Depopulation and devastation: using GIS for tracing changes in the archaeological landscape of Kharaib al-Dasht, a Late Islamic fishing village (Kuwait)

Paweł Lech | Piotr Zakrzewski

Polish Centre of Mediterranean Archaeology, University of Warsaw, Warszawa, Poland

Correspondence
Paweł Lech, University of Warsaw, Polish Centre of Mediterranean Archaeology, Nowy Świat 4, 00-497 Warszawa, Poland.
Email: p.lech@uw.edu.pl

Abstract
This article presents a case study of the remains of Kharaib al-Dasht (Kuwait), a Late Islamic fishing village. Collaboration between archaeologists from Kuwait and Poland of the Kuwaiti–Polish Archaeological Mission led to a long-term research project of this archaeological site. In this contribution we are presenting the results of a geographic information system (GIS)-structured survey. Different archaeological and geographical methods used in this work, including orthorectification and georeferencing of historical aerial photographs, enabled us to conduct a more in-depth analysis. The multi-layer GIS study resulted in a comprehensive recognition of the archaeological landscape of the site, and also helped us to determine the sources of changes and possible threats to the heritage of Failaka Island.

KEYWORDS
archaeology, GIS, heritage, Kharaib al-Dasht, Late Islamic period, UAV

Those who make maps have power over those who do not (Blakely, 2015, 133).

1 | INTRODUCTION

Heritage protection is challenged by different demands of local preservation laws, economic conditions of the country in question and development of preservation services operating in the given area. Other crucial factors include the involvement of the local community, the willingness to preserve one's heritage and the existing natural conditions. Archaeological services responsible for heritage protection are no longer limited to traditional methods of excavation and conservation of finds. Nowadays, archaeology has many digital tools at its disposal which help to understand the dynamics of changes at any archaeological site, thus enabling a better threat assessment and implementation of countermeasures.

The present article focuses on Kharaib al-Dasht, a settlement on Failaka Island, Kuwait. The main task of our study was to estimate the extent of the site and investigate the dynamics of changes in the archaeological landscape. As the last century witnessed an intensive manmade transformation of Failaka and further development plans are already in progress,¹ it is vital to support the protection of the local heritage and document the known (and still unknown) Kuwaiti heritage, including archaeological sites.

To fulfil this task, all the different digital tools used in archaeology were employed (Chapman, 2006; Church, Brandon, & Burgett, 2000, 135–155; Connolly & Lake, 2006; Gillings & Wheatley, 2002; Herrera, Parcero-Oubiña, & Fábrega-Alvarez, 2017; Roosevelt, Cobb, Moss, Olson, & Ünlüsoy, 2015, 325–346; Westoby, Brasington, Glasser, Hambrey, & Reynolds, 2012). A wide range of available past and present imaging techniques were used and combined, such as historic

¹Retrieved from http://www.gckuwait.com/portfolio_page/failaka-island-master-plan/, 6 April 2019.
aerial photographs, old and modern satellite imagery, topographical maps and products of photogrammetry created from unmanned aerial vehicle (UAV)-captured images. Based on these datasets, it was possible to establish the most plausible original layout of the Kharaib al-Dasht settlement, estimate the extent of the damages made in the past 50 years, as well as to set aims for further archaeological works in the area of site. All the data, combined with the knowledge obtained from excavations, was used for preparing a comprehensive geographic information system (GIS) analysis of modern endangerments for multi-period archaeological sites present on Failaka. Such approach may also improve the understanding of the relation between human activities and the landscape. Failaka Island in general, and Kharaib al-Dasht in particular, were perfect for such tasks owing to their small closed environment.

