Integrated Spatial Planning Toolkit

Module X: Technical Paper on Spatial Data Infrastructure Standards

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Background:

The United Nations Development Program - Regional Centre in Bangkok (UNDP-RCB) is managing a project funded by the Government of Japan titled "*Better Informed Environmental Decision Making through Integrated Spatial Planning*", which is under implementation in the Asia-Pacific Region. A Toolkit designed to assist governments develop their capacity for Integrated Spatial Planning is being developed as part of this project. This document comprises the first draft of Module X of this Integrated Spatial Planning Toolkit, on Spatial Data Infrastructure Standards.

Technical Paper on Spatial Data

Introduction

Spatial Data Infrastructure standards

Spatial Data Infrastructure (SDI) comprise of those policies, organisational remits, data, technologies, standards, delivery mechanisms, and financial and human resources necessary to ensure that users of spatial data are supported in meeting their objectives by improving capacity for geographic information exchanges, harmonization and integration.

SDI Standards describe objects, features and items that are collected, automated or affected by the activities or the functions of organisations. The development, publication and acceptance of data standards are important goals of an integrated information management solution. Such standards are essential for all users and producers of data and information. They are particularly important in any co-management, co-maintenance or partnership arrangements where data and information need to be shared or aggregated.

Benefits of the implementation of SDI standards include:

- Increased data compliance
- Improved data compatibility and interoperability
- increased data sharing
- improved data quality, by increasing the number of individuals who find and correct errors
- improved data consistency
- increased data integration
- improved documentation of information resources
- improved control over data updating activities and new versions of datasets
- improved data security and reduced translation and validation costs
- decreased loss of resources, time and expenses associated with the generation, maintenance and integration of data
- better informed decisions, due to higher data quality and accessibility
- better understanding of data
- expanded market potential

Existing spatial data standards

International spatial data standards are being prepared by several organizations, including:

- **The International Standards Organisation (ISO):**
  ISO's Technical Committee on Geographic Information (TC211) aims to achieve standardization in the field of geographic information. ISO/TC211 is working on over 50 spatial data standards, of which more than 20 have been published covering spatial schema, temporal schema, rules for application schema, methodology for feature cataloguing, quality principle, metadata, portrayal and encoding (see http://www.isotc211.org/).

- **The Open Geospatial Consortium (OGC):**
  The OGC is an international consortium consisting over 300 organisations collaborating to develop geographic information applications and specifications on spatial data. OGC submits specifications for ISO standardization via ISO/TC 211. Existing OGC standards include those on web mapping (see: http://www.opengeospatial.org/).

- **The International Steering Committee for Global Mapping (ISCGM):**
  The ISCGM is a Committee of nation states committed to developing a Global Map to facilitate environmental protection and sustainable development. Global Map consists of geographic data sets of known and verified quality, with consistent specifications (see: http://www.iscgm.org/cgi-bin/fswiki/wiki.cgi).

- **The United Nations Geographical Information Working Group (UNGIWG):**
  UNGIWG is a network of professionals working in the fields of cartography and geographic information science to building the UN Spatial Data Infrastructure needed to achieve sustainable development. UNGIWG aims to address common geospatial issues - maps, boundaries, data exchange, standards - that affect the work of UN Organizations and Member States (see: http://www.ungiwg.org/about.htm).

- **The Global Spatial Data Infrastructure Association (GSDI):**
  The GSDI Association an inclusive network of organizations, agencies, firms, and individuals from around the world aiming to promote international cooperation and collaboration in support of local, national and international spatial data infrastructure developments that will allow nations to better address social, economic, and environmental issues (See: http://www.gsdi.org/).

Other notable organizations supporting the establishment of international spatial data standards by working with ISO TC211 and OGC include:

- Committee on Earth Observation Satellites/Working Group on Information Systems and Services (CEOS/WGISS)
- Defence Geospatial Information Working Group (DGIWG)
- EuroGeographics
- European Commission Joint Research Centre (JRC)
- European Space Agency (ESA)
- European Spatial Data Research (EuroSDR)
- Food and Agriculture Organization of the United Nations (FAO/UN)
- IEEE Geoscience and Remote Sensing Society
- International Association of Geodesy (IAG)
- International Association of Oil and Gas Producers (OGP)
- International Cartographic Association (ICA)
- International Civil Aviation Organization (ICAO)
- International Federation of Surveyors (FIG)
- International Hydrographic Bureau (IHB)
- International Society for Photogrammetry and Remote Sensing (ISPRS)
- Panamerican Institute of Geography and History (PAIGH)
- Permanent Committee on Spatial Data Infrastructure for Americas (PC IDEA)
- Scientific Committee on Antarctic Research (SCAR)
- United Nations Economic Commission for Europe (UN ECE) Statistical Division
- United Nations Economic Commission for Africa (UN ECA) 14
- United Nations Group of Experts on Geographical Names (UNGEGN)
- Universal Postal Union (UPU)
- World Meteorological Organization (WMO)

Regional spatial data standards are also being developed by the Permanent Committee on GIS Infrastructure for Asia and the Pacific (PCGAP) and the Australia and New Zealand Spatial Information Council (ANZLIC).

- **The Permanent Committee on GIS Infrastructure for Asia and the Pacific (PCGAP):**

PCGAP is a committee of Asia-Pacific nation states aiming to maximize the economic, social and environmental benefits of geographic information by providing a forum for nations from Asia and the Pacific to develop a regional geographic information infrastructure (see: http://www.pcgiap.org/).

- **The Australia and New Zealand Spatial Information Council (ANZLIC):**
  ANZLIC is an intergovernmental council developing nationally-agreed (Australia and New Zealand) policies and guidelines aimed at achieving best practice in spatial data management (see: http://www.anzlic.org.au/).

These international and regional associations are still in the process of developing and publishing accepted standards that cover the wide range of spatial data infrastructure components. Furthermore, the work thus far produced by many of the international associations, with the exception of ISO, is somewhat difficult to access without thorough research. Even ISO has reported that the TC211 and OGC standards have not had widespread adoption by the GIS software developers or users, whether they be governments, non-government organizations, academic institutions or individuals (http://www.isotc211.org/Outreach/ISO_TC%20_211_Standards_Guide.pdf).

This Technical Paper

In the absence of internationally accepted standards that are easily accessible to the public, this toolkit provides a baseline, yet comprehensive, reference for developing standards in spatially enabled projects and programs, including those implemented government and non-government organizations alike. It draws on the existing work of the above associations and others in providing simplified yet powerful standards recommendations to those governments, project managers and spatial data users who need them now.

It is advised that the above associations are also referred to for up to date information on international and regional standards when formulating standards based on those presented in this toolkit. Likewise, the suggested further reading can be referred to when time and resources permit. If more than one standard exists, it is further recommended that standards are adopted in the following order of priority: 1. International standard, 2. Regional standard, 3. National standard, 4. Provincial standard, and 5. Local standard. It is also advised that open standards are used, which are standards, openly accepted and implemented by governments, private organisations, universities and vendors around the world. The authority of the standard and the title and version of the standard should be referred to when documenting which standard was used.

The topics covered in this Technical Paper are:

Spatial Planning Applications

Spatial planning applications broadly consists of those software applications that enable integrated spatial planning and are vital to determining how spatial data Infrastructure will work. While there are many different approaches that can be used, the approach recommended here involves the use of Geographic Information Systems (GIS) to create, view and view data; a relational database management system (RDMS) to store and manage data; and a server to exchange and share the data between other spatial data users (See Figure X).

