*Sporaeginthus subflavus*			Uncommon resident		x			
TOTAL	133	2	0	133	60	41	15	84	16
VU = Vulnerable									
NT = Near Threatened									

APPENDIX 5

Baseline study. Aquatic and Riparian Ecology

1. Introduction

The Corumana Dam situated 90 km north-east of Maputo in the Moamba district, on the Sabíe River, functions primarily to supply water for downstream irrigated agriculture, with a secondary purpose the generation of 14.5 MW installed hydroelectric energy. The catchment area for the dam is 7,048 km^{2,} the catchment MAP is 773 mm and the naturalized MAR is 670.5 Mm^3 (Appendix 2). The annual flow distribution in the Sabíe River is very variable, with flow volumes normally between 0 and 1,000 Mm^{3}a^{-1} (recorded period of 85 years). The most noteworthy peak occurred in 2000, with a value of over 2,500 Mm^{3}a^{-1}, due primarily to the 1 in 100 year flood experienced in February 2000. The annual observed discharge from the Corumana Dam into the downstream environment of the Sabíe River (for the period 1990 to 2009) also varied between 0 and 1,000 Mm^{3}a^{-1}, with a peak in 2,000 of over 3,500 Mm^{3}a^{-1}. Construction of the dam was curtailed in 1989, without the gated spillway and saddle dam being constructed (LAYMEYER INTERNATIONAL, 2003). The current full supply level (FSL) is 111 masl, with mean inflow of 17.6 m^{3}s^{-1}, of which 9.5 m^{3}s^{-1} may be released as firm water yield.

The necessity for this study is borne out of the fact that the present intention is to complete the gated spillway, raise FSL to 117 masl and to construct the saddle dam. The firm water yield will increase to 10.2 m^{3}s^{-1} and energy generation will increase by 4.8 GWha^{-1}.

Importantly, it is estimated that the incremental inundated area, at FSL of 117 masl will reach for approximately 730 m into South Africa and the Kruger National Park, across the International Border (Appendix 2).

This area falls within the Northern Lebombo Bushveld, characterized by the regionally unique Rhyolite of the Jozini Formation and lesser basalt of the Letaba Formation, both of the Lebombo Group (Karoo Supergroup). Dykes of granophyre (Jurasic) form ridges with stony, shallow lithosoils, and rocky outcrops (Mucina and Rutherford, 2006). The riparian vegetation comprises a dense, untransformed belt of large woody species including *Ficus sycomorus* and *Breonadia salicina*, as well as in-stream and channel stands of the non-woody *Phragmites mauritianus*. The channel type in the Sabíe River in the region is of a broad anastomosing bedrock form (Heritage et al, 1997) with a wide variety of habitats. The morphological units present almost certainly include bedrock pools, riffle-pool sequences, lateral, point, bedrock core and lee bars, bedrock and alluvial backwaters, rip channels, boulder beds, alluvial and bedrock distributaries and islands.

The region is considered by SANParks to be of high conservation importance in that it is only one of two within the Kruger National Park confines of the Sabíe River that scores as natural and unmodified (category A) within the ambit of the ecological categories as employed in the South African Scoring System (SASS5) for aquatic ecosystem health (Sithole, pers. comm.).

The Corumana Dam and downstream riverine environment is different in that it is predominantly outside a protected area and is bounded by significant anthropogenic activities including subsistence agriculture, artisanal fisheries and rural residential development. The geological formations through which the Sabíe River flows in Mozambique includes *rochas ácidas e intermedius* along the border and in the region of the Corumana Dam, *rochas básicas* in the region of the dam and downstream of it and *arenitos, argilas e rochas afins* and *aluviões* further downstream. The Sabíe River downstream of the Corumana Dam is dominated by single and braided alluvial channels bordered by a well-defined alluvial floodplain.

This report includes a baseline aquatic study and determination of the Ecological Category for the riverine and riparian vegetation, aquatic macro-invertebrates and fish fauna of the Sabíe River, upstream (25^{o}11.081'S, 32^{o}01.869'E) and downstream of the Corumana Dam (25^{o}12.297'S, 32^{o}08.642'E and 25^{o}17.748'S, 32^{o}16.796'E), using the techniques VEGRAI (Kleynhans et al, 2007), SASS5 (Dickens and Graham, 2002) and FAII (Kleynhans, 1999).

Impacts to be considered include threats to the aquatic fauna and wetland habitats and species and the development of the aquatic environment and fish fauna in the newly inundated area.

2. Materials and methods

2.1. Sampling sites

Sampling sites for the baseline Study for Aquatic ecology is shown in Fig 1.

Figure 1. Sampling sites for Baseline study Aquatic ecology.

2.2. Riverine and riparian vegetation

The riverine and riparian vegetation was assessed at Station 1 (upstream of the Corumana reservoir in the Sabíe River; 25°11.081'S, 32°01.869'E) and Station 3 (downstream of the Corumana Dam in the Sabíe River; 25°17.748'S, 32°16.796'E). Although Station 3 was originally chosen to assess the riverine and riparian vegetation, aquatic macroinvertebrates and fish fauna, only the former was assessed at the site as it was found to be unsuitable for the latter two assessments. An additional station further upstream was chosen for the macroinvertebrate and fish surveys.

The Riparian Vegetation Response Assessment Index (VEGRAI), Level 3 (Kleynhans et al, 2007), is composed of a number of metrics (cover, abundance and species composition) and metric groups (marginal and non-marginal zone), which are rated in the field. The status of indigenous riparian vegetation (woody and non-woody) in the reference and current states is described for each metric. Differences between the two states are then compared as a measure of vegetation response to an impact zone. Exotic vegetation is also assessed separately.

The metrics are rated and weighted and an Ecological Category (EC) for the riparian vegetation state determined, between A and F (Table 1).

The rating system comprises a six-point scoring system, where 0 represents no discernable change from reference conditions to 6 representing extreme modifications from reference. The vegetation component (woody and non-woody) in each vegetation zone is considered in terms of its importance in maintaining the condition of the vegetation zone under reference conditions. The vegetation component considered the most important in influencing the EC of the vegetation zone if it changed is ranked 1 and awarded a weight of 100%, and the next most important component is ranked 2 and awarded a rating proportionately less than 100%, and so on. The weighting of metric groups (vegetation zones) follows a similar approach.

Field forms were completed for VEGRAI determination, plants were collected for later identification and photographs were taken to provide additional information.

Table 1. Ecological Categories for EcoStatus determination of riverine and riparian vegetation.

Ecological Category	Description	Score (% of total)
A	Unmodified, Natural	90 – 100
B	Largely Natural with few modifications. A small change in habitats and biota has taken place, with ecosystem function essentially unchanged.	80 – 89
C	Moderately Modified. Loss and change in habitats and biota has occurred, with basic ecosystem functions predominantly unchanged	60 – 79
D	Largely Modified. A large loss of habitats, biota and basic ecosystem function has occurred	40 – 59
E	Seriously Modified. There is extensive loss of habitats, biota and ecosystem function.	20 – 39
F	Critically Modified. Almost complete loss of habitat and biota. In the worst case scenario, basic ecosystems function has been destroyed and the changes are irreversible.	0 - 19

(After Kleynhans et al, 2007, modified from Kleynhans, 1996 and Kleynhans, 1999).

2.3. The aquatic macroinvertebrates

The aquatic macro-invertebrates were assessed at Station 1 (upstream of the Corumana reservoir in the Sabíe River; 25°11.081’S, 32°01.869’E) and Station 2 (downstream of the Corumana Dam in the Sabíe River; 25°12.297’S, 32°08.642’E).

The South African Scoring System, version 5 (SASS5) was employed to determine the diversity of the macro-invertebrate fauna and to determine an EC for the Sabíe River at Stations 1 and 2. Station 2 was chosen in preference to Station 3 as the downstream site as, in contrast to Station 3, which comprises an alluvial channel only, Station 2 includes all the habitats essential for the determination of SASS5.

The total SASS5 score and Average Score per Taxon (ASPT) for the aquatic macro-invertebrates found in the three biotopes, namely S [Stones In Current (SIC), Stones Out Of Current (SOOC) and bedrock], Veg (marginal and aquatic vegetation, in and out of current) and GSM (Gravel, Sand and Mud), was determined (Chutter, 1998; Dickens and Graham, 2002; Dallas, 2007). The overall assessment of the suitability of biotopes was based on the Integrated Habitat Assessment System (IHAS) and Overall Biotope Suitability Score (SASS5). The determination of ecological categories was according to Dallas (2007), across 6 bands, where Band A reflects unmodified natural conditions through to F, the latter reflecting a critically or extremely modified status (Table 2; Figure 2).

Table 2. The Biological Bands and Ecological Categories for the interpretation of SASS5 data. (After Dallas, 2007).

Biological Band / Category	Ecological Category Name	Description	Colour
A	Natural	Unmodified, natural	Blue
B	Good	Largely natural with few modifications.	Green
C	Fair	Moderately modified	Yellow
D	Poor	Largely modified	Red
E	Seriously Modified	Seriously modified	Purple
F	Critically Modified	Critically modified	Black

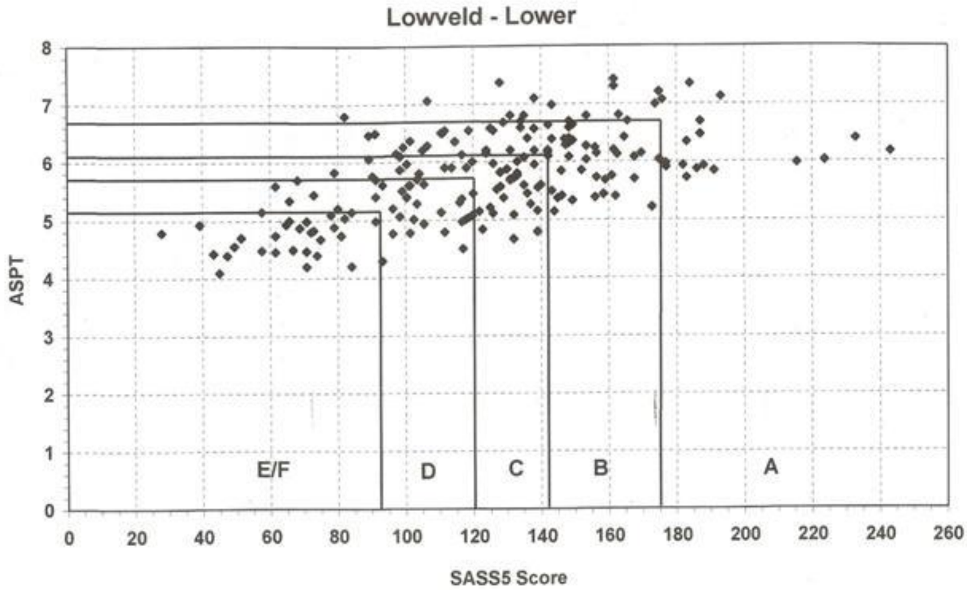

Figure 2. The Biological Bands for the Lowveld, Lower Zone. (After Dallas, 2007)

The aquatic macroinvertebrates were returned to the river after scoring was completed in the field. In the case of specimens that required further verification or study, these were preserved in 70% ethyl alcohol, stored in collecting vials and examined later using a stereo microscope.

2.4. The fish fauna

The fish fauna was assessed at Station 1 (upstream of the Corumana reservoir in the Sabíe River; 25°11.081'S, 32°01.869'E) and Station 2 (downstream of the Corumana Dam in the Sabíe River; 25°12.297'S, 32°08.642'E).

The Fish Assemblage Integrity Index (FAII) developed by Kleynhans (1999) was used to assess the fish fauna. The FAII is based on the fish species expected to be present within the biological segments (fish habitats) of the Sabíe River assessed. The fish are categorized according to an intolerance index which takes into account trophic preferences and specialization, flowing water requirements during different life stages and association with habitats with unmodified water quality. The intolerance index, the expected frequency of occurrence and expected health of the fish species at the two stations was used to formulate an index for the situation expected under minimally impaired conditions and compared with the observed conditions following sampling. The observed situation is expressed as a fraction of the expected situation, deriving a FAII index. As is the case for VEGRAI and SASS5, there are six assessment classes for the FAII (Table 3).

The fish fauna was sampled using four methods, where possible, including,

- electro-fishing using a SAMUS725 electro-fisher;

- cast netting using a 4 m diameter cast net;

- ”fyke” netting using 5 customized, rigid, cylindrical traps of 1.0 m length and 650 mm circumference with an internal diameter of the entrance of the cone into the trap, at both ends, of approximately 60 mm; and

- gill netting using a 50 m net with 90 mm mesh size.

Fish were identified in the field, or where necessary, preserved in 5% formaldehyde, for later verification or study using a stereo microscope. Fish were handled for the shortest possible time and returned to the river once examined.

Table 3. The assessment classes used for the FAII. (After Kleynhans, 1999).

Class rating	Description of generally expected conditions for integrity classes	Relative FAII score (% of expected)
A	Unmodified, or approximately Natural	90 – 100
B	**Largely Natural with few modifications**. A change in community characteristics may have taken place, but species richness and presence of intolerant species indicate little modification.	80 – 89
C	**Moderately Modified.** A lower than expected species richness and presence of most intolerant species. Some impairment of health may be evident at the lower limit of the class	60 – 79
D	**Largely Modified.** A clearly lower than expected species richness and general absence of intolerant species and moderately intolerant species. Impairment of health may become very evident at the lower limit of the class.	40 – 59
E	**Seriously Modified.** A strikingly lower than expected species richness and general absence of intolerant and moderately intolerant species. Impairment of health may become very evident.	20 – 39
F	**Critically Modified.** An extremely lowered species richness and an absence of intolerant and moderately intolerant species. Only tolerant species may be present with a complete loss of species at the at the lower limit of the class. Impairment of health generally very evident.	0 - 19

3. Results

3.1. Riverine and riparian vegetation

In the VEGRAI assessment for Station 1 (SAB001), six woody and 11 non-woody plant taxa were identified for the marginal zone (Annexure A below). In the non-marginal zone, 11 woody taxa and one non-woody taxon, were identified. The marginal zone was dominated by non-woody taxa including *Phragmites mauritianus* and *Miscanthus junceus*. The non-marginal zone was dominated by E*uclea natalensis angustifolia* and *Kigelia africana*.

