Applied Science and Innovative Research
ISSN 2474-4972 (Print) ISSN 2474-4980 (Online)
Vol. 2, No. 3, 2018
www.scholink.org/ojs/index.php/asir

Original Paper

Global Positioning System/Geographic Information System Environment for Engineering Infrastructure Facility Monitoring

Gunel F. Bahramova[1], Bahar N. Aliyeva[2], Namig Rahimov[1] & Rustam B. Rustamov[3*]

[1] Geotechnical Engineering Department, Encotec Company, Baku, Azerbaijan

[2] Freelance Geotechnical Engineer, Sydney, Australia

[3] Institute of Physics National Academy of Sciences, Baku, Azerbaijan

[*] Rustam B. Rustamov, Institute of Physics National Academy of Sciences, Baku, Azerbaijan

Received: August 2, 2018 Accepted: August 18, 2018 Online Published: August 28, 2018

doi:10.22158/asir.v2n3p118 URL: http://dx.doi.org/10.22158/asir.v2n3p118

Abstract

Oil and gas companies need to ensure continuous operation of critical equipment, no matter how remote. This means knowing exactly where your fleets and equipment are, how they are performing and identifying problems as they occur.

There are number of existing security systems developed to protect linear systems like oil pipelines for transportation of oil and gas products from the first point of development up to collection stations. In the current stage is the gap of the oil and gas pipeline systems security purposes of use of space technology advances. This paper dedicated to the subject of linear pipeline monitoring with use of global positioning system for observation of changes of land in the areas actively functioning of natural disaster factor (Babatunde, Chris, Rupert, & Phil, 2015).

Keywords

Monitoring, remote sensing and GIS, space image, linear system, image processing, satellite data, field data, field and space data integration

1. Introduction

1.1 Remote Sensing (RS) and Geographic Information System (GIS)

For the time being space technology advances found application in some subject of engineering infrastructure life cycle playing vital place in solving number of engineering problems as well as protecting and saving facilities. One of the flexible instrument in such task execution is the use of remote sensing method with development of geographic information system technology. It achieves due to the spatial information analyze developed by processing of satellite data collected by use of remote sensing method. In the meantime, it is an excellent information source makes possible successfully collection required data for further reuse, share when necessary, analyze depends of expected task execution. In the other hand, it opens an excellent environment for management all subjects of project items in any stage of its implementation, which is highly important for saving the time and resources as the opportunity for low cost management purposes.

The fact is that there are options where GIS provides tools for:

- modeling information to support more intelligent, faster decisions;
- discover and characterize geographic patterns;
- optimize network and resource allocation; and
- automate workflows through a visual modeling environment.

In the meantime, through the use of 2D and 3D software application it can be achieved a more interactive way of seeing data, visualizing change over time and space to identify patterns and trends, and disseminate knowledge to engineers, managers, clients, regulators, and field-based personnel.

There is no doubt that the study planet structure and natural disasters such as earthquakes, volcanoes, landslides, floods take the key place for Azerbaijan. As it says by scientists the world's atmosphere is becoming more turbulent and unpredictable which demand to come up with approach and developing a new instruments being able to reduce and prevent as much as possible damage to life and property.

It makes important engagement of engineers in geology/geotechnical/chemical and any other related scientists to take high attention to study the structure of the earth and develop models/methods/instruments to learn about continental drift and simulate/predict/forecast the faults in the Earth's crust. At the same time the study the causes and nature of volcanoes and learn about soil eruptions is very important for the country. As far as obvious landslides study are also important in engineering activities consequences needed to be undertaken during all stages of project design. It is important in the exploitation stage of engineering facilities as well.

The fact is that permanent monitoring of the Earth in the areas of engineering facilities is require for engineers, architects and project designers as an source and key instrument in construction and designing new engineering infrastructure with consideration features of environmental changes (Pipelines, CIA Factbook, n.d.).

The use and application advances of a high technology in particular space technology in the case of offered conception is a vital for achievement, satisfied accuracy in the process of monitoring of Earth observation for dynamic changes of the environment. It is important to reduce risks of pipeline systems in the active natural disaster areas.

