Creating of Digital Relief Map for Regional Hydrogeological Model of Latvia

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Abstract. **This paper describes creating of the digital relief of Latvia. Its plane approximation step is 500 m, with the hydrographical network included. As initial data for creating of the relief, two data sets provided by the Latvian Geospatial Information Agency (LGIA) were used. This work is targeted on preparing and checking of these initial data. Problems of acquiring elevation data for rivers and lakes are considered. The geospatial data of LGIA, which were used for creation of the digital relief by the Environment Modelling Centre (EMC) of the Riga Technical University (RTU), were reviewed. The methods for identifying of faulty geospatial data are considered. Two reliefs – the LGIA provided digital relief and the EMC created digital relief are compared. The comparison shows that both reliefs are not perfect, due to faulty initial data and the large plane approximation step used.**

Keywords: **digital relief, interpolation, hydrogeology, comparison**

I. INTRODUCTION

The digital relief of Latvia was created by EMC as a part of RTU project that was supported by the European Regional Development Fund. This relief will be used as a piezometric boundary condition and as the upper surface for the regional hydrogeological model (HM) of Latvia.

The EMC created digital relief (further – EMC relief) has 951×601=571551 grid nodes. The HM hydrographical network containing largest rivers and lakes was incorporated into it. The EMC relief was obtained by using the GDI software set [1] [2].

As sources of initial data, two LGIA data sets were used. The first data set (further D1) is a matrix with elevation data that cover territory of Latvia on the grid with the 70 m plane step. However, these data were not used, due to reasons considered in the next section. The second data set (further D2) includes vector-type data about the isolines, rivers, lakes, ground and water surface elevation marks. The data are stored as the ESRI Shapefiles [3]. The D2 set was used for creating of the EMC relief.

II. INTERPOLATION OF THE RELIEF FROM THE D1 SET

The D1 data include grid nodes with elevation values, which are independent from each other. To glance over, the LGIA digital relief (further - LGIA relief) seems to be close to the ground surface of Latvia, see Fig. 1.

The LGIA relief was created by using on D1 the Nearest Neighbour method included into the Surfer 10 software.

