THE WORKING FOR WATER PROGRAMME

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

NATIONAL INVADING ALIEN PLANT SURVEY INCEPTION REPORT

Report No. 304201 **November 2003**

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Executive Summary

National Invading Alien Plant Survey Inception Report

A national review of the potential impacts of invading alien plants commissioned by the Water Research Commission in 1997 estimated that approximately 10.1 million hectares (6.8%) of South Africa and Lesotho is covered by alien vegetation with various degrees of density. The extent of the invasive vegetation, especially in areas such as the Eastern Cape and Limpopo Province is unclear, and the Working for Water Programme (WfW) recognises that improved data on the status of invasions is required, not only to better quantify the impact on water resources, but also for improved strategic planning capability. This desktop study was therefore commissioned as a first step to assessing the current extent and status of invading alien plants (IAP) data in South Africa.

The project had the following objectives:

- To conduct a desktop audit of existing data sets and information sources involving:
  - The survey, collection and manipulation (where necessary) of available GIS data;
  - Compilation of metadata; and
  - A quality assessment of collected data for utilisation.
- To conduct a gap analysis in terms of:
  - The extent to which the data could be utilised; and
  - Geographic coverage, considering conservation value, socio-economic, agricultural potential and hydrological factors.
- To facilitate a workshop with WfW personnel, with the aim of assigning a preliminary prioritisation to the identified gaps; and
- To detail field survey methods for the identified gaps.

Results of the data survey, which was conducted from August 2002 until February 2003, indicate that there are no comprehensive data sets other than the WfW, Centre for Scientific and Industrial Research (CSIR) and Southern African Plant Invader's Atlas (SAPIA) data. There are limitations on the CSIR data set in terms of scale. Isolated pockets of data from various sources, mainly in the Western Cape, Eastern Cape and KwaZulu-Natal, which will be useful for WfW's future planning, have been identified and collected. Mpumalanga, KwaZulu-Natal and the Eastern Cape have large areas of forestry, for which only MONDI and SAFCOL have indicated that weed data within forest compartments exists. There are no major mapping initiatives with the exception of Swaziland, which has an alien invader atlasing project planned.

When taking into account the WfW Natural Biological Alien (NBAL) data, the Western Cape, KwaZulu-Natal, Gauteng and Mpumalanga are relatively well covered by IAP data, while there is a paucity of data for the Limpopo Province, North West, Eastern Cape, and the Northern Cape. No data was identified or received for the Free State Province, other than the CSIR NBAL data. In this light, the SAPIA is a crucial information source for strategic planning.

Specialist botanists assisted in identifying geographical gaps, in terms of areas where IAP surveys and mapping need to be carried out, at the quaternary catchment level. A preliminary model was designed to prioritise identified catchment gaps and to compare these to the existing WfW project areas. Factors deemed important for defining WfW project areas, and that were taken into account in the model included conservation value, hydrological, agricultural and socio-economic factors. The results of the model are presented for each province, as maps. The model is intended to function as a framework model for discussion and review, and is not intended to be prescriptive. The major objective is to kick-start a more integrated planning process within WfW. It is recommended that additional botanical factors, for example rate of spread of aliens, need to be included.

Field survey and mapping methods for closing the identified gaps are discussed. Survey methods should be chosen on a case by case basis, taking into consideration the biophysical properties of the identified areas. It is recommended that further refinement of the prioritisation model be undertaken, incorporating updated, more accurate factor data sets as they become available, and completed using raster-based spatial modelling techniques. Further iterations of the model will be necessary to review the strategic planning of project areas.

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National Invading Alien Plant Survey Inception Report

1 INTRODUCTION AND BACKGROUND

A national review of the potential impacts of invading alien plants commissioned by the Water Research Commission (1997) estimated that approximately 10.1 million hectares (6.8%) of South Africa and Lesotho is covered by alien vegetation with various degrees of density. The extent of the invasive vegetation, especially in areas such as the Eastern Cape and Northern Province is unclear, and the Working for Water Programme recognises that improved data on the status of invasions is required, not only to better quantify the impact on water resources, but also for improved strategic planning capability.

In this light, Steffen, Robertson and Kirsten Consulting (SA) (SRK) was appointed by the Department of Water Affairs and Forestry's (DWAF) Working for Water Programme (WfW) to assess the current extent and status of invading alien plants (IAP) data in South Africa.

This report serves several functions:

- To summarise the details and findings of the data survey and audit;
- To present metadata on the collected data;
- To detail the potential for using each data set;
- To detail identified gaps and preliminary prioritisations for the data and the current WfW project areas;
- To detail field survey methods to close identified gaps; and
- To make recommendations as to the way forward.

2 PROJECT SCOPE

This desktop assessment of the extent of invasive aliens data required the survey and audit of available data sets of invading alien plant distribution, and the identification of current or future mapping initiatives. The following specific project objectives were identified:

- Conduct a desktop audit of existing data sets and information sources involving:
    - The survey, collection and manipulation (where necessary) of available GIS data;

- Compilation of metadata to document the source and reliability of data; and
- A quality assessment of collected data for utilisation.
- Conduct a gap analysis in terms of:
  - The extent to which the data could be utilised; and
  - Geographic coverage, considering conservation, socio-economic, agricultural potential and hydrological factors;
- Facilitate a workshop with WfW personnel, with the aim of assigning a preliminary prioritisation to the identified gaps; and
- Detail field survey methods for the identified gaps.

3 METHODOLOGY

3.1 Desktop survey and data audit

The desktop survey was conducted from August 2002 until February 2003 by means of a survey questionnaire, which was distributed by electronic mail to potential data holders. The survey questionnaire is attached in Appendix A. Telephonic interviews and electronic mail communications were also carried out. All communication and contact information was entered into a "Contacts Database," which was designed in Microsoft Access. A list of people and organisations surveyed is presented in Appendix B. Feedback information received was evaluated as to whether the specified data would be collected.

3.2 Collection, manipulation and metadata capture

Requested IAP data was received on CD-ROM and by email (mainly in ESRI shapefile, ArcInfo and ERDAS Imagine formats). The data was divided up into provinces, and a map compiled as such using ArcGIS 8.2 software. Data sets were converted to decimal degrees in order to integrate alien data with ancillary data for analysis purposes. Metadata was captured according to the Federal Geographic Data Committee (FGDC) standards for all data sets, with the exception of the WfW data, and for data sets which already had detailed metadata. ArcCatalogue 8.2 was used for this purpose.

Furthermore, ancillary data sets, which were deemed useful for the gap analysis and prioritisation, and for WfW's future needs, were collected from various sources. Data in the following categories was collected:

- Topo-cadastral;
- Hydrological information: catchments, rivers and compulsory water use licensing catchments;
- Land-cover and capability, and vegetation type; and
- Conservation-related information, for example wetlands, and conservation planning data including irreplaceability and priority conservation grids.

A comprehensive list of the IAP data sets and other ancillary data identified is presented in Appendix C, while hardcopies of the metadata are given in Appendix D. Electronic metadata are provided with the data, in XML format.

3.3 Quality assessment of data for utilisation

Each IAP data set was categorised according to defined criteria, consistent with WfW data standards (WfW, 2003), and qualitatively rated as to its utility value. The criteria considered important for assessing utility value are given below:

- The presence of the following:
  - Genus/Species attributes;
  - Density attributes; and
  - Metadata.
- Date of Data;
- Scale: data were categorised into:
  - High: more detailed than 1 : 10 000
  - Medium: between 1: 10 000 and 1 : 50 000
  - Low: between 1:50 000 and 1:250 000
  - Very low: less detailed than 1:250 000
- Accuracy, as estimated by the distributor.

