

GIS APPLICATION IN OIL AND GAS EXPLORATION & PRODUCTION ACTIVITIES BASED ON PAST EXPERIENCE

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Exploration and Production (E&P) is the earliest activities done in oil and gas business. E&P lifecycle consists of Exploration, Appraisal, Development, Production and Abandonment phase. A lot of data types have been produced through this lifecycle.

E&P activities are mainly divided into two areas namely subsurface and surface. For offshore activities, subsurface is an area below the seabed. These data consists of geological and geophysical (G&G) elements to analyze the hydrocarbon accumulations or prospects area. Surface consists of the data covered from the water column to the seabed data such as platform, pipeline and infrastructure data which support the E&P activities.

Subsurface data produced are inclusive of seismic, well, drilling and reservoir engineering data. Seismic data consists of seismic sections, seismic navigation, seismic shot-points maps, bathymetry data, velocity, etc. A wildcat well will be drilled to gather information of the hydrocarbon properties and rock lithologies. Well data consists of well location, well logs, core samples, check shots, well testing and Vertical Seismic Profiling (VSP), reservoir pressure and sampling data, etc. Well data often aided by seismic data is used for appraisal rather than exploration.

Surface data consists of facilities such as site survey data, platforms, pipelines, engineering drawings, Health, Safety and Environment (HSE) and others associated data.

This paper is prepared to introduce and share knowledge of the data types produced from the E&P that contains geospatial elements and will be the basis for GIS applications in oil and gas business. Some findings from the past experience were reviewed to show the GIS applications in oil and gas exploration workflow.

Keywords: E&P data, Integration, GIS Applications

1.0 INTRODUCTION

Nowadays, hydrocarbon exploration and production (E&P) has become more challenges than before. As oil and gas fields become more difficult to locate and evaluated, the new developments and innovations to increase the technology for new discovery of the prospects has increased the volumes of E&P data massively. The proliferation of data volumes has caused many geologists, geophysicists and drilling engineers to ask themselves two basic questions about their seismic, wells and others project data: “What do I have?” and “Where is it located?” To handle this kind of “spatial” problems, Geographical Information Systems (GIS) has been particularly important in E&P activities for data collection, organization, synchronization and distribution of all E&P data such as seismic and well-logs data and maps.

E&P data often maintain many types of data sources such as geology and geophysics (G&G), geochemistry, wells in which GIS is an invaluable tool for integration of many different data types. This includes making maps on screen, producing hard copy maps and delivering maps as well as spatial data search, queries and analysis for better solutions in successful of E&P workflow.

This paper concludes by summarizing the data types produced in E&P activities that will be the basis of the GIS implementation in oil and gas activities.

2.0 EXPLORATION AND PRODUCTION (E&P) ACTIVITIES

Much of the E&P data maintained by petroleum companies has spatial elements and therefore readily lends itself to being used and managed from within GIS. This spatial element has been used to integrate all the information throughout the E&P business lifecycle.

E&P lifecycle is shown below:

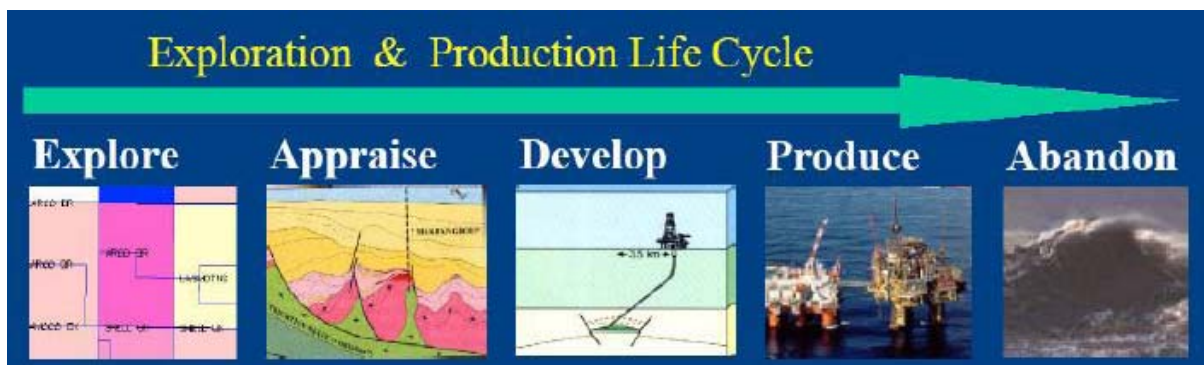


Figure 1: Exploration and Production Lifecycle (Bart Hulshof, Shell)

2.1 Exploration

Exploration phase is the earliest activities carried out before any fields discovered. During this period, the geological history of the area will be studied and the likelihood of hydrocarbons being present quantified. Prior to spudding the first well, a work programme will have to be carried out. Fieldwork, magnetic surveys, gravity surveys and seismic surveys are traditional tools employed.

2.2 Appraise

Once exploration well has encountered hydrocarbons, considerable effort will still be required to accurately assess the potential of the findings. The amount of data acquired so far does not yet provide a precise picture of the size, shape and productivity of the accumulations.

The appraisal phase will contain the subsurface development options, the process design, equipment sizes, the proposed locations, and the crude evacuation and export system. This phase will be accompanied by a cost and planning schedule.

2.3 Develop

Based on the results from appraisal phase, a field development plan will be executed. This phase is to serve a conceptual project specification for subsurface and surface facilities and the operational and maintenance philosophy required to support a proposal for the required investments. Development phase consists such as fabrication and installation of the e.g. platforms, pipelines, subsea manifolds, etc. facilities at the proposed location

2.4 Produce

The production phase commences with the first commercial quantities of hydrocarbons ("first oil") flowing through the wellhead. This marks the turning point of view, since from now on cash is generated and can be used to pay back the prior investments, or may be made available for new projects.

2.5 Abandon

The economic lifetime of a project normally terminates once its net cash flow turns permanently negative, at which moment the field is abandon and decommissioned. Drilled wells will be plugged and processing facilities dismantled on a phased basis, thus avoiding high spending levels just as hydrocarbons run out. In offshore abandonment phase, costs can be very significant and less easily spread as platforms cannot be removed in a piecemeal fashion.

3.0 E&P DATA TYPES

Exploration and production (E&P) data are related physically to the earth surface or subsurface. Much of the geological and geophysical data maintained by oil companies has a spatial elements and this “key” has been readily to being used as integration in GIS.