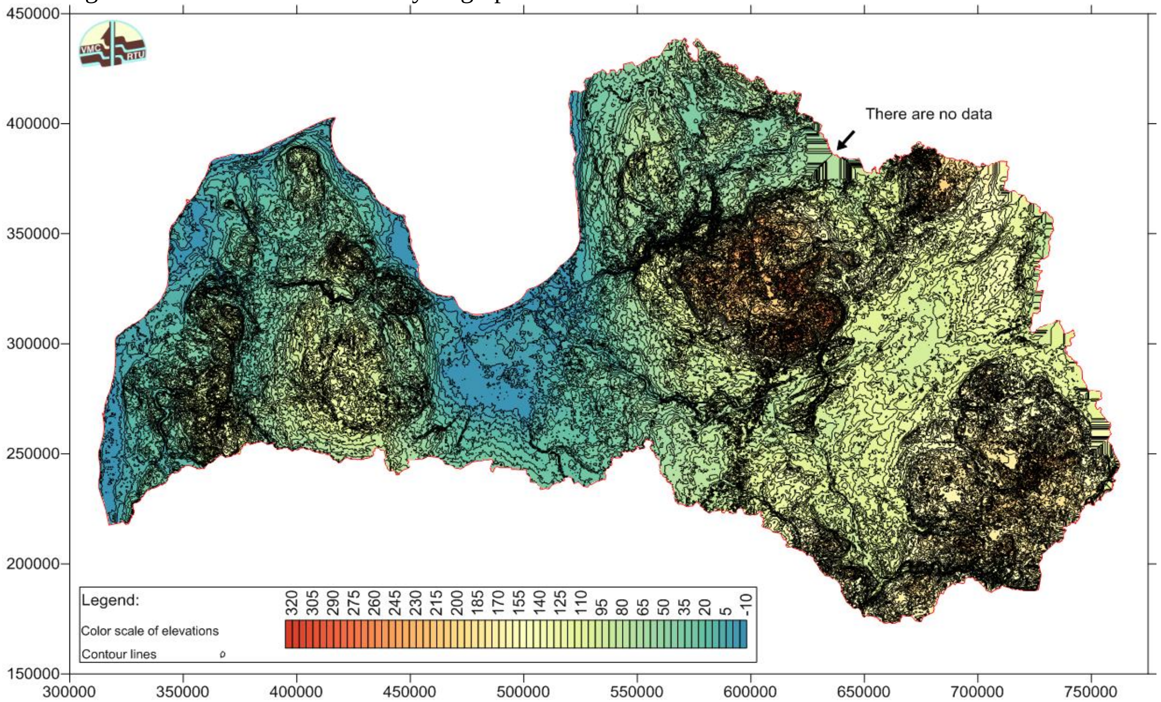

Fig. 1 The LGIA digital relief interpolated with the approximation step 500 m

In an early stage of the project, it was believed that the D1 data set was the best source for the EMC relief. Unfortunately, D1 set does not contain information regarding hydrographical network and elevation data are absent in some places near the eastern border zone of Latvia. The D1 data are obtained from orthophotographs.

For obtaining long line profiles of rivers, D1 was unproductive. As it is shown in Fig. 2, the long-line profile of the Lielupe River obtained from the LGIA relief, does not match the real profile. The LGIA long-line profile error is up to 15.19 m. The second example is the elevation data for the Kishezers Lake (see Fig. 3) where the lake surface is far by being flat. These both examples show that D1 cannot provide reliable information for the hydrographical network elements.

Firstly, it was tried to incorporate the hydrographical network into the LGIA relief. After several attempts, obviously faulty D1 data were found, such as 0 m asl in the places where the elevation must be above 100 m asl. In Fig. 3, the real ground elevation mark with altitude 18 m asl differs from the D1 data up to 7 m. Unfortunately, it is difficult to correct these errors, because the current value of initial data does not depend from any other value in D1. Two scenarios of improving D1 are possible: by excluding interpretation faults of orthophotos or by comparing this data set with other, more reliable data set.

III. Preparing of the Vector-Type Data

The D2 data contain vector-type data that can be used for obtaining of a digital relief. It is large – more than 1 million isolines, several thousands of ground and water level marks.

D2 also contains errors. Fortunately, most of these errors can be detected and corrected.

Elevation values can be checked and compared with the nearest data of D2 or with the data from other topographical maps. The ground relief of Latvia is rather flat, and it is not so hard to assign the right value if the initial data are not correct.

The altitude of the Latvia ground surface is in the interval from 0 m asl (Baltic Sea level) to 311.5 m asl (Gaizins Mountain level). This information was used for the first search of faulty isolines data. 2926 isolines were outside the interval (0.28% of isolines data set). For the second search of errors, within the real ground elevation interval, a semi-automatic approach was used and the special software developed.

Two rules were used for searching isoline errors:

1. The isoline subset with the right altitude in the area of a given radius (100 m), mostly not exceeds constant amplitude of values (35 m).
2. When the endpoint of one isoline is equal to the other isoline endpoint, their altitude values must be equal.

