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THE APPLICATION OF GEO-INFORMATION TECHNOLOGIES TO THE EFFICIENCY IMPROVEMENT OF THE MANAGING SYSTEM FOR GAS SUPPLY FACILITIES AND PROCESSING THE RESULTS OF GAS PIPELINES NETWORK MONITORING

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ABSTRACT

The article considers the possibilities of using geo-information technologies for managing gas supply facilities. Specific GIS solutions are proposed for the creation of a unified system that integrates executive, technical and management documentation with a digital model of the gas pipeline network. It is concluded that the spatial approach to information based on electronic maps and corresponding geo-databases allows not only to take into account the geometric and technical features of each section of the pipeline, but also simplifies the solution of the management and monitoring tasks, increasing the level of safe operation of pipelines for various purposes.

Keywords: GIS, gas pipeline, gas supply, electronic cards, geo-database, gas accounting, monitoring, security.

INTRODUCTION

Each aspect of hydrocarbons exploration, processing, storage, distribution means some risks associated with environmental impact and issues to maximize effective and economically profitable operation (Strizhenok and Tcvetkov, 2017). But, often, all the risks are difficult to assess and expensive to foresee. By systemizing reliable scientific and technological information, it is possible to ensure the integrity of data on oil and gas sector objects at all stages of their life cycle (from design to liquidation) and significantly simplify the operation and monitoring of engineering network facilities.

In the Russian Federation to date, the total length of the linear part of the main pipelines is more than 200 thousand km, of which: the main gas pipelines - 166 thousand km; Trunk oil pipelines - 52, 5 thousand km. (http://www.gosnadzor.ru/public/annual_reports) the annual growth of distribution gas pipelines is about 30,000 km.

It is known that the most of the Russian gas transmission system was built in the 70-80s of the last century. A sufficiently high level of safety and reliability of gas supply systems installed with a large safety margin makes it possible to ensure the stable operation of gas distribution systems. However, to date, the depreciation of fixed assets on the linear part of the main gas pipelines is more than half, or rather - 57.2%.(Savonin *et al.*, 2017) And taking into account the fact that the length of gas distribution pipelines in the Russian Federation and the volumes of gas transportation over the past 10 years have increased by 1.5-2 times, accidents on gas pipelines of various diameters range from 30 to 40 cases per year on average.

One of the reasons for this is the low efficiency of existing monitoring services (Pivovarova and Makhovikov, 2017). Often, the services for tracking the actual situation at the enterprises are limited to registering physical processes, while the competent and widespread use of geo-information technologies make possible the synthesis and analysis of observations, management decisions and adjustments of activities. So known cases from the world practice show the non-application of spatial analysis tools and the lack of integration of spatial information systems with existing control systems leads to serious emergencies and human casualties (http://www.exprodat.com/featured):

- PG&E admits violating federal law requiring pipeline inspections every five years – On September 9, 2010, a 30-inch-diameter segment of an intrastate natural gas transmission pipeline owned and operated by the Pacific Gas and Electric Company (PG&E), ruptured in a residential area in San Bruno, California. The rupture produced a crater about 72 feet long by 26 feet wide. The section of pipe that ruptured, which weighed about 3,000 pounds, was found 100 feet south of the crater. PG&E estimated that 47.6 million standard cubic feet of natural gas was released. The released natural gas ignited, resulting in a fire that killed 8 people and destroyed 38 homes, damaging 70 more. It was later discovered that PG&E failed to check nearly 14 miles of gas distribution pipelines for leaks for up to two decades when it lost track of 16 maps needed to guide mandated safety inspections of its system.
- Maersk Victory jack-up sustains major damage - In 1996 the Maersk Victory jack-up sustained major damage when one of its legs broke through soft seabed limestone in St. VincentsGulf off South Australia. The incident happened while the rig was jacking up on location prior to spudding the first of two wells in the Stansbury basin on exploration permit PEL 53. The South Australia Department of Mines and Energy Resources (MESA) undertook an investigation and determined that the cause of damage was the failure of the sub-sea sediments beneath the rig. MESA concluded that there was a failure to fully evaluate the risks of the drilling location, a failure to fully evaluate the geotechnical data of the sub-sea sediments, and a

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failure in management systems and procedures for locating the rig.

