IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 3 Issue 5, May 2016.
www.ijiset.com
ISSN 2348 – 7968

Pipeline Operations & Integrity Management Using GIS & Remote Sensing Technologies (Applying on PDOC'S Export pipeline)

Khalid Awad[1], Eltaib Ganawa[2], Abderahim Salih[2], H.S.M. Hilmi[2] and Mustafa Y. M[3]

[1]Petrodar Operating Co.,
Khartoum- Sudan, kamerghani@petrodar.com

[2]Faculty of Geoinformatics, Future University,
Khartoum- Sudan, ganawa@uofk.edu

[3]Faculty of Agriculture, Alzaiem Alazhari University,
Khartoum- Sudan

Abstract

Satellite remote sensing has become a common tool of investigation, prediction and forecast of environmental change and scenarios. Remote Sensing and Global Positioning System (GPS) tools and technology in assisting level decision had become a vital option applicable to pipeline transportation and other industry infrastructure. Pipelines often cover thousands of miles and are located in remote areas that are difficult and expensive to monitor. Safe pipeline transportation of energy resources is a major concern for the public and the pipeline industry. For managing pipeline operational needs a GIS based multi criteria decision analysis system and process providing improved critical pipeline data quality by provide the structure for systematic logical evaluation /management of pipeline threats, incorporate technology and create incentives for technical advancements and their use. Identify high consequence areas along the route of the pipeline by obtaining the visual and detailed information about the geographical data. Analysis reveals important considerations to help users make decisions for future town planning. This GIS database could be expanded to analyse urban and vegetation coverage, storm water runoff potential threats, the database can also allowed for all spatial natural features to be accounted for in GIS alongside other forms of infrastructure. The advantage for making decisions based on the overall data from this system could provide spur economic revitalization, enhanced planning, economic development, and preserve important sites. Moreover, users appear to save time via GIS design and enhance decision making. The applicability of the GIS database has far-reaching potential in making effective decisions in town planning around the pipeline. In this study GIS is used to provide a compact space where all sorts of data relevant to Area can be stored in digital format, including images, maps, documents, photographs. This study discussed potential contributions of RS and GIS to planning discipline, and proposed a prototype, which would help in better management for the pipeline operation.

Keywords*: Management, GIS RS, Route, Shape file, Raster, Victor, Theme, Buffer, Attributes, Dem, Satellite, GPS.*

1. Introduction

1.1. Background

Advances in geospatial sensors, data analysis methods and communication technology present new opportunities for users to increase productivity, reduce costs, facilitate innovation and create virtual collaborative environments for addressing the challenges of security improvement and risk reduction. Sensor developments include a new generation of high-resolution commercial satellites that will provide unique levels of accuracy in spatial, spectral and temporal attributes. Advances in Information systems, satellites imaging systems and improved software technologies have led to opportunities for a new level of information products from remote sensed data. The integration of these new products into existing response systems can provide a wide range of analysis tools and information products that were not possible before. Here in this research we try do give an option tool in long crude pipeline operation management to help in decision making and planning for Petrodar Operating Company export pipeline. Petrodar Operating Company Ltd. is an operating company to carry out exploration, development and production of oil for Block 3E, 7E and 3D in Sudan which are located in the south east of Sudan with a total concession area of 72,420 sq. km

ISSN 2348 – 7968

1.2. Problem Statement

Find and prove new management method for PDOC'S pipeline and for its reporting and documents of operation.

1.3. Objectives

- Integrated Satellite Based Detection System for Pipeline Monitoring
- Develop an organized, logical approach to computer-assisted processing of earth resources data for effective natural resource management.
- GIS-based Multi-Criteria Decision Analysis
- Implementing a system and process for managing pipeline operational needs.

1.4. Scope

The scope of this article is involved in Petrodar Operating Company export pipeline operation management support decision making instrument to help in operation philosophy achievements and for the future optimization through spatial statistics and hydraulic trends parameters by identification of key spatially parameters affecting the Pipeline a long its route.

1.5. Study area

The study area is the area that covers the route states of Petrodar operating Co. Pipeline which are the Upper Nile in South Sudan, and White Nile, El Gezira, Khartoum, River Nile, Red Sea states in Sudan. Fig 1.1. The route of the pipe line start at Longitude (32°28'25.10244"E) &Latitude (10°27'21.75675"N) through the previous states to the Bashair Marin Terminal at the Red Sea Longitude (47°24'35.023" E) & Latitude (17°08'077.677 "N).

