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RESEARCH ARTICLE

Stone and Water: A Case Study of Integrated Hydraulic Structures within the Late Antique Monumental Architecture of the Bozpar Valley in Southern Iran

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Abstract

This paper presents the results of a geoarchaeological study of the ancient hydraulic structures in the Bozpar Valley and an analysis of their relationship with the standing monuments, especially the two palatial structures known as Kushk-e Ardashir and Zendan-i Soleyman. It presents a raison d'être for each identified structure regarding its hydraulic function and physical integration within the monumental landscape. Then, it suggests an interpretative pattern in their spatial relation to the mentioned monumental structures. The study area is a small and remote valley in the Zagros highlands in southern Iran. It borders the modern provinces of Fars and Bushehr and is historically associated with the Greater Fars region. The monumental structures in this area belong to the Sasanian architectural tradition. Here, their integrated hydraulic structures are investigated interdisciplinary via remote sensing. The analysis indicates different functions for the two monuments: a representative and official kushk and a [seasonal] leisure palace. Based on the nature and function of the integrated hydraulic structures, the former monument seems to relate to food production activities and the latter to currently unidentified activities other than daily life. The results of this study provide further evidence of integrated hydraulic structures in Late Antique Iran and shall trigger comparative studies from neighbouring regions in the future.

Keywords: Iranian Highlands; Landscape Archaeology; Remote Sensing; Late Antiquity; Zagros.

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Introduction

The Sasanian Empire has long been known for massive transformations of its built landscape, including peculiar "landscape signatures" (Whitcomb, 2014). Investigating these large-scale projects has an established tradition in the archaeology of Late Antiquity (Christensen, 1993; Wilkinson and Rayne, 2010; Mousavi and Daryaee, 2012; Simpson, 2014; Canepa, 2018). The architecture of monumental structures and newly founded cities has been discussed repeatedly (Pope, 1933; Schmidt, 1933; Herzfeld, 1936; Huff, 1986; Mousavi and Daryaee, 2012; Simpson, 2014; Canepa, 2018). Other scholars emphasise the crucial role of centralised and industrial agriculture as the primary form of land use for creating the typically Sasanian landscape signatures (Neely, 1974; Wenke, 1976; Christensen 1993; Hartnell, 2014). Some other scholars even find the combination of these two elements, agricultural land use and prestigious monuments (such as border walls and fortifications), as the common signature landscape of the Sasanian period (Alizadeh und Ur, 2007) and argue for a complex relationship between continued traditions of water management (Adams, 1962; 1965; Simpson, 2014).

There is strong evidence that failed irrigation systems subsequently led to a gradual political collapse, which started at the imperial frontiers in Late Antiquity (Alizadeh *et al.*, 2021). This argument has also been put forward based on data from lowland Khuzestan (Wenke, 1976). Such anthropogenic footprints are associated with prestigious and well-known monuments in well-watered plains with perennial rivers (Wilkinson *et al.*, 2012). All these arguments focus on large-scale land use and, although valid, subsequently neglect a crucial point, which is the irreversible and immense human imprint by a series of smaller-scale, local projects for transforming land use and settlement dynamics in the Late Antiquity (Hauser *et al.*, 2023; Rashidian, in press).

The challenge comes with the relative lack of data on the location and function of small-scale land use elements, especially the integrated hydraulic structures in monuments of Late Antiquity. Many of these structures lie on the remote and peculiar small valleys of highland Zagros and have never been the focus of an archaeological investigation. In some cases, such as the present study area, these monuments are reported and wondered about (Mostafavi, 1964; Callieri, 2006; Askari-Chaverdi, 2014; Callieri, 2014), yet their anthropic landscape was never studied.

Typical examples of such land-use modification are found in wetlands turned into circular ponds connected to several canals, integrated into the official first palace of the Sasanian rulers, like the Ardashir palace in the Firuzabad plain in southern Fars (Djamali *et al.*, 2021). Recent geoarchaeological investigation of this hydraulic structure sheds light on the transformation of the Firuzabad Plain's landscape as the Ardashir-Khurra plan and its ideological value for future rulers. Similar case studies are known in neighbouring areas, including hydraulic structures associated with monuments of a specific function (Ajorloo, 2011; Maresca, 2019; Rashidian and Askari-Chaverdi, 2022).

Nevertheless, the data gap prevents a

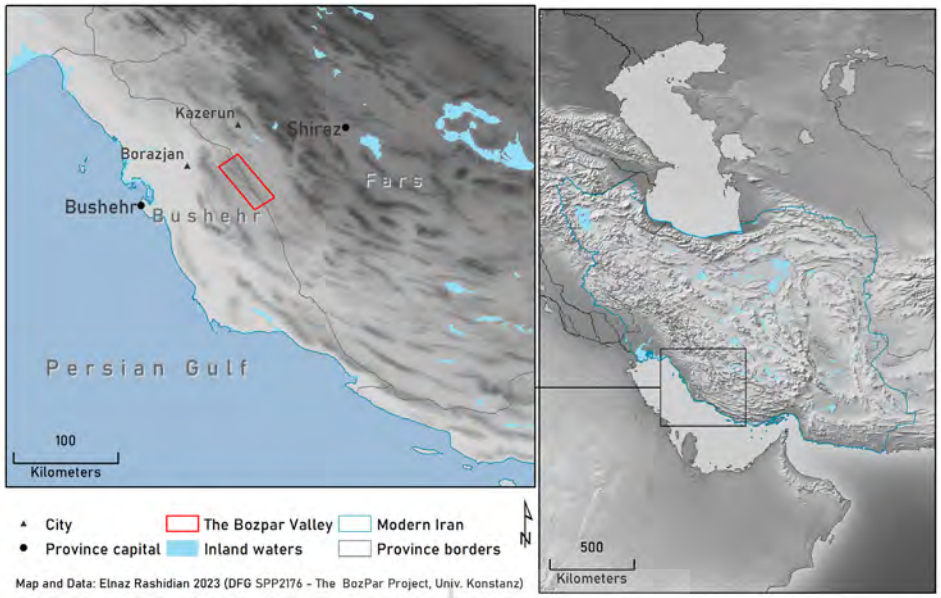

Fig. 1. The Bozpar Valley in Southern Iran

holistic and comprehensive understanding of the landscape signatures and their legacy throughout Late Antiquity into the later phases. By studying such landscapes and their human imprint, especially the integration of the hydraulic structures in their remaining monuments, one shall fill this gap and present a new perspective on Late Antique landscapes.

In this sense, one of these less-studied landscapes was recently investigated to understand its settlement dynamics and subsequent landscape change in Late Antiquity. The study area is the Bozpar Valley, a narrow and remote valley in the Zagros highlands bordering the modern provinces of Fars and Bushehr in Southern Iran.

The aim of this paper is twofold: (i) to present a first-ever quantitative analysis and classification of identified hydraulic structures in a remote highland valley of Zagros, belonging to the Late Antiquity, and (ii) to suggest an interpretative pattern in their spatial relation to the monumental structures of the study area. Similar case studies are based on single settlements or a single category of hydraulic structures. The Bozpar case study is unique and a first step toward better comprehending Late Antique landscape manipulation in the Zagros highlands.

The Study Area

The Bozpar Valley lies on the fold-thrust belt of the Zagros highlands in southern Iran (Fig. 1). No prehistorical settlements are known from this area. Historically, this remote valley belongs to the Ardashir Kura and the Greater Fars region (Rashidian, in press; Hauser *et al.*, 2023; Labisi, 2023).

The Bozpar landscape consists of a narrow and elongated valley floor in a northwest-southeast orientation, about 40km long and up to 3km wide with an average elevation of 1100m above the sea level (asl), separated from the northern

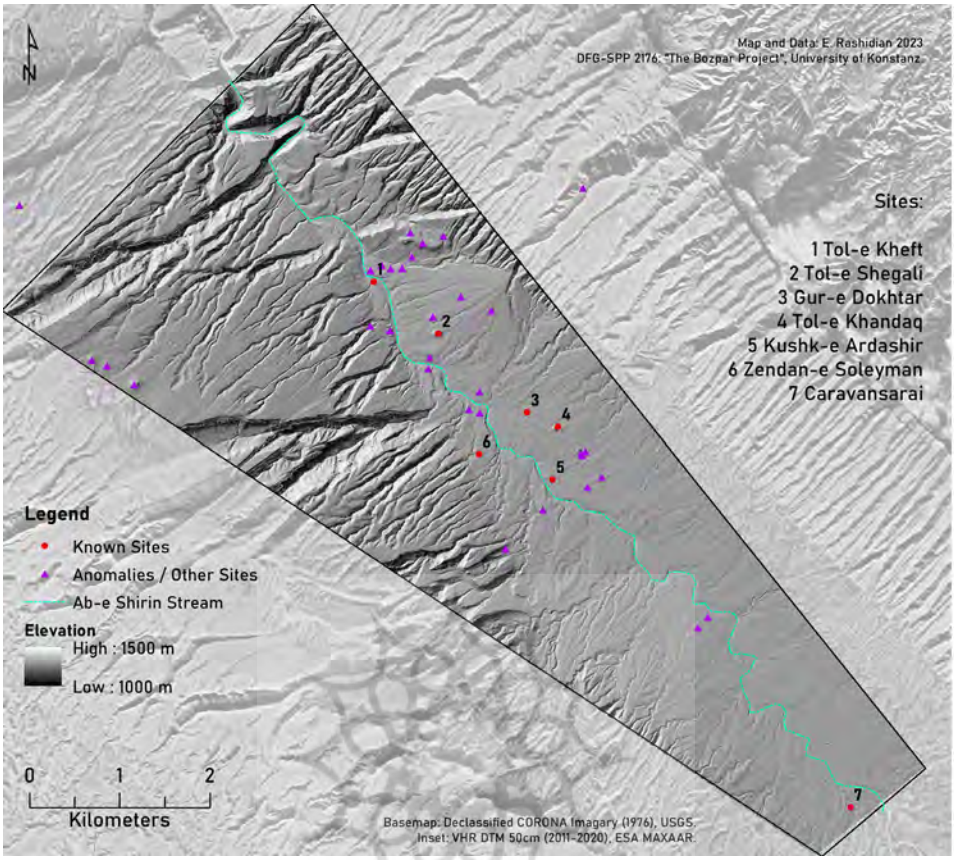

Fig. 2. The Topography of the Study Area and the Mentioned Sites

plain of Sar Mashhad and the southern valley of Tang-i Eram by distinguished hillsides of up to 1500m, the Asan anticline in the north and the Bozpar anticline in the south. The Valley is accessible by the northwest Gorge of Kheft, and several routes of pastoral nomadic communities pass through the hillsides connecting the southern Fars highlands to the Persian Gulf coasts of Bushehr.

The landscape is watered through three sources: (i) a seasonal stream named Ab-i Shirin (*i.e.,* the sweet water), dividing the floor in its length with a well-defined channel up to 5m deep and up to 30m wide; (ii) the incised and active gully erosions on both hillsides, while the south series is steeper and much more eroded and the north series has developed a stream channel in several locations; (iii) a series of karstic springs typical for the Zagros folded belt, providing water in areas where the high erosion of hillsides meets the thin topsoil of the valley floor.