Given that the station is within a statutory protected area, the impact of surrounding and upstream land use on both the marginal and non-marginal zones was found to be very low (rating of 1) to average (rating of 3). Artisanal fishing (rating of 1), the effects of the Corumana Dam (2, 3), water regulation and abstraction upstream in the protected area (1, 2) and the presence of vehicle tracks (1) were identified as impacts.

The invasion of the marginal and non-marginal zones by alien plants was found to be low, with the cover below 10%, intensity rating of 2 and extent rating of 3. These ratings are primarily due to the widespread presence of *Pistia stratiotes*, (Water Lettuce) (CARA category 1) (WESSA, 2008) and *Azolla filiculoides* (Water Fern).

The description for the reference conditions for Station 1 may be given as an open and reed and shrub dominated state. In the absence of Corumana Dam and no regulation of the water quantity in the upstream environment, it is possible that the reference state would be characterized by the greater presence of woody vegetation. The marginal and non-marginal vegetation in the region of Station 1 was significantly altered during the 1 in 100 year flood of 2000, a natural event. The monthly discharge, for example, from the Corumana Dam in February 2000 was 1642.85 Mm3, compared to figures ranging between 54.84 (July) and 606.97 Mm3 (March) for the rest of the year (Appendix 1).

The Level 3 VEGRAI value for Station 1 was calculated to be 85%, giving a VEGRAI EC classification of B, which may be described as Largely Natural with few modifications. A small change in habitats and biota has taken place, with ecosystem function essentially unchanged.

In the VEGRAI assessment for Station 3 (SAB003), the non-marginal zone predominated, with a very limited marginal zone on the left bank that was assessed. (Annexure B). In the non-marginal zone, six woody taxa and nine non-woody taxa were identified. Woody species included *Acacia xanthophloea*, *Ficus capreifolia* and *F. sycomorus.* Non-woody species included *Phragmites mauritianus, Sporobolus africanus*, *Paspalum dilatatum* and *P. scrobiculatum.*

The impact of surrounding and upstream land use on both the marginal and non-marginal zones was found to be of average intensity (rating of 3) and high extent (5). The impact on the marginal zone by stock and subsistence crop farming and rural residential development was estimated as low to average (2, 3) with respect to vegetation removal. Water quantity and quality would also be affected (2). The impact of these activities on the non-marginal zone is intensified (rating values of 3 and extent values of 5).

The invasion of the marginal and non-marginal zones by alien plants was found to be significant, with the cover in the non-marginal zone at 20 - 40%, intensity rating of 3 and extent rating of 4. Alien species include *Psidium guajava* (guava), *Mangifera indica* (mango) and *Musa acuminata* (banana).

The description for the reference conditions for the marginal zone at Station 3 may be given as a reed and shrub dominated state. The non-marginal zone may be described as being dominated by trees, reeds and shrubs.

The Level 3 VEGRAI value for Station 3 was calculated to be 55.6%, giving a VEGRAI EC classification of D, which may be described as Largely Modified. A large loss of habitats, biota and basic ecosystem function has occurred.

3.2. The aquatic macroinvertebrates

The total SASS5 score, number of taxa and ASPT for Station 1 (Figure 3) was found to be 206, 35 and 5.9, respectively (Annexure C). The taxa which scored 10 or more on the SASS5 scale of 1 to 15, included the Heptageniidae (flat-headed mayflies) (13), Calopterygidae (damselflies) (10) and Pyralidae (aquatic caterpillars) (12). There were no taxa that dominated the sample given that the estimated abundance for 10 taxa was B (10 to 100 individuals) and for the remaining taxa only one individual or A (2 to 10).

Using the Biological Bands for the Lower Lowveld (Dallas, 2007), the Ecological Category for Station 1 may be defined as A, Unmodified, Natural.

a) Alluvial pool

b) Bedrock, riffles and vegetation

Figure 3. Biotopes sampled at Station 1 in the Sabíe River.

The SASS5 technique involves the determination of the presence of taxa at higher order levels and therefore it is not possible to assess whether protected, red-listed, endangered or endemic species are present. Kristensen et al (2009), however, state that 8.6% of freshwater molluscs in southern Africa are regionally threatened. In the case of the dragonflies and mayflies, the majority of species (approximately 76%) are classed as Least Concern (Suhling et al, 2009). In the case of freshwater crabs, 94% of the species that could be assigned conservation status were assessed as of Least Concern (Cumberlidge and Daniels, 2009).

The overall biotope suitability for the biotopes sampled was 71% (SASS5) and the IHAS (McMillan, 1998) was 79%. The pH of the water was found to be 6.6 and the conductivity 15mSm-1. The water was a normal transparent colour, the flow low and turbidity very low. The nature of the Sabíe River channel, upstream from the International Border with Mozambique to the gauging weir a short distance downstream from the Lower Sabíe camp in the Kruger National Park, was scanned using Google Earth images (dated 10/10/2005) (Google, 2010), for length and width of reaches, channel form and the presence of isolated pools and likely pool-riffle sequences. Clearly, however, there are limitations to the determination of the latter using Google images, especially with an eye altitude of 1.43 km. The total distance of 11.312 km was divided into 12 reaches with channel width varying between 190 and 570 m (Table 4). Nine of the 12 reaches were dominated by anastomising channels and there appeared to be a total of 54 large, isolated pools and 144 areas where run/riffle sequences are likely to be present.

The total SASS5 score, number of taxa and ASPT for Station 2 (Figure 4) (downstream of the Corumana Dam) was found to be 50, 11 and 4.5, respectively (Annexure D). ***Using the Biological Bands for the Lower Lowveld (Dallas, 2007), the Ecological Category for Station 2 may be defined as E, Seriously Modified.***

a) Riffle SIC and SOOC biotopes sampled.

b) Downstream VEG biotope sampled.

c) Human activity at the station.

d) Upstream view from the station.

Figure 4. Biotopes sampled and human activity at Station 2.

The overall biotope suitability for the biotopes sampled was 54% and the IHAS (McMillan, 1998) was 60%. A road bridge crosses over the Sabíe River at the site. The pH of the water was found to be 7.0 and the conductivity 17mSm-1. The water was a grey colour, the flow low and turbidity very low.

Table 4. Description of the Sabie River channel from the Mozambique Border to the weir downstream of the Lower Sabie Camp, KNP.

Reach No.	Coordinates			Length of Reach (m)	Width of Reach (m)	Channel form/s	Isolated pools (n)	Riffles / Runs (n)
	Latitude	Longitude	Elevation (m)					
International Border with Mozambique								
1	25°11’09.15”S	32°01’27.70”E	121	1260	530	Anastomosing, single, braided, anastomosing	10	10
2	25°10’57.66”S	32°00’50.21”E	126	888	430	Braided, braided, anastomosing, anastomosing	4	9
3	25°10’41.33”S	32°00’37.06”E	128	639	370	Braided, braided, braided	6	9
4	25°10’21.55”S	32°00’23.86”E	130	698	340	Single channel, 2 single, braided, anastomosing	2	5
5	25°09’58.02”S	32°00’05.88”E	135	738	380	Anastomosing, braided, braided, single	0	9
6	25°09’39.35”S	31°59’42.82”E	137	1200	570	3 single, braided, braided, anastomosing, anastomosing	2	24
7	25°09’41.40”S	31°58’57.69”E	143	1312	420	Single, braided, braided, braided	4	21
8	25°09’45.99”S	31°58’14.23”E	143	1161	300	2 single, 3 single, braided, anastomosing, single, single	10	17
9	25°09’48.72”S	31°57’30.04”E	148	1375	330	Anastomosing, anastomosing, braided, braided, anastomosing	4	12
10	25°09’42.37”S	31°56’41.92”E	153	1028	230	Anastomosing, anastomosing, anastomosing, anastomosing, anastomosing, anastomosing	11	14
11	25°09’17.96”S	31°56’34.93”E	153	750	210	Braided, anastomosing, anastomosing, anastomosing, braided	0	12
12	25°08’55.37”S	31°56’33.89”E	155	263	190	Single channel, braided	1	2
Weir downstream of Lowe Sabie Camp, KNP								
TOTAL				**11312**			**54**	**144**

Note: Google (2010) images dated 10/10/2005; Eye Altitude 1.43km.

3.3. The fish fauna

The number of fish species collected at Station 1 (Annexure E) (6 species) was 15% of that potentially expected, using the illustrations for distribution records as given in Skelton (1993). The species collected included Smallscale Yellowfish (*Barbus polylepis*), Tigerfish (*Hydrocynus vittatus*), Sharptooth Catfish (*Clarias gariepinus*), Banded Tilapia (T*ilapia sparrmanii*), Redbreast Tilapia (*T. rendalli*) and the River Goby (*Glossogobius callidus*).

The number of fish species collected at Station 2 (Annexure F) (7 species) was 15% of that potentially expected, and included the Redeye Labeo (*Labeo cylindricus*), Tigerfish (*H. vittatus*), Brown Squeaker (*Synodontis zambezensis*), Johnston's Topminnow (*Aplocheilichthys johnstoni*) Banded Tilapia (*T. sparrmanii*), Mozambique Tilapia (*Oreochromis mossambicus*) and the River Goby (*G. callidus*). The number of species for the pooled data (combined stations) was 10 species.

Three of the species of fish collected at Stations 1 and 2 migrate during their life history for feeding (*H. vittatus*) and spawning (*L. cylindricus, H. vittatus, C. gariepinus*) purposes (Table 5). Of the 40 species of fish potentially found at the site, *Anguilla mossambica, A. bengalensis labiata, A. marmorata, Labeo rosae, L. ruddi, L. congoro* and L. *molybdinus* have a significant requirement at some stage during their life history for migration. All the species collected are classified as of Least Concern by the IUCN red data list (IUCN, 2010), except *O. mossambicus*, which is Near Threatened. The Orange-fringed Large-mouth, *Chetia brevis*, which potentially exists at the site, is listed by Skelton (1977) as Rare and by the IUCN (2010) as Endangered.

The FAII score for the pooled data was 74%, giving and Integrity Class rating of C, Moderately Modified. For the two individual stations, the results were 87%, Class B (Station 1) and 60%, Class C (Station 2) (Annexure G).

Species	Habitat Preference	Migratory Behaviour		Distribution	Conservation status (IUCN, 2010)
		Feeding	Spawning		
Barbus polylepis	Cool water, deep pools, flowing water, rivers and dams.	None	None	Southern tributaries of the Limpopo and Incomati and Phongolo systems.	Least Concern (LC)
Labeo cylindricus	Clear, running waters, rocky habitats. Dam rocky areas	None	Upstream migration, scales barrier rocks and weirs using mouth and pectoral fins.	Widespread. Zambezi system to Phongolo system.	LC
Hydrocynus vittatus	Warm, well-oxygenated water of larger rivers and lakes. Juveniles change habitat preference.	Habitat change from pelagic to vegetated areas linked to feeding.	Upstream and downstream migration for suitable sites.	Okavango, Zambezi to Phongolo systems. North and West Africa.	LC
Clarias gariepinus	Any habitat, favours floodplains, sluggish rivers, lakes, dams.	None	Migrates to flooded, shallow, grassy verges.	Throughout woodland-savanna zones of Africa.	-
Synodontis zambezensis	Pools and slow-flowing reaches of perennial and seasonal rivers.	None	None	Zambezi to Phongolo systems.	LC
Apocheilichthys johnstoni	Inshore, vegetated habitats, shallow, slow-flowing water.	None	None	Cunene, Okavango, Zambezi, Pungwe, north-eastern southern Africa.	LC
Tilapia sparmanni	Tolerant of broad range of habitats. Quiet, standing waters with vegetation.	None	None	Orange River, east and north to Zaire, lake Malawi, Zambezi.	LC
T.rendalli	Quiet, standing waters with vegetation.	None	None	Cunene, Okavango, Zambezi systems to Phongolo.	LC
Oreochromis mossambicus	All but fast-flowing waters.	None	None	East coast rivers, Zambezi to Cape Province.	Near Threatened
Glossogobius callidus	Pools on benthic surface, between cobbles or vegetation	None	None	East coast rivers of Mozambique and South Africa	LC

Table 5. Habitat preference, migratory behaviour, distribution and conservation status of the fish species collected at Stations 1 and 2.

4. Discussion and conclusion

The riparian vegetation at Station 1, upstream of the Corumana reservoir in the Kruger National Park and within the area to be potentially inundated at the FSL of 117 masl, is largely natural with few modifications. The present state of the riparian vegetation may be described as an open, reed and shrub dominated one, with little change having being brought about relative to the perceived reference state. The eco-classification (B) as determined for the site is expected given the fact that the immediate area has been protected for many years under the stewardship of The SANParks of South Africa.

The riparian vegetation has, however, undergone a significant, natural, change in the recent past, as a consequence of the effects of the 1 in 100 year flood in 2000. The change in state would have been from a tree, shrub and reed state, with high abundance and cover, into the present, more open one, with fewer large trees. In addition, the Corumana Dam, in operation since 1989, has had an effect on the immediate area. This effect includes the deposition of sediments at the site, the concomitant deposition of alluvial deposits over the bedrock dominated channel and a degree of loss, and change, in the nature of the available habitats in the marginal zone. These habitat changes would encourage a change to a reed dominated state. The extensive lateral alluvial bar along the left bank at the site was probably deposited there as a consequence of the 1 in 100 year flood. The non-marginal zone is clearly elevated from the marginal zone and is very sparsely populated with vegetation, resulting in an open environment. The present nature of the non-marginal zone is due to the effects of the 1 in a 100 year flood.

