UDK 528.48:341.222

REMOTE SENSING METHODS AND MATERIALS USAGE IN STATE BORDER DEMARCATION WORKS

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Key words: Geodesy; Remote sensing; Survey; State border demarcation.

Introduction

Organizing border demarcation activities and works we can conditionally divided them into following work performance of the basic steps: Work performance documentation and creation of instructions; Finding of State border lines and marking the area of project development and implementation; In the area demarcated state border line tagging, installation and reinforcement; The state border demarcation document assembly development for submission to governments - can also be called area strengthening state border technical and legal documentation in accordance with the intergovernmental contract conditions. One of the main loads and responsibilities in these activities at a transnational commission, along with the border engineering specialists, lies with the geodetic and cartographic, work organization specialists, now also known as a geo-information specialists. In geo-information technology application context, apparent essential remote sensing techniques and materials, the use of border demarcation work and activities within (10). Considering remote sensing techniques and material use the amount of interest, increase the use of geo-information in recent decades - also border demarcation work within the framework of steps to be surveying, remote sensing application volume increases. It can be observed in the assessment of the Latvian border demarcation work processes used technology changes during the period from 1991 to 2017. State border measurement works in demarcation process provides a number of different cartographic, topographic and geodetic survey works execution. Work begins with the preparation of a geographic work execution phase by creating a border zone overall (cross-border) geodetic reference network. Further, the design is provided (delimitation) state line position and initial marking area, moving to its tagging and securing the area. At the end of demarcation on geo-information specialists rests its major final work phase - ensure area strengthened state borders technical and legal documentation in accordance with the intergovernmental agreement conditions of execution - specifically develop, multiply and assemble them in the final border demarcation documents sets, usually such as the border description, border demarcation map boundary post coordinate catalogs and boundary post protocol volumes (12). Per task solving necessity in geo-information works are set appropriate quality requirements, which is also determined in remote sensing methods and material application likelihood and usefulness.

Border zone common geodetic reference network setup works after the quality requirements meet national geodetic parameters, they must be executed with all the state border mapping, geodetic and topographical measurement works. Remote sensing methods and materials are used here only as support measures improving work organization. The quality of support is usually provided by a dual independent measurement, measurement treatment process where the results are compared. This total support also serves as remote sensing work precision supply border demarcation process, so its quality is an important role in remote sensing techniques and materials use. In the following stages of the demarcation work, remote sensing material application impacts on amounts gradually increases (11). Their results allow to reduce the field measurement or procedure volumes, economize resources and reducing the erroneous inclusion the measurement work. Remote sensing material usage enables to achieve additional - independent measurement result control possibilities even in cases where

the two countries professionals is set complete and independent the measurement repetition criterion.

Projected state borderline finding and laying in are begins with project development, which consists of a more precise delimitation of the map displayed. Project uses work available at the beginning of cartographic material, which is more precise delimitation of raw materials. Unfortunately, usually it exhibits aging in relation to the existing terrain situation, which carries several additional problems for future work. Aging effects can be reduced by remote sensing materials, such as orthophoto, original aerial photographs, satellite images cosmic or laser scanning data. This material allows you to restore the available maps or even make completely new maps for these works. This can be afforded if the development can be found resources needed and can devote time. Discovered state borderline set results control is also used in remote sensing materials, and particularly if they are obtained during work or at the end of them. Such opportunities minimize repeated field visits, the measurement work volumes and in many cases, eliminates the need for mandatory border laying results of additional check-ups in area. These types of work do not require high mathematical accuracy requirements of the measurement and control of the execution, but they are important for making sure to find a place with the conclusion of international agreements nature, limiting area non-compliance after the fact.

Subsequent work forms remote sensing materials use requires higher precision. State border marking and securing in the area remote sensing capabilities allow to assess whether deployed and installed state borderline, installed boundary post is located in the designated areas, compared to both terrain situations, and after the set of boundary marks and border elements surveyed coordinates places its aligning and testing with remote sensing methods. Control effectiveness is increased if at the end of work acquired the latest remote sensing materials, which allows the identify installed state border location, status and in its process of strengthening of the installed boarder signs, as well as the quality of the survey results.

