

NUCLEAR WASTE RELATED SATELLITE MAPPING IN NORTHWEST RUSSIA

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ABSTRACT:

In the early phase of a project organized by the Norwegian Radiation Protection Authority (NRPA) dealing with monitoring of radioactive radiation from nuclear waste deposited at the former naval station Andreeva Bay in northwest Russia, a suitable base map at a scale sufficiently large to be used as a georeferencing tool for radiation measurements and also as a background map for presentations, was not available. It was therefore decided to use high resolution satellite imagery for this purpose, and a collaboration with the Geomatics section – IMT at the Norwegian University of Life Sciences (UMB), was established. A Landsat-7 ETM+ precision corrected scene from the USGS 15 meter resolution data collection was used as a basis for a georeference adjustment of a system corrected QuickBird sub-scene. By establishing an adequate transformations based on Ground Control Points (GCPs), between the adjusted QuickBird sub-scene and a local grid, it was possible to locate the original radioactive radiation measurements with acceptable precision within the UTM Sone 36 N WGS84 geographical reference frame. At a later stage of the project, after the Satellite Image Map preparation, a digital version in raster format of a Russian topographic map sheet at scale 1:50 000 became available. This dataset offered a possibility for the assessment of the combined Landsat-7 ETM+ / QuickBird rectification, and in addition an opportunity for an assessment of the influence of the terrain elevation on the geometry of the rectified satellite image.

1. INTRODUCTION

1.1 Background and organizational framework

The Andreeva Bay shore technical base (STB), located at 69°27'10"N and 32°22'00"E on the northwestern side of the Zapadnaya Litza fjord in Murmansk County, Russia, is one of the largest and most hazardous nuclear waste deposits in the northwest Russia, with large quantities of aging storage facilities for spent nuclear fuel (SNF) and radioactive waste (RAW). Established in the late 50-ties or early 60's, this naval facility performed activities related to the refuelling of Russian Northern Fleet as well as being a temporary storage site for SNF and solid and liquid radioactive wastes (SRW and LRW) arising as a result of civilian and military nuclear-propelled vessels operations and maintenance (Reistad et. al 2007)

Based on contracts between the Norwegian Radiation Protection Authority (NRPA) and the Russian site operator, the Russian Northern Radioactive Waste Handling Federal Enterprise (SevRAO), the first part of the survey project was carried out supported by Russian expert organisations. The complete survey was financed by the Norwegian Ministry of Foreign Affairs under the Norwegian Plan of Action for Nuclear Safety Issues.

The the main results of the Norwegian program to assist Russia in the completion of an environmental survey of the former Russian naval base in Andreeva Bay, was presented at the 11th International Conference on Environmental Remediation and Radiactive Waste Management ICEM2007 in

Bruges, Belgium in September 2007. under the title: "Site survey of former naval base in Andreeva Bay, northwest-Russia – Radiation levels and radionuclide concentrations on and below the surface level. (Reistad et. al 2007).

1.2 The geometrical aspect

The initial part of the survey comprised about 1030 points for the measurement of dose rate in two heights above the ground level (0.1 m, 1 m) and radionuclide concentrations, and the drilling of 50 boreholes for further examination of the radionuclide releases on site. During the field work the measurements of radioactive radiation carried out were georeferenced to a local geographical reference system established as a grid with 10 m and 5 m mesh size. The origo and orientation of the reference system was defined by one corner and the two adjacent walls of one of the largest buildings in the area. Unfortunately equipment for determination of location, based on global navigation satellite systems (GNSS) was not used in connection with these measurements. The map based on the local geographic reference system described above, is shown in Figure 1 below.