1.2 Investigated Area

The area under investigation is located at 60km to the south-west from Baku, Azerbaijan in the Gobustan district, near the Goturdagh mud volcano (Figure 1). The landscape is hilly with low or absent vegetation. Geodesic survey for the fourth cycle of monitoring was started in December 2015 with installation datum monuments. The cycles of five monitoring were embraced on February, June, October 2016 and June 2017 and the last one were conducted on December 2017.

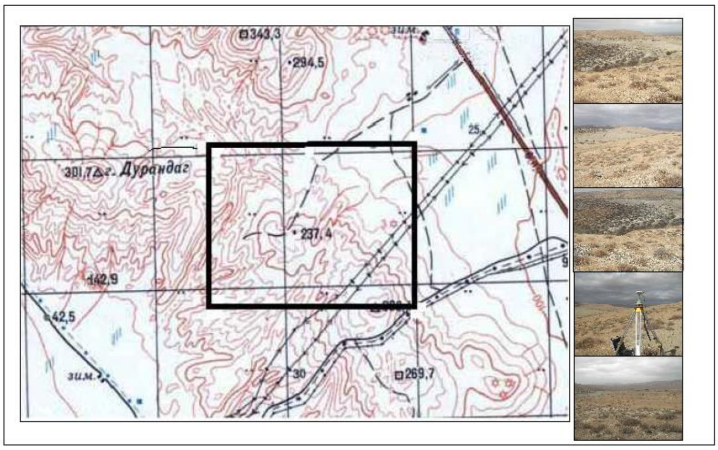

Figure 1. An Area of Investigation

2. Method of Measurement

2.1 Data Collection

Data collection consists specific functions for collect:

- precise site data used for predesign analysis;
- design; and
- calculations.

It is necessary to indicate content of data collection including:

- field survey;
- topography;
- soils parameters;
- subsurface geology;
- imaging;
- sensitive environmental areas;
- wetlands;
- hydrology; and
- other site-specific design-grade data and spatial image data processing.

The stages of data collection and processing (field measurements and remote sensing/geographical information system development) can be presented using below structure (Figure 2).

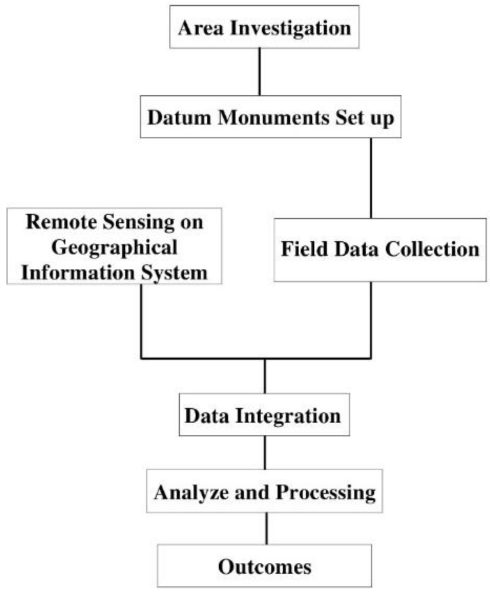

Figure 2. Field and Geospatial Data Collection and Integration

5 Datum (DM) and 15 Surface (SM) ground movement monuments and 6 Top-Dead Centre Target Points of pipe were installed during the first phase of field execution. Geodesic Surveyor performed field survey of ground movement monuments and Top-Dead Centre (TDC) Target points of pipe as a fourth cycle of monitoring to obtain their coordinates and elevation data. Together with the previous data obtained during first three monitoring cycles, these data is expected to be used for further monitoring stages.

The scope of fourth monitoring cycle was included the followings:

- Measurement of angles and directions of reference network;
- Determination of coordinates and elevations of surface (SM) ground movement monuments;
- Determination of coordinates and elevations of Top-Dead Centre (TDC) Target points of pipe; and
- Processing of the geodesic survey results.