Ensuring the last work phase - In the area fixed state borders technical and legal documentation in accordance with the intergovernmental agreement conditions, remote sensing methods and materials serving for final document as border demarcation map - the development base and boarder signs protocol execution material, and also as an effective document drafted by the control and verification of the possibility of collateral.

Time of demarcation work is often filled with the state border strip creation action, where the importance is in quality placing in the area and topographic measurement works by providing strip forming part of the alienation of property by boarder zone. This work processes at all stages can be linked to remote sensing techniques and materials applications, both performance and evaluation activities.

It should be recalled that in parallel to mentioned remote sensing techniques and materials application possibilities of the state border demarcation work processes they have a significant - an important role as the state border demarcation work execution of quality performance, evaluation tools and resources (7). Use of these materials allows to ensure executed works quality assessment of all works in demarcation carried out during borders installation and measurement activities, as well as developed cartographic and geodetic documentation quality and completeness checks. They are successfully used and in the future, will be used more. At the same time, it should be remembered that remote sensing is not withdrawn or does not replace all classically accepted geodesy quality control and inspection procedures.

Materials and Methods

Starting demarcation work organization for specialists as the main document act is usually limitation (and delimitation) contract, which contain Annexes as border delimitation description and map. Delimitation map is often built on the delimitation of the time available topographic maps of the base and if the greater the demarcation border length as possible a smallest detailed map scale serves as a delimitation map base - so maps the level of detail decreases with increasing length of the state border.

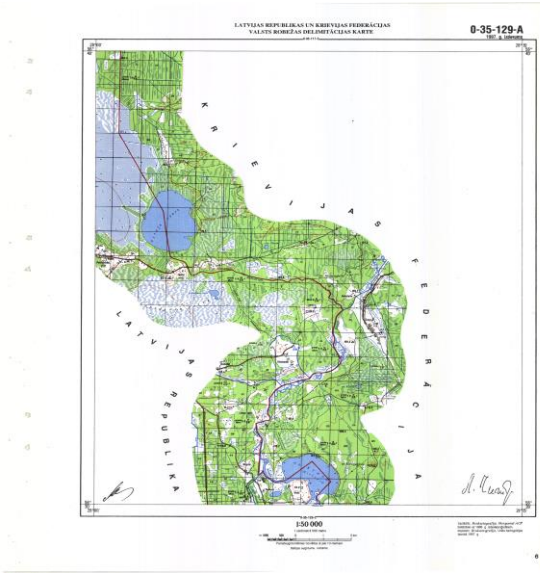

Figure 1 Latvia-Russia state border Delimitation map page sample

Latvia - Russia border delimitation case map was made up of scale 1: 50,000 topographic maps of the base, which was drawn up on the USSR Cabinet of Geodesy and Cartography government and Army headquarters Military topographical publishing originals, created in 1987 -1996 years (15). Realistically, no card sheet was not created less than 1990, so the year 2010, then the start of the demarcation works, their content was significantly outdated. *(Figure 1)* To compensate for both the level of detail and the aging effects on the future demarcation works execution generally demarcation works of the Commission are being sought both more detailed map scales and younger area of information materials. In Latvia - Russia border case as the most suitable was found in the topographic map in scale 1: 10 000 - which was developed by the State Land Service cartographers during the period from 2000 to the year 2006 *(Figure 2)*

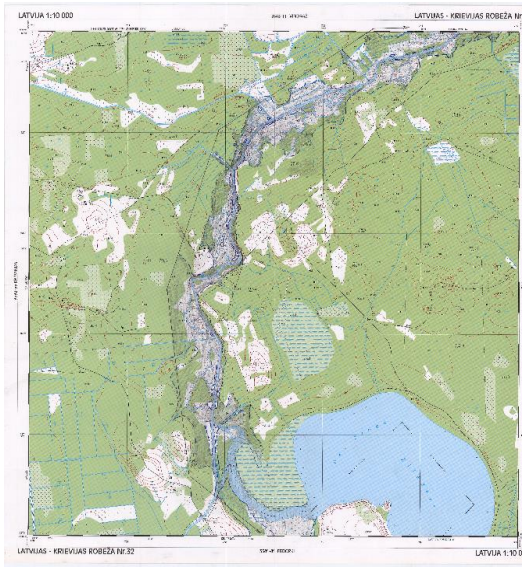

Figure 2 Topographic map 1: 10 000 State border region model sheet - made from 2000 to 2005