In E&P activities, two types of data has been produced which are subsurface and surface data. Subsurface data covered the data from the seabed beneath the rock formations layers. Most of the data for hydrocarbon evaluation came out from the subsurface eg. seismic, wells, reservoir, faults, geochemical, etc.

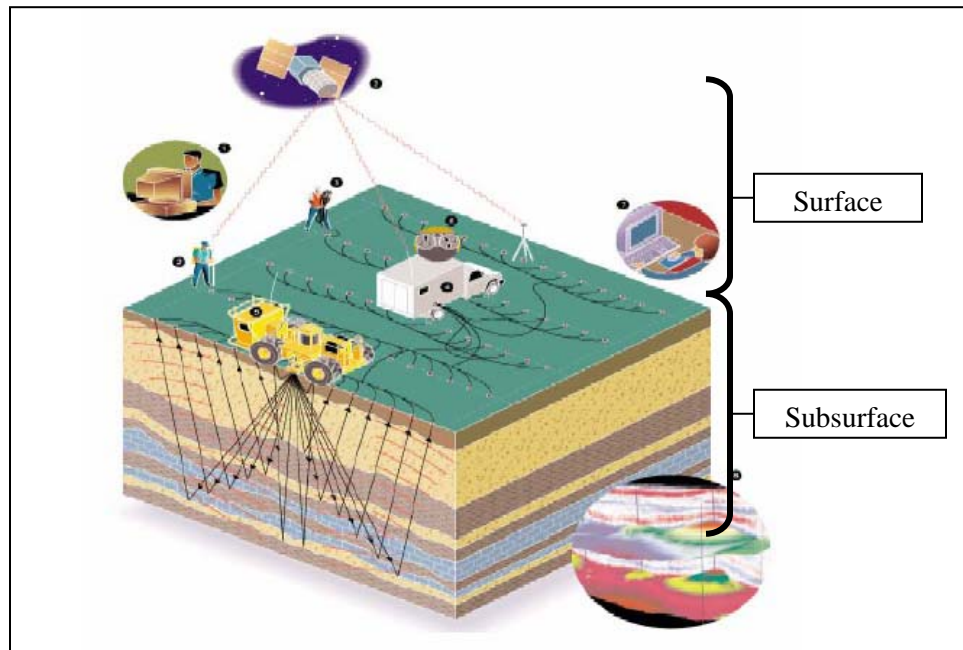


Figure 2: Surface and subsurface data types

3.1 Subsurface Data:

Subsurface data is gathered mostly from seismic survey. It contains data from the seabed through the rock layers to study and appraise prospects or hydrocarbon accumulations

- Regional geology, basins, sub-basins
- Gravity, magnetics
- Seismic sections, seismic navigation, shot-points
- Wells, VSP
- Reservoir, petroleum engineering
- Fault, shallow gas
- Play, prospects, leads, formation evaluation
- Oil/gas fields
- Subsea images, seafloor images
- Satellite images

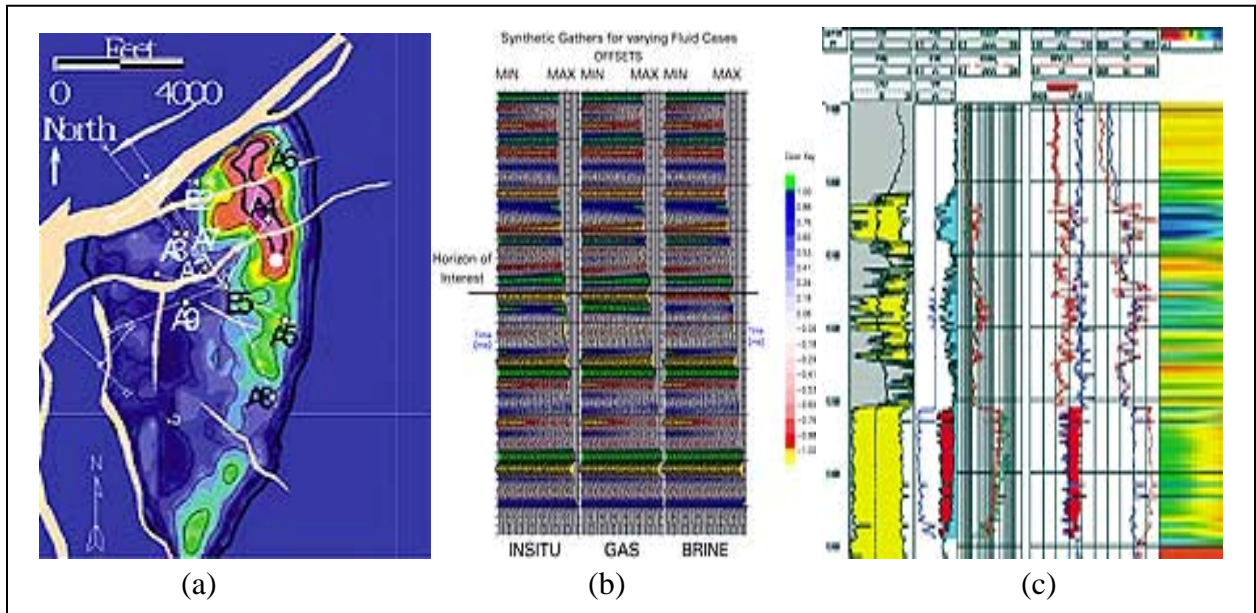


Figure 3: Subsurface data; (a) Basins & structure (b) Seismic (c) Well logs

All this subsurface data will then combine and interpreted by geologists, geophysicists and engineers to provide the best results of hydrocarbon in place accumulations of the study area. The results will be populated in terms of reservoirs type, volumes in-place, fault and traps mechanisms, shallow hazards, etc so that the next phase of the development will be executed in the HSE manner with optimized production.