- Anonymous North Sea example of incorrect rig positioning - During a jack-up rig move the engineer looking after the navigation didn't realize that he'd inadvertently changed the coordinate reference parameters he was using. Later radar positioning checks revealed it was 1.5 km off location, in another operator's block. The company in question had to move the rig at a cost of $750,000, and suffered reputation issues as the government reviewed its license arrangements (from the OGP Geomatics Committee geodetic awareness guidance notes document, which contains other examples of geo-reference integrity failures).

Obviously systematization is needed for the existing normative-technical documentation: situational and engineering-topographic plans and schemes of routes, technological schemes, technical certification and diagnostics, the time of the current and capital repairs - for many pipeline companies to solve this problem is a geographical information system (GIS).

MATERIALS AND METHODS

The first group of GIS users, led by companies such as Exxon and Shell, began activities in this field in the early 1990s. By the late 1990s, oil and gas service companies such as Landmark and Schlumberger began packaging GIS technologies in their commercial software products and began to develop the use of GIS in data management, exploration, stringing and maintenance of pipelines. (Merem *et al.*, 2010)

Currently, most of this market sector is occupied by the products of «ESRI», «MapInfo», «Intergraph» - software packages «ArcGIS», «MapInfo Professional», «GeoMedia Professional», respectively, together with additional modules and shells that expand their functional possibilities for modeling and analysis, communication and integration with the «DBMS» and functioning under the WEB interface.

In Russia, the own development of energy companies IT departments is also quite common, integrating access to such systems in client applications of users. Access from the GIS environment to accounting information allows specialists to see and evaluate the interaction of production (internal) and natural (external) factors. For example, monitoring of the melting of the continental permafrost as a result of production activity is relevant for the Russian north. In flat areas, a risk factor is the flooding of pipelines and other objects due to the disturbance of surface runoff during construction. Geo-information systems can detect problem areas and identify objects at risk through the use of aerospace imagery and information from accounting systems. It is also very effective to combine with field survey data that is linked to the main database by means of coordinates received from GPS receivers. Thanks to these capabilities provided by GIS, the timeliness and quality of solutions in the field of facility management is increased, risks of occurrence of emergency or emergency situations are reduced (Andrianov 2014).

Examples of GIS solutions in the gas pipeline management system of the Central region of the Russian Federation and the Yamal-Nenets Autonomous District of the Russian Federation are given further.

Using «GeoMedia Professional» GIS package to create a gas supply and support network monitoring pipelines for various purposes

One of the large-scale and successful GIS solutions in the market of geo-information technologies and web-oriented geo-information services is the project «Geo-information system of GUP MO «Mosoblgaz» of LLC «Gortis-SL». A key feature of the company in the information technology market is the successful experience of adaptation of software offered by large foreign IT companies, both to industry specificity and to the requirements of a particular customer. This allows you to significantly reduce the financial costs for customers to purchase licenses and reduce the dependence on software vendors (http://www.gortis.com/ru/gis-gup-mo-mosoblgaz).

For the construction of large-scale geo-information systems, the company uses the «Intergraph» product - the «GeoMedia Professional» program and its add-in - the «xMedia» software package, which is the result of many years of programmers' work and is a multifunctional tool for modeling and designing the domain in the framework of building corporate GIS. The main result and distinctive feature is the built-in GIS control system, designed to store information about the spatial position and characteristics of gas facilities. The system includes archives of executive documentation containing tens of thousands of files (executive drawings, schematic maps, equipment certificates), whereupon the spatial resources are managed in the future.