The Bozpar Valley is archaeologically less known than the neighbouring Sar Mashhad plain (Ghasemi, 2012). The standing monuments of this valley first appear in documents from the nineteenth-century British intelligence reports (Rashidian, in press: footnote 17;

Hauser *et al.*, 2023: 273). About a century later, the monuments were reported archaeologically (Sami, 1960; Vanden Berghe, 1961; Mostafavi, 1964). They have also been discussed from an architectural perspective (Vanden Berghe, 1989; Callieri, 2014; Labisi, 2020; Callieri *et al.*, 2021). A brief survey of the valley has been published recently, which gives a partial but crucial summary of additional sites to the previously known standing structures (Askari-Chaverdi, 2014). More recently, the two monumental sites of the valley have been investigated briefly for the purpose of their inclusion in the National Cultural Heritage Registry (Mousavi-Bideli and Azarian, 2020). Still, very little pottery belonging to the Late Sasanian period was found *in situ*. However, landscape archaeological analysis has yet to be attempted for this region.

The most prominent sites of the Bozpar Valley (Fig. 2) are the Gur-i Dokhtar monument, a funerary monument very similar to the tomb of Cyrus in Pasargadae, and two monumental buildings with stone masonry and typical elements of the Late Sasanian architectural tradition, Kushk-i Ardashir and Zendan-i Soleyman. At least two fortified mounds exist: Tol-i Khandaq and Tol-i Shegali. In addition to those monuments, a pottery production site at the northwest gorge was identified as Tol-i Kheft (Askari-Chaverdi, 2014). All these sites are concentrated in the northwestern part of the valley and seem to represent a settlement ensemble.[1] Another structure known as "Caravanserai" is located far from the rest of the ensemble at the south-eastern end of the valley floor and might be dated to later periods.[2]

Besides the archaeologically known sites, several unknown site complexes and anthropogenic anomalies were identified via remote sensing methods (Fig. 2). These include undated nomadic camps, water harvesting structures, buildings with unidentified functions, cemeteries and graves of later periods, remains of at least one ancient village probably dated to the Late Sasanian period,[3] walls, enclosures, and other structures probably related to food production. These structures have yet to be investigated. Extensive surveys can shed light on the nature and spatial relation of these recent finds, including their chronology and material culture, and complement our understanding of the Bozpar Valley's settlement dynamics.

Integrated Hydraulic Structures

This paper follows a particular concept of landscape archaeology (Wilkinson 2003), which considers entire cultural

[1] We identified this ensemble as a "*Dastgerd*" within the tradition of Late Sasanian and Early Islamic land use reforms. Based on our project in Bozpar, we present this idea and identify similar case studies in separate papers currently under review.

[2] The Bozpar project, as accepted by the DFG, intended to carry out a survey of the valley supported by remote sensing and a detailed study of the architectural complexes. Unfortunately, the pandemic and other events beyond our control prevented us from doing our fieldwork as planned.

[3] Extensive traces of these settlements are visible on older aerial photographs from 1976 (DAI Archive, Tehran; available on ARACHNE). We could identify and track remaining traces via remote sensing and available visual data.

landscapes as artefacts of human crafting and encourages a holistic study of the landscape as a framework of human dwelling and sociocultural evolution. In this sense, hydraulic structures are singled out as the most tangible elements of human imprint on a given landscape for comprehending the inter-relation of natural and anthropogenic elements. This results in a hybrid landscape, which contains traces of both elements and represents the next stage of the cultural landscape evolution. Hydraulic structures can be identified by investigating methods and techniques of hydraulic planning.

Hydraulic planning is a crucial element of human dwelling, especially in representative architectural units, which carry more than their primary function. Hence, one can comprehend the nature of human-environment interaction by investigating the applied methods of hydraulic planning in each cultural landscape. In this regard, the chosen water harvesting method in the Sasanian built landscape refers not only to the possibilities of the landscape and its hydraulic regime but also to the ideological concepts and spiritual practices of the ruling elite at that time (Maresca, 2019; Wilkinson and Rayne, 2010; Whitcomb, 2014).

This suggestion has recently been presented for the Fars region (Djamali *et al.*, 2021; Rashidian and Askari-Chaverdi, 2022; Rashidian and Djamali, 2023) and mentioned by others from different perspectives (Canepa, 2018; Maresca, 2019). The question of integrated hydraulic structures adds another dimension to this concept because it also refers to the function of the monument into which the hydraulic structure is integrated. Such complex questions can only be addressed by investigating several case studies to extract all possible interpretations. The present case study is one step toward this goal.

However, the landscape characteristics of the Zagros highland provide other sources of flowing water, such as seasonal run-off flowing in incised gullies and underground aquifers accessed by *Kariz* (also known as *Qanat*) shafts (Beaumont, 1971). These two water sources exist in the remote valley of Bozpar, while the others are less reliable. The question of intensified land use in this valley for a relatively short period has been addressed elsewhere, and several hydraulic structures were identified in the entire valley (Rashidian, in press). A detailed analysis of these structures shall follow here.

Materials and Methods

Following a preliminary analysis of the anthropic landscape of this study area (Rashidian, in press), this paper focuses on an advanced analysis of hydraulic structures in the Bozpar Valley and their spatial relations with the archaeological traces, especially the monumental structures known as Kushk-i Ardashir (hereafter *Kushk*) and Zendan-i Soleyman (hereafter *Zendan*) amongst others (Fig. 2). The present study consists of the following parts: first, a reconnaissance of hydraulic structures and their classification; second, an analysis of their spatial relation with the mentioned monuments.

The following materials were combined for a reconnaissance of the hydraulic structures in the Bozpar Valley: (i) Remote sensing analysis of world Imagery, Google

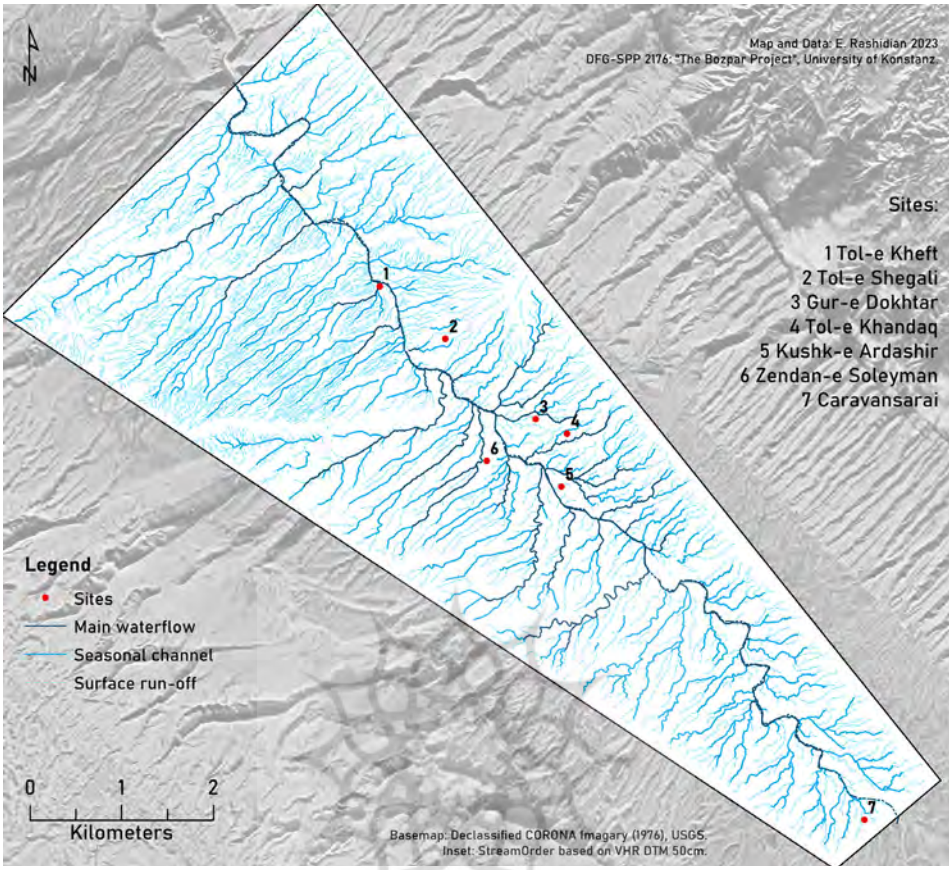

Fig. 3. The Hydrology of the Study Area and the Mentioned Sites

Earth Pro, (ii) VHR DTM 50cm resolution, extracted from ESA imagery between 2011 and 2020, acquired by the Bozpar project, (iii) Data from a field visit in spring 2022[1], and (iv) historical and textual evidence including geographical histories and declassified British intelligence reports of the nineteenth and twentieth centuries.

The data were extracted from the above sources and integrated into a geodatabase in an ArcGIS environment for further analysis. These include vector data extracted from georeferenced older maps and sketches and raster data from imagery and digital surface models (DEM and DTM). Data from a recent field visit completed and corrected these vectors to represent the actual traces on the ground. These datasets were analysed by tools within the Spatial Analyst, 3D Analyst, and Hydrology tools (ArcGIS Desktop version 10.6.). In our analysis of satellite imagery, we identified numerous archaeological sites, e.g. palatial structures, ancient fortifications, villages, and nomad camps, as well as features of various categories, e.g.

[1] The photographs and visual data are courtesy of M. Takalloo, who was accompanied by A. Asadi (Art University of Isfahan) during this visit. We are most grateful to them for granting us permission to use this data for our research.

Table 1. Categories of Identified Hydraulic Structures in the Study Area

Category	Meaning	Description	References
Bandsar	headwater weir	a series of inner-connected earthen walls supported by stones on the sloping hills of a valley with an inlet for surface water and an outlet for transporting surplus water into the valley floor.	(Tabatabaee Yazdi and Aliabadi, 2017)
Khushab	delta cross-dam	a mostly stone-built cross-dam at the end of a seasonal stream (or a gully) to hold the water as a pool for the dry season, mainly connected to the water supply network by an outlet channel with an on-off function.	
Joob	small field canal	narrow and long small open-head channels connected to the feeder channel for water transport into irrigated fields.	(Beckers, Berking and Schütt, 2013)
Dastkand	main feeder canal	vast and wide dug channels with a slope of 2 to 5° against the natural landscape, often with built-in stone coating and removable ceiling, used to bring the (sub)surface water into the network of smaller irrigation channels.	
Kariz	underground tunnel	a deep underground tunnel with access to a subsurface water aquifer, including a series of vertical shafts, from the first one (*madar-chah*) connecting the tunnel to an outlet (*mazhar*) and a channel (*joob*) to bring the water into the supply network for irrigation and daily use.	(Beaumont, 1971)
Chah	water well	a well with a built inlet, usually in square shape.	
Polband	dam-bridge / weir	a dam-bridge to regulate the water flow of seasonal streams.	(Planhol, 1988)
Barm	spring-fed pond	mainly circular pools dug at the outlet of a permanent (karstic) spring with an inlet canal and at least one outlet canal for water regulation.	(Djamali *et al.*, 2021)
unknown function		structures with a clear connection to water but unknown function based on current data.	

routes, enclosures, and gardens. For this analysis, hydraulic structures were identified, described in size, depth, volume, and direction, and classified into one of the known categories (Table 1).

