HAZARD CLASS OF WATER BODIES FOR ROADBED

Zavialov, Sergey Yu., *JSC Scientific Research Institute of Railway Transport (VNIIZhT), Moscow, Russia.*

ABSTRACT

The article explains the use of special methods to assess potentially dangerous water bodies in order to improve safety on a railway network. The negative impact of different in forms and dimensions manifestations of water element (including floods) may result in violation of integrity of railway tracks, its undermining, and in some cases can cause complete destruction, thus reducing transportation resistance in problem areas. For dynamic and static risk assessment of such situations the author offers selected basic parameters by which all water bodies are divided into six groups. With their help it is possible to organize preventive work in time in order to prevent or reduce effects of water emergency.

Keywords: railways, infrastructure, safety, water bodies, classification, assessment of danger, element, emergency.

Background. *The huge territory of Russia includes regions with completely different climatic conditions, which in their own way affect transport facilities. In [1] the negative impact of shoreline erosion on highways was revealed. Equally dangerous are water bodies for railways. Every year undermining of railway tracks occur, which periodically leads to a breach of regular communication, and sometimes to derailments of rolling stock.*

Objective. *The objective of the author is to present special methods to assess potentially dangerous water bodies in order to improve safety on a railway network.*

Methods. *The author uses general scientific methods, simulation, comparison, analysis, mathematical calculation, graph building.*

Results.

Where a danger is greater

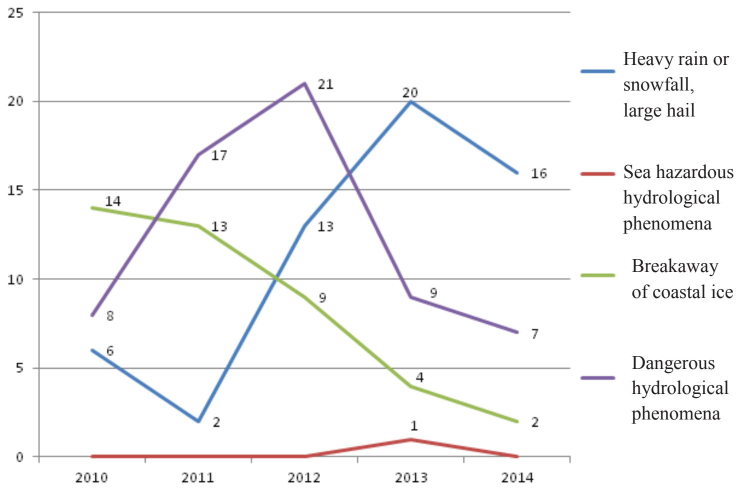
Russian Railways are one of the largest networks in the world, and they should constantly resist natural phenomena and natural hazards. These dangers include washouts of rivers, floods and other disasters caused by the change in geometric parameters of a water body, which entails damage to rail communication.

From 40 to 68 crisis floods take place annually in the country. According to Roshydromet [Federal service of hydrometeorology and environment monitoring] about 500 thousand sq. km are subject to crisis floods, about 150 thousand sq. km are subject to floods with catastrophic consequences. About 300 cities, tens thousand of settlements and a large number of

Table 1

Statistics of natural emergencies caused by water danger in Russia in 2010-2014

Emergency by type of occurrence source	2010	2011	2012	2013	2014	Total over 5 years
Heavy rain or snowfall, large hail	6	2	13	20	16	57
Sea hazardous hydrological phenomena	0	0	0	1	0	1
Breakaway of coastal ice	14	13	9	4	2	42
Dangerous hydrological phenomena	8	17	21	9	7	62
Total	28	32	43	34	25	162



Pic. 1. Dynamics of natural emergencies of water nature from 2010 to 2014.

infrastructure facilities are situated in those territories. After analyzing the official statistics of the Ministry of Emergency Situations [2], a picture of a water hazard can be quite definitely represented (see Table 1).

With these data it is easy to trace the dynamics of natural emergencies during the period (Pic. 1 and 2).

To prevent emergencies it is necessary to conduct timely monitoring of potentially dangerous objects [3]. In the registry of experts there is a list of hazardous water bodies, change of parameters of which is scrutinized. The most stressful time is during snowmelt and flooding. At this time, water bodies pose the greatest danger to a railway track, as the threat of flooding is extremely high.

In Russia, there is no single classifier of severity of water bodies. To create it methodology is necessary, which takes into account the damage as a result of safety violations caused by the water element. It is proposed to use two types of assessment: static and dynamic.

