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THE METHODOLOGY OF NATURAL HAZARDS MANAGEMENT IN KAZAKHSTAN

ABSTRACT. Over the last 10 years, more than 4,000 natural disasters have been recorded around the world; they resulted in death of more than half a million people, which is 1.5 times greater than in the previous decade. Similarly, in the Republic of Kazakhstan, there has been an increase in occurrence of natural and technogenic disasters, leading to human casualties and substantial material loss. The paper demonstrates that risk management is one of the promising ways for providing safety of human activities. The methodology of risk management described in the paper is based on scientific and technological achievements and involves assessment of risks of natural and technogenic emergency situations (ES) emergence and associated damage. The paper provides systematization of natural hazards with isolation of geological, geomorphological, hydrological, climatic, and other processes. The characteristics of spatial distribution are identified; the level of hazard and risk of adverse impacts is shown; and a series of thematic maps at various scales, spatial coverage, and content is compiled for the Republic of Kazakhstan territory with consideration given to goals, objectives, and level of risk management. The paper demonstrates that natural and technogenic hazards are discrete in terms of emergence and their onset is of short duration. Risk management is broken into the following phases:
1. Before the onset of ES;
2. During the immediate threat of ES and their onset;
3. After ES.
The methodology suggests that all efforts of risk-management implementation should be directed towards achieving acceptable level and safety.

KEY WORDS: natural and technogenic disasters, risk management, risk of emergence of natural and technogenic hazards, maps of natural hazards and risks

OCCURRENCE OF NATURAL HAZARDS IN THE WORLD

According to the Center for Research on the Epidemiology of Disasters [CRED...] and other sources, in the last century and the beginning of the current century, i.e., in 1900–2013, there have been about 21 thousand disasters[1] in the world[2], including 13 thousand natural disasters[3] and 8 thousand caused by humans[4]. They killed approximately 33 million people, of which 32.5 million were victims of natural disasters. Natural disasters amounted to 2.5 trillion dollars out of 2.6 trillion of the total loss. The largest number of disasters is caused by floods (32 %), storms (28 %), epidemics (10 %),

[1] Catastrophe – the death toll of more than 10 people, the number of victims is more than 100 people.
[2] World – continents Asia, America, Africa, Europe, Oceania.

[3] Natural disasters – droughts, earthquakes, epidemics, extreme temperatures, floods, insect infestation, avalanches, landslides, storms, volcanic eruptions, wildfires.
[4] Man-made disasters – industrial, technological and transportation accidents.

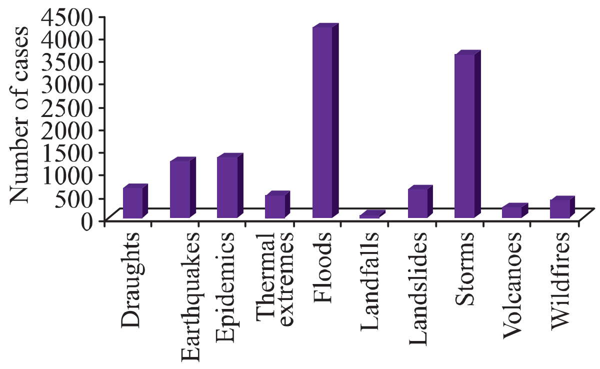

Fig. 1. Distribution of natural disasters by types.

and earthquakes (9 %) (Fig. 1). The maximum damage was inflicted by storms (940 billion dollars), earthquakes (760 billion dollars), floods (590 billion dollars), and droughts (126 billion dollars.). Drought, epidemics, floods, and storms led to the death of 11, 9.6, 6.9, and 1.4 million people, respectively.

Analysis of the temporal distribution of accidents shows that, during the XX and XXI centuries, there has been an increase (with minor fluctuations) of their numbers. The most intense growth of both natural and man-made disasters began in the second half of the XX century.

The period 1965–2013 was associated with 92 % (12.8 thousand of cases) of natural and 95 % (7.3 thousand) of technogenic disasters. This may be explained by both technical and natural factors. Technical factors include creation and improvement of systems for monitoring, collection, and analysis of data, and enhanced information and the volume of data included in the CRED database. Natural factors include industrial revolution, industrialization, and climate change. This period practically accounts for the entire loss associated with disasters; however, the number of victims of these disasters is only 16 % (5.3 million) of all cases that happened in 1900–2013.

Analysis shows that in 2000–2010, the number of natural disasters, their victims, and the damages rose 1.4, 1.3, and 1.6 times, respectively, compared with 1990–1999. The number of man-made disasters increased 1.6 times; the number of deaths and the loss increased 1.2 and 3.5 times, respectively.

The dynamics of disasters over 1900–2013 (Fig. 2–4) shows that while the second half of the XX century is associated with the growing number of disasters and losses caused by them, the number of casualties is declining. Thus, at the beginning of 1900–1965, there were 29 million deaths compared with 5.1 million in 1966–2013. There has been the continuous growth of the number of man-made disasters and associated losses; the maximum number of casualties – 283 thousand – is recorded in 1966–2013 compared with 56 thousand recorded in 1900–1965.

Such multidirectional temporal distribution of the tragic consequences of disasters can be attributed to several reasons, the most important of which are different capabilities of their occurrence and impact risk management.

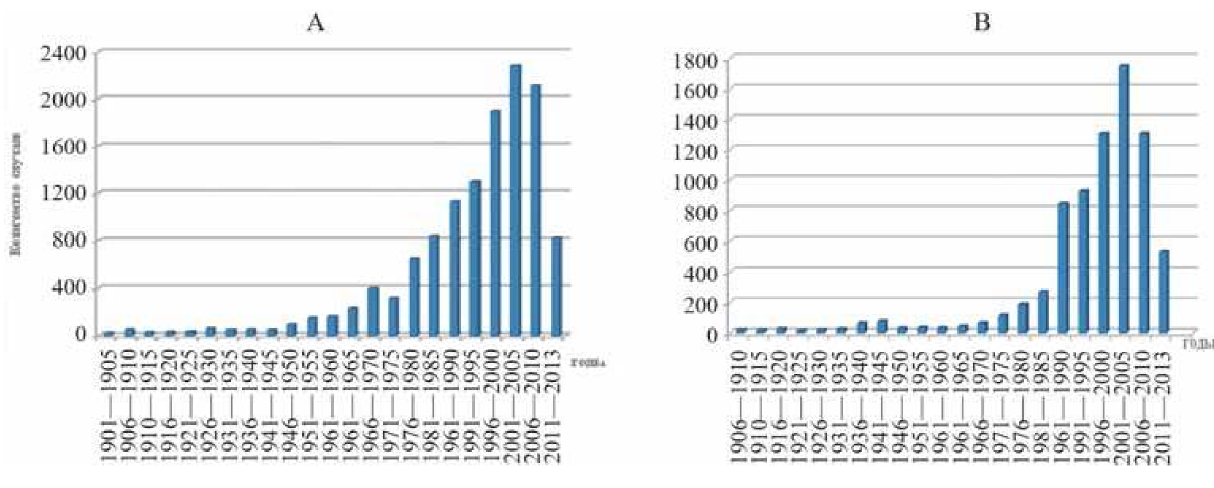

Fig. 2. The number of natural (a) and man-made (b) disasters in the world in 1901–2013.

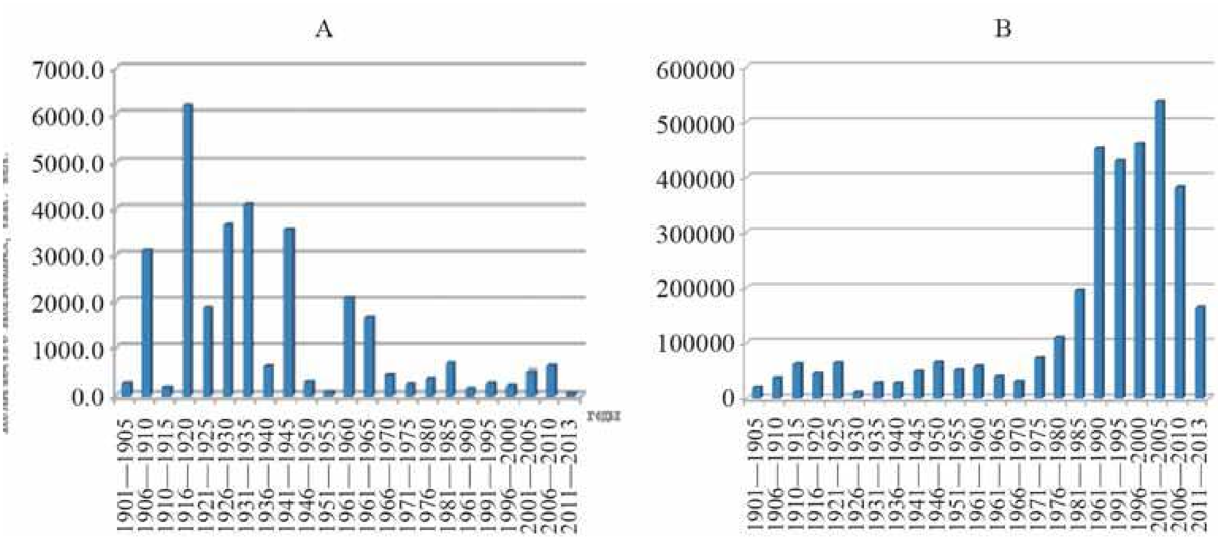

Fig. 3. The number of casualties (thou people) due to natural (a) and man-made (b) disasters in 1901–2013.

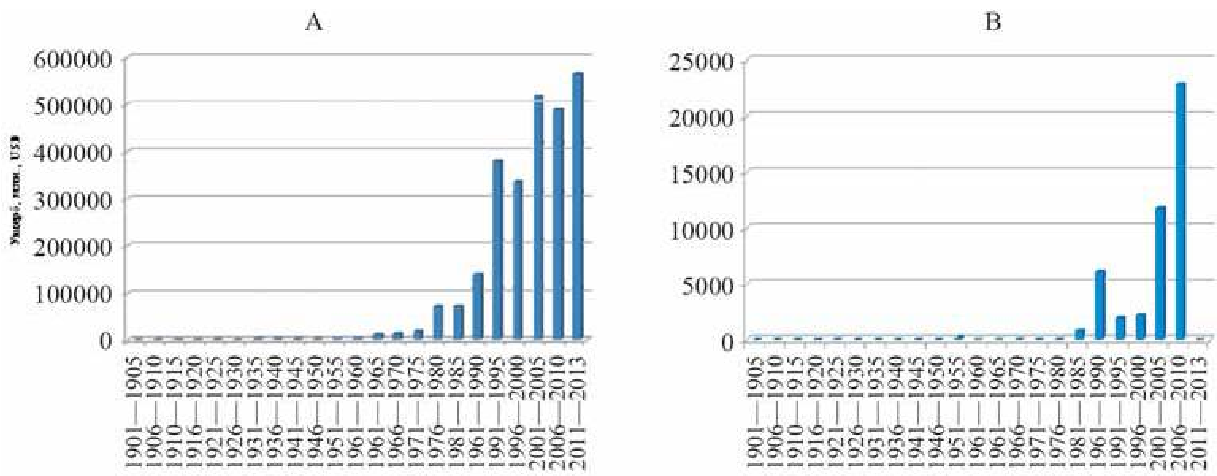

Fig. 4. The loss (mln USD) due to natural (a) and man-made (b) disasters in 1901–2013.