2 BACKGROUND: SITE LOCATION, LOCAL CONDITIONS AND PREVIOUS RESEARCH

For better understanding of the dynamics of changes in Failaka’s archaeological landscape and the nearest surroundings of the Kharaib al-Dasht settlement, a brief discussion on the historical background is required. Failaka is situated in the northern part of the Arabian Gulf, roughly 20 km away from Kuwait City. It is the third largest island of Kuwait, after Bubiyan and Warbach. Since antiquity, the island was of strategic importance due to its proximity to the entrance to Kuwait Bay, as well as to the mouths of Tigris and Euphrates. Although relatively small compared to the two other islands (44 km²) and very flat [the highest point reaches approximately 7 m above sea level (a.s.l.)], it proved to be an ideal place for settlements owing to its natural resources, most importantly large amounts of fresh water deposits and rich marine fauna. Furthermore, although the island is surrounded by shallow coastal waters, the significant tidal amplitudes provide ideal conditions for docking not only small fishing boats, but also large sailing vessels (Almutairi, 2011, 28–34; Salem, 2006).

According to the present state of research, Failaka was settled at least from the Bronze Age in the beginning of the second millennium BC by the Mesopotamians and, in the following centuries, it came under the influence of the Dilmun culture. The main archaeological sites of this period include Al-Khidr, Al-Khaznah and Al-Awazim. Already at the time, the island played an important role in the Arabian Gulf trade. This early chapter in Failaka’s history ended in the mid-second millennium BC, in the so-called Kassite period (Bibby, 1969; Højlund, 1987).

In the Hellenistic times, by order of Alexander the Great, the whole area of the Gulf was surveyed and mapped. The island was recognized as a suitable place for setting up trading operations and was colonized by the Greeks who named it Ikaros, as mentioned by ancient historians such as Strabo, 1989 (Geographica 16.3.2) and Arrian, 2013 (Indica 7.20.4). In the following decades, the Seleucids built a fort on the south-western coast of the island to control the wealthy trade routes of the northern Arabian Gulf, but they abandoned it after the collapse of the empire. The most noticeable remnant of those times seems to be the current name of the island, which most likely derives from the ancient Greek word meaning an outpost – φυλακιο(n) (Hansamans, 1967, 21–58; Calvet, 1983, 21–30).

Around the fifth–sixth century, a Nestorian community came to the island, searching for a secluded location. They settled in a large village of Al-Qusur, located in the centre of Failaka in a low-lying swamp area, and remained there until the seventh–eighth century (Bernard, Callot, & Salles, 1999). From then on, the island was continuously inhabited throughout the Islamic period (Patitucci & Uggeri, 1984) and by the end of the twentieth century, it had over 2000 residents who lived in the main village of Al-Zawr or in small farms scattered all over the island.

On 2 August 1990 the Iraqi forces invaded Kuwait and Failaka was taken by overwhelming forces. One year later, the allied troops forced the invaders to surrender using psychological warfare and bombings. This short period of occupation was quite devastating for the island’s infrastructure since the Iraqi army had not only mined the shoreline but also used the public facilities and buildings for target
practice. As a result of the Iraqi invasion, all Kuwaiti civilians were relocated from Failaka to the mainland, and even after the war, the island remained primarily military in character. Nonetheless, in the last few years it started to be regarded as a tourist destination once again.

Excavations on the island began in 1958 and continue to this day. Failaka is currently investigated by archaeological expeditions from France, Denmark, Italy, Slovakia, Georgia and Poland. Between 2012 and 2019, the Kuwaiti–Polish Archaeological Mission (KPAM) conducted seven seasons of fieldwork on the island. Our first project consisted of a large-scale survey along the coast, aiming to properly document new archaeological sites and verify then-available information on the previously identified settlements (Figure 1). Since 2013, the KPAM has been excavating the site of Kharaib al-Dasht, a Late Islamic fishing village situated in the north-western part of the island (Figure 2). The primary function of the settlement was determined based on finds related to fishing and fish processing, such as nets, weights, anchors, hooks, and ovens. This identification is further strengthened by the results of the underwater survey, which documented remains of fish traps located in the vicinity of the site (Nowakowska, 2017). It should be noted, however, that it is impossible to explicitly ascertain the chronology of such structures, as they are often used even today. Still, based on the written sources (India Office Records and Private Papers, IOR/R/15/2/368: 18, 1994) and parallel structures from Abu Dhabi (Beech, 2004, 46) it is plausible to assume that they were used extensively in the Late Islamic period by the inhabitants of Kharaib al-Dasht.