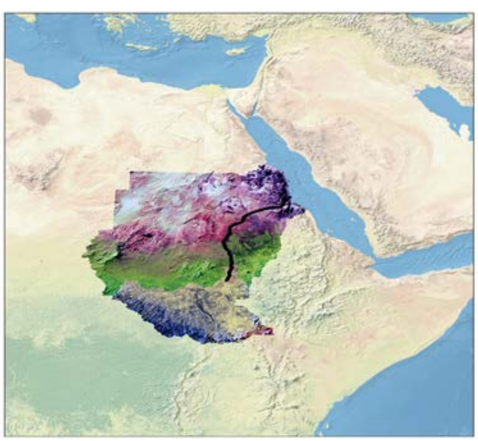

Figure 1.1: Study area and PDOC's Pipeline

1.6. Melut Basin Oil Development Project

The "Melut Basin Oil Development Project" consists of the following facilities:

A. Upstream Facilities:

- Flow lines.
- Gathering Pipelines.
- Field Processing Facilities (FPF)
- Centralized Processing Facilities (CPF).
- Power Stations.
- Power transmission lines.

B. Downstream Facilities.

- Field Pipeline from Palouge FPF to Al Jabalayn CPF
- Export Pipeline from Al Jabalayn CPF to Port Sudan Marine Terminal
- Pumping Facilities: 6 (six) Pump Stations for the Initial Phase, plus 5 (five) additional Pump Stations for the Future Phase
- SCADA and Telecommunication System
- Export Marine Terminal, located at Port Sudan.

This article describes the operations of the six Pump Stations installed along the 1,370 km of the 32-inches buried pipeline for the transportation, during the initial phase, of 200,000 BOPD Crude Oil, from Palouge Field Processing Facilities to the Export Marine Terminal. The pipeline (O.D. 32-inches - full "future" capacity 500,000 BOPD) It must be noted that the "put in service" of each of the six Pump Stations has to be coordinated with the operation of the remaining facilities making part of the whole "Crude Oil Export System Project".

2. Linkages of GIS to Remote Sensing

Today maps are not just made using GIS, but the infrastructure of utilities in the streets of our towns will be held in a GIS. To use GIS technology, a huge GIS database on geographical features is to be created. Creating such a database is a complex operation which may involve data capture, verification and structuring process. Because raw geographical data are available in many different analogue or digital forms like maps, aerial photographs, and satellite images, a spatial database can be built in several, not mutually exclusive ways, such as acquiring data in digital form from a data supplier, digitizing existing analogue data, carrying out field survey of geographic entities, and interpolating from point observations to continuous surfaces. Remote sensing data are a major source of data for the mapping of resources like geology, forestry, water resources, land use and land cover. Integration of the two technologies, remote sensing and GIS, can be used to develop decision support systems for a planner or decision maker. Remotely sensed images can be used for two purposes, as a source of spatial data within GIS and using the functionality of GIS in processing remotely sensed data in both pictorial and digital modes. Since digital remote sensing images are collected in a raster format, digital images are inherently compatible spatially with other sources of information in a raster domain. Because of this, "raw" images can be directly and easily included as layers in a raster-based GIS. Similarly, such image processing procedures as automated land cover classification result in the creation of interpreted or derived data files in a raster format. These derived data are again inherently compatible with the other sources of data represented in a raster format. Remote sensing images need not be digital in format to be of any value in a GIS environment. Visual interpretation of hardcopy images is used extensively to locate specific features and conditions, which are then subsequently geocoded for inclusion in a GIS. At the same time, the information resident in a GIS can also be used to aid in a visual or digital image interpretation process. For example, GIS information on elevation, slope, and aspect might be used to aid in the classification of forest types appearing in images acquired over areas of high relief. Thus, the interaction between remote sensing and GIS techniques is two-way in nature. Remote sensing images including the information extracted from such images, along with GPS data, have become primary data sources for modern GIS. Indeed, the boundaries between remote sensing, GIS, and GPS technology have become blurred, and these combined fields will continue to revolutionize the inventory, monitoring, and managing natural resources on a day-to-day basis. Similarly, these technologies are assisting us in modeling and understanding biophysical process at all scales. They are also permitting us to develop and communicate cause-and-effect "what-if' scenarios in a spatial context in ways never before possible. The importance of remote sensing, GIS, GPS, and related information technologies in the professional careers of today's students involved in measuring, studying, and managing earth resources cannot be over-stated. Hence, in recent years, remote sensing has become a powerful source of spatial data as an input for GIS through which a detailed map can be generated with the help of other collateral data derived from several other sources. There are two methods of extracting data for GIS from the remote sensing data. They are, Visual interpretation of satellite imageries in pictorial format, and computer processing of remotely sensed digital data. The output of either of these analysis methods can be considered an input for GIS for any kind of application. Fig. 2.2 shows an overview of the linkage of remote sensing and GIS. Proposed methodology in which GIS, satellite remote sensing and topographic mapping tools are basically used in order to develop a system that can be used for the integrated planning.

