Development of WIPO-based experimental model of radio monitoring of earth soil

N R Rakhimov¹, V Sh Mukhametshin¹, B N Rakhimov², O A Mirsagdiev², A A Berdiev² and D I Kobishcha¹

¹ Ufa State Petroleum Technological University, Branch of the University in the City of Oktyabrsky, Oktyabrsky, Republic of Bashkortostan, Russian Federation
² Tashkent University of Information Technologies named after Muhammad Al-Khwarizmi, Tashkent, Uzbekistan

E-mail: nemrah@mail.ru, info@of.ugntu.ru

Abstract. The paper considers the methods, equipment and results of landslide monitoring. Monitoring systems, covering early warning of a landslide threat that may trigger an emergency, are based on registration, analysis and processing of versatile information, including geophysical surveys, regime geotechnical, hydrometeorological and seismic observations. In the monitoring process, the technology and equipment used to obtain the above-mentioned data play an important role.

1. Introduction
In recent years, there has been a significant increase in landslide activity in the mountainous regions of many countries, against the background of the ongoing climate change and especially in those areas where the largest amount of atmospheric precipitation falls, which exceeds the norm. The result of a landslide can be death of people and colossal damage to the economy and infrastructure of the country. For example, for the period from 1993 to 2013 320 large landslides occurred in the Republic of Kyrgyzstan as a result of which 256 people died and the direct economic damage from landslides averaged $ 2.5 million per year [1]. In 2019, in the first seven months of this year in Vietnam, a total of 34 people died or went missing and the economic damage amounted to about 239 billion Vietnamese dongs as a result of landslides and natural disasters [2]. The above mentioned data set the specific task of observation, forecasting and assessment of landslide disasters in hazardous areas.

As it is known, a landslide is a sliding displacement of rocks that make up a slope, due to mechanical destruction or flow of rocks of the slope and its base without losing contact between the moving and stationary part of the massif.

The reasons for the formation of the landslide are the unstable state of deluvial clay soil and loam, heavily wetted by rains, cut by road cuts, a significant steepness of the slope and, possibly, microseismic vibrations caused by the movement of trains. A survey of the slope showed that there were numerous traces of solifluction movements of thin Quaternary sediments. The sod cover in many areas was torn apart by open gaping cracks, there are stepping, tuberosity, slugs and other characteristic microforms of the relief [3].

In addition, landslide phenomena can occur as a result of the development of oil fields without the organization of water injection into the reservoir and a decrease in reservoir pressure in the reservoirs,
which leads not only to a decrease in the degree of reserves development [4–9], but also to vertical displacements of rocks.

The solution to this problem is the organization and conduct of monitoring, where the processes of gravitational displacement of masses are determined to prevent landslide disasters. The monitoring process is an information system of available regime observations, as well as assessment and forecasting of the state of the exogenous geological environment.

The purpose of monitoring is to observe exogenous geological processes and identify their territorial distribution, taking into account natural and man-made factors to predict the development of hazardous exogenous geological processes and develop proposals for reducing damage from their possible activation. Monitoring of hazardous exogenous geological processes is carried out in natural and technogenically disturbed conditions in places of their active impact on settlements, infrastructure and economy [10].

It is necessary to take into account that landslides can vary greatly in their types, sizes, mechanisms and speeds [11]. Therefore, in their methodology and scope of coverage of the landslide monitoring program, they can also vary significantly depending on the level of risk and the degree of instability of landslide slopes.

With regard to the nature and scale of the development of mountainous areas in order to obtain representative information on changes in the state of the geological environment and predict landslide processes, monitoring is simultaneously carried out at three large-scale levels: regional, local and detailed [12].

**Regional monitoring** is spatial in nature and covers large economic and geographical regions. It gives a general idea of the susceptibility of the country's territory to landslide processes, the spatial and temporal changes of landslide-prone areas and the possible damage that landslides can cause to the environment and large-scale objects of the technosphere. The information obtained in the process of regional monitoring can be applied in the design of schemes for the location of productive forces and economic objects, infrastructure, a general integrated scheme for engineering protection of a territory from dangerous processes of gravitational displacement of masses [13, 14].