Working in «GeoMedia Professional» using the «xMedia» module, it is possible to build a technological scheme for the gas pipeline network (GP) for various purposes. As a rule, gas pipelines are divided into main and distribution networks. The structure of the distribution gas network is a set of looped networks of main directions of gas flows and dead-end networks of branches. The type of gas pipelines can also differ: underground, aboveground, and underwater. Also, the GP differed on operating pressure - low, medium, high I and II categories. All this is taken into account when working in the program, while placing the appropriate fittings, gas consumption facilities, distribution points and filling in attributive information.

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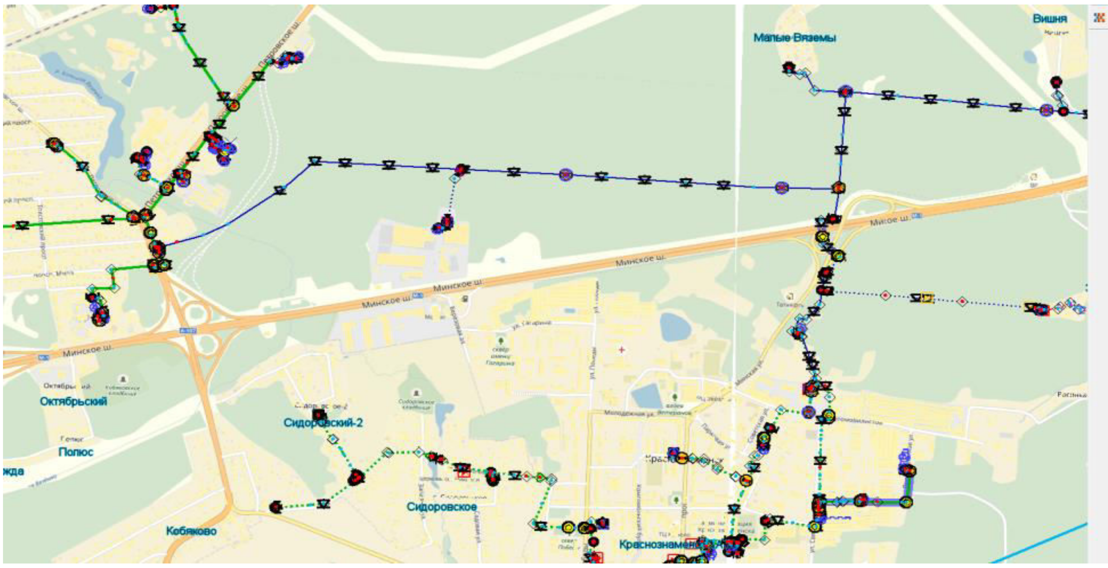

Figure-1. Fragment of the GP network of high pressure I and II category.

By scanning the executive plans scale 1: 500 - 1: 2000 produced vectoring gas facilities (GF) of the layers, the linkage topology GF filling characteristics. The attribute information of objects is always indicated:

- the name of the document file for accounting in the electronic archive;
- number of executive documentation on accounting in the electronic archive.

As a rule, the GIS-project includes the following thematic layers:

The «Gas Pipelines» layer - gas pipeline segments are vectorized by linear objects, i.e. the segment of the gas pipeline is a section of the gas pipeline having the same characteristics over its entire length (diameter, laying method) and bounded on both sides by other OGX (reinforcement). On maps and diagrams, GP segments are displayed by a polyline that defines the pipeline route.

The objects of the «Armature» layer can be represented in the form of three objects: low pressure, medium pressure or high pressure fittings. Displayed by vector objects and oriented along the GP segment. Data on diameter are taken from the execution plan and from the welding circuit.

The objects of the layer «Electrochemical corrosion protection» (ECP) are displayed by vector objects and are oriented along the GP segment.