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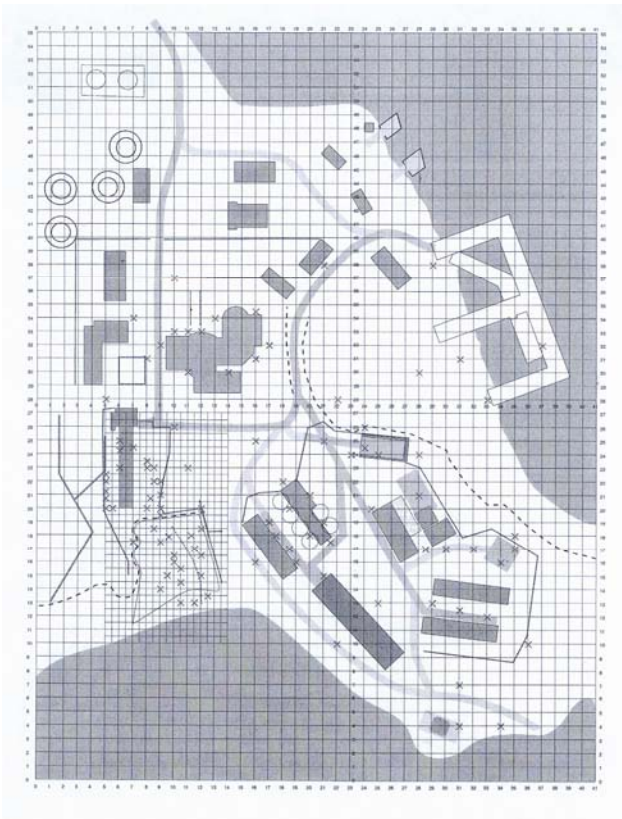


Figure 1. Original map with 5m grid from the initial field survey.

This survey was carried out in 2002-04 in cooperation with Russian governmental organisations. It was also established a 1:500 map covering the area, but this map was for unknown reasons not made available to NRPA by the Russians until the summer of 2007, and even at this time with the restriction that it could be used only for internal work, and not in any kinds of official publications. Since the 1:500 map, initially considered as an important tool to be used in the international remediation effort, was not public accessible, it was therefore decided that the second part of the survey comprising the analysis and documentation of the results, should be supported by another type of adequate maps, namely a Satellite Image Maps. These maps, geo-referenced to the UTM WGS84 system, were established on the basis of a high resolution commercially available satellite image from 2004. The idea was to use Satellite Image Maps for presentation as backdrop in combination with the measurement grid and results regarding radiation and activity levels in addition to coastline contour and selected infrastructure elements.

1.3 The role of UMB in the project.

An agreement between The Geomatics section, Department of Mathematical Sciences (IMT), Norwegian University of Life Sciences UMB (Universitetet for Miljø- og biovitenskap) and NRPA was therefore established with the purpose of undertaking the Satellite Image Map preparation component of the project, and it is this activity that is described in this paper

2. MATERIALS AND METHODS

2.1 Selection of high resolution satellite imagery

A search for suitable high resolution imagery acquired by the satellites IKONOS and QuickBird was carried out on the Internet, utilizing the on-line catalogues provided by the companies GeoEye (formerly EarthWatch) and DigitalGlobe. After having taken into consideration factors like area covered, cloud cover, season (snow cover/vegetation) and observation angle, a QuickBird scene acquired on July 1st 2004, was the final choice. The QuickLook (QL) of this scene is shown in Figure 2. Since the whole scene covered more than needed, the possibility of ordering a 5x5 km (minimum size) subscene was utilized. The extent of this 5x5 km subscene is also shown in Figure 2. Ideally the off-nadir angle could have been closer to the vertical than 19 degrees. Taken into consideration the fact that the terrain elevation within the central part of the Adreeva Bay STB does not exceed 30 meters above sea level, this off-nadir angle was deemed as acceptable