Static assessment

For statistical assessment it is necessary to select the most important parameters of railway track safety. They include [4]:

1) type of object (river, lake, artificial lake, etc.)..;

2) distance to a railway track;

3) features of mutual arrangement of a track and a water body;

4) number of emergencies or flooding in a given area over the medium term (5–10 years);

5) presence of drainage facilities and their technical condition;

6) characteristics of the object during flood and snowmelt;

7) intensity of train traffic and the number of tracks on the surrounding area.

Let's consider each of these parameters.

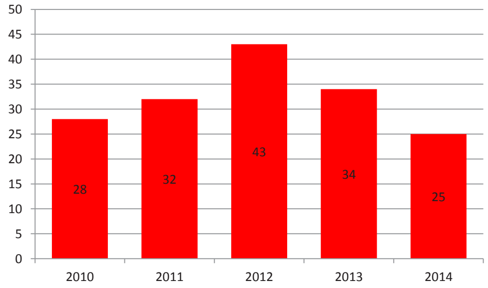
Type of object. *Water bodies include: 1) sea or their parts (straits, gulfs including bays, estuaries and other); 2) watercourses (rivers, streams, canals); 3) water basins (lakes, ponds, flood bypass conduits, reservoirs); 4) swamps; 5) natural outputs of groundwater (springs, geysers); 6) glaciers, snowfields. The type of object affects the nature of threats to railway tracks: it can be a danger of flooding of a track, wavedanger, danger of undermining or violation of track superstructure reliability.*

Distance to a railway track. *This is also an important feature, which means minimum distance from extreme point of a railway track to the closest to it point of a water body. The smaller is the distance – the greater is the danger. In case when a water body and a railway track are in different planes, the distance can be measured as the square root of the sum of the distance from the object to the railway track and height difference.*

Features of mutual arrangement of a track and a water body. *Here it is worth considering landscape features, presence of buildings and structures near objects, as well as any other obstacles that somehow can affect calculations and selection and construction of protective structures.*

Number of emergencies or flooding. *In the archives of Ministry of Emergency Situations of Russia, and also in the archives of Hydrometeorological Center information is stored about critical flooding of rivers and lakes. It is also advisable to add to this information an analysis of railway accidents caused by influence of water on the railway track.*

Presence of drainage facilities and their technical condition. *Often the problem of passage of water is associated with a lack of drainage facilities in the area, either with improper levels of its maintenance. Water masses can move branches, leaves and large debris of various kinds, which is ready to score sewer and foul, leading to inability to pass water masses.*



Pic. 2. Changes in the number of natural emergencies for 2010-2014.

Table 2

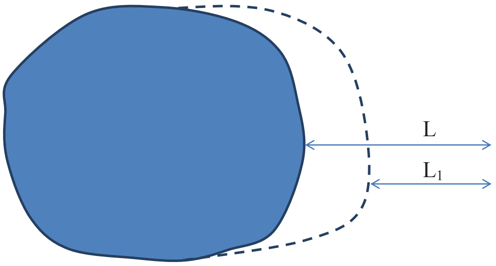
Classification of potentially dangerous water bodies, posing a threat to a railway track

Sum of scores for all criteria	Number of key criteria with scores 8 and more	Danger degree
Up to 20	0	Safe
Up to 20	1	Risk-relevant
21–40	0	Conditionally safe
21–40	1	Risk-relevant
21–40	2	Dangerous
21–40	3	Dangerous
21–40	4	Extremely dangerous
41–60	0	Potentially dangerous
41–60	1	Potentially dangerous
41–60	2	Dangerous
41–60	3	Dangerous
41–60	4	Extremely dangerous
61–70	4	Extremely dangerous

Characteristics of the object during flood and snowmelt. *During spring snowmelt and flood many potentially dangerous water objects behave unpredictably, but, based on historical data, it is possible to predict their possible behavior, and in conjunction with weather forecasts to determine an approximate date of snow melt. That is to take preventive measures to prevent critical cases of flooding or erosion.*

Intensity of train traffic. *This parameter can be characterized by railway track category, which depends on the number of trains passing per day along the track of highest category.*

All of these parameters should have its own degree of influence for each separate object, which can be measured on a scale from 0 to 10, where 0 – this parameter does not affect the degree of danger, and 10 – parameter with maximum degree of influence. The final grade is the sum of all parameters (P_{sum}) in the range from 0 to 70. The higher is the total amount, the more dangerous is the object in question. Moreover, it can be considered potentially dangerous, if one of the criteria (such as mutual arrangement of a track and a water body, number of emergency



Pic. 3. Scheme of symbols to calculate the danger coefficient.

situations and characteristics of the object during flood and snowmelt) gains 8 points or more.