2.1. The GIS database formulation

Satellite imagery must be pre-processed (geometric and radiometric correction) and then must be post-processed using the image enhancement method. Finally a GIS database link with the image data will be applied for developing a map. A GIS application provided a structure for presenting data in the form of maps for visual analysis, as points, lines and areas, but the power of GIS goes far beyond maps. In fact, mapping is a minor part of GIS application. The databases associated with GIS and the tools to manipulate those data sets are powerful tools for organizing, analyzing and interpreting data. Data are stored in a GIS in two main formats -vector and raster. Satellite images, raster and vector polygons. The geographical objects considered as necessary items were designed as point layer. Building layers where designed as polygon geometry with attributes. Use effective GIS map layers, pipeline & pumping facilities database. The Figure 2.1 below is representing steps for the main methods & procedures to for map production:

ISSN 2348 – 7968

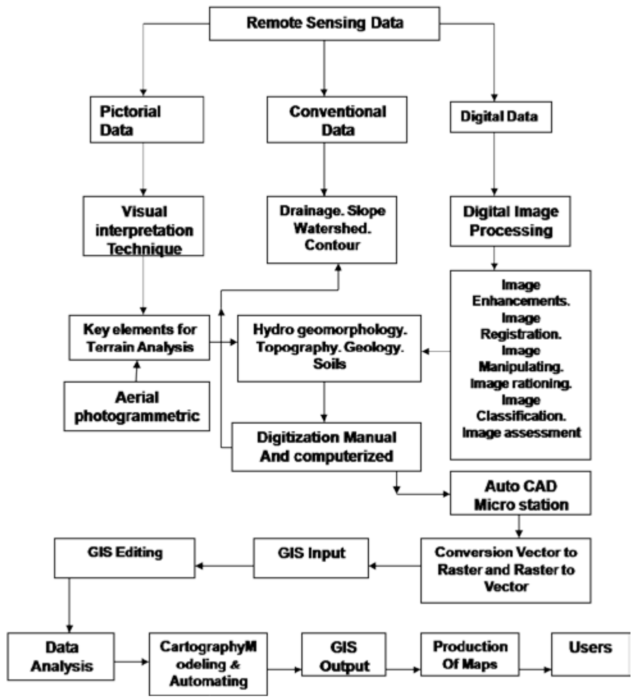

Figure 2.1: Overview of the linkage of remote sensing and GIS.

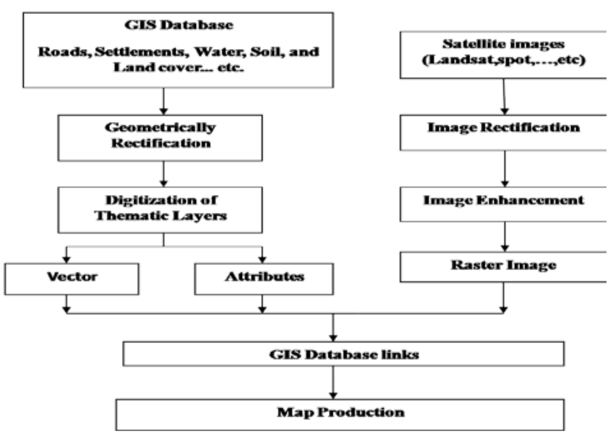

Figure 2.2: Main methods & procedures to for map production.

3. Methodology

Remote sensing was linked with GIS then used vector model as points, lines &polygon geometry with attributes. Moreover GIS map layers were used with pipeline& pumping facilities database to form thematic maps with the following Themes:

- Landcover
- water
- urban landscape
- soils
- Land use/cover change detection, urban growth detection.