Measures to reduce and prevent damage are being consistently incorporated in the fight against natural hazards in the second half of the XX century: monitoring the impact factors, forecast of occurrence, warning of the population, timely protective measures; these measures have led to the reduction of human casualties. At the beginning of the XX century, the death toll of man-made disasters does not correlate with the scale of production, but it increases with the volume and technological complexity of the latter, together with the number of employees and allocation of facilities in densely populated areas. Despite the development of safety systems, it is practically impossible to forecast the outcomes of technogenic disasters because of a large number of people that they impact.

NATURAL HAZARDS IN KAZAKHSTAN

Accidents in the Republic of Kazakhstan are accounted for in the global statistics beginning in 1991 – the year of obtaining the independence. According to the CRED criteria, the database for the period from 1991 to 2013 includes 19 cases of natural and 15 man-made disasters with the total number of 574 people killed, and the loss of 280 million dollars. The Ministry of Emergency Situations (PK emer.gov.kz) provides synthesis of information about disaster by using more detailed criteria that allow obtaining a more complete picture. According to the Ministry, every year in Kazakhstan, there are about 5,000 emergency situations (ES), natural and man-made, that impact more than 6,000 people; more than 1,500 people died. The average annual loss from disasters reaches 25 billion tenge.

In Kazakhstan, dangerous natural processes and phenomena that can harm human health, economy, and environment are widespread. In some years, material damage from natural disasters exceeded 20 billion tenge alone. Although natural disasters account for 20 % of all ES, the share of affected people reaches 73 %, which is more than 6,000 people per year with 460 fatalities (30 % of those killed in ES).

The most detailed data on natural disasters exist for the period 2004–2008; we will consider this period below. During this period, the number of natural disasters per year for Kazakhstan as a whole ranged from 3,900 to 5,500. The annual material damage amounted to more than 5 billion tenge (47 % of the total damage caused by ES). The largest number of natural disaster was noted in the Almaty, Aqtobe, East Kazakhstan, and South Kazakhstan regions

The number of victims of natural disaster ranged from 3,200 to 15,500 people. The greatest number of people were affected by dangerous infections (49 %), hydro-meteorological and geological processes and phenomena, and by accidents on water. Most of the victims were recorded in the South Kazakhstan, Zhambyl, and Kyzylorda regions. The death toll from natural disasters in Kazakhstan in those years ranged from 410 to 620. Most of the victims drowned in accidents on water. Deaths from hydro-meteorological and geological events occupy the second position. On average, 3.1 persons, per thousand, die from ES per year. In the Almaty and Aqtobe regions, the figure is close to 6, while in the cities of Astana and Almaty and the Kostanai region, it is less than 1.

Most losses (90 %) are attributed to hydro-meteorological and geological factors. They are followed by wildfires. The damage caused by natural disaster varies greatly from year to year. In 2004, 2006, and 2007, the loss amounted to less than 1 billion tenge, while in 2005, the loss reached almost 8 billion tenge. In 2008, in 8 months only, the loss exceeded 16 billion tenge. The average annual damage from natural disasters in 2004–2007 was 0.027 % of GDP. This parameter varies by region, from less than 0.001 % in the Almaty, Karaganda, and Aqtobe regions to more than 0.5 % in the South Kazakhstan and Zhambyl regions, where in some years damage from natural disasters reaches 2.2 % of GDP (Fig. 5–8).

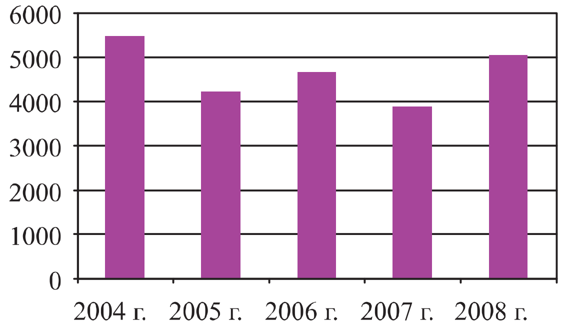

Fig. 5. The number of natural ES.

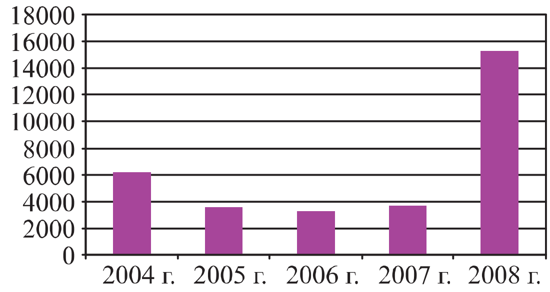

Fig. 6. The number of people affected by natural ES.

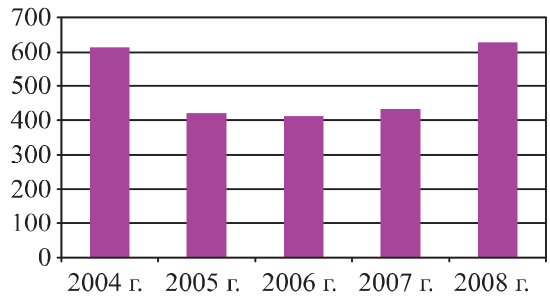

Fig. 7. The number of dead as a result of natural ES.

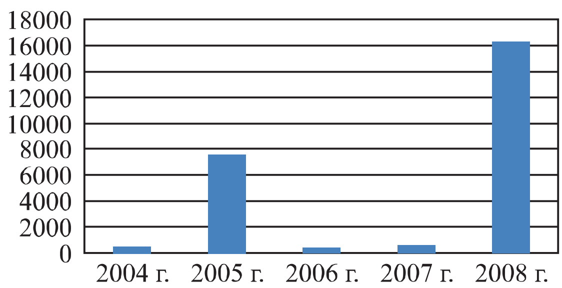

Fig. 8. Damage caused by natural disasters (mln tenge).

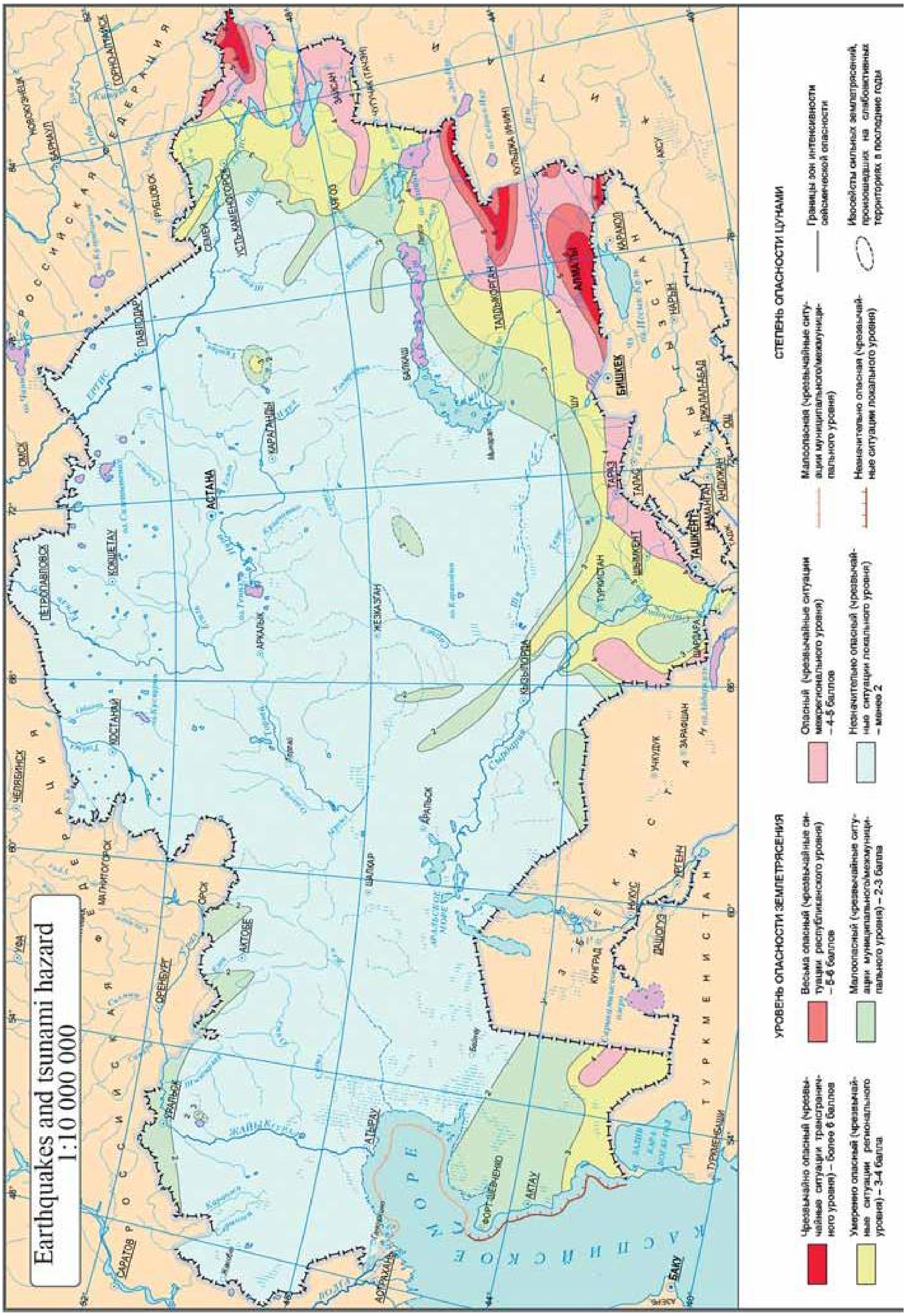

Fig. 9. Map of earthquakes and tsunami hazard (from the "Atlas of natural and man-made hazards and risks of emergency situations" Almaty, 2012). The earthquake danger decreases from red to green and light blue areas.

Fig. 10. Destruction of houses in the Lugovskoy earthquake in 2004.

Fig. 11. Aftermath of the Lugovskoy earthquake in 2004.

The greatest damage is caused by earthquakes, extreme floods, droughts, and weather (heavy snowfalls and heavy rains, snowstorms, high winds, etc.) phenomena. In the mountain and foothill areas, mudslides, landslides, and avalanches represent continuous danger. Their disastrous manifestation consistently increases, including the number of cases caused by inadequate human activities.

In Kazakhstan, the most earthquake-prone regions are the eastern and southern mountainous areas. The earthquake-prone areas, with the magnitude of 8–9 points, occupy nearly 10 % of the territory. The earthquake-prone area includes the cities of Almaty, Taldykorgan, Ust-Kamenogorsk, Shymkent, and Taraz (Fig. 9, 10, 11).

Susceptibility of the territory of Kazakhstan to dangerous exogenous geological processes and phenomena is the highest in the eastern and southern regions with mountainous terrain. Landslide-prone areas occupy about 20 % of the area of Kazakhstan. Landslides are common in the low mountain and foothill areas of Altai, Zhetysu Alatau, and Tien Shan, as well as in the valleys of major rivers: Yertys, Tobyla, Yesil, and Zhaiyk, and cliffs of the Ustyurt Plateau (Fig. 12, 13, 14).

