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# AUV Survey in the Loukkos River

An article by *Lloyd Huff, Athena Trakadas, Nadia Mhammdi, Hasnaae Jirari and Mohamed Geawhari*

In October 2009, a survey was conducted in the Loukkos River starting at the river mouth near the present day seaport of Larache, Morocco, and proceeding up-river past two possible locations for the ancient Port of the archaeological site of Lixus. The survey was conducted using both an autonomous underwater vehicle (AUV) and a small manned surface craft. The survey was planned to serve two purposes: 1. Archaeological search for a physical port at the ancient settlement of Lixus; and 2. Studies of coastal change in the Loukkos River. The survey techniques included: GPS navigating, single-beam echosounding, sub-bottom profiling and side-scan imaging. The results of the AUV survey in the Loukkos River: 1. Water depths in the Loukkos River, which varied from 0.5 to 20 metres at high water;

2. Delineation of different bedforms, which varied from virtually non-existent through ripples to dunes; 3. Interesting sub-bottom features which may be indications of ancient Lixus maritime infrastructure; and 4. A better understanding of the pros and cons of conducting riverine surveys with an AUV.

AUV | Loukkos River | Lixus | river survey | shallow water | Iver2

## Archaeological significance of the survey

The October 2009, AUV survey in the Loukkos River Survey was undertaken as part of an archaeological search for evidence of a physical port at the ancient settlement of Lixus. Tchemmich hill, a large limestone plateau overlooking the Loukkos river basin, is located approximately 6 kilometres up stream from the river's mouth. Tchemmich hill is the site of the ancient city Lixus, which has been the subject of many archaeological studies with the excavated area estimated to represent about 20 % of the total extent of the ancient city. Lixus was one of the main cities of Mauretania Tingitana, a Roman province and was an important city during the reign of Emperor Claudius I in the early 1st century AD.

The largest installation for garum manufacturing in Mauretania Tingitana was located at Lixus. Salt, which is essential for garum production, was locally available from the sea marsh adjacent to Lixus, however large amount of goods, both raw (fresh fish and empty amphorae) and manufactured (sealed amphorae, filled with garum) would necessarily have moved into and out from Lixus. Logically that would have led to significant waterside facilities such as dock or quay structures, fish-salting basins and storage magazines. There has been speculation into two possible locations of such facilities (Tissot 1878; Ponsich 1966; Aranegui, 2007) and it is not unreasonable to think that both locations might be correct, al-

though at different times, as necessitated by meanderings of the Loukkos River. Tchemmich hill has been subjected to a periodic archaeological excavations for almost a century and yet, neither of the two proposed locations of a land-marine interface at Lixus has been systematically investigated.

## Hydrographic aspects of the survey

Hydrographic data acquisition was conducted on the Loukkos River for eight days in October 2009. The field work actually began by »running the river« in April 2009 using GPS in a small shallow draft boat to confirm exactly where the river banks were in WGS-84. In July 2009, as part of the run-up to the AUV survey in the Loukkos River, a three-day AUV survey was orchestrated in the Great Bay of New Hampshire, USA, in which three Iver2 vehicles from Ocean Server Technology, Inc were simultaneously operated.

During the Loukkos River survey, the Iver2 AUV was supported and augmented by a seven meter long fishing boat, the »Idrissi II«. A small temporary covered area was erected on the boat, which housed and protected the survey equipment and computer monitors. The survey was staged daily, in and out of the port at Larache, and due to the unavailability of a secure marine facility in the port, the survey equipment, as well as the temporary covered structure was installed and removed on each day of the survey.

The particular Iver2 AUV used in this survey (Fig. 1) was equipped with a single-beam echosounder, a side-scan sonar and a self-contained GPS unit. The conventional information obtained from the AUV included backscatter images of the river bed and vertical beam soundings. The AUV side-scan data were also processed to provide »enhanced« information in the form of the location of the air-water-bottom, triple point of the river bank and AUV altitudes (Fig. 2). The former information, when obtained at different stages of the tide for any given section of river bank, allows a three-dimensional model to be developed of areas that may be too shoal to

Fig. 1: Iver2 at the end of a mission and ready for pick up



safely survey with a vertical-beam echo-sounder. This technique, an extension to Huff (1993) and Lutter (2002), is particularly useful for depicting the bottom shape on the inside bends of a river where the dominant sediment process is likely to be depositional. The latter significantly improved the along track delineation of different bedforms, because the AUV side-scan sonar ping rate was up to 15 times faster than that of the AUV vertical-beam echo-sounder.