3.1. Data Gathering and Integration

The joining of the Excels Facilities tables to the Spatial Facilities table allows for making pipeline shape file and this is the main operation for start the data gathering. The Pipeline Cumulative Running KPs by GPS GARMEN in UTM SUDAN ADINDAN (WGS 84) in Excel tables is obtained from Melut Basin Development Project; and all the Images& shape file had projected to UTM SUDAN ADINDAN (WGS 84).

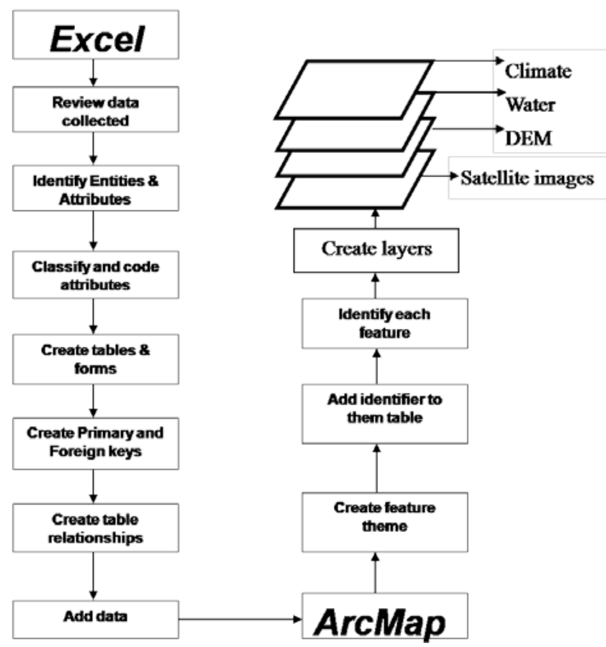

Figure 3.1: Initial Database& layers Development

In figure 2.3 above is the path way of steps flowchart for Database & layers Development and the steps for reaching the file document are as follows:

3.2. Data Review

Detailed GIS data and high-resolution aerial photography had obtained with most accurate and current data available to provide the most accurate results. This imagery had been obtained from a free photogrammetry vendor [High resolution satellite images (LandSat). They were in the raster format (note: they are in UTM projections, so my shape files were projected to UTM as well]. From these data, additional data were derived using queried analysis, GIS spatial analysis, and air photography

ISSN 2348 – 7968

interpretation. Additionally GPS field data collections were performed to gain additional specific data needed for the analysis. Data were subdivided into three perspectives, within each perspective was a common layer tier, and within each common layer was a suitability tier attribute the data was entered into different excel tables, converted to a dbase file, and used as the attribute tables to join its corresponding theme of the different critical facilities. Moreover additional Data was reviewed to identify entities and attributes and to facilitate the classification and coding of data of the Upstream Facilities & the Downstream Facilities.

Attributes were classified and coded to facilitate data entry and analysis. To minimize the number of tables required attribute codes were entered as look-up fields within the table structure.
The Primary key was posted into related tables to enable linkages and a "GIS_ID" key was established in the Facilities table to enable the linkage with the ArcMap theme table.

Every kind of object is modeled by an abstract data type. We use the vectorial geometry to represent the geographic objects. This kind of modeling matches the representation used by the user interface. The geometry used in the interface and in the database is based on standard geographic data. The database and the interface shall be used in the context of an interoperability GIS. In table 3.1 are the GIS Data and Common Sources.

Table 3.1: GIS Data and Common Sources.

GIS Data	
Classification Type	Source
High resolution satellite images	http://www.diva-gis.org/Data
DEM	http://www.diva-gis.org/Data
Water bodies & water lines	http://www.diva-gis.org/Data
Temperature	http://www.diva-gis.org/Data
Precipitations	http://www.diva-gis.org/Data
Soil	http://www.diva-gis.org/Data
Settlements	Central Bureau of Statistics
Pipeline coordinates	Melut Basin Development Project

The produced documents (maps& graphs) are as flows in Figures 3.2 - 3.14 illustrated in sequence one after another.