3.4 Gap Analysis and prioritisation model

3.4.1 Data utility value

The utility value of the data was assessed during the quality assessment as described in Section 3.3 above.

3.4.2 Geographical Coverage

A preliminary identification of gaps in IAP data and WfW project areas at the quaternary catchment level was carried out in a two step process, taking into consideration botanical, conservation hydrological, agricultural and socio-economic factors. The first step involved the identification of gaps by a team of specialist botanists, which considered conservation and botanical importance, while the second step involved the prioritisation of these identified catchments by means of a simple model. Furthermore, IAP information for each identified catchment was detailed by the specialists, and this includes the following:

- Genus/Species;
- Estimated density in three categories, high medium and low;
- Approximate distribution and landscape position within the catchment: riverine, midslope and topslope;

- Priority for mapping and clearing in terms of biodiversity and conservation importance in three categories, high medium and low; and
- Reason for assigned priority.

The team of specialist botanists are detailed in Table 3.1 below.

Table 3.1 Team of botanists who contributed to the gap analysis

NAME	PROVINCE
Barrie Low	Western Cape
Dave Richardson	Western Cape
Erich Fuls	Gauteng
George Bredenkamp	Free State, Mpumalanga
Mervyn Lotter	Mpumalanga
Noel van Rooyen	North-west, Northern Cape
Peter le Roux	KwaZulu-Natal
Pieter Winter	Limpopo
Roy Lubke	Eastern Cape
Susanne Milton-Dean	Western Cape, Northern Cape
Tim O'Connor	KwaZulu-Natal, Limpopo

The identified gaps were captured as ESRI shapefiles, and the related botanical information was entered into a Dbase (.dbf) format, and linked to the corresponding shapefiles in the GIS for query purposes.

While the necessity to produce results for decision making purposes is not overlooked, it is emphasised that the results from this process are not intended to be prescriptive, but rather that this process be viewed as a preliminary iteration of the gap analysis. Further work on refining and testing the model is required. The model is described below.

3.4.2.1 Prioritisation Model

A simple model was designed in order to evaluate identified gaps according to defined criteria, and thereby prioritise the gaps. A conceptual diagram of the model used is presented in Figure 1. The quaternary catchment gaps identified by specialist botanists were evaluated according to the following pre-defined criteria:

- *Conservation/biodiversity* factors: conservation planning data sets of irreplaceability, which is a measure assigned to an area which reflects the importance of that area for the achievement of conservation targets (National Parks & Wildlife Service, 2001), were utilised for KwaZulu-

Natal, the Cape Floristic Region (Cape Action Plan for the Environment (CAPE)) and the succulent karoo (Succulent Karoo Ecosystems Project (SKEP)). A data set of biodiversity importance per catchment compiled by Mpumalanga Parks Board, was utilised for Mpumalanga. Irreplaceability data sets have been compiled for the Gariep basin, Gauteng and the Subtropical Thicket Ecosystem Planning (STEP) project, but these were not available for use at the time the modelling was conducted. Apart from the conservation planning data set generated by the Gariep Basin Millenium Assessment which covers most of the Northern Cape and the Free State, the remainder of the country has no comprehensive and comparable data for conservation importance. Also, because of the inconsistency of data sets, the priority scores assigned by the specialist botanists were finally used as measures of conservation importance;

- *Hydrology*: priority catchments for compulsory water use licensing were identified by DWAF, and this was used as an indicator of hydrological importance;
- *Agricultural potential*: the National Department of Agriculture land capability data set (Schoeman *et al.*, 2002) was used for this factor as no other relevant data is currently available. Two scenarios were considered: (1) high potential lands suitable for arable agriculture were prioritised (Classes I to IV), and (2) lands suitable for grazing only were prioritised (Classes V to VII); Discussions with WfW indicated that it is predominantly the grazing lands that are being impacted upon by IAPs, and the productivity of these lands is thereby being decreased. IAPs also have an impact on the arable areas, and both of these factors were considered in separate iterations of the model.
- *Socio-Economics*: the Census 1996 data was used at a ward level to identify areas of poverty. Poverty areas were considered as areas where annual household income is less than R18000.

The abovementioned factors were captured and manipulated into a useable GIS format where required. Gaps were overlayed onto the four layers and rated accordingly. The rating categories are given in Table 3.2 below:

Table 3.2. Factor categories and scores

FACTOR	CATEGORIES	SCORE
Biodiversity/irreplaceability	High 80-100%	3
	Medium 40-80%	2
	Low 0 –40%	1
Specialist Priority	High	3
	Medium	2
	Low	1
Hydrology	Priority area	3
	Non Priority area	0

Grazing agricultural potential / land capability	Grazing comprising 0-50% of the catchment	1
	Grazing comprising 51-75% of the catchment	2
	Grazing comprising 76-100% of the catchment	3
Arable agricultural potential	Arable comprising 0-50% of the catchment	1
	Arable comprising 0-51-75% of the catchment	2
	Arable comprising 76-100% of the catchment	3
Poverty	Poverty area	3
	Non poverty area	0

The factor scores were then combined additively, resulting in a priority rating ranging from one to twelve. This was divided into three groups, Low, Medium and High priority, corresponding to the following total scores: 1-4; 5-8; and 9-12. A "fair rating" filter should be allowed for in order to evaluate the robustness of the model. This will need to be conducted at a provincial level, by provincial specialists.

3.4.2.2 Model Limitations

There are two major limitations of the model:

- The factor data used is insufficient.
  - The specialist botanists incorporated bias into the choosing of gaps due to localised knowledge;
  - The 1996 Census Data is out of date and is at the ward level which allows for errors in categorising catchments as poverty catchments. The use of this data may not be appropriate since "Poverty Nodes" have been previously identified in the Integrated Rural Development Plans (IRDP). Furthermore, the use of R18000 as a threshold may not be valid for all regions. The IRDP data was not used as the scale was deemed to general to be used for meaningful analysis;

- Hydrology: compulsory water use licensing areas as an indicator of hydrological importance is seen as insufficient as certain factors, for example groundwater abstraction has not been taken into account in certain areas, for example the Sandveld areas of the Western Cape;
- There is no up to date and reliable national assessment of biodiversity importance and so there are areas of the country which have no data. The CAPE and SKEP irreplaceability data are not consistent in their area of overlap and so reliability is questionable. The KZN irreplaceability data is not complete and therefore not all ecosystem components have been taken into account when modelling conservation importance. Wetland data is out of date and inaccurate. The Gariep irreplaceability data set is mapped at a scale of 1: 50 000 and so is not compatible with other data sets.
- Land capability is not an ideal data set for an indication of agricultural productivity. A map of rangeland potential and carrying capacity is being compiled by the National Department of Agriculture, and will be available in 2004. This would be an ideal data set to incorporate for the consideration of grazing lands.

• Modelling process limitations:
  - Due to the abovementioned data insufficiencies, only gaps identified by specialist botanists were subjected to the model. Areas without data therefore have not been evaluated; The exception is Mpumalanga where all catchments were modelled as data existed for all catchments;
  - No weighting of factors has been applied at this stage;
  - The model has not considered "invasion potential" or "risk" or rangeland potential (although as mentioned, land suitable for grazing was incorporated), which are important factors for consideration;
  - Scale: although quaternary catchment level analysis is necessary for national planning objectives, data has been "averaged" for the catchment which may have implications for the priority scores assigned to each gap. A more detailed level will be required for comprehensive planning.