Objects of the layer «Gas consumption objects» (GCO) are displayed by point objects. The conventional sign of the GCO (with the exception of the gas input) is placed in the geometric center of the image of this GCO on the topographic base. At the same time, the image of the GCO itself is transferred to the mapping layer of gas facilities by the copy method (its contour). Gas input is always shown.

The objects of the «Regulatory points» layer (RP) are displayed by point objects with a contour.

e «Elements of a gas pipeline» layer includes the following objects: transitions of steel-polyethylene material, diameter transitions, control tubes, plugs, and gas pipeline overlapping units.

The objects of the layer «Structures on gas pipelines» are displayed by point objects and also include "control tubes" displayed on linear objects - cases, which are used to protect parts of GP from high external loads and damages.

Also, there are created «GPU inflow points» and «gas accounting points».

For each layer, all attributive information is described in detail, for example: the type of gas pipeline lying (underground, overground); Wall thickness; A feature of the locality (rural or urban settlements), etc. The final view of one of the sections of the gas pipeline is shown in Figure-2.

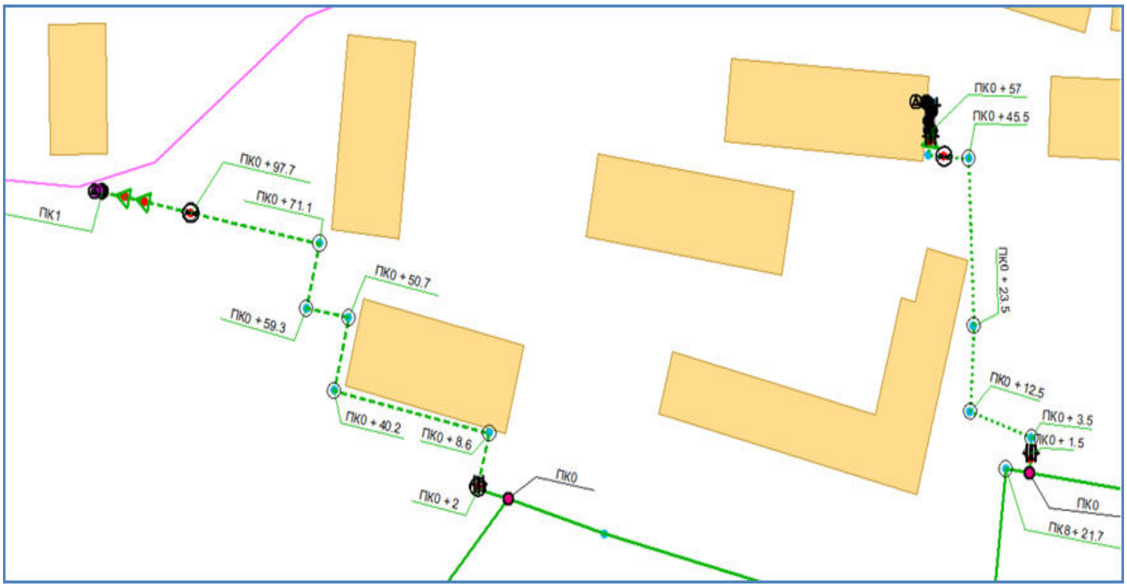

Figure-2. Result: topographic base, gas pipeline, reinforcement, tie-ins, transitions, staging.

Application of GIS-program «NextGIS QGIS" for determination of technical condition and monitoring of main gas pipelines

Another notable GIS package, actively used recently in the oil and gas sector of the Russian Federation, is «NextGIS QGIS» - a full-featured desktop GIS. Where «QGIS» is a well-established GIS-system developed by the international developer community (http://gisgeography.com/qgis-arcgis-differences), and «NextGIS» is a plug-in module presented by Russian specialists.