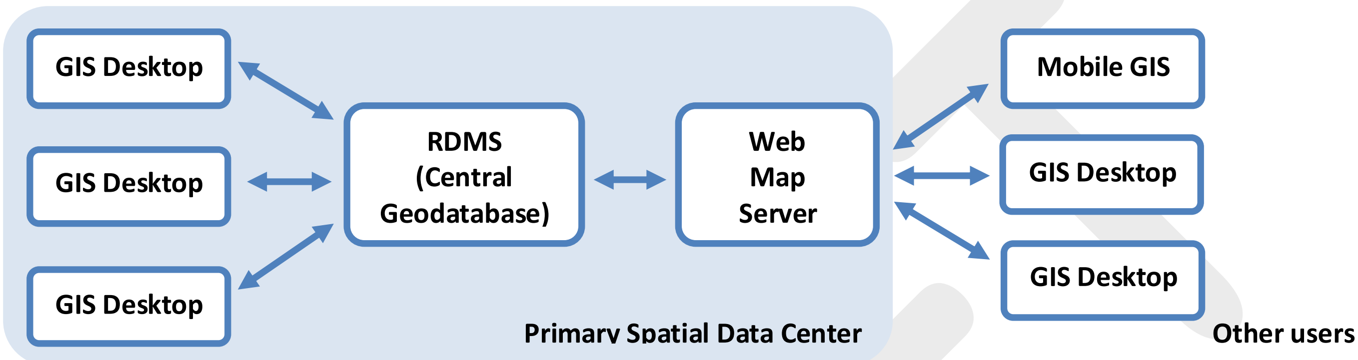

Figure X. Spatial planning software

In less complex scenarios, spatial data can be exchanged without the use of a Web Map Server. In this case data can be imported and extracted directly from the RDMS and exchanged using email or a portable data storage device like a CD or flash drive. In even simpler cases data can be exchanged directly between GIS users without the benefit of a central geodatabase.

Geographic Information System

It is advisable that individuals, teams and agencies involved in the project or program that requires the use of a Geographic Information System (GIS) use the same software. This is to promote efficiencies with data exchanges and consistencies in product outputs.

Selecting a GIS

Selecting the GIS most suitable for the variety of project/program needs is very important. The following is a list of considerations and recommendations to assist with the selecting a GIS:

- **Type of GIS**
  - Consider the purpose of the GIS and whether a simple desktop viewer, professional workstation or server based application is needed.
  - Ensure that the type of GIS is suited to its purpose for use.
- **Budget**
  - Consider the budget for hardware and software (including ongoing maintenance).
  - Ensure that the GIS is the most appropriate GIS is chosen for the job considering available funds.
- **Personnel resources**
  - Consider the experience of staff using the GIS.
  - Ensure that the complexity of the GIS is appropriate for the level of staff experience
  - Ensure that staff with appropriate skills are readily available to ensure smooth implementation
  - Ensure that training is available if needed.

- **Functionality**
  - *Functionality is the ability of the product to perform required tasks in a simple and straightforward manner. Two key elements of functionality are usability and adaptability.*
  - Consider the purpose of the GIS and whether data viewing, editing, storage, manipulation and analysis are needed.
  - Consider the functionality of the GIS, including usability and adaptability.
  - Ensure that the GIS has the appropriate functionality to suit existing and planned needs.
  - Ensure that the GIS has an easy to use and intuitive interface.
- **Performance**
  - *The performance relates to processing time and outputs. This is dependent on software design and engineering at the programming stage, and the speed and configuration of the hardware and networks they are running on.*
  - Consider the hardware requirements of the GIS.
  - Ensure that the GIS utilizes available hardware capacity without slowing computer performance.
- **Scalability**
  - *Scalability is the ability to increase the functionality and/or capacity of the GIS by expanding, migrating, upgrading or 'adding on' more or improved functions to the base implementation.*
  - Consider the future needs of the GIS.
  - Ensure that the GIS can be upgraded to suit future needs.
- **Maintenance and licensing**
  - *Most commercial GIS are sold with a one-off licensing fee. These may be for a single for a single-user computer, a single-user license that can be used on multiple computers at different times, or a multiple-use license that be used on a certain number of computers. Maintenance and technical support is sometimes sold as part of licensing agreements.*
  - Consider the number of GIS users and times at which the GIS will be in use.
  - Consider whether maintenance and technical support is needed.
  - Ensure the license is best suited to the needs of use.
- **Support**
  - Consider the level of support that will be needed.
  - Ensure that good support mechanisms are available, including manuals, training material, online help and technical support from vendors.
- **Format requirements**.
  - Consider the type of data to be used in the GIS.
  - Ensure the GIS has the ability to handle raster (pixel data) and vector (point, line, polygon data).
- **Interface with other software used and interoperability**
  - Consider the other software and data that the GIS will work with.
  - Ensure that the GIS will perform on the computer operating system in use.
  - Ensure the GIS will interface with other software being used.
  - Ensure that the GIS will recognize data file formats used in other GIS, including the ability to import, export, read, write and transfer data.
- **Reliability of GIS and vendor**
  - Consider whether the GIS has a proven record in the marketplace.
  - Avoid unproven products.
  - Avoid outdated products that are no longer supported.

- Avoid outdated products have not adopted recent open standards.
- **Standards**
  - Consider whether the GIS supports spatial standards, for example the Open Geospatial Consortium specifications, the World Wide Web Consortium standards and any national spatial data infrastructure standards.

Comparing GIS applications

There are over 25 notable GIS applications or GIS Suites available on the market. The following table lists these GIS applications and provides relevant information that can provide a starting point in the software selection process. Information indicates whether the GIS applications are commercial or free products; are open source; have data viewing, creation, editing, storage and/or analysis functionality; and are useable by the novice or expert. Information regarding whether the organizations that developed these GIS applications offer online technical support, have a GIS user forum and a large or small market share is also given. The subsequent table, Table X, displays the name of the organisations that developed these products, whether they have an office in Asia or the Pacific and offers links to the organisation websites where more information on the products can be found. A list of other GIS applications can be found on the OGC website at: http://www.opengeospatial.org/resource/products/#. This list also includes whether the GIS applications meet OGS standards and specifications.

