WFP SPATIAL DATA INFRASTRUCTURE (SDI) IMPLEMENTATION IN SUPPORT OF EMERGENCY MANAGEMENT

A. Ajmar[a], F. Perez[a], O. Terzo[b]

[a]ITHACA, via P.C. Boggio 61, 10138 Torino, Italy - (andrea.ajmar, francesca.perez)@ithaca.polito.it
[b]Istituto Superiore Mario Boella, via P.C. Boggio 61, 10138 Torino, Italy – terzo@ismb.it

KEY WORDS: Databases, Developing Countries, Hazards, Internet/Web, Decision Support, Spatial Infrastructures, Interoperability

ABSTRACT:

Short-term emergency response capacities, long-term risk reduction, development and environmental protection activities are sector where a Spatial Data Infrastructure (SDI) may strongly improve efficiency, facilitating access to geographically-related information using a minimum set of standard practices, protocols, and specifications. The production and use of geospatial information within the United Nations has been accomplished historically by its component organizations in accordance with their individual needs and expertise. This has resulted in multiple efforts, reduced opportunities for sharing and reuse of data, and an unnecessary cost burden for the United Nations as a whole. The ITHACA association is supporting UN World Food Programme (WFP) in developing and implementing an SDI solution based on UNGIWG (UN Geographic Information Working Group) recommendations that can be resumed by the following keywords: decentralized geospatial information framework, interoperability between spatial data infrastructures, to avoid duplication in data collection and management, to enhance decision-making, re-use and sharing. A geodatabase conceptual schema has been developed using a general purpose modeling language (UML, Unified Modeling Language) in order to be as far as possible interoperable and independent of any particular database management system (DBMS). Following the same principles, the geodatabase schema is maintained in XML format, allowing structured data sharing possible. A two level architecture has been defined in order to efficiently combine complex management and administration activities with interoperable and open source based applications and services, dedicated to the broader humanitarian community of users.

RÉSUMÉ:

Les activités de développement et de protection de l'environnement sont des secteurs où les Infrastructures de Données Spatiales (IDS) peuvent en améliorer sensiblement l'efficacité et faciliter l'accès aux informations de type géographique à travers une suite minimal de protocoles et spécifications standard. Ceci permet d'accroître les capacités de réponses aux urgences à court terme avec une réduction des risques à long terme. Depuis toujours les différentes structures de l'Organisation des Nations Unies produisent et utilisent des informations géospatiales en fonction de leurs respectifs besoins mais sous forme décentralisée, ce qui à réduit les opportunités de partage et réutilisation des données et, par conséquent, compliqué de façon inutile le travail au sein de l'organisation. L'association ITHACA est soutenue par le UN World Food Programme (WFP) pour le développement et la réalisation d'une solution IDS basée sur les recommandations UNGIWG (UN Geographic Information Working Group) qui peuvent être résumées en quelques mots: décentralisation des informations géospatiales, interaction entre les différentes infrastructures de données spatiales, réduction de la duplication et de la gestion des données, amélioration de la prise de décision, réutilisation et partage. Un schéma conceptuel a été développé en utilisant le langage UML (Unified Modeling Language) et ceci pour le rendre le plus possible réalisable tout en étant indépendant de n'importe quel Système de Gestion de Base de Données (SGBD). En suivant les mêmes principes, le schéma du geodatabase a été maintenu en format XML, ce qui a permit de rendre possible le partage des données structurés. Une architecture à deux niveaux a été définie, pour rendre plus efficace la complexité de gestion et d'administration des activités, avec l'utilisation d'applications et services open source dédiés aux utilisateurs du secteur humanitaire.

1. INTRODUCTION

Nowadays, the world is facing disasters on an unprecedented scale: millions of people are affected by natural disasters globally each year and, only in the last decade, more than 80% of all disaster-related deaths were caused by natural hazards.

When an event hits regions of the world where local authorities are not structured to deal with their complex effects, they normally ask the intervention of international organizations, such as UN agencies. Those organizations are in charge of the activation of emergency procedures in order to cover affected population's immediate needs and, with a long-term view, to prepare protracted relief and recovery operations.

The different events that may generate the need for an humanitarian intervention may be grouped in three major kinds:

- sudden disasters, which affect food access and/or cause population displacements;
- slow-onset disasters, as droughts and crop failures;
- complex emergencies, that can involve conflict, widespread social and economic disruption and large population displacements.

