A GIS for the Yenisei: an overview of maritime industrial archaeology on the Yenisei River and prospects for its development

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Abstract. In 2018, Reshetnev Siberian State University of Science and Technology launched the Geographic Information System Yenisei – Arctic Project with the objective of creating a digital cartographic system of the Yenisei River and its basin. Among the primary tasks is visualizing the riverbed using side-scan sonar and locating and cataloging submerged man-made objects, including those with certain historical value. In this report, the author addresses some issues relevant to maritime archaeology on the Yenisei River in connection with the project.

1. Introduction
In 2018, Reshetnev Siberian State University of Science and Technology (Reshetnev University), Krasnoyarsk, Russia initiated work on an interdisciplinary project titled the ‘Geographic Information System Yenisei – Arctic’. The main objective of the project, as follows from its title, is the construction of a specialized Geographic Information System (GIS) of the Yenisei River basin (Fig. 1). Along with collecting updated geographic and environmental data (Fig. 1), it is planned to include a large historical content into the system’s framework.

2. Project background
The river Yenisei and its largest tributaries (Fig. 2) boast a rich history of shipping and industrial activity that have deeply impacted the river and its basin. The history of shipping on the Yenisei dates back to the 17th century and is firmly connected to the arrival of the first Russian explorers. During the 17th and 18th centuries, multiple unsuccessful attempts had been made to establish a sea route from this river to European ports, a feat that was first accomplished only in the 1870s. Kara Sea shipping evolved with a particular intensity during the 1920s–30s; and in 1929, the first permanent seaport – Igarka was constructed on the Yenisei. Ever since, this Siberian river has been a key destination for seagoing vessels traversing the Northern Sea Route. Auxiliary inland river navigation also saw intense development during the Soviet era (1920–1991). The remnants of this activity are scattered along the riverbanks and in the waters of the Yenisei and its tributaries.
Until recently, there have been few cases of maritime archeological investigations in Siberia. The main reasons for this are, firstly, a settled notion that since the region is mostly landlocked and situated far inland, there is little potential for underwater archaeological research. Secondly, knowledge on the history of riverine and maritime navigation on the Yenisei especially during its development in the 18th, 19th, and 20th centuries is chiefly restricted to factual data, with only a handful of studies addressing the bulk of human interactions with the river. Overall, despite the existence of numerous investigations on the development of the Northern Sea Route and Arctic exploration, few of them can be classified as complex studies on the maritime history of Siberia. For instance, the authors of many standard references \[e.g., 1; 2\] focus more on the economic and political aspects of shipping along the Northern Sea Route and, to a lesser extent, the great rivers of Siberia – the Ob’, Yenisei, and Lena. Such topics as the history of local shipbuilding, navigation techniques, and seamanship are often overlooked despite their vital importance to understanding the history of human activity on the major waterways of Siberia. To our knowledge there are no up-to-date comprehensive investigations into the material world of the shipping industry of the 19th and particularly the 20th century, both as desk studies and \textit{in situ} research, a practice known as industrial archaeology.

This brings us to the third reason for the slow development of underwater archaeology in Siberia, which is the lack of adequate and readily available knowledge on the existence of local maritime historical monuments. Furthermore, such vital archaeological practices as underwater research are aggravated by the deficit of necessary equipment, which often has a high cost, thereby deterring research institutions from engaging in relevant studies. To add to this, proper training is required for the operating personnel of hydroacoustic systems and remotely operated underwater vehicles (ROVs), along with an adequate expertise in scuba diving.

Thus, the above-mentioned factors have restrained a full-scale emergence of marine and riverine archaeology in Siberia. At the same time, the massive investments into various industrial projects, such as the development of oil and gas mining, transportation systems, and other projects related to Siberia and the Arctic have resulted in the intensification of construction. In compliance with Russian legislation, particularly the Federal Law No. 73-FZ (25 June 2002), it is mandatory to perform thorough archeological investigation at projected construction sites prior to the building activities. This includes underwater archaeological sites.