Table X. Notable GIS applications for comparison

GIS Name	*Free*	*Open Source*	*Data viewing*	*Data creation*	*Data editing*	*Database storage*	*Data analysis*	*User levels ***	*Online Support*	*User forum*	*Market share ****
Capaware	√	√	√	√	√	√	x	1-4	√	√	3
GRASS GIS	√	√	√	√	√	x*	√	2-4	√	√	1
gvSIG	√	√	√	√	√	x*	√	1-4	√	√	1
ILWIS	√	√	√	√	√	√	√	1-4	x	√	2
JUMP GIS – various	√	√	x	x	√	x*	√	1-4	√	√	2
Kalypso	√	√	√	x	X	x	√	1-4	√	√	2
MapWindow	√	√	√	√	√	√	√	1-4	√	√	1
Quantum GIS	√	√	√	√	√	√*	√	1-4	√	√	1
SAGA GIS	√	√	√	√	√	√	√	1-4	x	√	2
uDig - various	√	√	√	√	√	x	√	1-4	√	√	1
Autodesk	x	x	√	√	√	√*	√	1-4	√	√	1
Axpand - various	x	x	√	x	X	x*	x	1-2	x	x	3
Cadcorp	x	x	√	√	√	√	√	1-4	√	√	2
Maptitude - various	x	x	√	√	√	√	√	1-4	√	√	3
ENVI	x	x	√	√	X	x	√	1-4	√	x	1
ERDAS - various	x	x	√	√	X	x	√	1-4	√	√	1
ArcGIS Desktop	x	x	√	√	√	√	√	1-4	√	√	1
GeoConcept - various	x	x	√	√	√	√	√	1-4	√	√	2
IDRISI Taiga	x	x	√	√	√	√	√	1-4	√	x	2

Intergraph - various	x	x	√	√	√	√	√	1-4	√	√	1
MapInfo	x	x	√	√	√	√*	√	1-4	√	√	1
SavGIS	x	x	√	√	√	√	√	1-4	√	√	3
Smallworld	x	x	√	√	√	√*	√	1-4	x	x	1
SPACEYES	x	x	√	x	X	x	x	1-2	√	√	2
SpatCom	x	x	√	√	√	√	√	1-3	√	√	3
SuperGeo	x	x	√	√	√	√	√	1-4	√	x	2
TatukGIS	x	x	√	√	√	√	√	1-4	√	√	2

* Many of these GIS can plug-in to other database management software, allowing data storage and complex querying, for example Oracle, PostGIS or Microsoft Access.

** User levels: 1-novice (viewing), 2- experienced (editing, simple analysis), 3- expert (analysis), 4- research (scripting, programming).

*** Market share: 1-high, 2-notable, 3-specialised market.

**** Bentley Systems and Manifold GIS are also notable GIS applications that are not listed here due to request from the developer organizations.

Table X. GIS applications and developer organization information

GIS Name	*Developer Organization Name*	*Website*	*Office in Asia*	*Office in the Pacific*
Capaware	Open: Technological Institute of the Canary Islands (ITC)	http://www.capaware.org/index.php?Itemid=58	N	N
GRASS GIS	Open: Research Institutes, Universities, Companies, Individuals	http://grass.osgeo.org/	N	N
gvSIG	gvSIG	http://www.gvsig.gva.es/index.php?id=gvsig&L=2	N	N
ILWIS	Open: ITC, 52°North	http://52north.org/index.php?option=com_content&view=category&layout=blog&id=16&Itemid=61	N	N
JUMP GIS Suite	Open: Tike Finland, University of Hannover, IGN France, UZH	http://www.openjump.org/wiki/show/HomePage	N	N
Kalypso	Open: TU Hamburg Harburg, Björnsen GmbH (DE)	http://kalypso.bjoernsen.de/index.php?id=1&L=1	N	N
MapWindow	Open: Utah State University, Idaho State University, AQUA TERRA, Consultants	http://www.mapwindow.org/	N	N
Quantum GIS	Open: Quantum GIS Development Team, Open Source Geospatial Foundation	http://www.qgis.org/	N	N
SAGA GIS	Open: University Hamburg	http://www.saga-gis.org/en/index.html; http://sourceforge.net/projects/saga-gis/	N	N
uDig Suite	Open: Refractions Research	http://udig.refractions.net/	N	N
Autodesk	Autodesk	http://usa.autodesk.com/	Y	Y
Axpand	Axes Systems	http://www.axes-systems.com/	N	N
Cadcorp	Cadcorp	http://www.cadcorp.com/	Y	Y
Maptitude Suite	Caliper Corporation	http://www.caliper.com/	N	N
ENVI	ITT	http://www.itt.com	N	N
ERDAS Suite	ERDAS	http://www.erdas.com/	N	N
ArcGIS Suite	ESRI	http://www.esri.com/	Y	Y
GeoConcept	Open: GeoConcept	http://www.geoconcept.com/?lang=en	Y	N
IDRISI	Clark Labs	http://www.clarklabs.org/products/index.cfm	N	N
Intergraph Suite	Intergraph	http://www.intergraph.com/default.aspx	Y	Y

MapInfo	Pitney Bowes	http://www.mapinfo.com/	Y	Y
SavGIS	IRD (Institut de Recherche pour le Développement - French research institut for developpement).	http://www.savgis.org/en/	Y	Y
Smallworld	GE Smallworld	http://www.gepower.com/prod_serv/products/gis_software/en/smallworld4.htm	N	N
SPACEYES	SpaceEyes	http://www.spaceyes.com/	Y	N
SpatCom	PT. Damai Insan Citra	http://www.spatcom.com/	Y	N
SuperGeo	SuperGeo Technologies Inc.	http://www.supergeotek.com/	Y	Y
TatukGIS	TatukGIS	http://www.tatukgis.com/Home/home.aspx	N	N

Recommended GIS

After reviewing the GIS applications available on the market, ArcGIS (commercial GIS), GRASS GIS and Quantum GIS (free open source GIS) are recommended.

ArcGIS Desktop, developed by ESRI, is an integrated collection of three GIS software products –ArcView, ArcEditor and ArcInfo –which increase in complexity and provide a standards-based platform for spatial data viewing, creating, editing, management and analysis. ArcGIS is capable of handling and transforming most spatial data file formats available into ArcGIS raster and vector and can perform the majority spatial analyses known. ArcGIS also supports sophisticated cartography and map printout options. ArcGIS has a strong database management system through ArcCatalog and can also plug into other database software like Oracle and Microsoft Access. ESRI has a wide support system provided through online and in-person technical helpdesks, online and in-person training, numerous user manuals and helpfiles, newsletters, and active user-community. ESRI further provides regular product updates and support for developers. ArcView can be used by both novices and experts researching new mapping techniques. ArcGIS products are widely used, including by the GSDI, ISCGM, PCGAP, FAO and USGS.

There are a number of other ESRI ArcGIS platforms that can be used in conjunction or separate to ArcGIS desktop applications. ArcGIS Server allows the distribution of maps and GIS capabilities via web mapping applications and services, and mobile GIS. This includes web mapping as well as data sharing, management, editing and analysis. ArcGIS Mobile helps organizations deliver GIS capabilities and data from centralized servers to a range of mobile devices. ArcGIS Online Sharing is a no-cost central Web-based repository through which ArcGIS users can easily search and share GIS, maps, layers, tools, map services, task services, software developer kits (SDKs), and other content via the Web. Two free ArcGIS applications are also available, ArcReader and ArcGIS Explorer. ArcReader is an easy-to-use desktop mapping application that allows users to view, explore, and print maps and globes. ArcGIS Explorer is a GIS viewer that gives you an easy way to explore, visualize, and share GIS information.

Geographic Resources Analysis Support System (GRASS GIS) is an official project of the Open Source Geospatial Foundation and is the most widely used and developed open source software package available. GRASS GIS is used for geospatial data management and analysis, image processing, graphics/maps production, spatial modeling, and visualization. It is capable of handling raster, topological vector, image processing, and graphic data and performing most spatial analyses that can be run with commercial GIS (including ArcGIS) and more. GRASS GIS is interoperable with most other GIS, can run on multiple platforms and can interface with many other software packages through a graphical user interface (GUI). However this interface is not intuitive for new uses and previous GIS experience and training in the GRASS is advisable before use. GRASS GIS has a strong user forum providing online support, upgrades and enhancements.