The right bank at Station 1 was not assessed in the study. The marginal zone here is similar to that of the left bank. The non-marginal zone is limited and leads to a steep incline. The area is within the area of the outer curve of the channel as it flows downstream into the Corumana Dam and is clearly incised as a result of scouring during high flows.

Inundation at the site will clearly lead to the loss of habitats, especially in the marginal zone. The impact on the non-marginal zone will not be as significant, given that no plants of high conservation value (all those collected may be classified as Least Concern) were observed at the assessed area, and that the area is open with low woody and non-woody abundance and cover. The inundated area will extend approximately two thirds into the first reach scanned (using Google, 2010 and LiDAR data, 2010), hence losing an equivalent extent of the anastomising channel. Given that the present FSL of 111 masl is characterized by the inundated area falling a short distance within the border on the Mozambique side, and the prediction for the FSL of 117 masl is for inundation up to 730 m into the Kruger National Park on the South African side. Clearly, though, the effect of reduced flow rate will result in sediment deposition and the development of alluvial deposits a short distance further, most likely within the reach at the site, as well as within the succeeding upstream reach. The estimation of potential sediment yield for the Lower Sabíe sub-catchment varied from <50tkm2a-1 by Donald et al (1995), 246tkm^{2}a^{-1} by Rooseboom et al (1992) to up to 620 tkm^{2}a^{-1} by van Niekerk and Heritage (1994). In this study (Appendix 1), the value was reported to be $310tkm^2a^{-1}$, based on the technique employed by Rooseboom et al (1992). The presence, therefore, of at least a further 7 upstream reaches, totalling approximately 8 km, within the Northern Lebombo Bushveld, is an important consideration in determining the impact that the inundation will have on the conservation of habitats and biota of high value in the region. Although any loss should be avoided, it appears that approximately 1,195 m (reach 1 and half of reach 2) of a total of 7,896 m (reaches 1 to 8, within the Northern Lebombo Bushveld) or 15% of the bedrock anastomising reach within the Northern Lebombo Bushveld will be transformed. Within this is approximately a quarter of the first reach, or 315 m is already transformed.

The environment around the edges of the Corumana reservoir was not included in the VEGRAI assessments. The FSL level of 117 masl for Corumana Dam will increase the surface area of the dam from 6,902 ha to 8,509 ha (23%), adding a total of 1,607 ha to the water body surface. The associated loss of riparian vegetation, the existence of which is primarily induced by the presence of the dam embankment perimeter, will in time be replaced by riparian vegetation extending over a greater distance. The vegetation around the fringes of the dam include *Epaltes gariepina – Chenopodium* sp herbland closest to the water body, followed by *Paspalidium obtusifolium – Cynodon dactylon* grassland and then *Sorghum bicolor* grassland. There are stands of *Ficus sycomorus – Acacia xanthophloea* woodland in the northern bays of the dam (Appendix 3). None of the species stated here have high conservation value. The addition of nutrients to the main body of water, from decomposing vegetable matter, may result in an increase in primary production and the presence of isolated algal blooms, given that relative depth of the dam is low at 0.36%, the mean hydraulic residence time is three years, the water is moderately clear (Secchi Disk value of 1.5m) and the mean annual temperature is 24oC (Appendix 1). The presence of *Pistia stratiotes* (Water Lettuce) and *Azolla filiculoides* (Water Fern) in the Sabíe River (including Station 1), as well as *Eichhornia crassipes* (Water Hyacinth) further upstream, may exacerbate the potential problem of vegetative blooms in the Corumana reservoir.

The riparian vegetation at Station 3, a direct distance of 28 km downstream of the Corumana, is largely modified with a large loss of habitats, biota and basic ecosystem function. The present state of the riparian vegetation may be described as a reed and shrub dominated one, with significant change having being brought about relative to the perceived reference state. The reference state, in particular within the non-marginal zone, may be expressed as tree, reed and shrub dominated, with the greatest difference to the present state due to the presence of indigenous riparian trees. The eco-classification (D) as determined for the site reflects the significant presence of subsistence crop and stock farming and alien agricultural plants including P*sidium guajava* (Guava), *Mangifera indica* (Mango) and *Musa acuminata* (Banana). The alien agricultural plants grow unattended and uncontrolled in the marginal and non-marginal zones.

The condition of the riparian vegetation is certainly not the same all along the river channel downstream of Corumana Dam. The condition, as expressed for Station 3, is as a result of the presence of access routes to the riverine environment and the concomitant influence of anthropogenic activities. There are areas that may be classified within the ambit of the eco-status of C and B, at least. The assessment as determined in this study does at least indicate the greatest impact to which the riverine environment has been subjected in places.

The aquatic macro-invertebrate fauna at Station 1 reflects an ecological status within the in-stream environment that may be defined as unmodified and natural. The suitability of the biotopes sampled and present at the station also reflect a healthy position (SASS5, 71%; IHAS, 79%). The pH measured for the water was low (6.6) and the conductivity (15mSm-1) and clarity normal. The high SASS5 score (206) and number of taxa (35) certainly reflects a state close to the pristine one. It is thus important that the status quo be maintained. As stated for the riparian vegetation, inundation at the site and the concomitant deposition of sediments will lead to the loss of biotopes, especially in the marginal zone, in particular, the stones in current and stones out of current types. In addition, however, as stated for the riparian vegetation, the presence upstream of the site, of approximately 8km, of potentially unaffected bedrock anastomising channel within the Northern Lebombo Bushveld, is an important consideration in determining the impact that the inundation will have on the conservation of habitats and biota of high value in the region. Although any loss should be avoided, it appears that approximately 14% of the bedrock anastomising reach within the Northern Lebombo Bushveld will be further transformed.

The FAII for Station 1, independently of Station 2, yielded an eco-status (B) that may be described as largely natural with few modifications. This is line with that described for the riparian vegetation. The result was, however, based on an observed data set where the number of species collected was only 15% of that potentially expected. The fact that the results for the aquatic macroinvertebrates and fish fauna yielded the same eco-status suggests that the result for the latter is accurate. The only species significantly important with respect to migration from the observed data set for Station 1 is *Hydrocynus vittatus* (Tigerfish). The presence of the Corumana reservoir, however, provides a host of habitats in which the Tigerfish may flourish. Given that 40 species of fish potentially exist at the station, and of those that were not observed during the survey, 7 (17.5%) rely on migration for feeding or spawning. The impact of increasing the FSL of Corumana Dam to 117 masl will not change the status quo with respect to fish migration.

LAHMEYER INTERNATIONAL (2003) estimate that 26 fishing camps existed around the Corumana reservoir in 2001, with approximately 200 people involved in the artisanal fishing enterprises from the camps.The SIA field study found that there are approximately 400 fishermen involved in the artisanal fishing in the Corumana reservoir at present. 217 fishermen are registered in the Fising Associations.Fishing is carried out using gill nets from small boats.LAHMEYER INTERNATIONAL (2003) states that increasing the FSL of the dam to 117 masl will not impact deleteriously on the enterprises, but rather on the contrary, will potentially enlarge the existing fishery. Reservoir fish yield may be related to the magnitude of drawdown, the mean water depth and electrical conductivity. It appears that annual draw-downs of between 2.5 and 4.0 m is optimal. The average draw-down for the Corumana Dam appears to be 3.0 m (LAHMEYER INTERNATIONAL, 2003). In addition, fish yields per unit area may be related to reservoir electrical conductivity, with higher conductivities indicating greater concentrations of nutrients. An increase in mean depth will mean deeper waters will be less suitable for fish production. Electrical conductivity is unlikely to change significantly, but mean depth is expected to increase by 21%, with potential annual fish yield per unit area declining by a slightly smaller percentage. The reservoir surface area, on the other hand, will increase by 23%, and hence the annual reservoir fish yield will increase, by a smaller percentage. The result is that, whilst catch per unit area, and effort, may decrease, total annual reservoir fish yield will increase, leading to a small increase in the potential size of the fishery of two percent.

The most productive fish producing areas are located in shallower waters, mostly where the depth is less than 10m. An increase in FSL from 111 masl to 117 masl will increase the extent of the littoral zone of 10m or less from 32.3km^2 to 34.4km^2, or 6%. This implies that the fish production may also increase by around this percentage (LAYMEYER INTERNATIONAL, 2003).

Hence, an increase in mean depth will mean a decrease in total annual potential fish yield per unit area for the dam. The increase in surface area of 23%, however, will result in an increase in suitable habitat of 6%, leading to a net increase in the total size of the fishery of up to 2%.

The aquatic macro-invertebrate fauna at Station 2 reflects an ecological status within the in-stream environment that may be defined as seriously modified. The suitability of the biotopes sampled and present at the station also reflect an impacted position (SASS5, 54%; IHAS, 60%). The pH measured for the water was low (7.0) and the conductivity (17mSm-1) and clarity normal. It was difficult to find a site in the region that (1) possessed all the biotopes necessary for SASS5 and FAII assessments, was (2) accessible and not (3) impacted significantly by anthropogenic activities. The FAII for Station 2, independently of Station 1, yielded an eco-status (C) that may be described as moderately modified. The FAII for the pooled data for Stations 1 and 2 also fell within the ecostatus category C. Fish collected at Station 2 exhibited clear evidence of disease (lesions on the body wall). This is probably due partly to point source chemical pollution as a result of the significant use by local residents of the site for washing clothes. The riffles at the station are covered by solid residues originating from the use of soaps and detergents in the river by local residents.

Assuming a constant release from the Corumana reservoir throughout the year and using updated inflow hydrological data, results (Appendix 1) have shown that after increasing the FSL from 111 masl to 117 masl (with an increase in firm yield, reduction in spillage and higher evaporative loss) will reduce the downstream flows from the dam by 5.1%. Although the Corumana Dam has been in operation since 1989, the Environmental Water Requirements (EWR) for the downstream environment has not been determined and also fell outside the brief of the present study. This is a limitation of the present study An additional limitation to the present study is the dearth of available information employed in the assessment. Although appropriate historical information exists, it proved difficult to access it.

In conclusion, an evaluation of the impacts on the aquatic environment as a result of increasing the FSL of the Corumana Dam from 111 masl to 117 masl, are as given in Table 6.

The assessment of the present state of the riparian vegetation, macroinvertebrates and fish fauna in the Sabíe River in the region of the Corumana Dam may be described for the upstream environment as largely natural with few modifications and for the downstream environment as moderately to seriously modified, with a loss and change in habitats and biota, with ecosystem function changed.

Table 6. Summary of significance and probability of potential impacts.

Process Impacted	Extent of impact	Magni-tude of impact	Duration of im-pact	Signifi-cance ratings	Probabil-ity rat-ings	Confi-dence ratings
Threats to aquatic flora and fauna and habitats of conservation importance or concern, generally	Local	Low	Medium term	Low impact	Probable	Sure
Threat to upstream aquatic flora and fauna	Site specific	Medium	Long term	Low impact	Highly probable	Sure
Development of aquatic habitats and flora in the newly inundated area	Site specific	Low	Medium term	Very low impact	Probable	Sure
Development of fish fauna in the newly inundated area	Site specific	Low	Medium term	Very low impact	Probable	Sure
Impacts on aquatic flora and fauna of change of downstream flow	Regional	Low	Long term	Low impact	Probable	Sure

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Annexure A

VEGRAI LEVEL 3 ASSESSMENT

SABÍE RIVER STATION SABOO1

15/10/2010

ASSESSOR: LR Taylor

LATITUDE: 25^{o}11.081'S

LONGITUDE: 32^{o}01.869'E

QUARTERNARY CATCHMENT: X3

LONGITUDINAL BOUNDARY OF SITE:

This area falls within the Northern Lebombo Bushveld, characterized by the regionally unique Rhyolite of the Jozini Formation and lesser basalt of the Letaba Formation, both of the Lebombo Group (Karoo Supergroup). Dykes of granophyre (Jurasic) form ridges with stony, shallow lithosoils, and rocky outcrops (Mucina and Rutherford, 2006).

The channel type is of a broad (530m) anastomosing bedrock form (Heritage et al, 1997) with a wide variety of habitats. The morphological units present almost certainly include bedrock pools, riffle-pool sequences, lateral, point, bedrock core and lee bars, bedrock and alluvial backwaters, rip channels, boulder beds, alluvial and bedrock distributaries and islands.

There is a significant lateral alluvial bar on the left bank side of the river immediately upstream of the Corumana reservoir. This lateral alluvial bar may have been formed during the course of the 100 year flood event experienced in the region in February 2000.

RIPARIAN VEGETATION ZONES, MARGINAL:

The marginal riparian zone comprises a complex of active anastomising bedrock channels to the south (right bank) and a broad expanse of bedrock and alluvial deposits to the north (inactive channels), with occasional isolated pools. The vegetation is dominated by *Phragmites mauritianu*s stands, *Miscanthus junceum* and species of sedge (Cyperaceae), including *Schoenoplectus corymbosus*.

RIPARIAN VEGETATION ZONES, NON-MARGINAL:

The left bank is gently elevated and sparsely populated by large woody species, including *Diospyros mespiliformis*, *Philenoptera violacea* and *Kigelia africana*, amongst others. The right bank is steeply inclined with a limited non-marginal (lower and upper) zone.