In the frame of humanitarian operations, the *World Food Programme* (WFP) of the United Nations is in the front line. The WFP is the biggest UN Agency and responds to more than 120 emergencies per year worldwide.

According to the UN reform, WFP is also the leader of logistics for UN and international bodies during emergency response operations. To facilitate and support the coordination of logistics capabilities among co-operating humanitarian agencies, as well as to complement and support the global and field logistics clusters, is another major objective while planning an on-field action. It is done through the provision of Logistics Information Management, mapping, customs, commodity tracking tools and services. Inside the UN organization, that duty is responsibility of the *United Nations Joint Logistics Centre* (UNJLC). The UNJLC is a UN Common Service; it is a facility activated when intensified field-based inter-agency logistics information is required. Once mobilised, the UNJLC seeks the widest possible participation among all humanitarian logistics actors (UN and NGO alike).

During relief operations preliminary phases, short term analyses on the effects of a single event are critical for preparing detailed intervention plans and budget estimates. The use of remote sensing techniques, to perform accurate and timely assessments, combined with updated, reliable and easily accessible reference base datasets are a key factor for the success of emergency operations, helping to answer key questions as how much food aid is needed and how to deliver it to the hungry population.
Short-term emergency response capacities, long-term risk reduction, development and environmental protection activities are sector where a Spatial Data Infrastructure (SDI) may strongly improve efficiency.

The term Spatial Data Infrastructure (SDI) is often used to denote the relevant base collection of technologies, policies and institutional arrangements that facilitate the availability of and access to spatial data. A spatial data infrastructure provides a basis for spatial data discovery, evaluation, download and application for users and providers within all levels of government, the commercial sector, the non-profit sector, academia and the general public. Spatial data infrastructures facilitate access to geographically-related information using a minimum set of standard practices, protocols, and specifications. Spatial data infrastructures are commonly delivered electronically via internet.

The production and use of geospatial information within the United Nations has been accomplished historically by its component organizations in accordance with their individual needs and expertise. This has resulted in multiple efforts, reduced opportunities for sharing and reuse of data, and an unnecessary cost burden for the United Nations as a whole.

The ITHACA (*Information Technology for Humanitarian Assistance Cooperation and Action*) association is supporting UN WFP in developing and implementing an SDI as solution for several issues, related to distributed management and exploitation of spatial data, among them:

- inconsistent data in terms of content and format;
- existence of “invisible” data, not computerized or hidden in local computers;
- confidentiality and sensitivity of certain data and information;
- difficulties in implementing data/systems integration;
- poor application of standards;
- lack of extensive and reliable metadata catalogues;
- lack of streamlining of spatial analysis in decision making;
- unproductive competitive practices.

2. SDI ARCHITECTURE

2.1 Needs assessment

As a result of needs assessment round tables with WFP users, an architecture granting a solid back end and a flexible, interoperable and customized front end has been considered the best solution for managing data in a distributed environment. Back end component is accessed by high level users, in charge of database management and of performing complex data analysis procedures. Front end applications are mainly dedicated to analysis, processing of project specific geodata and exploratory aspects; simple editing capabilities should be also included.

Technical constraint related to low performance internet connection required to develop solutions for disconnected data management using database replica and guided procedures for data reconciliation.

Re-use and re-organization of currently managed dataset have been a priority in the data modelling phase, together with direct access to open geographic sources (SRTM data, archive satellite images, etc.) without any need for data pre-processing.

Finally, the development of suitable data management rules and map templates allows to create a “lowest common denominator” for geographic analysis and mapping, in support to decision making during emergencies.

2.2 System architecture

A two-levels architecture is proposed and implemented, to fulfil two major requirements:

- to increase performances by splitting the production and publication environments;
- to study new features in order to implement a progressive porting of the geodatabase from a commercial to a non commercial Database Management System.

Production/Editing environment: back end component accessed by high level users, in charge of database management and of performing complex data analysis procedures. The necessity of having ready-to-use and operative functionalities for ongoing activities and missions, granting high levels of data security and reliability, is the main factor suggesting the implementation of a commercial products based platform (
Table **1**).