These maps base is based on the development of remote sensing technologies were used materials such as the earth's surface aerial photography equipment and sometimes space satellite imagines with 1 meter resolution. Also - in order to achieve a better quality of information and off-road parts readability and in works involved all the 2010 year of available remote sensing of the original materials and their products - such as orthophotomaps *(Figure 3)* and orthophoto - plans.

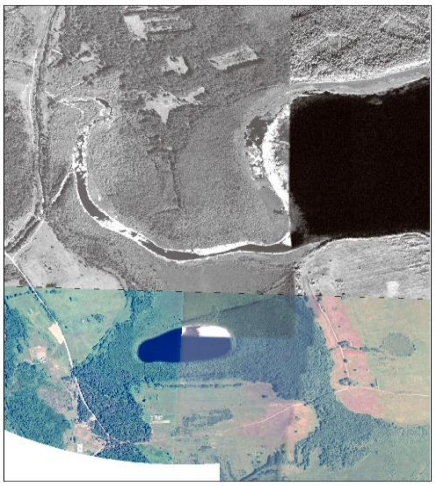

Figure 3 By 2010, the year's aerial and space images combined Orthophotomap

In order to ensure quality and speed up the state border line search works in the area - to compensate for the available geographic information security material weaknesses in the work of the initial stage of decisions were taken and implemented a number of measures that can be defined as a new remote sensing information

extraction measures (8). The first was carried out in the delimitation of the border location of the filming of the situation from the aircraft - a helicopter year 2010 in spring floods time. Using the obtained film materials was renewed situation on topographic map 1: 10 000 *(Figure 2),* including the outlines potential boundaries of watercourses, water flows and flooded areas. It was prepared in improved conditions for both the line search and initial markup works, as well as further state boundary marker installation location for design - so increasing their future secure retention in possible spring floods (2). At the same time in 2010, Demarcation Commission decision was taken on the new aerial photography cycle performances of the works of demarcation of job support on the Latvia - Russia State border, so preparing a basis for increased remote sensing methods and materials for use in the demarcation work being carried out. At the same time in 2010, Demarcation Commission decision was taken on the new aerial photography cycle performances of the works of demarcation of job support on the Latvia - Russia State border, so preparing a basis for increased remote sensing methods and materials for use in the demarcation work being carried out. During 2010, the aerial photography work order was prepared, agreed in demarcation commission, accepted contract and work was completed in spring 2011. Already in the summer of the same year of the resulting materials were created and available new orthophoto maps 1: 10 000 *(Figure 4),* with significantly improved resolution - not worse than 0.4 m pixels on the land. Previous year orthophoto resolution was slightly better than 1 m pixel on land. It has already of the preparatory phase demarcation works was created base for successful geodetic - cartographic border surveying works executions, including for use remote sensing methods and materials in the implementation and control of the results obtaine.

Figure 4 Orthophotomap from 2011 aerial photography materials

Already the new map shows that ortofoto technology came forward with a need uniform geodetic support the creation of the state border zone - the full inclusion of the two separate countries created geodetic network points in this territory. Such a unified geodetic support is essential for all future cartographic and geodetic works support processes to the state border demarcation (7). On the same common geodetic reference network, established process of remote sensing methods and materials based on this effect is more marginal and episodic, only as outlier detection possibilities. This network is directly related to the following made border installations and surveying works, documents producing and product quality assurance, including the use of remote sensing material quality. So consequence of these application possibilities to quality assessment. For Orthophoto development needs was carried out established support network points marking and results identification on images - which made it possible to significantly improve the accuracy of the new ortofoto maps, transforming the orthophoto as a logical follow-geodetic support thickened elements of the state border zone (13). To projected state borderline position determination and the initial postponement on the land of remote sensing applications materials importance in relation to the previous measures are growing. Firstly allowing in the planning time, increase the line search and suspension works quality by reducing the original design materials aging and performances restrictions caused problems. Here is the importance of such remote sensing materials involvement as orthophoto, original