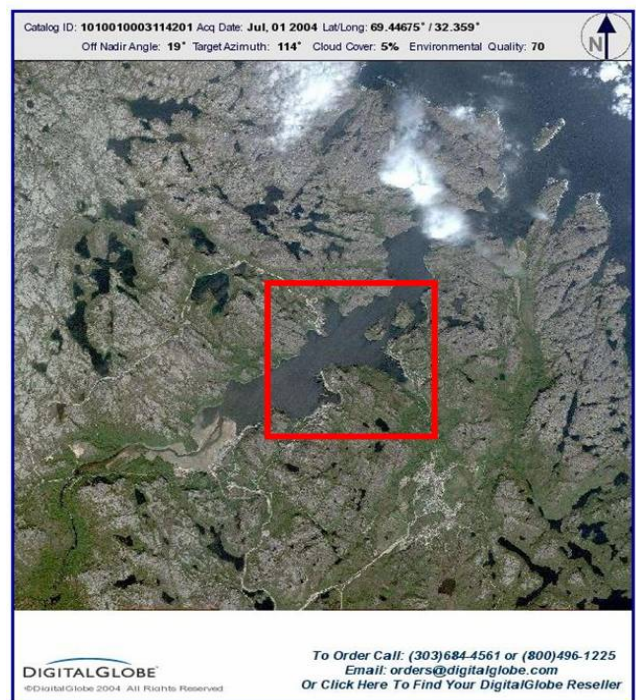


Figure 2. QuickLook for the selected QuickBird scene. The 5x5 km subscene which was ordered is indicated by red frame.

| Image Metadata | |
|-----------------------|------------------|
| ACQUISITION DATE | 2004-07-01 |
| CLOUD COVER | 5% |
| CATALOG ID | 1010010003114201 |
| PAN RESOLUTION | 0.68 meters |
| MULTI RESOLUTION | 2.72 meters |
| ENVIRONMENTAL QUALITY | 70 - Good |
| OFF-NADIR | 19 degrees |
| STEREO PAIR ID | NONE |

Table 1. Metadata for the selected QuickBird scene

2.2 Georeference adjustment

The QuickBird subscene image dataset was procured from the European Digitalglobe representative Eurimage. Product type was “Standard imagery”, which means that no GCPs had been involved in the geometric rectification, in other words; a so called system corrected satellite image. In the Eurimage product description for QuickBird data (Eurimage, 2008), the information regarding geometric accuracy is as follows:

“All Standard products may achieve an absolute geolocation accuracy of up to 14-meter RMSE (up to 23-meter CE90%), excluding any topographic displacement. Ground location is derived from refined satellite attitude and ephemeris information without requiring the use of Ground Control Points (GCPs)”.

There was a discussion within the project team about the possibility to improve this accuracy, and the idea to use Landsat-7 orthorectified imagery for this purpose came up. A suitable Landsat-7 ETM+ orthorectified dataset with spatial resolution 15m, was downloaded free of charge from the USGS GLOVIS (Global Visualization Viewer) web site. Initially the idea was to control the geometric accuracy of the Landsat-7 ETM+ orthorectified scene with topographic map data from testfields located within Norwegian territory. The control should be carried out by visual inspection using the “Blend” and “Swipe” functions in the ERDAS Imagine 9.1 digital image processing system when overlaying the topomap with a watermask obtained by an appropriate treshholding of the near infrared Landsat ETM+ band 4. If necessary, an adjustment of the Landsat-7 ETM+ geometry could be carried out based on this comparison.

The next step would then be to make a corresponding comparison between the system corrected QuickBird subscene, and the Landsat-7 ETM+ scene, now defined as the true geometric reference. If needed, a correction of the geometry of the QuickBird subscene could then be carried out. If the transformation involved could be considered as very close to a pure translation, resampling would not be needed. An adjustment of the georeferencing, or in other words; a change of the values for the coordinates of the upper left hand corner with an amount of ΔE and ΔN in the east-west and north-south directions respectively, would be sufficient.

Figure 3 shows the water mask obtained from the near infrared band 4 of an orthorectified Landsat ETM+ data set. Letters A-D in Figure 3 indicate topography map test areas within Norwegian territory. Letter F in Figure 3 indicates location of the Adreeva Bay QuickBird subscene.

Figure 4 shows a part of the topographic map test area B (see Figure 3). The geometric match between the water-mask and the topo-map is deemed as astonishingly good. The observed accuracy was regarded as sufficiently good, so no further geometric correction was necessary.

Figure 5 shows a geometric miss-match between the reference water-mask and the QuickBird subscene amountin to approximately 15m in the E-W as well as in the N-S direction.

Figure 6 shows the effect of a bidirectional 15 m georeference adjustment applied to the QuickBird Sub-scene.