As the next step, the spatial relationship of each category of hydraulic structure with these sites was analysed, and clusters and anomalies were identified in the process. As a result, an inter-

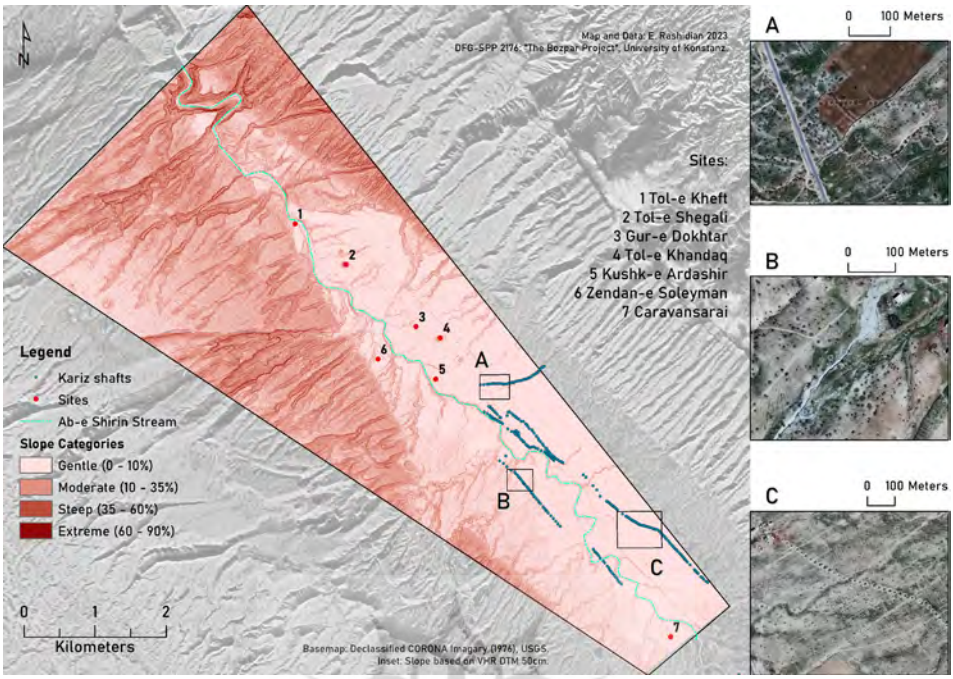

Fig. 4. The Slope Categories of the Area and the Mentioned Sites Showing the Kariz Hydraulic Structures with Three Examples

pretation of the function and relation of these structures and their respective monumental structures was possible.[1] The results provide a framework for further investigation of a cultural landscape with a tangible Late Antique imprint in terms of intensified land use and probably a change of ownership (Rashidian, in press; Hauser *et al.*, 2023).

Results and Discussion

Following the preliminary identification of the hydraulic structures (Rashidian, in press), this paper focuses on an advanced analysis of hydraulic structures in the Bozpar Valley and their spatial relations with the archaeological traces, especially the monumental structures, *Kushk* and *Zendan*[2]. First, the identification process is explained. Then, the details of these identified features relevant to the two monuments are reported. A discussion of their nature as artefacts follows.

Hydraulic Structures in the Bozpar Valley

A series of geofactors, including surface water flow and slope, have been studied to determine the landscape's characteristics and potential water availability. Spatial analysis of these factors comprehends the landscape's hydrology and provides a quantitative framework for a comparable analysis of the identified

[1] We should add a cautionary note since none of the structures has been excavated so far, while several are heavily disturbed and thus difficult to describe in detail, which in some cases rendered their interpretation uncertain.

[2] G. Labisi conducted an extensive architectural study of these two monuments, resulting in three papers currently under review.

hydraulic structures as archaeological remains.

The first geofactor is the water flow on the surface. The Bozpar Valley's hydraulic regime was analysed using surface water flow measurements. Three categories of available surface water could be identified: the shallow and short-term surface run-off, the seasonally active and highly erosional channels, and the main water flow with an incised bed (Fig. 3). The last one corresponds with the Ab-i Shirin stream. The results confirm that the standing structures, *Kushk*, and *Zendan* (and Gur-i Dokhtar, hereafter *Gur*), are at the locations with the most water availability, with *Kushk* being the least affected by the liability of surface water flow and *Zendan* being the most affected one.

The slope is another geofactor in water availability and a decisive element for implementing hydraulic structures. The analysis of the Bozpar Valley shows that the valley floor has a gentle slope (up to 10%), while the northern gorge has a moderate slope (up to 35%). The hillsides border the valley floor with a steep slope (up to 60%), with a sudden increase to extreme slopes (up to 90%) at the incised gulley corridors and near the peaks (Fig. 4).

One typical sub-surface water harvesting strategy of ancient Iran is one relying on the *Kariz* series (Beaumont, 1971). As shown here (Fig. 4), the currently identified *Kariz* shafts with their characteristic round shapes are concentrated on the south-eastern part of the valley and transport the water for distances of up to 2.5 km towards the valley floor and the standing structures. The *Kariz* shafts are mostly shielded from the high evaporation and erosion of the dry climate. The natural slope of the small valley surface, such as Bozpar, favours this technique. At least eleven *Kariz* series were identified in the study area, mostly located on the northwestern foothills towards the settlement ensemble in the middle, with an average length of 1.5 km and 70 shafts per series[1]. Several *Kariz* types exist in the study area, including vertical (Fig. 3, A) and horizontal (Fig. 3, B and C) series (Beaumont, 1971; Ahmadi *et al.*, 2010; Rashidian, in press).

The dating of these elements is currently unclear. However, a recent field visit confirmed that they have been out of order for quite some time. Our spatial analysis puts them in clear spatial relation to the known monuments of Late Antiquity, confirming our initial assumption.

A peculiar structure is found at the northern hillside to the north of the *Gur* monument, which deserves mention in this context (see location in Figure 2). While it had been suggested a possible defensive wall (Askari-Chaverdi, 2014), a possible interpretation as a high aqueduct seems more likely based on the structure's location and surroundings. If this interpretation is correct, the structure consists of a narrow and deep channel connecting two active gullies and transporting the runoff water from one on the western side to the eastern

[1] Most shafts are not visible to GIS tools as circular anomalies due to irregular vegetation cover and high surface erosion, which blurs their outline. Studies from neighbouring regions (Ahmadi *et al.*, 2010; Beaumont 1971) suggest that the *Kariz* series were more extended and had more shafts per series as stated. Accurate statistics can be presented only after fieldwork.

for further transportation into the valley floor and away from the *Gur* monument. Hence, the structure operates both for water transportation and flood regulation purposes.[1] Alternatively, as reported in the western highlands, this could be the remaining standing structure from a drop-tower mill complex (Neely, 2011, Fig. 4), such as examples in Dehloran (Neely, 2022) and the neighbouring Behbahan plains (Khosrowsani, 2021).

We have no direct evidence to date the hydraulic structures in the Bozpar Valley. However, the Sasanian dating for such water harvesting structures is supported by parallels with similar evidence from the western highlands in the Dehloran valley, where *Bandsar* and *Khushab* sets of rubbles and stones are excavated and yielded Sasanian pottery (Neely, 2022). These will be discussed in detail in connection with the *Kushk* below. The integration of bathhouses and mills in multi-functional public buildings of the Sasanian period is also known in central Iran, one example being the Deyr-i Gachin site complex (known as Carvansarai) near Ray (Shokoohy, 1983).

Although this paper does not engage in an architectural study of these monuments,[2] the following statements are of relevance for comprehending the integrated hydraulic structures:

- Both *Kushk* and *Zendan* are located higher than their immediate environs. This seemed at first to be a constructed platform. However, further investigation identified these as the construction material of the collapsed buildings, which has taken a solid shape in the last centuries since the initial collapse. This suggestion is supported by observations from the buildings' inside during the recent field visit, showing that the floors were filled with at least 2.5m of debris.

- The main entrance of the buildings cannot be determined with certainty due to the heavy debris of the collapsed parts and lack of excavation data. At first glance and based on comparative case studies such as the Ardashir Palace in Firuzabad (Huff, 1986), it seemed logical to assume that the *Barm* (see Table 1 for definition) of the *Kushk* complex marks the public entrance of the main building. However, further investigation indicated otherwise. The *Barm* might be integrated into the *Kushk* monument as an attached element of a destroyed smaller pavilion, similar to known examples in the west Zagros highlands (Canepa and Hardy, 2018). Regarding *Zendan*, the situation is even more complicated. The main building is heavily disturbed by secondary attachments and reuses, and a rectangular enclosure seems to connect several presumed pavilions with integrated hydraulic structures in the monument. One argument for determining the two buildings' entrances is the presumed communication route connecting the south of the *Kushk* complex to the north of the *Zendan* complex. Traces of this element are visible in older aerial photographs

[1] Unfortunately, we have not been able to visit the structure on the ground so far. However, the current interpretation is based on remote sensing data. In contrast, the hills are very easy to defend and hard to pass at this location, making a defensive structure redundant.

[2] See Labisi, 2023 and in press for the architectural study.

(DAI Archive, 1976) but almost wholly degraded the current landscape.

- Neither *Kushk* nor *Zendan* seems to be connected directly to the Ab-i Shirin stream for their water supply, thus confirming the suggestion that this stream has never been a perennial and reliable water source. Nonetheless, *Kushk* seems to integrate the stream channel into its monumental architecture through a *Polband* (see definition in Table 1 and location in Fig. 6) on a direct axis from the main building to the other side of the channel and to provide access to the remotely located *Zendan* complex through the mentioned presumed connection route. All known hydraulic structures reach and join the stream channel at their very end. This marks the lowest point of water flow, meaning that the stream channel was integrated into the monuments' hydraulic planning as a primary drainage channel in the wet season and not a water source.

Using a series of watershed analyses centring the buildings, two areas were identified concerning the water management of the site complexes. Based on these two areas, two separate categories of handling water can be differentiated in the monuments, resulting in specific integrated hydraulic structures. One is the water source, which is secure and safe (and flowing) and transported toward the monuments; the other is flood protection (and drainage), which shall be transported away from the monuments and kept in control at a safe distance to the buildings and securing the surface, as known from contemporary sites (Alizadeh *et al.*, 2021). Hydrological analysis of geodata, including DTM and TIN, led to the estimation used in this analysis. The results also demonstrate the difference between the water sources of the two site complexes.

In the absence of material remains from archaeological excavations and a precise stratigraphical sequence, several questions remain unanswered regarding the settlement history of the study area. Our lack of data[1] from the fortified settlements of Khandaq and Shegali (Fig. 2) and the nature of the heavily disturbed mounds near *gur* (Fig. 5) ward off any comprehensive, holistic analysis of the ancient hydraulic planning. The two known monuments of *Kushk* and *Zendan* represent the anthropic imprint of the whole valley[2]. Additional integrated hydraulic structures exist in relation to these settlements but have not been analysed due to the data gap.

[1] Diagnostic Sasanian Pottery was reported from these two sites by Askari-Chaverdi (personal communication, 2022).

[2] In recent years, the two site complexes were subject to preliminary archaeological reconnaissance by the Iranian Centre for Archaeological Research (ICAR, Tehran). Unfortunately, these internal reports (in Persian) are not published (and are unavailable to the public). They were solely based on a brief survey measuring the sites to enlist them in the national cultural heritage registry. The site boundaries were estimated in these reports based on immediate and visible material culture and structures. The site boundaries in this paper are based on the existence of integrated hydraulic structures (limited by watershed analysis and identified via remote sensing, as well as correlated with available visual data) in the environs of the sites' visible structures. These are much larger compared to the registered site boundaries, as seen in Figure 6 for *Kushk* and Figure 10 for *Zendan*.