In the northern part of the site (Figure 3), there were unearthed architectural remains dated to the end of the eighteenth century and the beginning of the nineteenth century. These were crude structures, probably only seasonally occupied, which were located in the area featuring an abundance of ovens and hearths, used for fish processing. A more typical residential architecture of the Late Islamic period was attested in the central part of the site, represented by uncovered fragments of two houses, which also yielded finds related to fishing and fish-processing. East of the houses, there was unearthed a massive structure, interpreted as a mosque, with wide stone walls, pillars and a large courtyard (Mierzejwska, 2019; Pienkowska & Mierzejewska, 2018).

3 | TOOLS, COLLECTED DATA AND RESULT OF DATA INTEGRATION

The data integration, wide-range analyses, general collaboration and all visualizations was provided by ESRI software – ArcMap 10.6.1, which constituted an essential element for constructing the framework for spatial data management. It was also the main tool for combining all the different types of information. The application of ArcMap in this study was fundamental in conducting close scrutiny of the cycles of changes in the landscape. Autodesk AutoCAD 2017 was used for digitalization of archaeological plans and data collected with a total station. Efficient tools required for the preparation of precise photogrammetric documentation were provided by Agisoft Metashape Professional 1.6.1.10009. This version was designed for authoring GIS content and was used to create orthophotomaps and digital elevation models (DEMs) of Kharaib al-Dasht and its surroundings.

First, we collected all available data and prepared it for further integration. Archival aerial photographs were obtained from several sources. Aerial photography of the Arabian Gulf was acquired regularly not only for topographic usage, but also for military purposes, for instance spying. Therefore, high-resolution black and white photographs are usually clear and detailed. Owing to this, it was possible to prepare orthorectified mosaics for GIS integration in ArcMap. By courtesy of Shehab A.H. Shehab from the Department of Antiquities and Museums of the State of Kuwait, we were provided with 141 archival aerial photographs of Failaka, taken in 1960 and 1976.
The overlap of photographs was around 60% (Figure 4). Based on these raw images, orthophotomaps were made in Agisoft Metashape Professional. It is an effective tool for constructing orthophotomaps from archival aerial photographs, even without flight parameters or camera EXIF metadata as in the case of scanned photographs (Cogliati, Tonelli, Battaglia, & Scaioni, 2017, 19–16; Gennaretti, Ripa, Gobattoni, Boccia, & Pelorosso, 2011, 542–556; Gonçalves, 2016, 123–126; Pinto, Gonçalves, Beja, & Pradinho Honrado, 2019). What is more, the software’s efficiency is much higher in flat areas, rather than in complicated terrain (Pinto et al., 2019), making it all the more suitable for use in flat, semi-desert surroundings of Kharaib al-Dasht.

Next, we georeferenced the orthophotomaps in ArcMap. Georeferencing and rectifying of photomosaics was based on characteristic topographic points still present in Failaka’s landscape. Ground control points (GCPs) were identified during a land survey and on modern maps. Examples of GCPs used in the present study include stone fish traps, visible contours of farmyard buildings and characteristic rock formations. Although the changes in land cover often hindered the identification of GCPs visible on archival photographs, this step was nonetheless worthwhile and it produced satisfactory results (Ma & Buchwald, 2012). The accuracy of created orthophotomaps was verified against 1980 topographic plans prepared for the Municipality of Kuwait by Asia Air Surveys and revised by Hunting Surveys (Borehamwood, UK).² Cartometric analysis was introduced to review the accuracy of new maps created from old aerial pictures. Correct georeferencing of photographs was of vital importance, as they were to be used as spatial raster data in all subsequent analyses. Finally, two sets of photographs taken in October 1960 and June 1976 were orthorectified and served as the basis for comparative studies (Figure 5).