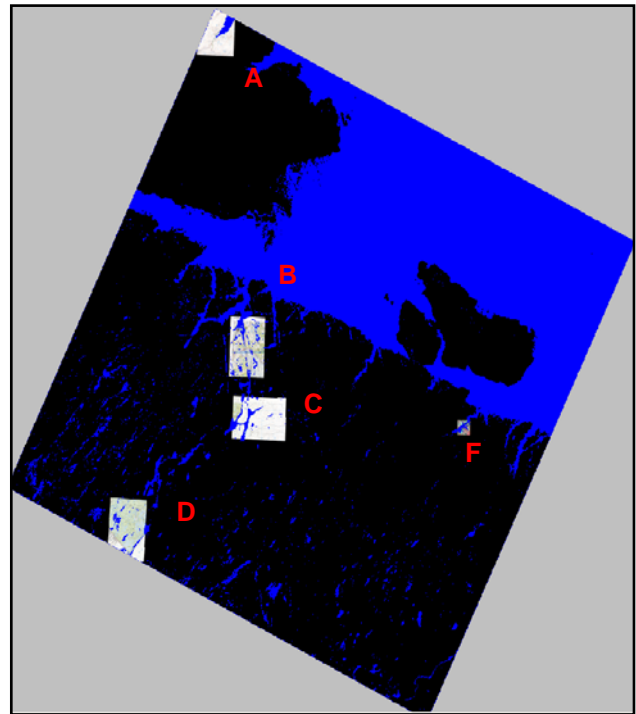


Figure 3. Water mask (blue) obtained from the near infrared band 4 of an orthorectified Landsat ETM+ data set. Letters A-D indicate topography map test areas within Norwegian territory. Letter F indicates location of the Adreeva Bay QuickBird subscene.

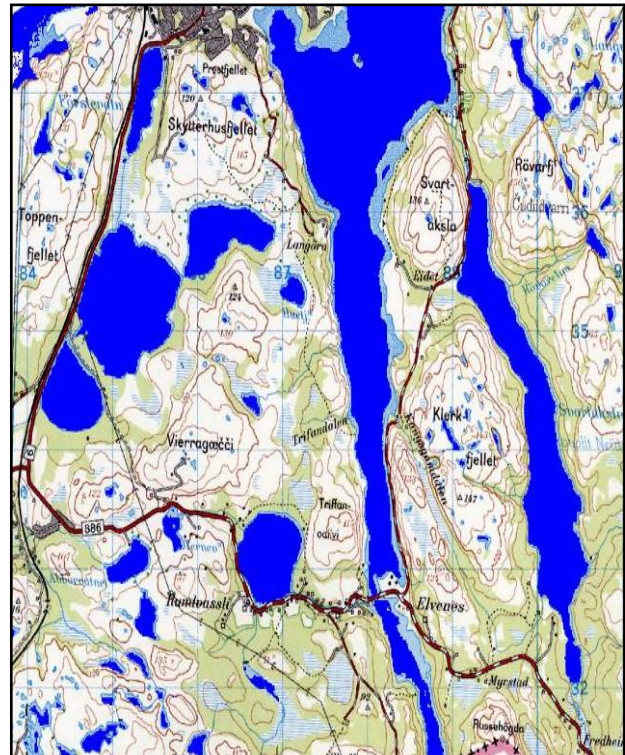


Figure 4. Comparison between water-mask derived from band 4 of orthorectified Landsat-7 ETM+ scene and topo-map. Topo map test area B (see Figure 3) is shown here, and the geometric match between the water-mask and the topo-map is deemed as astonishingly good.



Figure 5. Comparison between water-mask derived from orthorectified Landsat-7 ETM+ near infrared band 4 and original system corrected QuickBird sub-scene.

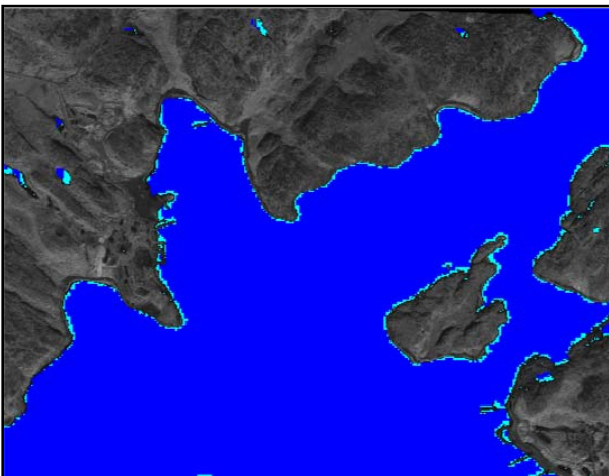


Figure 6. Comparison between water-mask derived from orthorectified Landsat-7 ETM+ near infrared band 4 and QuickBird sub-scene after georeference adjustment.