aerial photography, satellite imagery or laser scanning data. In these borders in the case, in addition to remote sensing materials were also involved in border visual inspections - by the video filming from the helicopter, the results (14). Remote sensing materials and of those manufactured products can be actively used in the same border line searching's and suspensions operations in the area, as the field works teams support materials, improving work efficiency and problem-solving capabilities. Also, at the end to this type of works remote sensing materials are used for line positions and suspensions evaluation of the results. They allow reducing the repeated field visits, surveying works volumes or even often to the exclusion of the need for suspensions results mandatory in addition to the inspection area. These types of work does not ask high mathematical accuracy of the measurement and control of the execution, but they are of great importance to find and validate a places compliance with the conclusion of international agreements nature, limiting the of non-compliance after the fact.

Moving on to the next job demarcation process - the country's borders marking and strengthening the area may already find that here the use of remote sensing materials already raises higher precision parameters. They will increase both as the verification of boundary marks placement and borderline corroboration the project with the situation in the area. As well as evaluating the programmable bandwidth cleaning estimates and identifying the boundaries of the line and boundary marks placement spot potential problems and their prevention capacity, and in addition to the need for the boundary mark installation e.s. *(Figure 5)*

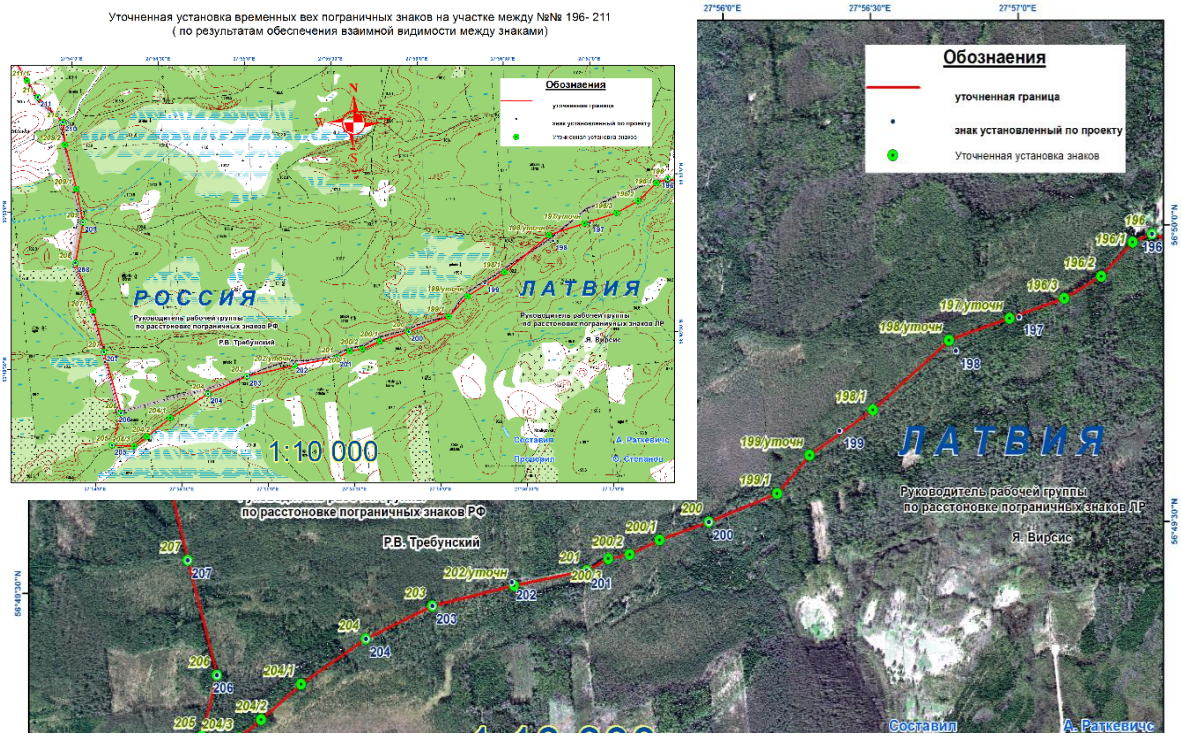

Figure 5. State border marking and strengthening project-clarifying example.