Structures Relevant to Kushk

The *Kushk* monument consists of the remains of an elegant building with evident elements of Sasanian architectural tradition. The surviving walls are about 1.3m thick and up to 8m high. A portion of about 30×25m is still standing; debris and remains extend to about 70×70m. The building is constructed of untreated stones and gypsum mortar. The building had a square room on its north-western side, originally covered with a dome, connected to a barrel-vaulted rectangular room and two rectangular narrow corridors. The south-eastern side of the building consists of a quadrangular room covered by a semi-dome on squinches communicating to the north-west and south-east with two rectangular rooms roofed by barrel vaults characterised by transverse arches ending with an apse covered by a semi-dome on squinches (Hauser *et al.*, 2023: 276). It was most probably a two-story building.[1]

Traces of secondary occupation surround the main building and, in some cases, alter the initial shape and size of the heavily disturbed structures belonging to the *Kushk* complex. Most recent structures can be associated with nomadic pastoral activities, including possible tent bases for seasonal dwellings, enclosures for husbandry, and small water reservoirs for animals. Unfortunately, these structures were built with materials from the original structures and even integrated initial structures into their plans. In recent decades, intensive agriculture has additionally destroyed traces of hydraulic structures. Therefore, the original state of the hydraulic planning of the *Kushk* monument might be impossible to determine fully without extensive excavation.

Several hydraulic structures were identified in the environs of *Kushk* using remote sensing methods and correlating field visit data incorporated into the archaeological evidence (Fig. 5). These are categorised according to their respective function (see Table 1 for the categories). Based on the analysis mentioned, the following statements can be made.

The *Kushk* complex receives its water from the northern hills of the Bozpar Valley, based on its location, and the accumulated water is distributed via hydraulic structures on the northeast and east of the building (Fig. 5, A and C). The Ab-i Shirin stream and the seasonal streams of the southern gullies do not contribute to its hydraulic system as water sources. However, the stream channel and at least three seasonal streams have been manipulated at the monument's location (Fig. 5, B), probably for reasons other than securing water supply. A massive structure, probably a *Polband*, is identified on the opposite side of the stream channel facing the monument.

The water sources for the site complex can be divided into two categories: (i) surface water from the northern gullies and (ii) subsurface water through the *Kariz* series. These two categories seem to follow preplanned axes imposed on the landscape (Fig. 6). The surface water is transported through a network of feeder channels and narrow canals connecting the manipulated gullies on the northern hillsides to the stream channel.

[1] See Labisi, 2023, for a detailed architectural study of this building and Labisi, in press for an analysis of its function.

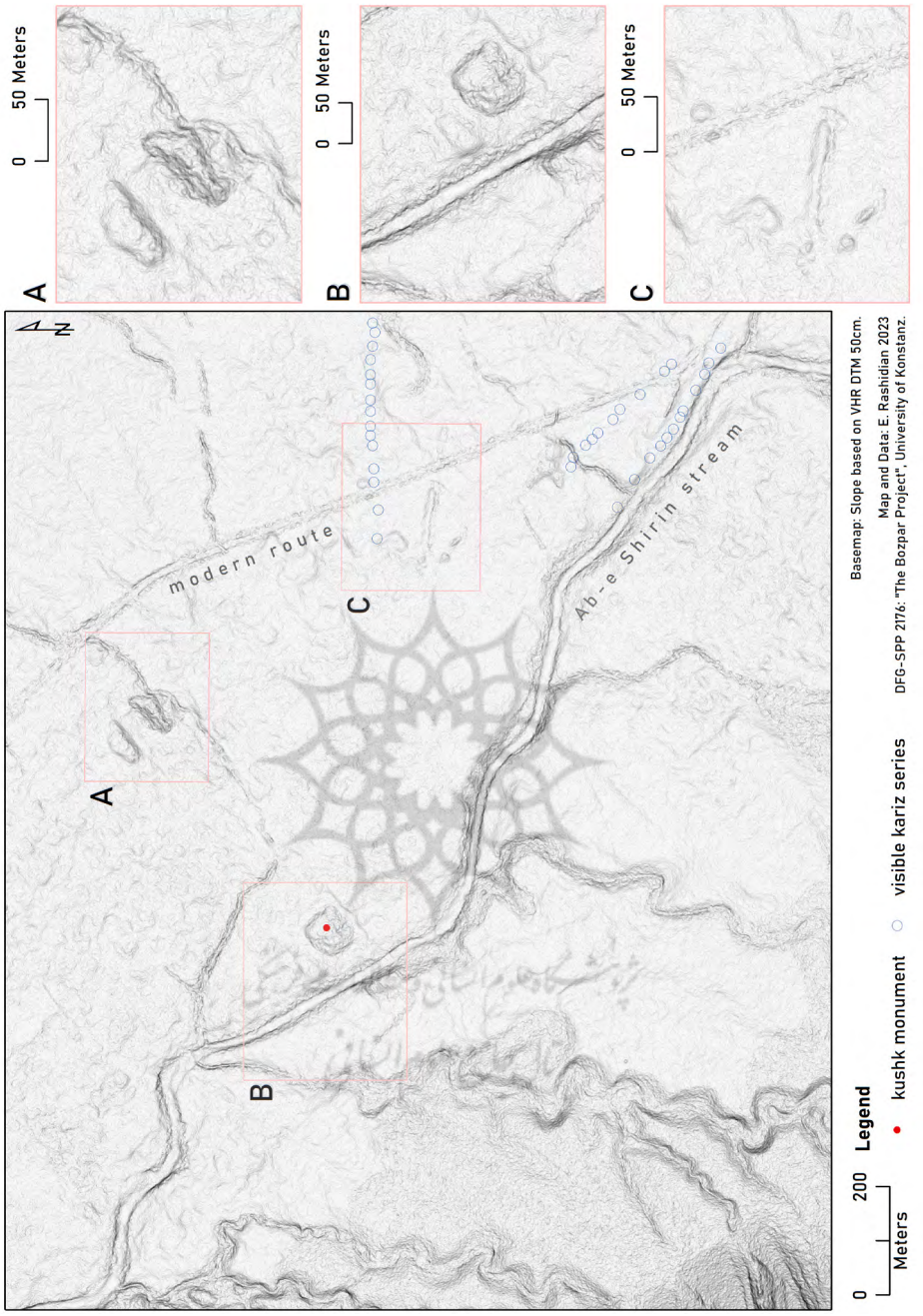

Fig. 5. Hydraulic Structures Relevant to the Kushk Monument: Traces of Unknown Structures, Including a Cistern at the End of a Dastkand, Probably a Drop-tower Water Mill (A), Straitened Stream Channel with Traces of Polband (B), and Traces of a Mazhar at the End of a Kariz Series (C).

These hydraulic structures supply the presumed gardens on the northern side and their water harvesting systems, such as *Bandsar* and *Khushab,* for agricultural

land use. The water is transported from the eastern (via the *Kariz* series) and northern areas (via the *Dastkand* and *Joob* series) into the complex and gathered in reservoirs as well as a *Barm* (Fig. 5, B).

The *Joob* series seems to have evolved into the current network of irrigation canals that are in use on the valley floor. Their original shape and length are harder to determine due to their lack of stone-bedded structure in contrast to the *Dastkand* series. However, their extent is preserved at some locations. They seem to have a clear spatial connection to the unknown feature north of the *Kushk* building (Fig. 5, A), a structure of two symmetrical elevations on the same extended axis of the *Kushk* monument (Fig. 6), where the *Joob* series[1] seems to connect a cistern (or another *Barm*) to the hydraulic network and move toward the northeastern side of the *Kushk*.

As the mentioned parallel structure is heavily disturbed by recent anthropic impacts, including new houses and water structures, identifying its initial size is almost impossible. However, the existence of a drop-tower mill connecting narrow canals on the eastern anomaly is confirmed by optical analysis of the VHR imagery. This finding further supports the suggested function of the *Kushk* site complex as an administration site for agricultural food production[2].

Based on the hydrology of the valley, the watershed of the valley floor was determined using tools in the ArcGIS environment, which showcases the unique location of the *Kushk* monument in terms of flow accumulation. The watershed analysis provides lines of accumulated water flow throughout the catchment area, which correlate with the direction and extent of the identified canal series (*Dastkand* and *Joob*) in both *Kushk* and *Zendan* monuments. Their orientation also follows the estimated slope categories (Fig. 4). These hypothetical lines are shown as the water axis for both monuments (Fig. 6; Fig. 10).

A few *Kariz* series transport underground water alongside the southeast hills into the valley floor to reach the *Kushk* site complex (Fig. 5, C). They supply water into a structure, probably a cistern, which is heavily damaged and currently not recognisable. However, the elevation model shows the extent of this structure, about 500m to the east of the *Kushk* building, where the visible traces of *Kariz* shafts disappear and a series of anomalies emerge. A recent field visit reported Sasanian pottery at this location (Askari-Chaverdi, 2014). Older imagery (Declassified imagery from 1968 and ESA

[1] The number and the extent of the series are not clear. There is either one *Joob* series in the middle of these two elevated rectangles starting from the presumed cistern and moving toward the *Kushk* in a straight channel, or there are two symmetrical channels, each bordering one of the rectangular structures and moving in the same direction in parallel. In the latter case, the two current channels (visible on satellite imagery) present the original water flow in this structure. Unfortunately, as fieldwork was impossible, the reconstruction is solely based on remote sensing correlated with limited data from a recent field visit.

[2] See our suggestion regarding this settlement ensemble and its identification as a Late Sasanian *Dastgerd* in separate upcoming publications.

VHR of 2012) shows traces of walls and other structures, which are not identified in the recent imagery and were probably obliterated due to agricultural activities on the surface. Excavations at this location can illuminate the nature of this hydraulic structure and verify its spatial relation with the *Kariz* series.

A circular pond dressed with stone masonry, a *Barm* (Table 1), is located on the northwest side of the monument, about 40 meters from the standing structure and an element of the greater enclosed area (Fig. 7, A). The *Barm* is the most crucial integrated hydraulic structure in the *Kushk* monument.[1] In his brief survey of the valley in 2014, Askari-Chaverdi documented the pond as a circular sink with stone masonry-constructed walls and visible traces of steps.[2] Data from a recent field visit shows that the *Barm* is still visible on the ground but filled with further sediments, so its initial depth and shape cannot be estimated without extensive excavation. Its construction material is also confirmed to be stone masonry similar to the *Kushk* (Fig. 6).

The *Barm* structure is a perfect circle with an 8m radius and a stepped depth of at least three levels marked by stone masonry. The constructed stones are smoothed and present visible traces of coating and plaster. The pond has been disturbed by recent agricultural activities.

Based on comparative studies of similar structures in central Iran, such as the Sasanian palace near Tepe Hissar in Damghan (Schmidt, 1933) and the structure known as the manor house of Hajjiabad (Azarnoush, 1994), a smaller pavilion[3] can be identified as an integrated element of the *Kushk* monument in Bozpar with a *Barm*.[4] Such architectural elements are also known from prominent Sasanian sites in west Zagros (Canepa and Hardy, 2018). Circular ponds as water reservoirs are also known from Sasanian public buildings in central Iran (Shokoohy, 1983), and currently destroyed examples were reported from several locations in the Iranian highlands in the nineteenth century (Flandin und Coste, 1851). This is supported by the existence of similar circular ponds in monuments referring to Anahita (Boyce *et al.*, 1989; Callieri, 2014).

Another integrated structure seems to be a currently destroyed *Polband* (see definition in Table 1) on the stream channel in front of the *Kushk* main building, connecting the monument to the southern hillside of the valley. Such "weir-bridges" are known as elements of infrastructure from other regions within the Sasanian territory (Huff, 1990; Maresca, 2019: 212). The stream channel seems to be manipulated and straightened at

[1] During his visit to the valley in 1973, Huff prepared a sketch of the ruins and documented the *Barm* in its circular shape. We are most grateful to him for sharing his unpublished drawings, notes, and memories of his visits to Bozpar Valley with us. A joint publication is under preparation [Huff *et al.*, forthcoming].