The company «Gazprom Space Systems» uses the program «NextGIS QGIS» to determine the technical condition of the linear part of the main gas pipelines and develop recommendations for preventing or reducing the negative impact of natural and man-made factors (http://kosmos.gazprom.ru). The data of space optical survey (0.5 m), aerial unmanned survey (0.1 m) and ground-based geodetic measurements are used. As a result, orthophotomaps of main gas pipeline routes, thematic GIS with monitoring results, reports on detected violations and detected dangerous factors are obtained (Figure-3).

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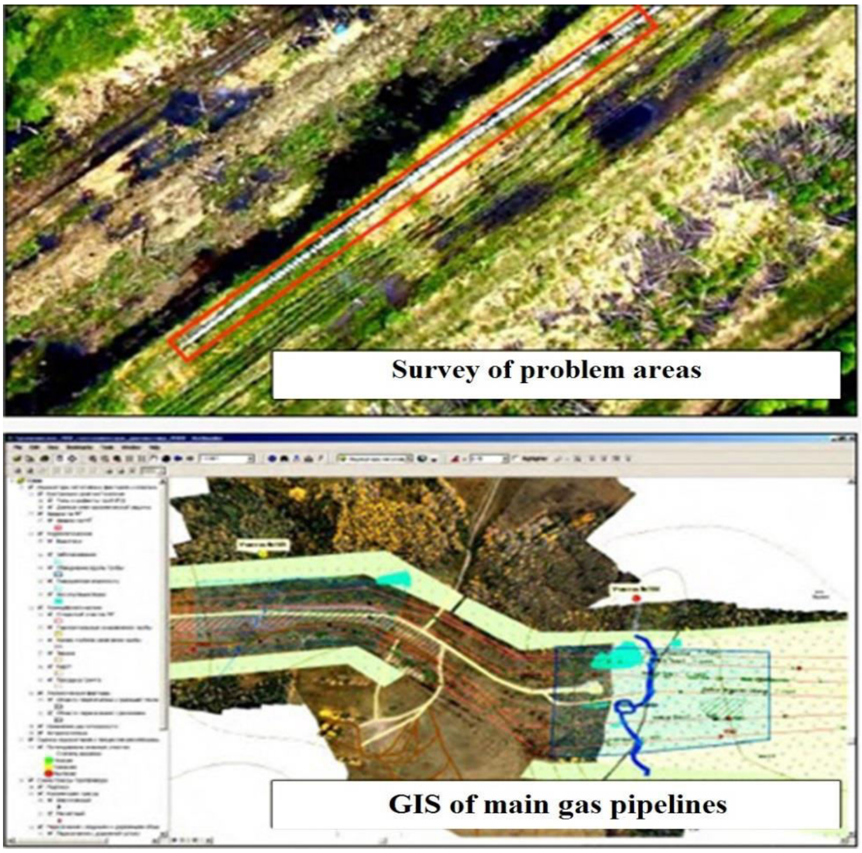

Figure-3. Geotechnical diagnostics of main GP, JSC «Gazprom space systems»

It is also possible to monitor security zones and minimum distance zones, where geodetic measurements, space and unmanned images are used as primary information, and the initial data are the executive documentation and cadastral maps. Further processing of this information follows: creation of ortho photomaps, interpretation of problem areas, after which the GIS will contain data on the position and category of the pipe, the boundaries of the guard zones and minimum distances zones, and the violations revealed (Figure-4).