Component	Description	Version	Type
Operating System	Ubuntu (linux)	7.10 (32bit)	Open Source
DBMS	Oracle10 G	10.2.0.1.0	Commercial
Gateway Software	ESRI ArcSDE	9.2	Commercial
GIS Client	ESRI ArcGIS	9.2	Commercial

Table 1 - Production/Editing environment architecture

Data security issue is granted by the applicability of several different approaches, such as:

- authentication, one-factor or two-factor;
- authorization;
- privileges;
- data encryption;
- Data Integrity algorithms;

- auditing;
- Virtual Private Database Column Masking, allowing only authorized users to see the content of certain table fields;
- Label Security Authorizations.

Publication/Analysis environment: front end applications, mainly dedicated to analysis, processing of project specific geodata and exploratory aspects; simple editing capabilities should be also included. This environment is developed on a completely open source platform, for high availability and interoperability of derived applications and services. This environment, in future perspective, may substitute in all functionalities the production/editing commercial based environment, once the development of certain functionalities for data management and security will be considered mature (Table **2**).

Component	Description	Version	Type
Operating System	Ubuntu (linux)	7.10	Open Source
DBMS	PostgreSQL / PostGIS	8.2	Open Source
Web Map Engine	Mapserver	5.0	Open Source
GIS WMS Client	Any OGC Compliant	9.2	Open Source / Commercial
Tools	Ora2Pg	4.7	Open Source
	Ogr2Ogr	1.7	Open Source

Table 2 - Publication/Analysis environment architecture

Summarizing, the actually implemented architecture includes a production geodatabase based on Oracle 10 G and a PostgreSQL/PostGIS database for the publication environment, acting as source for web mapping services. Several scripts have been implemented for exporting data from Oracle to PostgreSQL, by using ora2pg and ogr2ogr tools.

2.3 Architecture schema

System architecture definition (Figure 3) has been obtained keeping in consideration three different tasks that the system must perform efficiently:

- **Geodatabase network**: the architecture of the geodatabase servers, including:
  - the master Geodatabase (Oracle 10g), that contains all the database schema and the data;
  - the replica Geodatabase (Oracle 10g), containing a two-way replica of the master Geodatabase, for maintenance purpose and data consistency;
  - publication Geodatabase (PostgreSQL/PostGIS), a geodatabase replica to be accessed and used by web based services and applications.

- **Internal backup and restore network**: internal support network used to backup sensitive data on a tape driver, to reduce the cost of the storage system and to assure the maximum flexibility of the service. Policies and scheduling of backup operation are under definition, considering several different factors such as data volumes, update rates, data sensitivity and level of services that must be granted.

- **Web Server**: server(s) that provide the publication service of the geodatabase using GIS application. The architecture of the system is composed by two servers with the same hardware configuration. Three different hypotheses about the web-server publication service can be made:
- one server provides the effective service of publication while the second server supports the computing capacity to the first server;
- a cluster of two servers in active-active mode. They support each other to reduce the load and to grant the service in case of failure of one of the servers.
- a mixed approach: open-source GIS applications and enterprise applications like ArcGIS Server.

2.4 Privileges and data distribution methods

Four different roles have been defined and implemented, in order to administer and control how users may interact with the geodatabase:

- **Database administrator**, in charge of:
  - adding and removing users to/from the database server;
  - managing geodatabase and user security;
  - creating and deleting geodatabases;
  - attaching and detaching geodatabases;
  - doing backup and restoring geodatabases;
  - upgrading geodatabases;
  - compressing geodatabases;
  - starting, stopping, and pausing the database server.
- **Data creators**, read/write users with privileges allowing them to edit existing data and to create database objects (altering schema);
- **Data editors**, read/write users with privileges allowing them to edit existing data;
- **Data viewers,** with read only privileges.

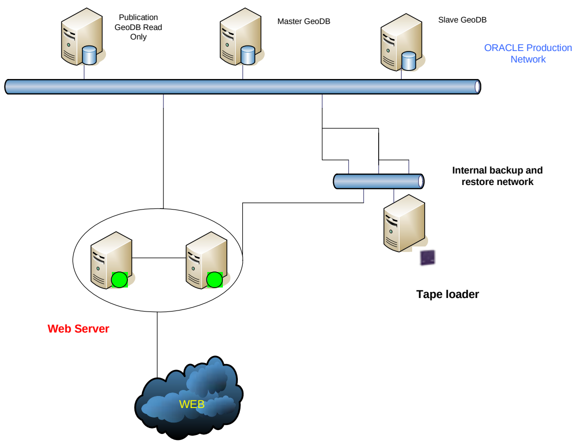

Figure 3 - Proposed system architecture

Moreover, based on the results of the needs assessment, four levels of users and relative privileges have been identified. Table 4 shows an example of users/privileges cases definition related to the UN JLC section. Such analysis constitutes the starting point for privileges definition over the whole geodatabase.