Avalanche areas cover an area of over 100 sq. km. Avalanches happen in Altai, on the Kalbinskiy Ridge, in Sauyre, Tarbagatai, in Zhetysu, Ile, Kung, and Terskey Alatau, and on the Uzynkar, Kyrgyz, Ugam, and Tau Ridges (Fig. 15–17).

Mudflows affect about 30 % of the territory of Kazakhstan; in particular, mountain regions of Altai, Zhetysu Alatau, and Tien Shan. Less exposed to the danger of mudflow are the Kalba, Sauyr, Tarbagatai, Karatau, and Mangistau Ridges. Suspended mud-like floods are possible on the Kazakh Upland (Fig. 18–21).

Weather natural hazards: strong winds, snowstorms, dust storms, heavy rains, snow, thunderstorms, hail, fog, and sudden variations in temperature, are observed throughout Kazakhstan. They can paralyze the economic activity within wide areas. Their damage can reach 16 billion tenge per year, and the death toll is more than 100 people. The most part of the territory of Kazakhstan is subject to atmospheric and soil drought, which causes great damage to agriculture (Fig. 22).

Among hydrological processes, the greatest danger is associated with snowmelt floods and high water. They occur annually in spring in all the rivers of Kazakhstan. There is winter high water on the Syrdarya River associated with water releases from the Shardarinsky Reservoir (Fig. 23, 24).

Wild forest, steppe, and forest-steppe fires are particular frequent in the northern, eastern, and south-eastern regions of Kazakhstan, where they cause considerable damage to forest- and farmland.

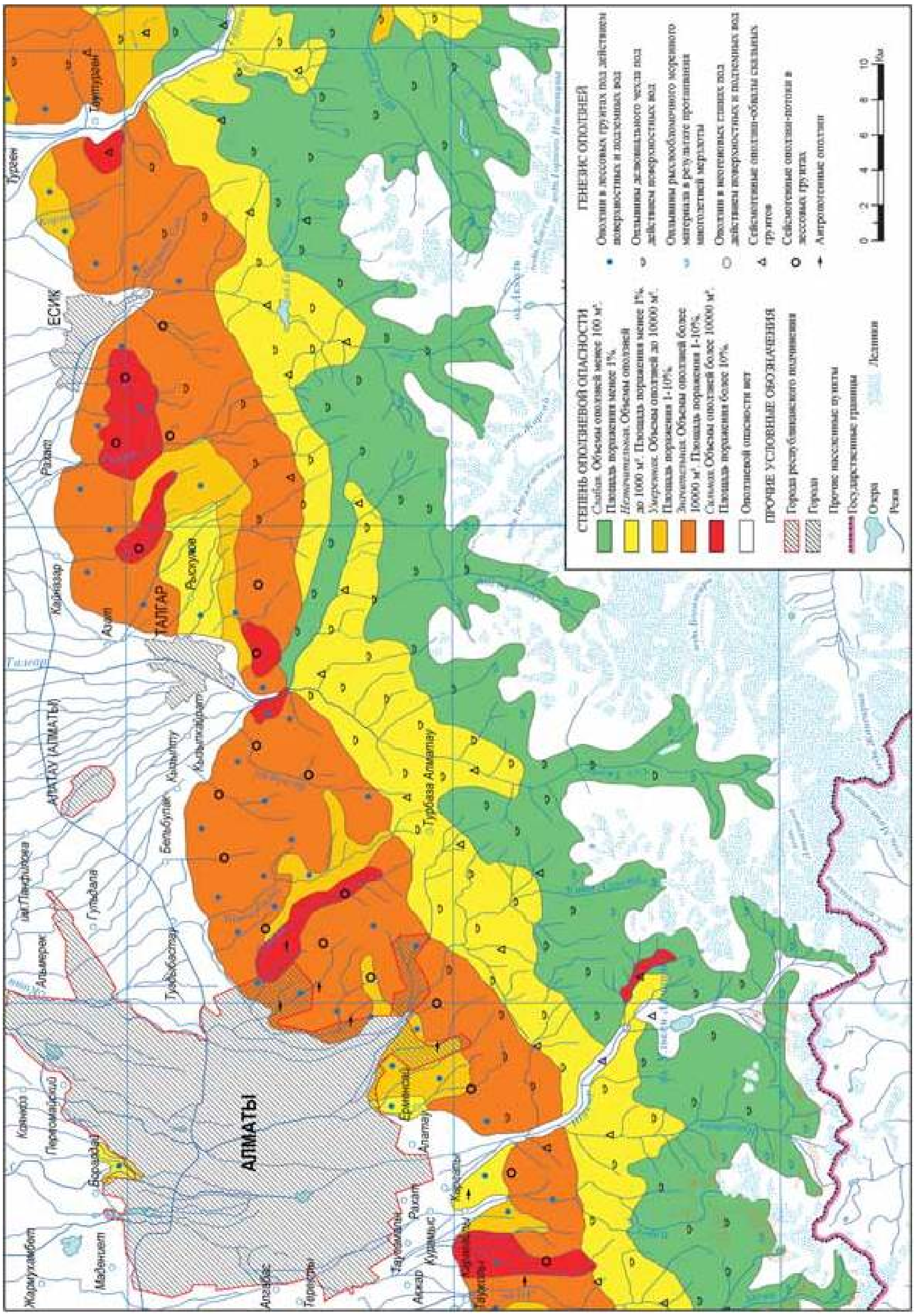

Fig. 12. Landslide hazard map of the northern slope of Ile Alatau (from the "Atlas of natural and man-made hazards and risks of emergency situations" Almaty, 2012). The degree of landslide hazard increases from green to red areas.

Fig. 13. Landslide in the basin of the Taldybulak River in Ile Alatau that destroyed buildings and claimed the lives of 30 people.

Fig. 14. Landslide in the basin of the Kargaly River in Ile Alatau that destroyed buildings and claimed the lives of 3 people.

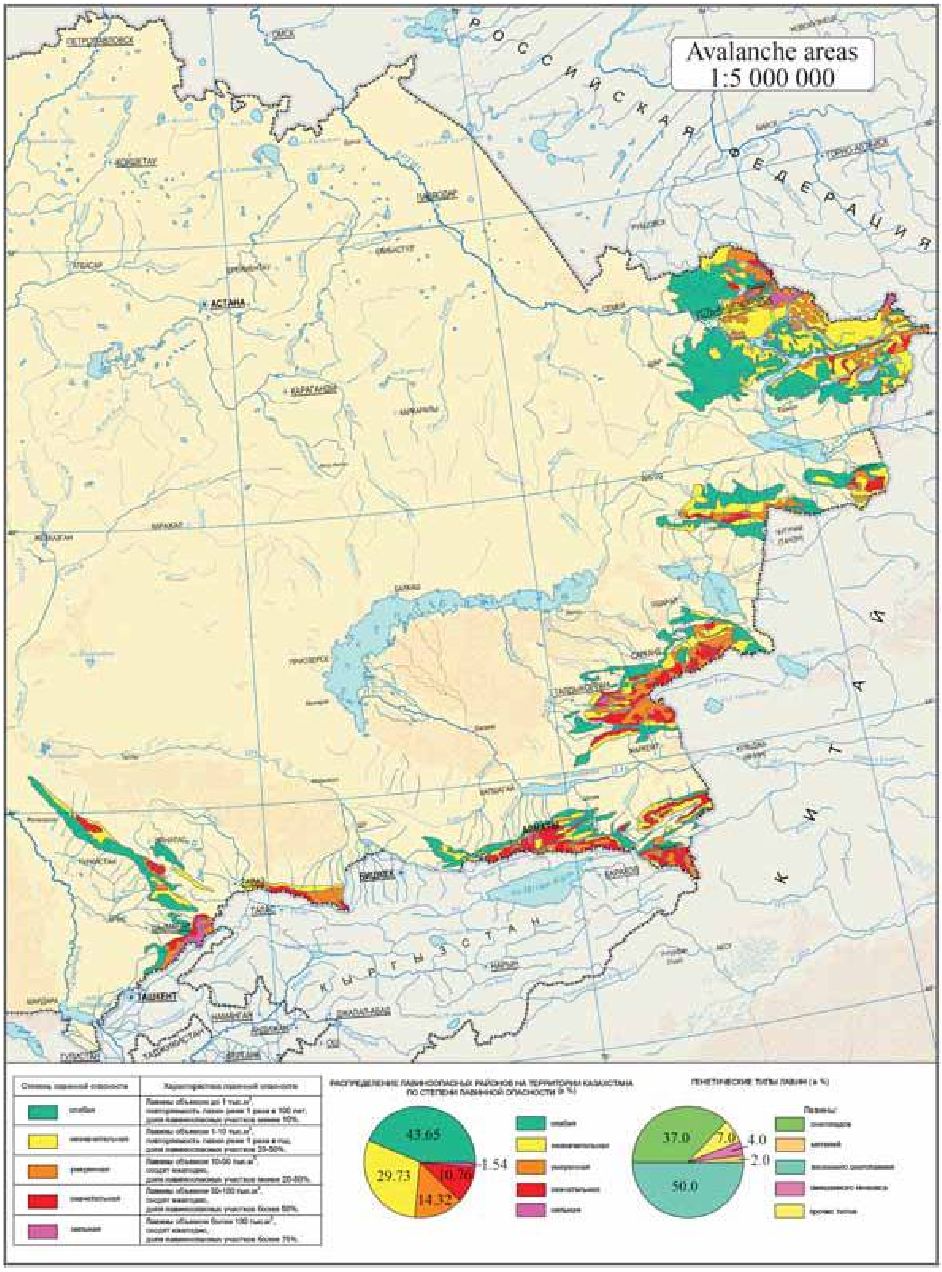

Fig. 15. Map of avalanche areas of Kazakhstan (from the "Atlas of natural and man-made hazards and risks of emergency situations" Almaty, 2012). The degree of avalanche hazard increases from green to red and pink areas.

Fig. 16. Large wet avalanche in the basin of the Koturbulak River in Ile Alatau, 2010.

Fig. 17. Wet avalanche in the Kimasar tract in Ile Alatau, 2010.

