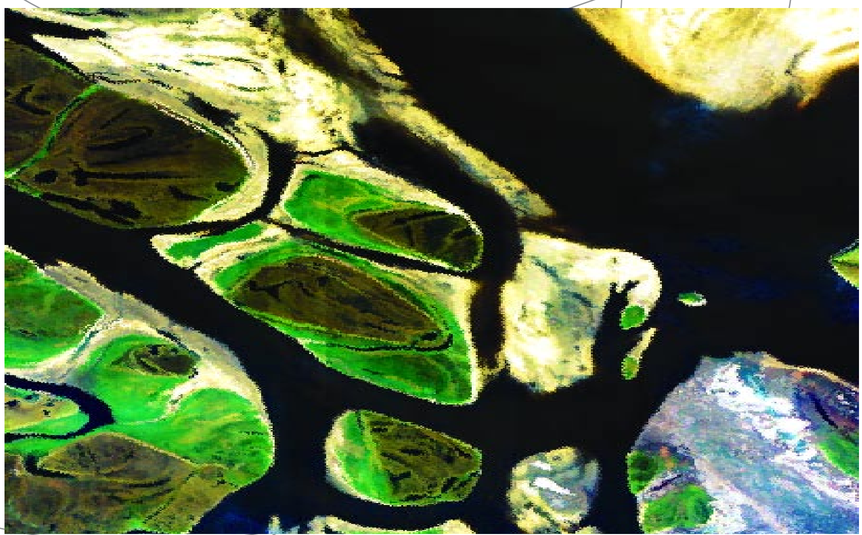
Ramsar Technical Reports



Low-cost GIS software and data

for wetland inventory, assessment & monitoring

John Lowry

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Ramsar

Ramsar Technical Report No. 2

Low-cost GIS software and data for wetland inventory, assessment and monitoring

John Lowry
Supervising Scientist Division, Department of Environment & Heritage, Australia

Ramsar Convention Secretariat
Gland, Switzerland
June 2006

Published by the Secretariat of the Convention on Wetlands (Ramsar, Iran, 1971)

This report should be cited as: Lowry, J. 2006. Low-cost GIS software and data for wetland inventory, assessment and monitoring. Ramsar Technical Report No. 2. Ramsar Convention Secretariat, Gland, Switzerland. ISBN 2-940073-30-9.

Series editors: Heather MacKay (Chair of Ramsar Scientific & Technical Review Panel), Max Finlayson (former Chair of Ramsar Scientific & Technical Review Panel), & Nick Davidson (Deputy Secretary General, Ramsar Convention Secretariat).

Editing & layout: Dwight Peck (Ramsar Convention Secretariat).

Ramsar Technical Reports are designed to publish, chiefly through electronic media, technical notes, reviews and reports on wetland ecology, conservation, wise use and management, as an enhanced information support service to Contracting Parties and the wider wetland community in support of implementation of the Ramsar Convention.

In particular, the series includes the detailed technical background reviews and reports prepared by the Convention's Scientific and Technical Review Panel (STRP) at the request of Contracting Parties, which would previously have been made available in most instances only as "Information Papers" for a Conference of the Parties (COP). This is designed to ensure increased and longer-term accessibility of such documents. Other reports not originating from COP requests to the STRP, but which are considered by the STRP to provide information relevant to supporting implementation of the Convention, may be proposed for inclusion in the series. All Ramsar Technical Reports are peer-reviewed by the members and observers appointed to the STRP.

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For further information please contact:

Ramsar Convention Secretariat
Rue Mauverney 28
1196 Gland
Switzerland
Fax: +41 22 999 0169
e-mail: ramsar@ramsar.org
Website: http://www.ramsar.org

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Foreword

At the first meeting of the Conference of the Parties to the Ramsar Convention, in 1980, and regularly since then, the Contracting Parties have recognized the need for wetland inventories in their planning for the wise use of the wetlands in their territories. In recent years, the Parties have adopted detailed guidance for the preparation of wetland inventories developed from a global review of wetland inventory and building on a pivotal workshop held during the 2nd International Conference on Wetlands and Development, Dakar, Senegal, 1999. There has also been increased attention within the Convention's Scientific and Technical Review Panel (STRP) to providing decision-makers and managers with practical advice on the roles of inventory, assessment and monitoring for maintaining the ecological character of Ramsar sites and other wetlands. This culminated in November 2005 at the ninth meeting of the Conference of the Parties with acceptance of an integrated framework for wetland inventory, assessment and monitoring.

All of these trends in the development of the Convention's body of guidance for Parties have been facilitated by the modern evolution of software, hardware, and procedures for handling Geographic Information Systems (GIS) data, especially at costs that are within the reach of a wide range of practitioners.

In this report, John Lowry, the GIS Officer at eriss, Australia's Environmental Research Institute of the Supervising Scientist, provides an overview of the present availability and uses of GIS data and surveys the most popular software products, particularly for the benefit of Parties that do not have a large fund of financial and staff resources to draw upon. Thus the information here supplies a very useful adjunct both to the various kinds of Guidelines already adopted by the COP and to others now in preparation.

The value of GIS and remote sensing for wetland inventory, assessment and monitoring is increasingly being illustrated in many practical cases around the world. This report complements the efforts to raise awareness about this technology and to bring it to the attention of a wider range of potential users and beneficiaries working to secure the wise use and maintenance of the ecological character of wetlands.

Heather MacKay	Max Finlayson	Nick Davidson
Chair of Ramsar Scientific & Technical Review Panel	former Chair of Ramsar Scientific & Technical Review Panel	Deputy Secretary General, Ramsar Convention Secretariat

Summary

Low-cost Geographic Information System (GIS) software and data have the capacity to be an extremely valuable tool for wetland inventory, assessment and monitoring applications. Specifically, their ability to integrate data from different sources, and then interrogate and query those datasets in a spatial context, can enable tasks to be undertaken in a cost and time-efficient manner. Potential applications include calculating the areal extent of wetlands; classifying wetlands; and identifying wetlands under threat. Significantly, the availability of low-cost GIS datasets is increasing, particularly through the use of Internet mapping technologies. In addition, many government agencies, and data custodians, are increasing and/or simplifying the processes involved in acquiring data.

However, potential GIS users need to be aware of a range of issues and limitations associated with the use of GIS software and data before they initiate a project using GIS products. These include issues associated with the scale at which a dataset may be employed and the nature and character of the data represented. In the latter case, for example, a wetland dataset may not reflect the full range of temporal characteristics of the wetland. Similarly, the successful integration of different datasets is dependent on the user being conversant with concepts such as projections, spatial completeness and topology before any analytical functions can be performed. GIS users also need to be familiar with the concepts of metadata and data management. The successful application of low-cost GIS data and software is dependent on the skills of the user.

GIS software and data are most beneficial to wetland inventory, assessment and monitoring applications when integrated with remotely sensed data, with the latter providing a temporal perspective of changes in the environment and means of identifying or classifying landscape features. Importantly, the use of GIS does not completely replace the need for ground truthing or other means of data validation, although it may be used to develop more efficient and effective validation programs.

1. Background and introduction

Remote sensing and Geographical Information System (GIS) technologies are increasingly employed as integral components of environmental management, assessment and monitoring activities world wide. In large part, this has been due to the increased accessibility over the past decade of spatial datasets and the profusion of remote sensing and GIS products with enhanced integration and querying capabilities.

In recognition of this increasing use of GIS and related technologies, the 8th meeting of the Conference of Parties to the Ramsar Convention (COP8, Valencia, 2002) requested the Convention's Scientific and Technical Review Panel (STRP), working with Wetlands International and the Ramsar Secretariat, remote sensing agencies and other interested parties, to review further the application of remote sensing data, low-cost GIS and classification systems in wetland inventory. These findings were to be presented at the 9th meeting of the Conference of Parties (COP9; Resolution VIII.6) to enhance the suite of guidance available to Contracting Parties on aspects of wetland inventory, assessment and monitoring.

In response, this review and guidance has been prepared to provide a general introduction to GIS issues, its application not only for wetland inventory, but also for wetland assessment and monitoring purposes and other applications, in order to cover the full scope of the integrated framework for wetland inventory, assessment and monitoring that was prepared concurrently by the STRP (COP9 Resolution IX.1 1 Annex E). The review outlines data management issues and provides guidance on a set of criteria which should be applied by those considering using GIS systems for wetland data handling and management. Information on available data viewer software and low-cost GIS products is provided, focusing on the suite of products produced by ESRI (the Environmental Systems Research Institute), which are in increasingly wide use. Similar analysis of other available software is not undertaken in this report.

Wetland inventory, assessment and monitoring require different types of information depending on the knowledge needs. While all three activities are related, and practitioners advocate multi-scalar approaches at different geographical scales, these activities rely on the use of many different data sources. A number of initiatives have addressed or are addressing the use of remote sensing and/or GIS for wetland applications. For example, the Asian Wetland Inventory (AWI) (Finlayson et al. 2002) recommends a hierarchical map-based approach, with four levels of detail related to map scale that are contained within a standardised GIS format.

The Millennium Ecosystem Assessment has evaluated the condition, status and trends in global ecosystems, including wetlands (Finlayson et al. 2005), and applications of remote sensing (DeFries & Pagiola 2005). The European Space Agency's project Treaty Enforcement Services using Earth Observation (TESEO) has evaluated the use of remote sensing for wetland inventory, assessment, monitoring and site management, and further such work on a number of Ramsar sites is underway through its GlobWetland project (D. Taylor pers. comm.).

What are Geographic Information Systems?

A GIS is a system for management, analysis, and display of geographic knowledge, which is represented using a series of information sets. The information sets include geographic datasets (file bases and databases of geographic information - features, networks, topologies, terrains, surveys, and attributes); collections of geo-processing procedures for automating and repeating numerous tasks and for analysis; and metadata.

The conservation, restoration, and management of wetlands require knowledge of the wetland's functional relationships and key components of soils, elevation, hydrology, and hydrophytic plants, as well as influencing functions such as climate, wildlife, and human interventions. A GIS can spatially represent all these components, compile and store data, analyse, retrieve information, update, query, filter, sort, display, and be used to determine patterns and relationships by theme overlays.

From the outset, it is important for the potential GIS users to identify what their requirements and capabilities are and what they hope to achieve through the use of a GIS system. This will help them to assess the level of GIS software required, and then assist in selecting the specific packages which are commercially available. The criteria provided in section 9 are designed to assist users in making these choices.

Most GIS software packages currently in operation utilise either the MS Windows operating system or at the very least a basic Windows-style graphical user interface. Consequently, the functions and tools in many packages are similar.

Most GIS now offer varying degrees of functionality for the two basic types of "map" or spatial data:

i) discreet object types of data (also known as 'vector' data); and

ii) continuous or gridded forms of data (known as 'raster' data).

Using 'vector' data, features such as sample locations may be represented as points, rivers or roads as lines, and vegetation communities as polygons in a dataset. Remotely sensed images (aerial photographs, satellite images) and digital elevation models are examples of raster datasets commonly used in a GIS.

GIS software can be divided into three broad categories, depending upon their power, complexity and cost:

i) ***Data viewer or reader***: provides basic data display, and viewing, and has limited data query and analysis capability (generally costs less than US$1,000 and is often available free of charge);

ii) ***Desk-top GIS***: enables data integration / compilation, editing, query and analysis (prices typically range from US$500-US$3,000 for the basic models of different packages); and

iii) ***Workstation (high end):*** has capability for high-level modeling, editing and analysis of datasets (cost can be over US$15,000 for a workstation GIS with the complete suite of GIS software extensions and add-ons).

Unfortunately, there is not always a correlation between price and the capability / functionality of the system or its 'user-friendliness'. Indeed, the ease of use can range from simple to extremely complex, irrespective of the level of the software being employed.