[2] A brief report on this brief visit was published (Askari-Chaverdi, 2014). We are most grateful to Askari-Chaverdi for making his unpublished photographs (including surface pottery and landscape features) available to us in 2020.

[3] A probable religious purpose for such pavilions cannot be excluded.

[4] The architectural study of the *Kushk* is in press (Labisi, 2023; Labisi, in press).

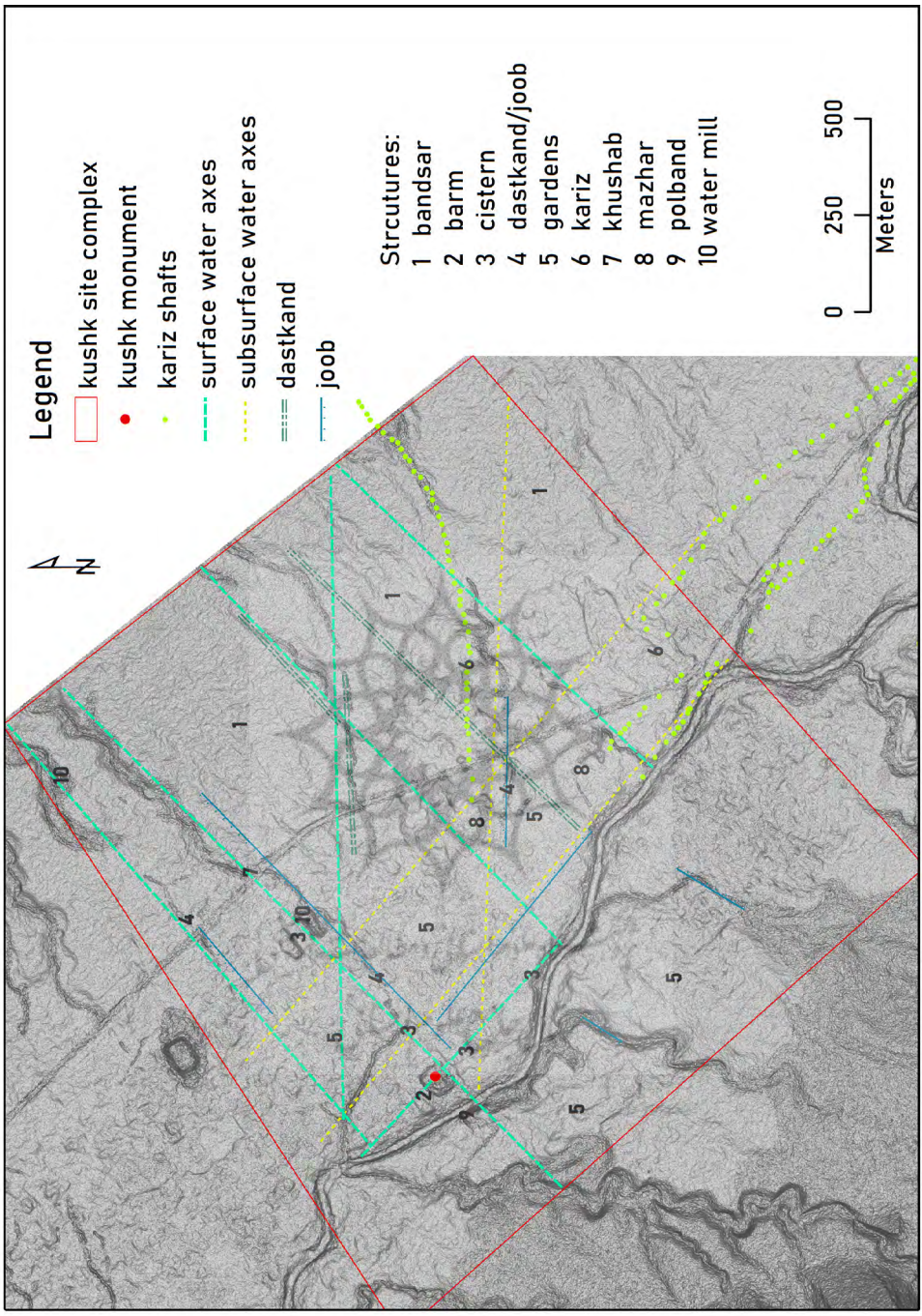

Fig. 6. The Kushk Site Complex and its Hydraulic Structures Showing the Axes of Water Sources and the Identified or Presumed Structures.

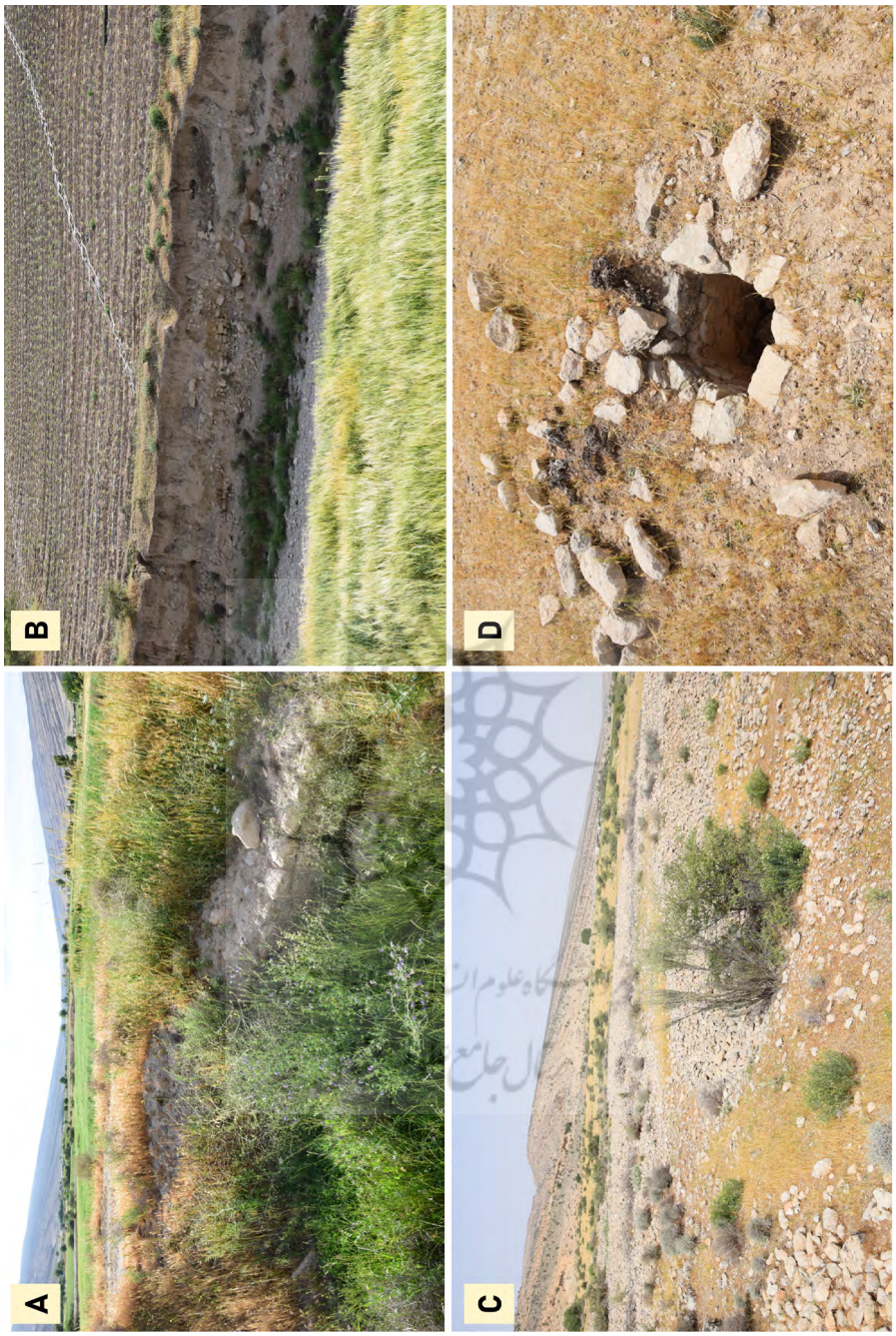

Fig. 7. The Identified Hydraulic Structures in Kushk and Zendan; Traces of the Barm in Kushk (A) and Zendan (C), the Polband in Kushk (B), and the Chah in Zendan (D). See Figure 6 and Figure 9 for Locations.

this location to ensure stable construction (Fig. 7, B). Similar structures exist in the neighbouring Sar Mashhad plain (Ghasemi, 2012: Fig. 9).

The straight channel at this location is anthropogenic as it does not fit into the natural stream channel's overall sinuosity and the stream's meandering nature. The identified change in the channel is abrupt and limited to about 500m precisely in front of the *Kushk* monument. In hydraulic terms, it can be identified as an anomaly. Therefore, assuming a correlation between the monument's construction and this modification is logical. A recent field visit confirmed the existence of remains of the presumed structure at the channel section, including several rows of stone masonry with an identical construction technique as the monument, as well as massive debris of the same material on the stream channel bed (Fig. 7, B).

Similar structures are known from other areas as signatures of the Sasanian built landscape, one prominent example being the three dam bridges on the Firuzabad river as integrated elements of the Ardashir-Khurra plan from the early third century CE (Huff, 1974; 1999; Norouzi, 2005; Rashidian and Djamali, 2023). Another Barm was recently found on the same plain regarding an unknown palatial structure (Rashidian and Askari-Chaverdi, 2022).

It is logical to assume a twofold function for the presumed *Polband* at this location: (i) as an architectural element connecting the *Kushk* building(s) to the other side of the stream channel, and (ii) as a hydraulic structure controlling the water flow of the Ab-i Shirin stream, primarily through the end of the wet season, probably for providing a higher water volume and filling the *Barm* at this location and for flood protection measures. Excavations at the cross-section of the stream channel can provide further evidence and verify this suggestion.

The most crucial hydraulic structures related to the *Kushk* site complex are traces of *Bandsar* and *Khushab,* which attest to an intensified agricultural land use contemporary to the monument (see Rashidian, in press: Fig. 5). Terracing hillsides for agricultural use, especially crops and fruit (and nut) plantations, has a long tradition in the Ancient Near East (Beckers *et al.*, 2013), especially in semi-arid Iranian highlands (Tabatabaee Yazdi and Aliabadi, 2017). Similar structures associated with Sasanian settlements have been reported in neighbouring areas (Neely, 1974; 2022). These examples share fundamental techniques and strategies, such as their construction materials (untreated stone and compact soil), their perfect adaption to the slope and orientation toward a primary water source, and their inlets and outlets for a controlled water flow toward the valley floor.

The *Bandsar* examples in the Bozpar Valley concentrate on the northern hillsides, where the slope is moderate, and the gullies have a less turbulent water flow in wet seasons. The typical *Bandsar* in Bozpar is about 100m wide and contained by a wall of several rows of untreated stone separating it from the higher and lower levels. It is attached to a main channel, a *Joob* of 0.5m width connected through inlets and outlets to secure water flow.

The *Bandsar* series of the *Kushk* site complex[1] seem to have contained tree

[1] The *Bandsar* ensemble directly north of the *Kushk* monument is considered an integrated hydraulic structure of the *Kushk* site complex

plantations due to their ordinary shape, compared to the *Bandsar* associated with the fortified settlement of Tol-i Khandaq, which seem to contain crops due to their smaller and less slope-oriented shapes. In the latter examples, the wall is not completely straight but shows a slight curvature toward the valley floor. The different techniques for terracing in adaption to agricultural products are reported from other areas (Beckers *et al.*, 2013; Tabatabaee Yazdi and Aliabadi, 2017) and can be assumed here, as well. This water harvesting strategy in the Bozpar Valley has been discussed in detail elsewhere (Rashidian, in press).