3.5 Field survey methods

This largely comprised a review of alien mapping methods drawn up by the CSIR (Smith *et al*., 1999) and the WfW programme DWAF (2003). Much of the mapping approach in the WfW programme has been derived from the work of Le Maitre and Versveld (1994), who developed a technique for alien mapping within the fynbos biome, using 1:50 000 maps.

Two phases of alien mapping are recognised:

• Reconnaissance phase – aliens are located and species are recorded. This is a rapid assessment where specific detail is not required. Aircraft-based mapping is usually suitable for this purpose;

- Operational phase – treatment of Management Plan Area (MPA) involves recording detailed information on aliens, and designating treatment areas for individual vegetation removal contracts. Ground based mapping is usually the best suited for this purpose. However, where invasions are homogeneous and easily mapped from the air, ground-based mapping might not be necessary.

For WfW to be successful, a common set of standards is required for the programme. These will ensure that all data (a) are directly comparable, and (b) can be used in data analysis and the management systems employed by WfW. These standards are:

- The project must be attainable;
- It must be appropriate to a particular landscape and catchment;
- It must be able to be used in WfW priority planning;
- It must be compatible with the national database;
- It must comply with WfW standards;
- It must be at an appropriate scale; and
- It must be at the species level.

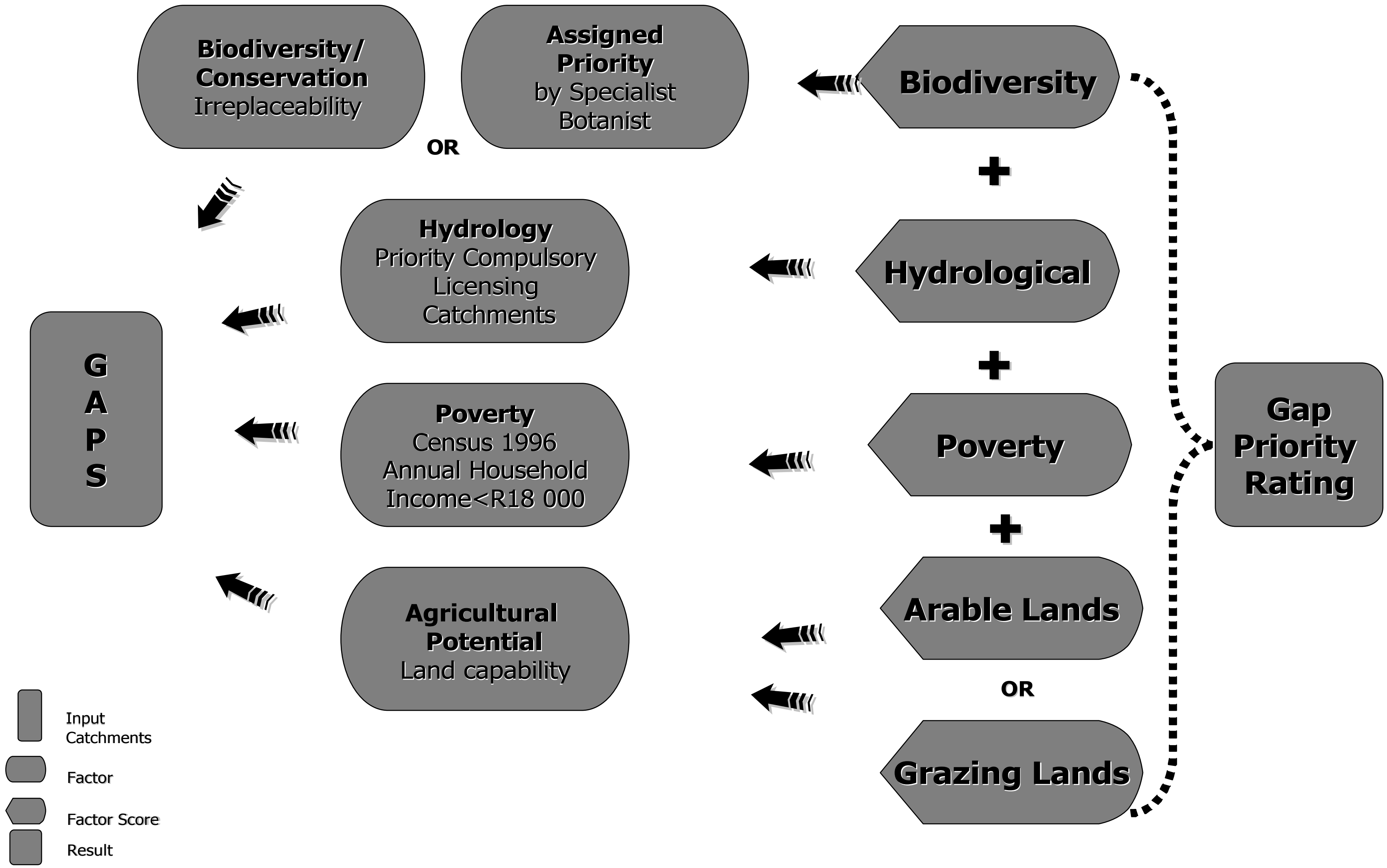

Figure 1 Conceptual Current Gap Analysis Model

4 RESULTS

The survey has revealed that few comprehensive data sets exist, other than WfW's National Biological Alien (NBAL) data. There are however small localised data sets, mainly in the Western Cape, Eastern Cape and KwaZulu-Natal, which will be useful for WfW's future planning. A list of the data identified, and the quality assessment thereof is presented in Appendix C, while provincial IAP maps depicting IAP data are presented in Appendix E.

When taking into account the WfW NBAL data, the Western Cape, KwaZulu-Natal, Gauteng and Mpumalanga have a relatively higher coverage of data than the remaining provinces. There is a paucity of data for the Free State, Limpopo Province, North West, Eastern Cape, Northern Cape and Swaziland. No data exists for the Free State Province, other than the CSIR NBAL data. In this light, the Southern African Plant Invaders Atlas data base (SAPIA), which covers the entire country, and has historical information, is a crucial information source for strategic planning.

Estimates for the area covered by IAP data for South Africa and Swaziland are broken down into provinces and are given in Table 4.1 below.

Table 4.1. Estimates of the area covered by IAP data per province

Province	Estimated Area covered by identified/collected IAP data[1] (km^2)	Estimated area covered by WfW NBAL data[2] (km^2)	Percent coverage (%) by WfW NBAL data	Percent coverage (%) by WfW and collected IAP data
Eastern Cape	1081[3]	254	0.15	0.79
Free State	-	9	0.01	0.01
Gauteng	17 102	686	4.04	104.66
KwaZulu-Natal	3761	2426	2.62	6.67
Limpopo	129	402	0.33	0.43
Mpumalanga	1729	918	1.15	3.33
Northern Cape	85 181[4]	537	0.15	23.43
North-West	-	441	0.38	0.38
Western Cape	7909	1145	0.88	6.93
Swaziland	entire	-	-	-

1 This excludes the Working for Water and CSIR NBAL, and Southern African Plant Invaders Atlas (SAPIA) data sets
2 Calculated from NBAL data received from WfW as at 21 December 2002.
3 Conservative estimates because certain data sets are unaccounted for.
4 Consists of Prosopis mapping entirely.

