WATER RESEARCH COMMISSION

GEOGRAPHIC INFORMATION SYSTEMS (GIS) AND THE INTEGRATED ENVIRONMENTAL MANAGEMENT (IEM) PROCEDURE IN THE PLANNING AND MANAGEMENT OF WATER RESOURCES

TASK 3: SABIE RIVER AND LETABA RIVER THEORETICAL FRAMEWORK

USERS MANUAL

W.F. VAN RIET, J.D. J VAN RENSBURG, R. DREYER, S. SLABBERT

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ABSTRACT

The development of an environmental database for use in the GIS is essential to the environmental planning of catchment basins.

The GIS is essential to the development of various land-use scenarios for the past, present and the future.

Research illustrated three major hydrological changes causing ecological impacts, i.e. monthly flow rates, flood peaks and sediment interception.

KEYWORDS

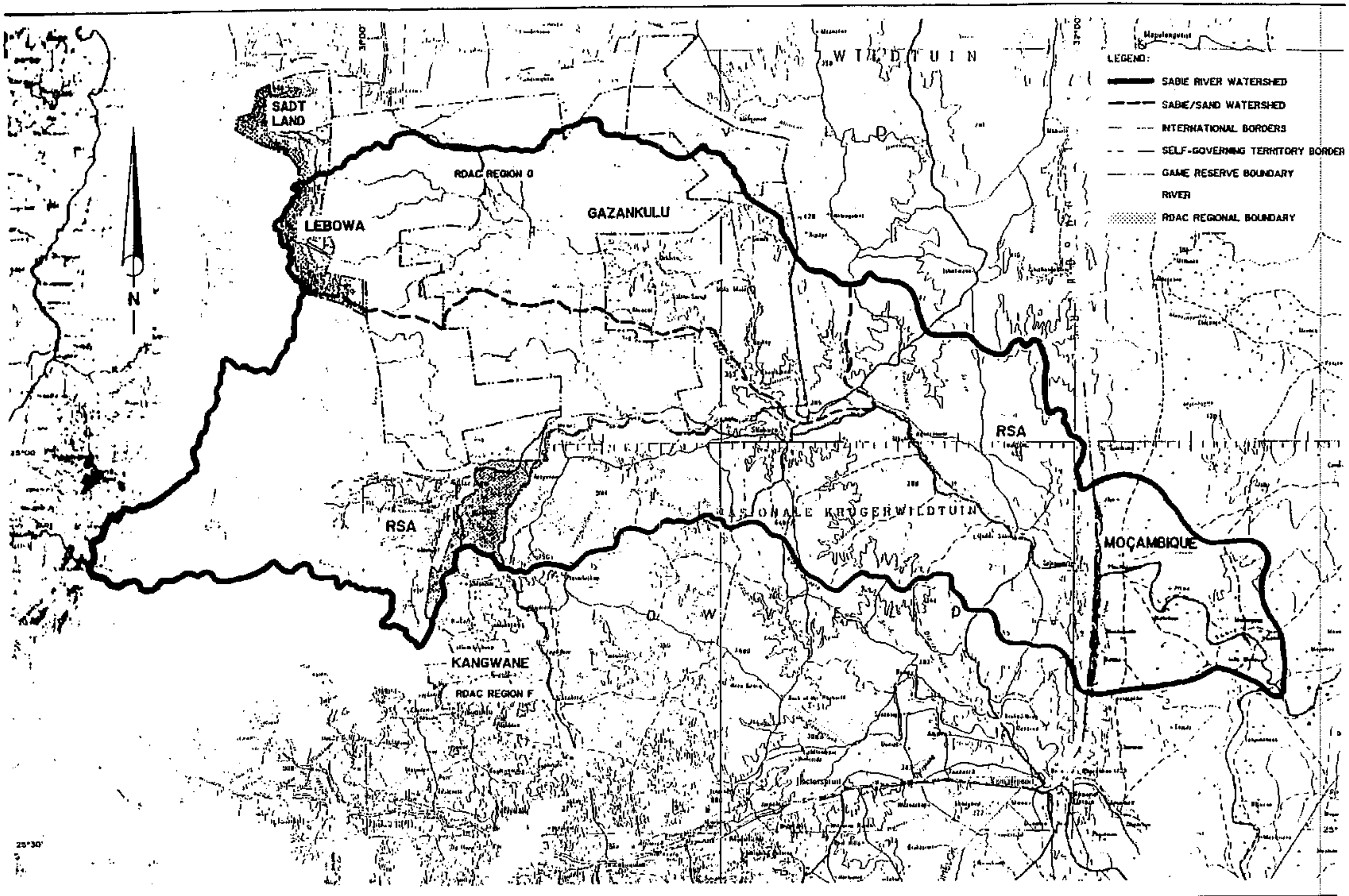
Catchment basins, water development projects, environmental impacts, hydrological modeling, geographic information systems, landscape architecture.

ACKNOWLEDGEMENTS

The authors would like to thank the Water Research Commission, the Department of Water Affairs and Forestry and the National Parks Board for their assistance during the execution of the project.

SABIE RIVER CATCHMENT BASIN

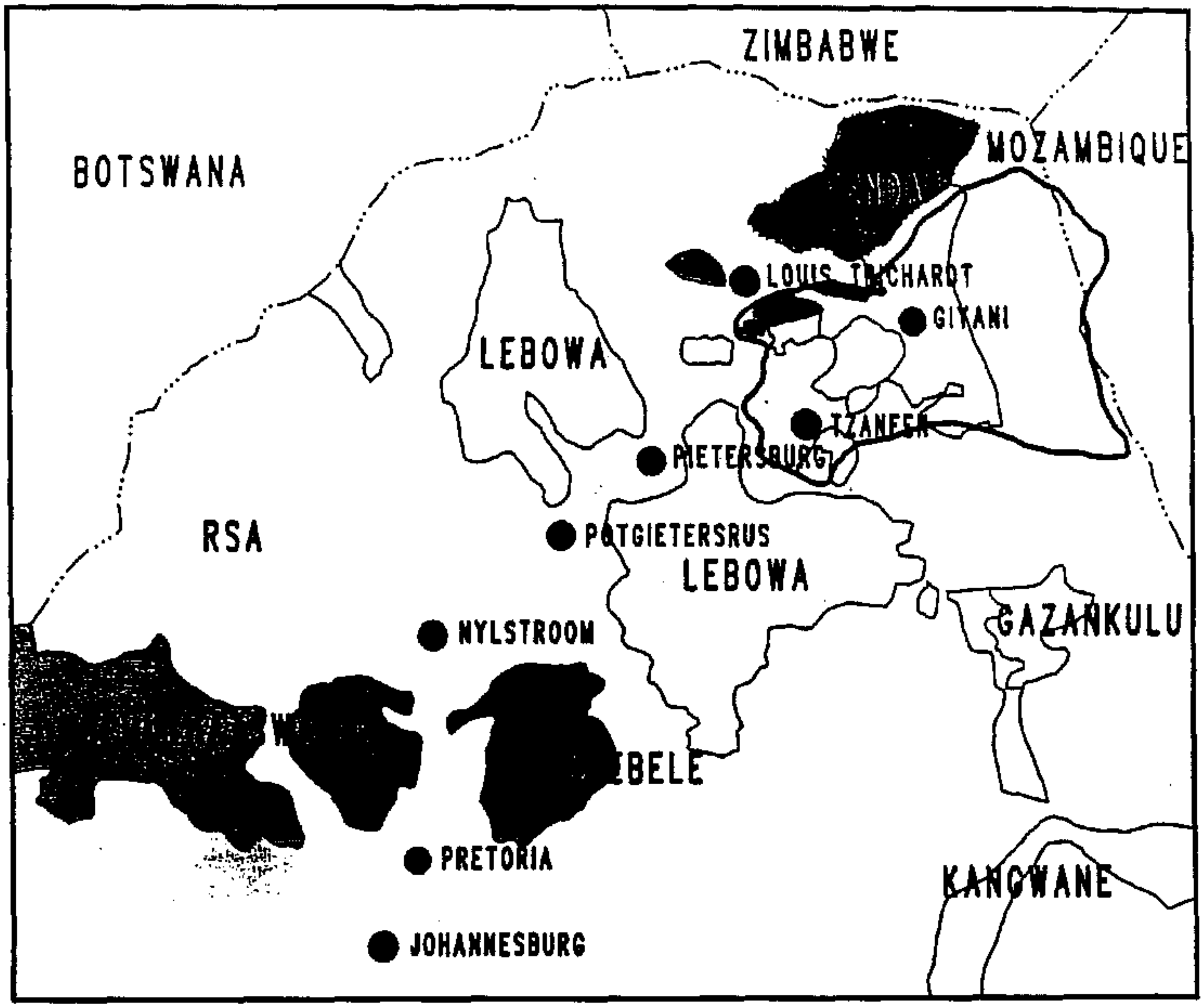
FIGURE 1



LEGEND:
SABIE RIVER WATERSHED
SABIE/SAND WATERSHED
INTERNATIONAL BORDERS
SELF-GOVERNING TERRITORY BORDER
GAME RESERVE BOUNDARY
RIVER
RDAC REGIONAL BOUNDARY
SADT LAND
LEBOWA
RDAC REGION G
GAZANKULU
RSA
NASIONALE KRUGERWILDTUIN
MOÇAMBIQUE
KANGWANE
RDAC REGION F
N

LETABA RIVER CATCHMENT BASIN

FIGURE 2


ZIMBABWE
BOTSWANA
MOZAMBIQUE
LEBOWA
GIYANI
PIETERSBURG
RSA
POTGIETERSRUS
LEBOWA
GAZANKULU
NYLSTROOM
PRETORIA
JOHANNESBURG
KANGWANE

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INTRODUCTION

When this project was initiated 4 years ago it was originally envisaged that its main aim would be the linking and integration of the IEM procedure with GIS technology to determine management procedures that would deal with the impact on the environment resulting from change in the catchment basin.

As primary focus we selected the Sabie River as a case study to implement these procedures. At the time the Kruger Park Research Programme was in its first phase of development. A whole range of individual research projects were initiated and directed by specialists in their fields of expertise from all over the country.

During the next 3 years these projects developed individually towards its own goals and objectives. But at the same time the need was felt for a more lateral and integrated approach coordinating these research projects towards a common goal.

To achieve this Prof. Charles Breen was appointed to conduct an overview of all existing projects and programmes and to propose a second phase for the Kruger Parks Rivers research programme. The first phase of this programme was completed at the end of 1993. The resulting report proposed a revised and refocused programme incorporating four main subprogrammes under a common approach with similar philosophy and goals.

Prof. Willem van Riet was appointed to the Steering Committee and assisted in the development of these proposals. As part of this Steering Committee he became aware of the similarity in the approach of this research project and that of the second phase of the Kruger Park Rivers research programme. This study was therefore adjusted to function in accordance with the guidelines proposed for the four main subprogrammes of the Kruger Park Rivers research programme. These four subprogrammes are as follows:

Decision support system

The decision support system is the major component of this project and deals with the integration of the IEM procedure of the Department of Environment Affairs and the ROIP procedure of the Department of Water Affairs and Forestry. As these two procedures are the most widely accepted DSS in South Africa today a new adapted IEM procedure for use in catchment basins was developed by this research programme.

Information systems development and management

As one of the goals of the programme was the development and integration of a GIS technology with the IEM procedure it was obvious that the whole process of information management was of crucial importance. In this programme we combined the question of information management and technology transfer into one chapter for theoretical investigation. The development of this component of this research project became one of the major achievements attained during the past 4 years. Much energy was spent on developing a GIS laboratory, understanding GIS software and integrating this technology in the development of an ecological database for use in the decision support programme.

The achievements and growth in the GIS laboratory at the Department of Landscape Architecture at the University of Pretoria contributed greatly to the success of this project.