Users		Visualisation	Interaction (query/geopro-cessing/routing)	Download	Edit	Commit
Public		limited	limited	no	no	no
Hum	Logs	yes	yes	maps + reports	attribute only	no
	GIS	yes	yes	yes	yes	no
HQ	Logs	yes	yes	maps + reports	attribute only	no
	GIS	yes	yes	yes	yes	ye s

Table 4 - UN JLC users privileges schema

The system is made of two Oracle database instances, one acting as master database and another, the slave GeoDB, hosting a full two-way replica for data production; that solution, together with adequate back-up policies, should grant data protection and integrity (Figure 5).

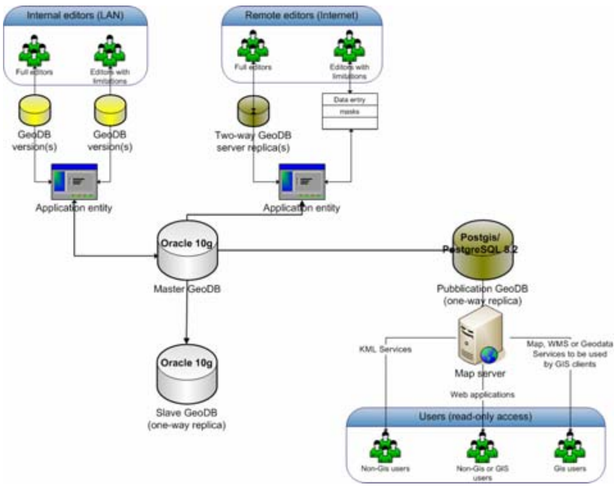

Figure 5 - Data distribution schema

Following that schema, LAN users that can connect directly to the master GeoDB may operate in function of their privilege levels on the database or on specifically created versions, to be reconciled or not with the parent one.

External users that have limited or no connectivity, may work on replicas that, once an editing activity is terminated, system administrators may synchronize with the master database. Moreover, users that are in charge of manipulating only the alphanumerical content of the database may work using specifically developed data entry applications.

The broader humanitarian community, made not only of UN officers but also of NGO's, local administrators, affected population, etc. can gain access to stored territorial information through suitable web-based services and applications provided by the application layer connected to the publication GeoDB replica. This environment is designed to be fully a standard and interoperable one (Table 6).

Open Geospatial Consortium®		
Components	**Production environment**	**Publication environment**
DBMS	Oracle 10g	Postgis/PostgreSQL 8.2
Gateway	ESRI ArcSDE	-
Geometry storage	OGCWKB SDO_GEOMETRY	WKB WKT
GIS clients	ESRI ArcGIS Desktop	Desktop or WEB based
WEB Applications	ESRI ArcGIS Server	WMS/WFS
Metadata and Catalogue	GeoNetwork	

Compliant product
Registered product

Table 6 - System standard compliancy

2.5 Back-up system and strategies

Physical back-ups are performed on tape for offsite storage and system restore. In addition, the master instances will be replicated in a near real time on a back-up site configured and kept aligned constantly with the master site.

A further development includes the creation of a Real Application Cluster based on Oracle 10 G, in order to increase performances by applying load balancing mechanisms.

The back-up site is configured to behave as a stand-by node: in case of a major failure of the main node, application layer can be redirect on the slave cluster in order to grant services without any significant failure (Figure 7).

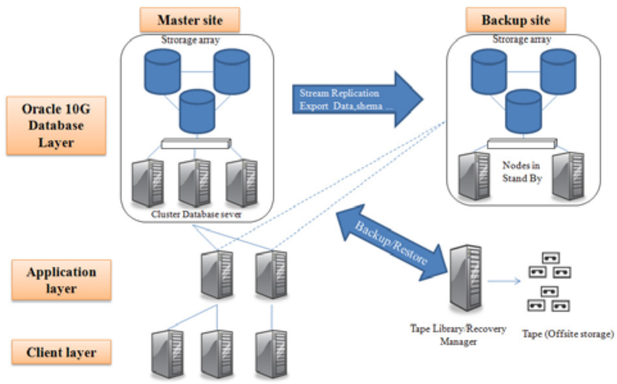

Figure 7 – Back-up schema

3. GEODATABASE CONTENT

Based on the data structure submitted and approved by WFP (ODAP and VAM) and UNJLC, a UML data model has been consolidated and implemented using an ORACLE 10g database as DBMS platform.