Within each of these three categories there are a large number of different types of GIS packages, each suited to particular uses, users, and budgets. The generic characteristics of these categories – price range, hardware and software requirements, user skill needs, and their potential applications – are summarised in Table 1. The prices for specific software packages are not provided, since prices vary from country to country and the price of the software may fluctuate as the value of the local currency fluctuates against the US dollar. Most software companies offer substantial non-profit, educational, bulk, and other discounts, which should be investigated on a case-by-case basis.

Recent developments in computing – the growth of the Internet, advances in Database Management System (DBMS) technology, object-oriented program-

Table 1: Characteristics of different categories of GIS

Characteristics	GIS data viewers	Desktop GIS	High-End GIS
Computer hardware required	Desktop personal computer, some can be run from a single compact disk without installing new software on the computer itself	Desktop personal computer, colour printer	Workstation (more powerful than a typical personal computer) and frequently a separate database server, digitizing hardware, high-end printer or plotter
Approximate cost for a first user in an organization	Free or low-cost	$US100-$1500 (as of year 2000)	$US 15,000 + (as of year 2000)
Primary users	Non-GIS staff, the general public	Full- or part-time GIS specialists, often in smaller organizations, and nonspecialists (for applications customized from standard software)	Full-time GIS specialists
Major uses	Querying and displaying a specified dataset provided by a public agency or other organization, sometimes even by a software company; usually cannot be further customized by users, or accept additional data	Database management, queries, and display, often at a project level	Full-fledged data & and application development, statistical analysis, and high-quality map production, often enterprise-wide or over a network

ming, and mobile computing – have led to an evolving vision and role for GIS (ESRI 2004). A recent focus has been the centralization of GIS software in application servers and Web servers to deliver GIS capabilities to any number of users over networks (Figure 1). Focused sets of GIS logic can be embedded and deployed in custom applications. And increasingly, GIS is deployed in mobile devices (laptop and palmtop computers) for field GIS applications.

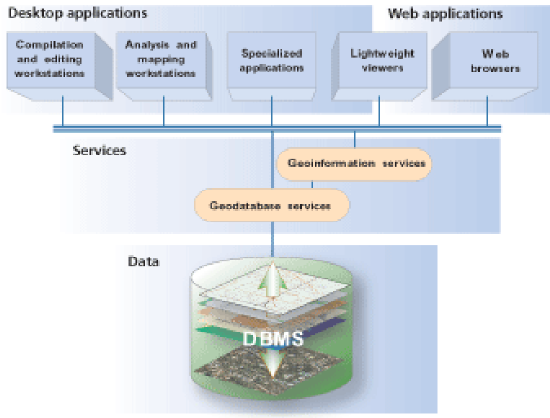

Figure 1. The application of GIS services through Web servers

It should be emphasised that the quality and usefulness of the products generated by a GIS will be affected by both the quality of the data and the quality and skill of the staff producing the data. Considerable attention should be paid to ensuring the quality and competency of both.

Attention should also be paid to the infrastructure required to use a GIS. Specifically, the computer on which the GIS software is installed, and on which data are generated and stored, should have sufficient capacity to run the program and open and view data without unduly slowing or hampering the operation of the computer. It is important to understand that the creation, manipulation and analysis of some datasets – particularly image or raster data – require extensive hard disk space, plus processing capability on the computer, both for opening and viewing the actual data itself and for dealing with temporary files which may be created during the analysis or manipulation of the data.

The question of scale

Most GIS datasets are usually created with a specific application in mind – be it representation of rivers, vegetation communities, lakes or areas subject to inundation. It is important to understand that these datasets are intended to be used within a specified scalar range.

The scale at which a dataset has been created reflects its intended use. For example, drainage features which have been compiled to a nominal scale of 1:1,000,000 are generally intended for broad-scale use, and thus should not be utilised at local or site scale. The accuracy and usefulness of key features of the data – such as their position, area and shape – will be degraded if applied at an inappropriate scale and will result in a misleading, inaccurate or erroneous interpretation of the features represented. Similarly, data compiled at a local (e.g., 1:100,000 - 1:250,000) or small scale (e.g., <1:50,000) would be inappropriate for broad-scale applications, as the level of detail is too great to be clearly or usefully represented.

Considerable thought should therefore be given to determining the most appropriate scale at which data should be either created or compiled. A key factor which should be considered is the intended use or application of the data – whether it is intended for local, regional or broad-scale application.

What are "low–cost" GIS?

For the purposes of this guidance, "low–cost" GIS refers simply to the cost of acquisition of the software and data. In this context, low-cost GIS software specifically refers to those software packages which fall into the categories of data viewers or readers or desktop GIS. 'Low-cost' does not include issues and costs of the ease of use of the software, staff training required, or the cost of annual support for the software. It is important to note that whilst the initial financial outlay for the software may be low, the overall investment in terms of training and technical support required may considerably exceed the initial outlay. Similarly, low-cost data refers to the cost of the data acquisition, rather than the processes or costs involved in data creation. Low-cost data are generally available at a large (broad) spatial scale. Finer scale data, with some exceptions, are not yet widely available on a low-cost basis.

Therefore, it must be emphasised that any agency or organisation which is in the process of acquiring low-cost GIS software or data should have sufficient resources for training, support, and data acquisition, in addition to the funds needed to acquire the software and initial datasets.

Notwithstanding the rapid advances and improvements in GIS software, and in the availability of GIS data, there are still a number of significant limitations in the application of GIS software and data to wetland inventory, assessment and monitoring. The primary limitations are inadequate training in the use of the GIS software and in the application of the specific datasets.

The creation and maintenance of metadata (information about the dataset(s)) is critical in addressing both limitations, as it describes the dataset. Metadata typically include information on the scale at which the data was created, the reliability of the dataset (including the scales at which it may be reliably applied), and the methods used for the creation of the dataset. This information in the hands of a competent user should prevent information being misused and misinterpreted.

2. Using low-cost GIS for wetland inventory

The increasing recognition of the importance of wetland ecosystems to the economic and environmental health of society has stimulated renewed interest in identifying the distribution, character and extent of wetlands. Significantly, the Ramsar Convention on Wetlands has advocated the development of national wetland inventories (Ramsar, 1996) and requested all Contracting Parties to collate appropriate information sets. Whilst a global review of wetland inventory undertaken for the Ramsar Convention (Finlayson & Spiers 1999; Finlayson et al. 1999) identified the extent of wetland inventory information available within each Ramsar region, it also identified substantial shortcomings in the knowledge of the distribution of wetlands and in the manner and methods which were used to collate this information.

That report (*Global review of wetland resources and priorities for wetland inventory – GroWI)* also contained recommendations covering the need to improve the accuracy of quantifying and describing the global wetland resource, as well as to provide the basic or core information needed for managing wetlands. It was recommended that national wetland inventory focus first on describing the location and extent of each important wetland as a forerunner to collecting further management-oriented information. In order to do this, standardized protocols for data collection, collation and storage which included the use of relatively new techniques and technologies for collecting and storing spatial information (e.g., remotely sensed data and geographical information systems - GIS) were considered essential, as was a centralized national metadatabase.

In response, and as a step towards assisting countries to improve the quality and extent of wetland inventory, in 2002 the Ramsar Convention adopted a Ramsar "Framework for wetland inventory (COP8 Resolution VIII.6). This framework, and some subsequently developed inventory methodologies such as the Asian Wetland Inventory, recommends a spatial-scale hierarchical approach to inventory (Figure 2) and places considerable emphasis on the appropriate use of remote sensing and GIS technologies in wetland inventory (Finlayson et al. 1999, 2002).

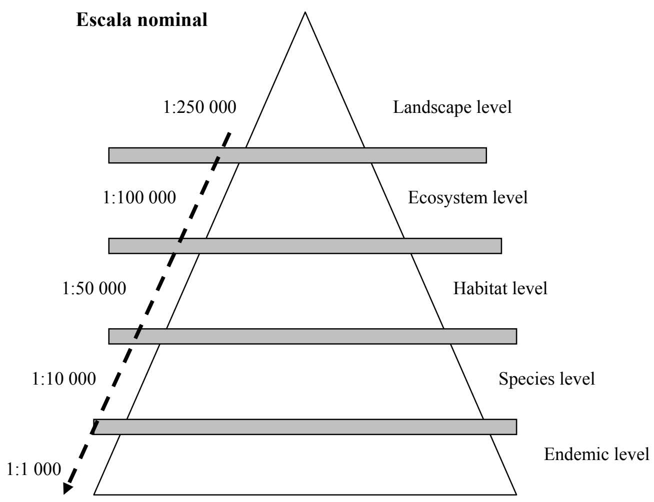

Figure 2. Hierarchical framework for wetland inventory

Whilst Finlayson & Spiers (1999) noted the absence of existing or available wetland information for much of the world, it is important to note that in many countries, other datasets – e.g., soils, topography, drainage – have been mapped, collated and compiled by national agencies, institutions and private organisations for many years. These datasets, which are becoming increasingly available at multiple scales, may be able to be used to support wetland inventory at national, regional or sub-catchment scale. Much of this information is now available at a nominal cost (or even completely free of charge) thanks to the development of the Internet, which has played a key role in the development of low-cost GIS datasets.

Equally important has been the increase in the range of desktop GIS packages and the increasing adoption of desktop GIS technology by natural resource management agencies. Another significant development has been the integration of Internet mapping and serving capabilities of GIS software, which allows spatial datasets to be created and then rapidly displayed and/or distributed through the Internet.

Notwithstanding the advances in the use and integration of GIS and Internet-based technologies, a number of significant issues remain which affect the distribution and availability of datasets. These include inconsistent and variable pricing policies for datasets (both within and between nations) and copyright / restrictions on the distribution of datasets. Fortunately, attitudes in the spatial data community are evolving, and this may become less of an issue in the future.

GIS can be used to integrate datasets to create a new dataset. For example, drainage datasets (linear features) may be integrated with polygonal features to represent the extent of wetland features in an area. Alternatively, these datasets may be used as surrogate datasets to represent wetland extent, in lieu of specific wetland datasets. Datasets may be classified according to the feature class, e.g. land subject to inundation, swamp, etc. (Lowry & Finlayson 2004), or the attributes – such as the waterlogging characteristics of soils – may be interrogated (e.g., Begg et al 2001). A case study example of such an approach is provided in Box 1.

With the increase in the use of GIS has also come an increase in the quantity of data generated. Much of it is now available for distribution, either through the Internet or through contacting the data custodian at minimal or even no cost.

The URL / Internet addresses of a selection of low-cost datasets are listed in Appendix 2. However, although much data are now available via the Internet, not all are available at low or no cost. This is particularly the case for those datasets needed for more detailed wetland mapping (such as the habitat or species level shown in Figure 2). The cost of data acquisi-

Box 1. Using GIS to map wetlands in the Northern Territory of Australia using aggregated soil and topographical data

As part of a larger assessment of environmental flow requirements, an inventory and risk assessment of wetlands was undertaken for the Daly basin (19,382 km^2) in the Northern Territory of Australia (Begg et al. 2001; Erskine et al. 2003; Begg & Lowry 2003). A desktop GIS was used to collate, interrogate and analyse soil and topographic data that had been collected previously for the purpose of land capability analysis. The aggregated data were used as a surrogate for mapping the distribution of wetlands in the Daly basin.

The land units mapped were composed of individual areas within which the soil, vegetation and landform exhibited a uniform pattern on aerial photographs. The wetland features mapped were classified using landform and hydroperiod as a basis and, to assist in the classification process, a ground-truthing exercise and a basin-wide low-level aerial survey were conducted. An example of one of the products produced through this process is shown in Figure 3.