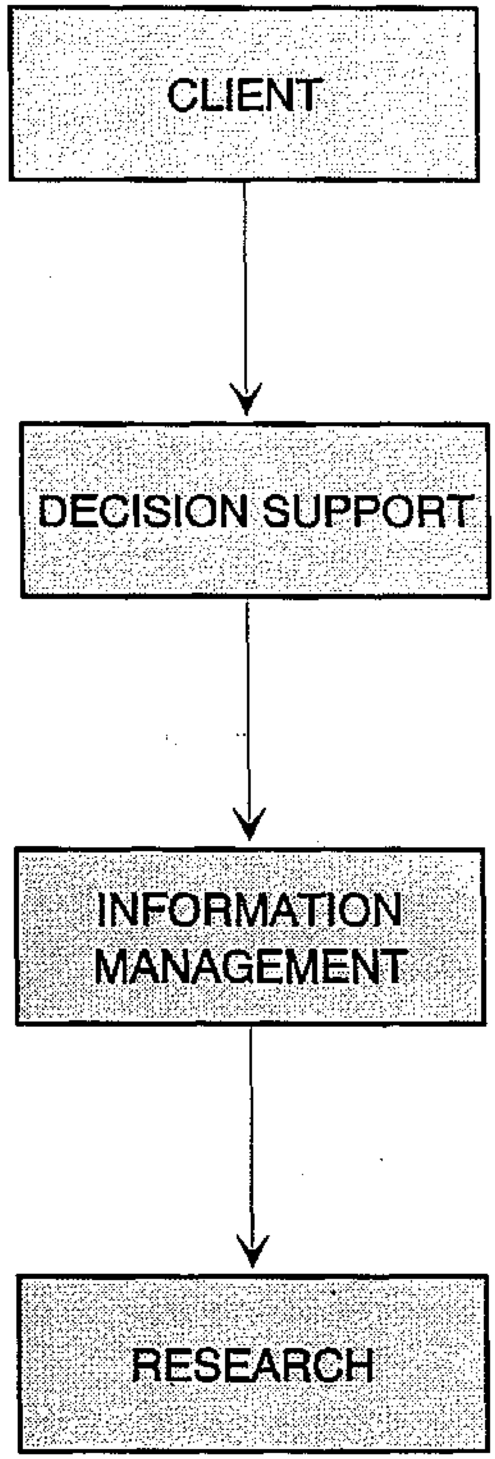
Research development and management

As research is basic to the success of the DSS this part of the Kruger Park Rivers research programme is very important. We did not conduct new research but we were fortunate to be able to use the research produced by the other programmes as well as catchment basin studies conducted by the Department of Water Affairs and Forestry for the rivers of the Kruger National Park.

It is important to view the results of this study in the light of the goals and objectives set for the second phase of the Kruger Park Rivers research programme. Many of the problems resulting from the integration of a DSS with information management and technology transfer were encountered during this study. Some of these were handled with success and others can contribute to the success of the Kruger Park programme in the future.

TABLE ONE

FRAMEWORK



CHAPTER 1 - DECISION SUPPORT SYSTEM

In order to manage for change it is important to understand and to define overall goals and objectives for such management actions. To obtain such direction we have looked at the management goals for natural environment as described by the Natural Union for Conservation of Nature. Conservation is defined as:

> *The management of human use of the biosphere so that it may yield the greatest sustained benefit to present generations while maintaining its potential to meet the needs and aspirations of future generations.*

From the above, three primary objectives have been derived.

- To maintain essential ecological processes and life support systems.
- To preserve genetic diversity.
- To ensure the sustainable utilisation of species and ecosystems.

Recent publication of the updated version of the Integrated Environmental Management (IEM) procedure by the Department of Environment Affairs and parallel development of the Relevant Environmental Impact Prognosis (ROIP) as part of the IEM by the Department of Water Affairs and Forestry necessitated the need for the combination of these two approaches into one integrated approach. Such integration is attempted in this report.

The study was completed using the IEM approach but with impact evaluation in accordance with the ROIP and RIMP procedures.

For the purposes of completeness, the two procedures are summarised as follows.

The Integrated Environmental Management Procedure (IEM)

The IEM procedure was originally developed by the Council for the Environment as a guideline to aid correct decision making with regard to the effect of project proposals on the environment. The procedure has been in use for a number of years. Dr Richard Fuggle of the Environmental Evaluation Unit at the University of Cape Town recently proposed a revised set of guidelines for the Department of Environment Affairs.

The most important difference between the two versions is the reduction of the original four stages to three. Stages one and two were combined into a single stage termed Stage 1: Plan and Assess Proposal. Stages 2 and 3 remained unchanged, namely: Decision and Implementation respectively.

The suggested method of study following the IEM procedure is as follows.

- **STAGE ONE: PLAN AND ASSESS PROPOSAL**

  Step One: Develop Proposal
  The proposed Interbasin transfer scheme.

  Step Two: Classification Of Proposal
  1. Discussion of relevant activities
  2. Discussion of relevant environments
  3. Impact identification
  4. Impact evaluation

  Step Three: Initial Assessment
  Initial assessment

- **STAGE TWO: DECISION**

  Step Four: Review

  Step Five: Conditions Of Approval

  Step Six: Record Of Decision

  Step Seven: Appeal

- **STAGE THREE: IMPLEMENTATION**

  Step Eight: Implementation

  Step Nine: Monitoring

  Step Ten: Auditing

The Relevant Environmental Impact Prognosis (ROIP) and The Relevant Impact Mitigation Prognosis (RIMP)

The ROIP procedure was developed and is currently used by the Subdirectorate Environmental Studies of the Department of Water Affairs and Forestry. The procedure was developed in conjunction with the IEM guidelines and can therefore be readily integrated therewith. The ROIP consists of four steps, namely:

Step One:	Introduction
Step Two:	Locality
Step Three:	Project Description
Step Four:	Description And Evaluation Of Environmental Impacts

It is clear from discussions with the Subdirectorate Environmental Studies that the ROIP procedure is compatible with the IEM procedure. It is suggested that the ROIP procedure is a formalisation of the Step Two in the IEM procedure: Classification, in as much as it formalises the method of impact identification and evaluation.

The main component in the ROIP evaluation procedure is a series of tables in which each impact is formally identified and evaluated according to the following four criteria:

SRCE:	Source of Data
DCD:	Data confidence degree
ISD:	Impact severity degree
SCD:	Severity confidence degree

The effect of mitigation on the impact assessment is dealt with during the Relevant Impact Mitigation Prognosis (RIMP) procedure. This procedure, also developed by the Sub-directorate Environmental Studies of the Department of Water Affairs and Forestry, addresses the suitability and efficacy of the mitigation measure and the severity of the impact after mitigation.

During recent studies completed on the transfer of water to the Mhlatuze River the consultants combined the ROIP and RIMP procedure and introduced the following list of assessments.

SRCE:	Number to identify the source of data from the reference list
DCD:	Data Confidence Degree, from 0 indicating no data available or that conclusions may be unreliable to 4 indicating sufficient data adequately verified
ISD:	Impact Severity Degree, from 0 indicating negligible impact to 4 indicating highly significant impact
SCD:	Severity Confidence Degree, from 0 for no confidence in the assessed severity (ISD) to 4 indicating full confidence.
MDC:	Mitigation Data Confidence, from 0 indicating no confidence in the appropriateness of mitigation to 4 indicating full confidence that the mitigation measure is the best available.

MID: Mitigation Impact Degree after applying mitigatory measures, from 0 indicating negligible to 4 indicating highly significant impact.

MCD: Mitigation Confidence Degree after mitigation, from 0 for no confidence to 4 indicating full confidence in the assessed severity of the impact after mitigation (MID).

These two procedures are combined into one adapted IEM procedure and is proposed and discussed in depth in the next section.

PROPOSED ADAPTED IEM PROCEDURE

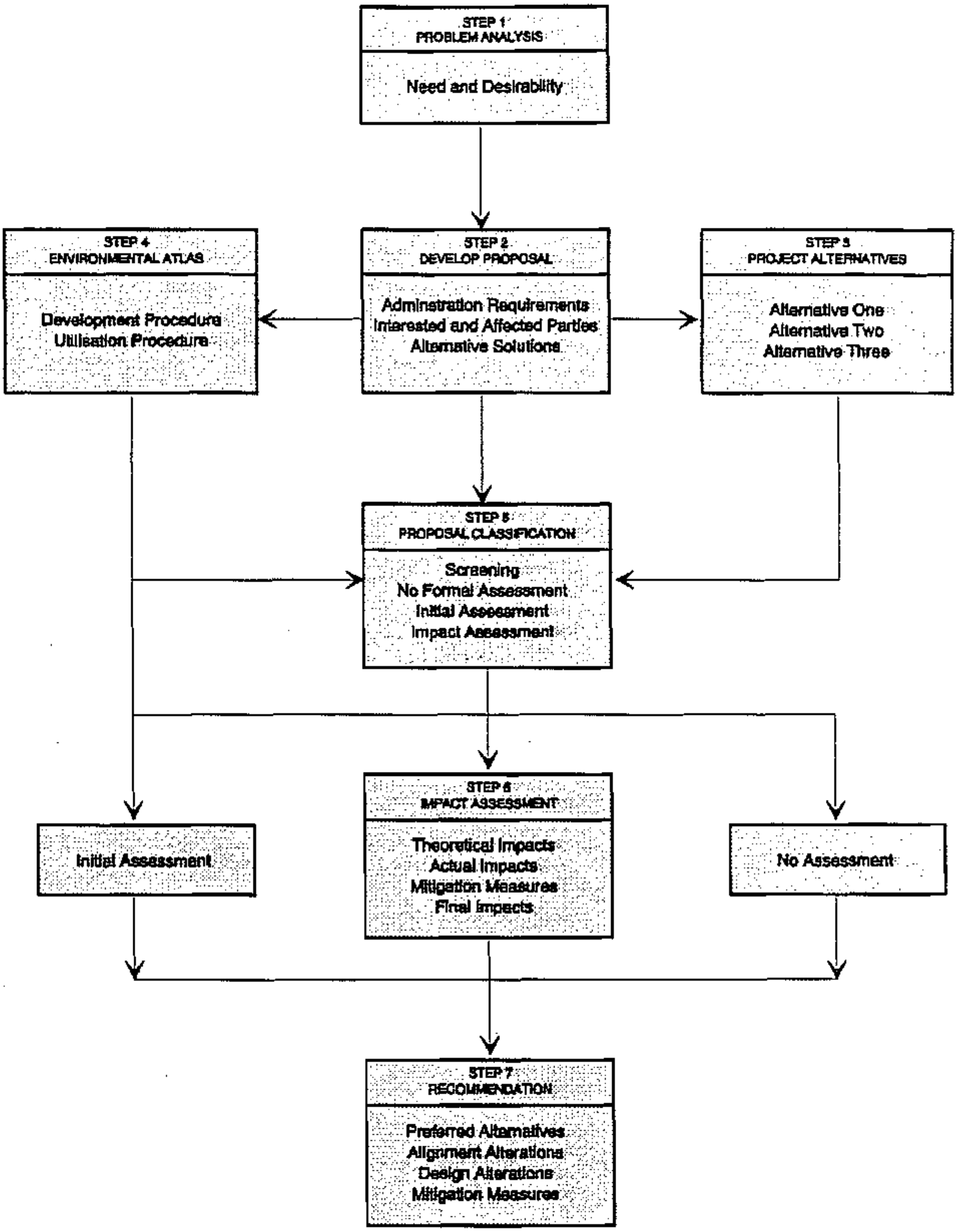
INTRODUCTION

The aim of this study is to relate the role of GIS (Geographic information systems) to the management of water related systems such as the planning of catchment basins. For this to be successful, a GIS is related to the IEM (Integrated Environmental Management) procedure and through the use of an ecological planning model (Van Riet, 1987) and an hydrological model (Schulze, 1989a, 1989b), and Pitman (1973) the environmental impact on daily flow rates and proposed mitigation measures for the catchment basin of a possible new dam, is determined.

The method of presentation will deviate from the normal in that the presentation will follow a series of steps in a flow diagram illustrating the IEM procedure. These steps will be based on the use of a GIS system (ARC/INFO™) and the various procedures required during the use of GIS in the planning of catchments. The procedure and the effect of each procedure resulting from the use of attribute tables or the various graphic information sets is illustrated on the computer screen.

The total process is linked by a program called ARCVIEW™ written for the purpose of ease of use by other researchers or project managers and can be run on both personal computer and workstation hardware.

DECISION SUPPORT PROCEDURE



INTEGRATED ENVIRONMENTAL MANAGEMENT PROCEDURE

The integrated environmental management procedure as adapted for use in this research project consists of the following broad groups of actions.

Step One	-	Problem Analysis
Step Two	-	Development Proposal
Step Three	-	Project Alternatives
Step Four	-	Environmental Atlas
Step Five	-	Proposal Classification
Step Six	-	Recommendation

The following steps illustrate the actions associated with the various steps in the proposed Integrated Environmental Management procedure:

STEP ONE - PROBLEM ANALYSIS

We consider the question of understanding the need and desirability of the proposed water related project of such importance that the discussion and analysis of the problem is taken out of the normal IEM procedure and discussed separately.

The increase in population densities, changing forms of land-use and the resulting growth in the demand for water will cause an increase in demand placed on the water resources of Southern Africa. These changes in land-use in catchment basins create negative ecological impacts in the downstream reaches of these rivers.

To counter the increased pressure on water resources, water development projects are designed and constructed. These development projects also result in environmental impacts in downstream reaches.

The changing forms of land-use can however also affect the success of water development projects proposed for these catchments.

The above is clearly illustrated by the conditions of the rivers of the Kruger National Park (KNP) which have been dramatically altered by large scale changes in land-use in the catchment basins.