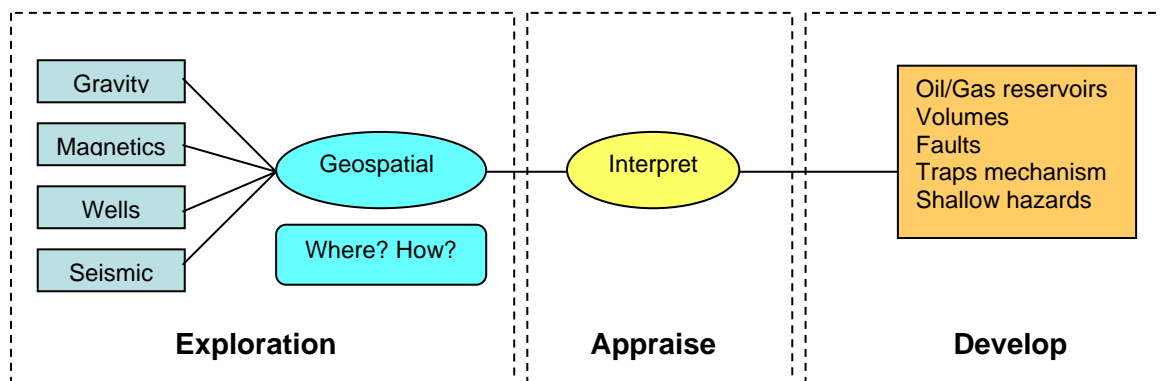


Figure 4: Subsurface data in E&P workflow

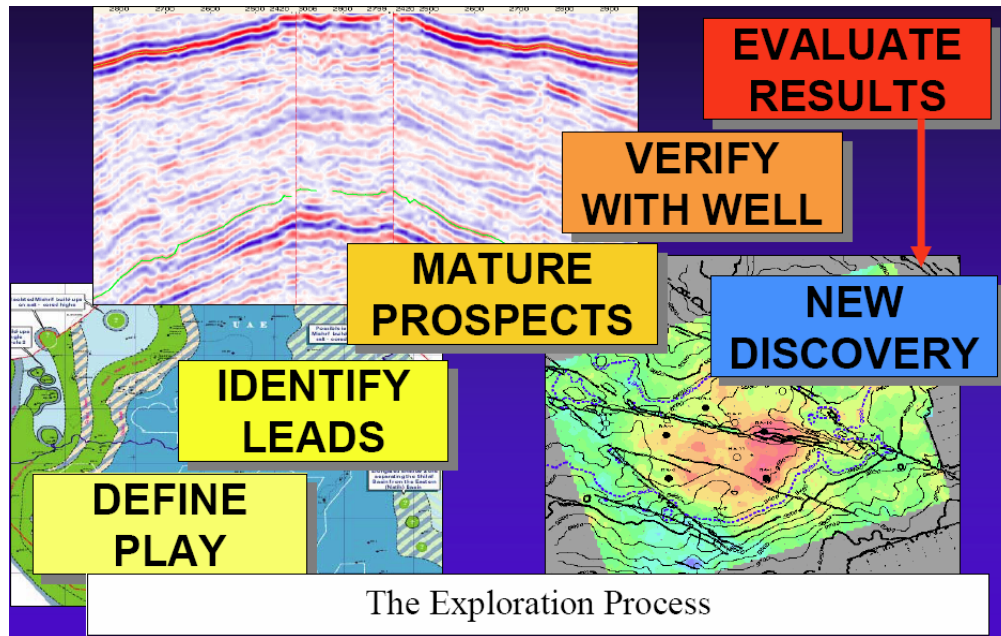


Figure 5: Exploration process from subsurface data evaluation

3.2 Surface

Once the subsurface data evaluation has been produced, the next phase of E&P will be carried out to extracted first oil from the subsurface. This will directly communicated with the surface data since all the structures and facilities will be constructed and installed on the earth surface.

Surface data consists of the data from the seabed/subsea to the water surface and all onshore-based locations. Subsea means the data, which is located on the seabed, mostly the structure of wellhead, manifold for subsea processing complex, pipeline, etc. However, subsea data can also be in the subsurface particularly the data from the seafloor images, bathymetry and all the G&G elements to study the hydrocarbons indicators before further exploration into subsurface will be carried out.

- Platforms, jacket, monopod
- Pipelines
- Wellheads, DTU
- Subsea manifolds
- HSE
- Processing terminals
- Concession blocks, sub-blocks
- Onshore pipelines
- Oil/gas distributions
- Transportations
- Vessels trackings
- FPSO, rigs, barges



Figure 6: Surface data; drilling rigs, pipelines, refineries, subsea facilities

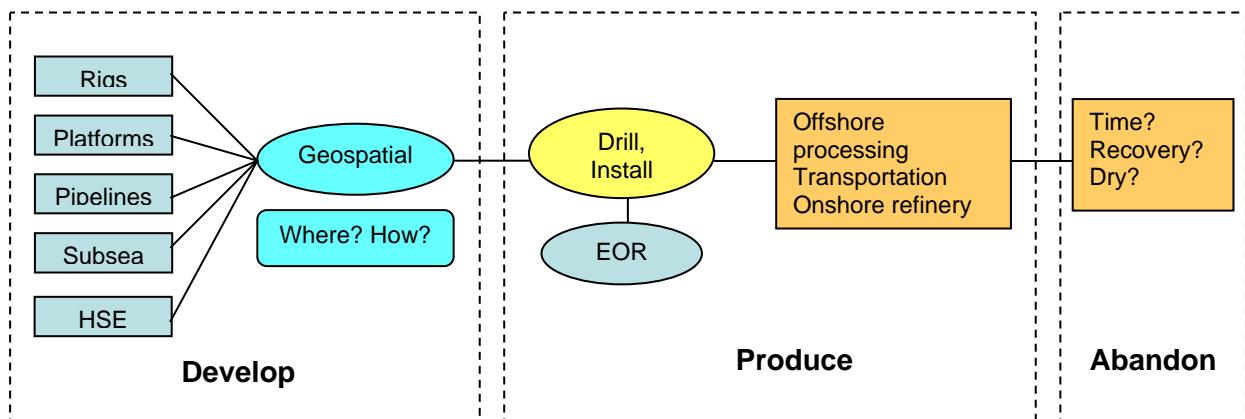


Figure 7: Surface data in E&P workflow

4.0 GEOMATICS MATTERS IN E&P BUSINESS

Exploration and Production activities mostly involved with spatial data elements. From play to prospects generation, seismic to drilled wells, structure and production installation until abandonment phase, geospatial plays an important roles in E&P lifecycle.

Most of E&P data particularly in G&G for interpretation and evaluation of play elements, prospects generation until reservoir characterization elaborates the area of hydrocarbon accumulations. It means, those information refers to the location of study (where?) and geospatial elements i.e. Easting, Northing, Latitude, Longitude or across-along track will indicates on the earth surface or subsurface.

Since all the data are located on the earth surface and subsurface, the need for the most accurate location or coordinate is important to define the correct oil/gas fields. Some problems regarding the geospatial or geodetic datum will cause a lot of unpredictable conditions e.g. Environment effects, block liaise, costs etc.