Remote sensing materials allow to assess - or deployed, installed state borderline and installed landmark in the designated areas, compared to both off-road situations, and after the set boundary mark and border elements surveying coordinates of places by aligning them with the remote sensing materials. Control efficiency increases - if derived the newest remote sensing materials, which have already been identified in the installed state border points and the strengthening of the process-installed landmarks. In such cases, you might check with high precision surveying objects coordinate accuracy and adequacy, checking drawn boundary marks abrisses with the situation. In addition can also be assessed that streamside installation - treatment works results comply with the requirements. In the same works, process can be prepared and issued a series of working papers for usage in the field teams, problem-solving teams, inspection and acceptance teams as well Border Guard services, whose development are based on remote sensing products or materials.

Results and Discussion

At the end of the works with in the wild area strengthening the state border technical and legal documentation, which are being developed within the framework of the state border demarcation documents - remote sensing materials significance becomes essential. So the state border describe and border demarcation map development of approximately 80% of the material are based on remote sensing base. Also, in boundary mark coordinate Directory and installed boundary mark protocols forming the usage of these materials are increasing. Here remote sensing materials not only serve as an effective a final document as border demarcation map - maps base (which approximately 80% based on remote sensing materials) and the boundary mark protocol design material, but also as the development process and performance monitoring and testing the possibility of collateral. Also in this works phase created different kinds of additional information materials, which are attached to the demarcation documents, for example - the island survey documents, complex border sections detailed survey documents, re-create the terrain or man-made situation object surveying. Basically, here ordered in various scale topographic surveying works which surveyors perform under field conditions, but the results obtained making control of Latvia - Russia border case, nearly 90% of the amount has been widely used in remote sensing techniques. The experience gained showed that if obtaining high-quality remote sensing output of these materials rose more than 50% could be realized cameral - using remote sensing techniques. Remote sensing capability allows without to the field to check: maps drawn up by quality; prepared a description of the boundaries; check drawn boundary mark protocols; the various topographical surveying control; as well as to check the boundary marks surveying results in prepared coordinate catalogue. In the Latvia-Russia border case, the use of remote sensing capabilities were tested measurement accuracy of nearly 60% of the surveyed boundary marks. Greater extent of the examination did not support in 2014 acquired remote sensing materials (with about 0.3 m pixel resolution). On the shooting time had not yet been installed in almost 30% boundary marks and only around 50% of the streamside was cleared of overgrowth - which often prevented in aero-scenes to see the milestones or boundary marks as they were under the foliage. In parallel to geodesic cartographic works allows control of remote sensing materials with great precision to assess the border will be installed - as accurately observed bandwidth, or in all cases is stripped from the overgrowth, or the band is not left in the commission of unauthorized objects, structures parameters and other indicators. The overall control efficiency increases - if are availability of the latest remote sensing materials - and especially if they meet the final demarcation of the time.

In the Demarcation time often filled with the same demarcation not combined works - among which is the state border strip creation works. The band postponement of the area include, topographic surveying works, forming part of the border zone expropriation of property and the border property forming bands. Here, in all cases, a significant role in projecting and surveying results of the quality assessment by remote sensing material application. Evaluating the Latvia - Russia state border demarcation works of the experience gained in connection with remote sensing methods and materials use and comparing the results with other Latvia state border demarcation cases marked expressed the possibility of remote sensing applications usage increase over time. Moreover, if later occurred the border demarcation works - as more important opportunity to use remote sensing volume is found in works the process execution. To the usage of remote sensing methods for volume, growth and efficiency significant influence showed to newer material mining options. They are associated with both the latest technology (photography, scanning) as well as a timely, correct phase of the works carried out by the output data mining activities. Remote sensing technology is particularly effective in cases where the border and the border zone is located in difficult terrain and vegetation conditions. In Latvia case it refers to the marshy forests, swampy-healed places where the transfer is not possible with the means of transport and is very cumbersome leaving on foot or even practically not negotiable not to mention the quality of

works performance measurement capabilities. In the location of the national borders similar situations is enough considerably, rarer seen almost ideal working conditions for state border area.