IMAGES OF THE REACH:

a) Overall view of the site

b) Main channel, viewed upstream

c) Distant lateral bar and Corumana reservoir

d) Marginal zone

e) Non-marginal zone viewed upstream

SPECIES LIST:

Species	Comment
Marginal woody	
Breonadia salicina, Matumi	Riverine fringe forest and active channel
Bridelia cathartica, Blue Sweetberry	Riverine fringe thicket and stream banks
Polygala unicinata (Milkworts)	
Rubiaceace (*Otiophora* sp?)	
Tephrosia cf *rhodesica*, Fish Poison-pea	
Verbena bonariense	
Marginal non-woody	
Acroceras macrum, Nile Grass	Vleis, riverbanks and damp places
Aspilia mossambicensis	
Indigofera sp. (*swaziensis*?)	Along riverine fringe forests.
Ludwigia octovalvus, Shrubby Ludwigia	Marshy areas along rivers
Ludwigia stolonifera	
Miscanthus junceus, Wireleaf Daba Grass	Riverbanks, vleis and standing water. **Dominant**
Otiophora sp?	
Persicaria atennuata	
Phragmites mauritianus	**Dominant**
Schoenoplectus corymbosus	Sedge
Sorghum bicolor, Common Wild Sorghum	Damp places along water courses

SPECIES LIST (Continued):

Species	Comment
Non-marginal woody	
Combretum microphyllum, Flame Climbing Bushwillow	Along rivers and smaller watercourses
Diospyros mespiliformis, Jackal-berry	Rivers and riverine fringes, rocky outcrops, low to medium altitudes
Euclea natalensis angustifolia, Bushveld Hairy Guarri	Bushveld rocky outcrops. **Dominant**
Flueggea virosa, White-berry Bush	Along rivers, on rocky outcrops
Gymnosporia maranguensis, Tropical Spike-thorn	Low-lying riverine alluvial soils
Indigofera sp	
Kigelia Africana, Sausage Tree	Floodplains and water courses. **Dominant**
Philenoptera violacea, Apple-leaf	Bushveld low to medium altitudes, alluvial soils close to rivers
Phyllanthus reticulates, Potato-bush	Low altitude riverine vegetation and thicket
Tephrosia cf *elongate*	
Vitex harveyana, Scrambling Fingerleaf	Between rock son sandy soil and on river and stream banks
Non-marginal non-woody	
Cyperaceae sp	

Comments:

Important taxa potentially found in the region and associated with riverine, wetland and riparian conditions include woody species *Acacia erubescens, Lannea schweinfurthii* var. *stuhlmanni, Pappea capensis*, *Strychnos decussata*, *Croton madandensis*, *Karomia speciosa*, *Barleria affinis* and *Helinis integrifolius*. Non-woody taxa associated with riverine, wetland and riparian conditions include *Digitaria eriantha eriantha* and *Panicum maximum* (Mucina and Rutherford, 2006).

LANDUSE AND IMPACT EVALUATION

MARGINAL ZONE: SURROUNDING AND UPSTREAM LAND USE

(any land use that causes an impact on the VEGRAI site)

LAND USE	IMPACTS Rating: 0 (no impact)-5(severe impact)					
	Removal		Quantity		Quality	
	INT	EXT	INT	EXT	INT	EXT
Nature reserve, game farming, natural areas	0	0	1	1	1	1
Picnic site / recreation area	0	0	0	0	0	0
Subsistence (rural) farming (not stock)	1	1	0	0	1	1
Stock farming	0	0	0	0	0	0
Firewood, reed, medicinal plant utilization	0	0	0	0	0	0
Forestry	0	0	0	0	0	0
Irrigation farming (formal) crops	0	0	0	0	0	0
Residential, urban	0	0	0	0	0	0
Residential, rural	0	0	0	0	0	0
Large dams	0	0	0	0	3	3
Weirs and farm dams	0	0	1	1	0	0
Mining, quarrying (including obsolete)	0	0	0	0	0	0
Sewerage treatment and releases	0	0	0	0	0	0
Infrastructure (formal roads)	0	0	0	0	0	0
Infrastructure (vehicle tracks)	0	0	0	0	1	1

Infrastructure (rails)	0	0	0	0	0	0
Infrastructure (foot- and livestock paths)	0	0	0	0	0	0
Rubbish dumping	0	0	0	0	0	0
Industrial	0	0	0	0	0	0
Other: Specify						
OVERALL RATING (representative of the maximum rating above	1	1	1	1	3	3
CONFIDENCE	4	4	3	3	3	3

NOTES:

The marginal zone is largely unaffected except for the presence of the Corumana reservoir immediately downstream of the station. The dam has the effect at the station, and further upstream, of reduced flow and increased sedimentation. The implication of that is increased turbidity due to physical components in the water column and the reduction of habitat diversity, in particular those present in rif-fles. The effect on the site of the removal of marginal vegetation is very low and the effect of water quality change average. In terms of the latter, cognisance must be taken of the effect of the Corumana Dam and the presence of a number of upstream dams and weirs.

LANDUSE AND IMPACT EVALUATION

NON-MARGINAL ZONE: SURROUNDING AND UPSTREAM LAND USE

(any land use that causes an impact on the VEGRAI site)

LAND USE	IMPACTS Rating: 0 (no impact)-5(severe impact)					
	Removal		Quantity		Quality	
	INT	EXT	INT	EXT	INT	EXT
Nature reserve, game farming	0	0	0	0	0	0
Natural areas	0	0	0	0	0	0
Picnic site / recreation area	0	0	0	0	0	0
Subsistence (rural) farming	1	1	0	0	1	1
Stock farming	0	0	0	0	0	0
Forestry	0	0	0	0	0	0
Irrigation farming (formal) crops	0	0	0	0	0	0
Residential, urban	0	0	0	0	0	0
Residential, rural	1	1	0	0	1	1
Large dams	0	0	2	2	2	2
Weirs and farm dams	0	0	2	2	0	0
Mining, quarrying (including obsolete)	0	0	0	0	0	0
Sewerage treatment and releases	0	0	0	0	0	0
Infrastructure (formal roads)	0	0	0	0	0	0
Infrastructure (vehicle tracks)	1	1	0	0	1	1
Infrastructure (rails)	0	0	0	0	0	0

Infrastructure (foot- and livestock paths)	0	0	0	0	0	0
Rubbish dumping	0	0	0	0	0	0
Industrial	0	0	0	0	0	0
Other: Specify						
OVERALL RATING (representative of the maximum rating above	1	1	2	2	2	2
CONFIDENCE	4	4	3	3	3	3

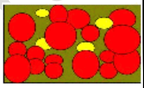
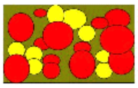
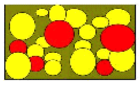
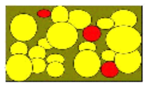
NOTES:

The non-marginal zone is largely unaffected, except for the fact that the inundation of the zone may be reduced due to the presence upstream of dams and weirs. The presence of the dam may well lead to an increased inundation of the non-marginal zone immediately upstream of the dam.

EXOTIC INVASION

Use COVER of alien vegetation compared to indigenous vegetation to provide an estimate of the proportional invasion as a percentage according to the range below. Red (or Dark Grey if printed on a black and white printer = exotics) (Figure supplied by Douglas Macfarlane)

Use the rating table at the end of the field form to determine the rating. Note that the reference conditions will always be zero in this case (delete last two rows in each table below and provide a single space for zone rating)

INVASION BY EXOTICS						
Red/dark grey circles representing aliens						
COVER of aliens	100-80%	80 - 60%	60-40%	40-20%	20-10%	<10%
Indicate (X)						

MARGINAL

Invasion by exotics (%)						
Cover of aliens	100-80	80-60	60-40	40-20	20-10	<10
Indicate (X)						X

LOVER (or non-marginal in case of Level 3 assessment)

Invasion by exotics (%)						
Cover of aliens	100-80	80-60	60-40	40-20	20-10	<10
Indicate (X)						X

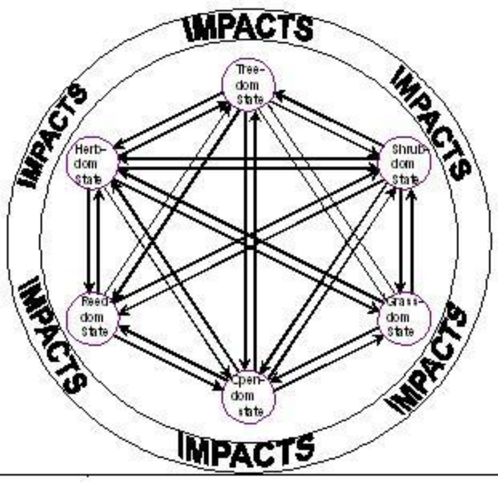
EXOTIC VEGETATION	Marginal		Non-marginal			
			Lower		Upper	
(indicate with a tick)						
Species						
Pistia stratiotes (Water lettuce)	X					
Azolla filiculoides (Water fern)	X					
Argemone mexicana (Mexican Poppy)	X					
	Int	Ext	Int	Ext	Int	Ext
EXOTIC VEGETATION: OVERALL RATING (Use rating in figures above for intensity)	2	3	0	0		

This table for Level 3 users only.

User information compiled on exotic vegetation to derive the potential impact on species composition. Provide a rating of 0 – 5 in the Marginal and Non-Marginal columns and provide a motivation in the comments block.

Species Composition			
Vegetation Components	Marginal rating	Non-marginal rating	Comment
Woody	0	0	Only the Mexican poppy found, sporadically present in marginal zone.
Non-woodu	1	0	Both species of plants found are aquatic and may have a limited impact on indigenous marginal species.

REFERENCE CONDITIONS

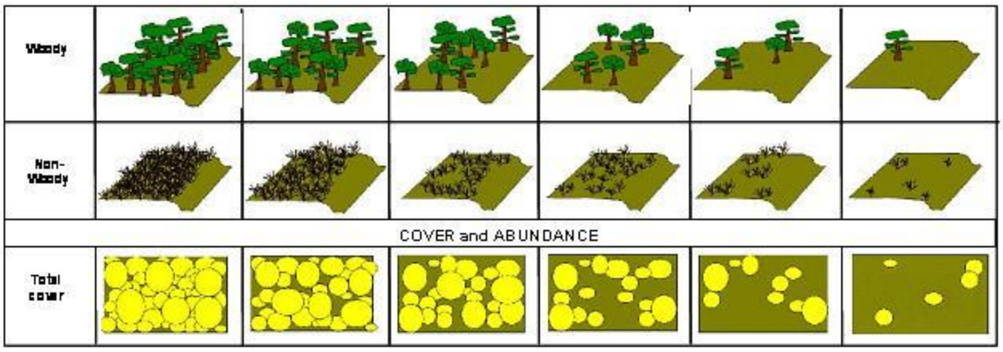


IMPACTS TO REMOVE	RESPONSE METRIC	DESCRIPTION OF STATE CHANGE (In all descriptions try to make reference to zones and states outlined in the figure above)
Vegetation Removal	Cover	No vegetation removal, except for the natural 100-year flood event of February 2000, where the reach was altered from a state dominated by riverine woody species (Matumi forest) to an open and reed and shrub dominated state. **The reference state should be classified as an open and reed and shrub dominated state,** as is the present condition. There is no, or at most very little, change to cover and abundance.
	Abundance	
	Population structure	
	Species Composition	
Exotic invasion	Cover	There will be very little change in state as the exotic invasion is limited to the sporadic presence of the Mexican poppy in the non-marginal zone and the aquatic species, water lettuce and water fern, in the marginal zone. The refer-ence state would be classified as **an open and reed and shrub dominated state**. There is no, or at most very little, change to cover and abundance.
	Abundance	
	Population structure	
	Species Composition	
Water Quantity	Cover	. The removal of the impact of water quantity relates to what the effect would be if there were no high and low water bridges and weirs in the Sabíe River system upstream of the reach and in the Kruger National Park. The reference condition would be characterized by greater flow and fewer perturbations and hence a more extensive reach of anas-
	Population structure	
	Abundance	
	Population structure	

	Species Composition	tomising channels and a more developed main channel. The effect would be a change in state to reference conditions where the open dominated state would be reduced and **the reach will be characterized by a tree and reed dominated state**. There will be an increase in cover and abundance of woody species and a reduction in cover and abundance of non-woody species.
Water Quality	Cover	The removal of water quality impacts would involve eliminating the effects of the Corumana Dam on the reach. Reduced sedimentation in the reach would be the result, leading to improved water quality. The reference condition will be associated with water of reduced turbidity, that is, improved clarity. Greater cover will lead to reduced water temperature, especially with respect to the water in stones out of current, pool and backwater habitats
	Population structure	
	Abundance	
	Population structure	
	Species Composition	

ABUNDANCE AND COVER

Use the top two rows (woody and non-woody) to assess abundance and the third row (circles) to assess cover. Tick the appropriate cell for present condition of INDIGENOUS VEGETATION. If possible, indicate the percentage in the range where you think it lies. Then, derive reference conditions using the reference conditions guide at the end of the forms and indicate which percentage range represents reference condition. Using the rating table at the end of the document, determine the appropriate rating to populate the model.



Conditions	**Woody (%)**											
	100-80		80-60		60-40		40-20		20-10		<10	
	cover	abund	cover	abund	cover	abund	cover	abund	cover	abund	cover	abund
	Marginal											
Present											X	X
Reference											X	X
	Non-marginal											
Present					X			X				
Reference					X			X				
Conditions	**Non-Woody (%)**											
	100-80		80-60		60-40		40-20		20-10		<10	
	cover	abund	cover	abund	cover	abund	cover	abund	cover	abund	cover	Abund
	Marginal											
Present							X	X				
Reference							X	X				
	Non-marginal											
Present											X	X
Reference											X	X

Annexure B

VEGRAI LEVEL 3 ASSESSMENT

SABÍE RIVER STATION SABOO3

16/11/2010

ASSESSOR: LR Taylor

LATITUDE: 25°17.748'S

LONGITUDE: 32°16.796'E

QUARTERNARY CATCHMENT: Site in Mozambique, 28.8km directly downstream of X3 in the RSA.