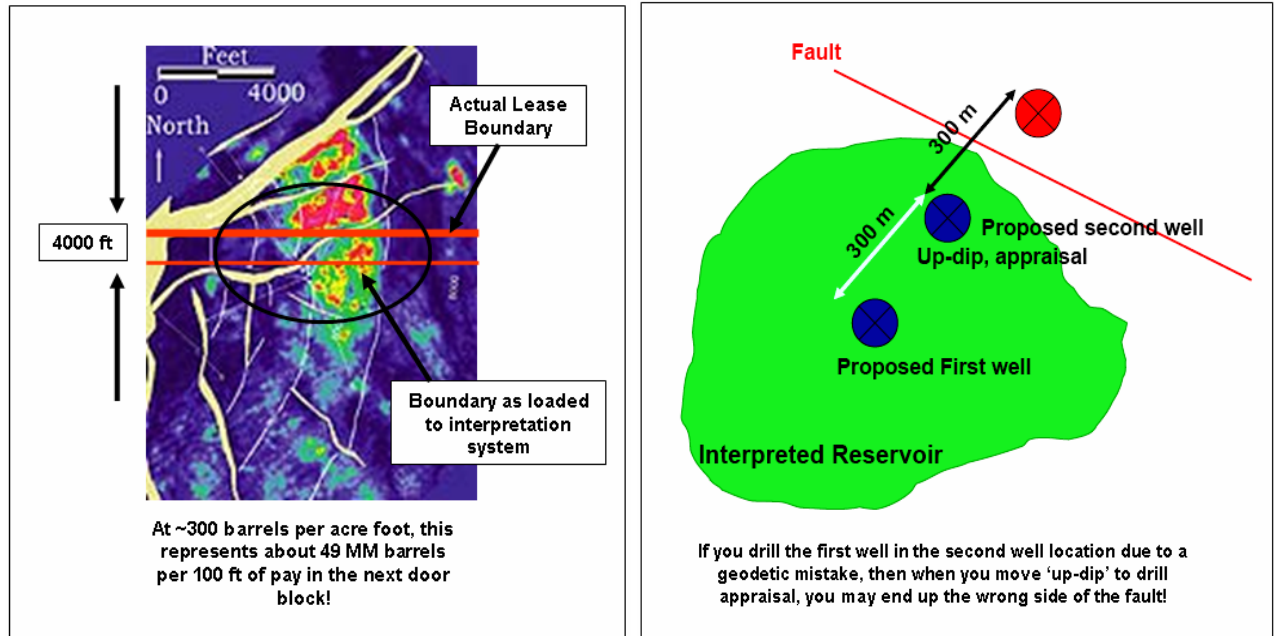


Figure 8: Example of geodetic problems in E&P business

Good Interpretation + Bad Positioning = Useless

Good Positioning + Bad Interpretation = Useless

Good Interpretation + Good Positioning = New Discovery

Around the world, exploration and production geoscientists, GIS specialists, pipeline engineers are discovering the power of geospatial tools. Oil and gas professionals are applying geo-technologies in seismic surveys, surface modeling activities, pipeline routing, environmental risks assessment study and well management.

5.0 INTEGRATION OF GIS INTO E&P

Currently, most of major oil companies using GIS for their E&P business drive workflows. Since the E&P data contains a multitude of spatial data on potential hydrocarbon accumulations as well as data on reserves, well locations, seismic surveys, satellite & aerial imagery, surface topography and existing infrastructure information the major challenges in managing such a portfolio are that of ensuring data is kept up-to-date in a secure environment, a consistent evaluation with a clear audit trail is applied throughout and the data is available for integration with E&P business risk planning engines. GIS based management tools and processes have been applied to address these challenges for more than a decade.