Comparing the experience gained with the latest advances in geoinformatics technologies and remote sensing capabilities turning to remote sensing data acquisition flesh out the area of the section. Using compact technical capabilities and reducing the complexity of the procurement procedure, whose previous work experience was limited or completely prevented in a timely manner to get the desired output of remote sensing data, in addition to remote sensing techniques offer the opportunity to use the volume of demarcation works. Latvia - Russia border case complicated procedures affecting failed to book laser scanning works, which increased the time and costs of rural surveying.

To date, a real improvement for the demarcation in both the quality and volumes to remote sensing technology opportunities associated with UAVs applications whose needs are already available in small-sized, but very high quality photography and laser scanning equipment. For processing of data available almost fully automated software products. Own UAVs pilotage does not need highly prepared specialist aerobatic aircraft. These aircraft operating and maintenance costs are negligible compared to the classically equipped aerial photography aircraft - so the resulting product cost becomes very attractive. If this accompanied by data mining efficiency and simplicity that in the near future remote sensing methods and data use volumes border demarcation process should be increased to a significant extent. As an additional possibility of remote sensing increasing stimulating factor to take into account, modern Geographical Information System (GIS) for use possibilities development in demarcation works realisation. They offer excellent opportunities for manipulation by remote sensing and other geo-information data, creating both new and more efficient work performance opportunities and a range of new spatial information products and services to the demarcation operators and drivers. Also, articles added to the sample of examples created using GIS software options.

The gained experience and perspective opportunity to view not only relevant to a new border demarcation works. They need to learn to fully realize the country's - such as Latvia, which currently demarcation works will be concluded for the entire national border. As with any construction project being placed into service in the state border required for its maintenance, which should be started immediately after its commissioning. In the maintenance regime to a greater or lesser extent, sooner or later, in the whole border or one of its phase will need to perform the work forms that will be more or less equivalent to the demarcation of their service, including with regard to the creation of a geographic competence measures. The reason - the natural and the human impact on the installed border long-term sustainability. The results are already clearly visible already demarcated state border cases *(Figure 6).* In addition, such as changes detection effective use the remote sensing techniques in combination with GIS capabilities.