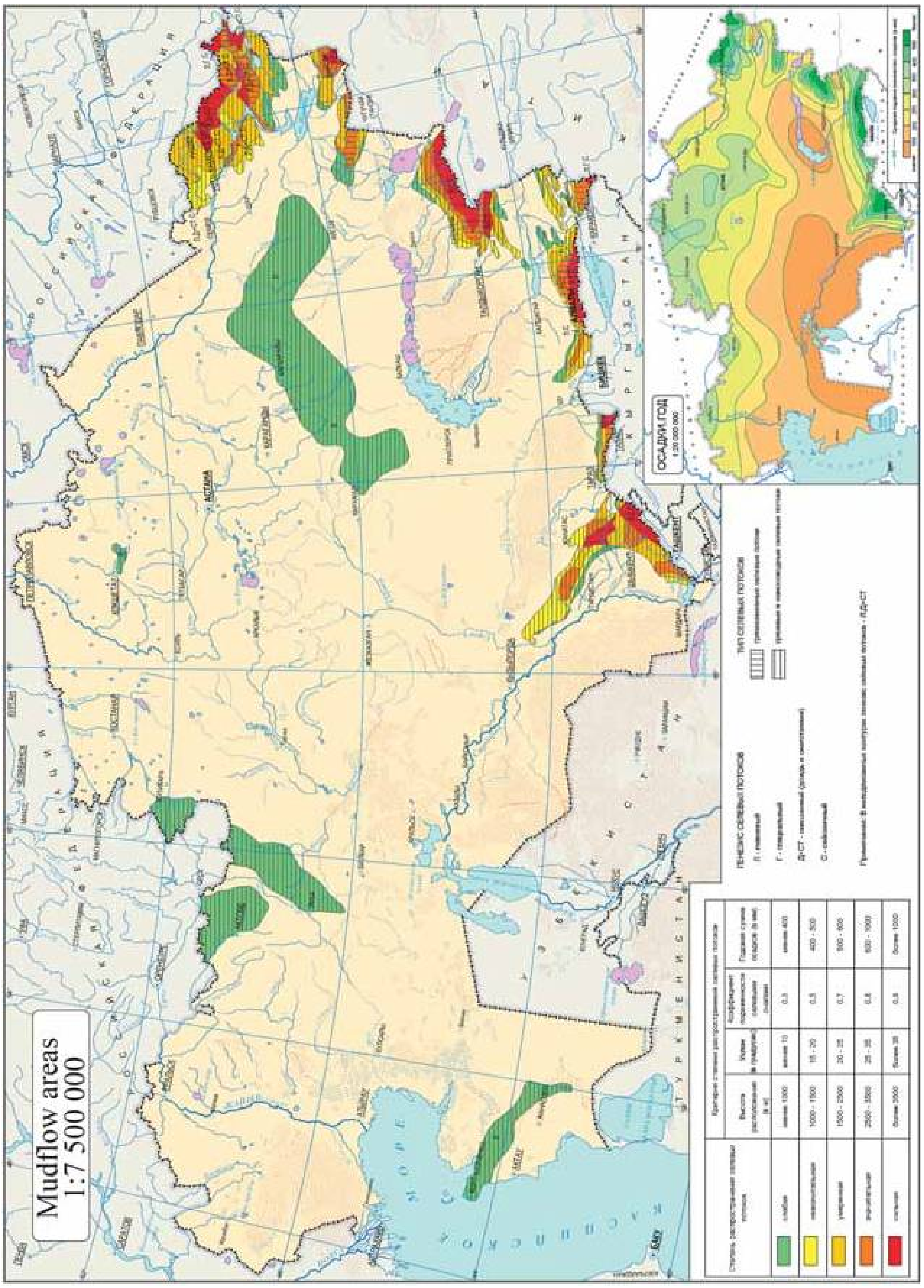

Fig. 18. Map of mudflow areas in Kazakhstan (from the "Atlas of natural and man-made hazards and risks of emergency situations" Almaty, 2012). The occurrence of mudflows increases from green to red areas.

Fig. 19. Passage of mudflow in Esik (Ile Alatau) in 1963.

Fig. 20. Mudflow in the basin of the Kishi Almaty River (Ile Alatau) in 1973.

Fig. 21. Traces of the passage of mudflow in the Ulken Almaty River basin (Ile Alatau) in 2006.

Fig. 22. Dust storms in the Aqtobe region (image from space).

IMPROVEMENT OF MEASURES TO COMBAT NATURAL HAZARDS

The inevitable result of natural and man-made disasters is worsening of the socio-economic issues, particularly in intensively cultivated and densely populated regions. According to experts, if the trend of growth continues, in the next decade, an increase in economic losses from them will be comparable with the growth of GDP. Therefore, the world community is revising its attitude towards disasters as inevitable phenomena and is treating them with more of confidence that it is possible to prevent them, mitigate, reduce human losses, and material damage through greater and active use of scientific and technological achievements.

Adopted at the UN Conference on Environment and Sustainable Development (Rio de Janeiro, 1992), the principle of pre-emption (precautionary) clearly defines priorities in dealing with security issues. The provisions of the concept of sustainable development with respect to natural disasters have been developed in the materials of the UN Conference on Disaster Risk Reduction in 1994 (Japan). Its declaration states that the effort for the reduction of damage from natural disasters should be an important element of the government strategy of all countries of the world. The Declaration of the Habitat II Conference in Istanbul (Turkey, 1996) adopted the Agenda – the principles, commitments, and plan of action related to the protection of human settlements. Two years later, in Moscow (Russia, 1998), the International Conference "Global problems as a source of emergency situations," was held during the International Decade for Natural Disaster Reduction. The conference participants expressed concern about the vulnerability of people to natural disasters.

In January 2004, Kobe (Japan) hosted the UN World Conference on Disaster Reduction, which adopted the Hyogo Declaration and Framework for Action 2005–2015 that stipulates building the resilience of nations and communities to disasters. The following priority items, among others, are listed in the program: identification (including inventory), assessment, monitoring disaster risks, early warning alerts, use of innovative knowledge to reduce underlying risk factors, and disaster preparedness.

Despite this well-founded proposal, the number and the damage caused by natural disasters have not been reduced; this was noted in the resolution of the UN conference "Rio + 20" (2012) which explicitly states that over the past 20 years after the adoption of the Declaration on Sustainable Development, the progress in protection against natural disasters has not been as effective as expected.

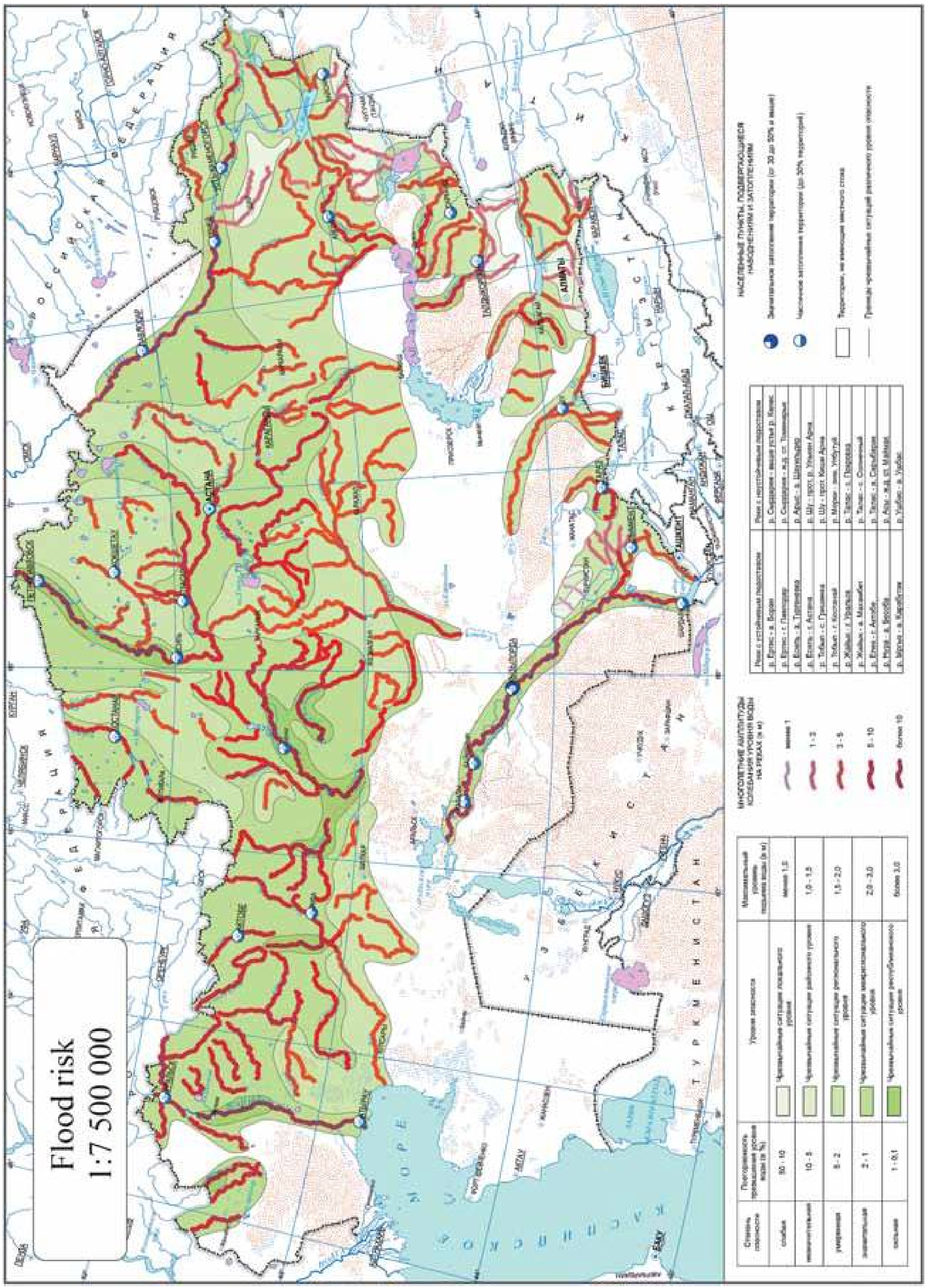

Fig. 23. Map of flood risk in Kazakhstan (from the "Atlas of natural and man-made hazards and risks of emergency situations" Almaty, 2012).
The flood risk becomes higher (local-regional-national) from light to darker green areas.

Fig. 24. Flooding in the Syrdarya River basin.

THE NEW STRATEGY AGAINST NATURAL HAZARDS

The system of proposals discussed above demonstrates that in the studies of assessment and risk management, the priority goal is safety. It is clear that in order to achieve this goal, a new Paradigm should be implemented: measures for providing safety of the population and socio-economic facilities, which have been founded earlier based on the concept "react and manage," should give place to a new principle "forecast and prevent." The new quality of relations should realize a new pragmatic approach, i.e., effective risk management, which is associated with organization of human activities and society in a way that prevents reaching the upper limit level of impact of natural processes; exceeding this limit may lead to catastrophic consequences. Of course, the main problem in dealing with the prevention and reduction of the damage is a well-thought, responsible, and effective policy of public authorities, based on the legislative and regulatory documents.

THE SYSTEM OF NATURAL HAZARDS MANAGEMENT

The establishment and functioning of the risk management system requires a system of focused activities, including scientific and applied research on the development of methodologies and management practices and the creation of schemes and projects to protect specific objects.

Solving the problem of natural risks management is largely determined by the choice of methodology. As is known, the development of the methodology is an important step in any field of knowledge. The fist step should include formulation of scientific ideology, philosophical approach, and outlook in the study area; the second step involves development of a set of rules and regulations and methods and tools that provide for the solution. The Institute of Geography of the Ministry of Education and Science (MES) of the Republic of Kazakhstan has developed methodological framework for management of natural risks: it has formulated the conceptual framework, suggested a synergetic approach to the problem in general and ways of solving particular problems; and conducted tests using empirical evidence that supports the study objective and its connection reality, its nature, and the laws of development and functioning; the framework has been partly implemented in the course of scientific research [Medeu, 2008, 2011].

Under this framework and in the course of development of the new ideology and new paradigm for providing security, an algorithm for natural risk management has been also developed. The algorithm means management of identified and assessed natural risks using the principle of reasonable efficiency and the division of responsibility between the state, the population, and economic entities. It was proposed to treat management as a system that includes processes for formulation of problems, missions, and goals, identification and assessment of risks, selection of risk management strategies and of best practices and ways of risk reduction, and implementation of administrative decisions (Fig. 25).

