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To cite this article: D S Ivanov *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **666** 042007

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Concerning the Planned-High-Altitude Position of the Underwater Crossing of Hatassy-Pavlovsk MGL Across the River Lena

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Abstract. One of the determining factors for the efficiency of the main gas lines in Yakutia is their interaction with complex geotechnical and operating conditions. The most complex structures are underwater crossings of pipelines across the water bodies. Underwater crossings are among the high-risk systems; they are the most critical. The terms of accident elimination at underwater crossings are much longer than those of similar damage on the linear section of pipeline. Besides, their repair during operation is comparable in complexity and cost to the construction of a new underwater passage. This article provides data on conducting monitoring studies of the state of the Hatassy-Pavlovsk MGL across the channel part of the river Lena, determination of the planned-high-altitude positions of two pipelines on the floodplain sections of the route, on channel processes that affect SSS of welded joints of the pipes and determine the operational reliability and durability of the MGL. The determination of riverbed deformations in the area of the underwater crossing of the main gas line (MGL) is one of the most important issues of the research. Changes in the characteristics of the river flow, safety and service reliability of the underwater crossing of MGL across the river Lena depend on the riverbed deformations. The quicksand disturbance along the course of the river Lena significantly affects the nature of ice drift and spring floods. Due to the erosion of bottom sediments and soil heaving on the coastal slopes of the Hatassky channel, as well as its shallowing, the underwater crossing of the gas pipeline is completely seized by freezing ice and soil of the coastal slopes and is tightly clamped. Studies have revealed the seasonal loosening of the surface pipeline and scour at its underwater part, wearing away of the riverbanks, as well as anthropogenic impact under changing climatic conditions.

1. Introduction

Main pipelines are among high-risk systems. Ensuring durability and safety, providing resources are important tasks not only for researchers, design engineers, but for specialists in operation, control, monitoring, and supervision as well.

Underwater crossings of the main gas pipelines are complex engineering facilities with the following distinguishing features:

- passing through several sections sharply differing from each other in the nature of their impact (coast, flood plain, channel part);
- required balancing of the pipeline that compensates its positive buoyancy;
- difficult access for repair and maintenance work;



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- a pipeline can undergo deformations and destruction in the coastal area in cases of natural disasters (earthquake, landslides, etc.), river meandering (changing of the riverbed position), erosion of the banks;

- a pipeline undergoes scour in the channel part up that leads to denudation and suspension. It is affected by the meandering of the river as well;

- possible influencing factor in the floodplain area is the mechanical pressure of the soil on the pipeline caused by its freezing [1].

The problems of ensuring the operational reliability of underwater crossings are of particular importance since failures and accidents on them far exceed similar incidents on the linear part by their economic and environmental consequences. The majority of the operating underwater crossings in the country was installed using an open-cut method by underwater trenching (in rare cases, along the bottom). The laying of pipelines across water bodies in the traditional way involves the excavation of significant volumes of soil and depends on the climatic conditions. Moreover, ballasting the pipeline requires additional materials, and this leads to higher construction costs. (according to VNiR BI3-2 Administrative Regulations and Cost Model).

The watercourse of the river Lena from the gauging station (g/s) of Pokrovsk to the g/s of Namtsi village undergoes significant erosion during ice drift, especially during the formation of an ice jam, as well as in wet years. The data obtained during hydrometric studies show that the riverbed processes in the area of Tabaga village are characterized by a clear predominance of lateral erosion. The right bank of the river, especially below the water stage gauge, is intensively eroded about 20 m per year. On the left bank, on the contrary, there is sand alluvium with an intensity of 0.5 m per year. The analysis has revealed that the deformation largely depends on the river discharge. In general, the reformation of the river body is 1.7–7.5 million m³ per year on a 4.5 km long section [2].

Determination of riverbed deformations in the area of the underwater crossing of MGL across the river Lena is one of the most important issues of hydraulic research. The riverbed deformation affects not only the river flow characteristics that should be taken into account in the pipeline layout, but also the safety and reliability of the underwater crossing across the river, and the volume of construction work and operating expenses.

The gauging station at Tabaga village is located 1597 km from the mouth of the river Lena at a distance of 1200 m above the projected combined bridge crossing. The underwater crossing of the Hatassy-Pavlovsk main gas pipeline across the river Lena is located approximately 9000 m below Tabaga g/s. To be noted, the zero kilometer marker is in the sea reach of the Bykov Cape.