LONGITUDINAL BOUNDARY OF SITE:

The site is characterized by a steep, incised northern bank and a gently inclined southern bank. The latter comprises a broad alluvial floodplain. The human activities include subsistence crop and stock farming and rural residential development. The predominantly single, alluvial, river channel is braided for a short distance upstream of the site and includes a vegetated island.

RIPARIAN VEGETATION ZONES, MARGINAL:

The marginal riparian vegetation is well-developed along the southern bank and includes stands of *Phragmites mauritianus* and woody components including *Ficus sycomorus*. Alien species include the banana, *Musa acuminata*. The northern bank marginal zone is limited and includes stands of *Phragmites mauritianus*. The more accessible northern bank was assessed in this study.

RIPARIAN VEGETATION ZONES, NON-MARGINAL:

The non-marginal environment along the southern bank is more extensive than the northern bank. This is primarily due to the fact that the southern bank comprises an inactive, broad alluvial floodplain. Subsistence agriculture is practiced within the floodplain, where possible. The northern bank is significantly transformed by human activities, including subsistence crop and stock farming and rural residential development.

IMAGES OF THE REACH:

a) Left bank, non-marginal, downstream

b) Incised left bank, upstream

c) Right bank, marginal zone, 1

d) Right bank, marginal zone, 2

SPECIES LIST:

Species	Comment
Marginal woody	
Ficus sycomorus, Sycamore Fig	
Marginal non-woody	
Phragmites mauritianus, Reed grass	
Non- marginal woody	
Acacia xanthophloea, Fever Tree	
Ficus capreifolia, River Sandpaper Fig	
Ficus sycomorus, Sycamore Fig	
Grewia microthyrsa, Raisin Bush	
Phyllanthus reticulatus, Potato Bush	
Tacazzea apiculata, Crawcraw Vine	
Non- marginal non-woody	
Sporobolus africanus, Ratstail Dropseed	
Centella asiatica	
Cissampelos mucronata	
Cyperus variscus	
*Paspalum dilatatum,*Dallis Grass	
Paspalum scrobiculatum, Veld Paspalum	
Phragmites mauritianus, Reed Grass	
Thelypteris confluens	

LANDUSE AND IMPACT EVALUATION

MARGINAL ZONE: SURROUNDING AND UPSTREAM LAND USE

(any land use that causes an impact on the VEGRAI site)

LAND USE	IMPACTS Rating: 0 (no impact)-5(severe impact)					
	Removal		Quantity		Quality	
	INT	EXT	INT	EXT	INT	EXT
Nature reserve, game farming, natural areas	0	0	0	0	0	0
Picnic site / recreation area	1	3	0	0	1	3
Subsistence (rural) farming (not stock)	3	5	2	5	2	5
Stock farming	2	3	0	0	1	3
Firewood, reed, medicinal plant utilization	1	5	0	0	1	3
Forestry	0	0	0	0	0	0
Irrigation farming (formal) crops	0	0	0	0	0	0
Residential, urban	0	0	0	0	0	0
Residential, rural	2	5	1	3	1	3
Large dams	0	0	1	5	1	3
Weirs and farm dams	0	0	0	0	0	0
Mining, quarrying (including obsolete)	0	0	0	0	0	0
Sewerage treatment and releases	0	0	0	0	0	0
Infrastructure (formal roads)	0	0	0	0	0	0
Infrastructure (vehicle tracks)	1	3	0	0	1	3

Infrastructure (rails)	0	0	0	0	0	0
Infrastructure (foot- and livestock paths)	0	0	0	0	0	0
Rubbish dumping	0	0	0	0	0	0
Industrial	0	0	0	0	0	0
Other: Specify						
OVERALL RATING (representative of the maximum rating above	3	5	2	5	2	5
CONFIDENCE	3	3	3	3	3	3

NOTES:

The marginal zone is significantly affected in terms of vegetation removal by rural residential activities and subsistence farming. The abstraction of water for the domestic and farming activities would have a limited influence on water quantity. Water quality would be affected by the subsistence farming activities, in particular with respect to soil erosion and the change in physical water quality.

LANDUSE AND IMPACT EVALUATION

NON-MARGINAL ZONE: SURROUNDING AND UPSTREAM LAND USE

(any land use that causes an impact on the VEGRAI site)

LAND USE	IMPACTS Rating: 0 (no impact)-5(severe impact)					
	Removal		Quantity		Quality	
	INT	EXT	INT	EXT	INT	EXT
Nature reserve, game farming	0	0	0	0	0	0
Natural areas	0	0	0	0	0	0
Picnic site / recreation area	1	3	0	0	1	3
Subsistence (rural) farming	3	5	1	3	1	3
Stock farming	3	5	0	0	1	3
Forestry	0	0	0	0	0	0
Irrigation farming (formal) crops	0	0	0	0	0	0
Residential, urban	0	0	0	0	0	0
Residential, rural	3	5	0	0	1	3
Large dams	0	0	1	3	1	3
Weirs and farm dams	0	0	0	0	0	0
Mining, quarrying (including obsolete)	0	0	0	0	0	0
Sewerage treatment and releases	0	0	0	0	0	0
Infrastructure (formal roads)	0	0	0	0	0	0
Infrastructure (vehicle tracks)	1	3	0	0	1	3

Infrastructure (rails)	0	0	0	0	0	0
Infrastructure (foot- and livestock paths)	1	3	0	0	1	3
Rubbish dumping	0	0	0	0	0	0
Industrial	0	0	0	0	0	0
Other: Specify						
OVERALL RATING (representative of the maximum rating above	3	5	1	3	1	3
CONFIDENCE	3	3	3	3	3	3

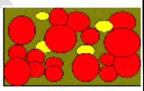
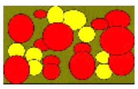
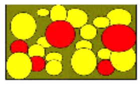
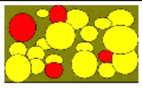
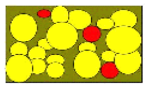
NOTES:

The non-marginal zone is significantly affected, by human activities, including subsistence crop and stock farming and residential development.

EXOTIC INVASION

Use COVER of alien vegetation compared to indigenous vegetation to provide an estimate of the proportional invasion as a percentage according to the range below. Red (or Dark Grey if printed on a black and white printer = exotics) (Figure supplied by Douglas Macfarlane)

Use the rating table at the end of the field form to determine the rating. Note that the reference conditions will always be zero in this case (delete last two rows in each table below and provide a single space for zone rating)

INVASION BY EXOTICS						
Red/dark grey circles representing aliens						
COVER of aliens	100-80%	80 - 60%	60-40%	40-20%	20-10%	<10%
Indicate (X)						

MARGINAL

Invasion by exotics (%)						
Cover of aliens	100-80	80-60	60-40	40-20	20-10	<10
Indicate (X)						X

LOVER (or non-marginal in case of Level 3 assessment)

Invasion by exotics (%)						
Cover of aliens	100-80	80-60	60-40	40-20	20-10	<10
Indicate (X)				X		

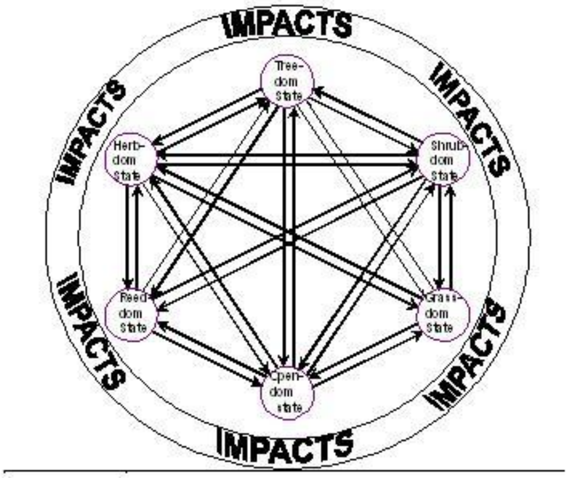
EXOTIC VEGETATION	Marginal		Non-marginal			
			Lower		Upper	
(indicate with a tick)						
Species						
Psidium guajava (Guava)			X			
Mangifera indica (Mango)			X			
Musa acuminata (Banana)	X		X			
	Int	Ext	Int	Ext	Int	Ext
EXOTIC VEGETATION: OVERALL RATING (Use rating in figures above for intensity)	2	3	3	4		

This table for Level 3 users only.

User information compiled on exotic vegetation to derive the potential impact on species composition. Provide a rating of 0 – 5 in the Marginal and Non-Marginal columns and provide a motivation in the comments block.

Species Composition			
Vegetation Components	Marginal rating	Non-marginal rating	Comment
Woody	1	3	Guava, Mango and Banana extensively found throughout area, especially in the non-marginal zone.
Non-woody	0	0	

REFERENCE CONDITIONS

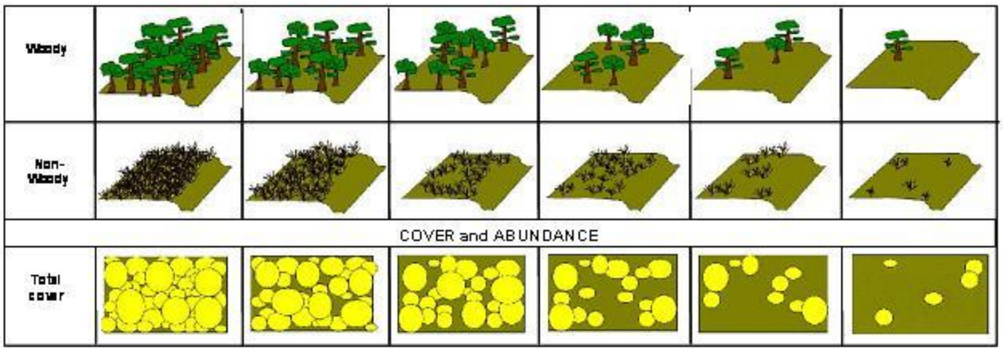


IMPACTS TO REMOVE	RESPONSE METRIC	DESCRIPTION OF STATE CHANGE (In all descriptions try to make reference to zones and states outlined in the figure above)
Vegetation Removal	Cover	The reference state in the marginal zone would be dominated by reeds and shrubs, with abundance for the woody component of 10 to 20% and for the non-woody component of 40 to 60%. Cover in total would be in the region of 80%.The non-marginal zone would be dominated by trees, reeds and shrubs. Woody abundance would be 40 to 60% and non-woody 20 to 40%. Note that the above estimations do not take the potential effect of the February 2000 flood into consideration.
	Abundance	
	Population structure	
	Species Composition	
Exotic invasion	Cover	The most dramatic effect of the removal of alien vegetation, as presently experienced, would change the state from the present open and shrub dominated state to a tree, shrub and reed dominated state, particularly in the non-marginal zone.
	Abundance	
	Population structure	
	Species Composition	
Water Quantity	Cover	Notwithstanding the potential effect of regulation on the downstream environment, the removal of the effect of water quantity impacts on the marginal and
	Abundance	

	Population structure	non-marginal zone would have a limited effect on state change. If any influence occurs, it would be to support the likely reference state for the reach dominated by trees, shrubs and reeds.
	Species Composition	
Water Quality	Cover	Water quality is impacted upon by deterioration due to increased physical water pollution and pollution by domestic detergents. The removal of these impacts would change the state of the marginal zone to a limited extent in that conditions for fully aquatic vegetation would be improved.
	Abundance	
	Population structure	
	Species Composition	

ABUNDANCE AND COVER

Use the top two rows (woody and non-woody) to assess abundance and the third row (circles) to assess cover. Tick the appropriate cell for present condition of INDIGENOUS VEGETATION. If possible, indicate the percentage in the range where you think it lies. Then, derive reference conditions using the reference conditions guide at the end of the forms and indicate which percentage range represents reference condition. Using the rating table at the end of the document, determine the appropriate rating to populate the model.



Conditions	Woody (%)											
	100-80		80-60		60-40		40-20		20-10		<10	
	cover	abund	cover	abund	cover	abund	cover	abund	cover	abund	cover	abund
	Marginal											
Present											X	X
Reference							X			X		
	Non-marginal											
Present							X	X				
Reference			X			X						
Conditions	Non-Woody (%)											
	100-80		80-60		60-40		40-20		20-10		<10	
	cover	abund	cover	abund	cover	abund	cover	abund	cover	abund	cover	Abund
	Marginal											
Present							X	X				
Reference					X	X						
	Non-marginal											
Present									X	X		
Reference							X	X				

ANNEXURE C

SASS Version 5 Score Sheet

Version date: Apr 2008

Date (dd:mm:yr):	15/11/2010				(dd.ddddd)
Site Code:	SAB001	Grid reference (dd mm ss.s) Lat:	S	25 deg 11.081'	#VALUE!
Collector/Sampler:	Dr LR Taylor, Mr R Tate, Mr J Best	Long:	E	32 deg 01.869'	#VALUE!
River:	Sabie River	Datum (WGS84/Cape):		WGS84	
Level 1 Ecoregion:	3: LOWVELD	Altitude (m):		116 m	
Quaternary Catchment:	X3	Zonation:		F: Lowland River	

Temp (°C):	22.9 (8:09)	**Project**		Flow:	Low
pH:	6.6	Project Name:		Clarity (cm):	To bottom
DO (mg/L):		Mozambique 4 Dams Project: Corumana Dam		Turbidity:	V Low
Cond (mS/m):	15mS/m			Colour:	Normal Transparent

Site Description:
Bedrock anastomosing channel type, 50m from the International Border. Main channel, near the steep-sloped right bank, flows into the Corumana Dam. A number of smaller in-stream channels towards the left bank. The latter comprises a more gradual slope.