Aerial survey was an essential part of the project, conducted using DJI Phantom 3 Advanced UAV. After evaluating the extent of the site (known from the 2012 KPAM survey), it was decided that six GCPs needed to be established, located in the corners of the planned research area and in places of extremely high and low elevation. The general accuracy of the GCPs used to georeference and to scale the photogrammetric model was set to 0.005 m and the average error of checkpoints was 0.0252 m. The GCPs were marked by A4 sheets of white printing paper, arranged in a form of cross and nailed to the ground. The measurements were taken directly following the UAV’s flight with total station theodolite (TST) – Leica builder R200M. The coordinate system used was based on local benchmark of the Kuwait Transverse Mercator (KTM) grid (Mugnier, 2010). As the study area measured approximately 1 km², the aerial survey, including establishing of GCPs, was conducted by a team of three people in the course of a single day in April 2018. The aerial survey yielded 206 images, taken at average flight altitude of 114 m (Figure 6). As

²The topographic plans were also provided to us by courtesy of Shehab A.H. Shehab, Department of Antiquities and Museums of the State of Kuwait.
the topographic network was already established owing to previous documentation works, it was relatively easy to integrate the newly acquired datasets. The collected images were used to prepare an orthophotomap of site, a DEM (with resolution 17.7 cm/pix and point density 32 points/m²) and a so-called Swiss Hillshade DEM. Orthophotomap was prepared in Agisoft Metashape Professional. Based on the records from Agisoft Metashape Professional, orthophotomap total error of X, Y, Z and XY for GCPs is estimated to be 2.12 cm. Data exported from this program were used for preparing previously mentioned DEMs in ArcMap. The final results obtained from the aerial survey became the next element for further GIS-based studies (Figure 7).

Although at the time when the survey was conducted, our team did not face any serious challenges, that would not be the case in the later season. DJI's flight control systems for the UAV differentiates between unrestricted and restricted zones, the latter being typically assigned to such locations as airports, energy infrastructure, military infrastructure or areas with very dense population. The zones were created to protect airspace and to prevent the drone operators from causing potential harm. This, however, may sometimes be a source of problems for archaeologists, and other data collectors. Flights in such zones can be authorized only by verified DJI accounts. In the case of our study, at the time of the data acquisition and for this particular UAV model, flights were permitted in this airspace above the site. However, since 2019, the entire area of Kharai al-Dasht has been labelled as a restricted zone, due to its proximity to the military base. Now, in order to conduct aerial operations above this site, a special authorization is required (Figure 8).

Data collecting survey resulted in seven GIS-based cartographic products – a UAV-made orthophotomap, two types of DEMs, two sets of orthorectified archival aerial photographs, QuickBird 2 Earth Observation Satellite orthophotomap dated to 25 October 2007 and a large scale topographic map of Kharai al-Dasht. All these products represent important stages of both the historical and geographical layout of the site.

The next stage of the research was focused on utilizing the analytical capacities of ArcMap. Remains of a thriving Late Islamic fishing village are still clearly visible on the orthorectified aerial photographs from 1960 (Figure 9). Structures can be easily identified based on shadow marks, which reveal slightly elevated and upright features, even if they are completely covered with sand. They proved to be much more useful than soil marks, as the homogeneous character of desert soil and black-and-white characteristic of archive aerial photographs made it impossible to perform any analysis based on soil marks. As there are no earlier cartographic sources available for this area, this orthorectified map served as the basis for further analytical work. These are the first photographs that show the whole area of the site and its vicinity with proper accuracy. They show a number of easily distinguishable rectangular constructions ranging in size from 10 m x 10 m to even 50 m x 50 m. In addition, the visible remains of palm trunks and small mounds aided the process of recognition of the potential extent of the village. All those landmarks were selected, marked and transferred as a separate layer to the geodatabase.

The efforts toward integration of geospatial data resulted in precise identification of changes in the vicinity of Kharai al-Dasht in the last 60 years. The area around the site was heavily modified by human activity. The recorded changes could be divided into four categories, based on their...
source – pollution, military and industrial constructions, paving of roads, and finally excavations, which also led to irreversible changes in the landscape. All these features were recreated in topographical form (as points, lines and polygons) as subsequent layers in our geodatabase in ArcMap (Figure 10).