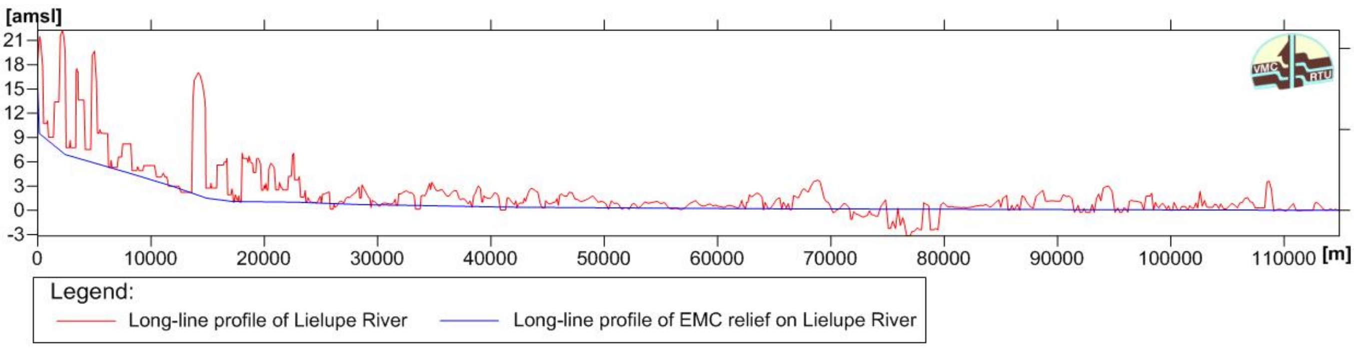

Fig. 2. Long line profiles for the Lielupe River

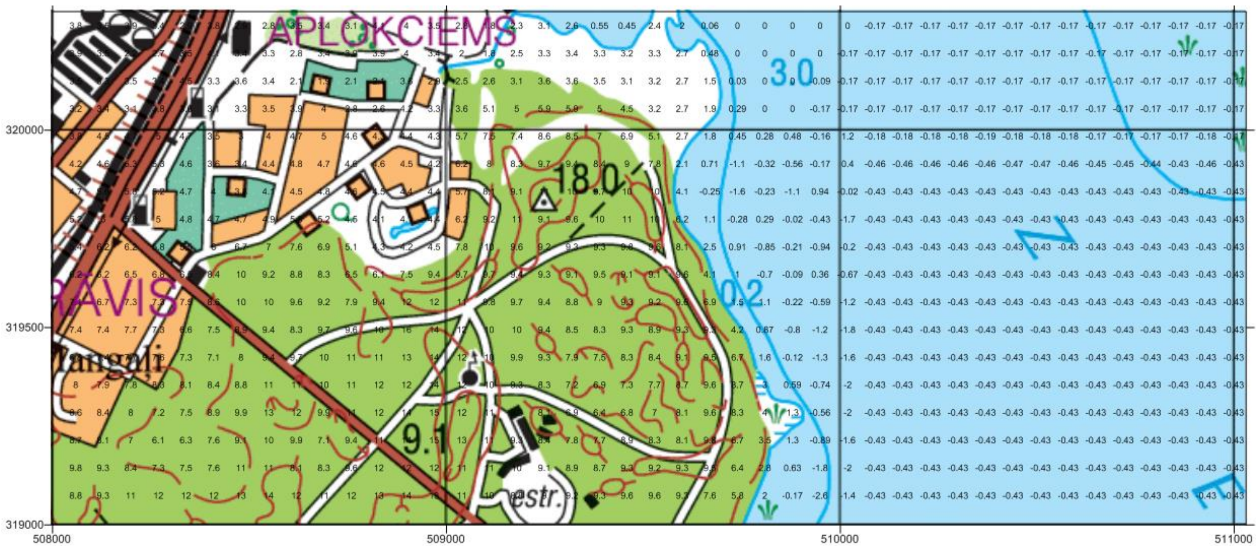

Fig. 3. The part of a map with the Kishezers Lake, the D1 data values are exposed

Searching of errors was done for each isoline point using these two rules. Approximately 4000 isoline pairs have been found which do not match the rules. These data was checked manually. Crude errors were found for 1172 isolines (0.11% of isoline data) and they were eliminated. The next search step was based on considering the difference between the EMC and LGIA reliefs. It turned out that faults mostly were found for the LGIA relief (see the section "Comparison of the Reliefs").