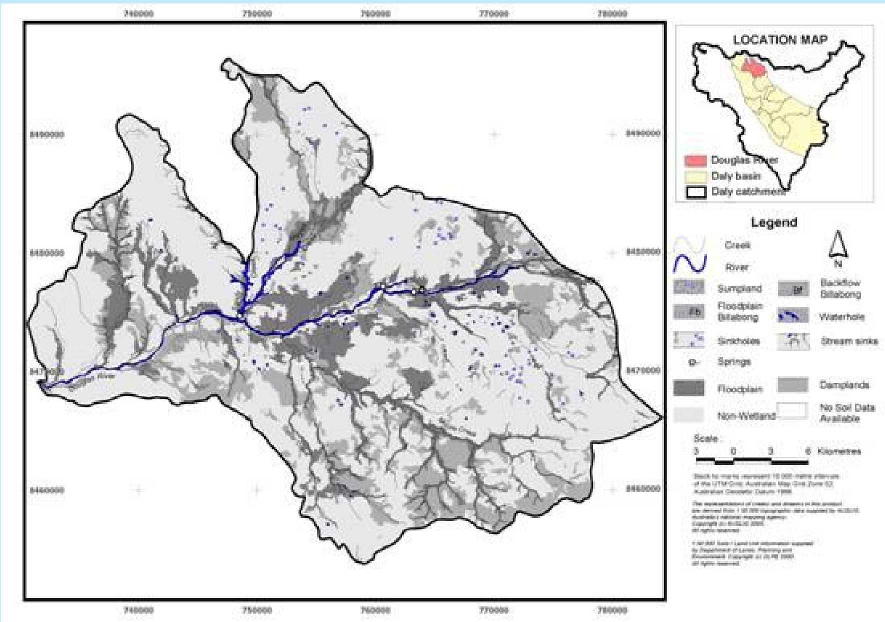

Figure 3. Distribution of wetlands in the Douglas River catchment of the Daly Basin

This exercise demonstrated the value of mapping wetlands using existing soil and drainage data as surrogate data. Considering that prior to the idea of combining such data the location of wetlands in the Daly basin was virtually unknown, the analysis, which was performed at no extra cost, has gone a long way towards providing such information.

tion may range from a nominal cost of provision (for example, the cost of a CD plus an administration fee) to an attempt to reclaim the costs of data creation. Therefore, it is very important when embarking on a wetland inventory task using GIS technology to allow adequate funds for the purchase of data, particularly if a multi-scalar hierarchical approach is being employed. The costs of acquiring remotely sensed images, if acquired on a temporal basis, and at multiple scales, are likely to exceed the cost of the initial acquisition of the GIS software.

3. Using low-cost GIS for wetland assessment

Remote sensing and GIS technologies provide an environment in which wetland assessment may be undertaken efficiently. However, it is important to understand that the specific range of applications which can be undertaken depend in large part on the software being used and the data available. Simple assessment tasks, for example overlaying multiple datasets, can be undertaken using a data viewer acquired at no cost. However, higher-level ecological risk assessment, model building, or spatial analysis tasks require a higher-capacity desk-top GIS program.

GIS and remote sensing play a key role in wetland assessment as outlined in the Ramsar Convention's risk assessment framework (Figure 4), developed by van Dam et al (1999) and adopted by the Contracting Parties in Ramsar COP7 Resolution VII.10). Although GIS techniques can be employed at any stage of the model, they are particularly useful for identifying the extent of the problem and the extent of the risk. GIS and remote sensing together can be used to help monitor the effectiveness of the risk management and/or reduction techniques. Specifically, the ability to integrate and overlay multiple layers of data over an area of interest which could be modeled, queried and analysed in order to try and determine the impact and extent of a particular risk provides a particularly powerful tool to wetland managers undertaking wetland assessment. For example, using these GIS techniques, Begg et al (2001) were able to conduct efficiently and economically a preliminary assessment of the risks to the wetlands in the Daly basin in the Northern Territory of Australia, an area of some 20,000 km^2.

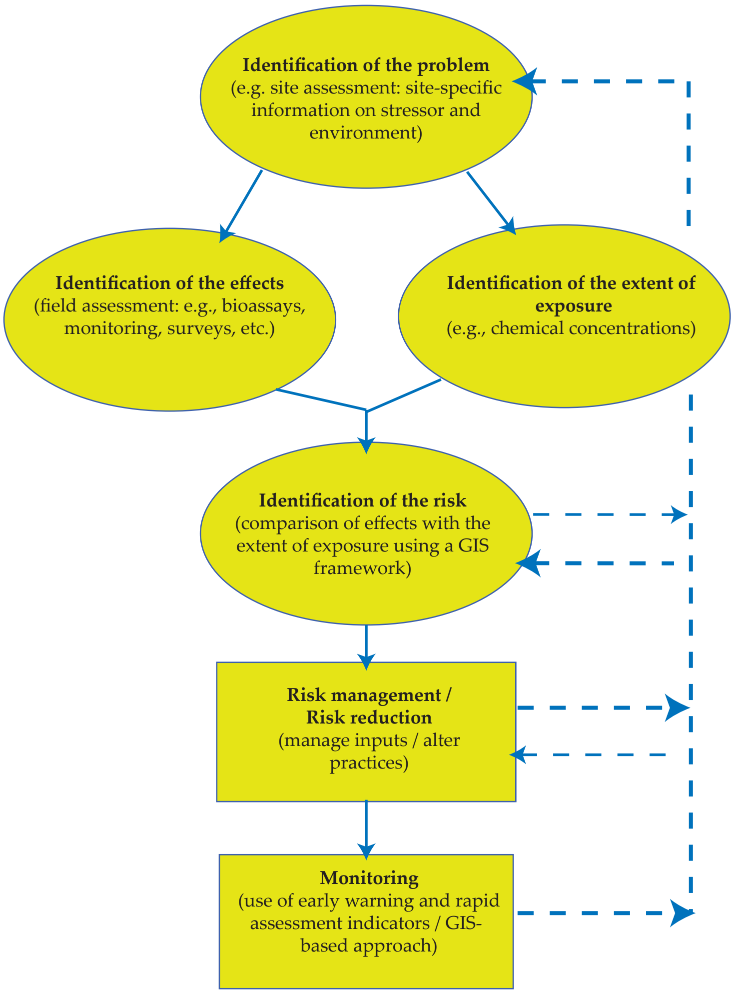

Figure 4. A model for wetland risk assessment (from van Dam et al. 1999)

4. Using low-cost GIS for wetland monitoring and surveillance

The integration of remote sensing and GIS technologies has the capacity to provide wetland managers with a set of tools for wetland monitoring and surveillance that are powerful, efficient and cost effective. New remotely-sensed technologies with enhanced spatial, spectral, and temporal resolutions are increasingly available. At the same time, the cost of image acquisition, particularly of the older and broader-scale images, is decreasing. Data are now becoming available from a variety of sources: for example, see Johnston & Barson 1993, Hess & Melack 1994, Taylor et al 1995, Sahagian & Melack 1997, and Srivasta et al 2002.

As with GIS data, many remotely-sensed datasets may now be downloaded through the Internet at negligible cost. The range of remotely-sensed data now available means it is possible to apply a hierarchical approach to monitoring (at similar spatial scales to those advocated for wetland inventory), with different datasets or data types being used at different spatial scales. Once the wetland extent or condition has been mapped or classified using remote sensing software, these can be stored in a GIS as a vector dataset. Once in a GIS environment, it is possible to monitor changes to the environment in the area of interest and relate them to other feature datasets, such as infrastructure, climate, and hydrology, held in the GIS.

A further advantage of integrating GIS and remote sensing is that the ancillary datasets held in the GIS (e.g., soil waterlogging characteristics) could be used to help classify wetland features in the remotely sensed image.

The main advantage of integrating remote sensing and GIS is that it enables a wide range of questions pertinent to wetland monitoring and surveillance to be answered. The application possibilities are almost limitless and only dependent on the study criteria. Questions could include:

1) Where are wetlands being lost or reduced?
2) How quickly are wetlands being destroyed?
3) Where are the remaining wetlands located?
4) Are the wetland declines significant?
5) Which areas remain flooded throughout the entire year?
6) Which sites are of priority for restoration?
7) Are there any endangered species located in the wetland ecosystem, and if so, where are they located?

Low-cost GIS is a valuable tool for supporting the monitoring of wetland environmental impacts, for example, the temporal mapping of changes in alien aquatic weed distribution, and it aids in the interpretation of such information. Such analyses could include measuring areas by the vector polygons, determining buffers and distances, determining intersection map elements, highlighting species distribution or diversity, habitat locating, water flow modelling, designating areas susceptible to floods, or monitoring contaminants. Maps can be zoomed to provide more explicit detail of a particular location, provided the information is incorporated into the relational database.

Other possible applications of GIS for wetland monitoring include creating wetland biological diversity maps and environmental sensitivity maps using categories that rank specific criteria.

Monitoring and surveillance data for wetlands is becoming available from an increasing range of sources. For example, the Kyoto and Carbon Initiative (http://www.eorc.nasda.go.jp/ALOS/kyoto/kyoto_index.htm) led by the Japanese Aerospace Exploration Agency plans to use satellite-based radar sensors to produce a range of datasets that may be used to map and monitor wetland characteristics. Planned products which could be used in a low-cost GIS include datasets representing the spatio-temporal inundation characteristics of wetlands, as well as datasets identifying the impacts and effects of disturbances in wetland environments.

Additional Web sites concerning wetland monitoring and surveillance include:

http://maphost.dfg.ca.gov/wetlands/metadata/wet_met.htmfrom
http://www.jacksonbottom.org/wetlandsmonitoring.htm
http://home.thezone.net/~kyake/Sites/intro.htm

5. Available low-cost 'desk-top' GIS products

Although many low-cost GIS systems are now available, those low-cost systems developed by ESRI are increasingly widely used. Currently ESRI has four products – two data readers (ArcExplorer and ArcReader) and two desktop GIS packages (ArcView 3* and ArcView 9*) – which can be regarded as 'low-cost'. ESRI can be seen as the 'leader' in terms both of the extensive adoption of its products and of its influence on the development and application of new concepts and features in GIS systems. An assessment of aspects of these ESRI systems in relation to the skill level required for operators of the different packages, the 'user-friendliness' of the packages, the capabilities and features, and their hardware and operating system requirements is provided in Appendix 3.

For further information about other desktop GIS systems, see the following Web sites:

http://www.icls.harvard.edu/GIS/MGMT5.HTM
http://www.gisportal.com/gis3l.htm
http://www.freegis.org/
http://www.mapcruzin.com/free_gis.htm

It is important to note that the capabilities of desktop GIS products are being steadily enhanced, as are the capabilities of the desktop computers upon which they are hosted. The power to perform complex spatial analysis, and to produce stunning maps, is increasingly being made accessible to more and more users.

6. Data management for GIS applications

The expansion of use of GIS products and datasets has enabled many individual organizations to produce many of their own datasets. Simultaneously, there is widespread recognition that it is often cheaper and more efficient to source data layers and tables from third parties. In order to obtain maximum value out of a GIS, both approaches, irrespective of whether data are generated locally or acquired and shared amongst multiple users, require establishing efficient and effective data management mechanisms.

The distributed nature of GIS uses and applications has many implications for data management and interoperability between multiple GIS organizations and systems. These range from ensuring that files are maintained in a compatible format (enabling them to be imported or exported readily) to using standardized projection systems and datums. For maintaining compatible formats, recent software releases have made it much easier to integrate data from different sources, including other proprietary software packages. However, it is advantageous if all data are stored and maintained in a common, readily accessible format. Regarding projection systems and datums, this could be addressed by ensuring that all collaborators understand which datum and projection system best applies to their respective area of interest. Additional considerations include ensuring that standard procedures are used in the creation and naming of the datasets. This can mean simply ensuring that file names do not exceed a specified length (e.g., eight characters) or do not contain non-standard characters which would render them unreadable with some software programs.

GIS data formats are more complex than many other document types traditionally used on a personal computer. Usually there are several separate files used to store information about a single GIS set of objects. For example, an ArcView shapefile is composed of, at a minimum, three separate files (identified by having *.shp, *.shx, and *.dbf suffixes). Managing GIS data can be very challenging, especially when using certain older types of software or those which are not fully cognizant of the nature of the files with which they are working.