A Knudsen Model 320 Echo Sounder was operated from the »Idrissi II«. The Knudsen 320 was specially configured to transmit/receive a 5 to 10 kHz linear chirp using a conical transducer, which was mounted on the end of a vertical aluminium pipe and set 30 cm below the water surface. A Garmin Model 17-HVS GPS unit was attached to the top end of the same vertical pipe. Data from the GPS and echo-sounder were monitored in real-time from within the temporary enclosure set up on the »Idrissi II«. Profiles of the river bed and several notable sub-bottom variations in the sediments were among findings based on data obtained with the Knudsen 320 (Fig. 3).

Power (240 V AC and 12 V DC) for the onboard electronics was provided by a gasoline-powered generator, which was suspended from the boat gunwales on four hollow-core polypropylene lines. This technique of securing the generator led to Younes (Captain and owner of »Idrissi II«) being asked by other local fishermen if we were crazy. It may have raised suspicions about our sanity, but not having the generator sit directly on the boat's floorboards lowered the noise background in the echo-sounder by approximately 10 decibels.

The AUV was controlled by pre-programmed missions that were planned and graphically displayed on a laptop computer, using proprietary Ocean Server software and the April 2009 GPS locations of the river banks. Each specific mis-

sion plan called for the AUV to be launched from »Idrissi II«, and later, after completing its mission, it would be recovered onto »Idrissi II«. It was the ability of an AUV to faithfully run a pre-programmed path that made it especially attractive for surveying in the Loukkos River. An AUV eliminates image instability induced when using a short cable for towing side-scan sonar in shallow water. More importantly in an AUV operation it is not necessary to have a good coxswain with superior boat handling skills who can adhere to a complex survey plan in order to achieve high quality side-scan data.

The grand plan for surveying in the Loukkos River with an AUV involved a sequence of local exercises to build confidence in operating the Iver2. The AUV was initially run under manual control from a laptop computer via wireless communications from the beach of a small cove near the port of Larache. A significant amount of time was dedicated for the »Idrissi II« to practice approaching and picking up the AUV. For a time, the Iver2 was operated either tightly coupled to the survey boat or loosely coupled to the survey boat. There was a great feeling of success among the survey team when the AUV was allowed to run totally free of the survey boat.

In October 2009, survey data were successfully acquired on approximately 59 linear kilometres of survey track lines run in the Loukkos River. Eventually, after a fatal error occurred in the wireless link used to communicate with the Iver2 and the Knudsen 320 experienced a power supply failure, operations were suspended before completing the total survey plan.

In October 2010, the Morocco Maritime Research Group will return to the Loukkos River and again use an Iver2 AUV as part of the continuing search for evidence of a physical port at the ancient settlement of Lixus. □



Fig. 2: Section of AUV side-scan showing bedforms and river bank triple points (highlighted in red)

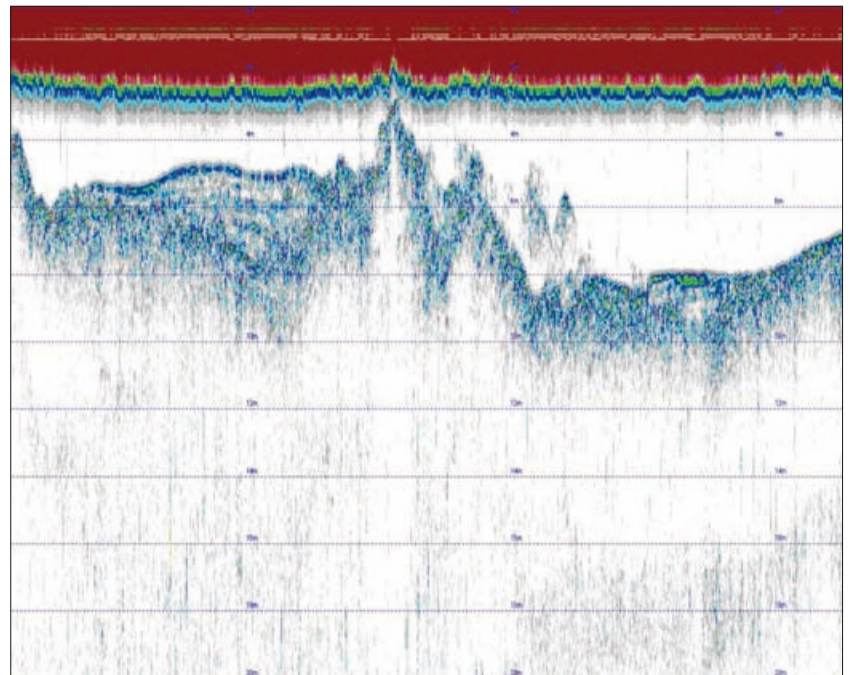


Fig. 3: Sub-bottom structures and Fish seen in Knudsen 320

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