World Geodetic System 1984 (WGS-84) was used as the reference geodetic system for horizontal projection. Kroonstad Datum (MSL Baltic Sea) was applied for the local vertical datum.

The coordinates of the Datum (DM) monuments were calculated with average square error of 5mm.

Equipment/Method Used for Topographical Survey and image processing

The topographical survey was performed by tachometric survey with the contour interval 0.5m with use of electronic tachometer TS 16 (by Leica) with plugged-in application program.

Topographical equipment has been checked at site prior to commencing work each day and when required.

Field Works

The works were performed as follows:

- Determination of horizontal and vertical position of DM points in WGS-84 system.
- Measurement of angles and directions of triangulation network.
- Adjustment of linear-angular and elevation network.
- Determination of horizontal and vertical position of SM points.
- Determination of horizontal and vertical position of TDC points.
- Processing of geodesic survey data.

In the initial stage of the field works it has been established DM points meeting the requirements identified by the owner of the oil pipeline system). Those requirements were important for the high accuracy of measurement achievement. An establishment of DM points has been shown in the Figure 3 (a, b).

In the meantime, it has been visited to the site for satellite data processing validation based on the fixed data features measurement taken from the site.

Establishment Datum Monuments (DM)

Triangulation network represents the series of triangles. Coordinates of all Datum (DM) monuments are determined in WGS-84 system. Satellite positioning receivers SR20 (produced by Leica) were used for determination of plane coordinates and elevations. Measurements were carried out in a static mode.

The aim of geodesic survey of datum (DM) ground movement monuments was to determine the change in their coordinates and elevations between first, second, third and fourth monitoring cycles.

a b

Figure 3. Establishment of Datum Monuments

The fourth stage of measurements started after equalization of line-angular reference network. Geodesic survey of surface (SM) monuments was performed with use of direct angular and linear interference method.

Measurements were carried out with use of electronic tachometer TS 16 (by Leica) from the reference network point by three receptions with required closing to the adjacent datum (DM) monument. A landmark with reflector was centered on a measured point with use of bipod. Coordinates and elevations of each point were determined from two points of reference network.

Elevations of points were determined with use of trigonometric leveling method.

Determination of horizontal and vertical position of each Top-Dead Centre (TDC) Target point was performed from two points of reference network with use of direct angular and linear interference method.

3. Measurement

Measurements were carried out with use of electronic tachometer TS 16 (by Leica) from the reference network point by three receptions with required closing to the adjacent datum (DM) monument. A landmark with reflector was centered on a measured point with use of tripod. Coordinates and elevations of each Top-Dead Centre (TDC) Target point were determined from two points of reference network.

Elevations of points were determined with use of trigonometric leveling method.

Geodesic and topographical information stored in the electronic memory of tachometer was imported into computer with use of Leica Geo Office Tools software. The average square error of measurements accuracy is 5mm.

Triangulation network represents the series of triangles. Coordinates of all Datum (DM) monuments are determined in WGS-84 system. Satellite positioning receivers SR20 (produced by Leica) were used for determination of plane coordinates and elevations.

Measurements were carried out in a static mode. Initially before installation of Surface (SM) and Datum (DM) monuments temporary points TP1 and TP2 coordinates were determined in WGS-84 system.

The process and conditions of measurement were the followings:

- The basic receiver was located at the geodesic reference network point with known coordinates during the whole measurement process;
- The second receiver was placed at the determinate point with satellite data set during 0.3-1.0 hours (depending on the distance from the basic station);
- Processing of field data consisting of adjustments of measurements and transformation of data (Pulkovo 1942 Zone 8) system was performed with use of Leica Geo Office software.

The purpose of triangulation network measurements was to determine the relative position of Datum (DM) monuments with the highest possible accuracy.

Total station software added proportional correction to the measured lines for:

- Atmosphere;
- Mean sea level reduction;
- Bringing oblique line to horizon.

Measured lengths of triangulation sides and received from GPS survey are given in the Table 1.