To obtain data for the hydrographical network, the D2 data were applied. Unfortunately, there geometry of rivers and lakes was too complex. As an example, the Memele River was presented by polygons (coastlines) and polylines, which were impossible to join or merge. The only way of overcoming this obstacle was digitizing the river middle line manually through the coastlines of a river. The Memele River length in the territory of Latvia is approximately 122 km. Only 20 water elevation marks of the river are given. They represent only 0.68% of needed data for 2914 points along the river line.

Some water elevation marks of D2 have wrong values. To correct them, all water level marks values for rivers and lakes were compared with data of topographic maps and isoline data.

IV. Preparing of the Hydrographical Network

The territory of Latvia is rich in surface waters; there are 12400 rivers and 5175 lakes [4].

Most of these objects are small. The hydrographical network of HM includes only large rivers and lakes (192 rivers and 67 lakes), see Fig. 4.

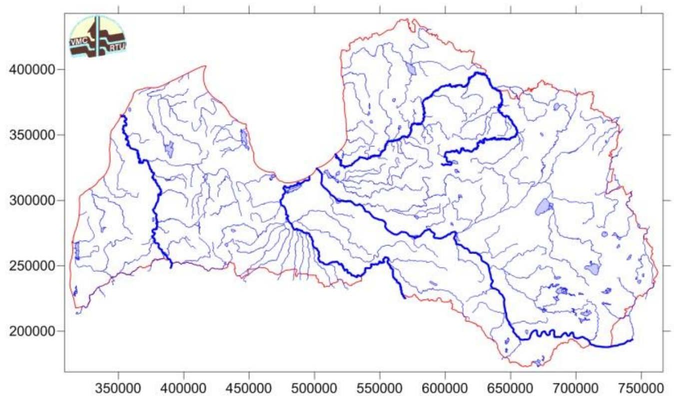

Fig. 4 Rivers and lakes of the hydrographical network

The water levels of lakes were based on their elevation marks. The water level is constant for a lake. Assigning the level values for rivers was more difficult, because each point of the river must have its water level value. Rivers in the catchment area are cross-linked. The tributary mouth must match the water level value of the river into which it flows.

Water levels for the river profile line were obtained by the CRP software [1], [2]. The minimum data needed for CRP were the river water levels of its entry and mouth. The entry level was mostly unknown. This value was interpolated from the EMC relief [4]. The river mouth levels are often known: they are the Baltic Sea level or the lake level in which the river inflows. Some rivers flow out from the territory of Latvia. Then a last water elevation mark outside the boundary was used as a river mouth value. Most of the smaller rivers flow into the larger rivers. The only way, how their mouth value can be obtained, is to use a water level value of the larger river in the junction point. To obtain the water level data for every river in the hydrographical network, the iterative approach was used. To get the right set for river levels, four iterations were necessary.

Some rivers have their mouth point in a place where the other river has its entry. Then it is difficult to obtain coherent water level values for both rivers, except the case when the junction point water level is known. To solve this problem, joining of river geometries was used. As an example, the case of the Lielupe River that begins from the Musa River and Memele River is considered. To obtain right water levels for these three rivers, the Lielupe River was merged with the Memele River. Another problem was caused by rivers which flow through lakes. The river must run from higher to the lower level, but a lake has its constant level. To overcome this contradiction, the river was divided into the parts – the first part before lake, the second part after lake. As an example of this situation is the Dubna River which flows through the Visku Lake and the Carmins Lake.

Only descending water level values from the entry to the mouth of a river were accepted. However, the levels interpolated only from water elevation marks, happen to be above the EMC relief. To improve initial data, data from points where isolines intersect river were added.

Methods and algorithms for obtaining water levels of rivers are described in [4] and [5].

V. Obtained Result

The EMC relief (see Fig. 5) of Latvia was developed iteratively. In the first stage, the geometry of isolines was interpolated. In the second stage, the areas of lakes and the lines of the rivers were incorporated into the relief. The initial data D2 were improved by using methods described above.