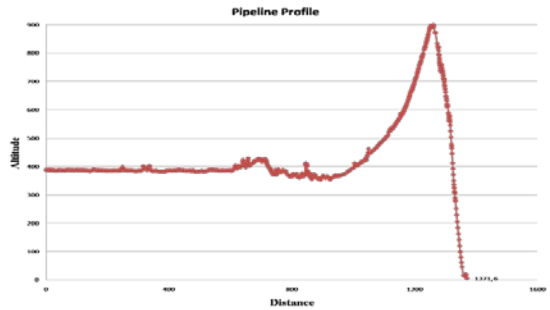

Figure 3.2: PDOC'S Pipeline Profile

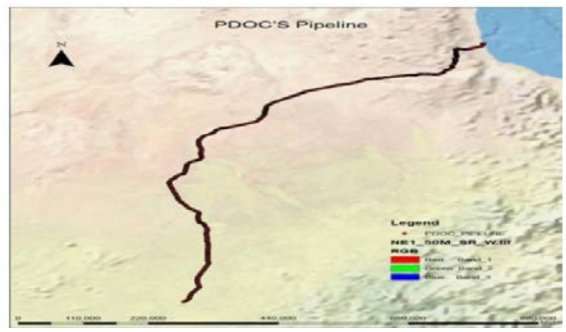

Figure 3.3: PDOC'S Pipeline shape file and landstat image map.