4.1 Eastern Cape

4.1.1 Data

The Eastern Cape is characterised by a paucity of IAP data (Table 4.1), especially in the central, northern and western regions (Fig 2.1; Appendix E). The coastal catchments are generally reasonably covered by WfW project areas, although NBAL data is sparse. Three comprehensive IAP data sets (Appendix C) other than WfW, CSIR and SAPIA, are shown and include:

- the Addo Planning Domain;
- MONDI Forests Open Area Management Plans in the vicinity of Maclear; and
- Coega Development Zone.

4.1.2 Gaps and priorities

Figure 2.2 and 2.3 show the WfW project areas and the identified gaps with priority ratings considering grazing and arable areas respectively. The current WfW project areas cover the southern coastal regions and are scattered over the north-eastern areas of the province. Large areas of the interior, with the exception of Mountain Zebra National Park and Lubisi Dam Qamata, have no active project areas or data. Under the grazing scenario, gaps of high and medium priority are located mainly in the north-eastern areas of the province. The arable scenario presents a similar picture, although there are fewer high priority catchments, and generally these are medium priority. The list of gaps and their associated IAP attributes are presented in Appendix F. Catchments flagged as priorities for compulsory water use licensing located in the northern areas of Knapdaar, Aliwal North, Burgersdorp and Molteno, could also be considered (Fig 2.2 and 2.3).

4.2 Free State

4.2.1 Data

Apart from 9km^2 WfW NBAL data, the CSIR NBAL data was the only data covering the Free State Province. It is therefore the most poorly covered province (Table 4.1). The CSIR data includes mostly detailed mapped riverine areas in the north eastern area of the province, and areas mapped at a large scale in the western parts and the eastern parts around Harrismith (Fig 3.1).

4.2.2 Gaps and priorities

Gaps have been identified in three areas: the eastern, southern and western parts of the province (Fig 3.2 and 3.3). These are related to the major river system of the Vaal and its associated catchments. Under the grazing scenario, two of the six high priority catchments occur in the western part around Wolwespruit and Jacobsdal, while three occur in the north eastern parts around Cornelia and the Vaal Dam. The final gap occurs on the Lesotho border in the south of the province near Zastron. A similar pattern occurs for the arable scenario in the southern and western areas of the province, but new high priorities are located around, Mirage, Dover, Cornelia and Kransfontein.

There are few WfW project areas within the province, especially in the central catchments of the province. The project areas existing are associated with the presence of dams or lakes, or conservation areas. There are a large number of catchments flagged as hydrological priorities, especially the Vaal catchment areas in the north and the south-western areas around the Kalkfontein and Gariep dams, of which only two catchments are covered by WfW project areas.

4.3 Gauteng

4.3.1 Data

Although Gauteng appears well covered by data (Table 4.1 and Fig 4.1), this high percentage is due to the Gauteng Natural Resource Audit alien data set, compiled by the Institute for Soil, Climate and Water for the Department of Agriculture, Conservation, Environment and Land Affairs (DACEL). This data set has mapped woody aliens only, and does not conform to WfW mapping standards. Its use is therefore limited for detailed planning. The WfW NBAL data covers a higher percentage of the Province than elsewhere, but its distribution is confined to the northern and north western areas of the province.

4.3.2 Gaps and priorities

The gaps and associated prioritisations are depicted in Figure 4.2 and 4.3. There are four catchments of high priority considering grazing (Fig 4.2), most notably the catchment around Magaliesberg. The medium importance of catchments adjacent to this area related to the World Heritage site in Krugersdorp in terms of conservation importance. The arable scenario provides six catchments of high priority (Fig 4.3).

4.4 KwaZulu-Natal

4.4.1 Data

Together with the Western Cape, KwaZulu-Natal has useful IAP data sets and consequently has relatively high data coverage of 6.67 % (Table 4.1). WfW data covers 2.62 % of the province, and is concentrated in the northern areas, north of Mtunzini, stretching inland towards Vryheid, and in an area stretching from Durban, through Richmond and Bulwer, to the Drakensberg. The catchments of this area are well covered by project areas (Fig 5.1). The parks and conservation areas are also well covered by data.

4.4.2 Gaps and priorities

Figure 5.2 and 5.3 show identified gaps and associated priorities. Botanical attributes are given in Appendix F. Few WfW project areas correspond with the hydrological priorities assigned. A revision of project areas is required. There are 7 and 3 high priority gaps for the grazing and arable scenarios respectively, while medium priority gaps are concentrated in three main areas:

- Catchments along the Pongola River;

- Several catchments along the coast; and
- Catchments in the foothills of the southern Drakensberg around Underberg.

4.4.3 Mapping Initiatives

Mondi have mapped most of their open areas in the province (Fig 5.1), but approximately 4000 ha in the Midlands, and areas north of Ulundi and east of Utrecht will be mapped in 2003. The open area management plans mapping include information on the vegetation type, dominant and sub-dominant IAPs, estimated coverage, density, and maturity level. It is recommended that this data be obtained for consideration in future planning.

4.5 Limpopo

4.5.1 Data

Limpopo is poorly represented by both WfW and other IAP data sets, with the exception of CSIR data. Despite covering a large area of the province, this data is at a very coarse resolution, and is therefore of limited use. The MONDI Open Areas, and point data recorded from The Rivers Health Programme along the Luvhuvhu river, are the only other data sets to have been identified. Together the WfW and Mondi Open Areas cover only 0.43 % of the province (Table 4.1 and Fig 6.1).

4.5.2 Gaps and priorities

The Sour Lowland Bushveld (Low and Rebelo 1996), identified as a vegetation type of conservation importance (Winter pers. comm.) is reasonably well covered by data and project areas, although several high and medium priority gaps using both grazing and arable scenarios were identified here (Fig 6.2 and 6.3 in the vicinity of Louis Trichart and Tzaneen). No gaps have been identified for the western section of the province. Several of the WfW project areas coincide with hydrological priorities, but there are still many hydrological areas requiring investigation, for example the Mogolakwena and Elands catchments.

4.6 Mpumalanga

4.6.1 Data

Although restricted mainly to the eastern parts of the Province adjacent to the southern section of the Kruger National Park (Fig 7.1), approximately 3.33 % of the province is covered by IAP data (Table 4.1). This includes WfW NBAL and Mondi Open Area data. Point data recorded by South African National Parks for the Kruger National Park and along the Sabie River to the south of the Park. The CSIR data covers many of the riverine areas, but low scale mapping only covers the north-eastern parts. Many of the WfW project areas in the north-west have no NBAL data.

4.6.2 Gaps and priorities

Due to a more comprehensive biodiversity data set for the province, all catchments were evaluated in the model. Priorities are shown in Figure 7.2 and 7.3. There are no major differences between the priorities identified in the arable and grazing scenarios. There are however more high and medium priority catchments in the arable scenario and this is expected due to most of the province being suitable for arable agriculture. Many of the catchments in Mpumalanga are of high hydrological priority, mainly in the western section of the province and along the Komati River. Many of these are not covered by WfW project areas.

4.7 Northern Cape

4.7.1 Data

The Northern Cape is characterised by a paucity of WfW data, which covers only 0.15 % of the province (Table 4.1). The Agricultural Research Council has mapped *Prosopis* using satellite imagery for a large area of the Northern Cape, which consequently results in the province IAP data coverage figure being elevated to 23.43 % (Fig 8.1).