The problems normally associated with changes in catcmment basins can result from the following.

- Increasing population numbers and densities
- Changes and intensification in land-use
- Over utilization of water resources
- Negative environmental impact in down stream reaches

STEP TWO - DEVELOP PROPOSAL

The most important elements in Step Two are as follows:

- Establish administrative requirements
- Notify interested and affected parties
- Develop alternative solutions

These are important elements on which clarity must be reached before the actual alternative solutions to the previously determined problem can be developed.

The administrative requirements would cover both policy, legal and administrative requirements necessary for implementing any of the alternative proposals.

The importance of notifying interested and affected parties at this stage is critical as this would introduce the involvement of the public at an early stage. This public involvement will continue through to the screening and scoping aspects of Step 5 termed the Proposal Classification as well as various aspects of the formal review.

The development of alternative solutions to the problem is important as one of the most successful ways of dealing with environmental impacts is to look at a series of alternatives at the start of project development and design. Alternative sites or alignments are the most successful ways of reducing environmental impact. It is only after this option has been exhausted that mitigation measures should be called upon for assistance.

STEP THREE - PROJECT ALTERNATIVES

The normal reaction from planners and engineers is to call for and design water development structures. These structures normally include the following:

Water utilisation structures

Dam wall
Transfer pumps and pipeline
Receiving weir
Irrigation canals

Management procedures

Flow regulation
Flood retention
Sediment interception

Development of potential dam sites on the Sabie River

A detailed study was conducted by Chunnett, Fourie and Partners for the Department of Water Affairs and Forestry in the "Sabie River Catcmment study of development potential and management of the water resources: Volume 9 Appendix 2" report.

The factors affecting dam site selection as well as other considerations are discussed. It was from these findings that three proposed dam sites were chosen for further study through GIS.

The Injaka, Madras and Dingleydale dams were studied in further detail and an ecological impact assessment was carried out on each dam. The Injaka dam is discussed in detail in the SML document (Project 2: GIS and Hydrologic Modeling).

The Madras and Dingleydale dams are discussed further here. The broad description of dam sites is taken from the Chunnett, Fourie reports and the ecological impact assessment is done through GIS. Detailed construction information can be obtained from the Sabie River Report Volume 9.

The database should be consulted to see detailed catchment descriptions e.g. mean annual runoff and sediment yield figures have been calculated per subcatchment and expressed in volumes and percentage that each catchment produces.

Madras Dam

The Madras dam site is situated on the Sabie river between Gazankulu and Kangwane about 10km east of Hazyview. The total catchment area at the dam site is about 1539km².

The full supply level (FSL) of the largest dam investigated was taken to be at reduced level (RL) 472,0m.a.s.l., which will result in a gross storage capacity of approximately 256mm³ or approximately 57% of the MAR.

The design flood and probable maximum flood (PMF) for a catchment area of 1 539km² would be 7 400 m³/s.

The maximum expected reservoir volume losses due to siltation would be 12,0mm³ and 18,6mm³ after 20 years and 50 years respectively if no new dams are constructed upstream of the site, and 9,5mm³ and 17,0mm³ respectively if Injaka dam is constructed.

A dam with a gross storage capacity of 256mm³ and a FSL at 472m.a.s.l. will inundate a total of about 1 391ha (taken at non-overspill crest level (NOCL)), of which about 62ha consists of irrigated orchards and 105ha consists of cultivated land. A dam of this size will also inundate a portion of the main road to Paul Kruger gate in the Kruger National Park, a significant number of homesteads in Gazankulu, a holiday resort on the Sabie river as well as a few homesteads and a large number of holiday erven in the RSA.

Value Impact

For this study the dam is divided into the catchment area, dam area, and the lower basin. (immediate catchment to the downstream reach of the dam).

The database shows ecological, economic and social impacts on each region. These values have been determined previously for the broad catchment area (Refer to Task 1, Task 4 and the digital database).

The methods of value determination are also discussed.

The impacts for each area can be viewed through ARCVIEW™. (See PROJECTS.AV in digital database).

Dingleydale Dam

The Dingleydale dam site is situated on the Nwandlamuhari river in Lebowa about 7km east of the Hazyview/Acornhoek road. The total catchment area at the dam site is about 248km².

The full supply level (FSL) of the largest dam investigated was taken to be at reduced level (RL) 545,1m.a.s.l., which will result in a gross storage capacity of approximately 62,5mm³ or approximately 118% of the MAR.

The design flood and probable maximum flood (PMF) for a catchment area of 248km² would be 2 400m³/s respectively.

The maximum expected reservoir volume losses due to siltation would be 2,4mm³ and 3,7mm³ after 20 years and 50 years respectively if no new dams are constructed upstream of the site.

A dam with a gross storage capacity of 62,5mm³ and a FSL at 545,1m.a.s.l. will inundate a total of 875ha (taken at non-verspill crest level (NOCL)), which presently consists of about 65ha of cultivated lands and 190ha of irrigated orchards. A dam at this site will also inundate some portions of the existing secondary road network in Lebowa.

Value Impact

For this study the dam is divided into the catchment area, dam area, and the lower basin. (immediate catchment to the downstream reach of the dam).

The database shows ecological, economic and social impacts on each region. These values have been determined previously for the broad catchment area (Refer to Task 1, Task 4 and the digital database).

The methods of value determination are also discussed.

The impacts for each area can be viewed through ARCVIEW™.

Development of potential dam sites on the Letaba River

A detailed study was conducted by SRK and published for the Water Research Commission in the "Letaba River Basin Study of Development Potential Management of the Water Resources: Annexure 18" report.

The factors affecting dam site selection as well as other considerations are discussed. It was from the findings of this report that two proposed dam sites were chosen for further study through GIS.

The Crystalfontein and Ka-Muhlaba dams were studied in further detail and an ecological impact assessment was carried out on each dam. Broad information is available on all other potential dam sites. (See Appendix A and detailed construction information can be obtained from the SRK Letaba River report Annexure 18).

Ka-Muhlaba Dam

Broad descriptions of the dam site are taken from the SRK report, impacts are however calculated through the GIS study. The database should be consulted for detailed catchment descriptions. Mean annual runoff and sediment yields have been calculated to volumes and percentages for each subcatchment.

The Ka-Muhlaba dam site is located on the Letsitele River.

The catchment area is approximately 240 km^2. The Letsitele river rises in RSA then flows through the Ritavi 2 district of Gazankulu.

MAP over the catchment varies from over 1000 mm in the headwater area to about 800 mm at the dam site.

The Symons Pan evaporation over the catchment varies from under 1400 mm at the headwaters to about 1450 mm at the dam site.

The Mean Annual Runoff (MAR) is estimated to be 55 million m^3.

The upper reaches of the catchment area have a natural cover of North Eastern Mountain Sourveld vegetation. Approximately 3800 ha of this portion of the catchment have been afforested. Further down the river, the natural vegetation type is Lowveld Sour Bushveld. Some land along the Letsitele river valley is under intensive dry land arable farming. Other land is used for grazing and about 1900 ha of land is under irrigation.

The estimated maximum average sediment yield for the Letsitele catchment is 360 tons/km^2/year. Therefore, a total sediment load of 4 million tonnes can be expected to be deposited in the dam, assuming 100% trap efficiency, over a 45 year projected economic life of the dam.

The Mean Annual Runoff (MAR) of the catchment varies according to the quantity and type of development in the catchment in addition to the catchment characteristics. For this investigation a MAR of 46.0 * $10^6 m^3/a$ has been used.

Flood hydrology as determined by the SANCOLD Flood Guidelines recommend the following minimum values for design and safety evaluation floods for a high dam with a high hazard rating:

Recommended Design Flood (RDF) = 200 yrs
Safety Evaluation Flood (SEF) = 1,7 x RMF
or 1.1 x PMF

Where:

RMF = Regional Maximum Flood
PMF = Probable Maximum Flood

<u>Environmental impact assessment</u>

For the assessment of environmental impacts on each dam site, a separate dataset was developed. This may be viewed through ARCVIEW™ by selecting the PROJECT.AV file. The following is a summary of what the database shows visually.

<u>Inundation</u>

This is the direct physical impact the dam will have when most of the basin comprises grazing and dry land cultivation. Two settlements, Petaneng and Dan, located in the vicinity of the dam will also be affected. In the vicinity of the right abutment, approximately half of the village of Petaneng will have to be relocated.

The village of Dan is located upstream of the dam site. The south-western end of the village located on the left bank of the reservoir will be affected and will require relocation.

In addition, the R36 from Tzaneen to Lydenburg and the 11kVa line between Dan and Leyenye will have to be re-routed. (See Atlas database for more information: ARC/VIEW)

Value impact

(See database and views: ARCVIEW™)

For this study the dam is divided into the catchment area, dam area, and the lower basin (or immediate catchment to the downstream reach of the dam).

The database shows the ecologic, economic and the social impact on each region. These values have been determined previously for the broad catchment area (refer to main report and database). The methods of value determination are also discussed in the main report.

Because two dam sites are chosen in the same catchment, it was found that the lower reaches of the downstream area are common to both. This is referred to by the Atlas database as "lower basin 2".

The impacts for each area can be viewed through ARCVIEW™.

Crystalfontein Dam

(See database and views: ARCVIEW™)

Broad descriptions of the dam site are taken from the SRK report, impacts are however calculated through the GIS study.

The dam site is located on the Klein Letaba river.

The catchment area is approximately 1085 km². The Klein Letaba river rises in RSA then flows through Venda and Gazankulu.

MAP over the catchment varies from over 1000 mm in the higher south western parts of the catchment, about 500 mm in the west, up to 900 mm in the north and about 600 mm over the eastern portion of the Klein Letaba catchment. MAP at the dam site is about 700 mm.

The Symons Pan evaporation over the catchment varies from about 1500 mm in the west to 1600 mm at the dam site. The upper part of the catchment is relatively undeveloped and the natural vegetation cover is Mountain Sourveld and Lowveld Sour Bushveld. Forestry has been developed in the headwater area and covers about 1100 ha. The lower part of the catchment comprises mixed arable and grazing land in the vicinity of the river valley, surrounded by grazing land further away from the river.

The estimated maximum average sediment yield for the Klein Letaba catchment is 310 tons/km²/year (see Annexure 16) 15 million tons can be expected to be deposited in the dam, assuming 100% trap efficiency, over a 45 year projected economic life of the dam. (See database for more information).

The Mean Annual Runoff (MAR) of the catchment varies according to the quantity and type of development in the catchment in addition to the catchment characteristics.

For this investigation a MAR of 44,0 x $10^6 m^3/a$ has been used.

Flood hydrology as determined by the SANCOLD Flood Guidelines recommend the following minimum values for design and safety evaluation floods for a high dam with a high hazard rating:

Recommended Design Flood (RDF) = 200 yrs
Safety Evaluation Flood (SEF) = 1,5 x RMF
or 1.0 x PMF

Where:

RMF = Regional Maximum Flood
PMF = Probable Maximum Flood

Current land use in the basin is approximately 75% grazing and 25% dry-land arable. Urban development in the villages of Caledon and Wagendrift will be affected for levels above RL520 and RL530 respectively.

The new road being constructed from Middel Letaba dam to Wagendrift village will be inundated and require relocation. This also applies to the southern most Cabora Bassa powerline.

Value impact

For this study the dam is divided into the catchment area, dam area, and the lower basin (or immediate catchment to the downstream reach of the dam).