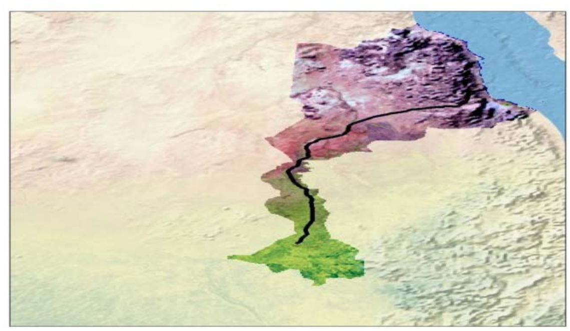

Figure 3.4: PDOC'S Pipeline route shape file layer over landsat image map

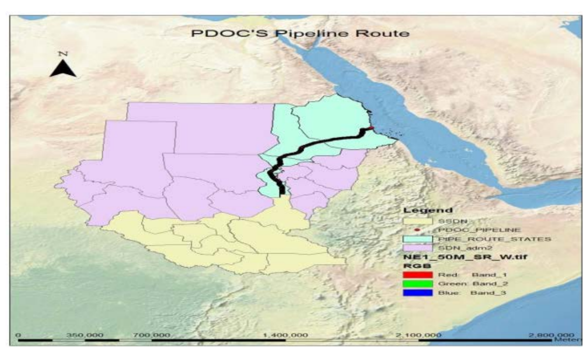

Figure 3.5: PDOC'S Pipeline route Political boundaries of SDN and SSDN map

ISSN 2348 – 7968

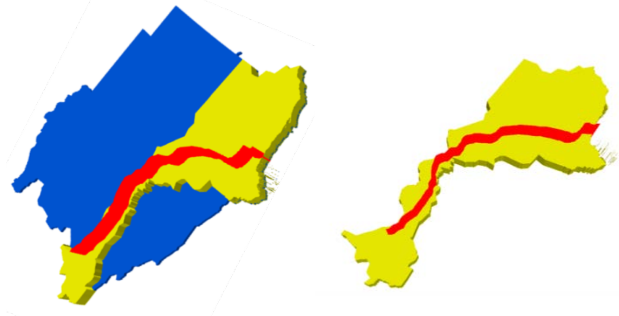

Figure 3.6: PDOC'S Pipeline route's in 3D

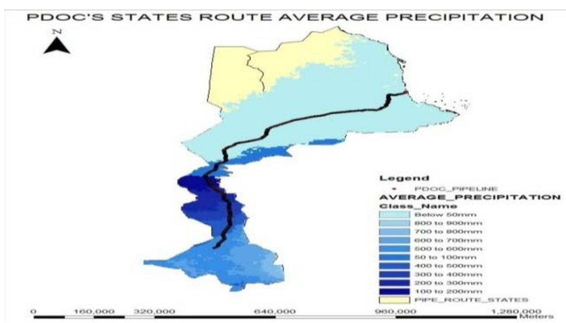

Figure 3.7: PDOC'S Pipeline route's average precipitation map

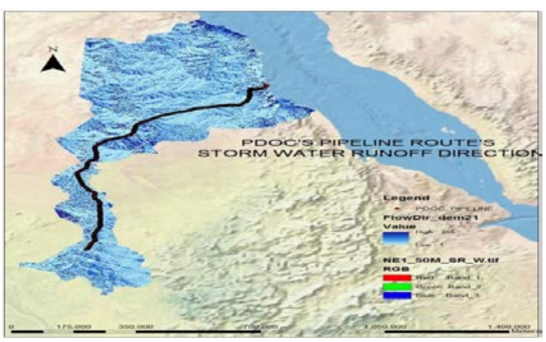

Figure 3.8: PDOC'S Pipeline route's storm water runoff direction map

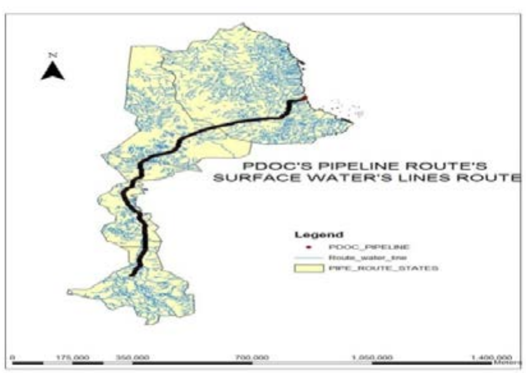

Figure 3.9: PDOC'S Pipeline route's surface water lines route map

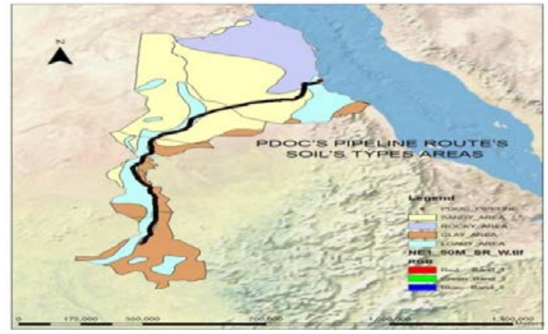

Figure 3.10: PDOC'S Pipeline route's soil's type's areas map

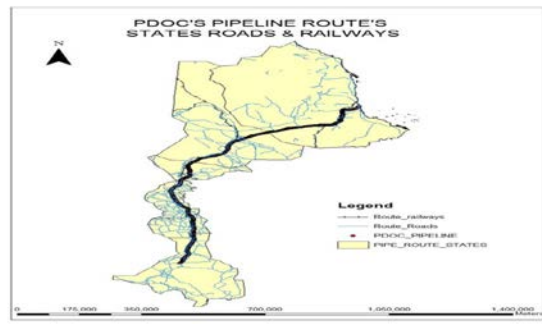

Figure 3.11: PDOC'S Pipeline route's states roads & railways map

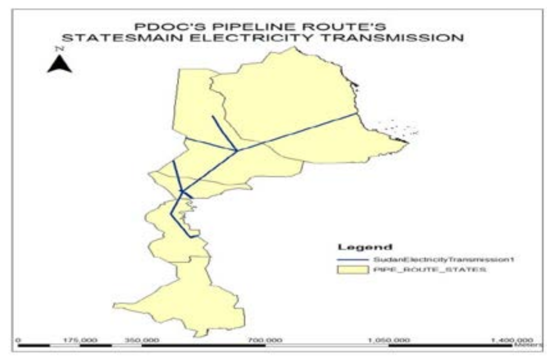

Figure 3.12: PDOC'S Pipeline route's states main electricity transmission lines map

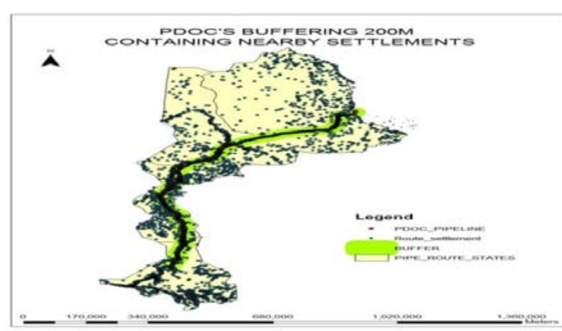

Figure 3.13: PDOC'S Pipeline Buffering 200m nearby settlements map

ISSN 2348 – 7968

Determination of important and necessary nearby settlements & determination of the optimum plan for urban planning consideration along the route for future town planning can be seen through buffer tool.

