ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

RISKS OF EXOGEODYNAMIC PROCESSES IN LATITUDINAL SEGMENT OF THE OB RIVER

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ABSTRACT

This paper dwells upon the risks of exogeodynamic processes in latitudinal segment of the floodplain swampy areas of the Ob River, Vakh River and Agan River. From the administrative point of view, these areas are located within Nizhnevartovsk sub district of Khanty-Mansiysk Autonomous Area – Yugra. Surface water exogeodynamic processes include fluvial, lacustrine, swamp and slope water erosion processes. From the economic point of view, the area is the place for a large number of oil production facilities. As for landscape, it is a segment of floodplain-bench, meadow, swampy and forest territory of the Ob River valley.

Keywords: geomorphological risk, surface water processes, exogeodynamic processes, technological impact, floodplain, swampy landscapes.

1. INTRODUCTION

Floodplain and swampy landscapes in the eastern latitudinal segment of the Ob River are subject to changes due to modern exogenous surface water processes [5] presenting risks for the economic activities and oil production in the area. We have considered the types of exogenous processes in terms of the classification suggested by V.B. Vyrkin [15], including, namely, fluvial, lacustrine, swamp and slope water erosion processes of terrain formation.

2. MATERIALS AND METHODS

The reference dictionary by E.A. Likhacheva and D.A. Timofeev [10] defines the term geomorphological risk as the probability of an unwanted geomorphiological event occurring (activated) and causing possible damage to any economic entities and the population associated with certain geomorphological conditions.

In his monographic study devoted to the system and morphological basis of earth sciences, A.N. Lastochkin suggested considering earth's surface to function as *physically active*, which does not limit its functions, but rather creates or generates locations and conditions for the development of any geological event with specific features. In such case, the terrain acts as a *differentiator* [9] for the risks of surface water processes. The latter belong to the group of hydrogenic exogenous terrain formation processes, which was noted by S.I. Bolysov [2]. The methods used in this research are based on the works of E.A. Likhacheva, V.P. Palienko, I.I. Spasskaya [1], Yu.G. Simonov, S.I. Bolysov, T.Yu. Simonova [11, 12, 14].

Various geodynamic events and phenomena in the taiga area are quite natural and are subject to endogenous and exogenous processes. However, such phenomena may be dangerous for man-made facilities. By analyzing geodynamic processes and possible hazards one may reduce potential risks: using topographic, climatic and hydrological data, one may predict the level of safety for settlements and oil production facilities located in the eastern latitudinal segment of the Ob River. Speaking about most crucial risks, we shall analyze flooding of floodplain landscape in the area under study. 10 meters for the Ob River and 6 meters for the Vakh River are critical and most dangerous water rise levels. Figure-1 shows maximal water rise levels in the Ob River and Vakh River in 1974-2015.

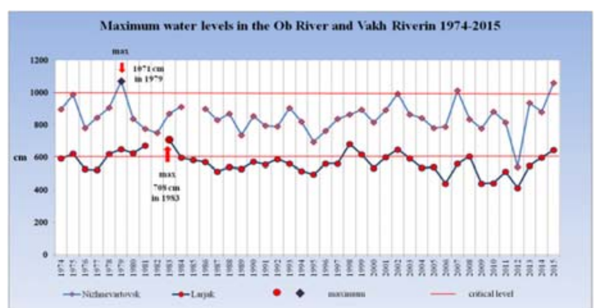

Figure-1. Maximum and critical water levels in the Ob River and Vakh River over the period of 1974-2015.

The following maximal water rise levels were registered at the Ob River gauging stations: In 1941 the water level at Alexandrovskoye gauging station reached 12.37 m, which led to the flooding at the level of 42.48 m; In 1979 the water level at the Nizhnevartovsk gauging station was recorded at the level of 10.71 m, which led to the flooding up to the mark of 40.69 m; In 2002, the water level reached 9.94 m, the flooding was marked at the level of 39.92 m; In 2007, the water level reached 10.12 m, which led to the flooding at the level of up to 40.1 m; In 2015, the water level reached 10.61 m, the flooding was marked at 40.59 m.