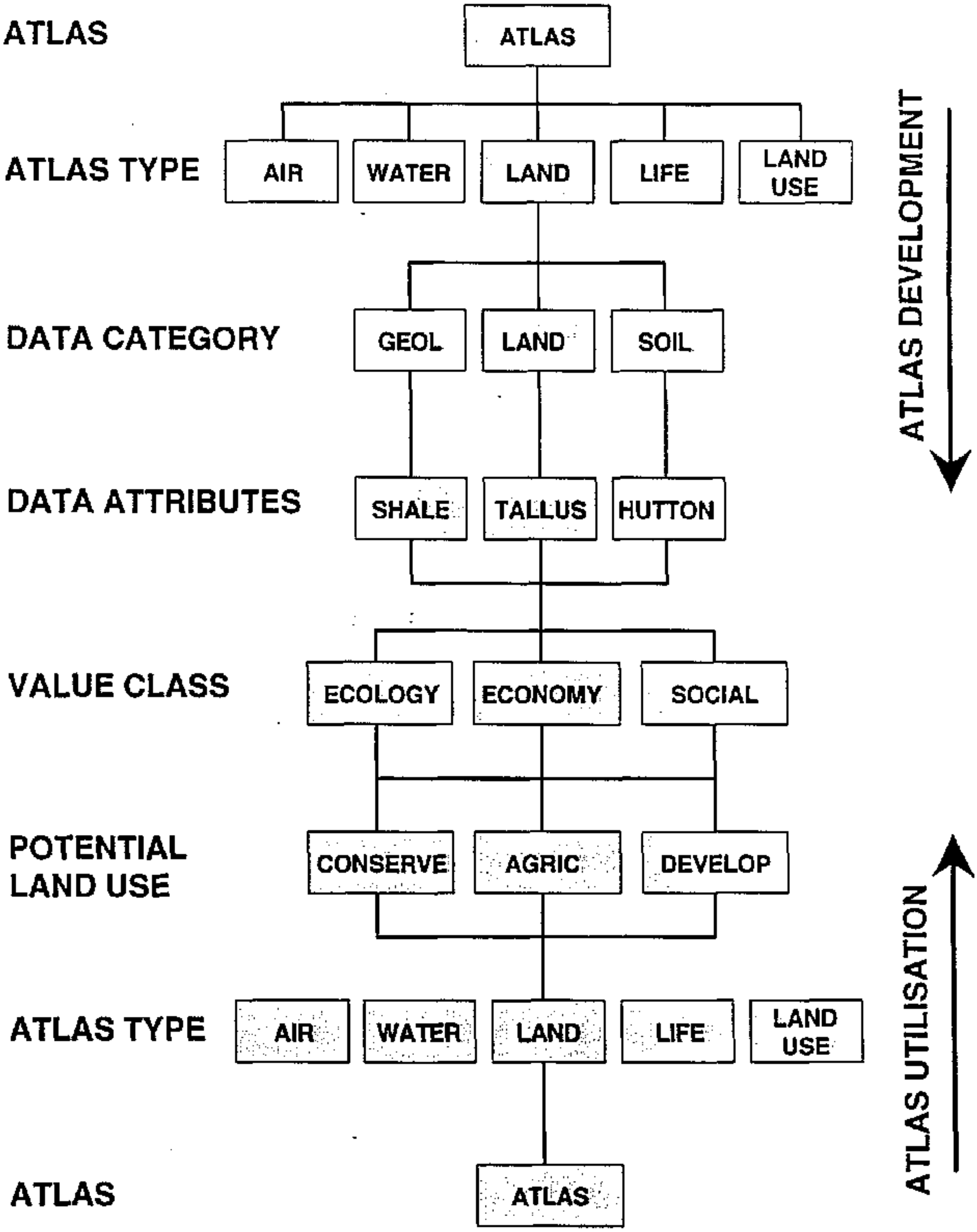
The database shows ecologic, economic and social impacts on each region. These values have been determined previously for the broad catchment area (refer to main report and database). The methods of value determination are also discussed.

The impacts for each area can be viewed through ARCVIEW™.

STEP FOUR - ENVIRONMENTAL ATLAS

Before one can understand environmental impacts it is important to understand the nature of change in the environment. The Kruger Park Rivers research programme has indicated that changes to the natural environment is dependent on an understanding of the dynamics of river systems and the natural and social processes occuring in their catchments. The major contributor to change in hydrologic systems results from two major components.

ATLAS FLOW DIAGRAM



These are climatic change and changes in land-use activities. These two forces affect on the one hand geomorphological processes resulting from changes to flood peaks, daily flow rates as well as sedimentation patterns, and on the other hand these changes in turn affect the biological processes giving rise to changes in life processes, changes in species dynamics and changes in ecosystems processes.

Changes to the geomorphic processes in turn affect the natural environment of the river reaches and in turn the habitat opportunities for the species composition of river reaches.

This step covers the development of the information management system and in this particular case it is a GIS based environmental atlas.

There are two basic phases in the development and implementation of the atlas. Phase one is the development of the procedures for establishing the atlas and phase two is the development of procedures for the implementation and utilisation of the atlas.

An understanding of these procedures is a prerequisite to the successful implementation of the concept since the development procedure forms the basis of the utilisation procedure.

ATLAS Approach

The terminology used is important and will lead to an understanding of the procedural functioning of the atlas. Each heading is related to a sequential step in a process used to develop the atlas and then used in reverse order during utilisation of the atlas.

The development of geographic information systems (GIS) has made the establismment of a digital atlas possible, and a good background understanding of GIS concepts will greatly enhance understanding of the atlas concepts. The advantages of GIS have led to the realisation that an atlas can be both functional and practical. The use of GIS tools such as ARCVIEW™ forms the basis to the approach followed in the development of the atlas procedure.

Atlas Type

The natural environment functions as an integrated whole with the various components contributing to the development of systems termed by ecologists as ecosystems. These systems can function at various levels leading from macro continental systems to micro systems such as small coastal dune systems.

To develop an understanding of these systems and how they function, the systems are normally subdivided and classified under separate headings. The sequence of these subdivisions is important to an understanding of each category since knowledge of each contributes to an understanding of the next category.

The climatic component of the environment and the physical component interact and combine with the biological component to create a framework within which a variety of processes operate at a variety of scales. To assist in understanding these systems the atlas is segmented into the following types:

- **Climatic (Air)**
- **Landscape (Land)**
- **Hydrological (Water)**
- **Biological (Life)**
- **Land use (Use)**

These five headings are used to create a classification system for the environmental data inherent to the establishment of the atlas.

Data Categories

Various categories of information are grouped within each of the above atlas types. These information types are basic to the atlas concepts as they determine the type of data which will be collected and entered into the GIS on which the atlas will be based.

The following data categories are involved:

Atlas type: Air
- Temperature
- Rainfall
- Wind

Atlas type: Land
- Geology
- Topography
- Soils

Atlas type: Water
- Catchments
- Rivers
- Wetlands

Atlas type: Life
- Vegetation
- Wild life

Atlas type: Land use
- Broad land use
- Infrastructure

Category Attributes

Each of the data categories listed above has certain descriptive characteristics or attributes. Geographic features are stored in the computer as polygons (area features such as geology or land use), lines (line features such as roads and rivers) or points (point features such as wells and boreholes). The descriptive or non-geographic data is stored in database files referred to as attribute tables.

The geographic features and their attributes are combined or merged through a GIS overlay procedure to create a landscape facet database. The landscape facet database constitutes the heart of the atlas, containing the necessary geographic and non-geographic information required. Updating of this database is a prerequisite to its successful implementation and will ensure an ever increasing and improving information base.

Attribute Values

The attributes represent characteristics of the environment and as such represent values when examining environmental information. The ecological value of a particular attribute might be that it maintains the functioning of the ecosystem and as such has ecological benefits. Social attribute values may include aesthetic or cultural advantages of certain characteristics. Economic attribute values may point to benefits related to construction cost or the presence of raw materials. The existence of infrastructure is an example of an attribute value which has a bearing on the cost of development.

Attribute values considered for the atlas are listed below:

- Life-supporting processes
- Biological diversity
- Sustainable resources
- Aesthetic features
- Cultural features
- Cost of construction
- Existing facilities

Attributes are evaluated through established database procedures and the results are transferred to the GIS attribute table. Re-evaluation becomes a relatively simple operation and can be performed repeatedly during later stages when larger volumes or higher quality information becomes available. In this manner the value component of the atlas can be updated or upgraded at various stages.

When the various values are grouped it becomes clear that in the list above, the first three values are linked to *ecological values*. The second two are *social values*. The last two are *economic values*. The evaluation of these attributes results in the grouping of values for the following classes.

- Ecological: Life-supporting, biological diversity and sustainable resource values

- Economic: Construction costs and existing facilities values

- Social: Aesthetic and cultural feature values

Land Use

The values of each of the attributes within each of the landscape facets for each value class are now linked to each of the atlas land use types. These values determine the opportunities or constraints within each of the landscape facets for the various land use types.

The following land use type opportunities or constraints are used in the atlas:

•	Conservation	Ecological and social values
•	Agriculture	Economic values
•	Development	Economic values

Atlas Types

The results of developing opportunities and constraints for each land use type are now presented for each for the atlas types such as air, water, land, life and land use.

Atlas

The final linking of the various atlas classes constitute the final atlas. The flow diagram illustrates the various steps discussed above.

This flow diagram is essential to understanding the procedures to be followed during phase two of the atlas, the implementation phase. The final step in the development procedure would become the first step in the implementation procedure when the atlas is utilised. (See Figure 2, page 28)

UTILISATION PROCEDURE

The development procedure allows for two completely different methods of utilisation. Firstly, the atlas can be utilised as a series of printed maps representing opportunities and constraints of the various atlas land use types. Secondly, the atlas can be utilised as a full GIS database accessed through the use of GIS viewing tools such as ARCVIEW™ through which complex queries and analyses can be performed and the impacts of different projects be determined. These two methods are discussed below.

Step one: Opportunities and Constraints Maps

In this instance three separate map sets representing conservation opportunities, development constraints and agricultural constraints respectively, can be made available at any scale, according to requirements. In this format the user would simply identify a parcel of land affected by the project on a standard map and after locating this parcel on the atlas map set, would identify the number of opportunities or constraints for each of the three main land-use types. This method is low key in nature and does not require a computer platform or any knowledge of GIS. It is envisaged that this method of using the atlas could be popular, although the user will be responsible for the cost of printing.

Step two: GIS Viewing method

The second method of using the atlas is more complex but much more powerful and will allow the user access to the GIS database through the use of GIS viewing software such as ARCVIEW™. In this specific method two approaches in the utilisation of the GIS database can be followed.

The first approach will be that the user will extract information pertaining to an identified land parcel in terms of the three atlas land use types and their associated opportunities and constraints.

Through this query procedure the user will be able to extract:

- all the attributes of each of the data categories.

- the number of opportunities or constraints for each atlas type and each of the three atlas land use categories.

- a description of reasons for the allocation of opportunities or constraints for each atlas type and land use category.

In the second approach the user would identify certain requirements in terms of the demand for conservation, agriculture or development, or combinations of these land use types. Through the use of GIS viewing software the user could query the database requesting parcels of land with high opportunities or low constraints for a specific land use. The GIS viewing tool would then search the database and highlight all the parcels of land meeting the required criteria, if any.

For example, the user could query the system to identify parcels of land with few development constraints as well as few conservation opportunities. This would yield land with development potential and low environmental impact, suitable for water resource development.

STEP FIVE - PROPOSAL CLASSIFICATION

This important step in the procedure determines which of the three intensities of impact assessment should be conducted. Three forms of assessment are suggested.

No assessment

This occurs where no formal assessment is necessary as the project does not affect the list of environmental characteristics or is classified under the list of activities.

Initial assessment

This occurs where the project is listed under the previously mentioned tables or whether uncertainty with regard to the severity of impact exists.

Impact assessment

This occurs rarely and will only be conducted if it is certain that significant environmental impacts will result from implementation of one of the proposed alternatives. This would be common to water resources development projects.

STEP SIX - IMPACT ASSESSMENT

It is during this step that the ROIP procedure is integrated into the proposed IEM process. The following four series of investigations are completed. These are:

Scoping

Scoping is undertaken to determine which issues should be investigated during the impact assessment. Scoping can be conducted by reviewing previous studies to determine potential and theoretical impacts.

It can also be undertaken by interaction with the interested and affected parties to determine whether any other issues need to be addressed. Scoping forms an important part of the interaction with the interested and affected parties and contributes to acceptance of results by these parties.

The potential environmental impacts have been determined in studies conducted for the Department of Water Affairs and Forestry such as the transfer scheme for the Mhlatuze river in Natal.

Direct on-site impacts
- Basin inundation
- Reduction of daily flow rates
- Reduction of frequency and extent of flood peaks
- Reduction of sediment yield

Indirect downstream impacts
- Changes to fluvial geomorphology
- Changes in chemical properties
- Changes in physical properties
- Changes to biological components

Environmental Impacts

The ROIP procedure identifies the following actions. Initially the source of data and the degree of confidence is determined. Thereafter the severity of the impact as well as the confidence in this severity decision is determined. Thereafter the mitigation measures as well as the confidence in these measures are determined. The final step in the ROIP procedure is to determine the severity of the impact after mitigation. This evaluation is forwarded to the project alternatives to be dealt with during redesign or forwarded to the next step, recommendations.

STEP SEVEN - RECOMMENDATIONS

The proposal contains an additional step to the adapted IEM procedure and suggest that recommendations resulting from the impact assessment can be dealt with in a variety of formats. These are so different in nature that a separate step is needed to illustrate these measures. These can be dealt with under the following headings.

The preferred alternative

The most obvious result leading from the impact assessment is to select the alternative with the least number of severe impacts.

Alignment alterations

If this is not possible due to loss in capacity of the project then changes to alignments or positions can be included in the planning exercise to reduce the identified severe impacts.

Design alterations

The next suitable measure is to alter the design specifications for the various components of the project resulting in these severe impacts.