4.7.2 Gaps and priorities

The hydrological priorities are reasonably well represented by WfW project areas, with the exception of those on south-eastern parts of the province (Fig 8.2 and 8.3). Three quaternary gaps, in the Richtersveld area, have been characterised as high priority in both the arable and grazing scenarios, while catchments stretching down the west coast have been uniformly flagged as medium. The grazing scenario results in more high priority areas, but in general medium priority gaps are consistent between the two scenarios. Priority ratings for catchments in Namibia should be ignored as agricultural potential was not used in their evaluation due to lack of data coverage. Catchments along the Orange river have been allocated a medium priority.

4.8 North-West

4.8.1 Data

This province is poorly covered by IAP data, which consists of WfW data covering 0.38 % (Table 4.1). This is however confined to the north western parts (Fig 9.1). Other than CSIR data, which is mapped at a low level of detail and covers a large area of the western region, no additional data sets were identified.

4.8.2 Gaps and priorities

No catchments of "high" priority were identified in the grazing scenario other than cross boundary catchments with Gauteng. Catchments of medium priority are located in the western areas, and some along the provincial border with the Free State (Fig 9.2). The arable scenario presents four catchments of high priority in the southern region of the province, bordering the Free State. There are few catchments of hydrological priority, and most, with the exception of those in the north eastern areas, north of Pilanesberg Game Reserve, are covered by WfW project areas.

4.9 Western Cape

4.9.1 Data

The Western Cape has several data sets other than WfW NBAL data (Fig 10.1). Along with WfW data, this results in a relatively high percent coverage of the province (Table 4.1). Data sets identified are the following:

- Agulhas Plain data from the Cape Planning Unit;
- Cape peninsula National Park;
- West Coast data from the Institute for Plant Conservation;
- Point localities of alien plants from Susanne Milton-Dean; and
- Botanical Society of South Africa - Point localities from the Cape Lowlands project for the Swartland and Overberg areas.

These are displayed in Figure 10.1.

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4.9.2 Gaps and priorities

It is evident that the hydrological priorities are generally not covered adequately (Fig 10.2 and 10.3). Five and four catchments of high priority were identified in both the grazing and arable scenarios respectively (Fig 10.2 and 10.3). Areas of medium priority have been identified in the Koringberg, Clanwilliam, Prince Albert and Stil Bay areas in the grazing scenario (Fig 10.2), while more medium gaps were identified using the arable scenario (Fig 10.3). These occur mainly along the west coast around Lambert's Bay, and Prince Albert area in the east of the province.

4.9.3 Mapping Initiatives

The Cape Peninsula National Park is currently updating the alien invasive plant map. This information should be available shortly.

4.10 Swaziland

4.10.1 Mapping Initiatives

A rapid assessment of IAPs in Swaziland will be undertaken early in 2003. A pre-Atlas project is underway, and is mapping aliens at an eighth degree grid cell scale. Species and density attributes are included.

5 FIELD SURVEY AND MAPPING METHODS

DWAF's approach to mapping alien vegetation is based upon Management Plan Areas (MPA's). Each polygon within a MPA uses NBAL identity to uniquely identify and attribute each polygon with a MPA. It is ultimately these areas which will require detailed mapping so that the identification and density of each species is known, and that effective management can therefore be exercised.

5.1 Review of methods

A number of methods are available for general vegetation survey and which can be used for alien mapping. These range from satellite imagery, through in-flight reconnaissance, video/aerial photography, to on the ground GPS. Remote sensing (e.g. Landsat/SPOT imagery) and spectral links with specific alien species has had, on the whole, limited success. For example, the technique is limited where natural vegetation and aliens have similar spectral patterns, and for mapping herbaceous species. Where the natural vegetation is grassland or even savanna with scattered trees, tall aliens can be detected. However, it is not regarded as an option in the Eastern Cape due to the heterogeneous nature of the landscape and vegetation of this Province. Recent advances in hyperspectral analysis are showing great promise, but this method still requires fine tuning and is also fairly costly. WfW (Eastern Cape) has suggested that satellite imagery might be useful for broad reconnaissance work. An assessment of the available methodology has thus been limited to that which is currently being used and evaluated by WfW. Such an assessment has been undertaken by the CSIR (Smith *et al*., 1999), a summary and modification of which is detailed in Table 5.1.

Table 5.1 Comparison of methods used in mapping alien vegetation. ***(Modified from Smith et al., 1999)***

CATEGORIES TO CONSIDER	HELICOPTER-BASED WITH GPS	VIDEO/AERIAL PHOTOS – IMMEDIATE FLIGHT	RECENT (<2 years) AERIAL PHOTOGRAPHY	FIELD MAPPING WITHOUT GPS	FIELD MAPPING WITH GPS
Time required	Quickest method, provided attributes are captured simultaneously, the GPS is set up correctly and the data it outputs is correctly formatted. Good weather is required to fly.	Large areas can be flown quickly, but processing is relatively laborious. Good weather is required to fly and then time to select images, interpret, ground truth and edit.	Large areas can be dealt with in short space of time. Mapping still needs to be captured	Maps of suitable scale must be available and reasonably accessible, else the person must be able to recognise and classify what they see. This can be the slowest method if time is required to walk the boundaries of the features to verify alien vegetation mapping or for detailed treatment area mapping. It can be sped up if the mapper delineates features from a vantage point first and then goes into each one to classify it. This vantage point method works particularly well for 1:250 000 and 1:50 000 scales. Maps still need to be captured after mapping is complete.	This is also relatively slow. The boundaries of features MUST be walked (or ridden). However, time is saved because no maps are drawn and the data is captured simultaneously, provided the GPS and related software are correctly set up.
Skills required	GPS training seems to be quick and straightforward but gaining experience and getting data in correctly can be time consuming. Accurate and quick aerial interpretation skills are also required. Good teamwork is also	Video interpretation requires time to develop skills in interpreting what is on the ground correctly. Experts are required to ground-truth the imagery. GIS / image processing skills are required.	Basic aerial photo interpretation required, with interpretation especially important for discerning alien vegetation. Data capture into GIS also required	Basic map reading, orientation and mapping skills are required. Vegetation interpretation skills are also required. Data capture facilities must be available to get the maps into a GIS.	Knowledge of the GPS and its software and good vegetation interpretation skills are required.