One of the critical hydrological processes along the watercourse of the river Lena is the disturbance of quicksand masses, which significantly affects the nature of the ice drift and spring floods. In this regard, the morphology of the Lena riverbed is very dynamic in the Tabaga-Kangalassy section, since the riverbed is referred to as a weakly stable or unstable type in this area. It undergoes severe deformation due to the sandy bottom. There are no complete objective materials on the riverbed deformation in this section of the river. Separate materials are available: Lena Basin Water Administration (Lena BWA) has the materials on meadstream changing, Vodokanal SC - deformation of the river bottom at the water intake site, Yakutsk weather control and environmental monitoring service FGBI - one line of Tabaga steam gauge for calculating the water discharge through the steam cross-section [3].

Scouring and sagging are observed during operation of the pipeline in the trench. They lead to stresses in the pipe wall, the level of which increases with the increasing length of the scoured section. In addition to static stresses, dynamic stresses occur due to sagging that caused by fluctuations of the denudated section in the water flow [4, 5].

The route of the underwater crossing of MGL is located in the area of permafrost soil, which has a thickness of more than 250 m. The standard thaw penetration is ~ 3 m on the terraces above the floodplain and ~ 3 m on the second bottom.

The width of the water surface during the low water period is 1120 m (at an average low water level of 86.3 m according to BES). The river bed width between the left and right bedrock coast is

1782 m. There is a sandy island (midstream sandbank) about 700 m wide along the left bedrock coast. Its maximum height above the average low water is 2.4 m. Part of the island submerges at a high water level.

According to M.V. Lomonosov Moscow State University, the maximum possible erosion of the bedrock coast can be 140 m on the left bank, 240 m on the right bank in 30 years of the pipeline operation.

The length of the underwater crossing of the trunk gas pipeline is 2,297 m, and the length of the reserve line is 2,245 m, taking into account the predicted erosion of the coast in 30 years.

The maximum depth of the riverbed during the low water period is 10 m (average low water level is 86.3 m by BES). The average current velocity on the verticals along the hydrodynamic flow axis is $0.8\div 1.0$ m/s during the low water period and $1.5\div 2.0$ m/s during the flood period. Surface current velocities may reach $2.5\div 3.0$ m/s during the flood.

These speed ratings increase significantly with ice jams and a sharp drop of water level when the jam is cleared [3].

An unnamed island opposite the Tabaginsky Cape splits the main river bed into two branches in the direction of the right bank. One of them is the Haptagaj channel, which has a rather strong current and a large amount of water flow discharge during the period of spring floods and summer-autumn floods. Hatassy-Pavlovsk TGPL crosses these two channels, the depth of which increases annually. Consequently, the erosion of the bottom and the island slopes in these channels increases.

During the operation of the underwater crossing of MGL across the river Lena, built in 2003 (1st line), incidents occurred in the channel part and floodplain sections of the gas pipeline.

September 26, 2006, there was a gas leak in the pipeline. A transverse crack with a length of 42.5 cm, with an opening in the range of $0.2\div 0.4$ mm, appeared in the heat-affected zone (HAZ) of the welded joint. The expenses on leakage elimination and repair operations exceeded 30 million rubles.

August 28, 2007, there was another accident in the underwater crossing of MGL across the river Lena. A transverse crack appeared along the welded joint of the pipe joint, i.e. most breaks occur in the zones of welded joints [8].

On August 5, 2013, during the scheduled works, which are tests on strength and tightness of the I-line of the underwater crossing of MGL, the pipeline was completely detached at the welded joint of the siphon in the area of P97.

The main line of the underwater crossing constructed in September 2003 and the reserve line constructed in April 2009 must undergo thorough field observations and comprehensive monitoring, taking into account the climatic, hydrogeological, channel permafrost-soil processes, as well as functional and non-functional impacts on the underwater crossing of MGL across the river Lena.

2. Material and research methods

Investigation of the planned-high-altitude position of the first line of the underwater crossing of MGL across the river Lena was accomplished from September to October 2008 using the OKO-2 GPR. The water level at the time of the survey corresponded to 86.73 m by BES. An approximate profile of the location of the first line of the underwater crossing was built based on the results of an instrumental inspection. Therein, the total depth of the siphon bedding was measured from the upper level of the water. The depth of the river bottom and the siphon bedding from the bottom level was also defined.