Quantum GIS (QGIS) is another official project of the Open Source Geospatial Foundation and provides a multi-platform desktop application for working with a variety of spatial data.Quantum GIS has a user friendly interface and can be operated by the novice GIS officer. It can perform a growing number of functions including the visualization, management, editing and analysis of data. Quantum GIS has a strong user forum providing online support, upgrades and enhancements through multiple plug-ins. One such plug-in links Quantum GIS into the more developed GRASS GIS. Therefore the user-friendly Quantum GIS can also perform complex analyses through the installation of both software applications. Support can also be received via a very active Quantum GIS mailing list. Quantum GIS is currently available in 26 languages.

Database Management System

It is recommended that a relational database management system (RDMS) is used to store and manage all spatial data. This is particularly recommended when large volumes of data are in use, multiple users access or exchange this data, or complex queries and data extractions are being performed.

Selecting a RDMS

Some of the benefits of relational database management systems are that they:

- Allow the storage and retrieval of data in a structured way
- Allow the storage of metadata
- Allow relational datasets to be linked and queried
- Allow complex queries and data analysis without desktop GIS
- Assist with ensuring that relational standards are consistent between all datasets
- Assist with ensuring that other standards are consistent between all datasets
- Allow multiple concurrent operations and multi-user access to datasets via locking functionality
- Allow user access to be controlled, with some users having full access to datasets and functionality and others having limited access to specific datasets and procedures that can be performed
- Allow for dataset security and encryption
- Allow the logging and auditing of all use of the datasets through process logs that track which users perform what procedures and when
- Allow some procedures to be reversed through undo logs and redo logs
- Allow the tracking of data ownership and value adding

Most RDMS will not treat spatial datasets any differently than ‘a-spatial’ or ‘normal’ datasets. However a few ‘spatially enabled’ RDMS can support geographic objects and can therefore be used as a backend spatial database for a variety of GIS applications. These RDMS may provide a spatial indexing system and schema for geometric data types and associated metadata. Some will also offer operators, functions, and procedures for performing spatial analyses.

The following is a list of considerations and recommendations that can be referred to when selecting a RDMS. The recommendations are similar to those to consider when selecting a GIS:

- **Budget**
    - Consider the budget for hardware and software (including ongoing maintenance).
    - Ensure that the RDMS is most appropriate RDMS is chosen for the job considering available funds.
- **Personnel resources**
    - Consider the experience of staff using the RDMS.
    - Ensure that the complexity of the RDMS is appropriate for the level of staff experience

    - Ensure that staff with appropriate skills are readily available to ensure smooth implementation
    - Ensure that training is available if needed.
- **Functionality**
    - Consider the purpose of the RDMS and what functions are needed (use the above list as a starting point).
    - Consider the functionality of the RDMS, including usability and adaptability.
    - Ensure that the RDMS can work with spatial data.
    - Ensure that the RDMS can be used to conduct spatial queries and analysis.
    - Ensure that the RDMS has the appropriate functionality to suit existing and planned needs.
    - Ensure that the RDMS has an easy to use and intuitive interface.
- **Performance**
    - Consider the hardware requirements of the RDMS.
    - Ensure that the RDMS utilizes available hardware capacity without slowing computer performance.
- **Scalability**
    - Consider the future needs of the RDMS.
    - Ensure that the RDMS can be upgraded to suit future needs.
- **Maintenance and licensing**
    - Consider the number of RDMS users.
    - Consider whether maintenance and technical support is needed.
    - Ensure the license is best suited to the needs of use.
- **Support**
    - Consider the level of support that will be needed.
    - Ensure that good support mechanisms are available, including manuals, training material, online help and technical support from vendors.
- **Interface with other software used and interoperability**
    - Consider the other software and data that the RDMS will work with.
    - Consider whether a third party application is needed to enable the RDMS to interface with the GIS application being used.
    - Ensure that the RDMS will perform on the computer operating system in use.
    - Ensure the RDMS will interface with the GIS application being used.
- **Reliability of RDMS and vendor**
    - Consider whether the RDMS has a proven record in the marketplace.
    - Avoid unproven products.
    - Avoid outdated products that are no longer supported.
    - Avoid outdated products have not adopted recent open standards.

Recommended RDMS

Three of the most popular spatially enabled RDMS are Oracle Spatial (Commercial), PostGIS (Open) and Microsoft Office Access (Commercial). They are introduced here to provide a starting point for consideration.

Oracle Spatial is a RDBMS produced and marketed by Oracle Corporation. In addition to performing the above characteristics of a good RDMS, Oracle Spatial provides a spatial indexing system and an expanded schema for prescribing the storage, syntax and semantics of geometric data types and the associated metadata (including raster data). Oracle Spatial also features several operators, functions, and procedures for performing spatial analyses operations. For example, performing area-of-interest queries, spatial join queries, network modeling, topology modeling and geometric calculations. Oracle Spatial can be used to support a variety of GIS applications, including

ArcView and most open-source GIS. Oracle provides a wide online support system and has a large active user forum. More information is available at: http://www.oracle.com/technology/products/spatial/index.html

PostgreSQL is a free and open-source object-relational database management system (ORDBMS). It offers most of the above database functions and uses a built-in language, PL/pgSQL, which resembles Oracle's procedural language, PL/SQL. **PostGIS**, developed by Refractions Research, is a plug-in that "spatially enables" the PostgreSQL server adds, allowing it to support geographic objects be used as a backend spatial database for a variety of GIS applications. PostGIS also offers several operators for performing spatial analyses and is being continually developed with new user interface tools, topology support, data validation, coordinate transformation and programming APIs. Both PostGIS and PostgreSQL have a large and active user community. They directly support most open-source GIS applications and link into ArcView via a third party connector. More information is available at http://www.postgresql.org/ and http://postgis.refractions.net/.

Microsoft Office Access, is a RDMS that is relatively popular for managing spatial data. While the Access database format does not support geographic features, it offers many of the above database features and can be used as a backend for storing and querying spatial data. It can be relatively easier to learn than Oracle Spatial and PostgreSQL/PostGIS. Nevertheless, database management experience and training is advised before designing or using any relational database management system. More information is available at: http://office.microsoft.com/en-us/access/default.aspx.

Web Map Service Servers

A Web Map Service (WMS) Server enables the serving of spatial data and map images from a GIS database over the World Wide Web. WMS Servers allow the generation of maps on request, using parameters, such as data to be displayed, map layer order, cartographic styling and symbolization, map extent, map layout and features, data format, projection and so forth. Other spatial data users can then access the internet, view the spatial data and map images, and load the data and images into their own GIS or RDMS. Some WMS Servicers also allow multiple users to upload data onto the pre-defined maps, thereby allowing collaborative web mapping.

Selecting a WMS Server

Selecting the most suitable WMS Server for the project will largely depend upon the experience of the staff that will be using it and the functionality of the WMS Server given its desired purpose. Most WMS Servers need to be managed by technically experience staff. The purpose of the WMS Server can be considered and whether it is required to generate maps that are:

- Animated, for example a time series movie showing the tracking of a cyclone;
- Dynamic, allowing user to request from the server what data is displayed;
- Realtime, for example traffic and weather monitoring maps;
- Personalised, allowing user to apply own data filters and cartographic symbolization;
- Interactive, allowing users to explore, navigate and interact with the map;
- Analytical, offering some spatial analyses functionality; and/or
- Collaborative, allowing user uploads.