The presence of at least two drop-tower water mills can be assumed in the *Kushk* site complex (Fig. 6). A third one has been suggested by locals at the location of a destroyed cistern southeast of the *Kushk*, which cannot be clarified due to heavy surface disturbance. These mills benefit from the accumulated water, which is released by leading water from a narrow canal to a circular stone [or brick]-made tower on the same level and then letting the water drop into the tower for several meters and moving the grinding stone as desired (Neely, 2011). As suggested here, the water would leave the structure afterwards and rejoin the canal to provide additional functions, such as watering the garden area.

A much-needed extensive survey and related excavation were not possible. Therefore, we do not know much about the details of the identified *Khushab* and mill structures within the *Kushk* complex. However, their existence and locations fit into the larger schema of hydraulic planning of this site complex and seem to find parallels at sites of the Late Antiquity (Beckers *et al.*, 2013; Nazari Samani *et al.*, 2014). Such mills are typical of Sasanian tradition and are reported in several neighbouring areas with spatial relations to extra-urban settlements of the Sasanian period (Neely, 2011; Hartnell, 2014; Khosrowsani, 2021). The crucial role of water-powered milling in the economy of the Sasanian period is known, and historical evidence supports archaeological findings in this matter (Gyselen, 1997).

In summary, the following hydraulic structures seem to be integrated into the *Kushk* monument: (1) at least three *Kariz* series, including their outlets (*Mazhar*) which transport water from the northeastern hills into the valley floor, providing water for surrounding gardens and filling rectangular cisterns for daily use. (2) A minimum of five *Dastkand* series channelling the surface water from the northern gullies through the hills into the valley floor for both water circulation and flood water management. (3) More than 200ha of *Bandsar* for agricultural land use on the northern hills of *Kushk*, and several Joob series directly connect-

for two main reasons: (i) the *Bandsar* water sources are connected to the canals (*Dastkand* and *Joob* series) within the monument and transport the water from the hillsides into the immediate environs of the buildings, and (ii) the *Bandsar* stone structures and terracing contributes to the flood protection of the monuments and provides controlled access to the surface water sources. On another note, the here proposed land use as fruit gardens adds another layer to the aesthetics of such a palatial structure fitting the tradition of paradise gardens of the Achaemenian to Sasanian periods, which are historically attested to the whole region.

ed to the *Dastkand* series for controlling the water volume and flood water management. At least one *Khushab* with an integrated drop-tower mill exists in the same area. At least two other drop-tower mills are identified attached to the *Joob* series of the site complex. (4) A *Polband* connecting the *Kushk* monument to the other side of the stream, (5) a *Barm* with a probable pavilion structure to the west of the main building. These hydraulic structures serve as elements of water management and add another layer to the aesthetics of the monument[1]. The case of *Polband* is less evident due to the completely ruined state of the construction.

Structures Relevant to Zendan

The *Zendan* monument consists of a heavily disturbed three-story building and several ruins surrounding it. The surviving portion of the main building measures 20×15m with thick walls of up to 1.3m of untreated stone with gypsum mortar and traces of plasters on the inner walls. The debris extends to an area of about 30×40m. The structure consists of a central room connected to vaulted rooms via corridors.[2] It lies less than 1km west of the *Kushk* monument on the opposite side of the stream on a steep slope at the foot of the southern hills belonging to the Bozpar anticline (Fig. 2). The local name for the building, implying a prison, cannot be confirmed as its primary function.

The site complex seems smaller than the *Kushk*; however, it is in the same Late Sasanian architectural tradition. It also includes another small building, about 50m northeast of the main building, consisting of at least two rooms with a surviving portion of 10×8m showing elegant openings and plastered inner walls. Traces of at least three heavily destroyed smaller buildings surround the main building at the *Zendan* site complex.

The location of the *Zendan* monument is not favourable in terms of geomorphology and hydrology. The building is in an area with a slope of 5% or more (Fig. 4). In comparison, the location of the *Kushk* monument erected on the valley floor has a slope of less than 1%. The monument is built higher than the stream in an area with at least three active gullies and considerable seasonal water volume. These gullies have such deep incised gorges that several 30m length and 4m width bridges have been built upon them in the last decades. However, these gullies provide only seasonal water flow and are mostly dried up during summer and autumn.

Similar to the *Kushk* area, two further areas regarding the water availability of the *Zendan* site complex could be identified: one containing structures for providing water to the monument and the other consisting of structures for flood protection and the drainage area west of the main building. However, the methods used for either purpose differ between the two sites.

Physically, the *Zendan* monument has no access to the stream as a water source. Furthermore, neither the *Kariz* series were identified as relevant to the *Zendan* monument, nor are there presently springs at this location. This fact leaves

[1] See Calieri, 2006 for this aspect in another type of Sasanian built landscape, royal rock reliefs.

[2] A detailed analysis of the building is currently being carried out and will be published by G. Labisi.

the three gulley channels as the primary water source for the monument. One of the gullies is even on the same level as the *Zendan* monument, with a meander about 40m west of the building (Fig. 9). A recent field visit confirmed traces of stoned markings on this gully's channel on the side facing the *Zendan* monument.[1] This is similar to the *Dastkand* in construction material and technique and supports the idea of anthropogenic modification of the gullies as a water source for this monument. This is a probable and secure water source precisely at the required location for gardens in the *Zendan* building. However, the nature and the details of this presumed and heavily disturbed hydraulic structure are yet to be identified.

A square well (*Chah*) has been identified in the environs of *Zendan* (Fig. 7, D), and a series of *Joob* and *Dastkand* exist, which seem to distribute the relatively high volume of gullies throughout the area surrounding the main building. The identified *Chah* is built with integrated stone walls, measures about 40cm, and its inner side has been plastered. Most probably, the well was secured by a roof or cover of other material. In its immediate environs, debris of stones with similar shapes and sizes are scattered. The well is filled with secondary debris and sediments, so its depth cannot be determined without excavation. This structure differs in size and shape from the typical milling wells dated to the Sasanian period, known from other regions, such as north Behbahan (Khosrowsani, 2021) and Dehloran (Neely, 1974; 2022). Additionally, this structure differs greatly from the well and kiln structures found at the Kheft site (Fig. 2).

No published illustration or descriptions of wells from the Late Antiquity are known to the author. However, square wells have been reported in the context of the built landscape of central Iran, for example, the Konjedi well ensemble (national reg.no. 24196, 2008) near Isfahan, which consists of at least two square wells with 40cm and 50cm in size and at least 8m depth. In 2018, a similar structure was discovered within the modern Isfahan city at the Sasanian fortified settlement called Tappeh Ashraf.[2] Square wells also exist in relation to fortified settlements of highland Zagros, for example, a stone-lined square well of 110cm in Seyfabad Fort,

1 Based on the data collected from the field visit, a rough volume estimation can be attempted for this gulley section. The gully is about 500m long, 8m wide, and 2m deep on average. This results in a volume of 8,000m³. Observations from the last decade based on the average annual precipitation and estimated water availability via satellite analysis suggest that this gulley has transported a high volume of water up to the capacity of its channel in four wet months and was dried up at the other eight months annually. Given that this hydraulic regime is similar to the one in Late Antiquity, this is a seasonally reliable water source but not fit for reliable daily use. Additionally, the steep slope of the gulley makes its water quality questionable for drinking as it will transport a rather high amount of soluble fine particles, if not otherwise enhanced. The water seems to be fit for watering garden areas at best. This would fit the suggested garden areas, shown in Figure 10.

2 Unfortunately, the site is heavily disturbed and not registered in the cultural national list for protection. The size of the well is not reported, only that it is a small square in shape and 6m deep.

southeast of Shiraz (Ghasemi *et al.*, 2020: 266). Historical accounts of Early Islamic times report a square well in the Sasanian caravanserai of Dayr-i Gachin, which could not be identified during the site's archaeological study (Shokoohy, 1983: 448-457). Although several structures are also known in sites with Sasanian and early Islamic material culture, such elements have yet to be studied archaeologically.[1]

Another prominent hydraulic structure is a network of *Dastkand* series (Fig. 8). The striking similarity in construction, material, and size in *Dastkand* and the mentioned *Chah* is noteworthy. The *Dastkand* series in the Bozpar Valley are straight channels made of stone masonry with an integrated flat roof of stones coated both inside and outside. The typical *Dastkand* of Bozpar Valley is 40cm wide, and the walls are up to 20cm thick, depending on the stones used (Fig. 8). At least three rows of stones were placed above the surface, and probably another three were below the surface.[2] Excavated examples of such canal techniques exist in the Sasanian heathland, Behbahan region (Khosrowsani, 2021), and on the frontiers of the Sasanian territory in Moghan (Alizadeh und Ur, 2007) and reported in Marv (Simpson, 2014). Similar cases are available across the Sasanian territory.

Such canals differ fundamentally from the Sasanian "royal canals" of Mesopotamia and lowland Susiana in size and function, which were prestigious projects and, in some cases, even navigable (Christensen, 1993; Wilkinson and Rayne, 2010). The Bozpar *Dastkand* canals were not primarily used for irrigation[3] but rather function as twofold water control features for (i) flood water management and drainage of the monument's environs and (ii) provide the monuments with surplus water during the wet season. The average slope of their contained area is 0.7, which results in a turbulent water flow and prevents low energy water flow or even stagnant water in the canal due to their relatively short length[4].

[1] Private wells in Sasanian Rishahr, near Bushehr, on the Persian Gulf coasts are reported within the houses of the elite associated with fine pottery (Whitehouse and Williamson, 1973: 40). However, the author found no description or schematic view of such wells. The question remains unanswered as to whether there were several types of wells in the Sasanian water strategy or whether using wells in regions with extreme water conditions, such as Bushehr, might have been secondarily privatised. At the moment, examples for both scenarios exist.

[2] Thanks to the visual data provided to us by M. Takalloo in 2022, the author estimated an average water volume for this water source using 3D analyst tools in the ArcGIS environment. Based on this calculation, an average volume of 15m³ flows through 100m of *Dastkand* with the mentioned size. Given the estimated length of the identified *Dastkand* series in the immediate environs of the Zendan monument as 500m, an average of 75m³ of water would be available to the dwellers at a given time. This estimation results in roughly 1.5ml per day by constantly flowing water.

[3] The need for irrigation in this special landscape was met by surface water harvesting techniques such as *Bandsar*, as attested in our recent publications (Hauser *et al.*, 2023; Rashidian, in press).