Based on the total score, each water body must be assigned with corresponding degree of danger (see Table 2).

As examples of the use of the proposed classification we take multiple objects and distribute them according to the degree of danger (parameters will be denoted via P_i, and the number of critical parameters, the estimation of which is equal to 8 or more will be denoted as N_{crit}).

Object № 1: $P_1 = 3$, $P_2 = 5$, $P_3 = 2$, $P_4 = 4$, $P_5 = 3$, $P_6 = 2$, $P_7 = 4$.

Final parameters: $P_{sum} = 23$, $N_{crit} = 0$. Based on the proposed classification (Table 2), this object can be considered conditionally safe. Additional measures to ensure traffic safety are not required here. The object is not included in the database of potentially dangerous objects and does not threaten the integrity of the railway track.

Object № 2: $P_1 = 1$, $P_2 = 8$, $P_3 = 2$, $P_4 = 2$, $P_5 = 3$, $P_6 = 2$, $P_7 = 1$.

Final parameters: $P_{sum} = 19$, $N_{crit} = 1$. This object belongs to risk-relevant. Despite relatively low total value of criteria, one of the criteria (distance to a railway track) takes a critical value, which indicates that the object requires periodic monitoring, which means that it must be included into a common database.

Object № 3. $P_1 = 1$, $P_2 = 8$, $P_3 = 8$, $P_4 = 8$, $P_5 = 3$, $P_6 = 8$, $P_7 = 1$.

Final parameters: $P_{sum} = 37$, $N_{crit} = 4$. The object in question is extremely dangerous, as four parameters take critical values. It is necessary to monitor this object, the probability of an emergency (flooding, undermining the track) is high.

In order to maintain the relevance of the classifier each potentially dangerous object has to undergo periodic re-evaluation (usually annually). In addition, it is necessary to account new water bodies that have emerged recently as a result of natural or man-made changes, as well as for other reasons.

Dynamic assessment

Dynamic assessment is advantageously carried out in two variants – operational and long-term. Operational option should be used for a rapid assessment of railway track safety from the water hazard in the presence of two measurements. This characteristic is important for those objects, that were not subject to monitoring earlier, or for the objects that have recently emerged in relation to natural or technological changes.

For such an assessment it is proposed to introduce the coefficient of the danger of the water body:

$$K = \frac{L_0 - L_1}{L_0},$$

where L_0 is original distance from the railway track to potentially dangerous water body (Pic. 3); L_1 is distance from the railway track to potentially dangerous water body, resulting in the current measurement.

It should be noted that the indicators L_0 and L_1 are measured as the shortest distance from the railroad tracks (the most extreme point of it) to the closest point of the potentially dangerous object. The number of measurements depends on danger degree of the object under study and may be increased if necessary.

After getting the value of the coefficient it is necessary to determine what class of danger refers to the object (Table 3).

Table 3

Assignment of danger degree in the presence of two measurements (operational dynamic assessment)

Value of coefficient K	Information about the object obtained, based on coefficient value	Danger degree
$K < 0$	The object does not represent any threat to traffic safety and the distance from the object to the railway track from the moment of previous measurement to the current increased.	Safe
$K = 0$	The boundaries of the object have not changed.	Conditionally safe
$0 < K < 0,3$	The object approached slightly the railway track, it is recommended to monitor it.	Risk-relevant
$0,3 \le K < 0,7$	Water body is a threat to the railway track, it is recommended to conduct enhanced monitoring.	Potentially dangerous
$0,7 \le K < 1$	It is an extremely dangerous condition. The track is close to the flooding. It is necessary to build protective or drainage facilities.	Dangerous
$K \ge 1$	Invalid state. The values of coefficient suggests that the track is already flooded. Measures are necessary to recover it.	Extremely dangerous

Table 4

Assigning a danger degree in the presence of n + 1 measurements (long-term dynamic evaluation)