Based on the aerial photographs from 1960 and 1976, it is possible to state that from the time of abandoning the settlement until the 1970s/1980s, the landscape changes were caused by natural factors. Weather and its effects were fundamental in causing the decay of old Kharai al-Dasht buildings. Due to the semi-desert characteristic of Failaka, all remains of constructions were covered with sand, creating small mounds which were still easily readable in the landscape (Figure 9). The most severe changes began to occur in the early 1980s, when a large water supply plant was built. This industrial construction partially covered the area of the archaeological site. The next large-scale investment was a military base, the rise of which is connected with war time activity during the first and the second Gulf War. These two buildings covered an area of 115 218 m², which constitutes approximately 18.2% of site area (estimated area of site is 632 990 m²). Among all the factors, these modern constructions proved to be the most harmful.

Another issue which could be extremely dangerous for Failaka’s heritage is pollution. In proximity to the Kharai al-Dasht area, an unmonitored landfill was created, accumulating wastes from cleaning of the modern town and nearest villages after the damages they suffered during the war. This type of contamination influenced an area of 67 256 m² of the site (10.6%), but is an issue characteristic for the entire island. The last two minor factors are paved roads, which cover
an area of around 4793 m² (less than 1%), and archaeological trenches, whose size can be estimated to be approximately 1200 m² (less than 0.2% of surface) (Figure 10 and Table 1).

All these elements create an apt image of man-made changes at this unique Late Islamic site. In total, almost 30% of the village area was irreversibly destroyed in a short period of the last 60 years of intensified human activity. The reconstruction of factor formation processes may prove helpful in the planning of further conservation and archaeological works.

### SUMMARY AND CONCLUSIONS

The use of digital technologies in representation and detection of archaeological heritage has increased significantly in recent years, with many projects aiming to integrate all kinds of remote sensing imagery (Verhoeven et al., 2013, 49–60; Vermeulen, 2013, 69–85). We could therefore benefit from the methodology and workflow developed by other archaeologists, especially during historical aerial photographs orthorectification. We agree that the highly accurate orthoimages are essential in any GIS-based archaeological landscape project (Pinto et al., 2019). The GIS-based landscape analysis conducted by the KPAM is another example of the demonstration that combining different datasets obtained during research may result not only in confirmation of previously known information but also in obtaining new ones. Integrated non-invasive survey methods offer new possibilities for recording spatial data. The advantages of integrated GIS data collecting systems in heritage protection are clearly visible, as the information is easier to gather, share and analyse (Reeler, 2015, 482–487).

GIS-based studies, combined with archaeological results, led to a tentative reconstruction of Kharai al-Disht street grid and the actual extent of the site. Based on these findings, it was possible to distinguish new zones of previous land use and organization of inhabitants’ activities. This is yet another important step towards the improvement of the understanding of Failaka’s heritage and its protection.

The crucial role of GIS at all stages of research cannot be overstated. Data collection and analysis, interpretation of archival and modern information, as well as visual capabilities of ArcMap made it possible to achieve more precise results and improve their representations. It should be also emphasized that GIS data are available for further queries, for instance Archaeological Predictive Modelling, which can be used for improving cultural heritage management (Wilcox, 2012, 353–358).

The concept of long-term dynamics is an important factor in the understanding of archaeological landscape changes. As the present case study covered only the period of the last 60 years, to receive a more complete image of Failaka Island, further investigations are required, which would take into account other layers of dynamics of changes. Therefore, our future goal is to attempt a reconstruction of the archaeological landscape of the whole island in the Late Islamic period.

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### CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article. No conflict of interest has been declared by the authors.

### DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

### ORCID

Pawel Lech https://orcid.org/0000-0003-3952-9801
Piotr Zakrzewski https://orcid.org/0000-0001-8569-3237

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