One of the key elements of data management is the creation and maintenance of metadata. Metadata document the history, methodology, accuracy and completeness of a dataset and provide a description of the dataset. Importantly, through COP8 Resolution VIII.6, the Parties to the Ramsar Convention have adopted a metadata framework for wetland inventory which utilises internationally recognised metadata elements as its core (Finlayson et al. 1999; Lowry 2002). As noted One of the significant features of ArcView 9.1 is the ability to create, edit, view and update metadata records for a dataset. Metadata records created in ArcView comply with the 1998 United States FGDC standard for geospatial metadata.

Each of these data management issues can best be addressed by ensuring that all GIS users and producers are adequately trained, both in the operation of the software and in the protocols that accompany the use and application of spatial datasets. Collaboration among GIS users is crucial, and adherence to industry standards and commonly adopted GIS practices is also critical to the success of any GIS. A GIS must support key standards and be able to adapt and evolve as new standards emerge. The creation and distribution of metadata for individual datasets provides the basis for addressing these issues.

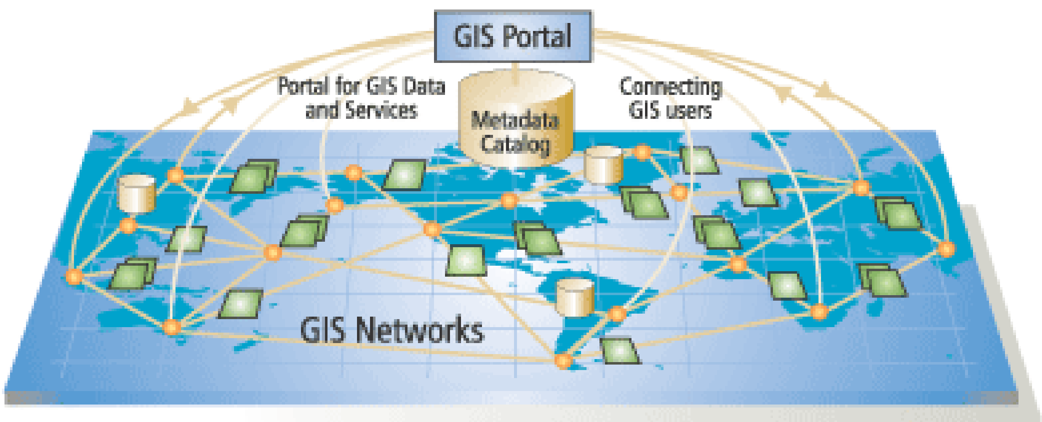

Figure 5. Schematic diagram of a Spatial Data Infrastructure (SDI) using GIS networks

7. Further applications of low-cost GIS networks

Hard-copy thematic maps or images have traditionally been regarded as the ultimate product of a GIS. However, an increasing trend amongst low-cost software products is the ability to serve and create spatial datasets over the Internet, enabling the data potentially to reach a much larger audience.

Internet nodes, called "GIS catalog portals", have been implemented to allow GIS users to register as well as discover geographic information for access and use. As a consequence, GIS systems are becoming increasingly connected on the World Wide Web for information sharing and use. This vision has been in existence for more than a decade and has often been described as a National Spatial Data Infrastructure (NSDI) or a Global Spatial Data Infrastructure (GSDI).

Such concepts are now in general use, not only at national and global levels, but also within states and local communities. The concept is collectively referred to as a Spatial Data Infrastructure (SDI).

A GIS network as an implementation of a Spatial Data Infrastructure (SDI)

A constellation of user sites discover, generate, publish and utilise shared geographic information on the World Wide Web. Through establishing a GIS network (see Figure 5):

i) geographic intelligence is inherently distributed and loosely integrated (rarely is all the necessary information present in a single database instance with a single data schema);

ii) GIS users count on each other for portions of their GIS data; and

iii) GIS networks enable users to connect to one another and share their geographic knowledge.

The three key building blocks for a GIS network

For an effective GIS network, the three key building blocks (Figure 6), which are further described below, are:

i) metadata catalog portals, where users can search for and find GIS information relevant to their needs;

ii) GIS nodes, where users compile and publish GIS information sets; and

iii) GIS users who search for, find, and connect to and use published GIS data and services.

GIS Catalog Portals

An increasingly important component in any GIS network is a GIS catalog portal with a registry of the numerous data holdings and information sets. A number of GIS users act as data custodians who compile and publish their datasets for shared use by other organizations. By searching a catalog portal, other GIS users can find and connect to desired information sets.

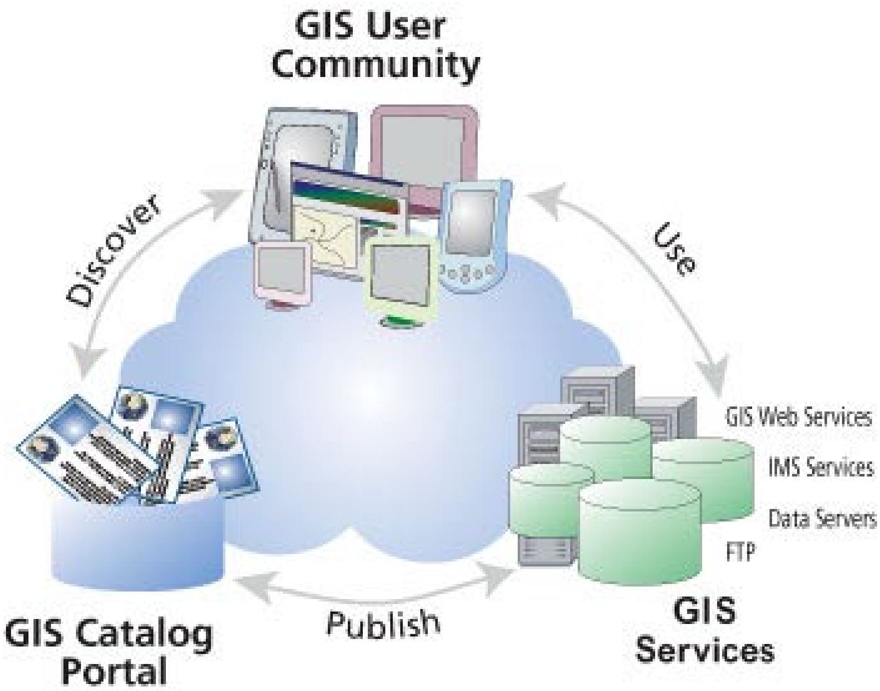

Figure 6. The inter-relationship between the three key building-blocks of a GIS network

The GIS catalog portal is a Web site where GIS users can search for, and find, GIS information relevant to their needs. This depends on there being a network of published GIS data services, map services, and metadata services. Through such a system, GIS data and services documented in catalog records in a GIS catalog portal can be searched to find candidates for use in specific GIS applications. Thus, a GIS catalog can reference data holdings contained at its site as well as at other sites. A series of available catalog nodes form a network – an SDI.

Periodically, a GIS catalog portal site can harvest catalogs from a collection of participating sites to publish one central GIS catalogue.

One example of a GIS catalog portal is the U.S. government's Geospatial One-Stop portal (www.geodata.gov). This portal will increasingly make it easier, faster, and less expensive for all levels of government and the public to access geographic information.

8. Selection criteria for low-cost GIS software and data

The criteria for selecting data and software often need to be decided on a case-by-case basis. However, in general the following criteria should be considered when selecting low-cost data from an external source for a GIS application:

i) ***Rationale***. Consider what you are actually trying to show, and what datasets you really do need. For the latter, you may be able to use more than one dataset to represent a particular feature, or a surrogate dataset may represent the feature more effectively than the specific dataset.

ii) ***Scale***. Is the scale appropriate for the level of study being undertaken? Is the scale of the dataset compatible with the other datasets which are being used in the GIS system? For example, drainage data compiled to a scale of 1:250,000 would be inappropriate to apply at a scale of 1:10,000.

iii) ***Projection and datum of the dataset***. Determine in what datum (e.g., WGS84) and what type of projection (a geographical coordinate system, or a projected coordinate system) the dataset was created. Is it the same system in which it is now maintained, and is it compatible with the other projections and datums employed by the other datasets? Although software programs are able to convert data from one datum and projection to another, it is preferable that all datasets use the same datum/ projection from the outset. Similarly, having datasets in multiple datums and projections can cause chaos and confusion to users who are not familiar with the concepts of projection and datums.

iv) ***Reliability***. What methods were used in the creation of the dataset? Was a recognised and/or clearly documented methodology employed in the creation of the dataset? For example, if the dataset is nominally compiled to a scale of 1:50,000, was the sampling intensity of the data collection process adequate to produce a 1:50,000-scale dataset? If the dataset represents a soils coverage, does it use a recognised soils classification?

v) ***Completeness***. Are the datasets spatially (or topologically) complete? That is, are all the polygons cleaned and built, with no overshoots or sliver polygons, and are all the polygons fully attributed? Does a metadata record exist for the dataset?

vi) ***Copyright***, distribution rights and legal issues. If it is planned to distribute a dataset acquired from a third party, then consideration must be given to a range of legal issues. Establish the right to reproduce and distribute each dataset from the custodian of the original dataset. It may be necessary to establish a license agreement with the custodian of the dataset, which will stipulate the terms and conditions associated with the use and distribution of the data.

vii) ***Cost***. Where datasets are free, cost may not appear to be an issue. However, many of the datasets which are currently available at minimal or no cost have significant limitations on their use – for example, they may only be useful at a very broad scale – and therefore it may be necessary to purchase data which is more appropriate for the scale and the nature of the study. In such cases, then all of the points listed above should be considered in conjunction with the price.

Similarly, the key issues which should be considered when selecting a specific software package are:

i) ***Software requirements***. What type of activity are you planning to use the software for? If the primary application of the software is for viewing existing datasets, then a data viewer may be most appropriate. However, if the primary use is the creation, editing and updating of datasets, then a desk-top GIS system would be the best option.

ii) ***Cost***. Depending on the intended use, cost may not be an issue. For example, if only simple data viewing applications are planned, than freeware software may be acquired at no cost. But other factors beyond the initial acquisition fee, such as training, may increase the price of 'freeware' software. If a specific set of analysis requirements exists (for example, editing shapes of polygons, updating attributes, or performing queries), then it may be necessary to purchase the software capable of processing the data. Be aware that, as with many consumer items, a high price does not necessarily always mean a useful product. If purchasing software, consideration should be given to:

- the capabilities of the software program – what features does it have? Can it be used for the application? Does the program have room for expansion or growth, enabling further or enhanced analysis in the future?
- the level and nature of sales support provided to the user by the manufacturer; and
- the types and nature of the training required to use the software to its full benefit: if the software is cheap to buy, but the training to use it is expensive, then it may be worthwhile acquiring software that is more expensive initially but involves lower training costs.

iii) ***Compatibility with other software programs***. This issue is particularly important if significant collaboration between organisations and agencies is occurring, since the compatibility (or otherwise) of datasets will have a significant impact on the data exchange and transfer process. Using a common data format and program can provide significant advantages to agencies collaborating on a project and assist greatly with data management – an often overlooked and neglected task. However, in the future, this may become less of an issue, as programs able to read and integrate multiple GIS formats become increasingly available.

iv) ***Optimum hardware capacity.*** The cost of desktop computer infrastructure is decreasing in real terms, so that the cost of GIS infrastructure and hardware is also decreasing. However, whatever software program is selected, it is likely to be updated (typically within a 12-24 month period), so the infrastructure should be selected to enable current activities to be undertaken and allow room for future expansion and growth. As noted earlier, image or raster datasets may be quite large and require large hard disk space as well as computer processing speed and capacity. Thus, the bottom line is that the hardware chosen should allow for the maximum range of activities to be undertaken.

v) ***User-friendliness.*** How easy is it for staff with varying degrees of computer and GIS experience to master and accomplish the tasks they wish to undertake using the GIS? If staff have no or very limited GIS experience, then this issue is crucial. The time and cost required to provide or acquire training in the software may outweigh any benefit from selecting a software program which has a low purchase price. Similarly, the ease with which the program performs specific functions, for example, using features such as MS Windows-driven wizards, is significant when staff have GIS experience.