**Local monitoring** implies observations within drainage basins or within the boundaries of the influence of large mining agglomerations and cascades of hydroelectric power plants. Covering territories with an area of 10 to 100 km$^2$, local monitoring should provide a more complete picture of the development of landslide processes within existing or planned mining complexes or large hydraulic structures. For regional and local monitoring of landslides in hard-to-reach mountain areas, aerospace methods are widely used, in particular, data from remote sensing of the Earth from space [12].

**Detailed monitoring** is connected to a specific landslide or area where slopes and downhill are unstable. The results of detailed monitoring provide specific information for forecasting and early warning of a landslide threat, prescribing risk reduction measures and preventing an emergency. For detailed monitoring, different research methods are used, as well as sets of special equipment, sensors and early warning devices about the threat of landslide danger.

### 2. Materials and methods

The monitoring equipment is a set of technical means designed to identify and warn about an emergency situation in the studied area, where soil masses are displaced, including bulk soils. Let us consider several technical tools for landslide monitoring.

Figure 1 shows a set of technical tools for downhole inclinometric survey. An inclinometer probe is used to measure the deviation angle of the downhole. The well drilled to the design depth is filled with a specialized inclinometric casing, which is an element of measurement using an inclinometric probe. The results of inclinometric observations allow estimating the magnitude of the lateral displacement of the soil and determining the depth of the displacement surface.

Figure 1 shows a set of technical tools for downhole inclinometric survey.
Figure 1. Downhole inclinometric survey equipment set

Figure 2 shows the device “Simeiz – RA”, which operates according to the method of recording the natural pulsed electromagnetic field of the Earth (NPEMFE). The method is based on arising in rocks under the influence of various stress fields formed by various geological objects and processes. The device “Simeiz – RA” allows carrying out:

1. The identification of deep stress zones in the rock mass, within which deformations develop. This problem is solved using the bottomhole modification of the NPEMFE method, which assumes dielectric casing of the wells.
2. The determination of the depth, size and shape of deformation zones obtained through the change in the parameters of electromagnetic pulses in boreholes, which, in turn, allow selecting effective design solutions to protect slopes from sliding [14].

Figure 2. “Simeiz – RA” device

3. Research methods and problem statement

We are currently working on the development of radio monitoring systems based on fiber-optic sensors.

The fiber optic sensor has a distributed structure. It can be used for a long time in adverse conditions: extremely high temperatures, electromagnetic influences, high pressures, in radiation, poisonous or corrosive environments that slightly affect optical fibers. The sensors are absolutely safe in gas and explosive environments. In addition, their principal advantage is the speed of information flow compared to other types of information transmission.

In terms of the advantages of fiber optic sensors, they are excellent for monitoring external changes. Some of the advantages of fiber optic sensors over conventional sensors are as follows:

- resistance to aggressive and flammable environments;
- immunity to electromagnetic and radiation interference;
- broadband (multichannel measurement over one fiber);
- high performance;
- distributed measurements (a system of sensors in one long fiber);
- long-term and continuous measurement;
- passive / low power (consumed);
- ecological durability;
- multifunctional measurement capability;
- simple integration into a wide variety of designs [14].

This paper is devoted to the description of the features of the system development. Initially, we gave the requirements for the developed system:

1. The determination of the displacement or deformation of the earth's soil along potentially dangerous sectors of the slope or terrain;
2. The periodic measurement of soil moisture, which has a great influence on the formation of landslides;
3. The synchronous data processing in a multichannel information-measuring system in the observed area;
4. The transmission of information about the state of the earth's soil in the form of digital reports via information (Ethernet, SMS, cloud) channels to the monitoring center.

4. Technical unit of the system

The main components of this system are the following:
- fiber-optic sensors: displacement and humidity sensors ($p_1...p_n; m_1...m_n$ respectively);
- SFP modules;
- Ethernet connectors;
- generator of conditional pulses;
- GPRS module;
- transmitter (27 MHz);
- special software.

The algorithm for the functioning of the technical system is shown in Figure 3. The generator of conditional impulses (5) generates discrete signals at a certain time interval (this interval can be changed for each individual case). The Ethernet SPI module is designed for assembling a device for controlling electrical devices via the Internet and transmitting data from sensors to display them on the website page.