K max \ $\bar{K}$	$\bar{K} < 0$	$\bar{K} = 0$	$0 < \bar{K} < 0,3$	$0,3 \le \bar{K} < 0,7$	$0,7 \le \bar{K} < 1$
$K_{max} < 0$	Absolutely safe				
$K_{max} = 0$	Absolutely safe	Consistently safe			
$0 < K_{max} < 0,3$	Consistently safe	Conditionally safe	Conditionally safe		
$0,3 \le K_{max} < 0,7$	Conditionally safe	Conditionally safe	Relatively safe	Relatively safe	
$0,7 \le K_{max} < 1$	Conditionally safe	Relatively safe	Relatively safe	Dangerous	Dangerous
$K_{max} \ge 1$	Relatively safe	Relatively safe	Dangerous	Dangerous	Extremely dangerous

For more dynamic and long-term evaluation it is recommended to perform calculation of coefficients with the number of measurements n+1:

- *Average danger coefficient*

$$\bar{K} = \frac{\sum_{i=1}^{n} \left(\frac{L_0 - L_i}{L_0}\right)}{n},$$

where L_0 is original distance from the railway track to potentially dangerous water body obtained by the i-th measurement (i = 1, …, n).

- *Maximum danger coefficient*

$$K_{max} = \frac{L_0 - L_{max}}{L_0},$$

where L_{max} is maximum distance from a railway track to a potentially dangerous water body from n measurements.

The determination of danger class of the object for long-term dynamic evaluation must be carried out on the basis of Table 4.

Conclusions. *Integrated use of static and dynamic danger assessment will allow to form a detailed and objective information on all potentially hazardous water bodies, posing a threat to the railway track. Creating an information base should be carried out in collaboration with organizations such as the Ministry of Emergencies, Hydrometeorological centre of Russia, and those that along with them conduct research and monitoring in the field of natural hazards and meteorological situations.*

Information based on proposed assessment will help to study the changes of water bodies for quite a long time, on the basis of what future forecasts can be built. It is advisable to store all the data on the server to make it available to employees of relevant departments, including center of man-made structures and other rail services that ensure safety of railway traffic, deal with man-made structures and water fight [5].

A special procedure should be used to evaluate probable emergencies, which are quite difficult to be predicted. In this case, it is necessary to be based on historical data and forecasts of relevant ministries and departments, results of monitoring of potentially dangerous objects, the intensity of which should increase in the most risky periods (usually, it is spring and early summer).

REFERENCES

1. Kovalev, P. D., Gorbunov, A. O., Plekhanov, P. A., Zarochintsev, V. S. The results of experiments in the area of highway erosion. *World of Transport and Transportation*, Vol. 12, 2014, Iss. 1, pp. 140–145.

2. Emergencies (statistics from 2003 to 2015.) [*Chrezvychajnye situacii (statistika s 2003 po 2015 gg.)*.] [Electronic resource]: http://www.mchs.gov.ru/activities/stats/CHrezvichajnie_situacii. Last accessed 07.12.2015.

3. Zheleznov, M. M., Zavialov, S. Yu. Operational monitoring of potentially dangerous interaction of railway with environment [*Operativnyj monitoring potencial'no opasnogo vzaimodejstvija zheleznoj dorogi s okruzhajushhej sredoj*].Rail transport at the present stage of development: Collecction of works of young scientists. Ed. by M. M. Zheleznov, G. V. Gogrichiani. Moscow, Intekst publ., 2013, pp. 214–218.

4. Zavialov, S. Yu. Specification of criteria for assessing danger degree of water bodies for rail transport [*Konkretizacija kriteriev ocenki stepeni opasnosti vodnyh ob'ektov dlja zheleznodorozhnogo transporta*]. *Rail traffic safety: Proceedings of the 16th scientific-practical conference.* Moscow, MIIT publ., 2015.

5. Zavialov, S. Yu. Technologies of monitoring and protection of railway track from external influences in interaction with environment [*Tehnologii monitoringa i zashhity zheleznodorozhnogo puti ot vneshnih vozdejstvij pri vzaimodejstvii s okruzhajushhej sredoj*]. *Geodezija, geoinformatika i navigacija–XXI vek: Tezisy mezhdunarodnoj konferencii*. Moscow, MIIT publ., 2012, pp. 120–122. ●

Information about the author:

Zavialov, Sergey Yu. – junior researcher of Joint Scientific Council of JSC Russian Railways, Ph.D. student of JSC Scientific Research Institute of Railway Transport (VNIIZhT), Moscow, Russia, zevus1987@mail.ru.

Article received 07.12.2015, accepted 13.01.2016.