[4] The spiritual aspects of flowing water in integrated hydraulic structures of Sasanian monuments have been discussed elsewhere. This topic has been touched upon by others (Ajorloo, 2011; Hartnell, 2014) and by the author separately for similar hydraulic structures (Djamali *et al.*, 2021; Rashidian and

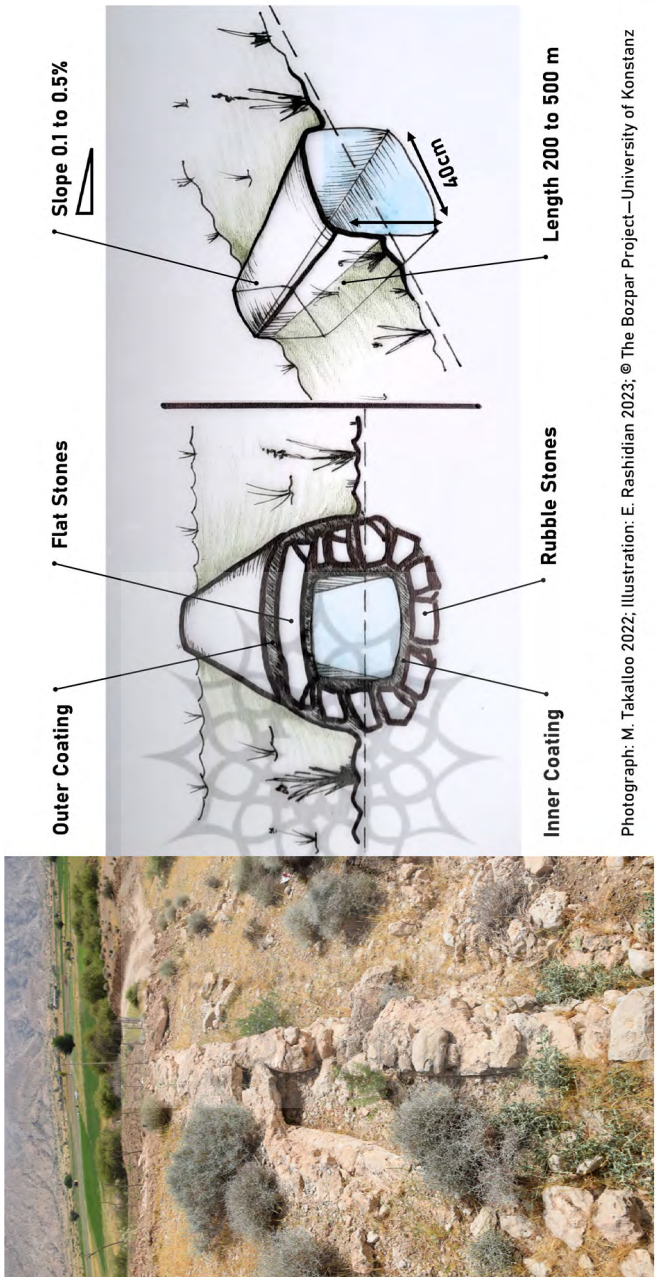

Fig. 8. A Common Dastkand in the Zendan Complex and Its Schematic View

A curious element of the *Zendan* site complex is a rectangular enclosure stretching about 60m in front of the building with 70m width and 250m length. The construction material is identical to that of the *Zendan* building. The enclosure contains an area of about 2.3ha in size. The primary function of this structure is currently uncertain. How-

Askari-Chaverdi, 2022).

ever, it is in direct contact with several *Dastkand* series, which seem to enclose the area, transporting water from the southern hills towards the structure and joining the stream channel at the end. The possibility of an open ground for a hunting show (as pleasure or practice) cannot be excluded.[1] Alternatively, the rectangular enclosure could have provided a particular garden area as a platform for leisure and entertainment (*i.e.*, dancing or musical arrangements) or certain ceremonies. This suggestion is supported by several smaller structures, probably for short-term dwellings on the western side of the main building[2] and three presumed smaller pavilions surrounding the enclosure (Fig. 9). These structures seem to belong to the initial plan of the monument and thus are contemporary to the rectangular structure due to their fitting into the axis and orientation as well as their regular distance to the main Zendan monument.

Another possibility, albeit less probable, would be a large shallow pond for ceremonial washing or activities related to water in a particular season, such as the one reconstructed and proposed for the palace of Khosrow in Qasr-i Shirin[3], which shall reflect the architectural ensemble as an aesthetic element of the monument (Canepa and Hardy, 2018: 57). Unfortunately, no identical structures are known from contemporary monuments in the region for better placement of this element besides a possible structure with similar size in the less-known site complex of Chaharbazar (Ghasemi *et al.*, 2020: 16).

However, other rectangular structures with identical construction materials and techniques are known from several Late Sasanian palaces in west Zagros, such as the palaces of Khosrow I and II in Qasr-i Shirin and Dastgerd-i Khosrow (near Ctesiphon), although with different size and orientation (Canepa and Hardy, 2018: 43). Elongated enclosures related to monuments are known as "paradise" from this period and continue as a cultural legacy throughout the later periods (Pope, 1933; Novák, 2002; Canepa, 2017). All known examples are associated with integrated hydraulic structures similar to our case study.

Therefore, this paper considers this enclosure an integrated hydraulic structure due to its apparent connection with the monument and water distribution via the identified *Dastkand* and *Barm* structure. One interesting question arises regarding the connection or multi-functionality of several identified enclosure walls and the *Dastkand* series, as they are identical in orientation and size as well as construction material at some locations. Curiously, such examples of enclosing walls with integrated and elevated channels for transporting water to provide for inner gardens exist in the mentioned sites from the Late Sasanian architectural tradition in west Zagros (Canepa and Hardy, 2018: 42-43). If true, this might also be similar in construction and technique to the presumed aqueduct north

[1] Examples are known from royal rock reliefs of Bisotun and Taq Bostan in West Zagros.

[2] Preliminary field trip data analysis suggests a structure with several rooms surrounding a central courtyard in the architectural tradition of the Late Sasanian period. Advanced architectural studies of these structures are ongoing and will be published by G. Labisi soon.

[3] See Labisi, in press for an alternative view.

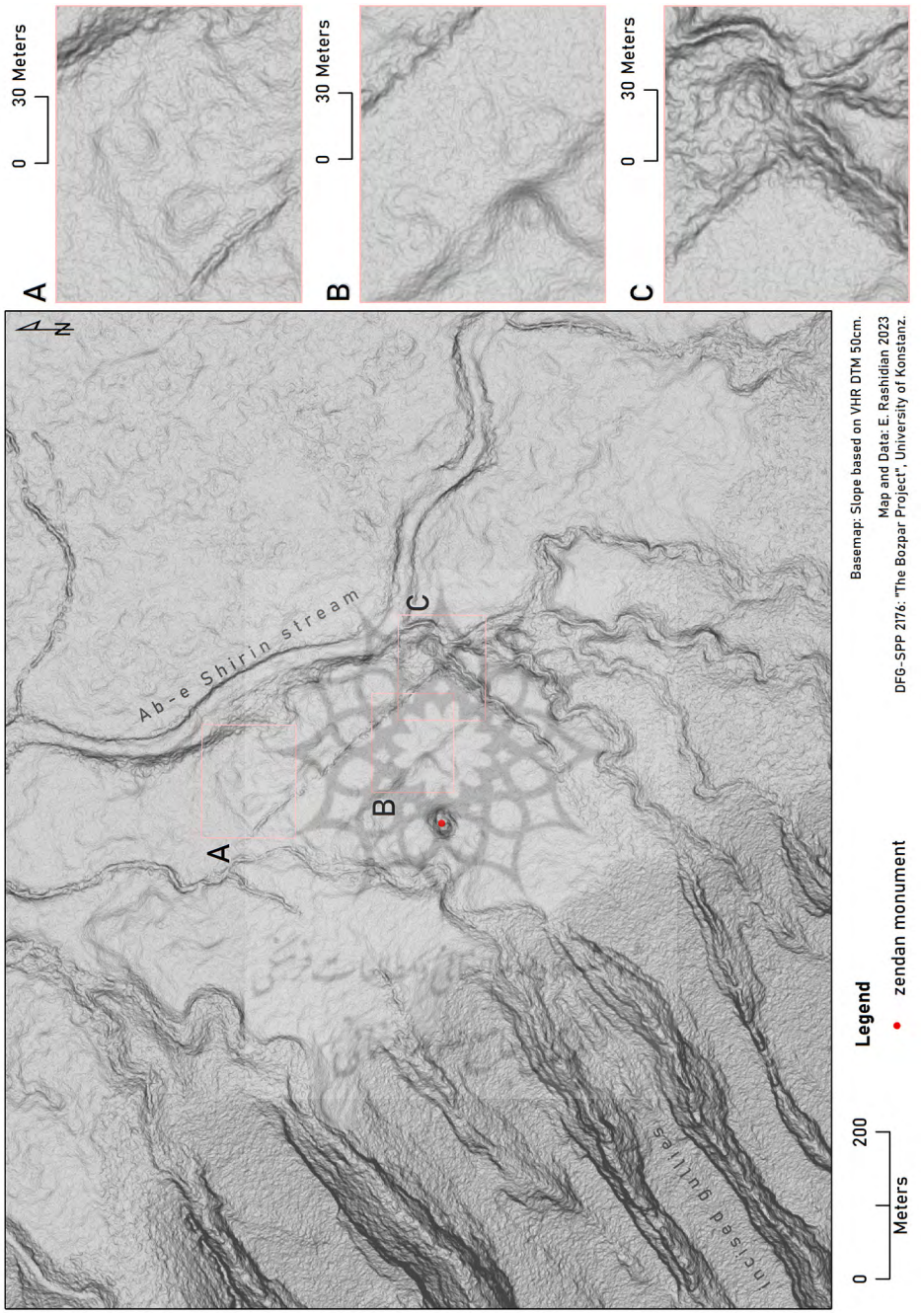

Fig. 9. Hydraulic Structures Relevant to the Zendan Monument: Traces of an Unknown Building with a Circular Pond, Probably a Smaller Pavilion (A), Another Building (Pavilion?) at the Rectangular Enclosure (B), and Traces of a Structure (Pavilion?) at the Junction of Several Dastkand Series (C).

of *gur* on the northern hillsides of Bozpar, mentioned earlier. Future excavation shall shed light on the extent and nature of this element in the Bozpar Valley.

Ruins of another structure exist about 200m to the northwest of the *Zendan* monument (Fig. 9, A). The presumed building is gravely damaged, so its initial form and function are not identifiable at this stage. However, a circular pond with a radius of 17m[1] seems to exist in front of the building (Fig. 7, C). The *Barm* lies higher than the stream; no active spring can be identified in its immediate environs. Yet, it seems possible that it could have been filled with water from the underlying horizons connected to the stream, which flows about 50m to its east. Visible traces show a similar construction with at least three steps into the depth,[2] as is the case with other known structures in Firuzabad (Djamali *et al.*, 2021; Rashidian and Askari-Chaverdi, 2022) and elsewhere in Bozpar (*Kushk* and Kheyrak).

Based on the presented analysis, several hydraulic structures were identified in relation to the *Zendan* site complex and its integrated water management (Fig. 10). The axis of water sources is related to the incised gullies. The ruins of the other buildings in the site complex seem connected through a *Dastkand* network and arranged around the rectangular enclosure. These structures have never been investigated archaeologically. However, given that the *Zendan* main building might have been a (seasonal) Late Sasanian leisure palace, these structures can be identified as pavilions[3] based on their size and location, as is the case in similar known complexes, for example, in Tepe Hissar in the Iranian central highlands (Schmidt, 1933). Similar architectural complexes are known in western Zagros highlands as royal hunting fields (Ajorloo, 2011).

One crucial element in comprehending the *Zendan* monument is its spatial relation to the *gur* monument. The *Zendan* main building crosses the middle of the rectangular shape, and the pavilions are on the same axis as the *gur* monument regarding architectural orientation and visibility (Fig. 2). This fact supports the hypothesis that *Zendan* was built for reasons other than *Kushk*, not for permanent dwelling but to pursue ceremonial or pleasure-related activities, probably related to *gur*. Hence, the *gur* monument might have been an existing and relevant fix point in planning the *Zendan* monument. This could explain the need for building the monument on the other side of the stream (contrary to all the other known structures in the entire study area; Fig. 2) and on a rather disadvantageous

[1] The exact radius is unclear due to secondary debris, and it might be 8m, the same size as the other *Barm* attached to the *Kushk* monument, or 18m, which is much larger than the *Kushk* Barm.