The module connects the SFP module (1) with the generator (5) via the TCP/IP interface. SFP (1,2) is an industrial set of modular compact transceivers used to transmit and receive data in telecommunications. The set operates at the physical level of information networks based on copper and optical conductors. We use this module as an electrical-to-optical converter or vice versa, i.e. in the system, it functions as a laser and an optical beam receiver.

Fiber optic sensors/cables follow the block diagram. The system assumes the use of two types of optical sensors. The main task of these sensors ($p_1...p_n$) (8) is to determine the displacement or deformation of the earth's soil. So called pure fiber optical cables are used as sensors, i.e. a number of discrete-point elements (Bragg intra-fiber diffraction gratings) are included in the optical fiber. Each of the elements is set to display a specific wavelength $\lambda_k$ of the beam. The Mandelstam-Brillouin scattering principle is applied here [15]. According to this principle, the location of slip or deformation of the soil is determined.

The studies show that excess in the norm of soil moisture in excess of 40-45% increases the possibility of a landslide. This process is due to the connection with the water saturation of the landslide body (atmospheric precipitation, rise in the level of groundwater, artificial waterlogging of soils). The second branch of sensors ($m_1...m_n$) (9) monitors precisely the measurement of the soil moisture index [15].

The sensors are illuminated by the SFP $T_x$ laser (1) the one side and on the other side they are connected to the SFP $R_x$ photodetector (2) and they are all fixed on any part of the slope. If a process begins to occur on the controlled surface, then the indicator of any sensor or several of them at the same time changes. Consequently, there is a sharp decrease in the intensity of the light flux of the photodetector $R_x$ (2). The Ethernet module converts the SFP (2) output signal into an electrical signal.
The data is sent to the GPRS transmitter using the Arduino platform and to the transmitter (6) i.e. we have two channels of information (7), which meets the goals of the organization of backup or redundant transmission channels.

The GPRS module supports the quad-band GSM/GPRS network and transfers information via Internet channels in the form of digital reports or directly in the form of SMS notifications. Moreover, we have the opportunity to receive information about the state of the site online. The module interacts with the microcontroller through the UART port, supports 3GPP and SIMCOM commands. In the monitoring center, the operator will have specially developed software with a detailed interface of the object (deformation, displacement, location, moisture level, etc.).

The main task of such a monitoring system is to provide clearly synchronous processing of different digital data coming from various sensors. In this area of knowledge, the results of our research have been published in several scientific journals [15-17].

Data processing is carried out in the information processing center, the possibility of dangerous and emergency situations is determined in order to take prompt action if necessary.

5. Results and Discussion
The results of the analysis of the monitoring of landslide dislocation and movements in a certain area, recorded using the abovementioned sets of equipment, instruments and sensors, can be used to obtain the main types (mechanisms) of landslide movement. Let us systematize the following most characteristic types of landslide movement, preceding the main, often catastrophic, displacement:

Irregular movements - consisting of slow or fast displacements of varying duration, followed by long breaks in movement;
Uneven movements of landslides - including repetitive movements of various amplitudes, as a rule, synchronous with seismic and/or other geodynamic events and alternating with interruptions in movement of varying duration from several months to several years;
Creep - including long, initially slow displacements of landslides, accelerating over time and ending with the collapse of the slope.

The revealed monitoring results allow carrying out protective actions in the following directions:
- operational forecast of changes in the state of soil mass to assess safety and substantiate decisions on
the necessary measures in emergency situations;
- to forecast the activation and development of landslide deformations on the slope and to warn in advance possible emergency situations associated with the intensification of landslide displacements on the slope;
- to compare the results of interrelationships between the records of the control points according to the monitoring of the state of the soil base of the road embankments, structural elements of engineering protection and landslide of the slope massif [15].

6. Conclusion

The use of modern, inexpensive and accessible information technologies for monitoring purposes allows observing and predicting exogenous geological processes, as well as developing sound scientific proposals to reduce damage from their possible activation.

The determination of the main parameters of exogenous geological processes, in turn, is the basis for the development and calibration of existing engineering models describing the mechanism of deterioration that threaten to get over the established tolerances and limits and develop as accidents and disasters.

Among the above-mentioned monitoring systems, the systems with fiber-optic sensors have additional advantages in structural monitoring of engineering structures, since they provide high quality measurements and increased reliability, simplification and reduction of operating costs. The unique properties of a fiber optic system allow them to be applied to systems for continuous monitoring of the earth's soil along slopes, especially to landslide processes.

