

Geological Information System of environmental and human intervention impact assessment on bodies of water of the Irkutsk region

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Abstract. In this paper the authors present a methodology on information support for research on human and environmental impact of Lake Baikal. The geoportal placed on the Internet allows researchers to create a common thematic database (tabular data) and map data (information layers) within the framework of the project, as well as to run Internet services for geoprocessing and complex data analysis problems solving. One of the key features of the engineered geoportal is the ability for users to create the structure of their databases independently (to add, to delete and to modify the tables structure) as well as to configure the run of geoprocessing services. Besides this platform allows you to take on projects on various subjects and with a large number of users simultaneously. They have took on works on 3D modeling of the surface topography of the coastal zone near the village of Listvyanka. Underwater terrain is combined with land relief. As a result catchment basins along which pollutants with groundwater enter the coastal waters of Lake Baikal have been identified. The data on pollution concentration sites is confirmed by practical measurements and coincides with the drainage areas.

1. Introduction

The coast of Lake Baikal becomes increasingly attractive place of tourist activity development year by year and remains one of the most relevant places with relation to ecological demands and restrictions as it concerns a unique natural object – Lake Baikal.

A serious impendence of ecological safety of Lake Baikal (one of few natural objects listed in UNESCO immediately according to all accepted criteria for uniqueness) is posed by accompanying economic activity, especially in the absence of engineering constructions [1]. It is explained by the fact that on the coast of Lake Baikal there is a large number of the local sections of mass tourism and rest that are characterized by permanently growth of tourist flow that finally leads to deterioration of the unique ecological system of Lake Baikal status for that reason acceptance of urgent measures for the analysis and assessment of the current state and for the forecast of geosystems dynamics on key sections, that subject to the most powerful anthropogenic loads: Listvyanka, the coast of the Small Sea, the coastal zone in evil Severobaykalsk and Baikalsk, is required. The situation is complicated by the fact that at present no groundwater flow from industrial enterprises, tourism objects, private farms and residential buildings to any surface water body is regulated by any normative documents and,



accordingly, there are no uniform methodological approaches to account for the influence of this factor on the ecological system of a surface water body.

Currently the group of authors meet the challenge of a scientific geoinformation system of ecological content creating which is at the initial stage of its formation, although it has a long history of development. Basic and operational geoinformation presentation of materials to ensure the problem solving of environmentally sustainable development of territories, based on new geoinformation approaches and technologies, has become a capstone of scientists' activities [2].

In this paper the authors present a methodology for information support for research on the human impact on the ecology of Lake Baikal [1]. The geoportal (<http://atlas.isc.irk.ru/>) placed on the Internet allows researchers to create a common under the project thematic database (tabular data) and map data (information layers) as well as to startup Internet services for the purpose of geoprocessing and complex data analysis. One of differential features of the engineered geoportal is the ability for users to create their databases structure [2] by themselves (to add, to delete and to modify tables structure) and also to adjust the geoprocessing services startup. Also, this platform allows you to take on projects on various topics and by a large number of users simultaneously.

2. Models and Methods

The subject-matter data of the geoportal being developed (<http://atlas.isc.irk.ru/>) is presented in the form of a data storage based on the results of the coastal zone of Lake Baikal for 2016-2017 studies containing information in the form of databases (DB) bounded to cartographic layers. Users are able add third-party vector and raster maps. Input and data editing system of the geoportal allows to load any table data in the form of adjustable structures for a particular user. The query subsystem is a powerful dynamically configurable set of filters for any of the database tables. As background maps of the geoportal they connect maps based on the WMS standard from known open GIS: Google Satellite, Yandex Maps, Open Street Map (OSM), 2GIS, Bing.

To present thematic data of research results on a geoportal they created databases that ensure the storage of the following parameters:

- Mineralization of the bottom water on the basis of measurements of Specific Resistance of Soil using electro-tomography methods obtained in the framework of the hydrological survey (using the CTD probe of the Sea Bird Electronics SBE-37 probe).
- Results of vertical electrical sounding.
- The chemical composition of water in rivers, streams, holes in beaches and Lystvenny Bay litters (the basis indexes is the concentration of elements in filtered water samples).
- The content of anthropogenic pollutants in natural environments that are in feedforward together within the framework of landscape-geochemical flows. Quantitative data on a number of pollutants and indicators for each sample is given: microbiological attributes, petroleum derivatives, temperature, suspended substance, mineralization, pH, cations, anions, microelements.
- Sanitary microbiology of the rivers of Listvyanka (the indicators of the base reflect the level of microorganisms that can affect people's health).

The authors created a digital model of the relief of Listvyanka village (figure 1) on the basis of a high resolution (10 meters per pixel) satellite image of WorldDEM (Airbus Defense and Space under the common name GEO ElevationServices). The area of the image is 31 650 km². The global digital model of WorldDEM was created based on the results of interferometric processing of tandem surveys from the TerraSAR-X / TanDEM-X radar satellites). The picture was purchased from Airbus.