Mitigation measures

If none of the above are possible then we would suggest that mitigation measures be applied through management techniques. Correct management techniques could go a long way to reducing the severity of environmental impacts.

Any of the above recommendations could result in a return to Step 3: Project Alternatives and a cyclic series of actions will result until the final report is completed and presented for the review phase.

CHAPTER 2 - INFORMATION MANAGEMENT AND TECHNOLOGY TRANSFER

INFORMATION MANAGEMENT AND TECHNOLOGY TRANSFER

INTRODUCTION AND BACKGROUND

The timeous and efficient execution of this project was largely due to the application of available technology in an appropriate manner in order to arrive at its conclusion. Advancement in information systems technology has gained rapid momentum during the last 5 years, and in particular, advancements in geographic information systems technology (GIS) were most notable. Researchers have been presented with more information processing tools than many can hope to utilise, and this situation is further complicated by the diversity of hardware and software platforms for GIS, insufficient volumes of digital data, duplication of effort in respect of data capture and processing, problems with existing digital data such as scale, resolution and detail level, copyright implications as well as a lack of general direction as to how technology is to be harnessed for effective use. It would seem as if most have been overwhelmed by technological progress and are uncertain as to utilisation of this technology and its application to their own field of research expertise without having to acquire vast amounts of computer expertise as well.

Researchers are further often subjected to the temptation of additional or derived benefits offered through use of computerised information systems, to the extent that it becomes easy to be deviated from original research or other goals simply because technology offers solutions to problems which might not have formed part of the original research proposal or which fall beyond the scope of the researcher's field of expertise. A situation of information management becoming the project goal in itself, or redirecting the entire research project can thus arise, generally with adverse implications. It was of utmost importance, therefore, to keep project goals and objectives clear and in pace with technology. This project has indeed shown that appropriate application of technology and its utilisation for other research is quite feasible.

INFORMATION SYSTEM GOAL (AIM)

The singular goal of the information management system is to provide a digital database on a suitable platform to enable efficient data capture, storage, retrieval, processing, dissemination and analysis in order to meet first of all the needs of researchers for this project in particular, and in the second instance also meet the needs of others such as other research projects, decision makers and interested or affected parties.

INFORMATION SYSTEM OBJECTIVES

The following objectives have been identified for execution of the project in order to attain the project goal:

- System definition
- Determination of information system requirements for the project
- Investigation into available technology and expertise.
- Selection and acquisition of appropriate system.
- Database design and system implementation.
- Data acquisition, capture and conversion.
- Development of database and analysis.
- Evaluation of results and database refinement.
- Ongoing investigation into technology updates.
- Final decision support system, reporting and technology transfer.

INFORMATION SYSTEM TASKS

System definition

A thorough investigation and definition of the proposed system (technology) had to be undertaken before commencement of the project in order to assure its eventual success and efficiency. This included all aspects of technology which comprises the following components:

- Information system tools

  These include all computer hardware such as central processing units, screens, keyboards, storage devices and interfacing, and peripheral equipment such as digitizers and plotters, as well as computer software which comprises the entire range of required software ranging from operating system software through geographic and alphanumeric database software to specialised application software.

- Information system management

  This includes expertise and knowledge of skill as well as the processes and procedures required to operate and manage the system efficiently.

- Data and information

  This is probably the most crucial component and constitutes the real capital investment in the system. Establishment of an appropriately structured and economical database is without doubt the most daunting task facing any project team since it is this aspect of the system which has the greatest potential for causing system inefficiency and/or failure.

- System support and training

  This includes hardware and software support and training, as well as subject matter expertise enhancement, which is a process that continues throughout operation and utilisation of the system.

Determination of information system requirements

Requirements in respect of the information system were initially grouped into the following categories:

- Functionality.

  The functionality of the system includes its ability to effect data capture, storage, retrieval, manipulation and analysis, output and reporting as well as the capability to integrate the human and machine components i.e. computer hardware and software with other system components including expertise, management and system support in order to effect a successful and cost effective system. The bottom line for requirements in respect of functionality was that the system should conform to all defined criteria as per the project goal, and deficiencies could be overcome without unnecessary and costly effort. This project required fairly advanced analytical capability of the system which narrowed the choice both in terms of the human and machine components significantly, and necessitated extensive investigation and evaluation.

  Requirements in respect of functionality did not remain static during the four years of project execution, but evolved through utilisation of the system in accordance with other project components, continually placing a greater burden on existing resources. This was fortunately met with an unprecedented upsurge in advancement in the field of geographic information systems technology. Aspects that were lacking in regard to system capability were addressed through in-house development of software, expertise, techniques, processes and procedures. Special attention was given throughout to the aspect of controlling system-generated project requirements and their impact on the project.

- Affordability

  The information management system had to be affordable in terms of the total project budget, which included a fair proportion of funds allocated to this aspect. Although the cost of technology has shown a real trend downwards since commencement of the project, geographic information systems technology was excessively expensive in 1990 and is generally still considered to be an expensive tool.

  The system also had to affordable in terms of its other components i.e. management, support and data.

- Cost efficiency

  Cost efficiency of the information system is probably the most difficult aspect to determine since it involves not only initial cost and budget figures for system tools, personnel and management, but also has to take into account productivity of the system as well as derived or perceived benefit from its utilisation. Since the latter is largely a matter of opinion, requirements in regard to cost effectiveness were initially limited to aspects such as repeated usage of information for multiple analyses, automating tedious or repetitive tasks, increased speed of operation and rate of research goal achievement, or better data management techniques.

- Ease of operation (user friendliness)

  Technology offered little in terms of easy, user-friendly GIS tools at the time when the project commenced during 1990, and requirements in this regard were proportionally scaled down and positioned at the lower end of the list. Extensive usage and utilisation of GIS technology was limited to a few researchers with an inordinate amount of computer expertise, and this situation was to continue until market pressures started to influence a trend towards more generally accessible systems and a reduced requirement for unnecessary complementary knowledge.

Investigation into available technology and selection of appropriate system

Investigation into available technology had originally started prior to the project proposal stage, as part of a wider system research exercise, and was concluded well before commencement of the project in 1990. The components of the system were investigated and selection made as follows.

- System tools (hardware and software)

  The development of GIS was undergoing rapid advancement and a variety of products became available at the time. The leading products were mostly mainframe and mini-computer based and were subsequently very costly. The choice of ARC/INFO™ GIS software both on UNIX and DOS platforms was largely influenced by the fact that the hardware/software combination offered the best solution to project demands and that major installations had already been effected at organisations such as the Department of Water Affairs and Forestry and Geological Survey. Although the total hardware/software cost was higher than originally budgeted for (approximately R200000), the selection of ARC/INFO™ was deemed the appropriate platform, a choice that has subsequently been proved correct.

- Management and support

  Although appropriate GIS and related expertise was a scarce commodity in 1990, the project was fortunate enough to attract suitable expert knowledge and management skills. The project team consisted of the following five members:
  Project leader
  System manager
  Administrative assistant
  GIS operators (2)
  Completion of the initial database allowed for reduction of some of the full-time project staff to part-time in order to balance the budget to compensate for higher than anticipated expenditure on system hardware and software. Hardware and software support and training was effected both in-house and through maintenance support contracts with vendors.

Database design and system implementation

The design of the geographic and alphanumeric database is based on and implemented as an ARC/INFO™ integrated data model which comprises a spatial database and relational database management system (RDBMS). Design of the individual database elements was implemented with as high a level of uniformity in order to effect the maximum degree of efficiency when utilising the information for analysis.

Implementation of the system consisted of the total spectrum of system components and elements such as hardware/software implementation, appointment and training of personnel as well as implementation of project objectives as system procedures and working protocols. Initial system implementation to the level of an operational information management system took approximately 3 months, which can be considered as a relatively short period of time.

Data acquisition, capture and conversion

Acquisition and capture of data was identified as the most critical project requirement since virtually none of the total number of project activities could proceed without the establismment of the information base. In view of the initial unavailability of required data, the largest proportion thereof was captured in-house. A policy of "insufficient data better than none" was adopted in order to facilitate project momentum, and as the project progressed and contact was established with other research organisations and project leaders, exchange of data became possible.

The greatest challenge in the field of data exchange was to overcome a prevailing unwillingness among organisations and individuals to make their digital data available to others, and contact had to be established along a broad front to effect trust between negotiating parties and to change attitudes from isolationism to co-operation and sharing of data. The variety of implemented systems necessitated conversion of data to and from a variety of required formats, and has contributed towards an extension of possibilities for acquisition and updating databases.

Development of database and analysis

Establishment of sufficient volumes of data captured in the system enabled development of a database structure. The final database is structured as follows:

- Land database

  The land database comprises the following data categories:
  Geology
  Land form
  Landtypes and Soils
  Sediment yields

- Water database

  The water database comprises the following data categories:
  Water courses (rivers)
  Watersheds (catchment boundaries)

- Air database

  The air database comprises the following data categories:
  Rainfall
  Temperature
  Evapo-transpiration

- Land use database

  The land use database comprises the following data categories:
  Broad land use
  Infrastructure such as existing towns, roads, railway lines, etc

- Life database

  The life database comprises the following data categories:
  Vegetation (land cover)
  Wildlife

All of the databases were processed and analysed through a variety of geographic manipulation and analysis techniques such as geographic merges, intersects and reselections to establish a land facet database which forms the core of the information base on which the project depends.

Evaluation of results and database refinement

Evaluation of the database and analysis have been identified as continuous processes that would be executed over the total project duration. Data sets which were established during the initial stages of the project were almost without exception subject to corrections and updating, and these were carried out as new or updated information surfaced or quality control procedures revealed problems or errors. Database refinement in terms of scale of capture was also applied in certain instances as better information became available.

Ongoing investigation into technology updates

Investigation into technological progress and advancement is another project task which was identified as a high priority continuous process of this project. All aspects of the information management system but specifically hardware, software and techniques were continuously reviewed and updated. Rapid changes to hardware and software platforms were experienced during the course of the project duration, none of which were budgeted for in the original project proposal. This project was able, however, to benefit from the infrastructure already established at the data processing facility in that technology updates funded through other projects were implemented without any cost implication to this project. This has illustrated the importance of a sufficient project base for any research institution in order to be able to distribute cost and benefit of technological progress to projects in a balanced manner.

Several updates of hardware and software as well as additional equipment and other application software were acquired or developed during project execution. This includes a broad spectrum of GIS, CAD and engineering application software, the latest technology mini- and micro computer equipment and peripheral equipment such as colour output devices.

Final decision support system, reporting and technology transfer

The project decision support system is embodied in the combination of an 80486 type micro computer platform with user-friendly GIS data viewing and querying software (ARCVIEW™ Release 1.0 from ESRI, California, USA) and the land facet database, together with appropriate data view files and abbreviated project report documentation. This decision support system constitutes the combination of information and expertise, and is probably the first in this field to be provided as project end product.

The decision support system can be transferred in various combinations of its components or in its entirety as an integrated project end product. It is envisaged that the most practical and economical method of transfer of technology from this project to other researchers or potential users is to provide a digital copy of the land facet database and view files together with the abbreviated project report. This includes a detailed database description as well as instructions for installation of the database and utilisation procedures. Users will have to provide their own hardware and software base, and in this manner the other components of technology in this instance i.e. information, expertise, processes and procedures can be transferred successfully.

CHAPTER 3 - ENVIRONMENTAL RESEARCH

Environmental research forms an integral part of the whole programme as it is in this area of research that the data is gathered and captured. The information management and decision support model is dependent on this information. As the Kruger Park Rivers research programme has already been in operation for a number of years most of the research has already been conducted or is in the process of being completed. In the case of our research programme we have not conducted any new research but depend on existing programmes.

The important point with research however is the fact that research is not developed in isolation but is dependent upon the goals and objectives stated in the decision support system model.