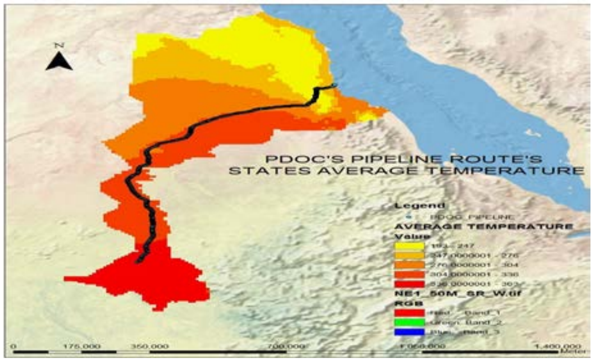

Figure 3.14: PDOC'S Pipeline route's states average temperature map

4. Results and Discussion

GIS had provided a Satellite Based Detection System for Pipeline Monitoring and accelerate pipeline integrity assessment in high consequence areas.

GIS had developed an organized, logical approach to computer-assisted processing of earth's features data that affect the pipeline during the time like the soil type along the route for continues analysis.

Determination of important and necessary nearby settlements & determination of the optimum plan for urban planning consideration along the route for future town planning.

Determination for storm water runoff direction and areas where water can affect the heating performance for the heavy crude transferred via the pipe by causing the drop down of the temperature, which it is critical in fuel management used in heating process along the pipeline.

5. Conclusion

Pipelines provide a safe and economic means of transporting fluids such as natural gas, crude oil, refined products and natural gas liquids products across great distances and over all manner of terrain. As manmade systems however, they can and do fail from time to time, sometimes with catastrophic effect. Repairs and environmental remediation, especially in sensitive areas, can however be very expensive. Using GIS based technology; an operator can view his pipeline in its environmental and safety context so as to quickly visualize high consequence areas and the need for possible upgrading of class location. GIS can also provide details of accessibility to a particular location; say a main line valve, in the event of an emergency. Structured queries of spatial, remote sensing and in-line inspection information improve the development of Integrity Management Programs and intervention strategies. For example, slope movements in sensitive areas can be tracked over time using historical data. Software applications have been developed which link the topography contained in the GIS database to a flow modeling capability and corrosion assessment module so that the internal corrosion of liquid lines can be continually monitored. Right of way management and emergency response planning have been significantly improved by locating the positions of habitable dwellings and public places within the GIS data base. In this study GIS is used to provide a compact space where all sorts of data relevant to Area can be stored in digital format, including images, maps, documents, photographs. Data have been already arranged so that it can be incorporated into displays like maps, charts, and tables, and can be in the service of sophisticated analytical procedures. Future analyses can be the basis for future planning, design, and site management decisions. Safety and environmental protection management are largely can be monitored and covered through the combined effect of GIS and Pipeline operation data to provide increased assurance of safety to the public in buffered pipeline route nearby settlements. The pipeline operation age is small (about eight years) so far its new to use GIS in management and planning for integrity & operation analysis for the company's management system and report structure cause the did not use it before in downstream department so for the benefits that I found it after application of GIS & Remote sensing techniques in pipeline data I found the following results.

6. Recommendations and Future Expectations

The research can recommend the following after practice some GIS & remote sensing techniques in this research as follows:

- Work Order, operation documents and reports must be linked to GIS system for easy spatial parts work distribution and organization.
- SCADA system must linked and be compatible with GIS system.

- Automate reports can be better for current reporting method & documents by combinations with SCADA & GIS.

References

1. Akinci, B., Karimi, H., Pradhan, A., Wu, C. & Fichtl, G. 2008. CAD and GIS interoperability through semantic web services. ITcon Vol. 13, pg. 39-55. Available from: http://www.itcon.org/2008/3

2. Alumbaugh, T & Bajcsy, P. 2002. Georeferencing maps with contours in I2K. Technical Report. National Center for Supercomputing Applications. Illinois.

3. Arctur, D. & Zeiler, M. 2004. Designing geodatabases. Case Studies in GIS Data Modeling. Redlands California: ESRI.
Anon, 1996. What are Geographic data? Available from:

4. http://www.spatial.maine.edu/~max/EDBT1.html. Last update: 26 July 1996.

5. Anon, 2012. Manitoba Eco-Network. GIS/Mapping Centre - What is GIS? Available from: (http://mbeconetwork.org/what_is_gis/)

Babbitt, L. M. & Godfrey, P. 2003. Water/Wastewater authority geodatabase design and implementation. Paper#328. Pennsylvania.

6. Berthiaume, J., Duhaime, R., Skids, D. & Shaw, N. 2005. CAD to GIS. A step-by-step guide to converting .dwg CAD files to GIS shapefiles. National Park Service GIS. U.S. Department of the Interior. Boston.