The mission of natural risks management is to contribute to sustainable development of the Republic by ensuring protection of the vital interests of all categories of the population, industrial and economic systems, and material and spiritual values of the environment in areas prone to the adverse effects of natural hazards. The fundamental (strategic) objectives of the management of natural risks that define its general direction is safety, which is achieved by taking into account the ways of socio-economic development and investment intentions of the state and using innovative technologies. Tactical management objectives include the choice of optimal solutions and acceptable methods of reducing the likelihood of hazards and the damage by increasing security of the recipients. Operational objectives include the most effective way to achieve practical implementation of the objectives of a higher level (Fig. 26).

The solution of basic and individual issues of risk management is not possible without **the creation of the information foundation**, i.e., a database on natural phenomena. The creation of a database includes analysis, interpretation, and systematization of information about the natural phenomena, the use of which is necessary for the development of management solutions to reduce and prevent damage. The structure and composition of the data must provide for the achievement of the ultimate objective of the study and its components should address the sub-goals of a lower hierarchical level. It should reflect the connection of phenomena "part – whole" and "cause and effect," as well the connection between groups of data corresponding to pieces of information about these phenomena.

The data may have different levels of generality. The minimum level of generality should allow identification of the phenomena in a studied aspect, while the maximum level should ensure the generation of particular objectives. In the latter case, it is possible to establish associative (non-hierarchical) relations between data groups; information models for evaluation of natural risks should be developed.

All information collected must be analyzed to determine its relevance and adequacy. The significance of the data is established by comparing them with a set of goals. After determining the value of the data, the data are either saved (memory formation) for later use, or are used directly. At the same time, adequacy of the data for risk management is assessed; the subsequent steps to obtain the missing information (increase in the depth of retrospection, specialized survey of the territory, etc.) are planned and implemented. As a result, the database must contain the interpreted, structured, relevant, and sufficient information for the development

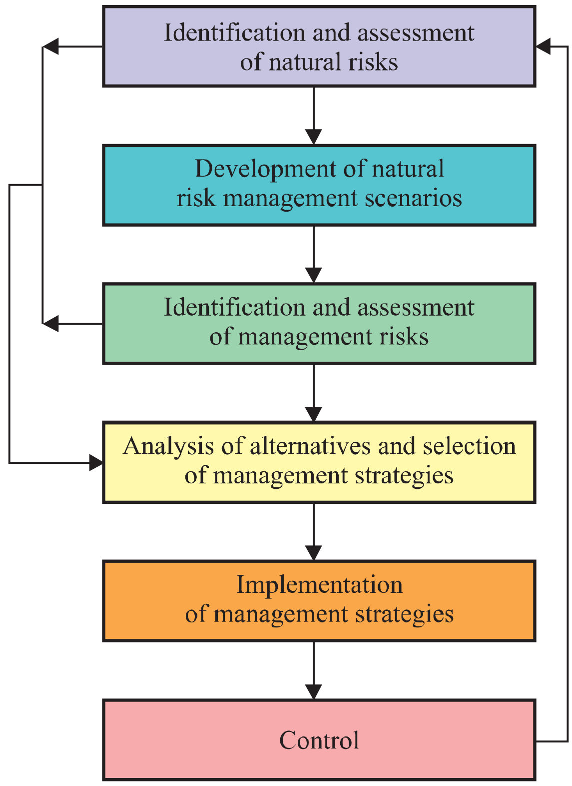

Fig 25. Algorithm for natural risks management.

of administrative decisions: information about the past events, conditions of their formation, and characteristics of the recipient areas of impact damage. Databases should be created with the use of GIS technologies for cartographic representation of information considering the possibility of using the data in interactive mode (Fig. 27).

An important aspect of developing this methodology is the clear definition of **the notion of assessment of natural risks**, because to date, various interpretations of it exist; they can be divided into two groups. In the first group, risk means hazard and probability of an adverse event or a process; in the second group, risk means potential consequences and loss. In developing this methodology for natural risks management, the risk caused by any natural phenomenon is determined by a combination of the risk of its occurrence and the risk of damage that it inflicted. Often, risk is the product of these parameters

$$R = P_{phen}Y,$$

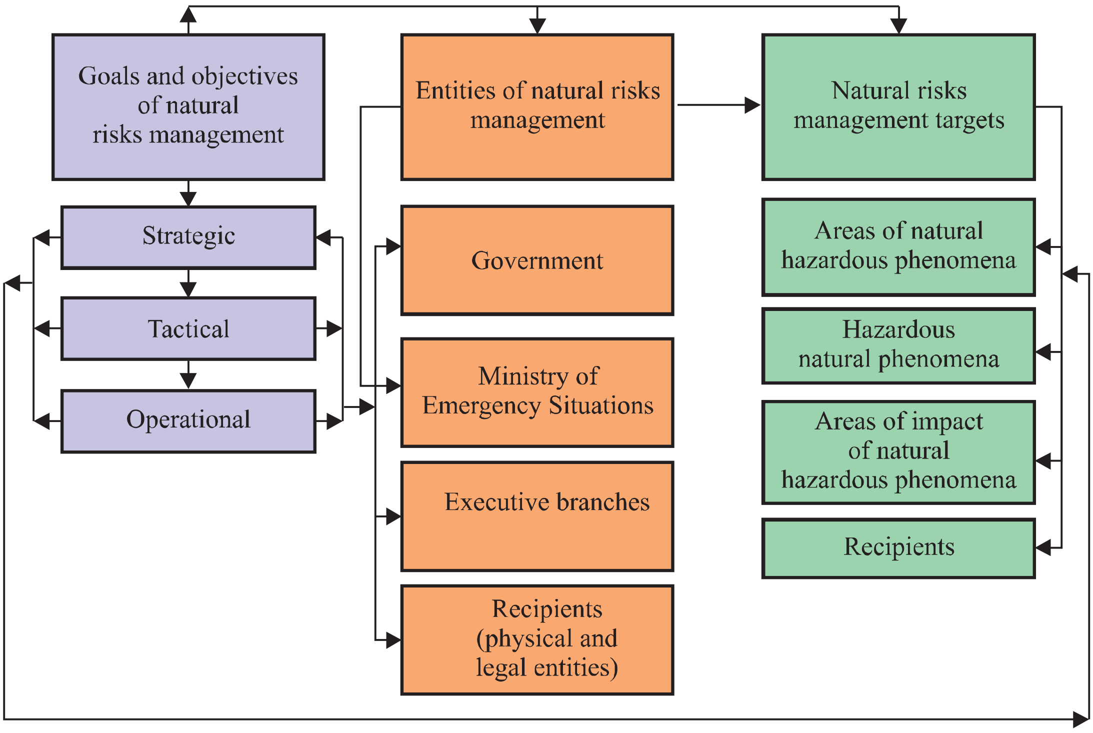

Fig. 26. Structural and functional schematic for risk management.

where R – the risk of negative consequences of a natural phenomenon; P – probability of occurrence of the phenomenon, Y – the value of the damage caused by the phenomenon.

However, since the factors in the above expression may be determined in various terms, including qualitative, in the most general form, the magnitude of risk is better represented as a function

$$R = F\,(R_{emergence}, R_{imact}),$$

where R – the risk of negative consequences of a natural phenomenon; $R_{emergence}$ – recurrence, probability, or distribution of events of various strength and scale; R_{impact} – damage caused by the phenomenon in sociological, technological, and environmental spheres considering the vulnerability and safety of the recipients.

We have developed a **method for natural hazard risks assessment** that contains, according to the definition stated above, the blocks for assessment of emergence of a phenomenon and of risk of the phenomenon impact, and the integral assessment of the risk of adverse consequences of the natural phenomenon in general.

The block of assessment of the risk of a phenomenon includes the following:

A). The stage of identification includes determination of a phenomenon that can destabilize the situation at a facility, area, or region; a general model (image) of the phenomenon is created; the model, with a certain level of adequacy, reflects its physical nature and the demands of management; it identifies factors that cause a dangerous evolution of events, their potential, and regulatory role. The analyzed factors cover the factors that have directly caused the formation and development of the phenomenon, as well as the subsequent factors or the "chain of causation." Choosing the horizon in this chain, and therefore the identification of the characteristics that describe the conditions of occurrence of a hazard, depends on the purpose and scope of the assessment; various scenarios of risk situations in the emergence and development of phenomena of different scales are developed; their critical thresholds, beyond which a dangerous phenomenon develops, are identified; the characteristics of

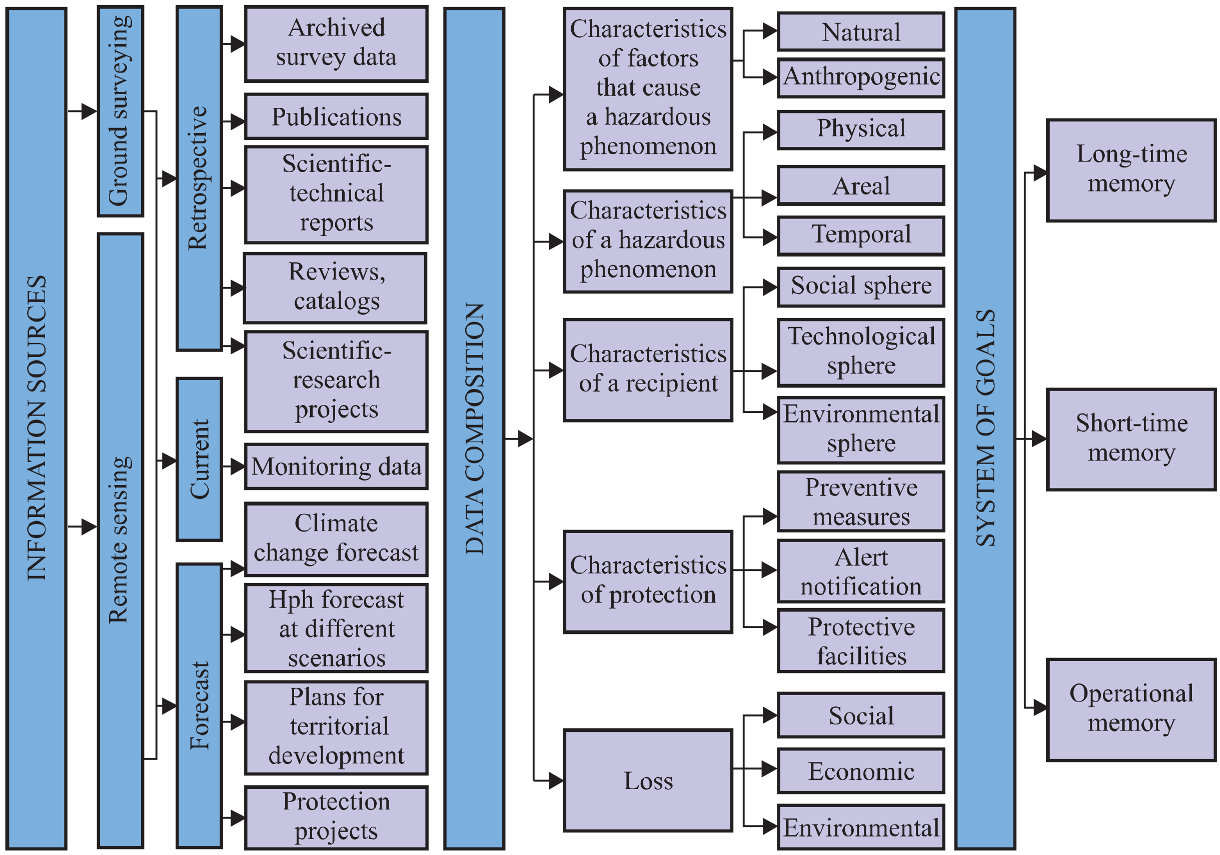

Fig. 27. Information model of natural hazardous phenomena (HPh).

the phenomenon under different scenarios of its emergence and development are identified. The implementation of the risk scenarios is shown in the example of mudflows (Fig. 28, 29, 30).