Table 1. Triangulation Measurement

From	To	Grid Distance	
		TS 09 plus	GPS
DM2	DM4	172.520m	172.518m
DM4	DM5	223.556m	223.549m
DM2	DM1	128.772m	128.760m
DM1	DM3	129.372m	129.368m
DM1	DM5	279.295m	279.291m

3.1 Geospatial Data and GIS Interpretation

The fact is that it is important and necessary to detect any changes of the land with linear infrastructure in the area with sensitive behavior into the natural processes. The area selected for investigation is highly danger due to the active volcanic natural processes. This circumstance makes necessary to conduct continuous monitoring of the area with pipeline system as an infrastructure for oil transportation (Colomina & Molina, 2014).

For this purpose within the period of 2016-2017 has been carried out of the geodetic measurements by determination of horizontal and high-rise land motion of 15 deformation reference points near the mud volcanos area. The area of liner system location is hilly and established reference points for monitoring are constructed mainly on slopes sine the area was such of nature. This approach of measurement system development was the way to run the definition and monitoring of landslide processes near the mud volcano.

The Figures 4 and 5 demonstrate results of observed landslide condition based on the used monitoring method.

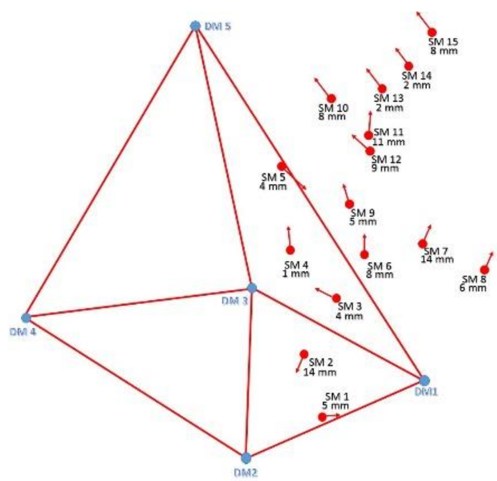

Figure 4. Displacement Vectors of Surface (SM) Ground Movement-Monitoring Monuments at Mud Volcano Complex and Wester Rout Export Pipeline (WREP) (from First to Second Surveys)

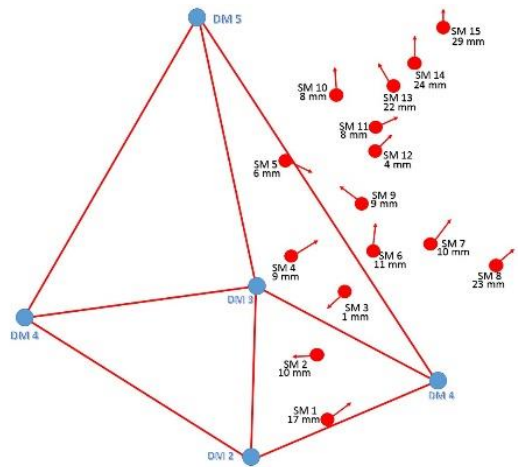

Figure 5. Displacement Vectors of Surface (SM) Ground Movement Monitoring Monuments at Mud Volcano Complex and Wester Rout Export Pipeline (WREP) (from First to Fifth Surveys)

It has been carried out five cycles of measurements/monitoring within 2 years in the different seasons. Initially before measurements it has been implemented on definition of planned and levelling positions of monuments of constructed for monitoring of geodetic network (Zimig, Hausamann, & Schreier, 2001; Jawhar, Mohamed, Mohamed, & Aziz, 2008).

The results of the measurements are observed of land deformation of land with increasing of shifting vectors in the direction of slope comparatively of reference points in the cycles of 2 and 5. As it is seeing from the Figure 5 the greatest landslide is monitored in the area close to the volcanic crater.