VI. Comparison of the Reliefs

The LGIA relief and the EMC relief were compared. To compare the reliefs, the EMC relief was subtracted from the LGIA digital relief by using the Surfer 10 software. Both digital reliefs are equal only in 382 nodes. In the location where the LGIA relief was below the EMC relief (see Fig. 6), the maximal difference was 134.54 m. It was in the node with the coordinate *X*: 425000 *Y*: 300000. Large difference values form a rectangle near this coordinate. There D1 contains wrong initial data with the zero value. The nearest right elevation mark on the topographic map is 136.7 m asl. In places where the EMC relief is below the LGIA relief, the difference is mostly due to the influence of the hydrographical network that is included into the EMC relief. The maximum difference 69.98 m was in the node with the coordinates *X*:550000 Y:335500. It was due to the Gauja National park hilly landscape. The average difference value was 0.98 m above the EMC relief.

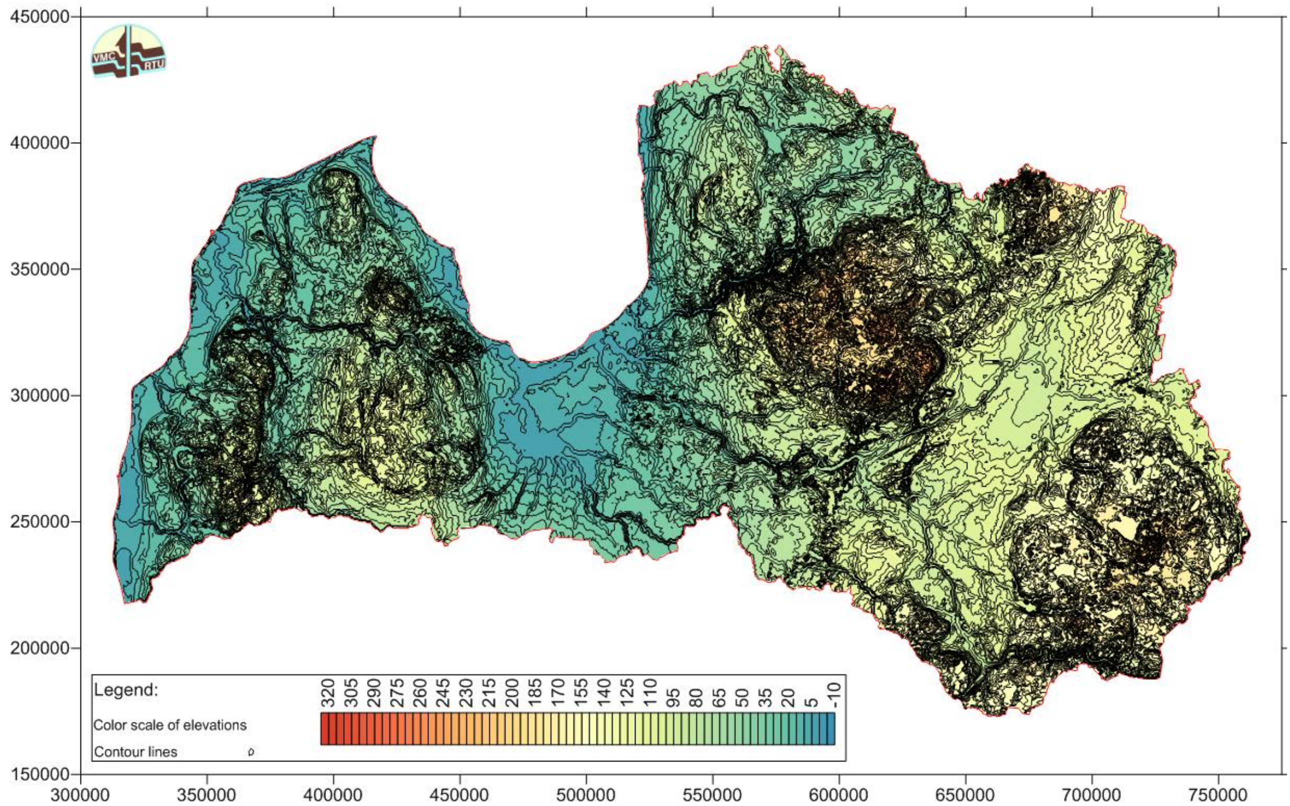

Fig. 5 The EMC relief of Latvia

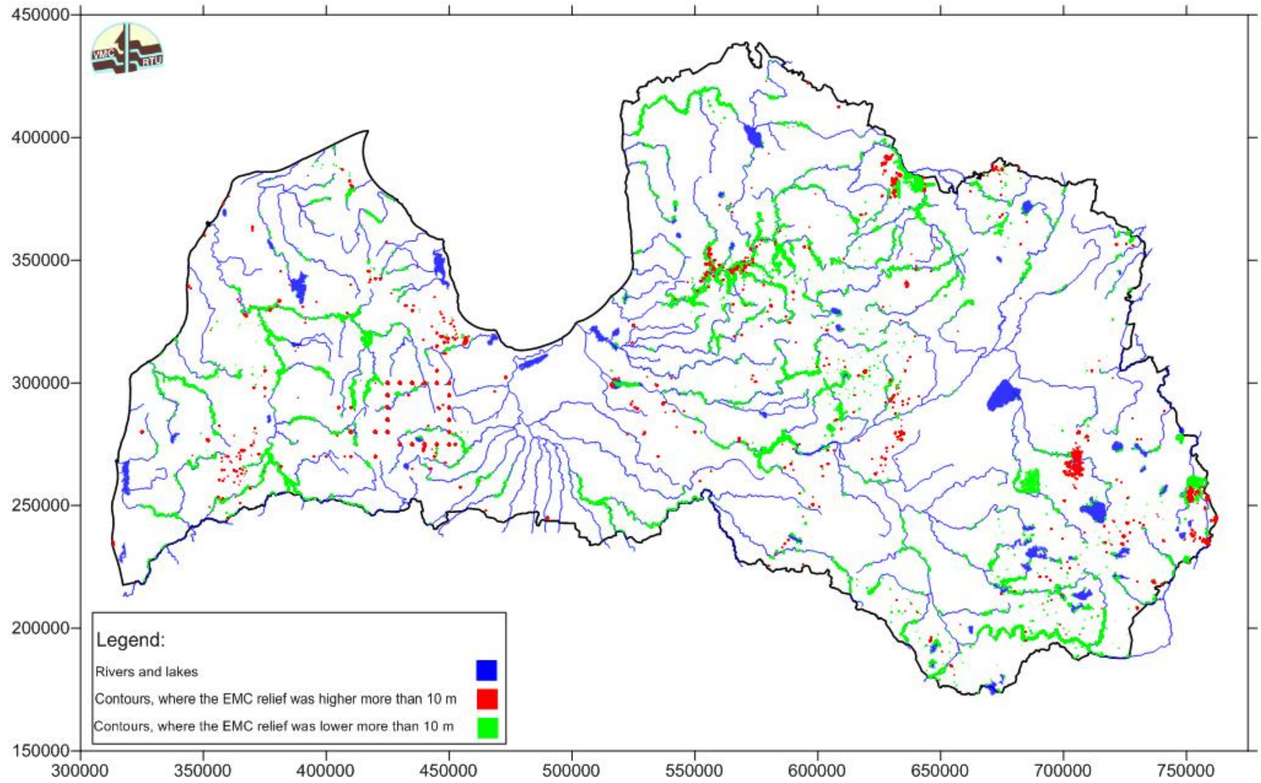

Fig. 6 The difference of reliefs

VII. Conclusions

The relief of Latvia has been created. Its main application will be the regional hydrogeological model of Latvia.

Methods for evaluating and improving initial data were described. The methods of creating long line profiles of rivers were proposed and the software for running these methods was created.