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Appendix 1. A selection of free or low-cost data viewers

Autodesk Express Viewer

Cost: Free

Notes: Released December 2002, this light-weight, free viewer enables non-Autodesk product users to view, pan, query and print DWG, DXF, and DWF format data. Enables users to easily view DWF data in compatible programs such as IE, MS-Word, and PowerPoint.

Contact/ more information: www.autodesk.com/expressviewer-download.

CartoMap

Cost: Free

Notes: Map viewing Microsoft® Windows® compatible software – supports SHP and MIF data formats and provides users with the ability to pan, zoom, query, and order layers.

Contact/ more information: http://www.cartoworld.com/products/cartomap.htm.

ER Viewer

Cost: Free

Notes: Enables users to save imagery as TIFF, JPEG, BMP, ERS, and BIL directly from ER Viewer. Fast interactive roaming and zooming of image files, measuring distances on the ground, and much more. ER Viewer allows you to integrate ECW compressed imagery into Microsoft Office applications such as Word, PowerPoint, Excel and Access. Supports the following data formats: .bil/.ers/.hdr; .alg; .ecw; .ers; .hdr; .tif; .bmp.

Contact/ more information: http://www.ermapper.com/erviewer/index.htm.

GeoExpress View

Cost: Free trial version, US$299 full version

Notes: Software enables DXF files to be overlaid over image files; has drawing tools to allow graphics and text to be added, edited and modified; capacity to rapidly pan, zoom and magnify portions of an image, display gridlines at various intervals, and print to a specified scale.

Contact/ more information: http://www.lizardtech.com/download.

Geographic Explorer

Cost: Free

Notes: Supports MIF, SHP, TAB, DWG, DXF, DGN, TIFF, BMP and JPG format files, enabling datasets to be explored directly from the desktop.

Contact/ more information: http://www.bluemarble-geo.com/products.asp?id=5.

GeoMedia Viewer

Cost: Free

Notes: Application for desktop viewing and distribution of geospatial data. It allows an organisation to maximize the value of its geospatial data by extending availability to novice users who wouldn't otherwise have access because of the barriers of purchasing and learning how to use a full GIS software application.

Contact/ more information: http://imgs.intergraph.com/gviewer/.

Geomatica FreeView

Cost: Free

Notes: FreeView allows the viewing, enhancing, and examination of remotely-sensed imagery such as LANDSAT, SPOT, RADARSAT, ERS-1, NOAA AVHRR, and aerial photography. Use FreeView to overlay GIS data and view the associated attribute data.

Contact/ more information: http://www.pcigeomatics.com/freeware/download_form_freeview.htm.

GIS Viewer 4.0

Cost: Free

Notes: Web-based tool for displaying and manipulating layers of geographical points and vectors and raster data such as maps and images. GIS Viewer 4.0 is designed to scale from datasets covering the entire earth to high-resolution imagery of fine details. Provides users with the ability to zoom, pan, query; automatic projection conversion among UTM, lat/long, Albers; vector, raster, transparent raster and point data support, and numerous other features!

Contact/ more information: http://elib.cs.berkeley.edu/gis/.

GlobalMapper

Cost: Free for limited trial version, US$179 for full version.

Notes: Supports viewing of most of the popular data formats, including DLG-O, DRG, DOQ, DEM, DXF, SDTS DLG, SDTS DEM, ECW, MrSID, ESRI Shapefiles, E00, GTOPO30, TerrainBase, ETOPO2 etc. Also supports the latest DEM and SDTS DEM formats, including decimeter DEMs. Additional functionality includes crop, reproject, and merge any combination of raster data, including DRGs. Free version has limited export capabilities.

Contact/ more information: www.globalmapper.com.

TatukGIS Viewers

Cost: Free.

Notes: Reads the following formats: Raster: TIFF/GEOTIFF, ECW, MrSID, BMP, SPOT, JPEG, PNG, PixelStore. Vector: SHP, E00, MIF/MID, TAB, DXF, DGN, TIGER

Contact/ more information: http://www.tatukgis.com/Home/home.aspx.

ViewFinder 2.1

Cost: Free

Notes: Viewing tool that provides the ability to display image files; spatially query image files prior to exporting; overlay, smooth, sharpen and enhance imagery; and reproject multiple images on-the-fly; rapidly navigate large imagery datasets; and move imagery from its existing projection system to one of many predefined output datums and projections, creating files in either the IMG or TIFF formats.

Contact/ more information: www.gis.leica-geosystems.com.

Appendix 2. URL addresses of Internet sites containing free or low-cost GIS data

http://www.freegis.org/geo-data.en.html
http://www.esri.com/data/download/basemap/index.html
http://www.ngdc.noaa.gov/mgg/shorelines/gshhs.html
http://www.ngdc.noaa.gov/mgg/topo/globe.html
http://edcwww.cr.usgs.gov/landdaac/gtopo30/gtopo30.html

Individual country datasets can be downloaded from:

http://geogratis.cgdi.gc.ca/clf/en

Specific feature datasets (e.g., wetlands, topography , drainage, etc.) may be obtained from:

http://www.wwfus.org/science/data/terreco.cfm
http://www.grid.unep.ch/
http://www-cger.nies.go.jp/grid-e/
http://edcdaac.usgs.gov/gtopo30/gtopo30.asp
http://www.fao.org/ag/agl/aglw/aquastat/main/index.stm
http://pubs.wri.org/pubs_description.cfm?PubID=3818

Appendix 3. A review of ESRI GIS products

This Appendix provides a review of some of the most increasingly widely-used GIS products, developed by the Environmental Systems Research Institute (ESRI). It assesses the skill level required for operators of the different packages, the 'user-friendliness' of the packages, the capabilities and features, and finally the hardware and operating system requirements for the respective packages.

ESRI may be seen in many regards as the 'leader' in terms both of the extent of the use of its products and of its influence on the development and application of new concepts and features in GIS systems.

1. ArcView

"ArcView" is the name assigned to the initial desktop GIS product launched by ESRI towards the end

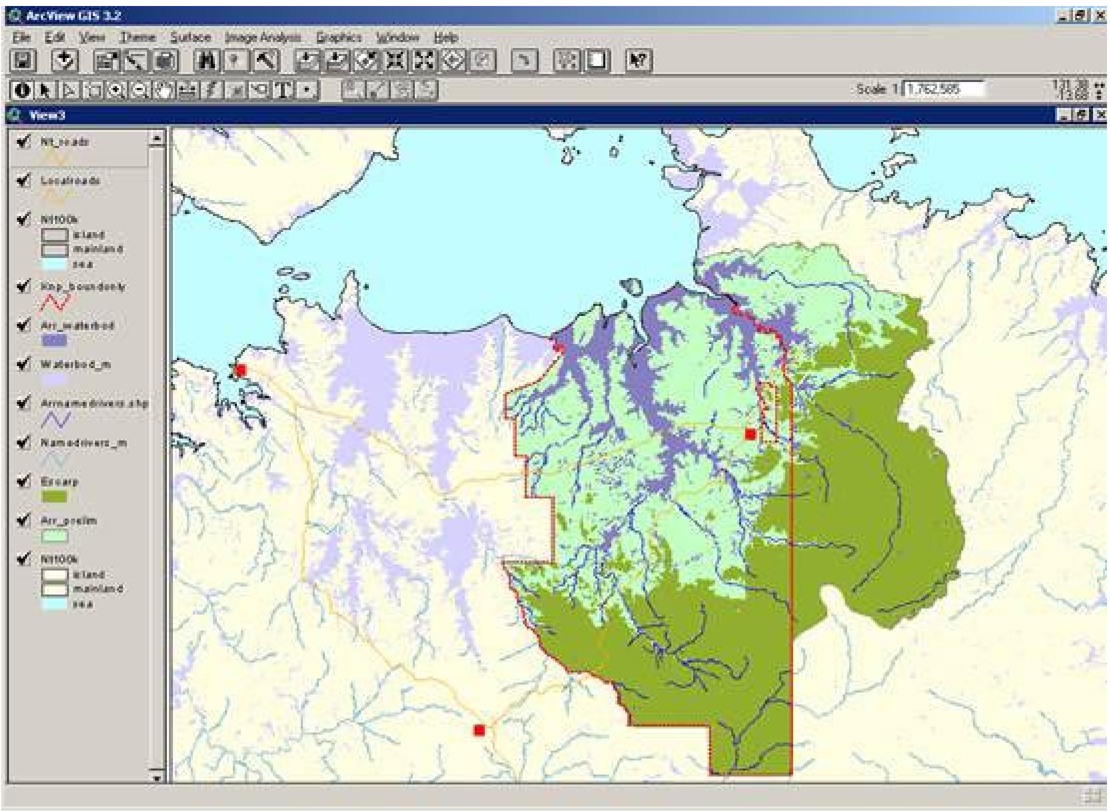


Figure A.1. ArcView 3.2 View interface

of the 20th century. Commencing with ArcView version 1 and proceeding through several updated and enhanced versions, the software has become one of the most widely used desktop GIS packages available on the global market, and its use is particularly prevalent in the natural resource management sector. Currently – and perhaps confusingly – two separate 'streams' of ArcView products (the ArcView 3 series and the ArcView 8 / ArcView 9 series) are in widespread use.

A significant limitation to the adoption of ArcView by many is its cost. Depending on the version, the price of a standard (non-discounted) users license typically starts at approximately US$1,900, excluding any extension software. At the same time, it should be recognised that ArcView incorporates a comprehensive range of capabilities, and significant discounts may be available.

1.1 The ArcView 3.* series

The ArcView 3 series is directly descended from the original ArcView 1 desktop system, which was developed using a native programming language known as Avenue. The latest (and most likely last) in the 3.* series is ArcView 3.3, with ESRI directing most of its developmental resources into the ArcGIS / ArcView 8.*/ 9.* series. The 3 series has been particularly adopted by the environmental and resource management sectors.

Potential users should note that only ArcView 3.3 is currently actively supported by ESRI; ArcView 3.2a is still supported via the Web, whilst support for the earlier versions is now only provided through discussion groups and archived notes. A representation of an active View in ArcView 3.2 is shown in Figure A.1.

Like most software packages, the ArcView 3 series has its good and bad points.

Skill level / user friendliness

A key element of the desktop GIS is the ability to perform GIS functions using a Windows-type environment from a standard desktop computer. From this perspective, the ArcView 3 series provided a significant enhancement in user friendliness over earlier versions of ArcView.

A significant advantage in using the ArcView 3 series is the very large user base which continues to exist, despite the launch and implementation of the ArcView 8 and 9 series. Whilst the early versions in the 3 series are no longer actively supported, support is still provided for ArcView 3.3. However, an active and helpful e-mail discussion group also provides support to the novice user. ArcView is able to be used on an extremely wide range of platforms, ranging from Unix to Windows NT to the Macintosh environments. Further, it is available in a variety of languages to suit the user, e.g., French, Arabic.

ESRI conducts ArcView training in its own right, as well as licensing partner companies or organisations to conduct training in the use of its software. While the courses are generally well structured and thought out, they are usually not cheap. Introductory courses typically run for 2 days; more advanced courses can run for 3 days. Special rates are available for students and may be negotiated for group bookings.

ESRI maintains a useful Web site, containing information and tips on ArcView use and suggested solutions to a range of frequently asked questions. Additional scripts and extensions may be downloaded free from this site: http://www.esri.com.

Capabilities and features

ArcView may be regarded as being at the 'high end' of the desktop GIS market, in the sense that it provides some high-end GIS features, such as the ability to clip features in one dataset based on a feature in another; create buffers from a selected feature; merge two datasets together; link data in a table or database to a feature layer or representation; intersect or union different datasets; or intersect or union features within a dataset.

ArcView enables a variety of different products to be produced, depending on the requirements of the user. These range from hard copy thematic maps to image files (*.jpegs, *.tiffs, etc.), to digital files which can be exchanged with other users or converted to other formats if need be. Data may also be exported as *.dbf or *.txt files if required. With additional software, it is now possible to serve GIS data created in ArcView over the Internet.