3.2 Digital Elevation Model

Shuttle Radar Topographic Mission (SRTM) has provided digital elevation data (DEMs) as the very popular method. It has been used software QGIS with directly interfacing of the SRTM DEM data. The data contains elevation information, which was used for selected area for investigation (Siddaraju, Nagaraju, Bhanuprakash, Shivaswamy, & Balasubramanian, 2017; Rodriguez, Morris, Belz, Chapin, Martin, Daffer, & Hensley, 2005; Coltelli, Fornaro, Franceschetti, Lanari, Migliaccio, Moreira, & Schwabisch, 1996). The DEM layer rendered in the gray single band. The next stage of application was rendering of the type to convert of the system into required format. At the same time the colors have been classified for the best performance and development of DEM layers properties. The result of processing with use of suggested software application and method has been demonstrated in the Figure 6.

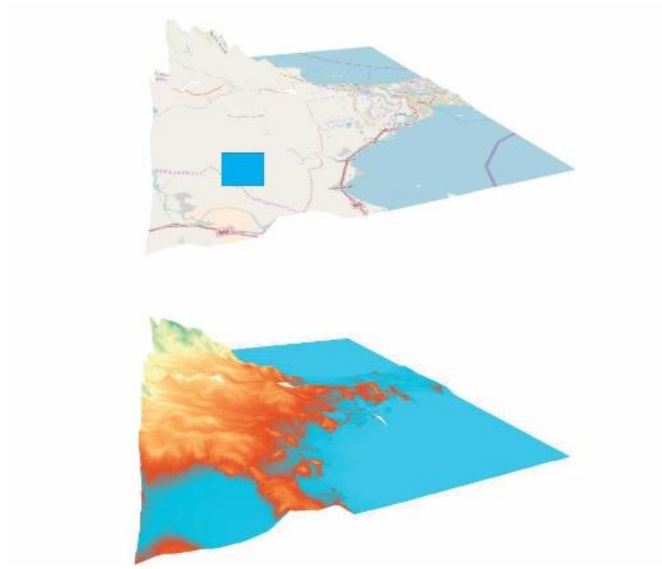

Figure 6. 3D Modelling of the Selected Area

3.3 Satellite Data Processing

Satellite imagery was used for processing stage. The image was georeferenced to UTM zone 39 North, WGS84 using a first degree polynomial rectification algorithm extracted from a digitized topographic map at the scale of 1:100 000. The root mean square (RMS) error was equal to 0.5 pixel (5 m). Figure 7 demonstrates results of processing with reflection of layers of GIS system (Rabus, Eineder, Roth, & Bamler, 2003).

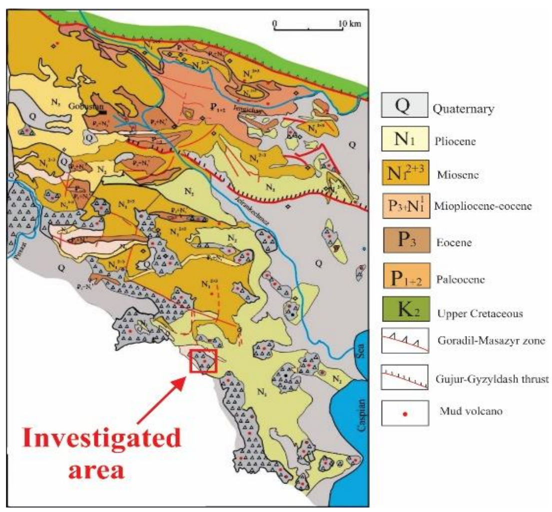

Figure 7. GIS Development of Selected Area

The image was classified between follow general classes:

1. Quaternary;

2. Pliocene;

3. Miosene;
4. Miopliocene-Eocene;
5. Eocene;
6. Paleocene;
7. Upper Cretaceous;
8. Goradil-Masazur Zone;
9. Guyur-Gyzyldash Thrust; and
10. Mud Volcano

3.4 Geological Map

İt has been presented geological map of the selected area. Geological map shows general geological features of Gobustan region (Figure 8). The main target of the research was mud volcanoes impact monitoring to the area. For this reason, it is important to fix any influences and land use changes of the area.