During the last two decades, there has been a significant increase of interest towards the exploration of underwater archaeological and historical sites in the Russian Federation \[3\]. Exploration is conducted by both professional and (often illegally) amateur divers. However, the geography of Russian maritime archaeology is chiefly limited to the Black Sea, the Baltic Sea, and the Far East. Most underwater investigations are performed using traditional methods, such as scuba diving.

Recently, there has been a worldwide boom in the usage of underwater acoustic imaging systems, both professional and recreational, e.g. fishfinders with integrated side-scan sonar (SSS) modules, and various ROVs. However, as aforementioned, this practice has found very limited application in Siberia. To our knowledge, there have been only a few cases of maritime archaeological investigation in Siberia and its coastal seas.
expedition was organized into the Kara Sea under the auspices of the Administration of Yamalo-Nenets Autonomous Okrug and the Russian Geographical Society. Using advanced sonar technology and ROVs the expedition revealed the remains of two Second World War Arctic convoys, including the wrecks of the ships Marina Raskova (sunk by a German U-boat in 1944) and Aleksandr Sibiriakov (sunk by the German battleship Admiral Sheer in 1942) [4]. Unfortunately, there is no knowledge of further follow-up research in connection with this project.

An ongoing project was begun in 2015 by a team of enthusiastic polar historians from Reshetnev University and the Krasnoyarsk Branch of the Russian Geographical Society. The objective of the project was to explore and document existing historical monuments related to the history of Arctic exploration, the Northern Sea Route, and shipping on the Yenisei. Without any funding, the team traveled almost 500 km by kayak from the town of Eniseisk to the village of Bor on the Yenisei River. Besides gathering extensive historical and ethnographic materials, the expedition established the probable location of the steamer Phoenix, which sunk on the Yenisei in 1892 after hitting an uncharted shoal in the rapids of the Osinivskii Porog. This steamer was delivered to the Yenisei in 1887 by Captain Joseph Wiggins (1832–1905) and was used by the Anglo-Siberian Trading Syndicate until being sold to a local Russian steamship company. The discovery was largely based on historical records and a report by the local hydrographic service of a shipwrecked vessel buried beneath the sands of the Feniksova Kosa island (Fig. 3). According to this report, fragments of the vessel’s superstructure are visible during low water levels. Unfortunately, none of the team members were able to revisit the island when the conditions for visualizing the wreck were fitting. Any archaeological investigations beyond determine the vessel’s location and implementing nondestructive methods were ruled out considering that a special permit is required by Russian legislation when the monument in question is over one hundred years old.

Further field investigations included the discovery of the steam schooner Thames in 2016. This vessel came to the Yenisei by sea in 1876. It sank in 1878 in the mouth of the river Sal’naia Kur’ia. Using archival data and secondary historical sources, the location of the wreck was determined. A series of dives revealed some ship details, which were first taken to be part of the superstructure, but after a follow-up study in 2018, showed that they were part of the hull that had been severely damaged during earlier dredging works.

The results of the field investigations in 2015 and 2016 convinced the team that in order to continue the research, it was necessary to obtain underwater imaging equipment that would allow collecting new data on the underwater historical heritage of the Yenisei River, its tributaries, and the coastal waters of the Kara Sea. Later archival research revealed that there were many more undiscovered shipwrecked vessels in these waters. It was decided that the most suitable imaging technique was the side scan sonar (SSS). The operating principles and exploitation of this device are exhaustively described in existing literature, among which [5] can be singled out as the most distinguished investigation. Strong currents and high sediment levels restrict the use of ROVs equipped with optical imaging devices. Besides, low temperatures, fast currents, and underwater obstacles make northern rivers such as the Yenisei difficult and dangerous places for human divers. Unlike ROVs and human divers, SSS allows covering large areas of the riverbed and determining the location of submerged objects, along
with assessing their initial condition. This enables the researchers to determine further investigation techniques and assess the potential of the overall study of a given historical monument.