B). The evaluation stage includes assessment of the probability of occurrence and development of hazard; it is either the probability of achieving the critical values of the factors shaping the phenomenon, or the likelihood of manifestation of various characteristics of the phenomenon itself in the course of implementation of various scenarios of its emergence. In quantitative assessment from the data on the shaping factors, the statistical nature of which is known, it is possible to use the composite method for determining the probability distribution function of the phenomenon under study by calculating the probability density of the combinations of various factors determining the phenomenon. If the theoretical distribution functions of the characteristics that form the shaping factors are not known, the risk of the phenomenon can be calculated as the probability of co-occurrence of critical values in all shaping factors using Bayes' formula. The characteristics of mudflows are determined from the frequency curves for their characteristics; the curves are, in turn, determined from empirical data or from mathematical models. Qualitative assessment of the numerical values of the emergence criteria, thus, of the phenomenon itself, and of the factors' frequency is substituted with the linguistic definition of the categories identified with the various levels of detail (high, medium, low, etc.). Procedures for quality assessment use the methods of qualitative analysis, i.e., fuzzy logic, qualimetry, etc.

C). The forecast assessment of natural risk is based on the information about the expected under global warming changes of the factors that lead to the emergence of a phenomenon and the possible changes of the actual characteristics of a natural phenomenon.

The block of impact risk assessment includes the following:

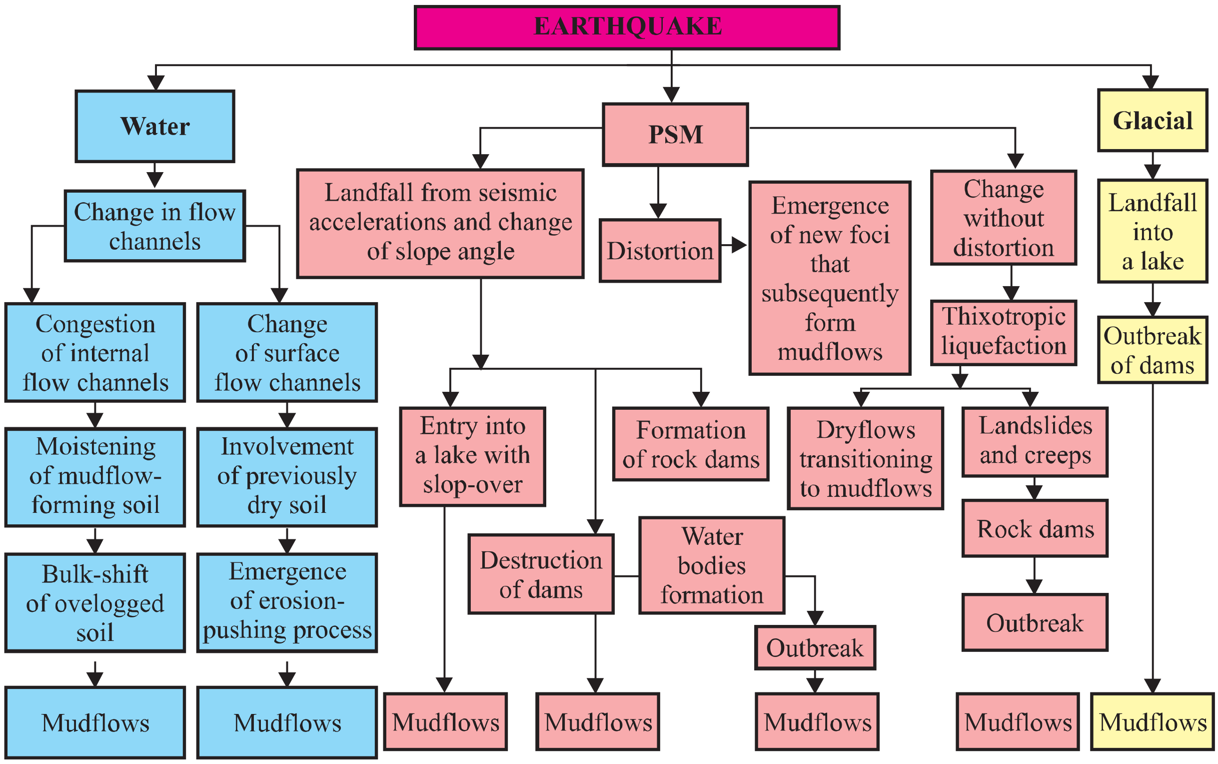

Fig. 28. Scenarios of risk evolution in the course of mudflow development.

- The stage of identifying the source of impact involves determination of the characteristics of the analyzed hazardous phenomenon, causing devastating effects; the areas of its impact are identified using historical data about the areal distribution of the phenomenon using mathematical models for the phenomenon (if any); the recipients of the direct exposure to the hazard are

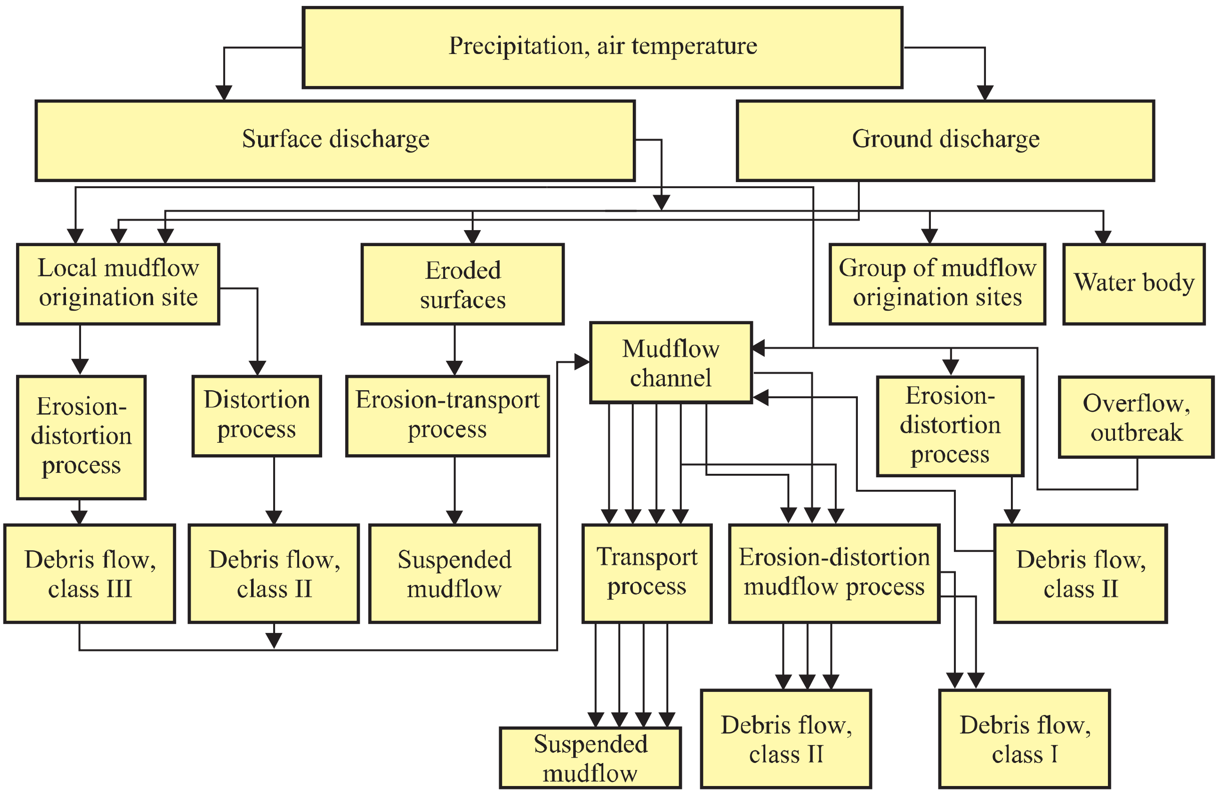

Fig. 29. Scenarios of risk evolution in the course of cloudburst mudflows development.

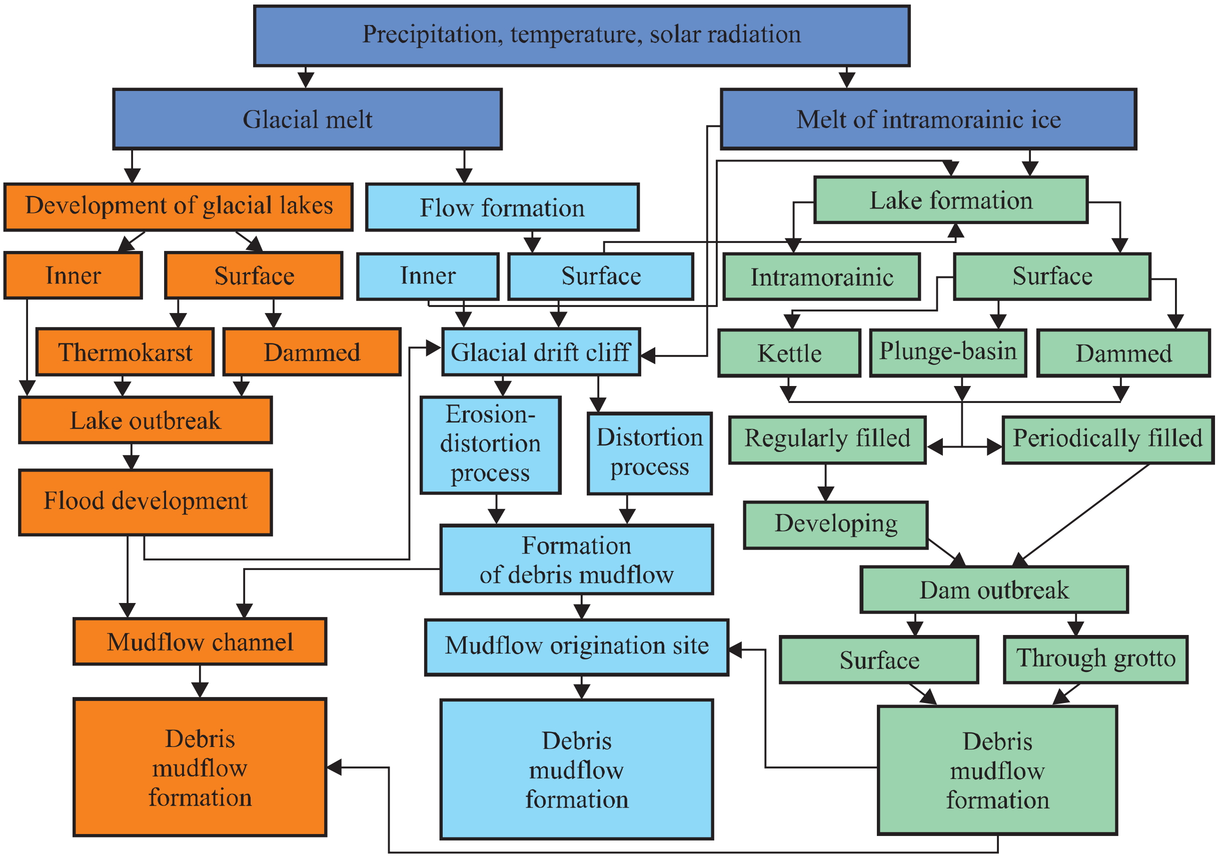

Fig. 30. Scenarios of risk evolution in the course of development of glacial mudflows.