A denudated section with a height of ~ 0.1 m was detected on the outer generating line of the gas pipeline at a distance of 1850 m from the left bank (Fig. 1a). The length of the section with minimal sanding (burying) reaches ~ 90 m, while the gas pipeline is located at an altitude of ~ 79.85 m by BES. Another denudated section of the gas pipeline was discovered at a distance of ~ 2800 m from the left bank. The peculiarity of this section is that the length of the elevated gas pipeline is ~ 60 m at an altitude of 84.43 m by BES. The outer generating line of the gas pipeline is at a depth of ~ 2.3 m from the water surface. The height of the lower generating line of the gas pipeline is ~ 2.2 m from the river bottom (Fig. 1, b). The elevation difference by BES between these sections, located at a distance of \sim

950 m, is 4.57 m, which is due to the general elevation of the gas pipeline to the coastal slope of the floodplain section of the right bank of the river.

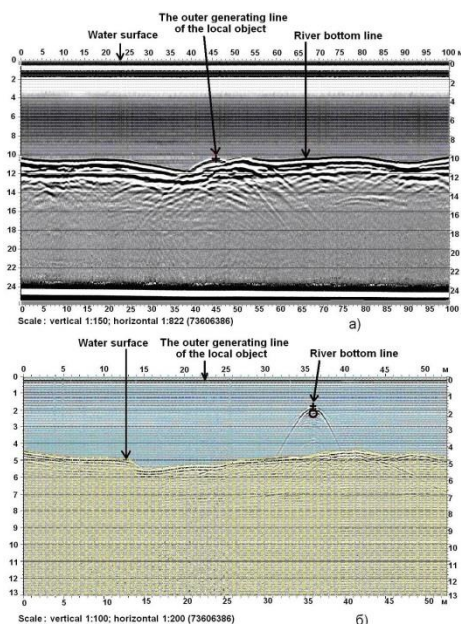


Figure 1. Radarograms received by the OKO-2M GPR: a) a distance of 1850 m, b) a distance of 2800 m from the left bank.

The denudated sections of the siphon are clearly detected during an inspection of the underwater crossing of MGL across the river Lena by the Hydra 500E SSS (Fig. 2).

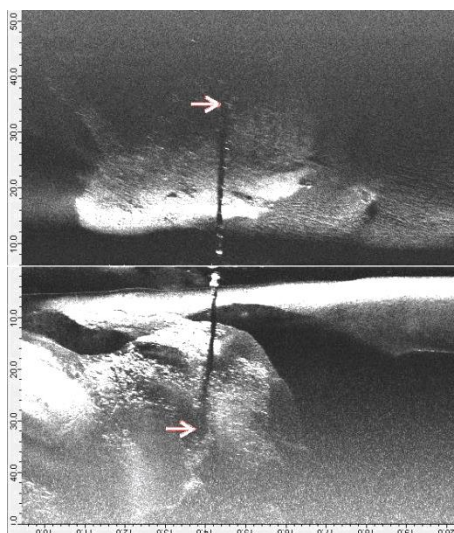


Figure 2. Bottom fragment, arrows indicate the denuded section of the pipeline.

Due to the intensive development of the river bottom erosion on the right bank near Bergehe Ues and Ues Kumakh islands, the siphon position of the two lines of the underwater crossing was investigated using OKO-2M GPR in the area of the excavated channel between these islands for the gas pipeline to reach the island of Manastyr and the Haptagai channel. As a result of measurements from August 28 to September 7, 2014, a sagging section of the II-line siphon was detected (Fig. 3, a). The length of the sagging section is approximately 25÷30 m. Here, the outer generating line of the gas

pipeline is located at a depth of ~ 4.6 m from the water surface, and the height of the lower generating line is ~ 1.6 m from the river bottom. An intense erosion is observed of the right bank of the channel along the direction of gas transfer (Figure 3, a). The two gas lines are covered with a layer of bottom sediments on both sides of this section. They are located at approximately the same depth from 1.5 to 2.0 m, respectively, from the bottom surface at a water depth of $\sim 4.0\div 5.0$ m (Fig. 3, b).