In 2018, after a long history of persuading various university authorities and funding organizations, the research team received its first sonar equipment including a StarFish 990F™ high-resolution side scan sonar manufactured by Tritech International Ltd for operation in shallow water, and a Humminbird ONIX 10 cxi SI Combo™ fishfinder. Due to the fact that Reshetnev University is, primarily, a technical educational and research institution, it was necessary to expand the overall objective of the project and transform it into a multidisciplinary investigation. For this purpose the research team recruited specialists working in the fields of remote sensing and geographical information systems, geodesists, mathematicians, and programmers. The project was now aimed at building a GIS of the Yenisei River for the purpose of aiding small craft navigation (local river transportation companies already had their own information system for navigation) and determining the dynamics of changes in the river topography and benthic environment. The task of studying underwater archaeological monuments remained. However, it was expanded to locating, mapping, and determining the potential risk of submerged manmade objects, including shipwrecked vessels, land vehicles, aircraft, and various structures.

3. Field investigations in 2018.
In 2018, the first series of field investigations was launched. Traveling aboard an inflatable two-tonner catamaran, Taimyr-600 (the same watercraft used in 2016 (Fig. 4)), two members of the research team, including the author of this paper traveled about 600 km from the village of Turukhansk on the Yenisei River to the city of Dudinka. Another 150 km north were traversed without making any underwater investigations. En route, the researchers studied three major areas: (1) the mouth of the river Sal’naia Kur’ia (Fig. 5) (the unusual geomorphology of this site was noted in 2016 [6] and, therefore, required further investigation); (2) the Igarskai Protoka (this was the site of the former seaport of Igarka and it was rightfully anticipated that the site contained large quantities of anthropogenic objects); (3) the area of 30-meter depths at the village of Potapovo. The collected data is currently being processed in order to be incorporated into the GIS.

Besides collecting geographic data, the expedition of 2018 had the objective of understanding how to operate the new equipment in the waters of the lower Yenisei. Among the primary problems was maintaining steady movement and constant speed of the towed transducer. The river currents are unstable and, therefore, greatly affect the behavior of the transducer. Thereby, in shallower areas it is preferable to use a hull-mounted transducer or mount the towed transducer on a metallic pole or pipe, which is firmly attached to the vessel. This option, however, requires calm waters and a low intensity of river traffic as the wake of bypassing vessels and river waves cause an intense roll motion of the pole-mounted transducer. In areas with many motorboats, such as the Igarskia Protoka, it was necessary to tow the transducer. Here local fishermen, often curious of the work...
done by the team, would pass within ten meters of the catamaran thereby generating severe wakes. However, despite its greater stability in rough seas, towing is more labor intensive and negatively affects image quality if the towing speed is abruptly changed by currents. Furthermore, underwater currents have different speeds and unpredictable movement patterns, making it difficult to maintain stable transducer movement. A stationary mount, on the other hand, is preferable when the study area has a constant depth. In this case the transducer is to a lesser degree affected by the current. However, it might be difficult to retrieve the transducer in case there is a threat of colliding with an obstacle.

Fig. 5. Sunken motorboat in Sal’naia Kur’ as seen on SSS. Port (a) and starboard (b) image.
Fig. 6. Examples of shipwrecked vessels on the banks of the lower reaches of the Yenisei.

Another serious problem was sun glare. The monitor manufactured by the Russian Tetis Pro Company for the Starfish SSS did not have anti-glare protection, despite being designed for operating in outdoor conditions. This made it necessary to place the monitor under a canopy, or work only during cloudy weather or when the sun was low. The latter may be a serious problem when the fieldwork takes place during the Arctic summer.

Overall, the sonar data gathered in 2018 provides interesting insights into the underwater world of the Yenisei. In fact, these are the first known images of the Yenisei’s riverbed. In another report included in this same volume, the author presents more detailed results of the investigation of the Igarskaia Protoka, which was thoroughly surveyed in 2018. In later publications, it is planned to cover other areas of the Yenisei.

4. Conclusion
In conclusion, it is necessary to stress on the importance of future maritime archaeological investigations of the Yenisei and its basin. There are still many more historical objects and sites that await their discovery and study, such as the remains of shipwrecked vessels shown in Fig. 6. The proposed Yenisei – Arctic GIS is expected to have a special layer that will cover these monuments and show their location and contemporary state. This investigation is essential to our understanding of the history of both shipping on the Yenisei, which lay at the heart of the economic and social development of this region, and shipping on the Northern Sea Route.

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