The database schema is composed by 2 different entities:

- **Base data** includes basic geographic and alphanumeric information, in order to produce basic geographic outputs and analysis (Tables 8 and 9).
-

  According to the geographical extension of areas of interest considered in WFP activities, globally consistent data (very little scale) or data concerning at least the main WFP action areas, have been included in this database. Moreover, particular attention has been paid to identify and include geographic data released into the public domain; these data cannot be copyrighted, restricted or licensed once they are released, allowing their right use and re-use for humanitarian aims.

- **Transportation**, with particular attention to sea and airlift capacity and availability, transport procedures and schedules, infrastructure assessments and updates, customs issues and logistics bottlenecks affecting the humanitarian community. Transportation dataset data collection is a direct responsibility of UNJLC and may derive from very different sources, such as pre-existing geodatasets, digitalization of paper sources, field missions with GPS, reports, interviews, etc. Table 10 reports a summary of data sources for the African transportation dataset.

BASE DATA – data sources
BOUNDARIES
VMAP0 – Vector Map Level 0 Data source: NIMA
Geographic area: world Scale: 1:1500000-1:750000
SALB – Second Administrative Level Boundaries Data source: UNGIWG
Geographic area: near global Scale: 1:1000000
POPULATION
LandScan – LandScan Global Population Data source: ORNL
Geographic area: world Spatial resolution: 1 km
INDUSTRY
VMAP0 – Vector Map Level 0 Data source: NIMA
Geographic area: world Scale: 1:1500000-1:750000
UTILITIES
VMAP0 – Vector Map Level 0 Data source: NIMA
Geographic area: world Scale: 1:1500000-1:750000
ELEVATION
VMAP0 – Vector Map Level 0 Data source: NIMA
Geographic area: world Scale: 1:1500000-1:750000
DTM from Shuttle Radar Topography Mission (SRTM) Data source: NASA - JPL
Geographic area: world Spatial resolution: 90 m
HYDROGRAPHY
VMAP0 – Vector Map Level 0 Data source: NIMA
Geographic area: world Scale: 1:1500000-1:750000
STRM Water Body Data (SWBD) Data source: NASA - JPL
Geographic area: near global
Drainage Basins Level 1, 2, 3 Data source: USGS – EROS
Geographic area: world Scale: 1:5000000
PHYSIOGRAPHY - VEGETATION
VMAP0 – Vector Map Level 0 Data source: NIMA
Geographic area: world Scale: 1:1500000-1:750000
Orthorectified Landsat Thematic Mapper Mosaics Data source: Geo Community
Geographic area: world Spatial resolution: 30m
GLC2000- Global Landcover Classification year 2000 Data source: JRC- IES
Geographic area: world Spatial resolution: 1 km
MODIS Land Imagery Data source: NASA EOS
Geographic area: world Spatial resolution: 250 m, 500 m, 1 km
MODIS NDVI Data Data source: NASA EOS
Geographic area: world Spatial resolution: 250 m, 500 m, 1 km
MODIS Land Cover Data Data source: NASA EOS
Geographic area: world Spatial resolution: 1 km, 5 km
Landsat 7 ETM+ Ortho GeoCover Imagery Data source: GLFC
Geographic area: world Spatial resolution: 30m
NAMES
Geonames – Geographic names Data source: NGA
Geographic area: world Scale: 1:5000000-1:10000
OTHER
DCW – Digital Chart of the World
Data source: ESRI for USDMA Data geometry: raster
Geographic area: world Scale: 1:1000000
VMAP1 – Vector Map Level 1 Data source: NIMA
Geographic area: local Scale: 1:250000