Recommended WMS Servers

Some of the major commercial GIS applications listed above support WMS. These include Bentley Systems GIS, ESRI ArcGIS, Pitney Bowes MapInfo and Manifold Systems GIS. Open source software that supports WMS include GRASS GIS, JUMP, Quantum GIS, gvSIG and uDig. Those applications with a WMS Server include ESRI ArcServer and Oracle MapViewer. Two open WMS Servers are recommended here, MapServer and GeoServer. These were developed in accordance with the OGC Consortium defined the WMS standard to define the map requests and return data formats. GoogleMaps/Google Earth is also very popular for uploading map data independently or with the support of a more complex WMS Server.

Map Server, a project of OSGeo, is an open source spatially-enabled internet application. It allows users to display and view geographic data, create maps and exchange data. MapServer supports several raster and vector data formats used by the various GIS applications. It offers advanced cartographic output, map element automation (scalebar, reference map, and legend), scale dependant feature drawing and application execution, feature labeling and projection support, amongst other functionality. While developed in C, MapServer supports popular scripting and development environments. MapServer is maintained by a growing number of developers and is supported by a diverse group of organizations that fund enhancements and maintenance. More information is available at: http://mapserver.org/about.html#about

GeoServer is another open source server that users to share and edit geospatial data. GeoServer, written in Java, was designed for interoperability and thus can read and publish a variety of data formats from most GIS applications and spatially enabled RDMS, using open standards. GeoServer additionally supports efficient publishing of geospatial data to GoogleEarth and GoogleMaps and supports advanced features like templates for customized pop-ups, time and height visualizations, and 'super-overlays'. GeServer is developed by a diverse number of individuals and organizations. More information is available at: http://geoserver.org/display/GEOS/Welcome.

GoogleEarthPro also allows spatial datasets created in a variety of GIS applications to be loaded onto the internet and viewed using GoogleEarth or GoogleMaps. GoogleEarth and GoogleMaps allows the viewing of spatial datafiles, in both raster and vector formats, without a GIS application being installed on the computer. Both GoogleEarth and GoogleMaps allow sophisticated cartography and 3D viewing and support collaborative mapping between an active community of spatial data users across the world. Google Earth is available in 37 languages. See http://maps.google.com/support/, http://earth.google.com/and associate webpages for more information.

File Format Standards

To allow for data exchanges between agencies using different GIS, spatial data stored in on file format can be converted into another file format using data interoperability software. While data conversions are possible, it is recommended that they be avoided because conversions can be time consuming process and inadvertently result in data corruption or other problems such as the loss of valuable metadata. Format translation systems further do little to support translation of semantics and therefore information regarding data visulation schmema, and so forth, can also be lost. It is therefore suggested that national guidelines be established that recommend specific spatial data file formats to be used by government agencies.

There is a large variety of spatial data file formats available. In fact, efforts have recently been made by the international community to minimise the number of spatial data formats and converge towards a reduced set (GSDI. 2004). The file formats listed below can be used a starting point for selecting a standard. They are common vector and raster data file formats that are supported by popular GIS applications and recognized by various third party interoperability software applications.

Vector data formats

- ArcInfo export format (E00)
- ArcInfo ungenerate format
- Atlas GIS file (BNA)
- AutoCAD drawing file (DWG)
- Autodesk Drawing exchange format (DXF)

Raster data formats

- ArcInfo GRID files (GRD)
- Adobe Photoshop image file (PSD)
- ARC digitized raster graphic (ADRG)
- ARC interchange raster image file (ADRI)
- Band interleaved by line (BIL)

- Computer graphics metafile (CGM)
- Digital line graph file (DLG)
- Encapsulated postscript file (EPS)
- ERDAS Imagine annotation layer (OVR)
- ESRI Coverage
- ESRI shapefile (SHP)
- Intergraph file format (MGE)
- Intergraph GeoMedia
- MapInfo format (TAB)
- MapInfo interchange format (MIF/MID)
- MapInfo native data format (DAT)
- MicroStation Design Files (DGN)
- Open GIS Simple Features
- Portable network graphics (PNG)
- Simple Vector Format
- Spatial data transfer standard (SDTS)
- Spatial Data Transfer System (SDTS)
- Standard interchange format (SIF)
- Topologically integrated geographic encoding and referencing/line census file (TIGER)
- Vector product format (VPF)
- Vector Product Format (VPF)
- Web Computer Graphics Metafile
- Windows metafile format (WMF)

- Band interleaved by pixel (BIP)
- Band sequential (BSQ)
- Bitmap file (BMP)
- Digital Elevation Model (DEM)
- Digital terrain elevation data (DTED)
- ERDAS Imagine 7.x file (LAN)
- ERDAS Imagine file (GIS)
- ERDAS Imagine native format (IMG)
- ERMapper compressed image file (ECW)
- Geo-referenced TIFF image (GeoTIFF)
- Graphic interchange format (GIF)
- Joint photographic experts group format (JPG)
- JPEG file interchange format (JFIF)
- MrSID compressed file (MrSID)
- Run length encoding compressed format (RLC)
- Spatial data transfer standard (SDTS)
- Sun raster file (SUN/RAS)

The national standard for spatial data file formats will largely depend on the GIS software being used because the data standards would be limited to those data file formats supported by the GIS application. With the popularity of the ArcGIS Suite of products as the standard GIS used by many organizations, ESRI file formats are used and recommended by several international associations including the GSDI, ISCGM, PCGAP, FAO and USGS. For vector data this includes the ESRI ArcGIS Shapefile or Coverage and ArcInfo export format. For raster data this includes the ESRI ArcInfo Interchange format and Geo-Tiff or Geo-GIF for images and remotely sensed data.

With the advent of by-passing the use of spatial data file formats developed by commercial organizations, the Spatial Data Transfer Standard (SDTS) and is also recommended. The Spatial Data Transfer Standard, developed by the USGS, provides a robust method of transferring spatial data between dissimilar computer systems with the potential for no information loss. It is a transfer standard contains spatial data, attribute, georeferencing, data quality report, data dictionary, and other supporting metadata all included in the transfer. More information is available at: http://mcmcweb.er.usgs.gov/sdts/.

Alternatively, an increasingly popular technique for storing and exchanging geographic information is through XML grammar. This is particularly the case for organizations using open source GIS applications, however datasets produced using commercial GIS products can also be transformed and exchanged with this process. Data Exchange formats are considered more robust than native data formats for most GIS applications, which contain only enough information for the originating GIS application to be able to use it properly. Exchange formats usually also carry some minimum metadata to describe the data set as well as data quality statements and schema transcribe the visualisation of the data (GSDI, 2004). Two popular technologies include Geography Markup Language (GML) and Keyhole Markup Language (KML).

Geography Markup Language (GML), developed by the Open GIS Consortium (OGC), serves as a modeling language for geographic systems as well as an open interchange format for geographic transactions on the Internet. GML supports both vector and raster type datasets and is used by OpenSource GIS. There are also open standards for schema governing the visualization of geographic data using GML. More information on GML standards can be found at: http://www.opengeospatial.org/standards/gml.