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APPENDIX A

POSSIBLE DAM SITES IDENTIFIED BY SRK

IN THE

LETABA RIVER BASIN STUDY

POTENTIAL DAMSITES

SITE NO	SITE NAME	SITE RATE	RIVER	LONG LAT	CATCHM AREA (km2)	REGION MAX FLOOD (m3/s)	MEAN ANNUAL RUNOFF (Hm3)	CAP/MAR (%)	VOLUME STORAGE VOLUME EMBANKM FILL	GEOLOGY				INFRA-STRUCTURE		LIMITATIONS TO SITE		
										FORMATION / COMPLEX	PREDOMINATE WEATHERING MECHANISM	POTENTIAL FOUNDATION PROBLEMS	POTENTIAL CONSTRUCTION MATERIAL PROBLEMS	NEAR ROAD (km)	NEAR POWE (km)	IMPACT ON ENVIRONMENT	DISRUPTION OF FLOW TO DOWNSTREAM USERS	INUNDATION OF SERVICES AND PROPERTY
KL1	Wakkerstroom	7	Klein Letaba	29 59' 23 23'	85	1220	6	300	14	Zbm Banderlierkop	Chemical	Variable depth Active clays Collapsable soil	Sand	1	33	Low to Medium	Domestic	Cahora Bassa po line. Road. Dryland.
KL2	Koedoespoort	7	Klein Letaba	29 58' 23 17'	350	2400	15	300	15	Zg/Zbp Goudplaats Gneiss / Banderlierkop	Chemical / Mechanical	Variable depth Collapsable soil	Sand	1	20	Low to medium	Domestic Irrigation	Road. Secondary rd. Dryland.
KL3	Lastpost	4	Mudelo	29 55' 23 17'	100	1320	3	300	11	Zg/Zbm Goudplaats Gneiss / Banderlierkop	Chemical / Mechanical	Variable depth Collapsable soil	Sand	2	25	High	None	None
KL4	Nieuwland	5	Seoketse	30 09' 23 17'	85	1220	6	300	12	Zg/Zbm Goudplaats Gneiss / Banderlierkop	Chemical / Mechanical	Variable depth Collapsable soil Flow along regio structure	Sand	1	3	Low to Medium	Domestic Irrigation	Road. Cahora Bassa line. Dryland.
KL5	Noblehof	10	Seoketse	30 10' 23 16'	100	1320	6	300	25	Zg/Zbm Goudplaats Gneiss / Banderlierkop	Chemical / Mechanical	Variable depth Collapsable soil Flow along regio structure	Sand	3	2	Low to Medium	Domestic Irrigation	Dryland. Secondary rd.
KL6	Bushy Park	10	Klein Letaba	30 10' 23 13'	500	2850	24	300	20	Zg/Zbm Goudplaats Gneiss / Banderlierkop	Chemical / Mechanical	Variable depth Collapsable soil Deep Alluvium		2	12	Medium to low	Domestic Irrigation	Secondary rd. Other roads Dryland.
KL7	Bellevue	12	Klein Letaba	30 13' 23 14'	730	3420	34	300	18	Zg Goudplaats Gneiss	Chemical / Mechanical	Variable depth Collapsable soil Deep Alluvium		3	15	Medium to low	Domestic Irrigation	Other roads Dryland.
KL8	Piesang Fontein	10	Klein Letaba	30 18' 23 14'	750	3470	37	270	16	Zg/Zbm Goudplaats Gneiss / Banderlierkop	Chemical / Mechanical	Variable depth Collapsable soil Deep Alluvium Flow // regln st	Rock	1	12	Low	Domestic Irrigation	Secondary rd. Dryland. Huts Building
KL9	Klein Letaba (Wagendrift)	13	Klein Letaba	30 19' 23 14'	930	3850	40	250	26	Zg/Vsh Goudplaats Gneiss / Schist	Chemical / Mechanical	Variable depth Collapsable soil Deep Alluvium		1	5	Low	Domestic Irrigation	Cahora Bassa line. Houses Dryland.

POTENTIAL DAMSITES

SITE NO	SITE NAME	SITE RATE	RIVER	LONG / LAT	CATCHM AREA (km2)	REGION MAX FLOOD (m3/s)	MEAN ANNUAL RUNOFF (Mm3)	CAP/MAR (%)	VOLUME STORAGE VOLUME EMBANKM FILL	GEOLOGY: FORMATION / COMPLEX	GEOLOGY: PREDOMINATE WEATHERING MECHANISM	GEOLOGY: POTENTIAL FOUNDATION PROBLEMS	GEOLOGY: POTENTIAL CONSTRUCTION MATERIAL PROBLEMS	INFRA-STRUCTURE: NEAR ROAD (km)	INFRA-STRUCTURE: NEAR POWE (km)	LIMITATIONS TO SITE: IMPACT ON ENVIRONMENT	LIMITATIONS TO SITE: DISRUPTION OF FLOW TO DOWNSTREAM USERS	LIMITATIONS TO SITE: INUNDATION OF SERVICES AND PROPERTY
KL10	Middelplaats	9	Tshilaluke	30 22' 23 13'	105	1350	3	300	29	Zg Goudplaats Gneiss	Chemical / Mechanical	Variable depth Collapsable soil Deep Alluvium	Impervious Rock	1	6	Low	None	Dryland.
KL11	Crystal-fontein	20	Klein Letaba	30 26' 23 14'	1085	4140	44	230	142	Vss Schiel	Chemical / Mechanical	Variable depth Collapsable soil Deep Alluvium		1	5	Low	Domestic Irrigation	Cahora Bassa line. Dryland. Secondary rd.
KL12	Ma-Mabidi	17	Klein Letaba	30 29' 23 15'	2940	6680	58	170	80	Zg/Zbu Goudplaats Gneiss / Banderlierkop	Chemical / Mechanical	Variable depth Collapsable soil Deep Alluvium	Impervious Rock	2	7	Low	Domestic Irrigation	Dryland. Other roads Major canal
KL13	Kamapuva	14	Klein Letaba	30 33' 23 18'	3115	6870	62	160	80	Zg Goudplaats Gneiss	Chemical / Mechanical	Variable depth Collapsable soil Deep Alluvium	Impervious Rock	2	7	Low	Domestic Irrigation	Dryland. Secondary rd. Major canal Mine
KL14	Basani	4	Trib. Klein Letaba	30 31' 23 19'	45	900	1	300	14	Zyn Giyani group	Mechanical	Permeability Schistbands Flow along regio structure	Sand Shallow soil	1	2	High	None	Other roads Dryland.
KL15	Tshivhulana	4	Nsama	30 39' 23 12'	160	1650	2.5	400	6	Zyn Giyani Group	Chemical/ Mechanical	Schist zones Permeability Variable depth	Shallow soil	1	3	High	Domestic	None
KL16	Ka-Mavalani	3	Nsama	30 44' 23 14'	240	2000	3.5	300	8	Zg Goudplaats Gneiss	Chemical/ Mechanical	Variable depth Permeability	Impervious shallow soil	2	8	Low to Medium	Domestic	Houses Secondary road
KL17	Musukhomu	2	Khambana	30 46' 23 13'	55	990	1	300	5	Zg/Zyn Goudplaats Gneiss/ Giyani group	Chemical/ Mechanical	Variable depth Schist zones Permeability Slip planes	shallow soil	5	6	High	Domestic	None
KL18	Khakhala	1	Nsama	30 50' 23 18'	430	2660	5.5	300	19	Zyn Giyani group	Chemical/ Mechanical	Schist zones Permeability Variable depth	Shallow soil	2	6	Medium to High	Domestic	Dryland Access road Secondary road Settlement

POTENTIAL DAMSITES

SITE NO	SITE NAME	SITE RATE	RIVER	LONG LAT	CATCHM AREA (km2)	REGION MAX FLOOD (m3/s)	MEAN ANNUAL RUNOFF (Mm3)	CAP/ MAR (%)	VOLUME STORAGE VOLUME EMBANKM FILL	GEOLOGY: FORMATION / COMPLEX	GEOLOGY: PREDOMINATE WEATHERING MECHANISM	GEOLOGY: POTENTIAL FOUNDATION PROBLEMS	GEOLOGY: POTENTIAL CONSTRUCTION MATERIAL PROBLEMS	INFRA-STRUCTURE: NEAR ROAD (km)	INFRA-STRUCTURE: NEAR POWE (km)	LIMITATIONS TO SITE: IMPACT ON ENVIRONMENT	LIMITATIONS TO SITE: DISRUPTION OF FLOW TO DOWNSTREAM USERS	LIMITATIONS TO SITE: INUNDATION OF SERVICES AND PROPERTY
KL19	Ka-Mapayeni	7	Klein Letaba	30 49' 23 23'	3595	7360	69.5	140	3	Zyo Giyani group	Chemical/ Mechanical	Schist zones Permeability Variable depth	Shallow soil	3	15	Low to Medium	Domestic	Irrigation
KL20	Ka-Nkomo	8	Klein Letaba	30 50' 23 26'	3730	7490	70	75	14	Zg Goudplaats Gneiss	Chemical/ Mechanical	Diabase dykes Variable depth	Impervious rock Shallow soil	3	17	Low	Domestic	Dryland Settlements Access roads Secondary road
KL21	Vuhehli	13	Klein Letaba	30 53' 23 25'	3770	7530	70	140	31	Zg Goudplaats Gneiss	Mechanical	Diabase dykes Shear zones Variable depth	Impervious rock Shallow soil	1	25	Low to Medium	Domestic	Dryland Access road
KL22	Macene	17	Klein Letaba	31 01' 23 29'	4850	7700	78	125	60	Zg Goudplaats Gneiss	Mechanical	Diabase dykes Shear zones Variable depth	Impervious rock Shallow soil	1	30	Low	KNP	Dryland Huts
KL23	Macetse	15	Klein Letaba	31 07' 23 34'	5350	8070	80	125	129	Zg Goudplaats Gneiss	Mechanical	Diabase dykes Variable depth	Impervious rock Shallow soil	1	30	High	KNP	Access roads KNP Huts
MID1	Bronkhorst-fontein	0	Middel Letaba	30 05' 23 31'	375	2490	8	300	8	Zg Goudplaats Gneiss	Chemical/ Mechanical	Variable depth Flow along regional structure	Rock Sand	1	4	High	Irrigation	Access road Main road Buildings Irrigation
MID2	Grootrivier	1	Koedoes	30 11' 23 32'	320	2300	6	300	11	Zg Goudplaats Gneiss	Mechanical	Variable depth Flow along regional structure	Rock	2	15	High	Irrigation	Irrigation Vineyards Other road
MID3	Rotterdam	7	Koedoes	30 16' 23 27'	710	3300	12	300	14	Zg Goudplaats Gneiss	Chemical/ Mechanical	Variable depth Flow along regional structure	Rock	2	11	Low	Domestic	Secondary road Dryland
MID4	Amsterdam	10	Masukodutsi	30 18' 23 24'	740	3450	13	300	26	Zg Goudplaats Gneiss	Chemical/ Mechanical	Variable depth Flow along regional structure	Rock	1	11	Low	Domestic Irrigation	Dryland

POTENTIAL DAMSITES

SITE NO	SITE NAME	SITE RATE	RIVER	LONG LAT	CATCHM AREA (km2)	REGION MAX FLOOD (m3/s)	MEAN ANNUAL RUNOFF (Mm3)	CAP/MAR (%)	VOLUME STORAGE VOLUME EMBANKM FILL	GEOLOGY: FORMATION / COMPLEX	GEOLOGY: PREDOMINATE WEATHERING MECHANISM	GEOLOGY: POTENTIAL FOUNDATION PROBLEMS	GEOLOGY: POTENTIAL CONSTRUCTION MATERIAL PROBLEMS	INFRA-STRUCTURE: NEAR ROAD (km)	INFRA-STRUCTURE: NEAR POWE (km)	LIMITATIONS TO SITE: IMPACT ON ENVIRONMENT	LIMITATIONS TO SITE: DISRUPTION OF FLOW TO DOWNSTREAM USERS	LIMITATIONS TO SITE: INUNDATION OF SERVICES AND PROPERTY
MI05	Sterkwater	7	Middel Letaba	30 18' 23 22'	735	3430	18	300	25	Zg Goudplaats Gneiss	Chemical/ Mechanical	Variable depth Flow along regional structure	Rock	2	9	High	Domestic Irrigation	Dryland
GR1	Koningskroon	5	Broeder-stroom	29 57' 23 50'	25	680	12	300	30	Zg Goudplaats Gneiss	Chemical	Diabase dykes Deep & variable Collapsible soil Flow // reg stru	Rock Sand	1	19	High	Domestic Irrigation	Farm access Forest Buildings
GR2	Grey Mist	5	Broeder-stroom	29 57' 23 51'	40	850	15	300	49	Zg Goudplaats Gneiss	Chemical	Diabase dykes Deep & variable Collapsible soil Flow // reg stru	Rock Sand	1	17	High	Domestic Irrigation	Farm access Forest Dryland
GR3	Goed-vertrouwen	5	Broeder-stroom	29 57' 23 54'	70	1110	23	300	47	Zg Goudplaats Gneiss	Chemical	Deep & variable Collapsible soil Corestones Diabase dykes	Rock Sand	1	16	High	Domestic Irrigation	Secondary road Forest Dryland Buildings
GR4	Thabeng	5	Helpmekaar	29 59' 23 52'	10	440	3	300	25	Zg/Vlg Goudplaats Gneiss/ Granite	Chemical	Deep & variable Collapsible soil Corestones Diabase dykes	Sand	1	12	High	Domestic Irrigation	Farm access Forest Dryland Telephone Lines
GR5	Rondefontein	2	Helpmekaar	29 59' 23 53'	12	480	3.5	300	18	Zg/Vlg Goudplaats Gneiss/ Granite	Chemical	Diabase dykes Deep & variable Collapsible soil Flow // reg stru	Sand	1	9	High	Domestic Irrigation	Access road Forest Buildings Telephone Lines
GR6	Phoenix	2	Helpmekaar	29 59' 23 54'	19	600	5.5	200	25	Vlg Granite	Chemical	Deep collapsible soils Flow along regio structures	Sand	1	6	High	Domestic Irrigation	Access road Farm house Pleasure resort Forest
GR7	Grenshoek	0	Trib. of Politsi	30 05' 23 46'	10	440	3	300	9	Vlg/Vt Granite	Chemical	Deep collapsible soils Diabase dykes	Sand	1	15	High	Irrigation Domestic	Forest Access road Irrigation
GR8	Vergelegen	8	Groot Letaba	30 06' 23 52'	320	2300	80	125	18	Vlg Granite	Chemical	Deep collapsible soils, Diabase d Flow // Tzaneen lineament	Sand	2	12	High	Irrigation	Secondary road Orchards forest Canal Other road