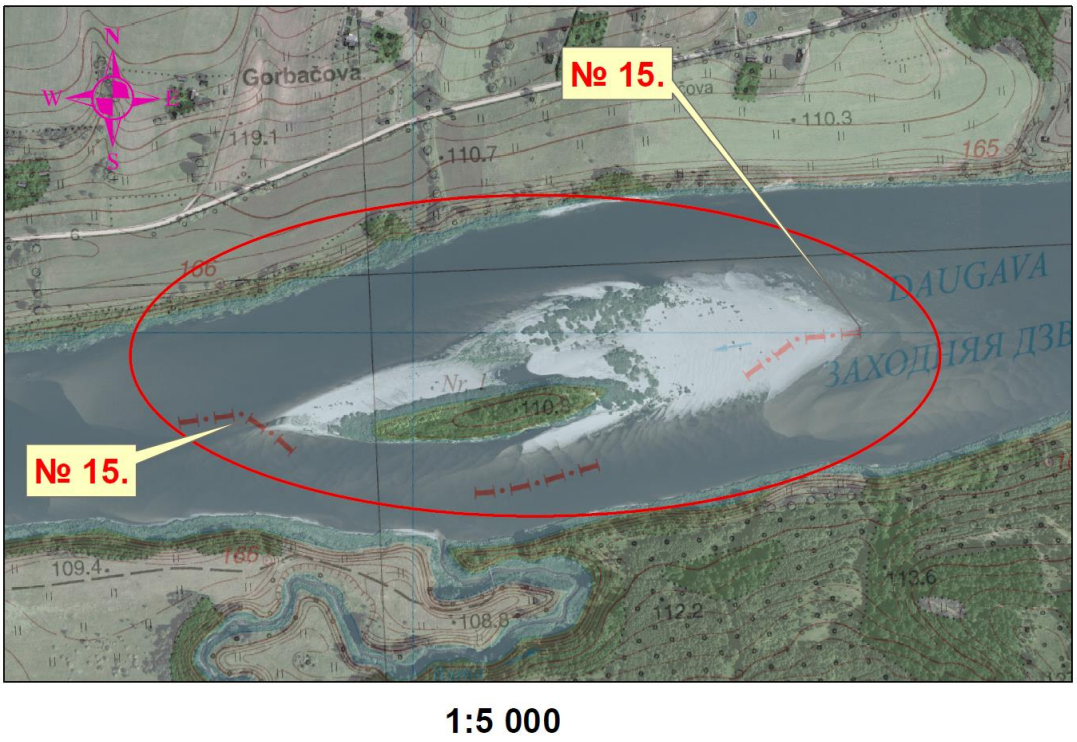

Figure 6 - The demarcation of the state border location of non-compliance with real off-road situation - the natural process of development result example.

Conclusions

1. The existing State border demarcation work experience assessment indicates the remote sensing material application the increasing importance of the border survey work execution and quality evaluation,

- *The more you bring opportunities to get a variety of high-quality remote sensing materials demarcation work process - that the more likely that they are to be use in the border surveying (and not just a surveying) works.*

2. Remote sensing technology use, along with the Geographic Information System (GIS) capabilities, opening up new development opportunities for the state border demarcation works of the organization,

- *Including the state border surveying works quality assessment.*

3. Remote sensing material application allows you to reduce the field measurement or control of procedures at the same time dramatically increasing the amount of controlled outcome;

4. Remote sensing material application at the same time with the works control possibilities increase allows to significantly save labour resources and reduce the time required for the checks;

5. Remote sensing material allows an extra - an independent, survey results control option in cases where the two countries are determined professionals a complete and independent surveying repetition criterion.

6. Modern remote sensing technology including the equipped with UAVs application possibilities, points to a radically higher and larger remote sensing material extraction and use prospects in the state border demarcation works.

- Substantially changes the state border surveying of the works organization, including the boundary surveying of quality assurance capabilities.