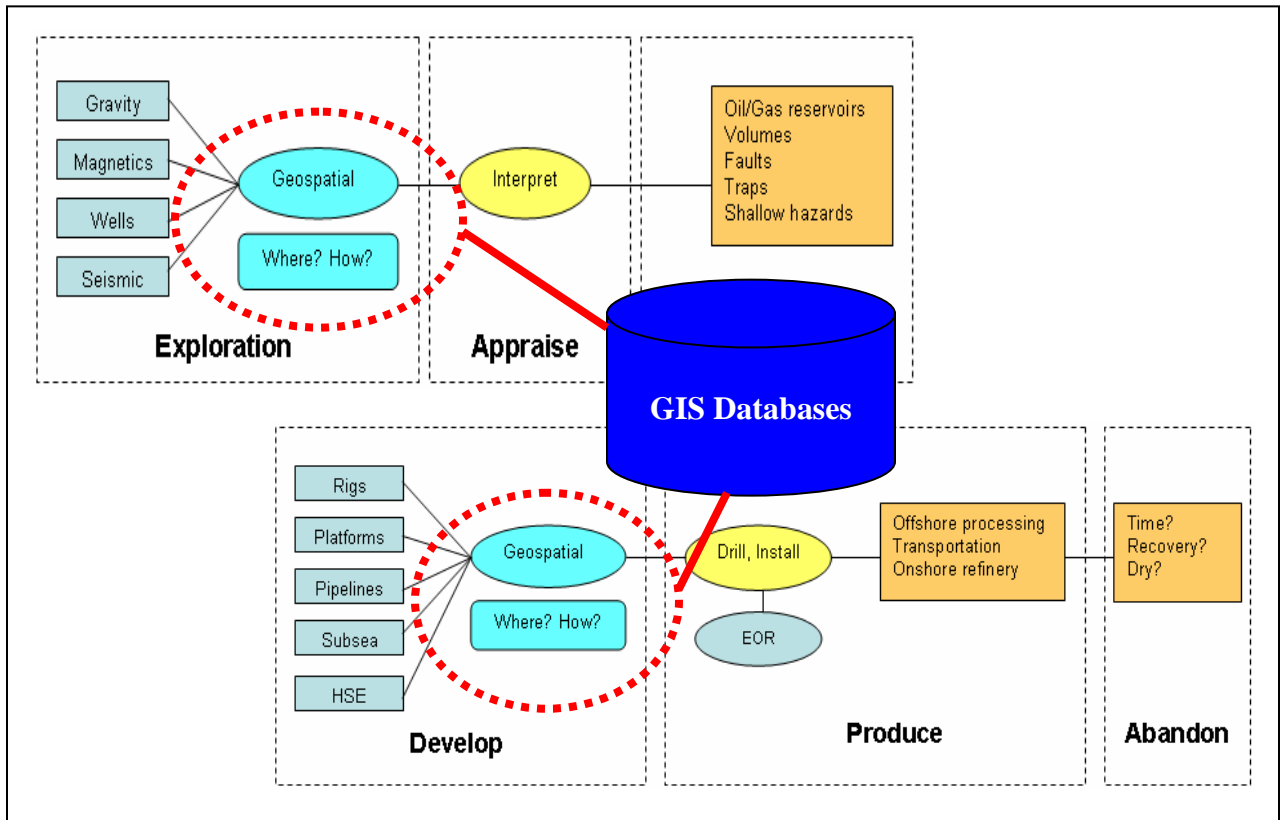


Figure 9: Geospatial integration in E&P workflow

Most of oil companies implemented GIS for data archiving, data preparation and data review because GIS is a powerful spatial tool integrated all G&G data through spatial integration concepts. G&G data usually interpreted and analyzed through commercialized softwares such as Zmap, OpenWorks, Petrosys. These systems stored all the databases in their own datasets.

Because data integration is one of the most powerful functions of GIS, the E&P GIS is much more than a geographic data visualization and analysis tool. It is strongly integrated with many of the E&P databases and applications. A user can, for example, select wells on a map, and access extended attributes from a wide array of tables in the well database and simultaneously display logs from the logs database.

The petroleum and facility engineers, geologists and geophysicists can now combine many pieces of information, including well profiles, surface topography, subsurface maps and other physical features, that allow them to test multiple design and selection scenarios easily and efficiently.

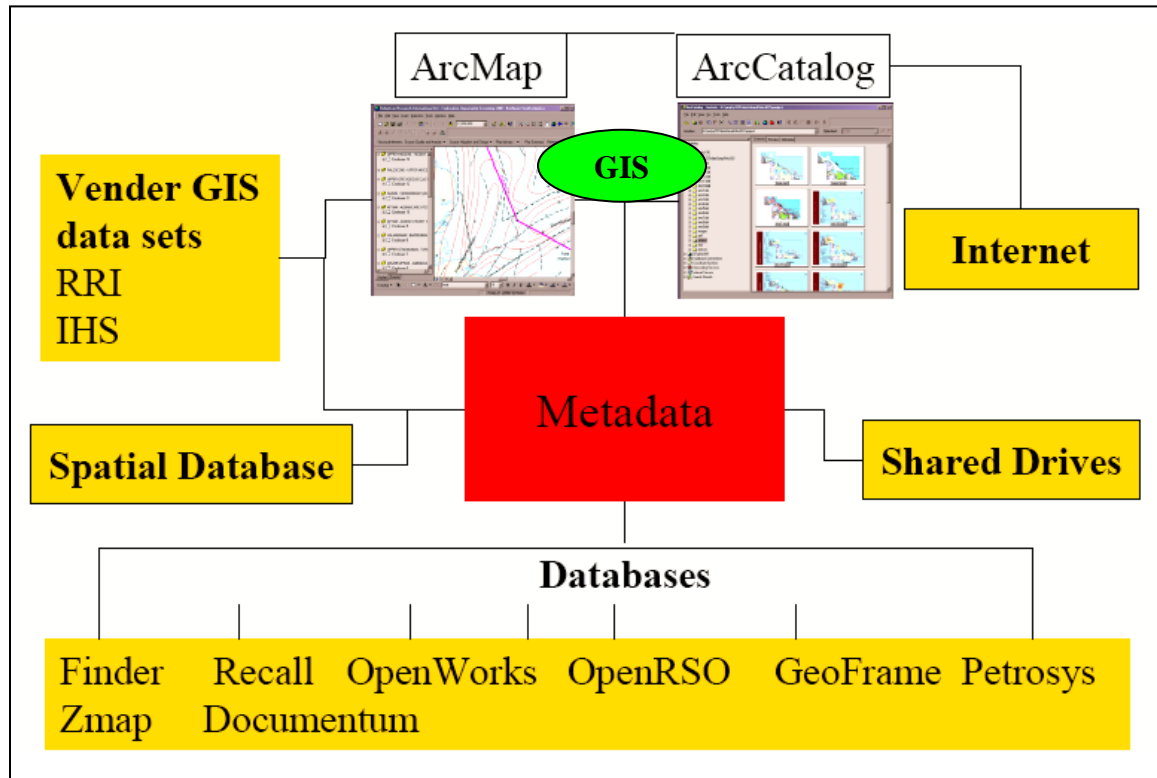


Figure 10: GIS integration with explorationists G&G workstations

6.0 GIS APPLICATIONS: SOME EXAMPLES IN E&P APPLICATIONS

Discovering new sources of petroleum ahead of the competition is one of the key ways to staying successful in the petroleum industry. A GIS can help geologists, geophysicists, engineers, etc. evaluate the potential for oil in promising locations.

Exploration often requires analysis of satellite imagery, digital aerial photo mosaics, seismic surveys, surface geology studies, subsurface and cross section interpretations and images, well locations, and existing infrastructure information. A GIS can relate these data elements to the location in question in map form and allow you to overlay, view, and manipulate the data to analyze and understand their potential.

There are six core activities of GIS that has been identified that can be applied in oil and gas exploration:

- (1) Data organization (involving data modeling, data compilation, and database construction)
- (2) Data visualization (producing data views and maps and graphically evaluating spatial patterns)
- (3) Spatial data search (query)
- (4) Combining (integration)
- (5) Data analysis
- (6) Prediction, particularly to support decision-making based on multiple factors of spatial information.

GIS technology today allows us to manage the spatial components of these everyday petroleum "business objects," such as leases, wells, pipelines, environmental concerns, facilities, and retail outlets, in the corporate database, and apply appropriate geographic analysis efficiently in a desktop-focused application.

Moreover, with GIS advancement today, it was built on an open standard technology that ensures GIS can be integrated with specialized solid 3D geosciences programs to solve complex geologic problems in modeling.

In order to apply the GIS in petroleum industry, ESRI Arc technology has become a widely known GIS by implemented their complex and integrated geodatabase concept. ESRI uses the term "geodatabase" to describe an integrated collection of geographic information. Geodatabases are managed using ArcGIS software and can store and retrieve virtually any type of spatially referenced data. Geodatabases can manage large volumes of data with high performance in a multiuser environment. Geodatabases manage all the basic geodata types, including simple feature vector data types (points, lines, and polygons), as well as more advanced features that use rules for defining relationships, topologies, and behaviors of features.