Figure-2 shows the ratio between the maximum water level, the height of the terrain and the hazard rating within the fluvial erosion-accumulation activity of modern exogenous processes.

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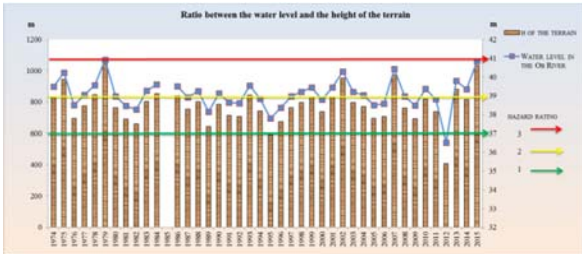

Figure-2. Ratio between the maximum water level and the height of the terrain (1 - safe level, 2 - minimal risk, 3- moderate risk).

From the economic point of view, the western part of Nizhnevartovsk region is the place for a large number of oil production facilities. As for landscape, it is a segment of floodplain-bench, meadow, swampy and forest territory of the Ob River valley (according to V.V. Kozina and N.N. Moskvina) [7, 8]. The segment is presented mostly by broad 18-40 km floodplain of the Ob River, near-terrace declines and partly by the above floodplain terrace I. The landscape is formed by meadow-swamp-forest vegetation. This area is subject to bank erosion at a rate of 5-10 m per year. Hazard rating is based on the absolute marks of geomorphological levels. The Ob River floodplain under study has three main geomorphological levels – low floodplain of 29-37 m, central floodplain of 37-39 m and high floodplain of 39-41 m. The first above floodplain terrace with absolute marks at the level of 41-50 m has up to 5 ° degree of slope due to the general flat nature of the area.

This part of the Ob River valley in Nizhnevartovsk region amounts to 9709 km^2, with license oil production sites occupying 88% of the territory.

Oil and gas production in Nizhnevartovsk region began in 1965. It started in Vakh-Agan subprovince with the area of 4897 km^2 subjected to massive human impact. This refers to the subprovince terrace I transiting to the above flood-plain terrace II with absolute heights of 50-60 m. A combination of pine, cedar and spruce forests and ridge, hollow and lacustrine swamps is quite typical for the area. Large lakes such as Samotlor, Kymylemtor and Beloye, located in the area, are subject to widespread abrasion processes. This subprovince contains large oil deposits, including Samotlor, Vatinskoye, and oil production facilities of other, smaller licensed sites. The total area of man-made objects amounts to 4604 km^2 occupying 94% of the territory. Major exogeodynamic processes include increased landscape hydromorphism manifested by 28% of wetlands and 6% of lake areas, which determines natural flooding hazard.

The Lyamin-Agan province (Surgut forest area) is a lake and swamp area formed on the above floodplain terrace II. The degree of slope is 1-2°, which is rather low. Therefore, the Agan River together with its tributaries fails to provide adequate drainage, which leads to a high level of swampiness reaching 90%. The total lacustrine area is 20%. Large lakes with the surface area exceeding 500 m^2 make up 6% of the catchment area of small Agan River tributaries. The catchment area of the Agan River amounts to 29,190 km^2. The catchment areas of the tributaries are the following: the Tromjogan River - 6110 km^2, the Nongjogan River - 1128 km^2, the Varjogan River – 4443 km^2, the Egurjakh River - 514 km^2, the Amputa River - 3010 km^2, the Puralnjogan River - 154 km^2, the Lagrnjogan - 782 km^2. The total area of the Lyaminskoye-Agan province is 56530 km^2, with 19420 km^2 in Nizhnevartovsk region, which is 34% of the province. A large part of the province is occupied by oil production license areas, covering an area of 11,758 km^2, which is 60.5 % of the province within Nizhnevartovsk region.