References

1. Graíina Siizienė. DEMARKUOTA VALSTYBES SIENA SU BALTARUSIJOS RESPUBLIKA, журнал GEODEZIJA IR KARTOGRAFIJA /

GEODESY AND CARTOGRAPHY 2008 год. 10.3846/ i 392-154 i .2008.34.75-81
2. Krikštaponis B. (2001) Analysis of the Geodetic Vertical Networks Development by Digital Levels. Summary of Doctoral Dissertation. Vilnius Gediminas Technical University, technological sciences, measurements engineering.
3. Ratkevičs A., Celms A., Kukule I., (2016) Geodetic base preparation for state border demarcation, Proceedings "Modern advancements on geodetic science and industry" volume II (32) of Western Geodetic Society of Ukrainian Society of Geodesy and Cartography, Lviv Polytechnic National University press, Lviv, 2016, 45 - 56 pp.
4. Ratkevičs A., Celms A., Baumane V., Reķe I., (2016) Decision of geodetic substantiation for border demarcation of Latvia, Universitatea Agrară de Stat din Moldova. Lucrări ştiinţifice – Chişinău, 2016. – Vol.46 : Cadastru şi drept, p. 108-11
5. Кашаев В.И., Шкурков В.В. Нормативные документы по обеспечению делимитации и демаркации государственной границы Российской Федерации. Геодезия и картография. №19 2003 г. М. Стр. 24-26.
6. Skeivalas J., Gecyte S., Alekniene E. (2008) Error's Models of Geodetic Vertical Network. In: 7th International Conference Environmental Engineering, May 22-23, 2008, Vilnius, p. 106-111.
7. Бурбан П.Ю. Демаркация российско-латвийской границы, Вестник Россреестра, №1(3), 2010 . С.39-42.
8. Архипов А.И. Установление и содержание государственной границы Республики Беларусь (1991-2010 гг.), Орша 2011г. 264 стр.
9. Архипов А.И., "Установление и содержание государственной границы Республики Беларусь (1991-2010 гг.)": учебно-методическое пособие, Орша, Оршанская тип., 2011. — 264 с. ISBN 978-985–7016–04–4
10. Бурбан П.Ю. Опыт использования спутниковых технологий и данных дистанционного зондирования Земли при демаркации государственной границы. «Земля Беларуси». №3, Минск 2012 г. Стр. 6-8.
11. Бурбан П.Ю. Геодезическое обеспечение демаркации точки стыка государственных границ. Современные достижения геодезической науки и производства. Сборник научных трудов Западного геодезического общества УТГК. Львов. 2013 г. С. 35-39.
12. Горобец В.П., Демьянов Г.В., Майоров А.Н., Побединский Г.Г. Результаты построения государственной геоцентрической системы координат Российской Федерации в рамках ФЦП «ГЛОНАСС». Геодезия и картография № 2 2012 г. стр. 53-57.
13. Инструкция о картографо-геодезическом обеспечении демаркации Государственной границы Республики Беларусь. (Комитет по земельным ресурсам, геодезии и картографии при совете Министров и Государственный комитета пограничных войск Республики Беларусь. 20.12.2004 № 50/14).
14. Руководство пользователя по выполнению работ в системе координат 1995 года (СК-95) ГКИНП (ГНТА)-06-278-04 М. ЦНИИГАИК 2004 г. 137 стр.
15. Бурбан П., Раткевичс А., (2016) Современные технологии при создании общего геодезического обоснования демаркации государственной границы. Geoforum 2016, Lvova, Современные достижения геодезической науки и практики, Выпуск 31, стр. 16, ISSN 1819-1339

Remote Sensing Methods and Materials Usage in State Border Demarcation Works

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State border surveying work - as part of Demarcation process include over than simple a number of different geodetic surveying work realisation. The Demarcation works the framework of within to carry out surveying and topographic surveying work to them can be

added the following measures: - establish common geodetic reference network in border land, where are included such works as in geodetic points surveying, the coordinate calculations and network alignments; - projected (delimitation) state border line position determination and the initial postponement of the current area; - the state border marking and the strengthening of the area; - organize in the wild area strengthed the state border technical and legal documentation, in accordance with the intergovernmental contract conditions. In these works, we meet more or less geodesic or topographic surveying amount of work, where result requires different usage and attainable quality indicators (1). Amount of usage, as well as the place and role in the implementation of various measures are different, ranging from a simple consumable product and the end by modern sense irreplaceable survey technologies and product range. In Common geodetic reference network in the works they serve as support and improve the organization, usually orthophoto. Project state borderline position determination and the initial postponement as a boundary line of the project and its implementation ameliorative material (orthophoto, aero images, laser scan results). The state border marking and the strengthening of the area as project development and implementation of ameliorative material (orthophoto, aero images, laser scan results). Organize process in the wild area of strengthed the state boundaries of technical and legal documentation as an essential drafting basic material such demarcation card boundary abriss and describes the compilation (3).

During the Demarcation works can include the national border of the band creation measures, where implemented topographical survey works, ensuring the border zone forming which are part of property alienation. Also, these work organization and control is used remote sensing technologies and materials, which, combined with geographic information system capabilities significantly, improve the results (4). Summarizing the Latvian State practice implemented by the State border demarcation work experience and their assessment of the obtained strong indications that remote sensing technologies and materials applications are of growing importance.

Remote sensing technology for use together with geographic information systems opens up new possibilities for development state border demarcation work of the organization.

The study was conducted based on Latvian - Russian state border demarcation process, survey works used in practice and the experience gained in 1999 -2017 years