Geodatabases also manage feature attributes, feature-linked annotation, terrains, survey measurements, addresses, 3D objects, CAD drawings, and images. ArcGIS software is used to maintain data quality and make it easy to control the editing of workflows. The result is that geodatabases can model the world better than any other geographic database management environment.

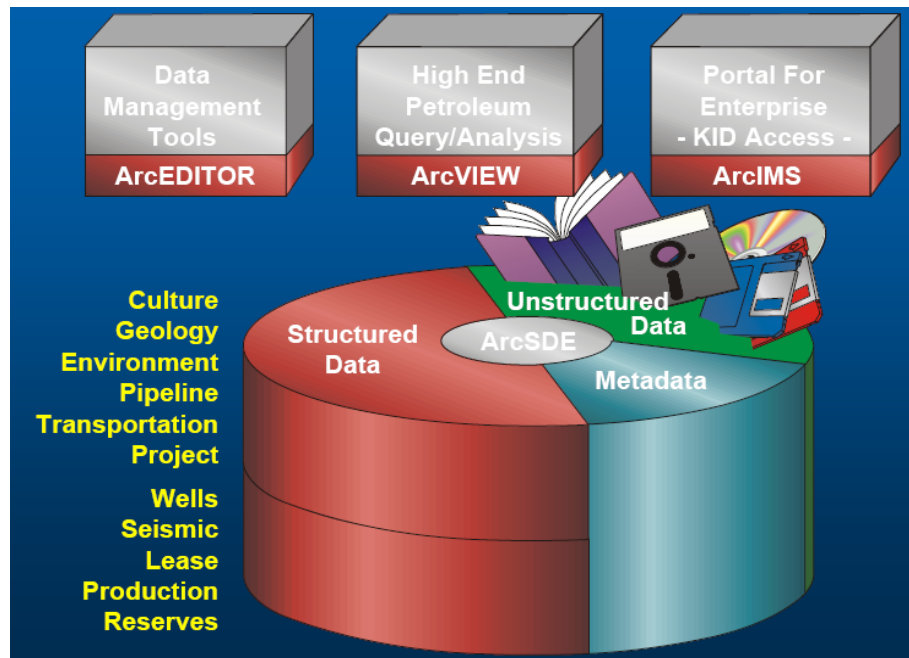


Figure 11: ESRI "Arc" technology in E&P business

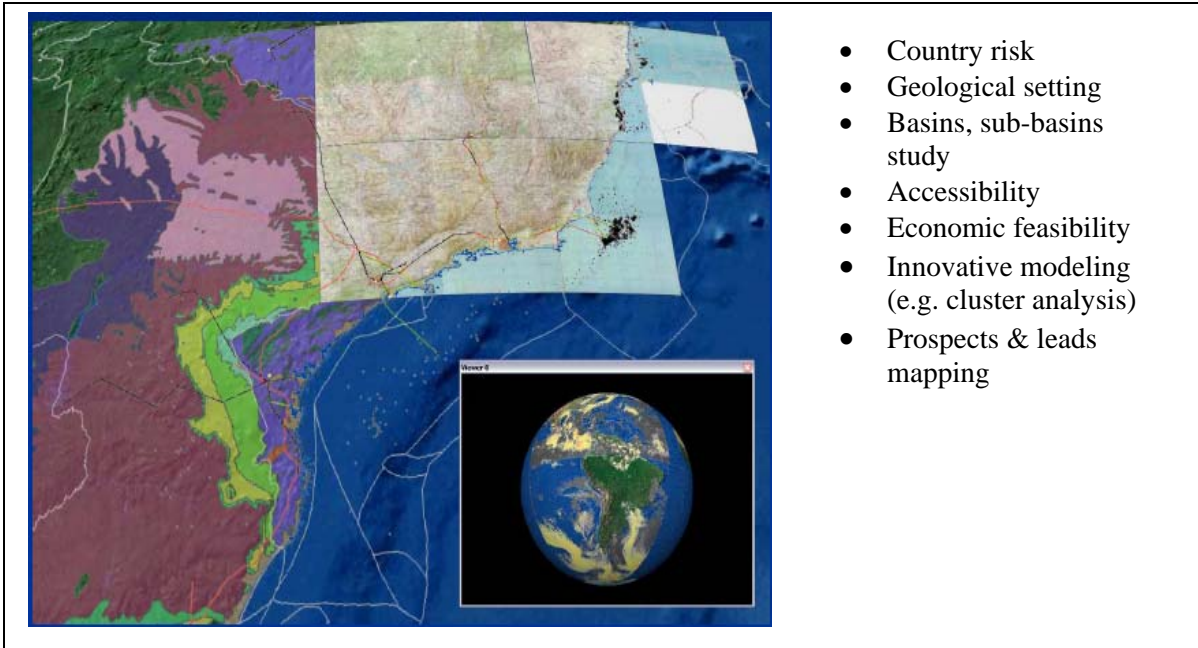


Figure 12: GIS applications in Exploration

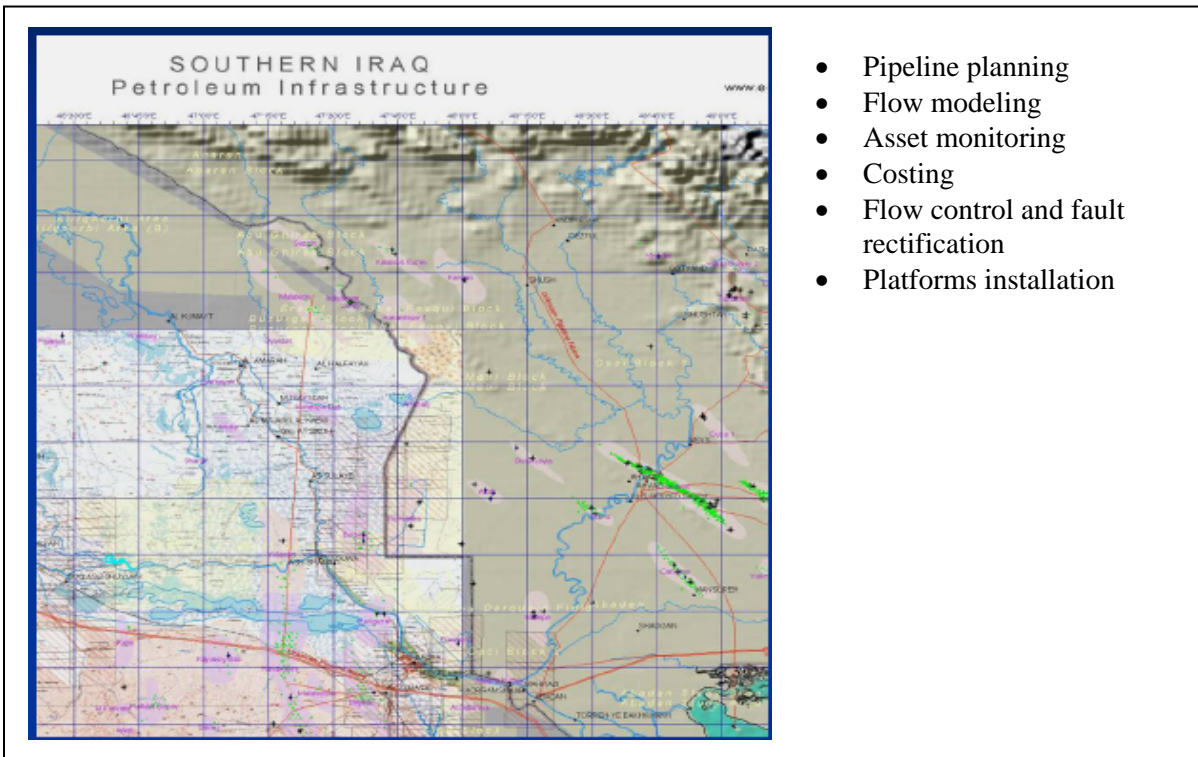


Figure 13: Facilities and Asset Management

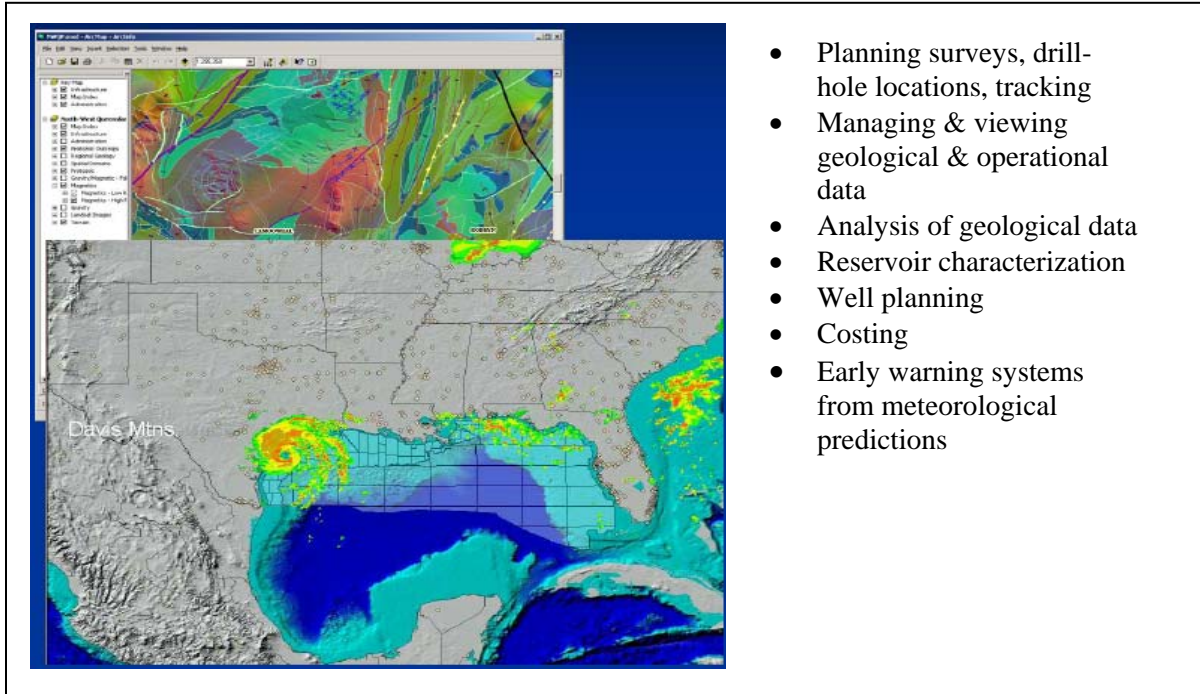


Figure 14: Exploration Operations

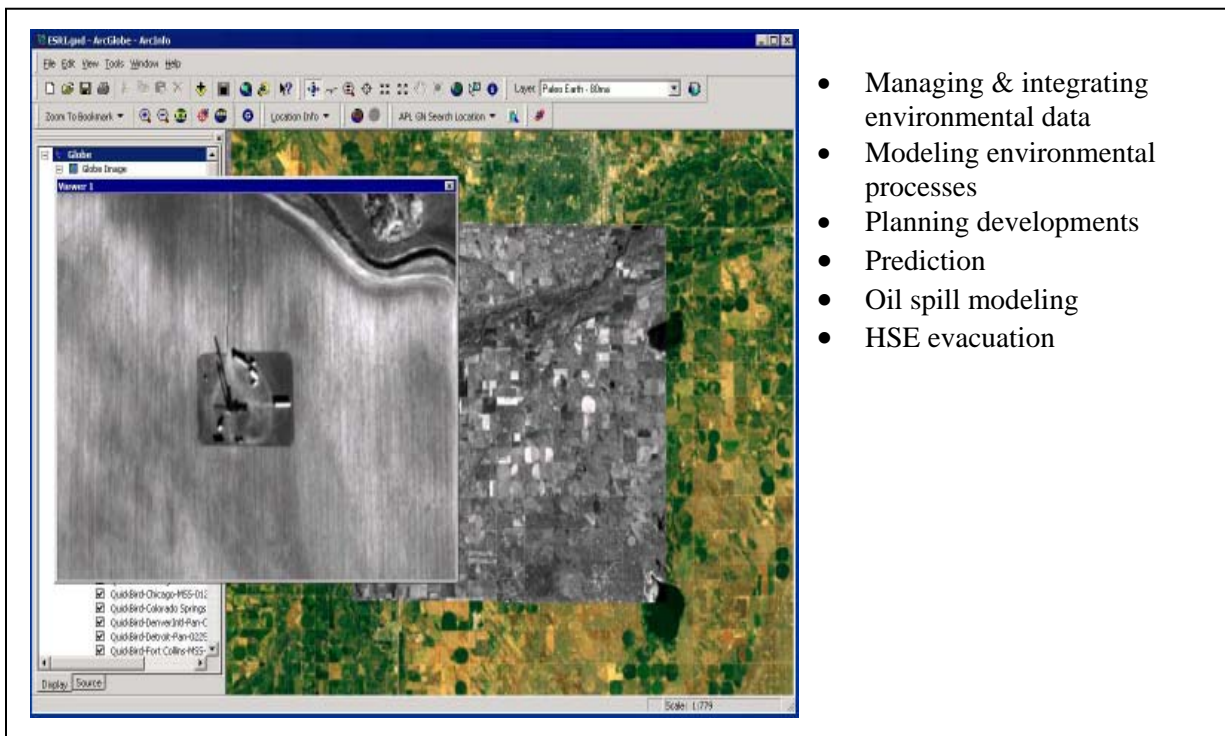


Figure 15: Environmental Assessments

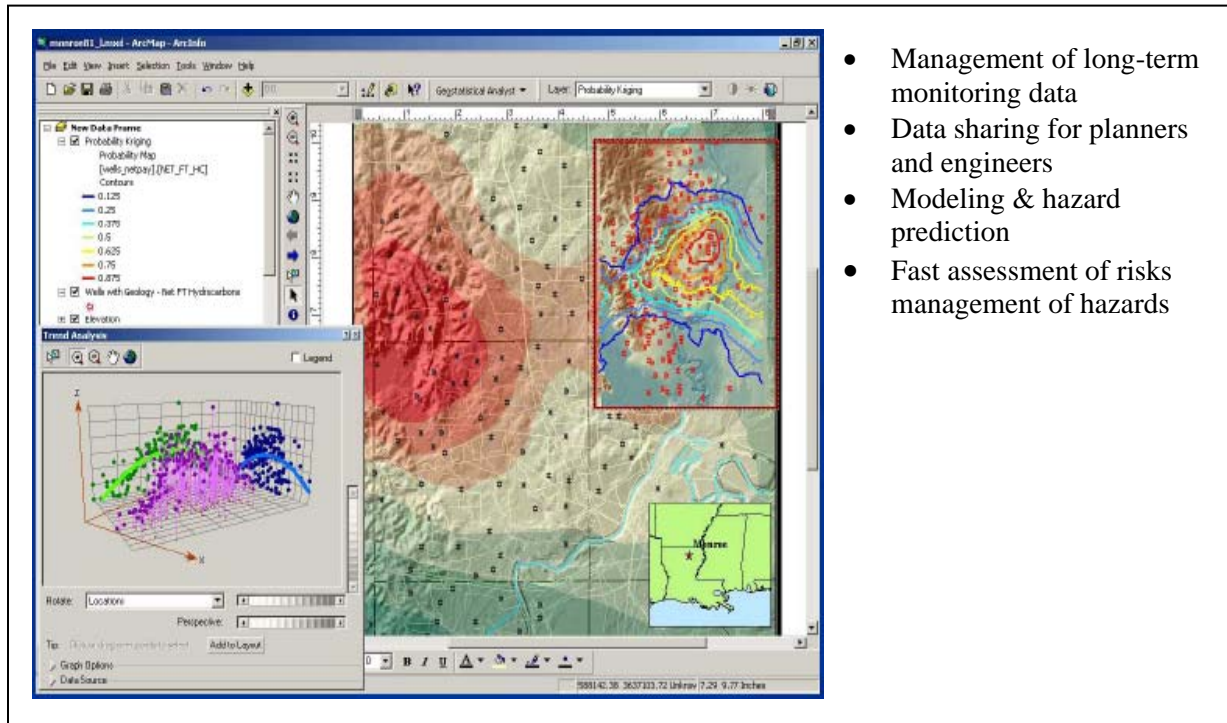


Figure 16: Environmental Monitoring & Rehab

7.0 CONCLUSIONS

GIS technology and related hardware and software have advanced to the stage where they offer tangible technical and economic benefits to the petroleum industry. Not only by improving current business processes by furthering better data sharing and more accurate mapping, it also support efforts at "business process re-engineering", where the technical professionals redefine their activities as they are able to access critical data in new ways.