The Vakh province (Vakh forest area) occupies the valley of the Vakh River and its tributaries. The area of the Vakh province under study belongs to the lower reaches of the Vakh River from the village of Okhteurje up to the place where the Vakh River enters the Ob. The Vakh province is a swamp and lake lowland territory of the middle taiga zone with the river catchment area of 77,820 km^2. The main tributaries of the river flow in from the north, including the Sorominskaya River with the catchment area of 1360 km^2, the Kolekjogan with the catchment area of 7909 km^2, the Sabun River (catchment area 9652 km^2), the Tygymsyjogan River (catchment area 3239 km^2), the Kysjogan River (catchment area 1889 km^2). A large part of the province with the area of 32,320 km^2 is located in Nizhnevartovsk region. License oil production sites occupy 5338.1 km^2, which is 16.5% of the province. The province is less swampy than Surgut forest area, with 32% of swamps and 4% of lakes in the territory. Swampy and lake, ridge, hollow and flat hill marshy terrains prevail in the area.

Nizhnevartovsk region is characterized by the following types of terrain: swamps - 51.2% of the territory, floodplains - 7.2 %, forests - 41.6%. License oil production sites occupy 27.2% of the area, including 15.1% of swamps and 6.4% of floodplains.

3. RESULTS AND DISCUSSIONS

Hydrological hazards with possible fluvial processes present the greatest risk for production facilities and man-made objects. Flooding with the absolute level of 40 m, occurring once every 28 years, is the maximum danger. In such cases, the width of the flooded zone ranges from 5 to 68 km, reaching 199 km in length and the area of 5588 km^2. At the same time, the share of license sites amounts to 4463 km^2, which is 79% of the flooded zone. The flooded zone includes such cities and towns as Nizhnevartovsk, Langepas, Megion, Izluchinsk, Vata, Pokur, Bylino, Pasol, Bolshetarkhovo, Zaitseva Rechka, Vampugol, Sosnino.

During the flood in the spring of 2015, the water covered the territories with absolute levels lower than 40.59 m, which led to the flooding of summer cottages, commercial engineering facilities, roads, transmission towers, and oil pipelines.

According to the Main Office of Russian Emergency Ministry in Khanty-Mansiysk Autonomous Area - Yugra, soil erosion occurring on July 20, 2015, on the 447th kilometer of Tyumen-Khanty-Mansiysk federal

 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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roadway (near the village of Demyanka) resulted in a subsidence, which led to roadway surface destruction, with a fracture about 12 meters in length. Figure-3 displays the destruction of Tyumen–Khanty-Mansiysk roadway.

Figure-3. A part of Tyumen-Khanty-Mansiysk roadway destroyed by flooding.

According to the data provided by the Federal Service for Supervision of Nature Resources (Rosprirodnadzor) in KhMAO-Yugra, an accident on the pipeline resulted in an emergency oil spill in Nefteyugansk area (1 km from Nefteyugansk) on June 23, 2015, with petroleum products entering in the Cheuskin canal. The estimated contamination area amounted to 500x800 m, with an oil film of 1 mm on the water surface.

Figure-4. Emergency oil spill in Nefteyugansk area.

Due to the fact that the alleged pipeline accident area was flooded, it can be assumed that the burst could have provoked a high level of flooding.

High levels of flooding are cyclical in nature. Occurring once every 9 years, they lead to absolute waster surface levels of 39 m. With such high levels, roads, oil cluster bases and pipelines are naturally subject to erosion.

Every 3 years the terrains with heights up to 38 m are flooded, resulting in partial or complete flooding of pipelines, which can later lead to accidents. Local roads, lacking a drainage system, are washed away, which in turn leads to roadway sagging and further destruction. Oil cluster sites are usually not subjected to erosion, since the platforms are raised 2 to 5 m high above the main relief. However, in 2015 high water level led to flooding of some oil cluster sites located in the floodplain of the Ob River valley. Low floodplain, with absolute heights of 37 m, is flooded every year. At the same time, there is no significant damage, since there are no man-made facilities located at this terrain level.

Table-1 contains a risk assessment with an account for the availability of the maximum flood levels registered over a long-term period and erosion and accumulation activity of modern fluvial exogenous processes.