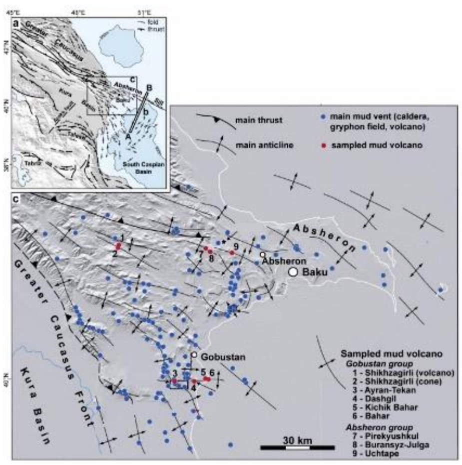

Figure 8. Geological Map of the Area

Figure 8 shows mud volcanos geographic locations in the selected area. It is additional information, which can be successfully integrated in the GIS system.

4. Conclusion

This paper has been dedicated to the development of geographical information system with use of remote sensing for liner transportation engineering systems safety. It has been demonstrated advances and advantage of is demonstrated technological/methodical aspects of global positioning system applications for monitoring and observation of any possible changes in the area of operating linear system.

It is performed of satellite data collection with integration of the field data. In the meantime demonstrated achievement of features of the layers of GIS for selected area. A stage of monitoring and observation of change detection of area is presented. It has been shown advantage of GPS technology in safety of the linear engineering infrastructures based on GIS environment.

References

Babatunde, O., Chris, C., Rupert, Y., & Phil, B. (2015). Real-Time Monitoring Of Buried Oil Pipeline Right-Of-Way for Third-Party Incursion. *International Journal of Innovative Science, Engineering & Technology*, *2*(2).

Colomina, I., & Molina, P. (2014). Unmanned aerial systems for photogrammetry and remote sensing: A review. *ISPRS Journal of Photogrammetry and Remote Sensing*, *92*, 79-97. https://doi.org/10.1016/j.isprsjprs.2014.02.013

Coltelli, M., Fornaro, G., Franceschetti, G., Lanari, R., Migliaccio, M., Moreira, J. R., … Schwabisch, M. (1996). SIR-C/X-SAR multifrequency multipass interferometry: A new tool for geological interpretation. *Journal of Geophysical Research*, *101*, 23127-23148. https://doi.org/10.1029/96JE01301

Jawhar, I., Mohamed, N., Mohamed, M., & Aziz, M. A. (2008). *Routing Protocol and Addressing Scheme for Oil, Gas, and Water Pipeline Monitoring Using Wireless Sensor Networks*. In Proceedings of the Fifth IEEE/IFIP International Conference on Wireless and Optical Communications Networks (WOCN2008), Surabaya, East Java, Indonesia.

Pipelines, CIA Factbook. (n.d.). Retrieved April, 30, 2011, from https://www.cia.gov/library/publications/the-world-factbook/fields/2117.html

Rabus, B., Eineder, M., Roth, A., & Bamler, R. (2003). The shuttle radar topography mission—A new class of digital elevation models acquired by spaceborne radar. *Photogramm. Rem. Sens.*, *57*, 241-262. https://doi.org/10.1016/S0924-2716(02)00124-7

Rodriguez, E., Morris, C. S., Belz, J. E., Chapin, E. C., Martin, J. M., Daffer, W., & Hensley, S. (2005). *An assessment of the SRTM topographic products*. Jet Propulsion Laboratory, Pasadena, California.

Siddaraju, K., Nagaraju, D., Bhanuprakash, H. M., Shivaswamy, H. M., & Balasubramanian, A. (2017). Morphometric Evaluation and Sub Basin Analysis in Hanur Watershed, Kollegal Taluk, Chamarajanagar District, Karnataka, India, using Remote Sensing and GIS Techniques. *International Journal of Advanced Remote Sensing and GIS*, *6*(1), 2178-2121. https://doi.org/10.23953/cloud.ijarsg.265

Zimig, W., Hausamann, D., & Schreier, G. (2001). *A concept for Natural Gas Transmission Pipeline Monitoring Based on New High-Resolution Remote Sensing Technologies*. Contributed Paper, International Gas Research Conference 2001.