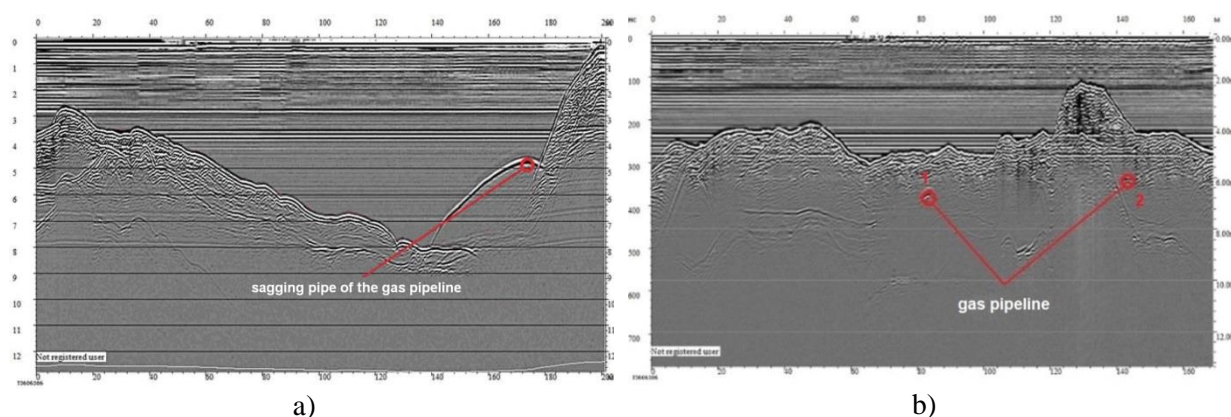


Figure 3. Positions of the Ist and IInd lines of the underwater crossing of MGL in the area of the right bank of the river: a) - sagging section of the II-line siphon, b) - the siphon depth of the two lines in the riverbed.

3. Results and discussion

The obtained results have revealed that the scour and denudation of the siphon are permanent from 2004 to 2014. The length of the denudated and sagging sections of the siphon along the discharge sections changes from year to year. Their coordinates change as well. On the scoured and sagging sections of the siphon, the bedload prevails below the siphon position along the river due to bedload erosion under the siphon and a constant increase in the height of its sagging. A comprehensive instrumental examination of the state of the underwater crossing of MGL allows detecting the siphon denudation and the height of its sagging.

Predicting the damage occurrence, timely elimination of its causes that could lead to accidents are of great importance for the safe operation of underwater crossings.

The dynamics of scouring and denudation of the siphon of the underwater crossing of MGL across the river Lena show that they are still detected in the section from PK 85 + 00 to PK 93 + 00 (800 m long), despite the constant preventive measures for its deepening and retrenching. The planned-high-altitude position of the siphon does not correspond to the design and is 3,9 m higher.

Mutual influence of the riverbed processes in the trench method of construction and the underwater crossing [9] leads to dangerous scour of the underwater crossing due to the following factors:

- natural reformation of the riverbed and banks;
- anthropogenic factors: underestimation of the influence of riverbed processes at the designing stage, errors in choosing the places for crossing the watercourse and calculating the trenching depths, the reformation of the riverbed and banks during the construction or reconstruction of crossings, bedding the pipeline above the designed marks, unauthorized excavation works in the zone of influence on the underwater crossing and others;
- technogenic factors: the work of hydraulic structures, agricultural activities, etc.

Generally, dangerous scouring occurs in a semi-stable riverbed of a water body with intensive channel processes, in which erosion of the floodplain and coasts reaches hundreds of meters, and bottom erosion reaches several meters per year.

4. Conclusion

An instrumental examination of the states of two lines of the underwater crossing of MGL in the floodplain sections of the route revealed the most dangerous and constantly developing deflections and subsidence of the gas pipeline due to frost heaving and thermal subsidence in the thermokarst section, as well as hydrological and hydromorphological processes.

As a result of erosion of bottom sediments and soil heaving on the coastal slopes of the islands and channels located on the right and left side of the river, the underwater crossings of the gas pipeline are completely grasped by freezing ice and soil of the coastal slopes and are rigidly jammed.

The uneven distribution of the planned-high-altitude positions of the I-st and II-nd lines of the underwater gas pipeline was detected on the floodplain areas from the right and left banks of the river, which is most likely due to the nonuniform heaving, ground thawing and freezing processes of the soil due to the heterogeneity of its composition, moisture distribution, density, freezing conditions and other along the underwater crossing of MGL route across the river Lena.

Therefore, the authors of the present article consider it necessary to conduct continuous monitoring with scientific support.

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