CATEGORIES TO CONSIDER	HELICOPTER-BASED WITH GPS	VIDEO/AERIAL PHOTOS – IMMEDIATE FLIGHT	RECENT (<2 years) AERIAL PHOTOGRAPHY	FIELD MAPPING WITHOUT GPS	FIELD MAPPING WITH GPS
	necessary.				
Accuracy	GPS accuracy can be very high if set up correctly. The mapped position of features relative to their real position depends on flying as close to the features' boundaries and as close to the ground as is possible and safe. Only the canopy can be interpreted. Lower storey aliens cannot be mapped, nor can rare occurrences always be seen.	If ground truthing and quality control is done properly, this is very accurate in terms of interpretation. Positional accuracy can depend on the quality of image rectification and the topography. Below-canopy species, rare to sparse occurrence and aliens that cannot be distinguished from indigenous vegetation cannot be mapped.	Accuracy highest with large scale (1:10 000) photo's, but diminishes with smaller scales	Interpretational accuracy can be very high, resulting in complete classification according to the standards. Positional accuracy can be highly variable. This method has the advantage of using observers eyes directly, especially useful for spotting rare individuals and small plants (< 2-5m canopies of colour similar to background such as blackwood in river bush and forest). The same goes for field mapping with GPS.	Interpretational accuracy can be very high, resulting in complete classification according to the standards. Positional accuracy can be very high if correct equipment and set-up are used. Small or thin features can be mapped accurately rather than having to map a line or point and buffer. Buffering results in areas that are too inaccurate to base a contract on.
Infrastructure required	Helicopters. Other aircraft can be used but helicopters are quick and most manoeuvrable. A good GPS and a computer to process the data, and someone proficient in GIS are also required.	Almost any aircraft, although fixed wing aeroplanes are fast. Video requires a substantial hardware and software investment e.g. frame grabbing and image rectifying, interface to GIS / digitising depending on how data are converted to coverages.	Minimal infrastructure – basically acquisition of appropriate aerial photo's and digitising facilities to capture and edit coverages.	Minimal infrastructure and a computer and digitiser facilities to capture and edit the coverages.	Good GPS, computer and software.
Cost	GPS equipment is getting cheaper, but helicopter hire is expensive. Post-	Video must be among the most expensive techniques; start-up costs are high and skills	Aerial photo's relatively cheap, but data capture can be expensive. Time required for	Field mapping itself can be quite cheap but data capture can be expensive. The time required may end up being	Differentially corrected GPS hardware is expensive. Real-time differential correction facilities add

CATEGORIES TO CONSIDER	HELICOPTER-BASED WITH GPS	VIDEO/AERIAL PHOTOS – IMMEDIATE FLIGHT	RECENT (<2 years) AERIAL PHOTOGRAPHY	FIELD MAPPING WITHOUT GPS	FIELD MAPPING WITH GPS
	processing can be quick if the data are correctly collected. If not, fixing the data can be expensive. Done correctly and carefully, helicopter-GPS is probably the least expensive for large-area, rapid mapping.	required are expensive, although when costed per hectare, the costs may be relatively cheaper.	the latter will also add to the overall costs.	expensive too.	considerably to the price (same points apply to helicopter-GPS mapping). However, if resources are shared and used continuously, the price per hectare coupled with the quality of the mapping can be very good value.
Terrain	In very rugged terrain, helicopter mapping works best with 1:50 000 maps or smaller fixed-wing aircraft, which are not manoeuvrable enough. Best for covering larger areas.	High relief is not suited to videography. Best for covering larger areas.	Any terrain, but best suited for flatter areas due to shading by cliffs and ravines	Any terrain. Best suited for detailed mapping in smaller areas and reconnaissance mapping in areas with good vehicle / foot access.	Almost any terrain. Some topography and land cover can obscure satellite signals. Best suited for mapping small areas at a time.

Each method needs to be treated on its own merits, given the variation in landform and topography experienced across the country. The two methods most commonly used are digitising off an orthophoto, and GPS field mapping (see below, under Section 5.1.2). It is recommended that the above modelling and planning be conducted at a provincial level if possible, with the most up to date data. Thereafter, gaps identified and the biophysical nature thereof will determine the most appropriate mapping methods to be used.

5.1.1.1 Orthophoto mapping

In the Eastern Cape a dedicated mapper has been appointed. Here use is made of 1:10 000 orthophotos with alien vegetation occurrence recorded on these maps. This is achieved with ArcView software, using digital 1:10 000 orthophotographs as a backdrop.

5.1.1.2 Video imagery

This has been used in KwaZulu-Natal, where quaternary catchments are flown. The images are captured digitally, geo-referenced and corrected. The technique is effective where there are major contrasts between natural and alien vegetation, but is only suitable for non-woody (i.e. grassland) vegetation.

5.1.1.3 Video photography

This is being used by the Institute for Soil, Climate and Water. A combination of video-photography and satellite imagery is used and, although in an experimental stage, appears to provide accurate data.

5.1.1.4 GPS (aerial flight)

The use of this method has met with mixed results in the Eastern Cape. Despite the accuracy of this method, there are a number of problems. These include occasional loss of satellite coverage (important in deep ravines) and a limited memory capacity.

5.1.1.5 Satellite imagery

Despite its apparent appeal, this technique has a number of limitations, including lack of contrast between natural and alien vegetation, poor detection of aliens in small diameter clumps of less than 30 metres, and steep slopes. Apparently successful and accurate mapping of *Prosopis* sp. has been carried out in the Northern Cape Province.

5.1.2 NBAL mapping

For the purpose of WfW programmes, alien vegetation can be mapped using two basic techniques:

- Digitising off orthophotos; and

- GPS field mapping.

Standards for mapping of each “alien polygon” are summarised in Table 5.2 (from DWAF 2003, Vol. 4.1).

Table 5.2 Alien polygon mapping standards

Format:	ArcView polygon shapefile in projection and datum specified by Working for Water. The projection will be Transverse Mercator and the datum will be WGS84.
Spatial accuracy:	Boundaries of alien vegetation polygons need to be mapped to varying accuracies depending on the density of alien vegetation within that polygon. The maximum spatial error per density are as follows: • Closed = 2 m • Dense = 2 m • Medium = 5 m • Scattered = 10 m • Very scattered = 50 m • Occasional = 50 m • Rare = 50 m
Topology:	All polygons in the final ArcView shapefile should have: • Vertex lengths of less than 5 m except along straight boundaries where 10 m vertices are acceptable • No sliver polygons • No overlapping polygons • A unique NBALID

The species attributes required for each polygon are as follows:

- Species – 3 most dominant species;
- Age or size (mature, adult, young, seedling, mixed age);
- Density (0.01% - rare; >0.01 – 1% - occasional; >1 – 5% - very scattered; >5 – 25 – scattered; >25 – 50% medium; >50 – 75% - dense; >75% - closed) (average for species within the area).

5.1.3 Digitising orthophotos

Standards for mapping orthophotos are shown in Table 5.3 (taken from DWAF, 2003 Vol. 4.1).

Table 5.3 Orthophoto mapping standards

Ground pixel resolution:	0.4 to 0.8m per pixel
Spatial accuracy (X,Y):	2 to 5m or better over 66% of the total project area.
Image quality:	The final ortho-rectified mosaic or orthophoto sheets should be uniform in terms of colour, brightness and contrast
Coverage:	The orthophoto mosaic should extend beyond the project boundary on all sides by a minimum of 200m

The above standards will apply whether the source of the imagery is aerial photography, medium format photography, digital camera imagery or satellite imagery. If existing photography is to be used to produce the digital orthophotography then the photography must have been taken in the past 2 years (DWAF, 2003).

5.1.4 Hardcopy working maps

These are required to establish the locality of the NBAL mapping project, to capture areas cleared to date and for capturing in the national GIS database.

5.1.5 NBAL mapping techniques

Table 5.4 below presents a comparison between the use of digitised orthophotos and GPS mapping (from DWAF, 2003 (Vol. 4.1)).

Table 5.4 Comparison of NBAL mapping techniques

CATEGORIES TO CONSIDER	AERIAL PHOTOGRAPHY WITH HEADS UP DIGITISING AND FIELD VERIFICATION	FIELD MAPPING WITH GPS
Time required	Large areas can be flown quickly, but orthophoto production is relatively time consuming. Good weather is required to fly the survey and then further time is needed to perform a Ground Control Point (GCP) survey, to scan the air photography, and to produce the digital orthophoto.	This method is also relatively time consuming. The boundaries of features MUST be walked (or ridden). Steep terrain and dense bush has considerable influence on speed of mapping. However, time is saved in the short term because no orthophoto's have to be produced and the NBAL attribute data is captured simultaneously with the field work.
Skills required	Air survey needs to be flown. Orthophoto production requires experienced photogrammetrist. Air photo interpretation requires time to develop skills in interpreting what is on the	Good knowledge of the GPS and its software. Good vegetation interpretation skills are required. GIS skills required to edit and clean GPS data and ensure final format complies with WfW standards.