identified in the socio, technological, and environmental spheres (the methods include development of short lists, networks, GIS); scenarios are developed – the scenarios provide for direct and indirect negative impact, forward and backward linkages, the chain reactions in the development of the phenomenon and its negative effects (a graphical representation of the impact scenario in a "tree-diagram" is useful), and a common list of recipients of the direct and indirect effects is formed; such characteristics of the recipients as their social, humanitarian, economic, etc., importance are identified together with vulnerability due to the characteristics of the recipient (permanent of temporal location, adaptation to the impact, etc.), protection by facilities, security systems, etc. The latter (vulnerability and security) reflect the probability of socio, technological, and environmental spheres of truly becoming the recipients of the negative impact of the phenomenon.

- Evaluation of the impact risk is carried out in a qualitative and quantitative manner. Since the recipients are objects of a different nature (socio-sphere, environmental sphere, techno-sphere), the qualitative assessment of the impact of the classifying criteria is based on the same, for all objects and systems, characteristics, i.e., stability; the impact classes define the extent of its breach and the consequences. The main classes of impacts are identified: a) acceptable risk – when system components have time to assimilate the effects due to self-restoration and self-regulation; b) critical risk – recovery is possible in the implementation of relevant activities; c) catastrophic – the limit of stability is exceeded and there are changes even with irreversible consequences, unrecoverable damage; there are also a number of intermediate classes describing the degree of approximation to the effects of the main classes. The description of the degree of impact uses linguistic variables (high, low, substantial, moderate, etc.);

assessment procedures are carried out with the use of quality control, fuzzy logic, etc. The quantitative (economic) impact assessment of natural phenomena is a monetary evaluation of the negative effects of development of hazardous processes described at the steps of the qualitative analysis and expressed in physical units. The quantitative assessment of the impact for socio-, techno-, and environmental spheres is based on market prices and takes into account damage, restoration costs, and losses using the probability theory and mathematical statistics methods.

- Forecast assessment of the risk exposure is based on information about changes in the composition and the number of recipients, their importance, vulnerability, and safety in accordance with the development plan and the development of the territories.

The block of the integrated risk assessment of the negative effects of any natural phenomenon includes the aggregate risk assessments of emergence and impact (Fig. 31).

Qualitative assessment is performed using methods of qualitative analysis, i.e., qualimetry, fuzzy logic, etc. Quantitative assessment is done using methods of mathematical statistics and the probability theory. The assessments are compiled with a different period of pre-emption according to the goals and objectives of management (annual risk, 5–10 years, and long-term perspective). The long-term assessment is based on the input forecast information on risk emergence and impact.

The research results yield spatial-temporal forecast a natural phenomenon adverse impact risk – mapping. A set of specialized maps is generated; the maps have different scales, meet certain objectives, cover varying areas, and have different content, depending on the goals, objectives, and the level of risk management. Such maps are the maps of factors causing the emergence of a natural hazardous phenomenon, of recipients with identification of their basic characteristics and protection, of risk of emergence and development of a hazardous phenomenon (Fig. 32)[5], and of integrated risk of adverse consequences of development of a natural phenomenon (Fig. 33)[6]. The maps should reflect the current and forecast condition of the mapped parameters. The system of such maps is a clear representation of research material and allows (through the use of GIS) simulation of various risk situations.

The obtained data on occurrence and frequency of natural disasters and associated risks allow identification of the structure of safety management systems with determination of responsibilities and relations of its elements.

Natural risks management is classified by objective, scope, objects, and subjects of management, and the timing of implementation of management activities. It is subdivided into national, regional, local, and facility, according to the scale of management. The subjects of risk management are the state bodies, regional and local authorities, and legal entities and individuals; the objects are hazardous natural and anthropogenic phenomena and recipients that are subjected to their negative effects and consequences.

The authorities must define strategy, tactics, and ways to solve urgent problems. These risk-management efforts should be aimed at achieving an acceptable level of safety. The criteria for the acceptable risk should be: the absolute primacy of the preservation of human life and minimization of the possibility of damage to a level not exceeding the cost of risk management. Decisions must be based on evidence-based scientific procedures. The most commonly used methods for this purpose are linear programming, simulation models, network models, queuing theory, decision-tree, game theory, etc. There is a widely suggested scenario that included analysis, the steps of determining the purpose of the formation of the scenarios, development of scenarios,

[6] The maps of mudflows are given as the examples.

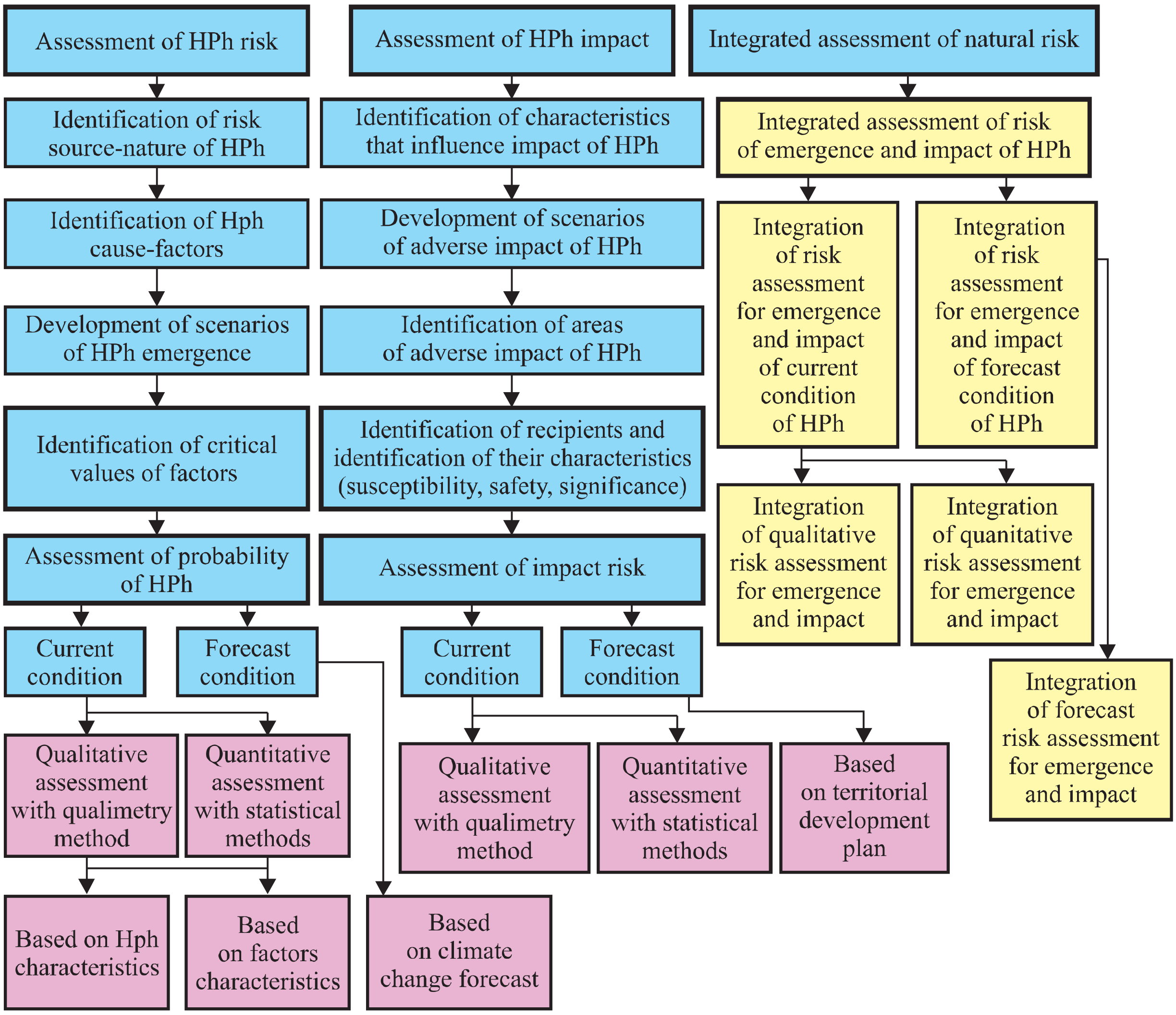

Fig. 31. Natural risk assessment algorithm.

determination of their characteristics, analysis and optimization scenario, and conversion of selected scenario into programs and plans. Solution of the problems of risk management widely utilizes the so-called method of decision-tree. Among its advantages are the convenience and clarity of graphical presentation and ease of calculations. The method of decision-tree is particularly effective when a complex problem can be split into relatively simple tasks, each of which is addressed separately and then brought back for synthesis in complex solutions. Thus, the decision-tree comprises a trunk and branches of different sizes, and they all form a single process run by the laws of probability.

Since natural and man-made ES are characterized by a discrete occurrence and short duration, risk management is carried out: (Fig. 34).

1. prior to the emergence of a disaster;
2. during the period of the threat and emergence of a disaster;
3. after the events.

During the period of stable situations, prior to the emergence of ES, the main areas of management are risk assessment, expert-analytical and consulting work, monitoring of ES factors, analysis of monitoring information for disaster risk assessments in real time, selection of the object, design and construction of protective structures, introduction of safe technologies, implementation of preventive measures that reduce the risk of hazardous processes, implementation of measures of recipients' adaptation to the dangerous impacts (including insurance), establishment of warning systems, emergency response, and control.