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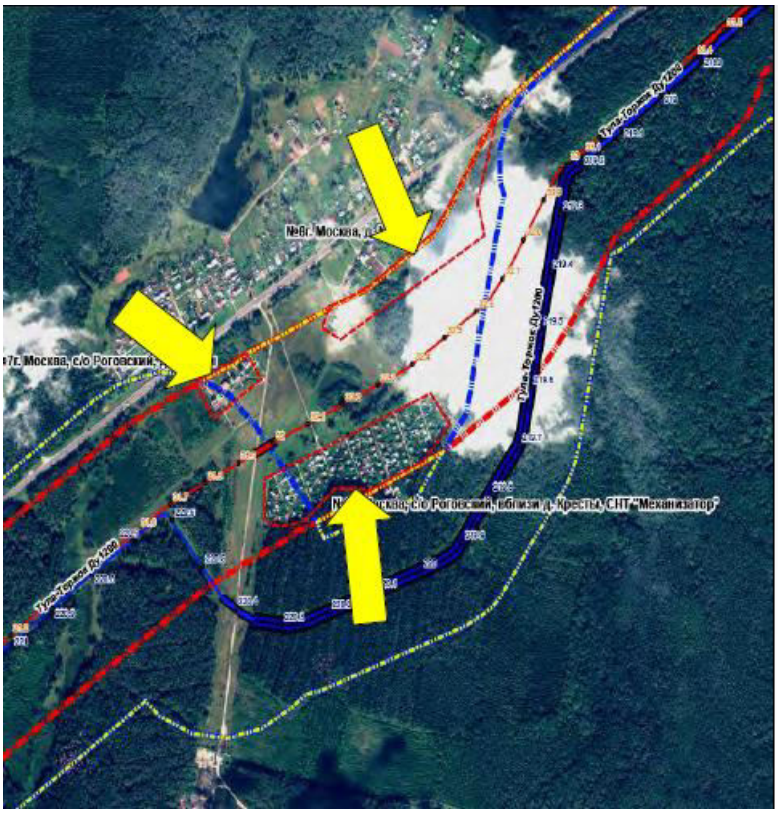

Figure-4. Orthophoto with violations of minimum distances.
MG Tula-Torzhok, JSC «Gazprom space systems»

The application of GIS is relevant when reconciling the results of monitoring with cadastral data, the elements of interest to us on the satellite image can be hidden by vegetation or other objects of infrastructure (Figure-5).

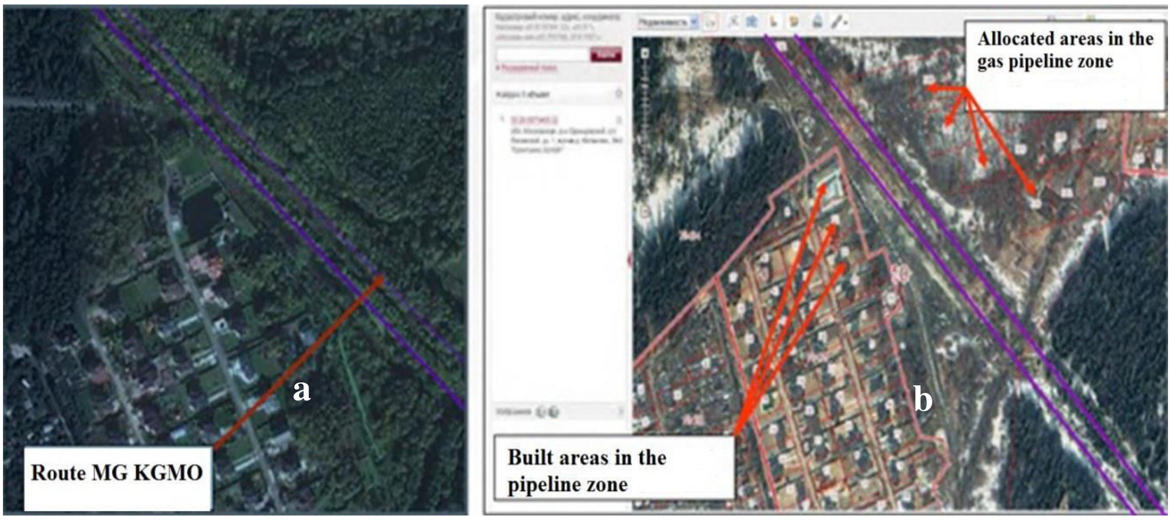

Figure-5. Reconciliation of monitoring results with cadastral registration data, JSC «Gazprom space systems» a - materials of the actual space survey
b-overlay of the cadastral block scheme

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Conducting industrial and environmental monitoring of main gas pipelines and oil pipelines is also possible with the support of GIS, displaying spatial data on the detected violations, which is shown in Figure-6.