CATEGORIES TO CONSIDER	AERIAL PHOTOGRAPHY WITH HEADS UP DIGITISING AND FIELD VERIFICATION	FIELD MAPPING WITH GPS
	ground correctly. Good vegetation knowledge and map reading skills required to ground-truth the imagery. GIS / image processing skills are required.	
Accuracy	If ground truthing and quality control is done properly, this is very accurate in terms of interpretation. Positional accuracy depends on quality of image rectification and the topography. Below-canopy species and aliens that cannot be distinguished from indigenous vegetation cannot be mapped without detailed field verification.	Interpretational accuracy can be very high, resulting in complete classification of species and ages according to the standards. Positional accuracy can be very high if the correct GPS equipment and set-up are used. Interpretation of densities of polygons and species can be more difficult than from air photography.
Infrastructure required	Requires air photography to be flown and digital orthophotography to be produced. Fixed wing aircraft and a 9" photographic camera are typically used. Photogrammetric software and a good PC are required to produce the orthophoto. A good computer with GIS software and large memory capacity required to store the digital orthophotography is required.	Good GPS, decent computer and GIS software.
Cost	For mapping of complete project areas (100+ km^2) this is a very cost-effective option. Rands per mapped alien hectare can be very high for jobs where the hectares of alien to be mapped are small. Orthophoto production constitutes a large proportion of overall cost.	A GPS with post-processing differential capabilities is expensive. Real-time differential correction facilities add further to the price. Cost per mapped hectare is low for small projects such as ad-hoc mapping or single contract mapping, but air photography soon becomes more cost-effective when larger areas need to be mapped.
Terrain	Best for covering larger areas. Terrain, accessibility and vegetation are not as much of an issue as for GPS mapping. However, not all species can be easily mapped from air photography. Indigenous vegetation is difficult to differentiate from alien vegetation and in many cases, alien plants may grow amongst the indigenous vegetation.	Some topography and land cover can obscure satellite signals. Steep terrain and dense bush can slow progress and make work very difficult. Best suited for mapping small areas at a time.

5.1.6 Heads up digitising and field verification

This mapping approach should consist of most or preferably all of the following stages:

- Orthophoto production (if required);
- Heads-up digitising in a GIS software;
- Field verification to capture age, species and density, and possibly also walk time, drive time, accessibility and slope per polygon mapped;
- Capture field verified data to GIS database;

- Compile data into final format according to Water*Works* specifications and requirements; and
- Check final data and deliver to Working for Water for approval.

All data need to be captured on a GIS, and require field verification.

5.1.7 GPS-based mapping and data capture

This mapping approach should consist of the following stages:

- Set up GPS with correct settings and appropriate data dictionary;
- Infield GPS mapping and data capture;
- Download GPS data to PC;
- Differentially correct GPS data (unless real-time Differential GPS was used);
- Export data to GIS format in required projection and datum;
- Clean, edit and smooth GPS data in GIS to ensure it conforms to WfW standards in terms of topology and accuracy;
- Check and finalise attribute data associated with each polygon mapped;
- Compile data into final format according to Water*Works* specifications and requirements;
- Check final data and deliver to Working for Water for approval;

For effective GPS use the GPS instrument needs to be set-up, on the ground mapping undertaken, and all data captured onto a GIS database.

5.1.8 Aerial photography

This is usually conducted at 1:30 000 or 1:20 000 scale and in black and white or colour. Contrast should be good so that vegetation detail can be clearly depicted. Adequate coverage of the area must be photographed with a minimum 5 km overlap on all boundaries of the survey area. Photographs should be taken vertically, with the sun no less than 30 degrees above the horizon (to avoid shadowing) effects. If existing photography is to be used to produce the digital images, it should conform to the above specifications and must have been taken in the past 2 years.

5.2 Costs

A summary of costs is provided in the recent evaluation of alien mapping carried out by the WfW Eastern Cape office in 2003 (see Table 5.5 below).

Helicopter mapping is possibly the cheapest for large areas, with video photography being the most expensive. Mapping of aerial photos appears to be the most economical but this must be weighed against the cost of reliability/photo age. GPS, which provides an accurate, on the ground, record of alien vegetation, is nevertheless expensive.

Table 5.5 A summary of the techniques and costs for mapping alien invaders.

MAPPING TECHNIQUES	COSTS/HA	"REGIONAL COSTS"	HA/DAY	ACCURACY	TIME NEEDED TO COMPLETE THE E CAPE IN YEARS***
Ground mapping	R3.021*	R48M	225	10-50 m	200 (1 person)
GPS helicopter	R0.88**	R14M	10 000	10-30 m	4.4 (1 chopper)
GPS helicopter with post field processing (estimated)	R1.80	R28.8M	10 000	10-30 m	4.4 (1 chopper)
Satellite-Video imagery (ARC)	R10.53	R168M	500	2-3 m	88
Video photography (MBB) with desktop data capture	R1.80	R28.8M	5000	10-50 m	8.8
Video Photography with field GPS data capture	R2.1	R33.6M	3800	10-50 m	11.69
Satellite imagery	R0.018	R297 400	20 000	30 m	2.2

* *This price was calculated using the services of a part time data technician at an hourly rate of R15.65*
** *This price excludes the post mapping processing, data manipulation and cartographic costings.*
*** *These extrapolations were made on the assumption that the E Cape covers approximately 16 x10^6 hectares.*

The regional costs are calculated to give a rough impression of the relative costs if the entire Eastern Cape was to be mapped using each technique individually. This is obviously not possible from a cost viewpoint and certain techniques being unsuitable under certain conditions – and merely included for comparative purposes.

Clearly the high costs of satellite/video photography are far outweighed by the relatively inexpensive methods of satellite imagery, GPS (helicopter) and video photography. However, accuracy is of crucial concern and this would tend to discount the use of satellite imagery and favour the GPS method. Ground mapping should also be a consideration, given the greatly heightened knowledge of terrain (and therefore approach to alien clearing) which is derived from this approach.

6 RECOMMENDATIONS AND WAY FORWARD

6.1 Desktop strategic planning

As a lack of IAP data exists, geographically and according to the WfW standards and requirements for IAP data, the SAPIA data will act as a crucial source for closing the gaps until comprehensive surveys are carried out. This data needs to be integrated into planning.

In light of the aforementioned limitations of the gap analysis model, and the necessity for efficient and repeatable strategic planning, it is recommended that a more comprehensive and rigorous spatial modelling approach be adopted, which is based on well documented Multi-criterion Evaluation (MCE) techniques. An example of a model, is that which is conducted through raster modelling in GIS software, based on the Weighted Linear Combination (WLC) MCE technique. In this technique, weights are applied to each factor through pairwise comparison, and factors are then aggregated linearly to produce a single priority layer. There are many variations to this approach, and need to be considered.