In the period of an ES threat, management activities consist of the emergency notification

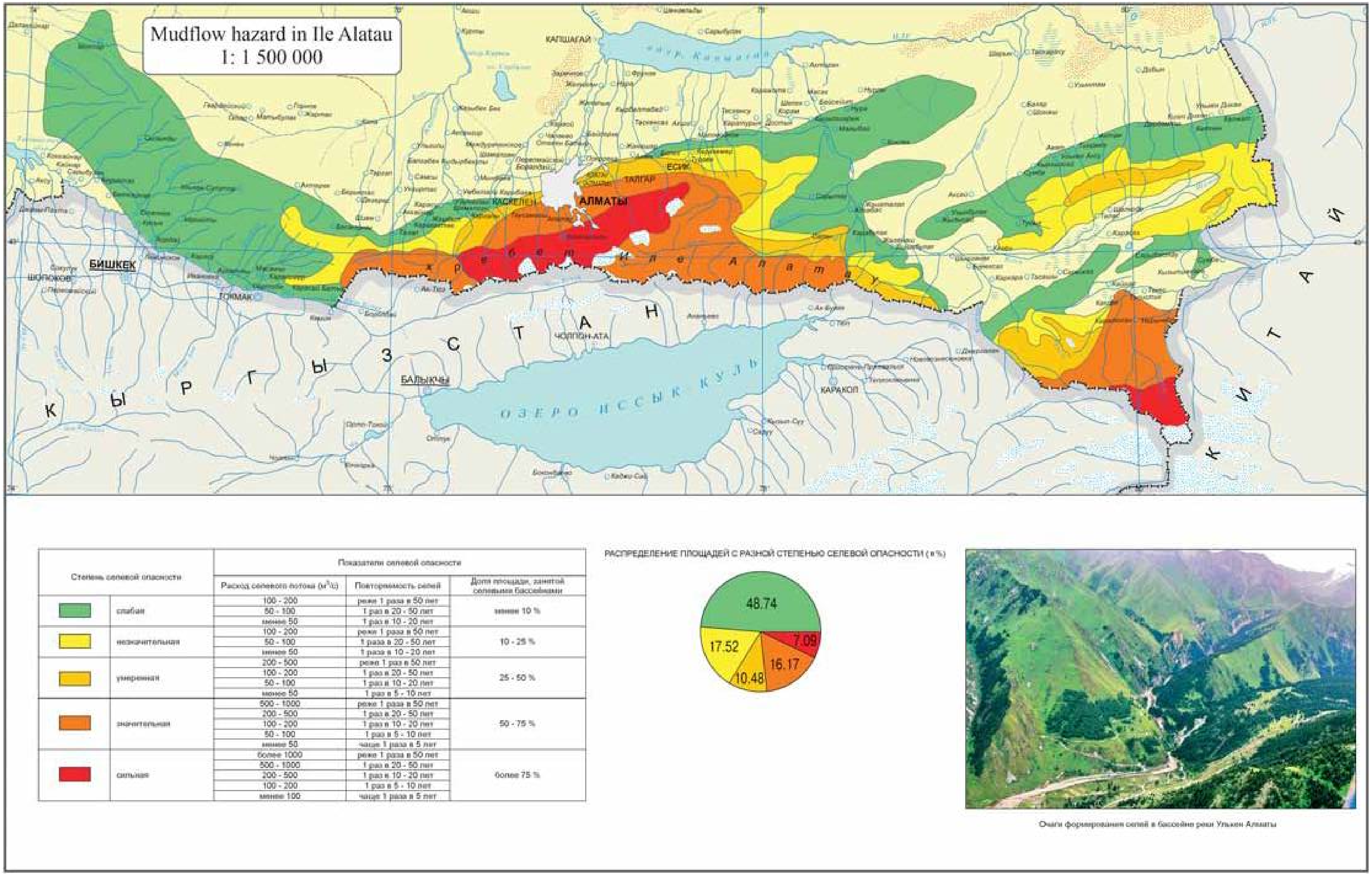

Fig. 32. Map of mudflow hazard in Ile Alatau (from the "Atlas of natural and man-made hazards and risks of emergency situations" Almaty, 2012). The degree of mudflow hazard increases from green to red areas.

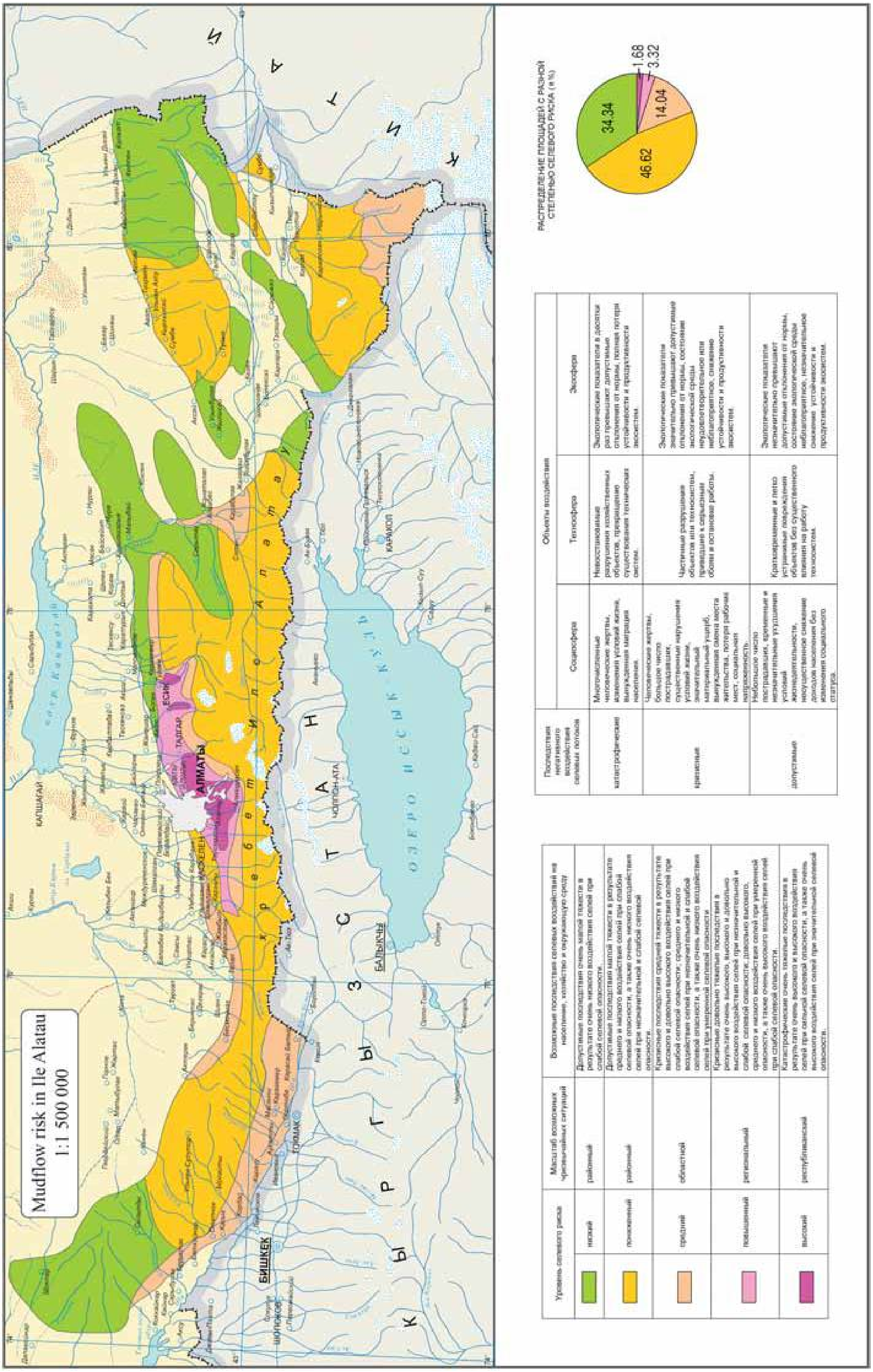

Fig. 33. Map of mudflow risk in Ile Alatau (from the "Atlas of natural and man-made hazards and risks of emergency situations" Almaty, 2012). The mudflow risk becomes higher from green to red and pink areas.

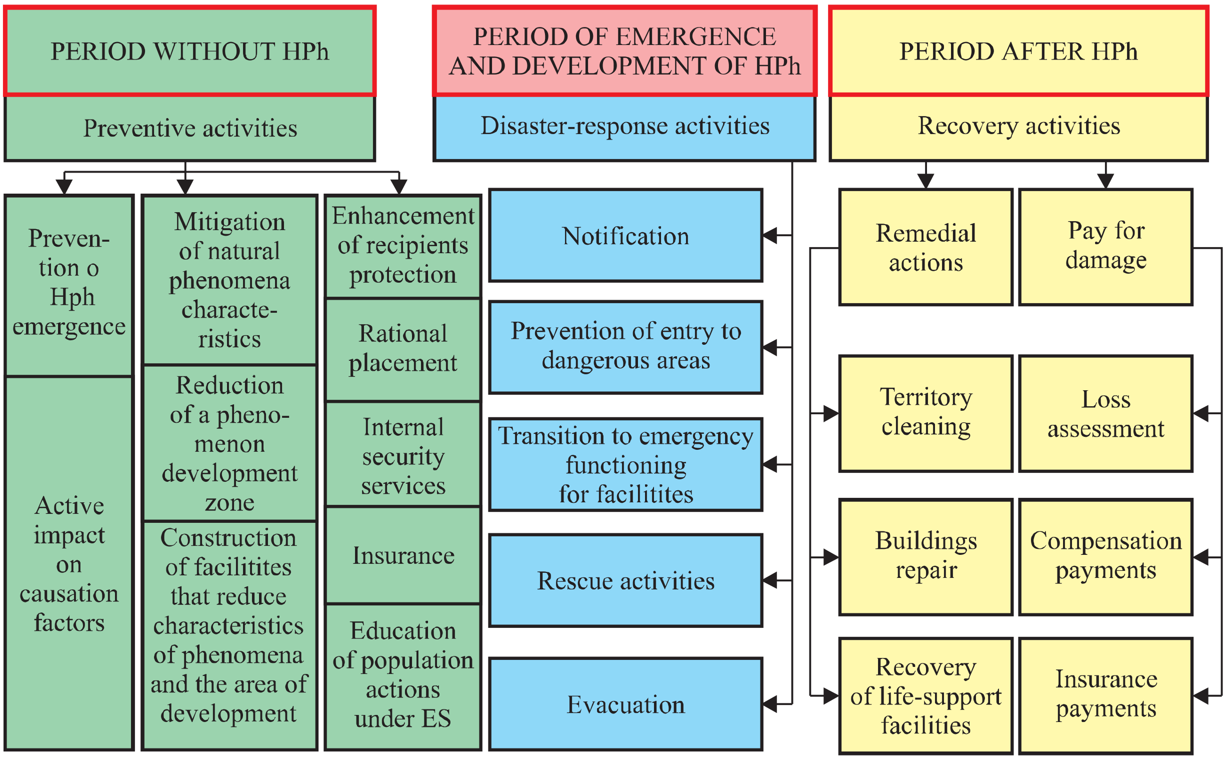

Fig. 34. Types of natural risks management.

of the recipients of its onset, emergency evacuation from the area of impact, and emergency measures to protect the objects from the damaging impact.

In the period of development of Es, management activities include emergency notification of recipients about the onset, urgent evacuation of the population out of the impact area, and emergency response activities for facilities protection from the destruction impact.

CONCLUSION

Summing up the above said, we can state that all over the world, including the Republic of Kazakhstan, there has been an increase of natural and man-made disasters involving loss of life and extensive material damage. Evidence-based scientific approach has been employed in accordance with the strategy of the international community to prevent and reduce the adverse impacts of disasters. One promising way to achieve security is to manage natural and man-made risks. The methodology of risks management developed by the MES Institute of Geography provides the science-based and integrated use of both existing methods for providing safety of the people and property and new activities insuring completeness, effectiveness, and adequacy. The practical implementation of the methodological foundations of risks management can make a significant contribution to the sustainable economic and social development of the country. ■

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