POTENTIAL DAMSITES

SITE NO	SITE NAME	SITE RATE	RIVER	LONG / LAT	CATCHM AREA (km2)	REGION MAX FLOOD (m3/s)	MEAN ANNUAL RUNOFF (Mm3)	CAP/ MAR (%)	VOLUME STORAGE VOLUME EMBANKM FILL	GEOLOGY: FORMATION / COMPLEX	GEOLOGY: PREDOMINATE WEATHERING MECHANISM	GEOLOGY: POTENTIAL FOUNDATION PROBLEMS	GEOLOGY: POTENTIAL CONSTRUCTION MATERAL PROBLEMS	INFRA-STRUCTURE: NEAR ROAD (km)	INFRA-STRUCTURE: NEAR POWE (km)	LIMITATIONS TO SITE: IMPACT ON ENVIRONMENT	LIMITATIONS TO SITE: DISRUPTION OF FLOW TO DOWNSTREAM USERS	LIMITATIONS TO SITE: INUNDATION OF SERVICES AND PROPERTY
GR9	Campsies Glen	6	Selokwe	30 11' 23 44'	35	800	8	300	10	Vlg Granite	Chemical	Deep collapsible soils, Diabase d Flow // Tzaneen lineament	Sand	1	4	High	Domestic Irrigation	Forest Access road
GR10	Deerpark A	0	Nwanedzi	30 17' 23 43'	50	950	4	300	14	Vlg Granite	Chemical/ Mechanical	Deep collapsible soils Flow along regio structures	Sand	1	10	High	Irrigation	Orchards Access road Dryland Buildings
GR11	Deerpark B	3	Nwanedzi	30 20' 23 43'	130	1500	9	300	14	Vlg Granite	Chemical/ Mechanical	Moderately deep collapsible soil Corestones Diabase dykes	Rock	1	13	High	Irrigation	Orchards Buildings Dryland
GR12	Nwamitwa	8	Nwanedzi	30 24' 23 45'	220	1920	10	300	9	Vlg/Zg Granite/ Goudplaats Gneiss	Mechanical	Variable depth Diabase dykes	Rock	1	10	Low	None	Village Dryland
GR13	La Motte	7	Nwanedzi	30 28' 23 46'	360	2440	12	300	17	Zg Goudplaats Gneiss	Mechanical	Variable depth Diabase dykes	Rock	1	3	Medium	Irrigation	Secondary road Orchard Farm house Dryland
GR14	Delhi	11	Groot Letaba	30 25' 23 50'	1400	4600	218	50	16	Rrn Rooiwater Complex	Chemical/ Mechanical	Moderately deep Deep alluvium Flow along regio structures	Rock	1	2	Medium	Domestic Irrigation	Power line Road - all type Irrigation Buildings
GR15	Jasi	14	Groot Letaba	30 32' 23 44'	1980	5530	225	25	90	Zg Goudplaats Gneiss	Mechanical	Alluvium Diabase dykes Variable depth	Impervious Rock Shallow soil	1	4	Medium	Irrigation	Irrigation Orchards Secondary roads Buildings
GR16	La Parisa A	8	Lerwatlou	30 33' 23 41'	175	1720	2	500	26	Zg/Zyo Goudplaats Gneiss/ Giyani Group	Mechanical	Schist zones Slip planes Diabase dykes Permeability	Impervious Rock Shallow soil	1	7	Low	Irrigation	Access road Houses Dryland
GR17	La Parisa B	7	Lerwatlou	30 35' 23 41'	185	1770	2	500	18	Zg Goudplaats Gneiss	Mechanical	Diabase dykes Variable depth	Impervious Rock Shallow soil	1	5	Low	Irrigation	Road Dryland

POTENTIAL DAMSITES

SITE NO	SITE NAME	SITE RATE	RIVER	LONG / LAT	CATCHM AREA (km^2)	REGION MAX FLOOD (m^3/s)	MEAN ANNUAL RUNOFF (Mm^3)	CAP/ MAR (%)	VOLUME STORAGE VOLUME EMBANKM FILL	GEOLOGY: FORMATION / COMPLEX	GEOLOGY: PREDOMINATE WEATHERING MECHANISM	GEOLOGY: POTENTIAL FOUNDATION PROBLEMS	GEOLOGY: POTENTIAL CONSTRUCTION MATERIAL PROBLEMS	INFRA-STRUCTURE: NEAR ROAD (km)	INFRA-STRUCTURE: NEAR POWE (km)	LIMITATIONS TO SITE: IMPACT ON ENVIRONMENT	LIMITATIONS TO SITE: DISRUPTION OF FLOW TO DOWNSTREAM USERS	LIMITATIONS TO SITE: INUNDATION OF SERVICES AND PROPERTY
GR18	Mawe	8	Merekome	30 34' 23 37'	160	1650	2	500	20	Zg/Re Goudplaats Gneiss/Eiland Granite	Mechanical	Diabase dykes Variable depth	Impervious Rock Shallow soil	1	2	Low	Domestic	Dryland
GR19	Constantia A	7	Merekome	30 38' 23 38'	225	1950	3	300	14	Zg/Zya Goudplaats Gneiss/ Giyani Group	Mechanical	Schist zone Slip planes, Diabase dykes, Permeabil Shear zones	Impervious Rock Shallow soil	1	4	Low	Irrigation	Secondary road Dryland
GR20	Constantia B	7	Groot Letaba	30 40' 23 39'	2530	6200	226	50	9	Zg Goudplaats Gneiss	Mechanical	Alluvium Diabase dykes Variable depth	Impervious Rock Shallow soil	1	2	Medium	Irrigation	Air strip Orchards, Irrig Buildings Secondary roads
GR21	Hans Merensky	0	Mashuel	30 42' 23 41'	20	610	.2	500	14	Zg/di Goudplaats Gneiss/Black Hills dyke	Mechanical	Diabase dykes	Impervious Sand Shallow soil	1	9	High	None	Nature reserve Orchard Other roads
GR22	Grootfontein	-2	Lenyenye	30 40' 23 46'	50	950	.5	200	5	Zg/di Goudplaats Gneiss/Black Hills dyke	Mechanical	Diabase dykes	Impervious Sand Shallow soil	1	17	High	None	Secondary road Farm house Access road
GR23	Vygeboom	5	Reshewele	30 43' 23 44'	30	740	.3	300	8	Zg Goudplaats Gneiss	Mechanical	Diabase dykes	Impervious Sand Shallow soil	5	6	Low	None	None
GR24	Nondwene	14	Groot Letaba	30 52' 23 41'	3080	6800	222	25	68	Zg Goudplaats Gneiss	Mechanical	Alluvium Diabase dykes Variable depth Flow // reg stru	Impervious Rock Shallow soil	1	2	Low	Irrigation	Buildings roads Orchards Irrigation
GR25	Kromrivier-fontein	6	Molototsi	30 24' 23 32'	140	1550	6	300	10	Zg/Vig Goudplaats Gneiss/ Granite	Chemical/ Mechanical	Variable depth Alluvium Tzaneen lineamen	Rock Impervious Sand	1	2	Low	Domestic	Dryland
GR26	Sterkfontein	7	Molototsi	30 28' 23 28'	335	2350	7	300	21	Zg Goudplaats Gneiss	Mechanical	Variable depth Alluvium Tzaneen lineamen	Rock Impervious Shallow soil	1	2	Medium	Domestic	Dryland Settlement

SITE NO	SITE NAME	SITE RATE	RIVER	LONG / LAT	CATCHM AREA (km2)	REGION MAX FLOOD (m3/s)	MEAN ANNUAL RUNOFF (Mm3)	CAP/MAR (%)	VOLUME STORAGE VOLUME EMBANKM FILL	GEOLOGY: FORMATION / COMPLEX	GEOLOGY: PREDOMINATE WEATHERING MECHANISM	GEOLOGY: POTENTIAL FOUNDATION PROBLEMS	GEOLOGY: POTENTIAL CONSTRUCTION MATERIAL PROBLEMS	INFRA-STRUCTURE: NEAR ROAD (km)	INFRA-STRUCTURE: NEAR POWE (km)	LIMITATIONS TO SITE: IMPACT ON ENVIRONMENT	LIMITATIONS TO SITE: DISRUPTION OF FLOW TO DOWNSTREAM USERS	LIMITATIONS TO SITE: INUNDATION OF SERVICES AND PROPERTY
GR27	Elandsfontein A	8	Mawa	30 29' 23 26'	75	1150	1	300	11	Zg Goudplaats Gneiss	Mechanical	Diabase dykes Variable depth Alluvium	Rock Impervious Shallow soil	2	6	Low	None	Dryland
GR28B	Elandsfontein B	7	Molototsi	30 30' 23 27'	430	2650	8	300	23	Zg Goudplaats Gneiss	Mechanical	Variable depth Alluvium	Impervious Rock	1	6	Medium	Domestic	Dryland Secondary road
GR29	Mulele	13	Molototsi	30 36' 23 28'	630	3190	9	300	140	Zya Giyani Group	Mechanical	Schist zones Slip planes Permeability Alluvium	Rock	3	5	Medium	Domestic	Dryland Secondary road
GR30	Pade	3	Molototsi	30 41' 23 32'	750	3470	10	300	27	Zg Goudplaats Gneiss	Mechanical	Variable depth Alluvium Shear zones Diabase dykes	Rock Impervious	3	8	High	Domestic Irrigation	Dryland Secondary road
GR31	Ka-Keyi	7	Molototsi	30 52' 23 36'	1020	4020	11	300	18	Zg Goudplaats Gneiss	Mechanical	Variable depth Alluvium Diabase dykes	Rock Impervious	2	12	Low	Irrigation	Cultivated Secondary road
GR32	Ka-Mushyani	9	Molototsi	30 54' 23 37'	1100	4170	11	300	35	Zg Goudplaats Gneiss	Mechanical	Variable depth Alluvium Diabase dykes	Rock Impervious	2	10	Low	Irrigation	Dryland Secondary road
GR32A	Makuba's Location	10	Mohawula	30 55' 23 40'	1130	4220	11	300	47	Zg Goudplaats Gneiss	Mechanical	Variable depth Alluvium Diabase dykes	Rock Impervious	2	10	Low	Irrigation	Dryland
GR33	M Bauls Ranch	3	Mbhawula	31 04' 23 37'	150	1220	1.5	300	20	Zg Goudplaats Gneiss	Mechanical	Variable depth Alluvium Diabase dykes	Rock Impervious	2	15	High	None	Dryland
GR34	Nyabutsi	12	Groot Letaba	31 07' 23 39'	4560	8250	230	50	71	Zg Goudplaats Gneiss	Mechanical	Variable depth Alluvium Diabase dykes	Rock Impervious	1	20	High	None	Gr Letaba Reser (Nature) Bulk camps Other roads