2.3 Image enhancement

In addition to the geometric correction in the form of a georeference adjustment, not involving any resampling, as described above in paragraph 2.2, radiometric enhancement was also applied to the QuickBird sub-scene. This enhancement comprised a linear contrast stretch combined with the so-called HPF (High Pass Filter) resolution merge algorithm available in the ERDAS Imagine 9.1 digital image processing software. The result of this sort of enhancement is shown in Figure 7 and Figure 8.

3. RESULTING MAPS

3.1 Plot of measurements

With the geometrically adjusted and radiometrically enhanced version of the QuickBird sub-scene as a reference dataset, it was possible by the use of ground control points to establish a

first order polynomial transformation between the original field map shown in Figure 1 and the UTM WGS84 Sone 36 geographical reference frame, as shown in Figure 9. Figure 10, Figure 11 and Figure 12 below show how the availability of the geometrically adjusted QuickBird subscene was used by the NRPA in their report as a backdrop-map for the presentation of georeferenced measurements related to radioactive radiation

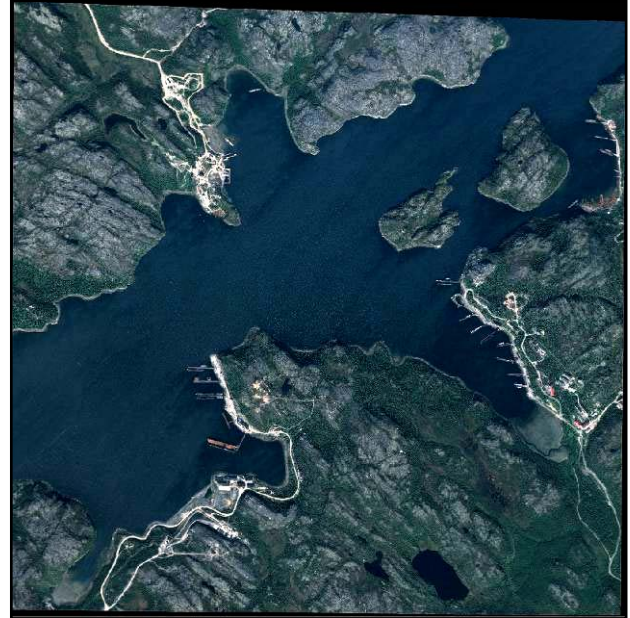


Figure 7. Final version of the QuickBird satellite image sub-scene. Geometric accuracy is improved in relation to the original dataset. Radiometric enhancement in the form of a linear contrast stretch combined with a resolution merge is also carried out. Reference system is UTM WGS84 Sone 36.

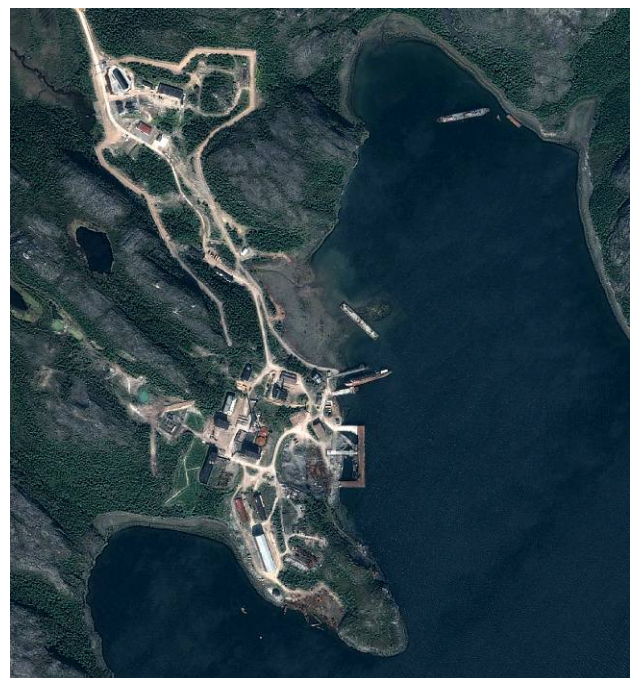


Figure 8. Enlarged version of the sub-scene in Figure 7, showing the Adreeva Bay area.