For a 3D model construction of the coastline relief they developed the original technology of coupling of the surface-water relief with the underwater relief [2]. The underwater relief was obtained after measurements using echolocation of the bottom relief of the coastline of Listvenichny Bay, field depth measurements were performed up to a 50-meter mark (figure 2).

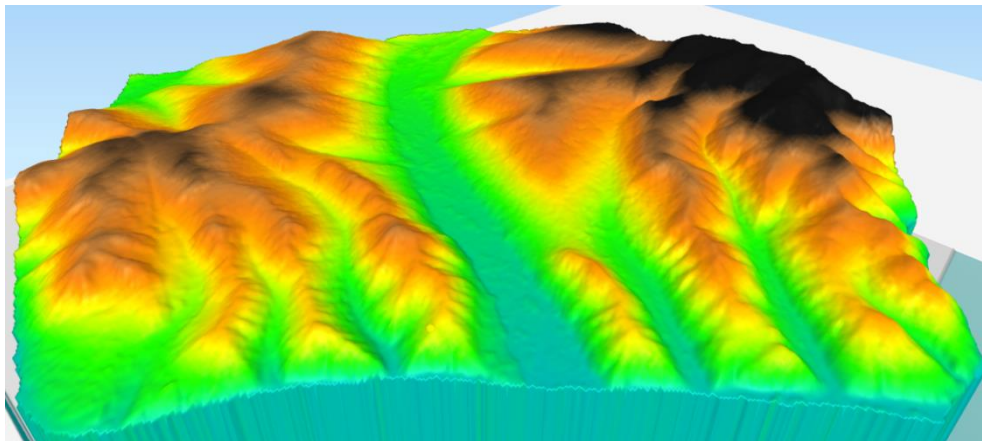


Figure 1. Digital model of the relief.

To combine the data on the surface-water and underwater terrain the original algorithm for constructing the Delaunay triangulation [2] with map layer restrictions was tested. While construction of the triangulation the role of every layer is indicated. Every layer can contain information on land relief, standing water level, contours of coastlines, underwater terrain. To work with underwater terrain, information on elevations of water is required. According to the data an auxiliary triangulation is constructed further on this showing information on bench marks is extracted to which the contours of the coastlines are attached and the depths are counted. As a result of these procedures a final agreed combined (surface with underwater) 3D relief model is obtained (figure 2).

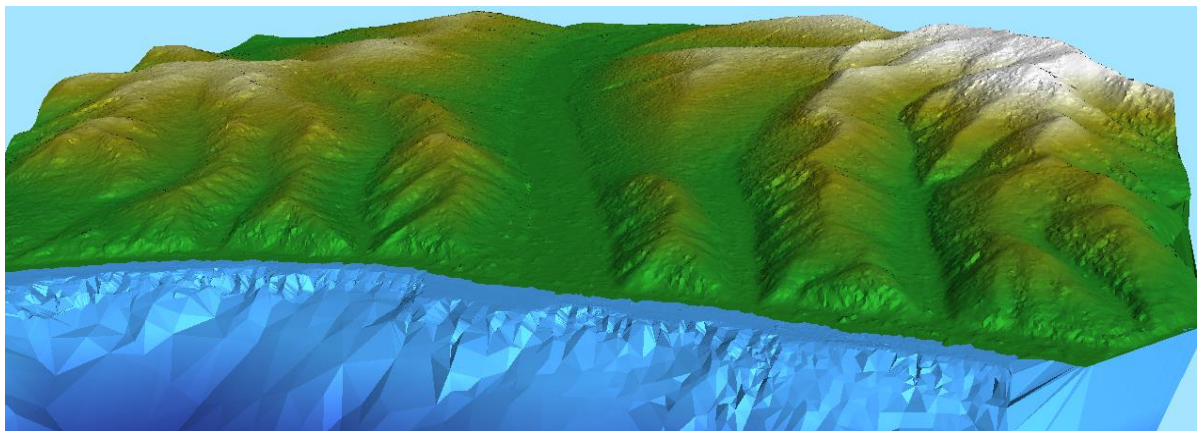


Figure 2. Combination of surface and underwater relief up to 50 m depth.

In consequence of a high-quality 3D model creation based on current GIS technologies using complex high-precision data on the surface and underwater reliefs, it is possible to evaluate the human impact on the coastal zone of Lake Baikal near Listvyanka village affecting the increase of the ecological crisis.