The digital relief to be used by the model was compared with the digital LGIA relief. Mistakes and faults were found. The difference of two reliefs may be used for improving and correcting of initial data.

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Janis Slangens was born 1940, Latvia. In 1969, he graduated Riga Polytechnical institute (since 1990, the Riga Technical university) as computer science engineer. In 1985, J. Slangens received degree of science candidate confirmed by thesis entitled "*Hybrid computers for solving boundary field problems* ". In 1994, this degree was transferred to the one of the doctor of engineering sciences.

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J. Slangens, K. Krauklis. Reljefa digitālās kartes izveidošana Latvijas reģionālajam hidroģeoloģiskam modelim
Rakstā ir apskatīti Latvijas digitālā reljefa ar režģa soli 500 m, kurā iestrādāts hidrogrāfiskais tīkls ar Latvijas lielākajiem ezeriem un upēm, galvenie izstrādes etapi. Reljefs kalpos par pjezometrisko robežnoteikumu un augšējo slāni Latvijas reģionālam hidroģeoloģiskam modelim, kas top Rīgas Tehniskā universitātes projektā "Hidroģeoloģiskā modeļa izveidošana Latvijas pazemes ūdenskrājumu apsaimniekošanai un vides atveseļošanai" ar Eiropas Rekonstrukcijas un Attīstības fonda atbalstu. Kā ieejas dati veicamajam darbam tika izmantoti Latvijas Ģeotelpiskās Informācijas aģentūras (LĢIA) piedāvātie datu komplekti. Īpaša uzmanība pievērsta ieejas datu sagatavošanai un pārbaudei. Apskatītas upju un ezeru ģeometrijas un to ūdens līmeņu iegūšanas un iestrādes problēmas reljefā. Tiek izvērtēti LĢIA ģeotelpiskie dati, kuri izmantoti reljefa izstrādē vai arī izvērtēta to izmantošana reljefa digitālā reljefa interpolācijai. Izskaidrotas nekorekto ģeotelpisko datu identificēšanas metodes, kas tika izmantotas vai arī tiek piedāvātas kļūdu izskaušanai. Ir salīdzināti RTU Vides Modelēšanas Centrā (VMC) izstrādātais digitālais reljefs ar LĢIA digitālo reljefu, interpolētu uz 500 m režģi. Salīdzinājuma rezultātā atklātas kļūdas vai neprecizitātes abos apskatāmajos reljefos. Galvenā problēma izstrādes gaitā – nepilnīgi un kļūdaini ieejas dati.

Я. Шлангенс, К. Крауклис. Разработка карты поверхности земли для региональной гидрогеологической модели Латвии
В статье рассмотрен рельеф поверхности земли Латвии, предназначенный для разработки региональной гидрогеологической модели в качестве верхнего пласта, а также в качестве пьезометрического граничного условия. Создание модели связано с выполнением проекта „Создание гидрогеологической модели Латвии для управления грунтовыми водами и оздоровления окружающей среды” Центром Моделирования Окружающей среды (VMC) Рижского Технического университета при поддержке Европейского Фонда Регионального Развития. Рельеф составляет 950×600=570000 узлов с шагом 500 м, включены уровни водоёмов – данные о 192 реках и 67 озёрах. Подвержены критическому анализу, приобретённые у Латвийского Агентства Геопространственной Информации (LĢIA) входные данные – рельеф Латвии с шагом 70 м, векторные данные изолиний, озёр, рек, а также отметки уровней водоёмов. Предложены методы обнаружения ошибок в вышеупомянутых данных. Описан метод присвоения значения уровня для рек и озёр в каждой точке, где наиболее сложной оказалась проблема присвоения уровня для рек, соединённых в единый бассейн. Сравнен рельеф LĢIA с рельефом VMC, обнаружены ошибки и неточности. Предложен полуавтоматизированный метод на основе сравнения рельефов для исправления ошибок в рельефе, созданном на основе ортофото.