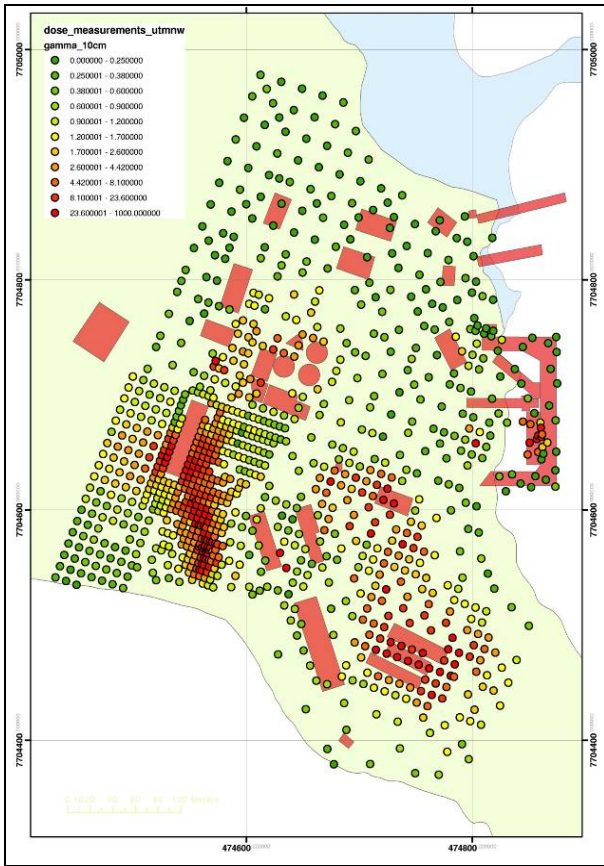


Figure 9. Measurement grid for dose-rate measurements (10 cm and 1 m above the ground surface). Values shown for 10 cm. The geographical reference system used is not longer the local one shown in Figure 1, but has now been changed to UTM WGS84 Sone 36.

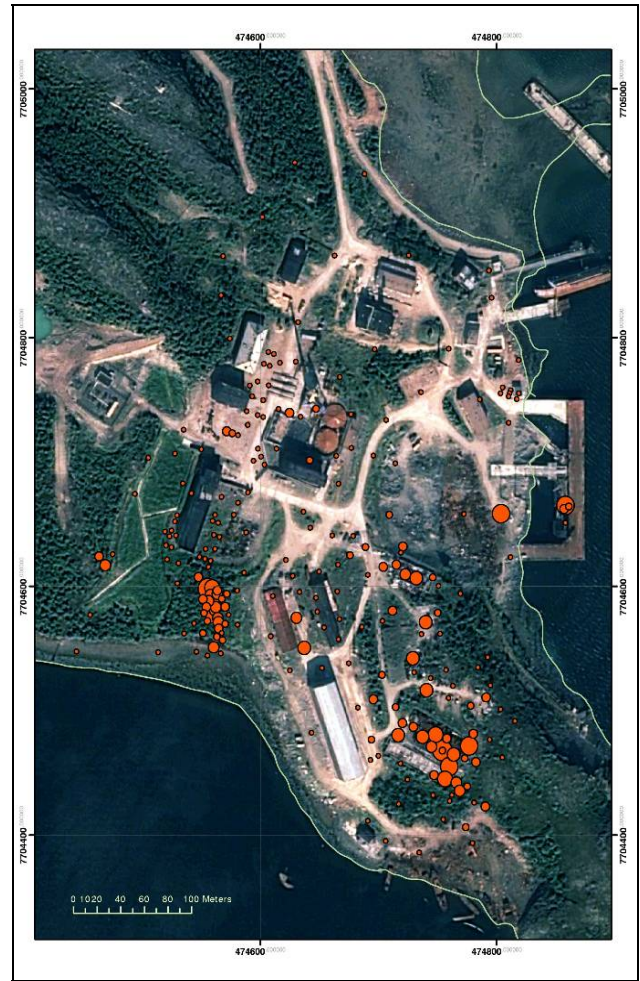


Figure 11. Sampling points for measurements of radionuclide concentrations (Cs-137, Sr-90). Values shown for Sr-90.