This model is conceptualised in Figure 11. Five factors including a SAPIA Index (which will need to be derived), biodiversity, hydrology, rangeland potential and invasion potential are weighted, and then aggregated to produce a single "biophysical" priority layer. This layer is then subjected to a poverty filter which results in the final priority layer. WfW project areas are then overlayed onto the grid for comparison.

In order to achieve this, the following processes and activities are required:

- Workshops with a core working group to review the current model, to design an appropriate model if necessary, and to formulate an action plan for the modelling process;
- Acquisition and analysis of SAPIA database and data set of rangeland potential;
- Updating and review of all criteria on a provincial basis through the collection of data, and holding of workshops with recognised local experts in order to produce standardised data sets for incorporation into the model.

6.2 Field Mapping

Accuracy and not absolute cost should be the defining criterion for selection of method. It is recommended that for Phase 1 (reconnaissance), use is made of satellite images and general aerial photography. Detailed work (Phase 2 (operational)) should employ a GPS method, coupled with digital 1:10 000 orthophotography. Ground truthing is probably necessary in many, if not most cases, for identification of species.

7 CONCLUSIONS

This report presents information on the results of the data audit, which indicate that there are few comprehensive data sets existing, other than the WfW and SAPIA data sets. The problems of scale with regard to the extensive CSIR data set are noted, and several localised IAP data sets have been identified. These are located primarily in the Western and Eastern Cape Provinces, and KwaZulu-Natal. A geographically large area in the Northern Cape is being mapped for *Prosopis* infestation, from satellite imagery, while a map of urban aliens has been compiled for the Gauteng Province. This has no species attributes and so its usability is limited. No data (other than CSIR or WfW) exists for the Free State, North West and Limpopo Provinces (with the exception of point localities of aliens mapped along the Luvhuvhu River as part of the Rivers Health Programme). Other State of the rivers reports have been compiled since data collection took place, and these data will need to be collected as and when the data becomes available. Mpumalanga, KwaZulu-Natal and the Eastern Cape have large areas of forestry, for which only MONDI and SAFCOL have indicated weed data within compartments exists. There are no major mapping initiatives with the exception of Swaziland, which has an alien invader atlasing project planned.

The gap analysis model presented provides a preliminary assessment of gaps, the methodology and modelling process of which needs to be revised and updated on a regular basis. This could provide the backbone for more integrated planning, as it includes biodiversity, hydrological, agricultural and socio-economic factors. It is recommended that additional botanical factors, for example rate of spread of aliens, needs to be included.

A review of IAP mapping and survey methods has been conducted in terms of methodology, advantages and disadvantages, and costs thereof. The specific methods to be selected for an identified gap need to consider the biophysical nature of the area.

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9 ACKNOWLEDGEMENTS

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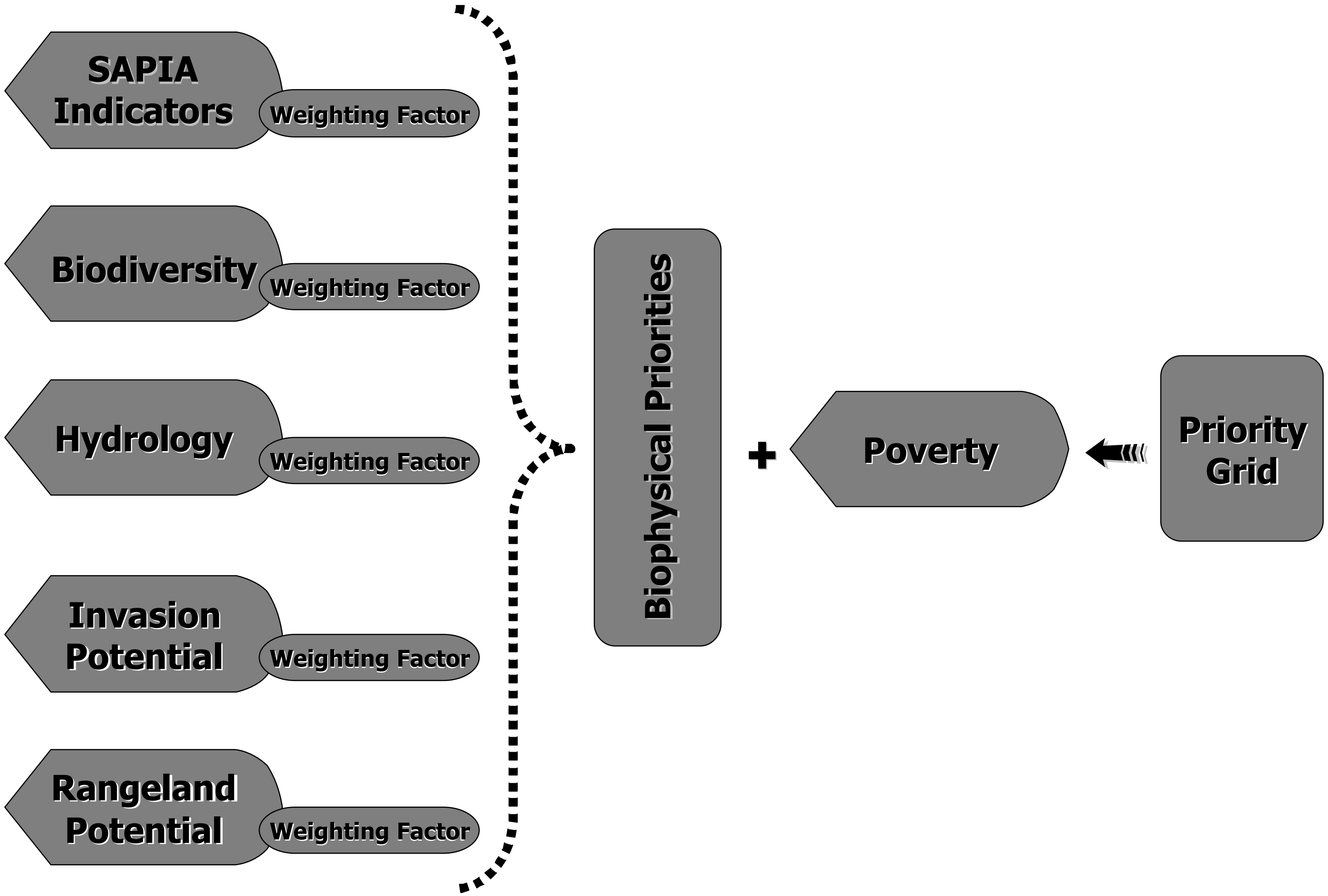

Figure 11 Recommended Spatial Gap Analysis Model

Appendix A

Survey Questionnaire

Appendix B

List of People and Organisations Surveyed

Appendix C

List of Data Sets and Analysis

Appendix D
Metadata

Appendix E: Figures 2 to 10

Provincial IAP and Gap Analysis Maps

Appendix F

List of Gaps and Alien Invasive Botanical Attributes per province

Eastern Cape

Free State

Gauteng

KwaZulu-Natal

Limpopo

Mpumalanga

Northern Cape

North West

Western Cape

SPECIALIST	ACRONYM
Barrie Low	BL
Dave Richardson	DR
Erich Fuls	EF
George Bredenkamp	GB
Mervyn Lotter	ML
Noel van Rooyen	NvR
Peter le Roux	PLR
Pieter Winter	PW
Roy Lubke	RL
Susanne Milton-Dean	SM
Tim O'Connor	TOC

Appendix G

Minutes of meetings

Appendix H

Progress Reports

Steffen, Robertson and Kirsten (South Africa) (Pty) Ltd

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