3. Results and Discussion

Analyzing the research of 2015-2017 it was noted that the anthropogenic pollution end of May is increasing in comparison with early May. As an explanation there is a hypothesis that the result of this increase is the growth of the tourist flow and correspondingly the increasing water removal of tourist sites (cafes, hotels) located in the shoreline of lake Baikal. Comparative analysis of geophysical data also showed high reliability of the data obtained by this method on subterranean flows location having

subaqual discharge in the reservoir, as well as the stability of the location of underground drains, and in fact the direct dependence of groundwater runoff on the tourist flow.

To confirm the hypothesis it was suggested to analyze the waste water from the objects of the tourist infrastructure using tools of modern GIS. It is known that the groundwater movement conforms with gravity and is carried out in the form of flows through communicating pores or cracks. In this case the groundwater surface hugs in some ways the surface relief and underflow moves from elevated areas (starting from the watershed divide of groundwater) to lower areas (ravines, rivers, lakes, seas) where they are discharged in the form of descending sources (springs) or by a hidden subaqual distributed method (for example, under the waters of river beds, lakes and seas bottom). In view of the surface topography of the village Listvyanka hotels and cafes are located in the river valleys and along the shore of lake Baikal. It is assumed that discharge of waste waters from specific tourist sites will be in the sector of the corresponding watershed divide.

The authors carried out work on the modeling of catch basins in this area (for the catchment basins maps creation freely distributed Quantum GIS was used):

At the first stage you need to get rid of speckles in the data by applying a Gausa filter for smoothing that will help to avoid the formation of small deeps. For this purpose it is necessary to use the Gaussianfilter geo-algorithm from the SAGA GIS collection.

At the second stage they construct catchment basins using the `r.watershed` tool from the GRASS GIS collection (figure 3).

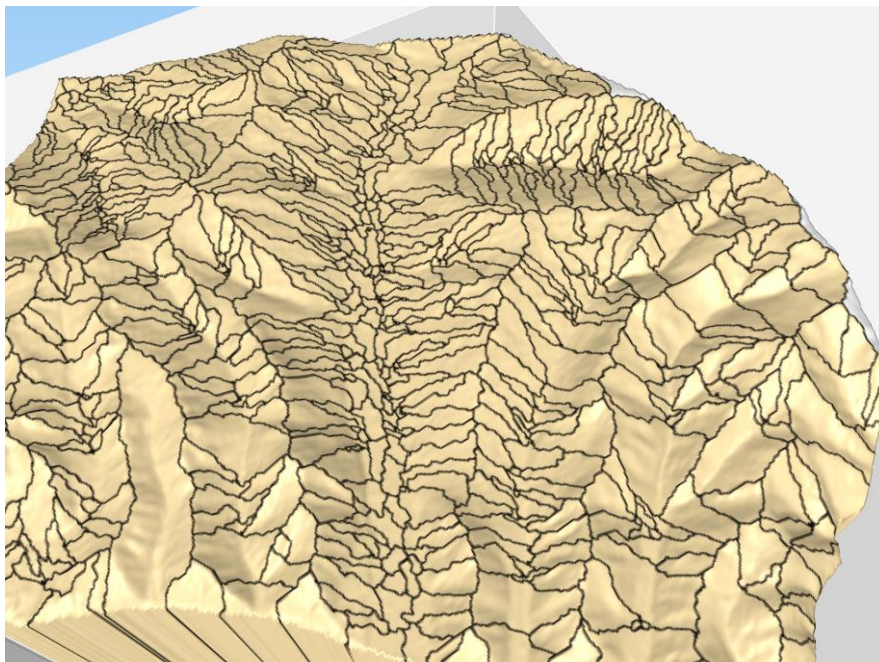


Figure 3. The result of catchment basins construction.

At the third stage it is necessary to perform generalization using the `v.generalize` GRASS GIS feature. But at first you need to transfer the raster into a vector view using the `r.to.vect` GRASS GIS algorithm. It may also be necessary to combine small catchment basins into larger ones using the QGIS command order: Vector / Geoprocessing / Integration. The result of small basins integration is shown in figure 3.

Further the number of tourist infrastructure objects located in a certain water collection zone was estimated. For this purpose a layer "Hotels and cafes" was obtained based on the data from the parcellary plan and other sources on the number of touristic objects. This layer was put onto the layer of the catchment areas (figure 4).

As a result of the analysis of the obtained data it was discovered that the human pollution indexes in the sub-aquiferous discharge areas of the relevant catchments basins are closely related to the number of tourist infrastructure facilities located in a particular catchment area.