One limitation (which is by no means exclusive to ArcView) is transposing what the user sees on the screen and what comes out of the printer (in computer-speak, WYSIWYG - "What You See Is What You Get"). ArcView is not WYSIWYG. The colours visible on the screen do not translate literally onto the sheet of paper, especially if shading or hatching is used. It is possible to produce a colour chart to know what colours on the screen will look like on a paper, but this is not available as a default function.

The ability to query a dataset is one of the key features of a GIS. ArcView enables the user to query a dataset through building and using SQL-type query expressions. While this requirement is not a limitation in itself, ArcView provides no guidance or help to those unfamiliar with the terminology or syntax required to build an expression. Thus, building a query can potentially be a frustrating experience.

The default range of symbols and icons available for use in ArcView has steadily increased. However, many of the symbols are American-centric, which limits the value of the increased numbers of symbols to non-Americans. Fortunately, it is possible to create and add your own symbols to the symbol palette of ArcView.

Like many programs, ArcView often seems to have the innate capability of sensing when it is the worst time to crash, and then doing so, usually causing the loss of unsaved material, plus sometimes corrupting project files into the bargain. The only sure and easy solution to error problems like this – such as 'segmentation violation' – is to save regularly.

Overall, ArcView is a relatively user-friendly software package which is easy to learn to use and capable of performing a wide range of GIS functions.

ArcView Version 1.0 has been made available free of charge to users, since it has been superseded several times by the improvements contained in later versions of ArcView and lacks many of the GIS features which are now taken for granted. It will be interesting to see the period of time before current versions of ArcView are superseded, and if (when) they become available at no charge.

One strength of ArcView is that it is relatively easy to customise the interface to suit the requirements of the user. The programming code is Avenue, which is provided with each copy of ArcView. ESRI can provide training in Avenue if required. In addition, ESRI has developed a range of 'extensions' which enhance or expand the basic capabilities of ArcView, many of which can be purchased, such as Spatial Analyst (enhances spatial modelling and analysis capabilities). In addition, several companies, organisations and individuals have developed their own extensions for a variety of purposes, some of which are freely available from the ESRI Web site.

Importantly, it is possible to transfer easily shapefile datasets created in ArcView 3 to ArcView 8 and back again. However, customised features developed for the ArcView 3 series in Avenue are not able to be readily incorporated into the ArcView 8 system, which is based on a different programming language. In many instances, these customised scripts and features can represent a significant investment in time and capability, which may be one reason why many users continue to use the 'older' version of ArcView in preference to the latest version.

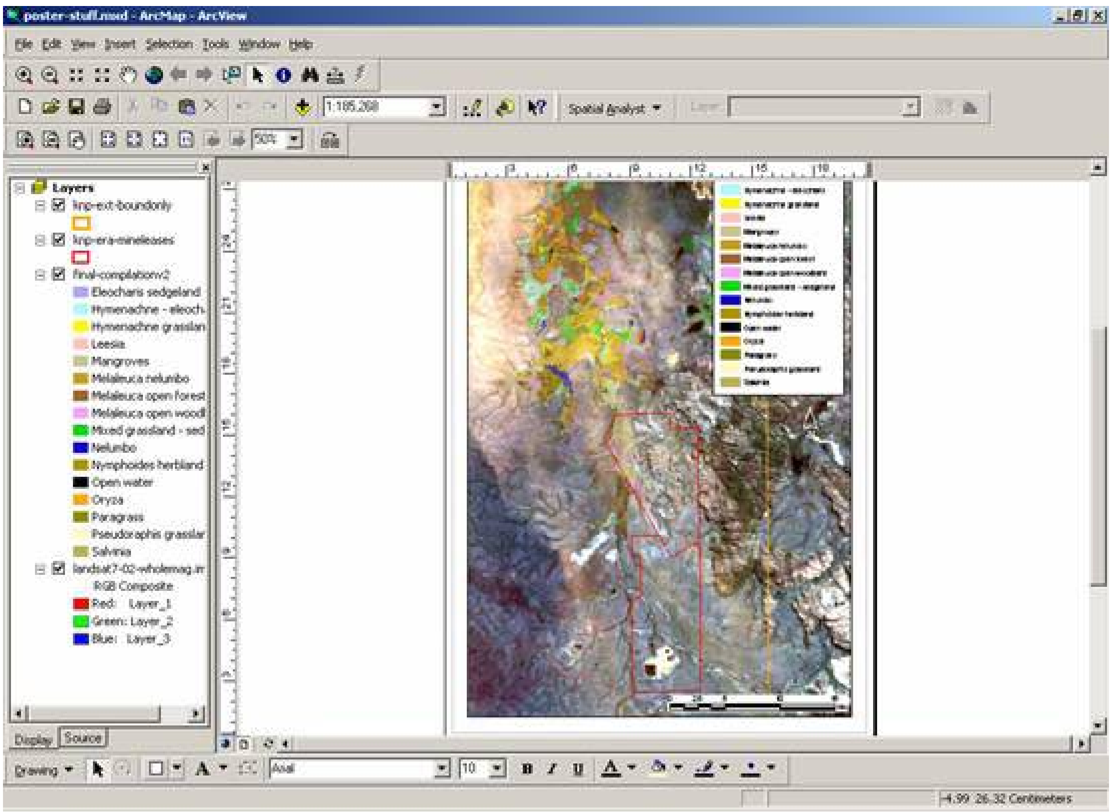


Figure A.2. The ArcMap interface

Hardware requirements

The minimum hardware specifications to run ArcView should be within the range of most organisations or groups. A computer with a 166MHz Pentium processor could run ArcView, although not very fast or efficiently. With increasing processor size comes the ability to manage, interrogate and display large files quickly.

1.2 ArcView 8

In April 2001, ESRI announced the release of ArcView 8.1. Aside from the jump in version numbers (from 3.x to 8.x), the release was seen as particularly significant because it marked the first release of a complete, single, integrated system for geographic data creation, management, integration, and analysis – otherwise known as ArcGIS.

At the time this report was initially written (July 2004), ArcView 8.3 was the then-current version, and consequently represents the subject of the following review and evaluation. It should be noted, however, that in the intervening period, two further versions of ArcView have been released, and the current standard is ArcView 9.1. It is important to note that while there have been some enhancements in user options and user-friendliness between ArcView version 8.3 and 9.1, both versions use the same programming language and infrastructure and contain the same basic features. Consequently, the evaluation of ArcView 8.3 is still essentially valid for ArcView 9.1.

The short period within which new versions of the software have been developed and released emphasises the short time frame within which GIS software developers respond to user comments and requirements to incorporate enhancements, and iron out problems, within their software products. Future developments and trends in later versions are likely to focus on managing datasets, and increasing the accessibility of data, such as serving it through the Internet.

The concurrent launch of the term ArcGIS caused (and continues to cause) some confusion in differentiating ArcGIS from ArcView. ArcGIS is billed simply as a "modular" system in the sense that it is scalable, allowing users to build the system in pieces, to suit their specific requirements.

Components of ArcGIS include ArcReader, ArcView, ArcEditor, ArcInfo, and the ArcSDE and ArcIMS servers. ArcView 8 is thus one of the components of the ArcGIS suite, and it is itself made up of a number of components, which include ArcMap, ArcCatalog, and ArcToolbox. ***ArcMap*** (Figure A.2) is used for all mapping and editing tasks as well as for map-based analysis.

ArcCatalog (Figure A.3) is used to browse, manage,

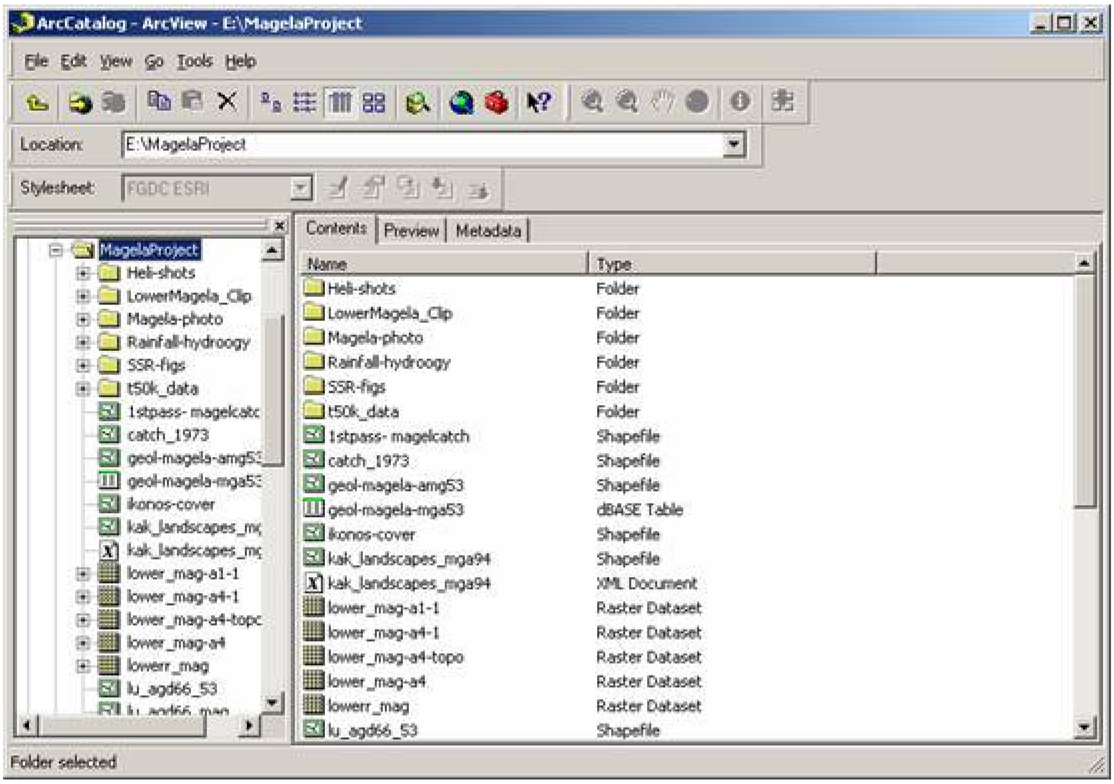


Figure A.3. The ArcCatalog interface

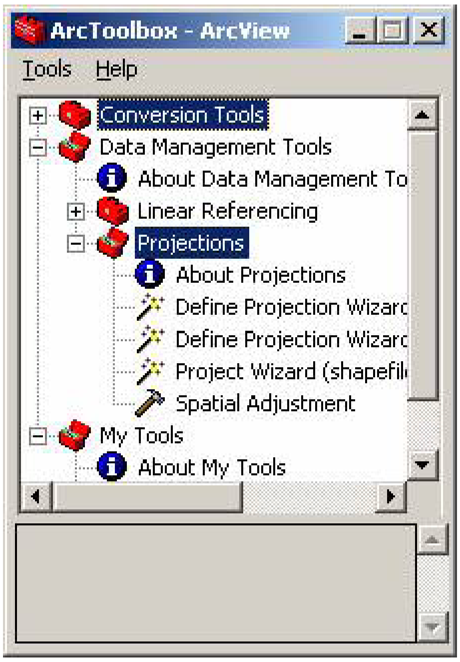
create, and organize your geographic and tabular data.

ArcCatalog enables spatial datasets to be managed, renamed, copied and deleted from within the GIS environment. The ArcView 3.x Shapefile Manager dialog is the closest equivalent to ArcCatalog, but it is not as powerful. Using the ArcCatalog tool, it is possible to browse and preview data (including the attributes also!) stored on a local computer, network, or even on the Internet. Significantly from a data management perspective, ArcCatalog enables the user to edit and create metadata for individual dataset.

ArcCatalog contains menus that provide access to more tools and wizards for converting data to different formats. The format of the original data source determines which data converters are listed. Using ArcCatalog, it is possible, for example, to convert shape files to geodatabases, coverages to shapefiles, rasters to MrSid, rasters to TIFF, and tables to geodatabases. These features were not readily available in the earlier ArcView 3.* software.