Riparian Disturbance: No significant impact. Gravel road access to river, remnants of International Border fencing.

Instream Disturbance: No significant impact. Remnants of International Border fencing.

Biotopes Sampled (tick & rate)	Rating	Weight			Time (min)
Stones In Current (SIC)	5	3.0			800
Stones Out Of Current (SOOC)	3	3.0			1100
Bedrock	3	1.0			180 mins
Aquatic Veg	3	2.5			
MargVeg In Current	4	2.0			
MargVeg Out Of Current	4	2.0			
Gravel	4	0.5			
Sand	3	4.0			
Mud	3	1.5			
Hand picking/Visual observation	None		13.8	Category	
OVERALL BIOTOPE SUITABILITY		0.0	71%	A	

Taxon	QV	S	Veg	GSM	TOT
PORIFERA (Sponge)	5				
COELENTERATA (Cnidaria)	1				
TURBELLARIA (Flatworms)	3	A	1		A
ANNELIDA					
Oligochaeta (Earthworms)	1	A			A
Hirudinea (Leeches)	3	A	1		A
CRUSTACEA					
Amphipoda (Scuds)	13				
Potamonautidae* (Crabs)	3				
Atyidae (Freshwater Shrimps)	8		B		B
Palaemonidae (Freshwater Prawns)	10				
HYDRACARINA	8	A			A
PLECOPTERA (Stoneflies)					
Notonemouridae	14				
Perlidae	12				
EPHEMEROPTERA (Mayflies)					
Baetidae 1sp	4			1	
Baetidae 2 sp	6	A	B		B
Baetidae > 2 sp	12				
Caenidae (Squaregills/Cainfles)	6	A	B	1	B
Ephemeridae	15				
Heptageniidae (Flatheaded mayflies)	13	A			A
Leptophlebiidae (Prongills)	9	A	A	1	B
Oligoneuridae (Brushlegged mayflies)	15				
Polymitarcyidae (Pale Burrowers)	10				
Prosopistomatidae (Water specs)	15				
Teloganodidae SWC (Spiny Crawlers)	12				
Tricorythidae (Stout Crawlers)	9	A			A
ODONATA (Dragonflies & Damselflies)					
Calopterygidae ST,T (Demoiselles)	10		A		A
Chlorocyphidae (Jewels)	10				
Synlestidae (Chlorolestidae)(Sylphs)	8				
Coenagrionidae (Sprites and blues)	4		A		A
Lestidae (Emerald Damselflies/Spreadwings)	8				
Platycnemidae (Stream Damselflies)	10				
Protoneuridae (Threadwings)	8				
Aeshnidae (Hawkers & Emperors)	8	A			A
Corduliidae (Cruisers)	8				
Gomphidae (Clubtails)	6	A	A		B
Libellulidae (Darters/Skimmers)	4	A	A	1	B
LEPIDOPTERA (Aquatic Caterpillars/Moths)					
Crambidae (Pyralidae)	12	1			1

Taxon	QV	S	Veg	GSM	TOT
HEMIPTERA (Bugs)					
Belostomatidae* (Giant water bugs)	3	A	1		A
Corixidae* (Water boatmen)	3				
Gerridae* (Pond skaters/Water striders)	5				
Hydrometridae* (Water measurers)	6				
Naucoridae* (Creeping water bugs)	7		1	1	A
Nepidae* (Water scorpions)	3	1			1
Notonectidae* (Backswimmers)	3				
Pleidae* (Pygmy backswimmers)	4		A		A
Veliidae/M...veliidae* (Ripple bugs)	5		B		B
MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)					
Corydalidae (Fishflies & Dobsonflies)	8				
Sialidae (Alderflies)	6				
TRICHOPTERA (Caddisflies)					
Dipseudopsidae	10				
Ecnomidae	8	A	1		A
Hydropsychidae 1 sp	4	A			A
Hydropsychidae 2 sp	6				
Hydropsychidae > 2 sp	12				
Philopotamidae	10				
Polycentropodidae	12				
Psychomyiidae/Xiphocentronidae	8	A			A
Cased caddis:					
Barbarochthonidae SWC	13				
Calamoceratidae ST	11				
Glossosomatidae SWC	11				
Hydroptilidae	6	1			1
Hydrosalpingidae SWC	15				
Lepidostomatidae	10				
Leptoceridae	6		A		A
Petrothrincidae SWC	11				
Pisuliidae	10				
Sericostomatidae SWC	13				
COLEOPTERA (Beetles)					
Dytiscidae/Noteridae* (Diving beetles)	5		1		1
Elmidae/Dryopidae* (Riffle beetles)	8	A	1	1	A
Gyrinidae* (Whirligig beetles)	5	A	1		A
Haliplidae* (Crawling water beetles)	5				
Helodidae (Marsh beetles)	12				
Hydraenidae* (Minute moss beetles)	8				
Hydrophilidae* (Water scavenger beetles)	5	1			1
Limnichidae (Marsh-Loving Beetles)	10				
Psephenidae (Water Pennies)	10				

Taxon	QV	S	Veg	GSM	TOT
DIPTERA (Flies)					
Athericidae (Snipe flies)	10				
Blepharoceridae (Mountain midges)	15				
Ceratopogonidae (Biting midges)	5				
Chironomidae (Midges)	2	B	A	A	B
Culicidae* (Mosquitoes)	1		A		A
Dixidae* (Dixid midge)	10				
Empididae (Dance flies)	6				
Ephydridae (Shore flies)	3				
Muscidae (House flies, Stable flies)	1				
Psychodidae (Moth flies)	1				
Simuliidae (Blackflies)	5	B	1	1	B
Syrphidae* (Rat tailed maggots)	1				
Tabanidae (Horse flies)	5	A			A
Tipulidae (Crane flies)	5	B			B
GASTROPODA (Snails)					
Ancylidae (Limpets)	6				
Bulininae*	3				
Hydrobiidae*	3				
Lymnaeidae* (Pond snails)	3				
Physidae* (Pouch snails)	3		1		1
Planorbinae* (Orb snails)	3				
Thiaridae* (=Melanidae)	3	A			A
Viviparidae* ST	5				
PELECYPODA (Bivalvles)					
Corbiculidae (Clams)	5	1		1	A
Sphaeriidae (Pill clams)	3				
Unionidae (Perly mussels)	6				
SASS Score		162	116	50	206
No. of Taxa		28	21	9	35
ASPT		5.8	5.5	5.6	5.9

Other biota:
Two Banded Tilapia, *Tilapia sparmanni* , and two Sharptooth Catfish, *Clarias gariepinus* , collected in SOOC sample.
Two River Goby, *Glossogobius callidus* , collected in VEG sample.

Comments/Observations:
IHAS (McMillan, 1998) score was 79%. Using Lowveld Lower Biological Bands (Dallas, 2007), the Ecological Category for the site is Unmodified, Natural.

Procedure:
Kick SIC & bedrock for 2 mins, max. 5 mins. Kick SOOC & bedrock for 1 min. Sweep marginal vegetation (IC & OOC) for 2m total and aquatic veg 1m^2. Stir & sweep gravel, sand, mud for 1 min total. * = airbreathers
Hand picking & visual observation for 1 min - record in biotope where found (by circling estimated abundance on score sheet). Score for 15 mins/biotope but stop if no new taxa seen after 5 mins.
Estimate abundances: 1 = 1, A = 2-10, B = 10-100, C = 100-1000, D = >1000 S = Stone, rock & solid objects; Veg = All vegetation; GSM = Gravel, sand, mud SWC = South Western Cape, T = Tropical, ST = Sub-tropical
Rate each biotope sampled: 1=very poor (i.e. limited diversity), 5=highly suitable (i.e. wide diversity) Rate turbidity: V low, Low, Medium, High, Very High
Rate flows: Zero, trickle, low, medium, high, flood Rate colour: transparent, tea brown, light brown, dark brown, light green, dark green, yellow, red, grey, milky white, black

Flow	Tu
Zero	V
Trickle	Lo
Low	Mo
Medium	Hi
High	V
Flood	

ANNEXURE D

SASS Version 5 Score Sheet

Version date: Apr 2008

Date (dd:mm:yr):	17/11/2010				(dd.ddddd)
Site Code:	SAB002	Grid reference (dd mm ss.s) Lat:	S	25 deg 12.297'	#VALUE!
Collector/Sampler:	Dr LR Taylor, Mr R Tate, Mr J Best	Long:	E	32 deg 08.642'	#VALUE!
River:	Sabie River	Datum (WGS84/Cape):		WGS84	
Level 1 Ecoregion:	3: LOWVELD	Altitude (m):		84 m	
Quaternary Catchment:	X3, Mozambique	Zonation:		F: Lowland River	

Temp (°C):	23.6 (6:40)	**Project**		Flow:	Low
pH:	7.0	Project Name:		Clarity (cm):	To bottom
DO (mg/L):		Mozambique 4 Dams Project: Corumana Dam		Turbidity:	V Low
Cond (mS/m):	17mS/m			Colour:	Grey

Site Description:
Braided channel with pool-riffle sequences. Left Bank bedrock section with shallow in-stream riffle. Right Bank alluvial sections with *Phragmites mauritianus* stands. Bridge over the river and significant access point for infomal water abstraction and washing.

Riparian Disturbance: Significant impact. Bridge and access point for informal water abstraction and washing.

Instream Disturbance: Significant impact. In-stream channel used for washing and informal water abstraction. Significant soap and textile debris.

Biotopes Sampled (tick & rate)	Rating	Weight			Time (min)
Stones In Current (SIC)	4	3.0			630
Stones Out Of Current (SOOC)	3	3.0			815
Bedrock	3	1.0			105
Aquatic Veg	2	2.5			
MargVeg In Current	3	2.0			
MargVeg Out Of Current	3	2.0			
Gravel	4	0.5			
Sand	2	4.0			
Mud	1	1.5			
Hand picking/Visual observation	None		10.5	Category C	
OVERALL BIOTOPE SUITABILITY		0.0	54%		

Taxon	QV	S	Veg	GSM	TOT
PORIFERA (Sponge)	5				
COELENTERATA (Cnidaria)	1				
TURBELLARIA (Flatworms)	3				
ANNELIDA					
Oligochaeta (Earthworms)	1	A			A
Hirudinea (Leeches)	3				
CRUSTACEA					
Amphipoda (Scuds)	13				
Potamonautidae* (Crabs)	3				
Atyidae (Freshwater Shrimps)	8		A		A
Palaemonidae (Freshwater Prawns)	10				
HYDRACARINA	8				
PLECOPTERA (Stoneflies)					
Notonemouridae	14				
Perlidae	12				
EPHEMEROPTERA (Mayflies)					
Baetidae 1sp	4				
Baetidae 2 sp	6		B		B
Baetidae > 2 sp	12				
Caenidae (Squaregills/Cainfles)	6				
Ephemeridae	15		1		1
Heptageniidae (Flatheaded mayflies)	13				
Leptophlebiidae (Prongills)	9				
Oligoneuridae (Brushlegged mayflies)	15				
Polymitarcyidae (Pale Burrowers)	10				
Prosopistomatidae (Water specs)	15				
Teloganodidae SWC (Spiny Crawlers)	12				
Tricorythidae (Stout Crawlers)	9				
ODONATA (Dragonflies & Damselflies)					
Calopterygidae ST,T (Demoiselles)	10				
Chlorocyphidae (Jewels)	10				
Synlestidae (Chlorolestidae)(Sylphs)	8				
Coenagrionidae (Sprites and blues)	4				
Lestidae (Emerald Damselflies/Spreadwings)	8				
Platycnemidae (Stream Damselflies)	10				
Protoneuridae (Threadwings)	8				
Aeshnidae (Hawkers & Emperors)	8				
Corduliidae (Cruisers)	8				
Gomphidae (Clubtails)	6				
Libellulidae (Darters/Skimmers)	4				
LEPIDOPTERA (Aquatic Caterpillars/Moths)					
Crambidae (Pyralidae)	12				

Taxon	QV	S	Veg	GSM	TOT
HEMIPTERA (Bugs)					
Belostomatidae* (Giant water bugs)	3				
Corixidae* (Water boatmen)	3				
Gerridae* (Pond skaters/Water striders)	5				
Hydrometridae* (Water measurers)	6				
Naucoridae* (Creeping water bugs)	7			1	1
Nepidae* (Water scorpions)	3				
Notonectidae* (Backswimmers)	3				
Pleidae* (Pygmy backswimmers)	4				
Veliidae/M...veliidae* (Ripple bugs)	5		A		A
MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)					
Corydalidae (Fishflies & Dobsonflies)	8				
Sialidae (Alderflies)	6				
TRICHOPTERA (Caddisflies)					
Dipseudopsidae	10				
Ecnomidae	8				
Hydropsychidae 1 sp	4	A	1		A
Hydropsychidae 2 sp	6				
Hydropsychidae > 2 sp	12				
Philopotamidae	10				
Polycentropodidae	12				
Psychomyiidae/Xiphocentronidae	8				
Cased caddis:					
Barbarochthonidae SWC	13				
Calamoceratidae ST	11				
Glossosomatidae SWC	11				
Hydroptilidae	6				
Hydrosalpingidae SWC	15				
Lepidostomatidae	10				
Leptoceridae	6				
Petrothrincidae SWC	11				
Pisuliidae	10				
Sericostomatidae SWC	13				
COLEOPTERA (Beetles)					
Dytiscidae/Noteridae* (Diving beetles)	5				
Elmidae/Dryopidae* (Riffle beetles)	8				
Gyrinidae* (Whirligig beetles)	5				
Haliplidae* (Crawling water beetles)	5				
Helodidae (Marsh beetles)	12				
Hydraenidae* (Minute moss beetles)	8				
Hydrophilidae* (Water scavenger beetles)	5				
Limnichidae (Marsh-Loving Beetles)	10				
Psephenidae (Water Pennies)	10				

Taxon	QV	S	Veg	GSM	TOT
DIPTERA (Flies)					
Athericidae (Snipe flies)	10				
Blepharoceridae (Mountain midges)	15				
Ceratopogonidae (Biting midges)	5				
Chironomidae (Midges)	2			1	1
Culicidae* (Mosquitoes)	1				
Dixidae* (Dixid midge)	10				
Empididae (Dance flies)	6				
Ephydridae (Shore flies)	3				
Muscidae (House flies, Stable flies)	1				
Psychodidae (Moth flies)	1				
Simuliidae (Blackflies)	5				
Syrphidae* (Rat tailed maggots)	1				
Tabanidae (Horse flies)	5			1	1
Tipulidae (Crane flies)	5				
GASTROPODA (Snails)					
Ancylidae (Limpets)	6				
Bulininae*	3				
Hydrobiidae*	3				
Lymnaeidae* (Pond snails)	3				
Physidae* (Pouch snails)	3				
Planorbinae* (Orb snails)	3		1		1
Thiaridae* (=Melanidae)	3	B		A	B
Viviparidae* ST	5				
PELECYPODA (Bivalvles)					
Corbiculidae (Clams)	5				
Sphaeriidae (Pill clams)	3				
Unionidae (Perly mussels)	6				
SASS Score		8	27	17	50
No. of Taxa		3	6	4	11
ASPT		2.7	4.5	4.3	4.5

Other biota:
Gravel, stones and boulders in riffles completely covered by filamentous algae. Hydropsychidae included *Amphisyche scottae.*

Comments/Observations:
IHAS (McMillan, 1998) score was 60%. Using Lowveld Lower Biological Bands (Dallas, 2007), the Ecological Category for the site is Seriously Modified.