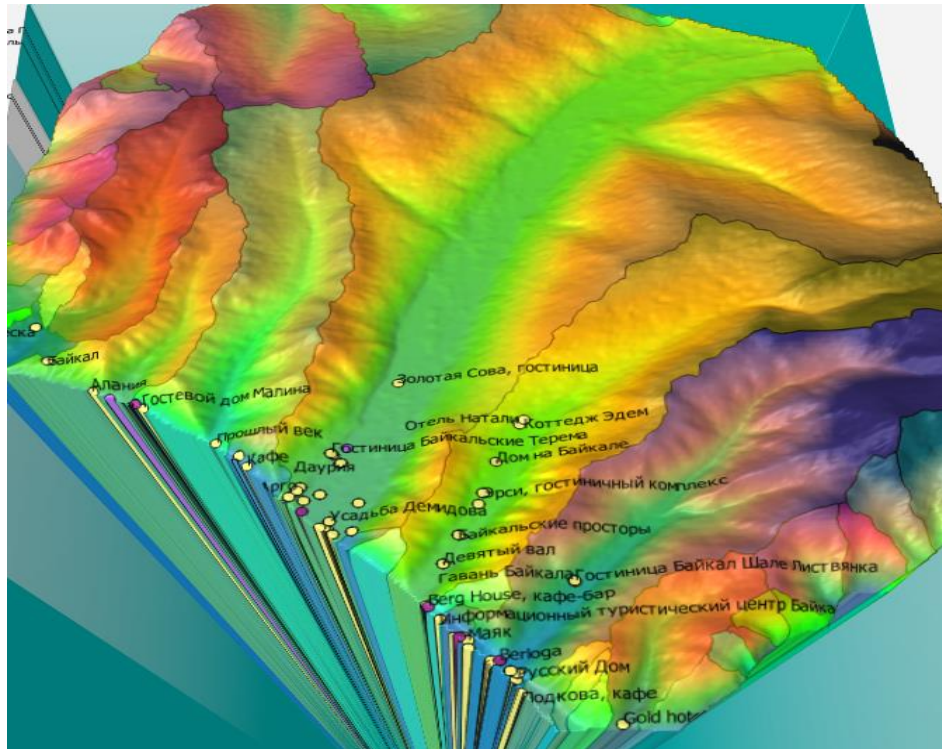


Figure 4. Watershed divide with hotels and restaurants.

4. Conclusion

As a result of the performed works developed the architecture and created a preproduction model of GIS to support research on the anthropogenic impact on the ecology of the coastal zone of Lake Baikal. The system provides a centralized formation of thematic and cartographic databases of research results for all investigators, monitoring of the ecological situation, a complex analysis of the human impact on the ecology of the coastal zone of Lake Baikal.

A digital elevation model based on a high resolution satellite (10 meters per pixel) WorldDem was created. A fancy technology of coupling between a surface relief with an underwater relief has been developed. Underwater relief was obtained with the help of echolocation survey of the bottom relief of the coastal zone of Listvenichny Bay (depth measurements were carried out up to a 50-meter mark).

The analysis of waste water transfer from the objects of the tourist infrastructure with the help of GIS tools according to the data on relief of drainages and estimation of the number of tourist infrastructure facilities near every basin.

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References

- [1] Grachev M A 2016 Maybe-Bag and Let it Be. Ecological crisis on Baikal: A mystery of the

Century Science First-Hand **68** 6–19

- Bychkov I V and Nikitin V M 2015 Control of level of Lake Baikal: problems and possible issues *Geography and Environmental Resources* **3** 5–16
- Bezrukov L A, Saveliev V A, Nikolskii A F and Podkovalnikov S V 1997 Baikal and hydropower: ecology and economy *Geography and Natural Resources* **4** 158–68
- Atutova A A, Pronina N M and Tulohonova A K 1999 *Hydropower and Condition of an Ecosystem of Lake Baikal* (Novosibirsk: publishing house SB RAS) p 280
- Itskovich V B, Shigarova A M and Glyzina O 2015 Change in the Hsp70 content in the Baikal endemic sponge *Lubomirskia Baicalensis* during decolorization and under hypothermia *Aktualnye Problemy Nauki Pribaikalya* 135-8
- Vashchenko B 2015 Aliens in Baikal *National Geographic Russia* **146** 6
- Kravtsova L S, Izboldina L A and Khanaev I V 2012 Disturbances of vertical zoning of green algae in the littoral area of the Listvennichnoye Bay, Lake Baikal, as a result of local anthropogenic effect *Doklad RAS* **2** 227-9
- Kravtsova L S, Izboldina L A and Khanaev I V 2014 Nearshore benthic blooms of filamentous green algae in Lake Baikal *J. Great Lakes Res.* **40** 441-8
- Timoshkin O A, Samsonov D P and Yamamuro M 2016 Rapid ecological change in the coastal zone of Lake Baikal (East Siberia): Is the site of the world's greatest freshwater biodiversity in danger? *J. Great Lakes Res.* **42** 487-97
- [2] Abasov N V, Bolgov M V, Nikitin V M and Osipchuk E N 2017 On regulation of the urovenny mode of lake Baikal *Water Resources* **44** 407-16
- Skvortsov A V 2002 *Delaunay Triangulation and its Appliance* (Tomsk: Tomsk University press) p 128