The ranking system considers categories of certain landscapes affected by a surface water process. Table-2 shows a ranging of affected areas affected by exogeodynamic processes [15, with data added by the authors]. Each category has its own rank given in ascending order, where 1 is safe level, 2 is minimal hazard, 3 is moderate hazard, 4 is acceptable hazard, and 5 is extreme hazard.

Table-1. Risk assessment with an account for the available maximum flood levels.

Earth's surface level	Average height	Availability	Rank
Low floodplain (up to 5 m)	37 m	97%	1
Average floodplain (6-7 m)	39 m	37%	2
High floodplain (8-10 m)	41 m	1.2%	3
Above flood-plain terrace I	41–48 m	1%	4
Above flood-plain terrace II	49–55 m	-	5

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Table-2. Ranging of areas affected by exogeodynamic processes.

Category	Affect prevalence	Prevalence ratio	Rank
I	Very low	< 0.01	1
II	Weak	0.01-0.1	2
III	Average	0.1-0.3	3
IV	Strong	0.3-0.5	4
V	Very strong	0.5-0.7	5
VI	Extremely strong	>0.7	

Table-3 show the prevalence ratio for surface water process affects in the Middle Ob River and Vakh-Agan provinces of the floodplain-bench, meadow, swampy and forest territories of the Ob River and Irtysh River valleys.

Table-3. Prevalence ratio for surface water process affects.

Geomorphological level	Total area, km^2	Total area of process prevalence, km^2	Prevalence ratio	Ranks
Swamp				
Terrace II	2208	432	0.2	3
Terrace I	1749	365	0.2	3
Floodplain	2321	230	0.09	2
Fluvial (abrasion)				
Terrace II	267	18.5	0.06	2
Terrace I	113	0.5	0.004	1
Floodplain	414	80.2	0.19	3
Ob River floodplain	210	90.6	0.43	4
Vakh River floodplain	160	57.8	0.36	4
Total	370	148.4	0.4	4
Slope water erosion (linear erosion)				
Terrace II	33	10.05	0.3	3
Terrace I	34	14.3	0.4	3
Floodplain	23	10.1	0.4	3

4. CONCLUSIONS

Currently, the surface water class of exogenous relief formation is in the steady linear state, minding open non-linear structure of its nature. In case steady conditions are disturbed, the processes develop in a non-linear unstable mode, and in case unsteady conditions become more acute, the processes develop in an extreme mode. In our opinion, surface water exogeodynamic processes are the most hazardous for natural objects and man-made facilities in the area under study.

This nonlinear unstable development mode is accompanied by fluctuations resulting in the system "wobbling". Further on, the system can develop in one way or another subject to different, often random factors. Increasing fluctuation reduces forecast reliability and extreme development of natural and man-induced processes leads to emergencies resulting in significant damage. To prevent and timely respond to such situations, V.V. Kayakin [4] offers to take into account several safety criteria when considering natural and man-induced processes. The stability criterion shows the steady and safe linear mode of processes development. The safety criterion characterizes the end of the safe mode and transition to the dangerous, unstable nonlinear mode of process development. We think this criterion corresponds to the minimum and moderate risk equaling 2 or 3 points correspondingly. The extremality criterion marks the beginning of the fast development mode (emergency situation) and corresponds to the acceptable risk of 4 points. It is essential to monitor the most sensitive performance indicators reflecting the development modes for natural and man-induced processes and the condition of a facility or an object. By comparing the observed indicator values to the criteria of safety, stability and extremality criteria, one is able to evaluate the development modes for processes and the condition of a facility or an object, which supports decision-making in preventing and responding to emergencies.

According to L.S. Kozhevina [6], negative modern exogenous processes presenting risks to the man-made facilities and technosphere are a natural mechanism for sustainable development of geological and geomorphological components and the entire geosystem. As we can see, swampy and floodplain landscapes are subject to much man-induced load. By analyzing exogeodynamic processes and identifying potential hazards we can reduce geomorphological risks.

ACKNOWLEDGEMENTS

The research is a part of the state task No. 2014/801 given by the Russian Ministry of Education.

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