ArcToolbox (Figure A.4). The ArcToolbox for ArcView contains 36 of the most commonly used tools and extensions for data conversion and management.

For ArcView 8, the tools in ArcToolbox fall into two toolsets: Conversion Tools and Data Management Tools. There is also the ability to create a third folder, for customised or custom-made tools. The number of available tools varies depending on the type and number of modules and extensions held with the ArcGIS license. For example, the Toolbox for ArcInfo



Firgure 4.4. The ArcToolbox interface

contains 170 tools!

ArcSDE - adds database services to the ArcGIS family.
ArcIMS - provides Internet enabled services.

ESRI have extended the desk-top GIS concept to include the ArcEditor and ArcInfo modules. However, while these latter two do enhance the modeling, editing and geoprocessing capabilities of a desktop GIS, they significantly enhance the price as well. As this guidance focuses on low-cost applications, these modules are not further described.

ArcView 8.3 maintains the base functionality of ArcView GIS 3.x, but with a host of improvements. Some of the features provided in this release include:

- a catalog for browsing and managing data;
- on-the-fly coordinate and datum projection;
- metadata creation;
- customization with built-in Visual Basic for Applications;
- new geographic editing tools;
- support for static annotation; and
- enhanced cartographic tools

A feature of the new product suite is the ability to add data directly from the Geography Network (www.geographynetwork.com), which is a source of global spatial datasets. With a few simple commands, data from the Geography Network may be instantly integrated into ArcMap for visualization and analysis. Adding data are simple: a separate window pops-up providing instant access to a wealth of data available via the Geography Network server. Once selected, the data themes are loaded into the current data view and can immediately be queried, themed, or analysed (Figure A.5).

ArcGIS provides flexibility when configuring a system since it is modular and scalable. It is modular in the sense that the system may be acquired in pieces. ArcView provides data visualization, query, analysis, and integration capabilities along with the ability to create and edit simple geographic features.

In ArcView 8, as in ArcView 3, it is possible to create and edit shapefiles. It is also possible to display ArcInfo coverages, but as with the earlier versions of ArcView, it is necessary to convert the coverage to a shape file before it can be edited. Alternately, the coverage may be imported into a GeoDatabase, a new feature to the ArcGIS family. A geodatabase is essentially a 'wrapper' that stores multiple data layers, and adds some functionality, such as linked annotation Both ArcCatalog and ArcToolbox provide wizards for importing and exporting coverages and shapefiles, albeit one coverage or shapefile at a time.

Shapefiles created in ArcView 3.x and 8.x are indistinguishable from one another and are fully cross-compatible, i.e., they may be used in either version.

In ArcView 3x converting the active theme to a shape file (SHP) was accomplished by using the "Convert to Shapefile" command. In ArcView 8, converting a layer to a shapefile is easily done by right-clicking the file in the Table of Contents and selecting the Data Export option.

In ArcView GIS 3.x, raster data sources such as satellite images, aerial photographs and scanned documents are added as themes to a view. In ArcView 8, raster data sources may be added as layers to ArcMap. More than 21 different raster formats are supported by ArcView 8.x.

ArcView Extensions

The following are the ArcGIS 8.3 extensions that operate with ArcView 8.3:

Spatial Analyst - used for surface creation, raster analysis, and grid algebra, it combines the capabilities of ArcView Spatial Analyst and ARC GRID. Supports TIFF, BIL, SunRaster, USGS DEM, SDTS, and DTED data formats.

ArcGIS 3D Analyst - combining the capabilities of ArcView 3D Analyst and ARC TIN, 3D Analyst enables three-dimensional visualization and analysis. This is the tool to build surface models, perform perspective viewing, rotate, tilt, and fly-through simulations, and to model real-world surface features.

ArcGIS Geostatistical Analyst - surface interpolation and exploratory spatial data analysis.

ArcGIS StreetMap USA - street display and geocoding, initially for the US and Europe. Supports a number of common geocoding functions.

ArcPress for ArcGIS - a graphics metafile rasterizer used to enhance the process of printing large or high-quality maps. It boosts the capabilities of low-end printers by rendering PostScript quality images on non-PostScript devices. Users will realize increased colour output control and printing speed.

MrSID Encoder - the MrSID Encoder for ArcGIS enables you to efficiently use very large georeferenced images in ArcGIS – it can handle rasters up to 50 MB. An optional extension will support images up to 500 MB in size and will provide for multiple image mosaicing.

ArcPublisher - the ArcGIS Publisher can be used to create published map files (.pmf) from any ArcMap

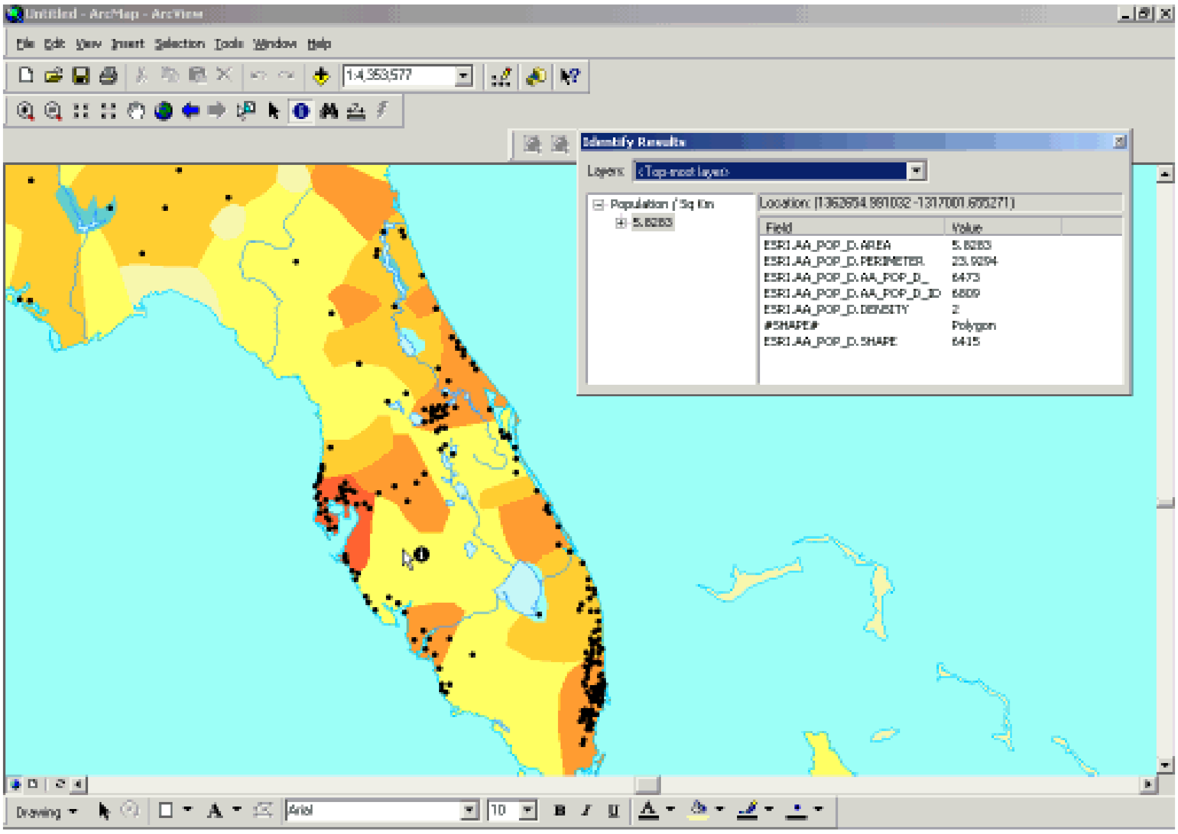


Figure A.5. Data extracted from Geography Network

document (.mxd). Published maps can be viewed using any ArcGIS Desktop product, enabling maps to be shared with a wide range of users.

It is important to note that these extensions are additional to the basic capability of ArcView 8.3. While they may be acquired as part of ArcView software package, it will be necessary to purchase the extensions listed above if you wish to utilise their specific functionality. According to ESRI, additional extensions are planned for release in the future.

Many of the extensions that were available in ArcView 3.x, such as the CAD Reader, Digitizer, Geoprocessing, Graticules and Measured Grids, Legend Tool, Report Writer, and all the image support extensions, are now built-in features and functions of ArcView 8. For example, in ArcView 3.x, the CAD Reader extension enables users to add Computer Aided Design (CAD) drawing files as themes to a view, whereas ArcView 8.x has the ability to automatically read CAD drawing files and add them as layers to ArcMap. Users who want to perform geographic analysis on features in the CAD file can simply double-click on the CAD file, click the CAD feature to add, and click Add. To edit a CAD feature, the file must first be converted to a shapefile.

While extract functionality was provided in ArcView 3.* through the use of the Avenue programming language, in ArcView 8x extra functionality and customised features may be added by writing macros in Visual Basic for Applications (VBA), which is included with the product. Developers can also create extensions for ArcView 8 using ArcObjects™ in standard development environments such as Visual Basic, C++, or Delphi.

System requirements recommended for using ArcView 8.3

These are:

- Intel Pentium 3
- Minimum 450 MHz with 128 Mb RAM
- Recommended 650 MHz or higher with 256 Mb RAM or higher
- Windows NT sp 6a/Windows 2000 / Windows XP

A significant difference between ArcView 8.3 and later versions, e.g., ArcView 9.1 (the current version), is the increase in computer capacity required. If ArcView 9.0 is to be installed on a computer, the recommended CPU speed is 1 GHz or higher, with a minimum of 512 Mb RAM. Note that the recommended configuration is essential if a user intends to utilise extensions such as 3D Analyst.

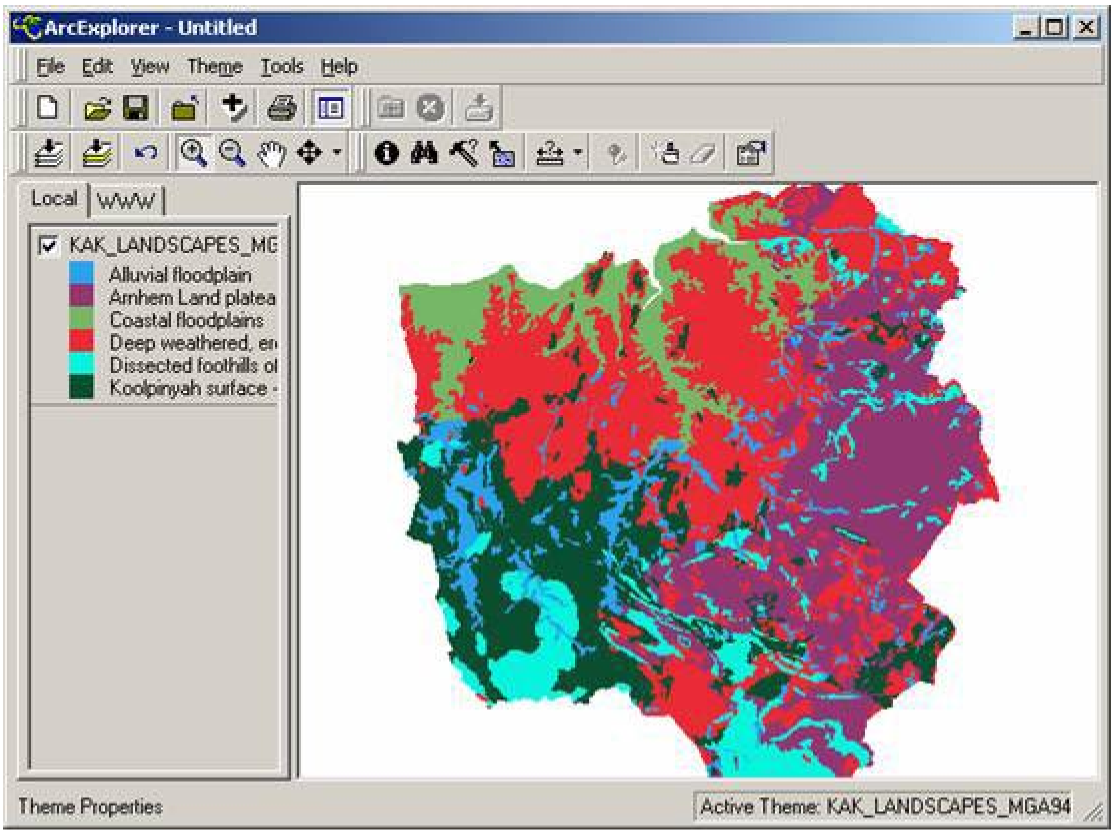


Figure A.6. The ArcExplorer interface

Users are not required to uninstall ArcView 3.x to install and run ArcGIS 8.3. ArcGIS 8.3 defaults to a \arcexe81 folder and will not conflict with ArcView 3.x.