Figure 10. Map of the Andreeva Bay, geo-referenced to the UTM WGS84 Sone 36 system, with main structures and buildings



Figure 12. Location of boreholes drilled as part of the survey of the contaminated site area around Building 5, the DSU and the SRW storage facility

4. COMPARISON WITH TOPOGRAPHIC MAP

4.1 Availability of Russian 1 : 50 000 topographic map.

In the beginning of 2007, at a very late stage of the project, after the Satellite Image Map preparation had been completed, a digital version in raster format of a Russian topographic map sheet at scale 1:50 000 became available. This dataset offered then a possibility for the assessment of the combined Landsat-7 ETM+ / QuickBird rectification, and in addition an opportunity for an assessment of the influence of the terrain elevation on the geometry of the rectified satellite image. A subset of this map is shown as Figure 13.

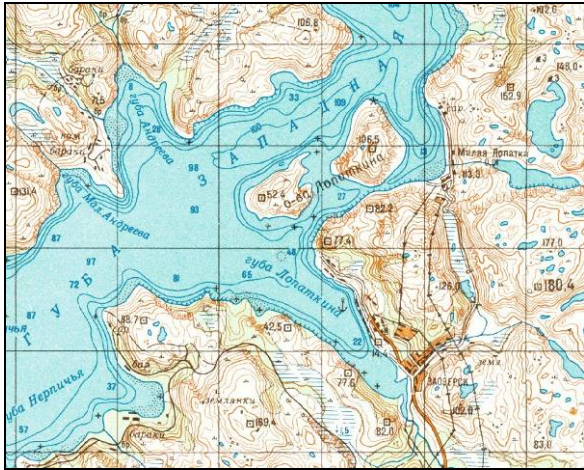


Figure 13. Sub-set of Russian topographic map at original scale 1:50 000 in raster format. Contour interval is 10 meters.

4.2 Map comparison

Due to the so-called “Double Standards of Map Accuracy in Soviet Cartography” (Postnikov, A. V., 2002), it was uncertain what a comparison between the geometrically corrected QuickBird sub-scene and the topographic map would look like. The result is shown in Figure 14, as an overlay image from ERDAS Imagine with the “Blend” function active. The geometrical match between the two sets of geodata could hardly be better.

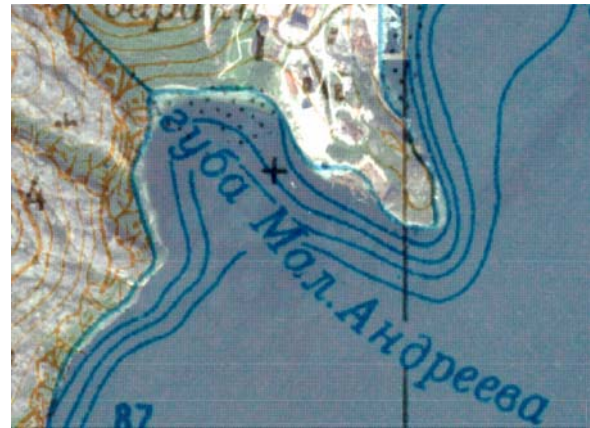


Figure 14. Comparison between the geometrically corrected QuickBird sub-scene and the 1 : 50 000 topographic map.

The vertical distance between the contours in the topomap is 10 meters. The possibility of generating a digital elevation model from the topomap has been considered, but was beyond the scope for this project. The intention is however in the near future, to carry out the generation of such a digital elevation model as part of ongoing research in the Geomatics section at IMT-UMB. If such an elevation model is established, the possibilities for orthorectification of the QuickBird sub-scene in question will be investigated.

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