Table 8 - Base map data sources

BASE DATA		
Datasets	**Classes**	**Description**
Boundaries	BNDCoastline	*Coastlines (lines)*
	BNDOceanSea	*Oceans and Seas (areas)*
	BNDPolA	*Political Boundaries (areas)*
	BNDPolL	*Political Boundaries (outlines)*
Elevation	ELVCntline	*Contour lines on land (lines)*
	ELVDepthline	*Depth lines (lines)*
	ELVDtm	*Digital Terrain Model (raster)*
	ELVElevPoint	*Elevation points (points)*
Hydrography	HYDBasin	*Drainage basins (areas)*
	HYDCanal	*Inland water canals (lines)*
	HYDInWaterA	*Inland water bodies (areas)*
	HYDInWaterL	*Inland water paths (lines)*
	HYDMiscWaterL	*Miscellaneous water elements (lines)*
	HYDMiscWaterP	*Miscellaneous water elements (points)*
	HYDSwbd	*SRTM Water Body Areas (areas)*
Physiography	PHYGroundCover	*Ground cover broad classes (areas)*
	PHYLandCover	*Land cover (1km resolution) (areas)*
	PHYLandsatMos	*Orthorectified Landsat TM Mosaics (2000)*
	PHYModisLC	*Modis Land Cover data (raster)*
	PHYModisLI	*Modis Land Imagery (raster)*
	PHYModisNDVI	*Modis NDVI data (raster)*
Population	POPAnthrFeatP	*Anthropic features (areas)*
	POPBuiltUpA	*Built-Up areas (areas)*
	POPPopDensity	*Population density (raster)*
Industry	INDIndA	*Industries (extraction/fish) (areas)*
	INDIndP	*Industries (extraction/fish) (areas)*
Utilities	UTITransmLines	*Transmission lines (power, pipelines, etc.)*
	UTITransmNodes	*Transmission nodes (plants, pumping, etc.)*
Names	NMSAdmReg	*Names of administrative region features*
	NMSHydType	*Names of hydrographic type features*
	NMSHypType	*Names of hypsographic type features*
	NMSLocType	*Names of locality or area type features*
	NMSPopPlace	*Names of populated place features*
	NMSSptType	*Names of spot type features*
	NMSStrType	*Names of street, highway, road or railroad type features*
	NMSUndType	*Names of undersea type features*
	NMSVegTyp	*Names of vegetation type features*

Table 9 - Base map feature classes

TRANSPORTATION	
Source type	**% on total**
Field Mission with GPS	*36.2*
Field Mission no GPS	*0.5*
Report	*4.2*
Interview	*1.9*
Digitized	*9.4*
Pre-existing geodataset	*38.5*
Unspecified	*9.4*

Table 10 - Data sources for Africa Transportation dataset

4. INTEROPERABLE SERVICES AND APPLICATIONS

Web services and applications will allow an interoperable level of access and management of the database. Services are intended as user interface elements that accept input from the user selection, process it, and optionally put the result back in the clipboard. Table 11 contains a list of services requested by the users or proposed in the framework of ITHACA collaboration with WFP.

Type	Subtype	Description	Requirement
Editing	Geometry	Perform editing operation on base geometries	Check procedures before changes are committed in the master db
	Attributes	Update database attributes thought the definition of data entry masks	- Guided by database constraints (domains) - Following a predefined flow (UNJLC)
Data replica-tion	Data management	Create replica of information contained in the geodatabase	- Synchronization - Replica of current displayed set
	KML/KMZ	Subset extraction and delivery	Single layers or complete maps
Satellite image catalogue research functiona-lities	Disaster management	Research and access to satellite images and derived information produced in case of past emergencies	
Early warning tools	Flood modelling	Provide flood extent estimates during an emergency	- Usable with limited input datasets - Rapid set-up and result delivery
	Climate drought estimate	Drought indicators, automatic alert triggering, food shortages estimates	
Early impact tools	Affected areas	Delineation of affected areas from satellite identification of hit areas	
	Affected population	Estimates of population affected by an event	Include simple socio-economic modelling
Reporting	Logistic assessment	Automatic generation of reports containing maps and textual description	
Map Source Image Creation	Logistic in-field support	Generation of base layer representation as background map	- For GARMIN devices (UNJLC) - Vector and/or raster
Logistic tools	Snow cover	Automatic detection of areas covered by snow	- Intersection with logistic network components

Table 11 – List of required services

5. CONCLUSIONS

At the actual status of the project, the production/editing environment is fully implemented and operational. It actually includes more than 10Gb of raster data and nearly 6Gb on vector data and stand-alone tables. Database management rules have been implemented in order to maintain high levels of efficiency in data delivery.

After a first stage of tests performed by headquarter based users, the system will be now opened to be accessed by WFP Regional Offices, in order to test the efficiency and behaviour under different network connection levels. Procedures and workflows for data management in disconnected environments have also been developed, granting the possibility that new data, often acquired on the field in difficult situations, can be easily integrated in the master database.