In E&P business, the term of "synchronization" is very important to provide the successful GIS implementation. The geodatabase through Spatial Data Engine (SDE) concept are the most important thing as key of integration. SDE eliminates the need for proprietary files and access software, leverages the large GIS technology market, and offers higher performance than anything else of which we are aware. It enables much better organization of GIS data into central repositories, minimizing multiple copies of the same data (or, worse, almost the same data), and offers at last the possibility of different vendors application software accessing the same data.

For the oil industry, SDE could become a standard GIS access method if:

- A common data model were adopted for standard data types like well and seismic locations
- Oil and service company take-up occurs in developing of GIS datasets
- Data and knowledge sharing with GIS communities like using forums and conferences, to see if others share the E&P business interest in creating and benefiting from such a GIS standard.

7.1 Future expectations

Although GIS technology brings many benefits to the oil industry already, it still can be made better. Where our requested improvements can be stated and implemented in a generic way, they can benefit all users of GIS. Some things on our "oil industry wish list" include:

- Improved integration with relational databases. This is the most challenge in E&P business. As E&P data is always up-to-date with the new exploration discovered, the need of the standard SDE databases to maintain the existing datasets must be realized.
- A truly paradigm, where locations on the earth include "metadata" like geodetic datum, Cartesian projection/spheroid parameters, etc.
- Better management and access of seismic data and well logs.
- Improved "conflation" tools, which is the process of merging two or more GIS datasets, so that the output has the highest-accuracy data from all the inputs. As surveying tools and GIS data from satellite and orthophoto images continues to improve, existing maps and GIS datasets must be "high-graded", i.e. adjusted to remain consistent with the newer data. Managing this process may well be the biggest challenge.
- Three-dimensional (3D) GIS will be the next challenge in E&P business. Right now, our use of GIS stops at the earth's surface. To visualize subsurface reservoirs, we must change to completely different systems, which rarely present a "seamless" interface to the GIS.

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References

The Integration of GIS and Geophysical Data in Hydrocarbon Exploration and Exploitation
Mohd. Zukhairi Bin Abd. Latef, B.Eng Thesis 2005, UTM, Skudai

Developments in Petroleum Science: Hydrocarbon Exploration and Production
Frank Jahn, Mark Cook & Mark Graham, Elsevier

Spatial Technology Development & Impacts on Petroleum Industry
Marianne Brodgate, ESRI Australia

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