Keyhole Markup Language (KML), developed by Google for visualizing and exchanging geographic information over the internet. KML also but also controls geographic the annotation of maps and images, and the user's navigation of maps, in the sense of where to go and where to look. KML is being further developed by OGC and utilizes certain geometry elements derived from GML, including point, line string, linear ring, and polygon. More information on KML standards can be found at: http://www.opengeospatial.org/standards/kml.

Another XML based protocol for exchanging information is Simple Object Access Protocol (SOAP). More information on SOAP can be found at: http://www.w3.org/TR/soap12-part1/.

File Organization Standards

Organization of spatial datasets in a common manner makes navigating databases and finding data much more efficient than otherwise. The benefit of a consistent approach to file naming and directory structures is that users 'speak the same language', knowing where to look for information and where to put new data (ANZLIC, 2007- Module 3).

It is recommended that spatial datasets be organized according to the following elements (FAO, 2003):

1. Subject categories
2. Map scales and/or cell resolutions
3. Map extents
4. Temporal characteristics of the geographic information
5. File formats of the datasets
6. Reference systems

The topic categories defined in the ISO/DIS 19115 document on metadata, listed in Table X, provide a good starting point for subject categories. However further subdivisions to better classify the database information might be required. Depending on the size and purpose of the spatial data and GIS database, it may then be necessary to store the datasets in separate folders according to the elements in the above list.

Table X: ISO/DIS 19115 Topic Categories

Name	Code	Definition
Farming	001	Rearing of animals and/or cultivation of plants Examples: agriculture, irrigation, aquaculture, plantations, herding, pests and diseases affecting crops and livestock
Biota	002	Flora and/or fauna in natural environment Examples: wildlife, vegetation, biological sciences, ecology, wilderness, sealife, Wetlands, habitat
Boundaries	003	Legal land descriptions Examples: political and administrative boundaries
Climatology, Meteorology, Atmosphere	004	Processes and phenomena of the atmosphere Examples: cloud cover, weather, climate, atmospheric conditions, climate change, precipitation
economy	005	Economic activities, conditions and employment

		Examples: production, labour, revenue, commerce, industry, tourism and ecotourism, forestry, fisheries, commercial or subsistence hunting, exploration and exploitation of resources such as minerals, oil and gas
Elevation	006	Height above or below sea level Examples: altitude, bathymetry, digital elevation models, slope, derived products
Environment	007	environmental resources, protection and conservation Examples: environmental pollution, waste storage and treatment, environmental impact assessment, monitoring environmental risk, nature reserves, landscape
Geoscientific Information	008	Information pertaining to earth sciences Examples: geophysical features and processes, geology, minerals, sciences dealing with the composition, structure and origin of the earth's rocks, risks of earthquakes, volcanic activity, landslides, gravity information, soils, permafrost, hydrogeology, erosion
Health	009	Health, health services, human ecology, and safety Examples: disease and illness, factors affecting health, hygiene, substance abuse, mental and physical health, health services
Imagery, Base Maps, Earth Cover	010	Base maps Examples: land cover, topographic maps, imagery, unclassified images, annotations
Intelligence, Military	011	Military bases, structures, activities Examples: barracks, training grounds, military transportation, information collection
Inland Waters	012	Inland water features, drainage systems and their characteristics Examples: rivers and glaciers, salt lakes, water utilization plans, dams, currents, floods, water quality, hydrographic charts
Location	013	Positional information and services Examples: addresses, geodetic networks, control points, postal zones and services, place names
Oceans	014	Features and characteristics of salt water bodies (excluding inland waters) Examples: tides, tidal waves, coastal information, reefs
Planning, Cadastre	015	Information used for appropriate actions for future use of the land Examples: land use maps, zoning maps, cadastral surveys, land ownership
Society	016	Characteristics of society and cultures Examples: settlements, anthropology, archaeology, education, traditional beliefs, manners and customs, demographic data, recreational areas and activities, social impact assessments, crime and justice, census information
Structure	017	Man-made construction Examples: buildings, museums, churches, factories, housing, monuments, shops, towers
Transportation	018	Means and aids for conveying persons and/or goods Examples: roads, airports/airstrips, shipping routes, tunnels, nautical charts, vehicle or vessel location, aeronautical charts, railways
Utilities Communication	019	Energy, water and waste systems and communications infrastructure and services Examples: hydroelectricity, geothermal, solar and nuclear sources of energy, water purification and distribution, sewage collection and disposal, electricity and gas distribution, data communication, telecommunication, radio, communication networks

File Naming Standards

File naming standards are essential when data is being exchanged between different parties or used by multiple people. Properly structured filenames ensure that each dataset is uniquely named within the database and that users of the database can immediately recognize key details pertaining to each dataset.

It is recommended to use 8-digit, alphanumeric, not case sensitive file-names to maintain compatibility with a larger variety of software packages and operating systems (FAO, 2003). The following naming convention, outlined in Table X, are recommended (FAO, 2003):

Table X: File Naming Standards (from FAO, 2003)

Start position	Nr. of digits in code	Code description
Digit 1	1	ISO Topic Category
Digit 2	2	Sub-Topic Category
Digit 4	3	Extent: the world, a continent, a country, a province etc
Digit 7	1	Reference system
Digit 8	1	Free digit - Sequential alphanumeric code to be used by the dataset creator to provide additional information such as time, subsequent versions of the dataset etc.*

* Datasets not requiring the use of digit 8 may set this digit to the ASCII Character Code 16 corresponding to the zero value (0). The meaning of, and reference to, digit 8 should be clearly reported as "Supplemental Information" in the metadata (ISO 19115 metadata element Metadata/dataIdInfo/suppInfo).

Metadata Standards

Metadata supports the organization of spatial data, data quality and data sharing capacity. Metadata promotes efficiency, allowing users to quickly (GSDI, 2004):

- view and comprehend the nature and content of spatial datasets (discovery metadata);
- ascertain that the data is fit for a given purpose, evaluate its properties, and to reference some point of contact for more information (exploration metadata); and
- understand how to access, transfer, load, interpret, and apply the data.

The ISO/TC211 metadata specifications outlined in Standard number 19115 on Geospatial Metadata is recommended for use when developing metadata standards. While these should be referred to, an introduction to suggested metadata content is outlined here. Typically metadata for data discovery purposes represents a minimum amount of information required to convey to the enquirer the nature and content of the data resource. Metadata generally falls into broad categories that answer the "what, when, who, where and how" questions about spatial data (ANZLIC, 2007; GSDI, 2004):

- What: title and description of the dataset.
- When: time period covered by the dataset, when the dataset was created and the update cycle, if any.
- Who: dataset originator or creator and supplier.
- Where: the geographical extent of the dataset
- How: how the dataset was created and how the dataset can be accessed

Suggested metadata content under these headings are as follows:

What

- Title
  - Informative and concise title (less than 80 characters), including the theme, geographic extent and time period of the data
- Abstract /Short Description
  - General information
  - Series name and the issue number if applicable
- Dataset type
  - Atlas, diagram, globe, map, model, profile, remote-sensing image, section, or view
- Data type
  - Points / vector data or raster data (images or grids)
  - Object type
  - Object count
  - Data file format
  - Data exchange format
  - Compression
- Coordinate system
  - Geographic coordinates (latitude and longitude)
    - Geographic Coordinate Units (ie decimal degrees)
    - Datum Name (ie. NAD27 or NAD83)
    - Other parameters
  - Planar projection
    - Map projection name (ie. Lambert Azimuthal Equal Area),
    - Other projection parameters
- Geographic features
  - Name of the features or table
  - Attributes of the features
    - Name of the attribute
    - Definition of the attribute
    - Attribute to measure, categorize, or characterize the features (for measured attributes include units of measure, resolution of the measurements, frequency of the measurements in time, and estimated accuracy of the measurements)
    - Values the attribute holds

When

- Time period covered by the dataset
  - A single day/time, a discrete set of days /times or a range of days/times (dates should be written YYYYMMDD, where YYYY is the year, MM is the month 1-12 and DD the day 1-31)

Where

- Geographic area
  - Bounding Coordinates: Westernmost longitude, Easternmost longitude, Northernmost latitude, Southernmost latitude

Who

- Formal authors of the published work
- Compilers and editors who converted the work to digital form
- Technical specialists who did some of the processing but aren't listed as formal authors
- Cooperators, collaborators, funding agencies, and other contributors who deserve mention.
- To whom should users address questions about the data?