Image formats compatible with ArcView 8.* are:

- Arc Digitized Raster Graphics (ADRG)
- Band Interleaved By Line (BIL)
- Band Interleaved By Pixel (BIP)
- Band Sequential (BSQ)
- Bitmap (BMP)
- Compressed Arc Digitized Raster Graphics (CADRG)
- Controlled Image Base (CIB)
- Digital Terrain Elevation Model (DTEM Levels 1 & 2)
- ER Mapper
- Graphics Interchange Format (GIF)
- ERDAS 7.5 GIS
- ESRI GRID file format
- ESRI GRID stack
- ESRI GRID stack file
- ERDAS Imagine
- JPEG
- ERDAS 7.5 LAN
- Multiresolution Seamless Image Database (MrSID)
- Spatial Database Engine Raster file format (ArcSDE Raster)
- Tagged Image File Format (TIFF & GeoTIFF)

2. ArcExplorer

ESRI now offers both Windows and Java versions of ArcExplorer. ArcExplorer 2 (Figure A.6) is the latest update of the Windows version of ArcExplorer. Internet Explorer 5 is needed for some of the Internet functionality. ArcExplorer 4 is the Java version, which offers cross-platform support for Windows, UNIX, Linux and Macintosh. Both versions of ArcExplorer may be downloaded free of charge from the ESRI Web site.

ArcExplorer is a lightweight GIS data viewer developed by ESRI and offers an easy way to perform basic GIS functions. ArcExplorer may be used for a variety of display, query, and data retrieval applications and supports a wide variety of standard data sources. It can be used on its own with local datasets or as a client to Internet data and map servers.

ArcExplorer is promoted as a vehicle for publishing data. The software may also be distributed with your data on CDs, so that users can then use the CD to install ArcExplorer on their machines and view your data easily and effectively.

ArcExplorer comes with a straightforward user interface that includes an intuitive menu bar and tool bars. With these, you can easily add themes from existing data sources, control theme characteristics, print your maps, zoom in/out, pan, identify map features, and display Map Tips. (Map Tips are dialog boxes that allow you to view the data associated with a feature on your map.)

As a complete data explorer, ArcExplorer lets you display and query a wide variety of standard data sources. Using ArcExplorer as a stand-alone desktop application, you can view and query industry-standard ESRI shapefiles, ArcInfo coverages, and ArcSDE (Spatial Database Engine) layers. You can also pan and zoom through multiple map layers and identify, locate, and query geographic and attribute data. ArcExplorer software's powerful symbolization tools can be used to create thematic maps based on attributes contained in the database, and even perform basic statistical analysis on the geographic data.

System requirements for using ArcExplorer

ArcExplorer 2 works on Windows 98/2000/NT/XP operating systems. Internet Explorer 4 is required for some of ArcExplorer 2's World Wide Web functionality. ArcExplorer 4.0.1 can be installed on a Windows, UNIX, Linux, or Macintosh operating system.

3. ArcReader

ArcReader (Figure A.7) is a free, easy-to-use mapping application that allows users to view, explore, and print maps. Specifically, ArcReader reads those maps which have been produced using the ArcPublisher module of the ArcGIS family. Within ArcReader, it is possible to view, interrogate and pan around a published map.

As with ArcExplorer, ArcReader is available free of charge and can be distributed with data on CD-ROM, but it is not able to automatically view or read GIS layers such as shapefiles, coverages or images. In addition to viewing the published documents, ArcReader can be used to print high quality maps or view map layouts. It is also possible to customize ArcReader applications or embed its capabilities into existing applications.

Overall, the advantages of ArcReader are:

- allows any user to view maps created with ArcGIS Publisher;
- provides read-only viewing and query capabilities to your enterprise GIS data;
- allows non-GIS users to work with maps;

- enables data and maps to be published on CD–ROM.

However, the significant disadvantage of ArcReader is that it is unable to read anything other than documents produced using the ArcPublisher extension.

System requirements for using ArcReader

These are:

Operating system: Windows NT 4.0; Windows 2000 or Windows XP (home edition and professional)

Memory: 128 MB RAM
Processor: 450 MHz

The respective characteristics of the different ESRI products are summarised in Table A.1.Note that some products which were developed to perform a specific function, such as data viewing, will not necessarily be able to perform the functions of a general purpose GIS package.

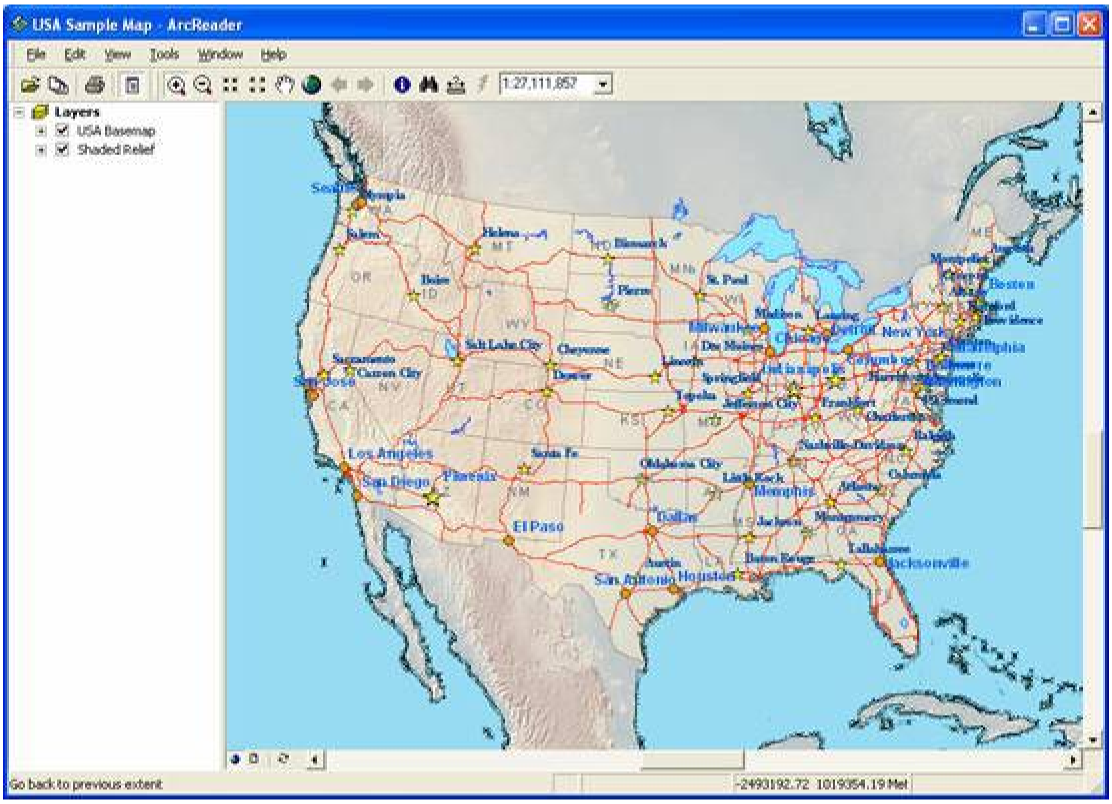


Figure A.7. The ArcReader interface

Table A.1 A comparison of ESRI products

Software		Multiplatform	Web support	Helpdesk	Training provided	Simple menu / toolbar structure	Use of 'Wizards' for tools	Easy to customise	Useful online Help	Large data reading range	Intuitive com-mands and symbols
ArcView 3 series	Rating	3	4	3	-	3	3	3	2	2	2
	Comments	Includes UNIX and Macintosh		For v3.3 only							
ArcView 8 series	Rating	2	4	4	4	3	3	4	3	3	2
	Comments	Focus on NT, Windows									
ArcExplorer	Rating	3	3	-	-	3	1	2	2	1	2
	Comments										
ArcReader	Rating	2	3	3	-	3	1	3	2	1	2
	Comments										

(Continued overleaf)

Software		Quick display / redraw	Ability to edit attributes	Ability to edit features	Standard Analysis functions	Outputs are 'WYSIWYG'	Projection capability	Metadata edit/ creation	Useful symbol/ text range	Cost	Overall
ArcView 3 series	Rating	1	3	3	3	1	3	1	3	USD1900*	4
	Comments			Shapefiles only							
ArcView 8 series	Rating	3	3	3	4	3	3	4	4	USD3100*	4
	Comments										
ArcExplorer	Rating	1	1	1	2	1	1	1	2	-	2
	Comments										
ArcReader	Rating	2	1	1	1	3	1	1	2	-	2
	Comments										With significant limitations

* approximate 2001 prices.

Notes on rating system:

1 – lacks the ability to perform a specific function or application

2 – reasonable, albeit unremarkable capacity; may not be able to perform all functions effectively or efficiently.

3 – able to perform specified function in an efficient, and relatively easy manner.

4 – excellent capacity to perform functions in an efficient and easy-to-use manner.

Ramsar Technical Reports

Ramsar Technical Reports are designed to publish, chiefly through electronic media, technical notes, reviews and reports on wetland ecology, conservation, wise use and management, as an enhanced information support service to Contracting Parties and the wider wetland community in support of implementation of the Ramsar Convention.

In particular, the series includes the detailed technical background reviews and reports prepared by the Convention's Scientific and Technical Review Panel (STRP) at the request of Contracting Parties, and which would previously have been made available in most instances only as "Information Papers" for a Conference of the Parties (COP). This is designed to ensure increased and longer-term accessibility of such documents. Other reports not originating from COP requests to the STRP, but which are considered by the STRP to provide information relevant to supporting implementation of the Convention, may be proposed for inclusion in the series. All Ramsar Technical Reports are peer-reviewed by the members, observers and invited experts appointed to the STRP.

Ramsar Technical Reports

Núm. 1. 2006 Guidelines for the rapid assessment of inland, coastal and marine wetland biodiversity (published jointly as CBD Technical Series No. 22). [sólo en inglés]

Núm. 2. 2006 Low-cost GIS software and data for wetland inventory, assessment and monitoring.
2007 La utilización de programas y datos de SIG de bajo costo para el inventario, la evaluación y el monitoreo de humedales

Núm. 3. 2006 Valuing wetlands: guidelines for valuing the benefits derived from wetland ecosystem services (published jointly as CBD Technical Series No. 27).
2007 Valoración de humedales: Lineamientos para valorar los beneficios derivados de los servicios de los ecosistemas de humedales

In preparation

- Guidelines for valuing the benefits derived from wetland ecosystem services
- A review of Ramsar sites and fisheries management
- The Convention's development of Criteria and guidelines for Ramsar site designation 1971-2005
- Methodologies for assessing the vulnerability of wetlands to change in their ecological character
- Reviews of environmental flow methodologies:
  - i. rivers;
  - ii. estuaries and near-shore environments;
  - iii. non-riverine inland wetlands
- A framework for a wetland inventory meta-database
- Implementation Plan for Global Action on Peatlands 2006-2008
- Review of wetland classification systems

Ramsar

Secretariat of the Ramsar Convention
rue Mauverney, 28
1196 Gland, Switzerland
ramsar@ramsar.org