POTENTIAL DAMSITES

SITE NO	SITE NAME	SITE RATE	RIVER	LONG / LAT	CATCHM AREA (km2)	REGION MAX FLOOD (m3/s)	MEAN ANNUAL RUNOFF (Mm3)	CAP/MAR (%)	VOLUME STORAGE VOLUME EMBANKM FILL	GEOLOGY: FORMATION / COMPLEX	GEOLOGY: PREDOMINATE WEATHERING MECHANISM	GEOLOGY: POTENTIAL FOUNDATION PROBLEMS	GEOLOGY: POTENTIAL CONSTRUCTION MATERAL PROBLEMS	INFRA-STRUCTURE: NEAR ROAD (km)	INFRA-STRUCTURE: NEAR POWE (km)	LIMITATIONS TO SITE: IMPACT ON ENVIRONMENT	LIMITATIONS TO SITE: DISRUPTION OF FLOW TO DOWNSTREAM USERS	LIMITATIONS TO SITE: INUNDATION OF SERVICES AND PROPERTY
GR35	Mahlangeni	4	Groot Letaba	31 09' 23 39'	9995	12020	311	30	7	Zg/Zgx Goudplaats Gneiss/ Gravelotte Gr	Mechanical	Schist zones Slip planes Permeability Alluvium	Rock Impervious	1	25	High	None	KNP Secondary roads Bulk camps
GR36	Letaba Ranch	-4	Mpandeni	31 08' 23 45'	115	1070	.5	200	8	Rib/Zgl Baderonkwe Granite/ Gravelotte Gr	Mechanical	Schist zones Slip planes Permeability Alluvium	Rock Impervious	1	23	High	None	Secondary road Game reserve
GR37	Shambali	2	Shambali	31 16' 23 42'	10	320	.1	1e3	15	Mt/Zgx Tlabavati Gabbro/Gravelotte Group	Mechanical	Diabase dykes Schist zones Permeability Variable depth	Rock	2	> 5	High	None	KNP
GR38	Tsale/ Shipikani	1	Shipikani	31 21' 23 43'	190	1300	1	300	10	Zm/Zgx Makhutswi Gneiss/Gravelotte Group	Mechanical	Schist zones Slip planes Permeability Alluvium	Rock Impervious	1	> 5	High	None	KNP
GR39	Malunzane	-1	Tsende	31 21' 23 29'	235	1530	1	300	4	Zg Goudplaats Gneiss	Mechanical	Alluvium Variable depth	Rock Impervious	2	> 5	High	None	KNP
GR40	Nwanedzi Drift	2	Nwanedzi	31 29' 23 48'	130	1140	1	300	24	Zm/Pma Makhutswi Gneiss/Karoo Sediments	Mechanical	Alluvium Variable depth	Rock Impervious	1	> 5	High	None	Secondary & Oth roads KNP
GR41	Greene	1	Makhadzi	31 39' 23 37'	20	450	.2	500	10	Jt Tsokwane Granophyre	Mechanical	Breccia dykes Flow parallel to lineaments	Impervious	1	> 5	KNP	None	KNP Access road
GR42	Ga-Mathandzila	4	Mathandzola	31 39' 23 46'	11	330	.1	1e3	10	Jt/Jl Tsokwane/ Letaba formation	Mechanical	Breccia dykes	Shallow soil	2	> 5	KNP	None	Game reserve
GR43	Ramitl	4	Shinobyani	31 46' 23 55'	12	350	.1	1e3	10	Jj Jozini formation	Mechanical	Breccia dykes	Shallow soil	1	> 5	KNP	None	Game reserve

POTENTIAL DAMSITES

SITE NO	SITE NAME	SITE RATE	RIVER	LONG LAT	CATCHM AREA (km2)	REGION MAX FLOOD (m3/s)	MEAN ANNUAL RUNOFF (Hm3)	CAP/MAR (%)	VOLUME STORAGE VOLUME EMBANKM FILL	GEOLOGY: FORMATION / COMPLEX	GEOLOGY: PREDOMINATE WEATHERING MECHANISM	GEOLOGY: POTENTIAL FOUNDATION PROBLEMS	GEOLOGY: POTENTIAL CONSTRUCTION MATERAL PROBLEMS	INFRA-STRUCTURE: NEAR ROAD (km)	INFRA-STRUCTURE: NEAR POWE (km)	LIMITATIONS TO SITE: IMPACT ON ENVIRONMENT	LIMITATIONS TO SITE: DISRUPTION OF FLOW TO DOWNSTREAM USERS	LIMITATIONS TO SITE: INUNDATION OF SERVICES AND PROPERTY
GR44	Ga-Modjadji	4	Molototsi	30 19' 23 36'	70	1110	5	300	7	Vlg Granite	Chemical	Diabase dykes Deep & variable Collapsible soil Tzaneen lineamen	Sand	1	15	Medium	Irrigation	Settlement Road
LET1	Litswalo	3	Letaltele	30 09' 23 59'	88	1240	30	300	12	Rrn/Vlg Roolwater Complex/ Granite	Chemical	Deep & variable Diabase dykes Flow along regio structure	Sand	1	5	High	Irrigation	Orchards Houses Secondary roads Telephone lines
LET2	Hobson's Choice	13	Letaltele	30 12' 23 58'	121	1440	32	300	25	Rrn Roolwater Complex	Chemical	Deep & variable Diabase dykes Flow along regio structure	Sand	1	5	Medium	Irrigation Domestic	Orchards Secondary roads Settlement Buildings
LET3	York	7	Thabina	30 17' 23 57'	169	1695	28	300	31	Rrn/Zgr/Q Roolwater Gravelotte/ Quaternary	Chemical	Deep & variable Schist zones Alluvium Thabina Fault	Sand	1	4	Medium	Domestic Irrigation	Main roads Dryland Settlement Secondary road
LET4	Ramalema	6	Thabina	30 17' 23 59'	124	1460	23	300	9	Zgr/Q Gravelotte/ Quaternary	Chemical	Deep & variable Schist zones Alluvium Thabina Fault	Sand	1	1	Medium	Domestic Irrigation	Power line Huts Dryland
LET5	Vulihva	9	Letaltele	30 13' 23 56'	171	1700	40	300	8	Vlg Granite	Chemical	Deep & variable Diabase dykes Flow along regio structure	Sand	1	5	Low	Irrigation	Orchards Drylan Secondary road Buildings Huts
LET6A	Ka-Muhlaba	16	Letsitele	30 17' 23 55'	240	2000	46	300	39	Zg Goudplaats Gneiss	Chemical/ Mechanical	Moderately deep	Sand	2	2	Low	Irrigation	Road Cultivated Settlement
LET7	Letsitele	13	Letsitele	30 21' 23 54'	473	2780	76	10	21	Zg/Rrn Goudplaats Gneiss/ Roolwater	Chemical/ Mechanical	Moderately deep	Sand	1	9	Medium	Irrigation	Dryland
LET8	Serare	10	Ngwabu	30 14' 24 01'	37	820	13	300	28	Zr/Zw Gravelotte Group	Chemical	Schist zones Slip planes Permeability	Sand	1	3	Medium	Domestic	Housing Dryland Mining claims

POTENTIAL DAMSITES

SITE NO	SITE NAME	SITE RATE	RIVER	LONG / LAT	CATCHM AREA (km2)	REGION MAX FLOOD (m3/s)	MEAN ANNUAL RUNOFF (Mm3)	CAP/MAR (%)	VOLUME STORAGE VOLUME EMBANKM FILL	GEOLOGY				INFRA-STRUCTURE		LIMITATIONS TO SITE		
										FORMATION / COMPLEX	PREDOMINATE WEATHERING MECHANISM	POTENTIAL FOUNDATION PROBLEMS	POTENTIAL CONSTRUCTION MATERIAL PROBLEMS	NEAR ROAD (km)	NEAR POWE (km)	IMPACT ON ENVIRONMENT	DISRUPTION OF FLOW TO DOWNSTREAM USERS	INUNDATION OF SERVICES AND PROPERTY
LE19	Nkowakowa	15	Letsitele	30 19' / 23 54'	247	2030	46	220	20	Zg Goudplaats Gneiss	Chemical/ Mechanical	Moderately deep	Sand	4	4	Low	Irrigation	Dryland Settlement Secondary road
LE110	Erifaro	6	Thabina	30 18' / 23 56'	177	1730	29	300	17	Rrb/Q Roolwater Complex/ Quaternary	Chemical/ Mechanical	Deep & variable Schist zones Alluvium Thabina fault	Sand	3	6	Medium	Domestic Irrigation	Dryland Settlement Secondary road
LE111	Sangoma	6	Thabina	30 20' / 23 55'	191	1800	30	300	11	Rrb/Q Roolwater Complex/ Quaternary	Chemical/ Mechanical	Deep & variable Schist zones Alluvium Thabina fault	Sand	4	8	Medium	Domestic Irrigation	Dryland Settlement Secondary road
LE112	Pitsi	10	Ngwabu	30 13' / 24 03'	26	690	9	300	30	Zw Gravelotte Group	Chemical	Schist zones Slip planes Permeability	Sand	1	10	High	Domestic Irrigation	None
SH1	Mbomene Confluence	4	Mphongolo	31 05' / 22 53'	500	2240	13	100	25	Zg Goudplaats Gneiss	Mechanical	Variable depth Permeability	Impervious Shallow soil Rock	1	20	High	KNP	KNP Secondary roads
SH2	Vlakkplaas	7	Shisha	31 14' / 22 55'	780	2790	20	300	30	Zg Goudplaats Gneiss	Mechanical	Variable depth Permeability	Impervious Shallow soil Rock	1	30	High	KNP	KNP Road
SH3	Mashobye	-1	Phuguane	30 53' / 22 59'	140	1100	2.5	400	5	Zg Goudplaats Gneiss	Chemical/ Mechanical	Variable depth Permeability	Impervious Shallow soil Rock	1	22	High	KNP	Secondary road Dryland
SH4	Shamangombe Confluence	-1	Phuguane	30 58' / 22 59'	290	1700	5	300	9	Zg Goudplaats Gneiss	Mechanical	Variable depth Permeability	Impervious Shallow soil Rock	3	28	High	KNP	KNP Secondary road
SH5	Frank Mennie	5	Shingwedzi	30 38' / 23 05'	50	700	1	300	6	Zg Goudplaats Gneiss	Chemical/ Mechanical	Variable depth Permeability	Impervious Shallow soil Rock	3	7	Medium	Domestic	None

POTENTIAL DAMSITES

SITE NO	SITE NAME	SITE RATE	RIVER	LONG LAT	CATCHM AREA (km2)	REGION MAX FLOOD (m3/s)	MEAN ANNUAL RUNOFF (Mm3)	CAP/ MAR (%)	VOLUME STORAGE VOLUME EMBANKM FILL	GEOLOGY: FORMATION / COMPLEX	GEOLOGY: PREDOMINATE WEATHERING MECHANISM	GEOLOGY: POTENTIAL FOUNDATION PROBLEMS	GEOLOGY: POTENTIAL CONSTRUCTION MATERAL PROBLEMS	INFRA-STRUCTURE: NEAR ROAD (km)	INFRA-STRUCTURE: NEAR POWE (km)	LIMITATIONS TO SITE: IMPACT ON ENVI RONMENT	LIMITATIONS TO SITE: DISRUPTION OF FLOW TO DOWNSTREAM USERS	LIMITATIONS TO SITE: INUNDATION OF SERVICES AND PROPERTY
SH6	Ireland	10	Shingwedzi	30 41' 23 04'	100	1000	1.5	300	30	Zg Goudplaats Gneiss	Chemical/ Mechanical	Variable depth Permeability	Impervious Shallow soil Rock	1	1	Medium	Domestic Irrigation	Secondary road
SH7	Jorrison	8	Shingwedzi	30 47' 23 05'	210	1450	3	300	15	Zg Goudplaats Gneiss	Chemical/ Mechanical	Variable depth Permeability	Impervious Shallow soil Rock	3	12	Low	Domestic Irrigation KNP	None
SH8	Alten	9	Shingwedzi	30 53' 23 09'	240	1550	3.5	300	22	Zg Goudplaats Gneiss	Mechanical	Variable depth Permeability	Impervious Shallow soil Rock	1	2	Low	KNP	None
SH9	Nwatlabutu	7	Shingwedzi	30 59' 23 10'	350	1870	5	300	80	Zg Goudplaats Gneiss	Mechanical	Variable depth Permeability	Impervious Shallow soil Rock	1	9	High	KNP	KNP Secondary road
SH10	Xikokola Confluence	7	Shingwedzi	31 03' 23 11'	450	2120	6.5	300	20	Zg Goudplaats Gneiss	Mechanical	Variable depth Permeability	Impervious Shallow soil Rock	2	18	High	KNP	KNP
SH11	Nkayini Confluence	7	Shingwedzi	31 03' 23 12'	640	2530	8	300	49	Zg/Zyo/Mt Goudplaats Gn Giyani Group Timavati Gabb	Mechanical	Variable depth Permeability Flow along regio structures	Shallow soil	1	30	High	KNP	KNP Secondary road
SH12	Shigamane	9	Shingwedzi	31 13' 23 13'	720	2600	9	300	60	Mt/Zyo Timbavati Gabbro Giyani Group	Mechanical	Variable depth Permeability Flow along regio structures	Shallow soil	1	40	High	KNP	KNP Secondary roads
SH13	Red Rocks	3	Shingwedzi	31 17' 23 11'	860	2930	10	100	15	Zg/Zyo/Q Goudplaats Gn Giyani Group Quaternary	Mechanical	Alluvium Variable depth Schist zones Permeability	Shallow soil	1	50	High	KNP	KNP Secondary road