Why

- Objectives of the research that resulted in this data set
- How the data should be used
- How non-specialists could misinterpret the data and what aspects of the data set should they be especially wary of interpreting

How

How the dataset was created

- Whether the source data were original observations made by the authors and their cooperators
    - Process description (methodology and procedures)
    - Process date and time
- Scale of the source data
- Time period represented by the source data
- Whether parts of the data previously packaged in a publication or distributed informally?
- Whether the source data published?
  Information obtained from each data source
- How the data as collected, handled, or processed
- When the processing occurred
- Integration and analysis techniques applied to the data
- Reliability, accuracy and quality of the data
    - Processes by which the attribute data have been reviewed or tested, including results
        - Positional accuracy and summary of the processes by which the geographic positions have been reviewed or tested, including results
        - Vertical accuracy and summary of the processes by which the elevations or depths have been reviewed or tested, including results
        - Completeness and summary of data gaps
    - Whether the observations mean the same thing throughout the data set
        - Contextual factors to be considered by someone who wants to understand the data
        - Whether the instrumentation or calibration change while observations were being made?

How to access the dataset

- Legal restrictions on access or use of the dataset
- Legal disclaimers
- The distributor's name and contact details
- Formats the data is available in
- How the data is made available
- Cost of the data
- Time to distribute the data
- Hardware or needed to use the dataset
- Archival procedures required to effectively manage and utilise the data
- Parameters for dataset visualisation

Metadata should also contain information concerning the metadata, for example:

- When the metadata were last modified
- Information on whether the metadata record has been reviewed or if it will be reviewed
- Who wrote the metadata
- To what standard the metadata are intended to conform
- Legal restrictions on who can get or use the metadata

Summary descriptions of content and quality, as well as contact information, that are required for inclusion in directory systems, can also be included in metadata.

Attribute Data Standards

Data attribute standards are recommended for consistent querying and analysis. They also enable analysts and planners using spatial data to guide the attribute information that is required during the data collection process. Due to the diverse range of geographic information, this report does not recommend attribute data content. However, the following documents can be referred to for existing attribute data satandards:

- The Feature and Attribute Coding Catalog created by the Digital Geographic Information Exchange Standard (DIGEST) of the Digital Geographic Information Working Group (DGIWG) in collaboration the International Organization for Standardization (ISO) and the International Hydrographic Organization (IHO).
- The United Nation Cartographic Section documents listing attribute specifications for the 1:1,000,000, 1:5,000,000 and 1:10,000,000 scale datasets.
- The National Mapping Program of the US Geological Survey (USGS) data specifications and technical instructions (including data dictionary) for digital datasets at maps scales ranging from 1:250,000 to 1:20,000.

Projection and Datum standards

When spatial datasets with different projections are displayed on the same map then the geographic features will not line up. Datasets must therefore be projected using the same equation before they can mapped together. Most GIS software can re-project spatial data, however the process is often complex, particularly when large amounts of data are involved. Loss of data quality due to resampling during projection can also result. It is therefore advised that a standard map projection be defined to minimize the possibility of problems during this process.

There are numerous methods with which to project the earth's surface onto a map plane and therefore a large variety of map projections. The map projections listed here are categorized into common classifications of equal-area projections, conformal, equidistant and azimuthal. These categories are so named according to the point of preservation of metric properties during the process of projecting the earth's surface onto a plane, such as area, angle, distance, and azimuth (ISCGM, 2008). Equal-area projections preserve area, whereas conformal, equidistant and azimuthal projections preserve angle, distance and azimuth, respectively. Equidistant projections preserve distance only on some fixed group of lines or curves, and azimuthal projections preserve azimuth from one fixed point to other point. Equal- area projection cannot be consistent with conformal projection. Equidistant and azimuthal projection may be consistent with other projections. In contrast, compromise projections do not preserve metric properties but rather find a balance between distortions and making things 'look right'.

Examples of projections under these categories are as follows:

Equal-area projections

- Mollweide
- Albers conic
- Albers equal-area conic projection
- Bonne
- Bottomley
- Briesemeister
- Collignon
- Flat Polar Quartic
- Gall orthographic (Gall-Peters, or Peters, projection)
- Goode's homolosine

Conformal projections

- Adams hemisphere-in-a-square projection
- Guyou hemisphere-in-a-square projection
- Lambert conformal conic
- Mercator
- Quincuncial map
- Roussilhe
- Stereographic
- Transverse Mercator projection

Azimuthal projections

- Azimuthal conformal or stereographic
- Azimuthal equidistant
- General Perspective
- Gnomonic
- Lambert azimuthal equal-area
- Logarithmic azimuthal
- Orthographic

- Hammer
- Hobo-Dyer
- Lambert azimuthal
- Mollweide
- Sinusoidal
- Tobler hyperelliptical
- Werner

Equidistant projections

- Azimuthal equidistant
- Equidistant conic
- Equidistant cylindrical projection
- Equirectangular
- Plate carrée
- Sinusoidal
- Soldner
- Two-point equidistant
- Werner cordiform

Compromise projections

- B.J.S. Cahill's Butterfly Map
- Buckminster Fuller's Dymaxion
- Miller cylindrical
- Robinson
- Steve Waterman's Butterfly Map
- van der Grinten
- Winkel Tripel

The chosen map projections will largely depend on the area over which the map covers and the purpose of the map. A set of map projections may be chosen that minimize the level of distortion of geographic features being represented under examination (FAO, 2003). It is ideal to choose a map projection that can be interpreted by common GIS.

The following projections, which are widely supported by most GIS software, are recommended (FAO, 2003):

- Flat Polar Quartic and Mollweide are equal-area projections suitable for world mapping
- Lambert Azimuthal Equal Area projection for continental mapping (which is particularly suited for regions extending equally in all directions from center points, such as Asia and Pacific Ocean). A center in 45N, 100E for Asia and 15S, 135E for Australia is suggested for these continents (cited in Steinwand, Hutchinson & Snyder, 1995)
- Lambert Conformal Conic projection and Albers Equal Area Conic for national mapping
- Universal Transverse Mercator (UTM) for tiled or sub-national mapping

It is further recommended that the WGS 84 datum based on IAG-GRS80 spheroid, which fairly represents every location on the earth's surface and is convenient for small-scale data (The UN Cartographic Section, FAO and ISCGM).