Procedure:
Kick SIC & bedrock for 2 mins, max. 5 mins. Kick SOOC & bedrock for 1 min. Sweep marginal vegetation (IC & OOC) for 2m total and aquatic veg $1m^2$. Stir & sweep gravel, sand, mud for 1 min total. * = airbreathers
Hand picking & visual observation for 1 min - record in biotope where found (by circling estimated abundance on score sheet). Score for 15 mins/biotope but stop if no new taxa seen after 5 mins.
Estimate abundances: 1 = 1, A = 2-10, B = 10-100, C = 100-1000, D = >1000 S = Stone, rock & solid objects; Veg = All vegetation; GSM = Gravel, sand, mud SWC = South Western Cape, T = Tropical, ST = Sub-tropical
Rate each biotope sampled: 1=very poor (i.e. limited diversity), 5=highly suitable (i.e. wide diversity) Rate turbidity: V low, Low, Medium, High, Very High
Rate flows: Zero, trickle, low, medium, high, flood Rate colour: transparent, tea brown, light brown, dark brown, light green, dark green, yellow, red, grey, milky white, black

Flow
Zero
Trickle
Low
Medium
High
Flood

ANNEXURE E	**TIME PERIOD:** 9:00 to 14:00	**GPS:**	**LOCALITY:**	**COMMENTS:**
DATE: 9/11/2010		25deg 11.082'S	Sabie River at International Border	Two River Goby's *Glossogobius*
Electrofishing (mins): 45	**Gill Netting (Habitat and mins):** 180	32deg 01.870'E	with Mozambique immediately up-	*callidus* caught in SASS5 VEG sample.
Shallow,Fast: √ Riffles with sig-	In in-stream shallow and slow-flowing pool.	Altitude 112m	stream of the Corumana Dam.	
nificant alluvial deposits.				Four Smallscale Yellowfish, Barbus polylepis
			Bedrock anastomosing channel-type.	collected, electrofishing. Not listed below.
Shallow, Slow: √ Riffles with sig-				
nificant alluvial deposits.				
			Fyke Netting (Habitat and mins)	
	Cast Netting (Habitat and no. of times):		5 Fyke Nets set.	
Deep, Fast: No sampling.	Total of 21 casts.		Riffles and polls with slow-flowing water	
Crocodiles and Hippopotami.	Alluvial, slow-flowing pools.			
	Main channel.		Set at 12:00 on 9/11/2010 and lifted at 9:00 on	
			10/11/2010.	
Deep, Slow: No sampling.			21 hours.	
Crocodiles and Hippopotami.				

NAME	**LATIN NAME**	**PAGE**	**HABITAT**	**Number / CPUE**			
(* ** * migratory)**				EF	GN	FN	CN
BULLDOG**	*Marcusenius macrolepidotus*	98	Well-vegetated, muddy, botomed and marginal, rivers, floodplains				
CHURCHILL*	*Petrocephalus catostoma*	99	Quiet reaches, rivers and floodplains				
LONGFIN EEL***	*Anguilla mossambica*	105	Pool or river stretch				
AFRICAN MOTTLED EEL ***	*Anguilla bengalensis labiata*	107	Pool or river stretch				
MADAGASCAR MOTTLED EEL ***	*Anguilla marmorata*	108	Deep rocky pools, nocturnal				
RIVER SARDINE	*Mesobola brevianalis*	119	Well-aerated, open river water, attracted to ligh at night				
BARRED MINNOW	*Opsaridium zambezense*	120	Clear, flowing water, pools below rocky rapids				
BROADSTRIPED BARB	*Barbus annectens*	136	Slow-flowing streams with vegetation				
LONGBEARD BARB	*Barbus unitaeniatus*	141	Wide variety, flowing and standing waters, dams and lakes				
BOWSTRIPE BARB	*Barbus vivparus*	143	Vegetated poolsof streams, rivers, lake edges				
EASTCOAST BARB *	*Barbus toppini*	146	Shallow, well-vegetated streams and pans				
BEIRA BARB	*Barbus radiatus*	148	Mrashes, marginal vegetation, streams, rivers and lakes, nocturnal				
THREESPOT BARB *	*Barbus trimaculatus*	150	Wide variety, hardy, especially vegetation				
STRAIGHTFIN BARB	*Barbus paludinosus*	160	Hardy, quiet, well-vegetated waters, lakes, swamps, marshes, rivers				
HAMILTON'S BARB	*Barbus afrohamiltoni*	162	Placid waters, pans, large pools				
REDNOSE LABEO ***	*Labeo rosae*	181	Sandy areas, large ivers				
SILVER LABEO ***	*Labeo ruddi*	182	Quiet, deep, muddy standing waters				
PURPLE LABEO ***	*Labeo congoro*	183	Strong-flowing, rocky reaches of large, perennial rivers				
REDEYE LABEO ***	*Labeo cylindricus*	184	Clear, flowing water, pools below rocky rapids				
LEADEN LABEO ***	*Labeo molybdinus*	185	Deep pools				
CARP	*Cyprinus carpio*	188	Wide variety, hardy, large water bodies, slow-flowing, standing				
IMBERI **	*Brycinus imberi*	201	Wide variety, rivers, floodplain pans, lagoons				
SILVER ROBBER **	*Micralestes acutidens*	203	Clear, flowing or standing open water				
TIGERFISH ***	*Hydrocynus vittatus*	206	Warm, well-oxygenated water, large rivers and lakes, surface	27 (6d)	1	2	18 (7d)
COMMON MOUNTAIN CATFISH	*Amphilius uranoscopus*	223	Clear, flowing water, rocky				
SILVER CATFISH	*Schilbe intermedius*	225	Standing or slow-flowing open water, vegetation, nocturnal				
SHARPTOOTH CATFISH	*Clarias gariepinus*	229	Any, favours floodplains, large sluggish rivers, lakes, dams	1			
BLUNTTOOTH CATFISH	*Clarias ngamensis*	230	Vegetated, swamps and riverine floodplains				
SAWFIN SUCKERMOUTH **	*Chiloglanis neumanni*	245	Rocky riffles and rapids, sometimes low-flow rocky pools				
LOWVELD SUCKERMOUTH	*Chiloglanis swierstrai*	247	Sandy stretches of flowing rivers, burrows into sand				
BROWN SQUEAKER	*Synodontis zambezensis*	249	Pools and slow-flowing reches, nocturnal				
JOHNSON'S TOPMINNOW	*Aplocheilichthys johnstoni*	274	Well-vegetated, very shallow, standing, gently-flowing, backwaters				
SOUTHERN MOUTHBROODER	*Pseudocrenilabrus philander*	296	Wide variety, usually vegetated				
ORANGE-FRINGED LARGE-MOUTH	*Chetia brevis*	297	Pools or standing water, dams				
BANDED TILAPIA	*Tilapia sparrmanii*	320	Wide variety, prefers, quiet, standing water, vegetation	8		2	3
REDBREAST TILAPIA	*Tilapia rendalli*	323	Quiet, well-vegetated, littorals, backwaters, floodplains, swamps	2			5
MOZAMBIQUE TILAPIA	*Oreochromis mossambicus*	325	Thrives in standing waters, wide temperature, salinity tolerances				
TANK GOBY	*Glossogobius giuris*	365	Quiet, sandy zones streams, backwaters, floodplain pans				

ANNEXURE F	**TIME PERIOD:** 6:30 to 9:30 and	**GPS:**	**LOCALITY:**	**COMMENTS:**			
DATE: 17/11 and 11/12/2010	11:15 to 12:00	25deg 12.207'S	Downstream site in Sabie River.	Conditions very unfavourable on			
Electrofishing (mins): 45	**Gill Netting (Habitat and mins):** 120 mins	32deg 08.642'E	SAB002.	17/11. Heavy rainfall and cold.			
Shallow,Fast: √Riffle across the	Across main channel.		Bridge over river and significantly				
main channel.			impacted area. Water abstraction and washing.	Conditions favourable on 11/12. Sunny			
				and warm.			
Shallow, Slow: √Bedrock area,				20 River Goby's, *Glossogobius*			
alluvial area across main channel,				*callidus* collected electrofishing.			
riffle.			**Fyke Netting (Habitat and mins)**				
	Cast Netting (Habitat and no. of times):		In littoral zone around main channel.	Also collected one *Macrobrachium lepidactylus*			
Deep, Fast: None.	10 casts.		150 mins.	female.			
	Combination of slow to medium-flowing water over						
	boulders and alluvial sediments.			Also collected *Caradina nilotica.*			
Deep, Slow: Alluvial areas in							
litttoral zone.							
NAME	**LATIN NAME**	**PAGE**	**HABITAT**	**Number / CPUE**			
(* ** * migratory)**				EF	GN	FN	CN
BULLDOG**	*Marcusenius macrolepidotus*	98	Well-vegetated, muddy, botomed and marginal, rivers, floodplains				
CHURCHILL*	*Petrocephalus catostoma*	99	Quiet reaches, rivers and floodplains				
LONGFIN EEL***	*Anguilla mossambica*	105	Pool or river stretch				
AFRICAN MOTTLED EEL ***	*Anguilla bengalensis labiata*	107	Pool or river stretch				
MADAGASCAR MOTTLED EEL ***	*Anguilla marmorata*	108	Deep rocky pools, nocturnal				
RIVER SARDINE	*Mesobola brevianalis*	119	Well-aerated, open river water, attracted to ligh at night				
BARRED MINNOW	*Opsaridium zambezense*	120	Clear, flowing water, pools below rocky rapids				
BROADSTRIPED BARB	*Barbus annectens*	136	Slow-flowing streams with vegetation				
LONGBEARD BARB	*Barbus unitaeniatus*	141	Wide variety, flowing and standing waters, dams and lakes				
BOWSTRIPE BARB	*Barbus vivparus*	143	Vegetated poolsof streams, rivers, lake edges				
EASTCOAST BARB *	*Barbus toppini*	146	Shallow, well-vegetated streams and pans				
BEIRA BARB	*Barbus radiatus*	148	Mrashes, marginal vegetation, streams, rivers and lakes, nocturnal				
THREESPOT BARB *	*Barbus trimaculatus*	150	Wide variety, hardy, especially vegetation				
STRAIGHTFIN BARB	*Barbus paludinosus*	160	Hardy, quiet, well-vegetated waters, lakes, swamps, marshes, rivers				
HAMILTON'S BARB	*Barbus afrohamiltoni*	162	Placid waters, pans, large pools				
REDNOSE LABEO ***	*Labeo rosae*	181	Sandy areas, large ivers				
SILVER LABEO ***	*Labeo ruddi*	182	Quiet, deep, muddy standing waters				
PURPLE LABEO ***	*Labeo congoro*	183	Strong-flowing, rocky reaches of large, perennial rivers				
REDEYE LABEO ***	*Labeo cylindricus*	184	Clear, flowing water, pools below rocky rapids	1			1 (d)
LEADEN LABEO ***	*Labeo molybdinus*	185	Deep pools				
CARP	*Cyprinus carpio*	188	Wide variety, hardy, large water bodies, slow-flowing, standing				
IMBERI **	*Brycinus imberi*	201	Wide variety, rivers, floodplain pans, lagoons				
SILVER ROBBER **	*Micralestes acutidens*	203	Clear, flowing or standing open water				
TIGERFISH ***	*Hydrocynus vittatus*	206	Warm, well-oxygenated water, large rivers and lakes, surface	3			
COMMON MOUNTAIN CATFISH	*Amphilius uranoscopus*	223	Clear, flowing water, rocky				
SILVER CATFISH	*Schilbe intermedius*	225	Standing or slow-flowing open water, vegetation, nocturnal				
SHARPTOOTH CATFISH	*Clarias gariepinus*	229	Any, favours floodplains, large sluggish rivers, lakes, dams				
BLUNTTOOTH CATFISH	*Clarias ngamensis*	230	Vegetated, swamps and riverine floodplains				
SAWFIN SUCKERMOUTH **	*Chiloglanis neumanni*	245	Rocky riffles and rapids, sometimes low-flow rocky pools				
LOWVELD SUCKERMOUTH	*Chiloglanis swierstrai*	247	Sandy stretches of flowing rivers, burrows into sand				
BROWN SQUEAKER	*Synodontis zambezensis*	249	Pools and slow-flowing reches, nocturnal	3 (1d)			
JOHNSON'S TOPMINNOW	*Aplocheilichthys johnstoni*	274	Well-vegetated, very shallow, standing, gently-flowing, backwaters				
SOUTHERN MOUTHBROODER	*Pseudocrenilabrus philander*	296	Wide variety, usually vegetated				
ORANGE-FRINGED LARGE-MOUTH	*Chetia brevis*	297	Pools or standing water, dams				
BANDED TILAPIA	*Tilapia sparrmanii*	320	Wide variety, prefers, quiet, standing water, vegetation	3			
REDBREAST TILAPIA	*Tilapia rendalli*	323	Quiet, well-vegetated, littorals, backwaters, floodplains, swamps				
MOZAMBIQUE TILAPIA	*Oreochromis mossambicus*	325	Thrives in standing waters, wide temperature, salinity tolerances	1			
TANK GOBY	*Glossogobius giuris*	365	Quiet, sandy zones streams, backwaters, floodplain pans				