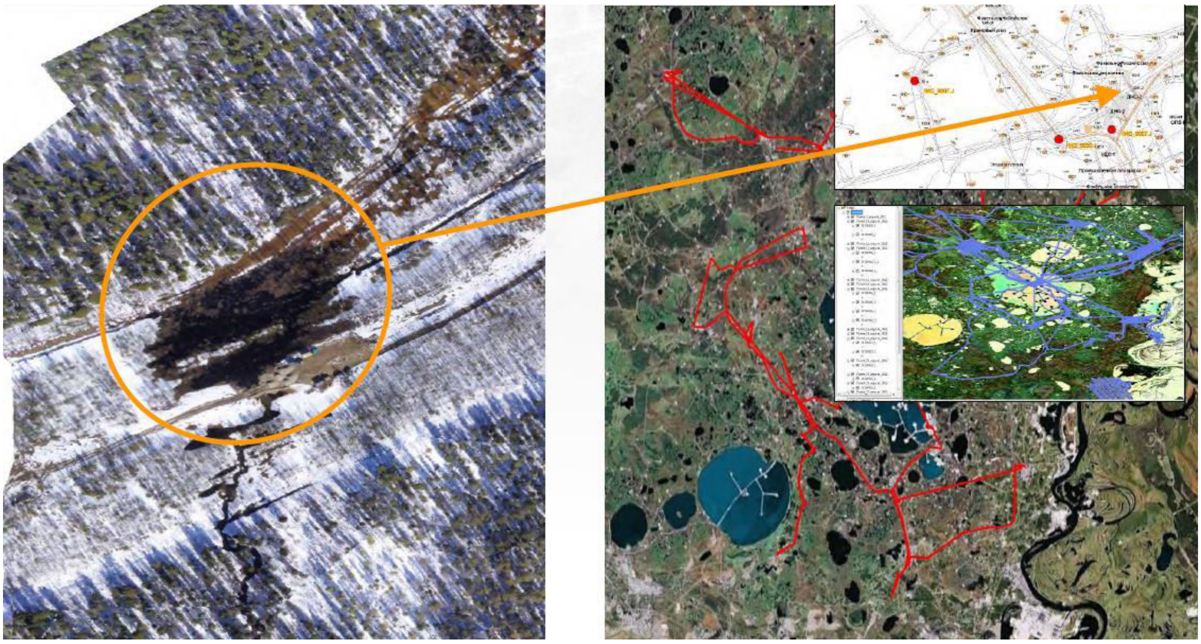

Figure-6. The mapping of the problem area in the GIS of the operational service, JSC «Gazprom space systems».

Thus, the representation of the network of gas pipelines in electronic form allows not only providing extensive visual information about the operation objects, which positively affects the efficiency of the control system, but also helping with technological and environmental monitoring of remote objects, significantly increasing the level of safe operation of pipelines (Struchkova *et al.* 2015).

CONCLUSIONS

Summarizing, it is possible to say with certainty that today geo-information systems are becoming more and more widespread in gas supply, becoming an important management tool at gas facilities, where the main activity is the process of uninterrupted natural gas supply to consumers. Monitoring of networks through GIS is necessary to screen and predict emergencies occurrence probability such as leakage in remote or abandoned pipelines, emission during transportation of gas that may arise due to low temperatures, icing, and the possibility of flooding, terrain heterogeneity, forest fires, seismicity, complex geological conditions (landslides, karsts) and the human factor (Kuanyshev *et al.* 2011, Chappell 2017).

Gas pipelines must be monitored to achieve high efficiency, maximum safety, minimum downtime and high product quality standards and environmental protection.

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