However, original un-projected data (also referred to as geographic projected) are also being widely used by GIS packages and should be considered as one of the standard projections for data interchange (FAO, 2003 and USGS, 1999.

Quality Standards

It is recommended that data quality standards are set so that datasets are accurate enough for the map purposes. Data quality standards should be specified for positional accuracy and informational quality. Positional accuracy is dependent upon the scale at which the data is produced and at which scale the dataset is meant to be used (FAO, 2003). Positional accuracy includes:

- Absolute accuracy: evaluates the measure of the maximum deviation between the location of the map feature and its location in the real world.
- Relative accuracy: a measure of the deviation between two objects on a map
- Graphic quality: the visual cartographic display quality of the data, and pertains to aspects such as the data's legibility on the display, the logical consistency of map graphic representations, and adherence to common graphic standards.

Informational quality reflects the accuracy of both map graphic features and attribute data. Informational quality includes:

- Completeness: percentage of features in the dataset that should be in it.

- Correctness: number of errors in the dataset.
- Timeliness: the currency of a dataset, with information on how up-to-date it is and on its expiry date.
- Integrity: internal consistency of the dataset.

Map scale and resolution standards should also be specified to assist with maintaining data quality, particularly positional accuracy. Map scale standards ensure that maps remain useable and are not more detailed than the quality of data allows or too course for analysis purposes. They specify the scale at which data is collected (dataset scale) and the scale at which this data is visualized on a map (map scale).

Similarly, standards governing map resolution, or Minimum Mapping Units (MMU) and map cell sizes, should be set to ensure that datasets and maps are neither too detailed or course than what is needed for the map purposes. Large MMU or cell sizes displayed at a small map scale will look course and blocky, often lacking the detail needed for the purposes of the map. In contrast, small MMUs and cell sizes produce a high quality with improved detail. However the data file size and time taken for computer processing will be much higher.

Positional Accuracy

With regards to absolute accuracy, it is recommended that no more than 5 percent of well-defined geographic reference points tested shall be in error by more than 0.6mm, measured at the publication scale (United Nation Cartographic Section). See below:

Map scale	Allowable error at map scale in mm	Allowable error in meters
1:1,000,000	0.6	600
1:5,000,000	0.6	3,000
1:10,000,000	0.6	6,000

However for global maps it is recommended that 90% of points will be within 2km of their actual location. In the case of data obtained from satellite images, the maximum error should be less than or equal to 0.5km (ISCGM, 2007).

It is recommended that the Landsat global mosaic be used as ground reference to reevaluate the positional accuracy(PCGIAP WG2, 2009).The Landsat global mosaic covers the entire globe and is freely available on the internet at: http://onearth.jpl.nasa.gov/wms.cgi? and http://glcfapp.umiacs.umd.edu:8080/esdi/index.jsp. It is recommended that using the global Landsat mosaic as the reference, the horizontal accuracy should be of 500m for 90 % of the points (accuracy for 1:1,000,000 dataset).

With regards to relative accuracy, it is recommended that decimal-degree (longitude/latitude) coordinates for geographic data should be recorded to a minimum 5 significant digits to the right of the decimal point and stored in double precision attribute or database fields, for national or regional maps (USGS http://mapping.usgs.gov/standards). For global maps, it is recommended that data is stored in decimal degrees to a minimum of three decimal points as (ISCGM, 2007).

Standards for graphic quality should ensure that maps and map content are legible and consistent with common cartographic standards. Refer to the technical Paper on Cartography in this series for more information regarding cartographic standards.

Informational quality

It is difficult to provide recommendations for establishing standards governing informational quality.

However with regards to completeness, it is recommended that not more than 1% of the features and attributes existing in the source data are missing in the output (FAO, 2003).

With regards to integrity, it is recommended that (adapted from FAO, 2003 and UN Cartographic standards):

- Missing or duplicate records or features are avoided
- Datasets have attributes attached and have topology created
- Features are split at administrative boundaries
- There are no coincident lines within a single coverage
- There are no intersections within a line coverage
- All polygons have labels apart from the universal polygon

Standards for correctness and timeliness will very much depend on the purpose of the map and recommendations are therefore not provided here.

Map scale

Recommended map scales are (adopted by the UN Cartographic Unit):

- 1: 5,000,000 for national mapping
- 1: 1,000,000 for continental mapping.
- 1:10,000,000 for global mapping

Datasets, originally produced at 1, 5 and 10 million scales, can also be used for representing features on maps at higher or lower scales. It is recommended that the scale range for producing maps be from 2 to ½ x the scale of the source data be (FAO, 2003):

Scale of source data	2x the scale of source data	½x the scale of data source
1:1,000,000	1:500,000	1:2,000,000
1:5,000,000	1:2,500,000	1:10,000,000
1:10,000,000	1:5,000,000	1:20,000,000

Minimum Mapping Units and Resolution

The following MMUs and cell-sizes for the above suggested scales are recommended as a trade-off between computer efficiency and shape definition (FAO, 2003):

Map Scale	MMU - Area on the map in mm^2	MMU - Area on the ground in Km^2	Side-length of squared MMU in m*	Pixels in MMU side**	Proposed cell-size in m
1:1,000,000	4	4	2,000	10	200
1:5,000,000	4	100	10,000	10	1,000
1:10,000,000	4	400	20,000	10	2,000

*   *The side-lengths of squares of MMU-equivalent areas*

**   *The number of pixels recommended for covering the side-lengths of squares of MMU-equivalent areas. The ratio Map-scale factor/Cell-size is constantly 5000 and the number of pixels per squared MMU is 100.*

Being calculated in meters, the above values cannot be used for un-projected (Geographic projection) data. While acknowledging the limitations in converting cell size in meters to cell sizes in degrees, particularly due to variation with latitude, it is recommended that the following standards be used (FAO, 2003):

Map Scale	Cell-size in m	Cell-size in degrees
1:1,000,000	200	0.001666 (6 seconds)
1:5,000,000	1,000	0.008333 (30 seconds)
1:10,000,000	2,000	0.016666 (1 minute)

References and Further Reading

Australia and New Zealand Spatial Information Council (**ANZLIC**), *Various publications* (Available at: http://www.anzlic.org.au/publications.html):

- Local Government spatial Information management Toolkit v2.0 (2007)
    - *MODULE 1: Spatial information management in local government*
    - *MODULE 2: An introduction to spatial information systems*
    - *MODULE 3: Data management principles*
    - *MODULE 4: Spatial data priorities, standards and compliance*
    - *MODULE 5: Finding and getting hold of spatial data*
    - *MODULE 6: Project management and justification*
    - *MODULE 7: Guidelines for selecting spatial information systems software and hardware*
    - *MODULE 8: Raising capability for using spatial information*
    - *MODULE 9: Map production guidelines*
    - *MODULE 10: Working together*
- Copyright, custodianship & privacy
    - *ANZLIC Spatial Information Privacy Best Practice Guidelines (v2 - February 2004)*
    - *Spatial Information Privacy Issues Discussion Paper (v2)*
    - *Guidelines for Custodianship (April 1998)*
- Data access & pricing
    - *Access to Sensitive Spatial Data (discussion paper : July 2004)*
    - *Guiding Principles for Spatial Data Access and Pricing Policy (November 2001)*
    - *Model Data Access and Management Agreement - data access and management protocol including a model data licence agreement for the supply of data (v1.3–April 2002)*
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