7. Booch, G., Rumbaugh, J., & Jacobson, I. 1999. The unified modeling language user guide. Boston EUA: Addison-Wesley.

8. Cheng, M. & Chang, G. 2001. Automating utility route design and planning through GIS. Automation in construction, 10(4):507-516.

9. Childs, C. 2009. The top nine reasons to use a file geodatabase. A scalable and speedy choice for single users or small groups. ArcUser, Spring 2009: 12-15.

10. Christodoulou, S., Deligianni, A., Aslani, P. & Agathoklous, A. 2009. Risk-based asset management of water piping networks using neurofuzzy systems. Computers, Environment and Urban Systems, 33(2):138-149.

11. Clarke, K. C. 1986. Advances in geographic information systems. Computers, Environment and Urban Systems, 10(3-4):175-184. Available from: http://lewisoaten.com/2010/04/24abrief-history-of-gis.html

12. Cowen, D. J. 1988. GIS versus CAD versus DBMS: What are the differences? Photogrammetric Engineering and Remote Sensing, 54(11):1551-1555.

13. CSISS, 2010. GIS Cookbook: Glossary. Center for Spatially Integrated Social Science. University of California. Santa Barbara, California. Available from: http://www.csiss.org/cookbook/glossary.php

14. Cummins, J. 2011. Geographic Information Systems. Difference between network dataset and geometric network. Available from: http://gis.stackexchange.com/questions/6885/difference-between-network-dataset and geometric-network.

15. Dai, F. C., Lee, C. F. & Zhang, X. H. 2001. GIS-based geo-environmental evaluation for urban land-use planning. Engineering Geology, bl (4): 257-271

16. Dempsey, C. 2011. Coverage definition. GIS Glossary – A through G. GIS lounge. Available from: http://gislounge.com/geospatial-glossary-a-through-g/
Ellul, C. & Haklay, M. 2006. Requirements for Topology in 3D GIS. Transactions in GIS. 10(2): 157 – 175.

17. ESRI, 2002a. ESRI developer network. Topology in ArcGIS. Redlands, California. Available from: http://edndoc.esri.com/arcobjects/9.2/NET_Server_Doc/manager/geodatabase/working_with_ge1536981934/topology_in_arcgis.htm

18. ESRI, 2002b. ArcGIS Brings Topology to the Geodatabase. Arc News Online. Available from: http://www.esri.com/news/arcnews/summer02articles/arcgis-brings-topology.html
ESRI, 2002c. ArcGIS Data Models: ArcGIS Water Utility Data Model. Available from: http://support.esri.com/en/downloads/datamodel/detail/16

19. ESRI, 2005b. GIS Topology. An ESRI White Paper. July. Redlands, California. Available from: http://www.esri.com/library/whitepapers/pdfs/gis_topology.pdf

20. ESRI, 2010a. GIS.com. The guide to geographic information systems. Available from: http://www.gis.com/content/what-gis

21. Harrison, D. S., Newton, R. A., Spickelmier, R. L., & Barnes, T. J. 1990. Electronic CAD Frameworks. Proceedings of the IEEE. California. 78(2): 393-417.

22. Heywood, I., Cornelius, S., Carver, S. 2006. An Introduction to Geographical Information Systems. Third Edition. England. Prentice Hall.

23. Hijmans, R. J., Guarino, L., Cruz, M. & Rojas, E. 2001. Computer tools for spatial analysis of plant genetic resources data: 1. DIVA-GIS. Plant Genetic Resources Newsletter, 127: 15- 19. Colombia.
Kennedy, M. & Kopp, S. 2000. Understanding map projections: GIS by ESRI. Redlands, California.
Kurnia, C., Hopkins, D., & Ho, M. 2005. Georeferencing ArcIMS Services. ArcUser, January-March 2005: 34-35. Redlands, California.

24. Law, D. 2007. Many choices. Many geodatabase types available with ArcGIS 9.2. ArcUser, 10(1): 1-4. Redlands, California. Available from: http://www.esri.com/library/reprints/pdfs/arcuser_geodatabase.pdf

25. Lee, J. 2004. A spatial Access-Oriented Implementation of a 3-D GIS Topological Data Model for Urban Entities. Geoinformatica 8(3): 237-264.

26. Parmenter, B. 2005. How to align a non-georeferenced image to an existing geographic layer or georeferenced image. Community and Regional Planning Program. University of Texas.

27. Tlokwe Municipality, 2009. Industrial land use policy 2009. Potchefstroom.