ANNEXURE G		Sabie River Sites SAB001 and SAB002								
Species		Habitat P/S	Food P/S	Flow R	HUWQ Association	Intolerance Rating	IR (Kleynhans, 1999)	F of occurrence	F affected fish	
	Mormyridae									
BULLDOG**	*Marcusenius macrolepidotus*	3	1	1	3	2	2.5	5(0)		
CHURCHILL*	*Petrocephalus catostoma*	1	1	1	3	1.5		5(0)		
	Anguillidae									
LONGFIN EEL***	*Anguilla mossambica*	3	3	5	3	3.5	3	3(0)		
AFRICAN MOTTLED EEL ***	*Anguilla bengalensis labiata*	3	3	5	3	3.5	3	3(0)		
MADAGASCAR MOTTLED EEL ***	*Anguilla marmorata*	3	3	5	3	3.5		3(0)		
	Cyprinidae									
RIVER SARDINE	*Mesobola brevianalis*	3	5	5	3	4	3.5	5(0)		
BARRED MINNOW	*Opsaridium zambezense (peringueyi)*	5	3	5	5	4.5	4.5	5(0)		
BROADSTRIPED BARB	*Barbus annectens*	3	1	1	1	1.5		5(0)		
LONGBEARD BARB	*Barbus unitaeniatus*	1	1	1	3	1.5	2	5(0)		
BOWSTRIPE BARB	*Barbus vivparus*	3	3	3	3	3	3	5(0)		
EASTCOAST BARB *	*Barbus toppini*	3	3	3	3	3		5(0)		
BEIRA BARB	*Barbus radiatus*	1	1	1	1	1		5(0)		
THREESPOT BARB *	*Barbus trimaculatus*	1	3	3	1	2	2	5(0)		
STRAIGHTFIN BARB	*Barbus paludinosus*	3	1	1	1	1.5		5(0)		
HAMILTON'S BARB	*Barbus afrohamiltoni*	3	3	1	3	2.5		5(0)		
SMALLSCALE YELLOWFISH	*Barbus polylepis*	1	3	3	3	2.5	2.5	5(3)	5(5)	
REDNOSE LABEO ***	*Labeo rosae*	3	3	3	3	3		5(3)	5(1)	
SILVER LABEO ***	*Labeo ruddi*	3	1	3	3	2.5		5(0)		
PURPLE LABEO ***	*Labeo congoro*	3	5	3	4	3.75		5(0)		
REDEYE LABEO ***	*Labeo cylindricus*	3	5	3	4	3.75	3.5	5(0)		
LEADEN LABEO ***	*Labeo molybdinus*	3	5	3	5	4	3.5	5(0)		
CARP	*Cyprinus carpio*	3	1	3	1	2		5(0)		
	Characidae									
IMBERI **	*Brycinus imberi*	3	1	3	3	2.5		5(0)		
SILVER ROBBER **	*Micralestes acutidens*	3	3	3	3	3		5(0)		
TIGERFISH ***	*Hydrocynus vittatus*	3	3	3	5	3.5		5(5)	5(1)	
	Amphilidae							5(0)		
COMMON MOUNTAIN CATFISH	*Amphilius uranoscopus*	3	5	3	5	4	5	5(0)		
	Schilbeidae									
SILVER CATFISH	*Schilbe intermedius*	3	1	3	3	2.5		5(0)		
	Clariidae									
SHARPTOOTH CATFISH	*Clarias gariepinus*	1	1	1	3	1.5	1.5	5(3)	5(5)	
BLUNTTOOTH CATFISH	*Clarias ngamensis*	3	3	3	3	3		5(0)		
	Mochokidae									
SAWFIN SUCKERMOUTH **	*Chiloglanis paratus*	3	1	3	3	2.5		5(0)		
	Chiloglanis pretoriae	3	5	5	5	4.5	5	5(0)		
LOWVELD SUCKERMOUTH	*Chiloglanis swierstrai*	3	3	3	3	3		5(0)		
BROWN SQUEAKER	*Synodontis zambezensis*	3	3	1	5	3		5(3)	5(1)	
	Cyprinodontidae									
JOHNSON'S TOPMINNOW	*Aplocheilichthys johnstoni*	3	3	3	3	3		5(3)	5(5)	
	Cichlidae									
SOUTHERN MOUTHBROODER	*Pseudocrenilabrus philander*	1	1	1	3	1.5	1	5(0)		
ORANGE-FRINGED LARGE-MOUTH	*Chetia brevis*	3	1	1	3	2		5(0)		
BANDED TILAPIA	*Tilapia sparrmanii*	1	1	1	1	1	1	5(5)	5(5)	
REDBREAST TILAPIA	*Tilapia rendalli*	1	1	1	1	1	1	5(3)	5(5)	
MOZAMBIQUE TILAPIA	*Oreochromis mossambicus*	1	1	1	1	1	1	5(3)	5(5)	
	Gobiidae									
RIVER GOBY	*Glossogobius callidus*	3	5	1	3	3		5(5)	5(5)	
TANK GOBY	*Glossogobius giuris*	3	3	1	3	2.5		5(0)		
	Species richness							42(10)		
KEY:	**Number of sites sampled**							2		
Sp. in red - Incomplete	**∑IT Exp**					22.5				
information.	**∑IT Obs**					22.5				
P/S - Preference/Specialization	**∑F Exp**							50		
R - Rate	**∑F Obs**							36		
HUWQ - Habitat, Unmodified,	**∑H Exp**								50	
Water, Quality.	**∑H Obs**								38	
IR - Intolerance Rating	**FAII Score (%), combined sites**									**74**
F - Frequency.	**Integrity class rating, combined sites**									**C**
5(0) - 5 expected, (0) observed	**FAII Score (%), SAB001**									**87**
	Integrity class rating, SAB001									**B**
	FAII Score (%), SAB002									**60**
	Integrity class rating, SAB002									**C**

APPENDIX 6

Findings of Public Consultation.

- Emerging Issues and Concerns

Detailed report on Issues and Concerns emerging from the Public Consultation Process can be found in Volume 2 Socioeconomic context (Social Impact Assessment) report for the Corumana Dam Project (Austral COWI, 2011). Report to National Directorate of Water Mozambique). Major issues emerging from the Consultation process is outlined below

1. Community Issues

During the consultation process, representatives from the local communities voiced concerns about the completion works at the Corumana Dam related to religion, social stability and economic gain.

A common concern voiced by communities and traditional leaders was that family cemeteries located within/close to the households would have to be removed if the household would be inundated due to the raising of the full supply level of the dam reservoir. Moving cemeteries and thus awakening the spirits of ancestors is considered a dangerous task that leads to social anxiety and might undermine the success of resettlement. It was suggested that rituals for spiritual cleansing and ancestors approval take place before and after removing the cemeteries.

Communities and leaders were also concerned about the labour force for the construction works. On one hand they all stressed that the use of local workers should be prioritized in order to curb unemployment and stimulate the local economy. On the other hand it is also feared that the sudden presence of large numbers of outsider construction workers-mostly male and single- would disrupt the social order and stability in local families, with dispute over local women and may increase the level of infection by HIV-AIDS amongst the local residents.

Regarding the working force it is also feared that the construction works would pay better than local agriculture wages thus taking over most of the available labour force and leaving the other economic sectors without workers. This could lead to shortages of food and labour conflict because there is a risk that local workers would no longer accept the local wages after completion of the construction works on the Dam. It was suggested that the Civil Works Contractor and local farmers reach a common agreement on wages and labour force needed.

Chavane and Jone community members expressed the fear that the resettlement will exacerbate the land tenure conflict with South African investors. It is a common belief that there is little land with good soil close to the available water at Corumana because South African investors are bying it. They fear that the selection of the resettlement area will favour the interests of these investors and that the local population will get bad quality land located far away from the reservoir which they fear can put their food security (agriculture and livestock) at risk.

Farmers in Sabíe have also expressed frustration over the fact that their agricultural activities lack water despite having a reservoir close by. This is due to the prohibition of installing water pumps.

The Fishing Community Council expects to derive positive benefits from the completion works because the increased water level and reservoir capacity will lead to increased fish stocks and space for more fishing boats. The fishermen pointed out that, prior to flooding, the areas to be inundated should be cleared of trees to reduce damage on fishing boats and gear due to inundated trees.

Ligongolo and Ndindiza community members fear that the rise of water level may result in increased incidences of attacks by crocodiles along the shores of the reservoir as the animals would be able to come closer to the villages.

Chavane community leaders also suggested to move the power line located close to the Reservoir.

Host communities have been involved in the identification of land for resettlement of neighbouring communities. Negative impacts regarding the hosting of displaced families from neighbouring communities are not foreseen.

2. Economic Stakeholder Issues

Economic stakeholders (both affected and interested parties) look forward to the increased water supply from the Corumana reservoir because of the increasing demand for water by commercial agriculture (particularly banana and sugar cane cultivation). However they are concerned about:

- The interruption of water supply during construction works; and

- The channelling of increased water supply to Maputo City implying little or no gain for commercial farmers. They would prefer that Corumana reservoir is left for commercial agriculture purposes only, while Maputo City water demand should be met by another Dam. Alternatively water for Maputo City should be taken at the confluence area, rather that directly at the Dam.

The Sabie Game Park was concerned with the damage caused by the raising of the full supply level of the Dam on their infrastructure and investments in communication and transportation. They fear not being fully compensated for the damages and might put investment plans on hold (while waiting for confirmation of the new water levels).

The Sabie Game Park expressed the concern over the resettlement of Magonela community. This community was already settled in 2002 following the creation of the Game Park and it is feared that a second resettlement might be stressful and cause further damage to these households. The Game Park also fears an increase in poaching as it is believed that local fishermen bring poachers to the Park via the Dam reservoir and with the increase in water level poachers would have the opportunity to go further into the Park.

Kruger National Park conveyed that they would be grateful if the following concerns could be investigated (Consultation Data Sheet submitted November 2010):

- A survey on how far the water will push up into the Sabíe River when the Corumana Dam is full;

- Model the expected sediment deposition patterns in the Sabíe River – also upstream from the full supply mark;

- Ecological impact of inundation and sediment deposition;

- Changes in Biodiversity and dynamics as a result of inundation and sedimentation;

- Describe the loss of geomorphological features and quantify the loss in terms of uniqueness of such features;

- Water quality at the inlet of the dam and outlet of the dam;

- Chemical quality in/of the sediments at the inlet, dam wall and outlet; and

- The socio-economic benefit that Mozambique will derive from additional yield of water.

Kruger National Park was particularly interested in the model results regarding the approximate extent of backwater effect and increased sedimentation into Kruger National Park as a result of raising the full supply level of the reservoir, in order for them to assess any need for relocation of habitats for endangered species such as breeding places for crocodiles in the Park.

Economic stakeholders also stressed the need to asphalt the current dirt road between Sabíe and Moamba villages and improve the maintenance of dirt roads linking communities around the Dam in order to maximize the benefit of the increased water supply. They have also called for the expansion of electricity to all the communities around the reservoir.

Electricidade de Moçambique pointed out that the Komatipoort Power Line is located close to the Dam reservoir and that if it would be affected by the raising water level and alternative technical solution is required.

The Cofamosa Sugar Cane Project mentioned a land tenure conflict between itself and a South African investor, involving 10,000 ha around the reservoir in the Jone area. They believe that if the increase in water supply is channelled to Maputo City rather than to local commercial agriculture it may exacerbate land and water tenure conflicts at Corumana.

3. Government Stakeholder Issues

The DWA raised the following issues regarding effects on Kruger National Park

- Will there be a study to show the flooding area in the Sabíe River when the Dam is finished;

- What model is envisaged for sediment deposition standards in the Sabíe River; and

- What are the socio-economic benefits for Mozambique from the new water yield.

District Government and National Water Directorate representatives have stressed the need to involve traditional community leaders in the EIA and SIA process to ensure a smooth construction process. Completion works "owned" by affected and interested communities and inclusive solutions established for and by the affected parties. In particular, communities and their traditional leaders should identify resettlement areas on which government is to decide upon.

The Moamba District and Sabíe Post Administrations hold high expectations on the Dams capacity to improve the living conditions for the local population, in terms of water supply, electricity and communication. They argue that the completion works should bring infrastructure development to Sabíe-Sede. The works should not only include water supply but also improving and expending of the health system, schools, electricity and communication services.