Catalogue services and access to metadata will be granted by the integration of the GeoNetwork application (http://geonetwork-opensource.org/), a de-facto standard at UN level.

Grid computing techniques are also in investigation phase, as a possible solution to improve system performance and availability.

In parallel, the actual level of knowledge and practice with data transfer tools allowed to populate the PostgreSQL/PostGIS geodatabase, the source for the publication/analysis environment.

On that basis, beta version of a web application publishing data provided by a WMS server is going to be released. Other than traditional navigation and query tools, the application is characterized to be displayed as a composite layout (including title, legend, scale bar and logos), as it is conceived for rapid production of reference standard maps by WFP users. Once map has been customized, it is possible to generate a PDF format file. The application also allows the export of a single layer in KML format (Figure 12).

The application has also the capability to include GeoRSS content, allowing the user to define an RSS provider and have its map updated with sudden events localization, such as volcano eruptions, earthquakes, floods, etc.

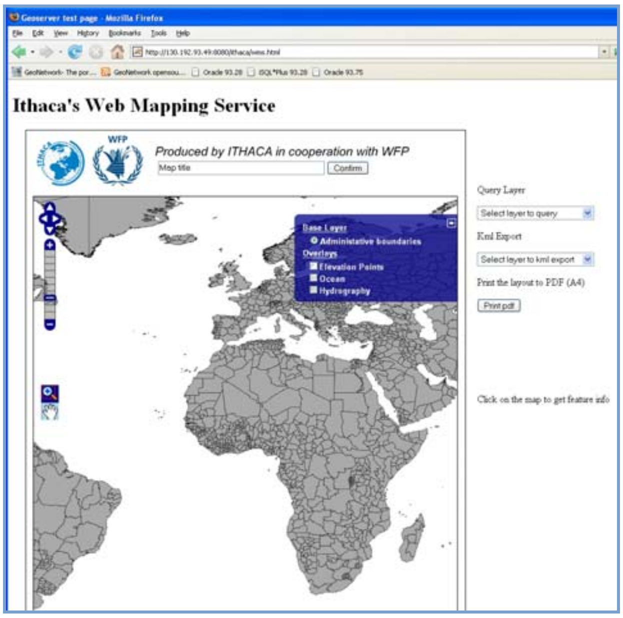

Figure 12 – Screenshot of the web application

REFERENCES

Crocker C., 2005, *The Oracle Enterprise Geodatabase (EDGB)*, Norcal URISA Chapter Meeting, http://www.fargeo.com (accessed 21 Apr. 2008)

Donsez D., 2003, *Les SGBDs Géographiques*, teaching material

Executive Office Of The President - Office of Management and Budget, 2002. “Circular No. A-16”, United States of America.

http://www.whitehouse.gov/omb/circulars/a016/print/a016_rev.html (accessed 21 Apr. 08)

Groot R. and McLaughlin J., 2000, *Geospatial Data Infrastructure: Concepts, Cases and Good Practice*, New York: Oxford University Press.

Li L., Chen A., Bai Y., Wei Y., 2006, *Implementation of Geospatial Product Virtualization in Grid Environment*, NASA's Earth Science Technology Office (ESTO) Conference – ESTC

Masser I., 2005, *GIS Worlds - Creating Spatial Data Infrastructures*, ESRI Press.

Mondini M., 2006, *La realizzazione di soluzioni interoperabili in una spatial data infrastructure,* X° Conferenza Nazionale ASITA, Bolzano, Italy

Nebert D., 2004, Developing Spatial Data Infrastructures: The SDI Cookbook, Version 2.0, Global Spatial Data Infrastructure Association. http://www.gsdi.org/gsdicookbookindex.asp (accessed 21 Apr. 08)

UNGIWG, 2007, STRATEGY for developing and implementing a United Nations Spatial Data Infrastructure in support of Humanitarian Response, Economic Development, Environmental Protection, Peace and Safety. http://www.ungiwg.org/docs/unsdi/UNSDI_Strategy_Implementation_Paper.pdf (accessed 21 Apr. 08)

UNGIWG, 2007, UNSDI COMPENDIUM. A UNSDI Vision, Implementation Strategy and Reference Architecture. http://www.ungiwg.org/docs/unsdi/UNSDI_Compendium_13_02_2007.pdf (accessed 21 Apr. 08)

Zwicker C., Pierce B., 2007, *Geodatabase – An Introduction*, ESRI International User Conference