The determination of the state of soil layers in places where landslides occur allows timely warning of the danger of accidents to residents living along (inside) hazardous areas. Systematic monitoring of landslides allows preventing the destruction of slopes (both natural and artificial), slopes, as well as avoiding emergency situations in buildings and structures, which means avoiding human losses.

References

[1] Torgoev I A System monitoring landslides in Kyrgyzstan 2013 Civil security technologies 10 4(38) 68-71
[2] Lomtadze V D 1978 Engineering geology Special engineering geology Moscow: Nedra 496 p
[3] Petina V I, Gayvoronskaya N I and Polygalova A Yu 2016 Monitoring of landslide processes on the territory of the Belgorod region: modern methods and means of their study Modern scientific researches and innovations 5(61) 528-534
[4] Zeigman Yu V, Mukhametshin V V, and Kuleshova L S 2020 Management of flooding of low-production deposits according to geological and field data IOP: Earth and Environmental Science (EES) 579 012019 1–6 DOI: 10.1088/1755-1315/579/1/012019
[5] Akhmetov R T, Mukhametshin V V, Kuleshova L S, Grezina O A, and Malyshev P.M. 2020 The generalized correlating function of capillary curves and the relationship of the filtration-capacitive parameters of reservoirs in Western Siberia with the size distribution of pore channels Journal of Physics: Conference Series (International Conference on Information Technology in Business and Industry (ITBI 2020)) 1661 012016 1–7 DOI: 10.1088/1755-1315/1661/1/012016
[6] Kadyrov R R, Mukhametshin V V, Galiullina I F, Kuleshova L S, and Safiullina A R 2020 Prospects of applying formation water and heavy brines derived therefrom in oil production and national economy IOP Conference Series: Materials Science and Engineering (ISEES 2020 – 3rd International Symposium on Engineering and Earth Sciences) 905 012081 1-6 DOI: 10.1088/1757-899X/905/1/012081
[7] Kuleshova L S, and Mukhametshin V V 2020 Justification for the selection of distances between wells to increase the efficiency of flooding by deposits in terrigenous reservoirs of Western Siberia Journal of Physics: Conference Series 1582 012057 1–4 DOI: 10.1088/1742-6596/1582/1/012057
[8] Mukhametshin V V 2020 Oil Production Facilities Management Improving Using the Analogy Method SOCAR Proceedings 4 42-50 DOI: 10.5510/OGP20200400464
[9] Mukhametshin V V and Kuleshova L S 2020 On uncertainty level reduction in managing waterflooding of the deposits with hard to extract reserves Bulletin of the Tomsk Polytechnic University, Geo Assets Engineering 331(5) 140–146 DOI 10.18799/24131830/2020/5/2644
[10] Sharapov R V 2013 Some problems of exogenous processes monitoring Fundamental research 1-2 444-447
[11] Torgoev I A 2000 Geoecological monitoring in the development of mountain resources in Kyrgyzstan Bishkek: Exponent 201 p
[12] Nazrishoev H A Monitoring of a regional natural system and its importance for studying of high-mountain lakes (on the example of the Sarez lake) GeoRisk World 1 54-59
[13] Express method for monitoring and forecasting hazardous geological processes 2012 Kiev URL: https://ru.geoground.net/novosti/ekspressnyj-metod-kontrolya-i-prognoza-opasnykh-geologitcheskikh-protsessov.html
[14] Buymistryuk G 2013 Fiber optic sensors for extreme conditions Control engineering Russia 3(45)
[15] Rakhimov T G, Rakhimov B N, Mirsagdiev O A and Berdiev A A 2019 Information and measurement technology based on fiber-optic sensors and systems Muhammad al-Xorazmiy avlodlari” ilmiy-amaliy va axborot tahliliy jurnal 4(10) 59-67
[16] Chalkova Yu S and Cherepanov B M 2007 Landslide processes, their forecasting and control Polzunovsky Vestnik 1-2 80-89
[17] Rakhimov B N, Rakhimov T G, Berdiev A, Ulmaskhujayev Z A and Zokhidova G 2019 Synchronous data processing in multi-channel information measuring systems of radiomonitoring Compusoft International journal of advanced computer technology 8(3) 3088-3091