[2] The author discusses the presence of such a circular pond with a building, most probably with an *eyvan*, in the Sasanian built landscape of highland Zagros in a separate paper titled "*The shape of water; geometrical aspects of water elements in the Sasanian built landscape at the example of circular ponds in highland Zagros*", currently in preparation. The author suggests a connection between the revival of the Anahita cult in the early Sasanian period and the ceremonial washing in a spring-fed pond with a circular shape as the best representation of Iranshahr based on Ardashir Papakan's reading of this idea. This crucial topic is out of the scope of this paper. However, the examples from Bozpar are also described in the mentioned paper.

[3] For a discussion of possible interpretations, cf. Huff *et al.*, [forthcoming]

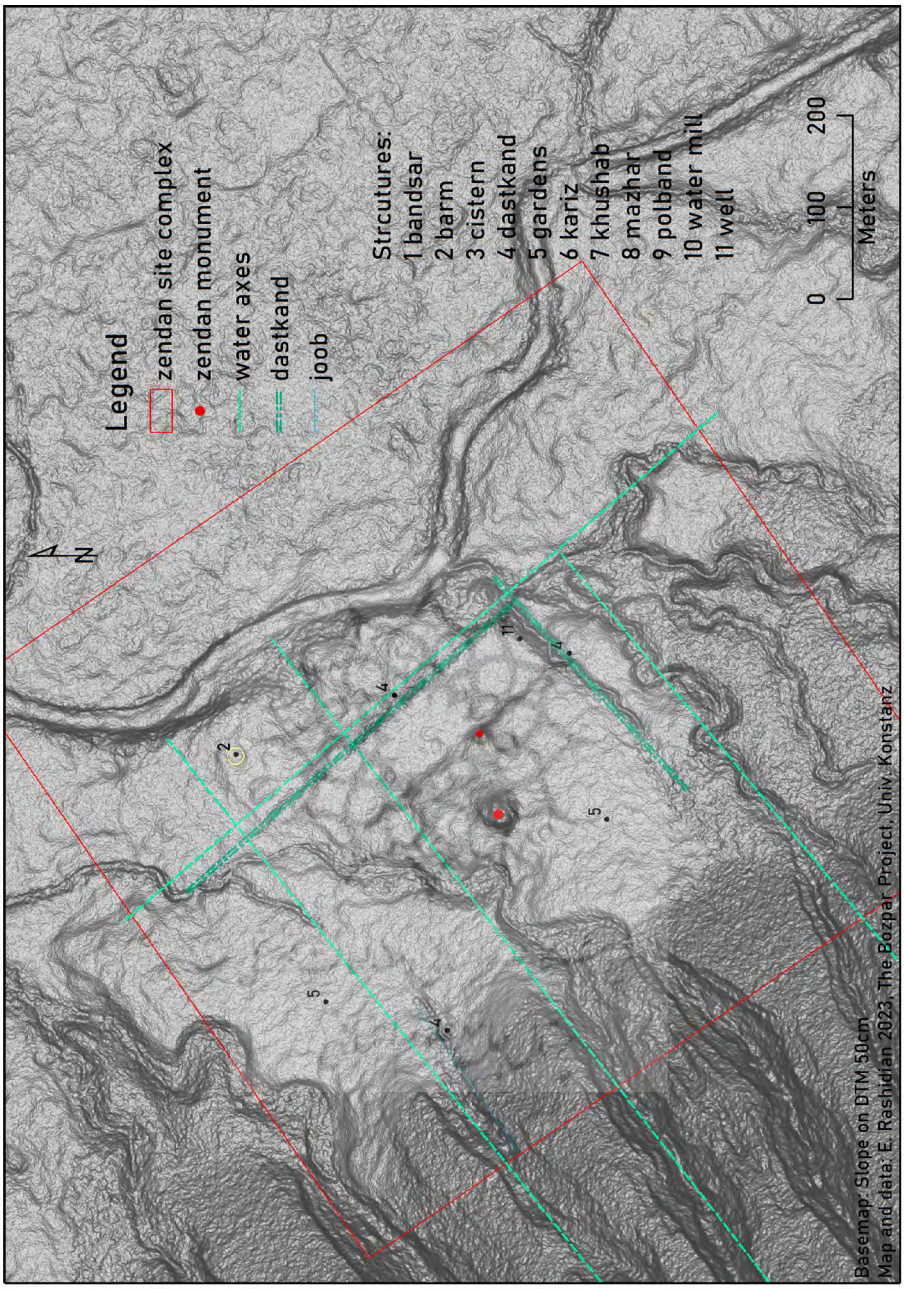

Fig. 10. The Zendan Site Complex and its Hydraulic Structures Showing the Axes of Water Sources and the Identified or Presumed Structures

location in terms of erosion, flash flood hazards, and water availability.

The integrated hydraulic structures of *Zendan* include the following: (1) at least three *Dastkand* series transporting the water from incised gullies of the southern

hills into the monument and controlling the water volume for flood water and erosion management and connected to a network of smaller *Joob* series for a better distribution; (2) at least one square *Chah* predominantly related to the ruins of the other remaining building near the *Zendan* monument, about 200m to its east in the vicinity of the stream channel in times of high ground water table, probably for daily use; (3) at least one *Barm* attached to a presumed smaller pavilion with apparent connections to the *Dastkand* series; (4) unknown structures on the channel of the central gulley about 40m west of the monument, probably including a small weir for access feasibility to the turbulent water flow. This is a speculation based on the heavily disturbed remains and similar cases. Extensive excavation shall examine this hypothesis.

In summary, the hydraulic structures of *Zendan* differ remarkably from those in *Kushk*. The lack of sub-surface water harvesting strategies (*Kariz* for *Kushk*), as well as surface water harvesting for agricultural use (*Bandsar* and *Khushab* for *Kushk*) in *Zendan*, indicate a different function for this monument compared with the *Kushk*.

Conclusion and Perspective

The use of seasonal water sources with a programme of intensive land use reform and the subsequent landscape transformation within the Sasanian built landscape, as proposed by our project, has recently been also discussed by Maresca (2019: 211). However, specific case studies have yet to be presented on this matter. The Bozpar Valley provides a singular example of this phenomenon. Based on the mentioned results, the following can be stated for the study area:

- The initial hypothesis of our project (Rashidian, in press; Hauser *et al.*, 2023; Labisi, in press) suggesting a drastic transformation in land use contemporary to the foundation of the monuments can be confirmed based on the clear spatial relation of the identified hydraulic structures and these monuments.

- Several hydraulic structures were integrated into the plan of the archaeologically known monuments in the Bozpar Valley, including *Kushk* and *Zendan*. These features are clearly relevant to the site complex and its interpretation and belong to a limited period of intensive land use and resource exploitation.

- The nature of the integrated hydraulic structure in the plans of the two monuments differs. The *Kushk* complex primarily includes sub-surface water harvesting such as *Kariz*, *Polband*, and *Barm* structures. This monument integrates the Ab-i Shirin stream into its hydraulic plan to some extent. On the other hand, *Zendan* seems to rely on surface water harvestings such as *Dastkand* and *Joob* series, manipulated gully channels which transported the water from flash floods into the site complex. A *Barm* is also identified at this location marking its importance as a probable ceremonial purpose. Further studies shall address the question of the monuments' nature and whether their divergence in respective integrated hydraulic elements may indicate a difference in their function, as suggested here.

- The *Kushk* monument is relatively secure in terms of both water sources and flood protection, while the *Zendan*

monument must have suffered from both water shortage in the dry season and flood hazards in the wet season. Hence, we suggest differences in function and occupation. The *Kushk* main building, most probably, housed representative and official purposes, while the *Zendan* complex might have been employed for seasonal pleasure and entertainment purposes. An architectural analysis of the monuments also supports this idea.[1] A critical point of interest is the location of the *Gur* monument, which stands on a visual axis to the *Zendan* monument and may have played a key role in the spatial arrangement of these site complexes.

While this paper presents new and compelling evidence for a holistic narrative of the settlement dynamics in the Zagros highlands, the extent of currently less-studied features in the landscape cannot be overestimated. Undocumented integrated hydraulic structures exist in several sites in Greater Fars and beyond. A perfect example is presented by the nearby site complex near the village of Kheyrak[2], which is situated just 7km to the northwest of the *Kushk* alongside the same stream of Ab-i Shirin, at the other side of the Kheyrak gorge, ruins of another Late Antique monument (national reg. no. 16257, 2016).

The main building is hidden within a modern palm tree plantation near the village. The site complex includes a strikingly well-preserved *Barm* in front of the ruins at a 25m distance. The *Kheyrak* complex is also known as Kushk-i Ardashir by locals and presents parallels in construction material and plan with the *Kushk* of the Bozpar Valley. Traces of *Bandsar* are visible on the northern hills of the gorge about 300m north of the monument and contain at least 50ha of arable land through this technique. Additionally, the monument is located on a small plain of at least 25ha with favourable conditions for gardening. No archaeological study has been conducted on this monument so far. This brief example shows the significant number of unknown elements in the Sasanian built landscape in the Zagros highlands that have been neglected in reconstructing the settlement evolution of Late Antiquity.

The remote landscape of this highland valley in the folded belt of Zagros is part of a larger area, which has witnessed a tangible transformation of land use in Late Antiquity following the Sasanian economic reform and the subsequent Arab invasion (Christensen, 1993; Gyselen, 1997; Mousavi and Daryaee, 2012). The Greater Fars region has been the heartland of the Sasanian Iranshahr (Daryaee and Rezakhani, 2016) and a core to the Iranian identity (Canepa, 2018). Several projects were first implemented here before expanding into the neighbouring areas of the Sasanian territory, including the bordering and frontier areas (Alizadeh and Ur, 2007; Simpson, 2014). This particular landscape transformation showcases the interaction of settled and nomadic populations in a time of attempts to centralise resource exploitation and politicise the landscape

[1] The results are in preparation and press in separate papers by G. Labisi.

[2] The author discusses this example and several others in a separate paper regarding their identification as *Dastgerd* ensembles, which is currently under review by Parthica.

transformation of the Iranian highland[1]. Hence, a study of the evolution of the settlement dynamics in this region can be vital in comprehending the late antique land-use strategies and the subsequent landscape changes of the Ancient Near East.

The Bozpar Valley offers an excellent example of such dynamics. While historical accounts of the suggested transformation are lacking for this region, the geoarchaeological evidence points toward less-studied settlement types alongside known types, such as newly funded cities and estates. One such settlement type is *Dastgerd* (Gignoux, 1994), an extra-urban estate with a specific function, mainly of agricultural nature, within a taxing unit of the Sasanian and early Islamic economic system (Kennedy, 2011: 72; Whitcomb, 2014; in press, 2023; Labisi, in press). Based on the landscape analysis and the archaeological evidence, the Bozpar Valley can be considered a *Dastgerd*[2] (Hauser *et al.*, 2023).

Further studies shall shed light on this topic.[3] If valid, a significant factor in Late Antique settlement dynamics of the wider region has been identified. This will provide a framework for comprehending the sociocultural transformation of Iranian highlands in later Sasanian and early Islamic times.

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[1] Unfortunately, we have no solid evidence of this presumed interaction in Late Antiquity. However, similar examples of population transfer and settlement strategies for pastoral communities are known from the Sasanian period. Additionally, the Bozpar valley has been home to pastoral communities for at least several centuries since the Late Antiquity, as the historical accounts suggest. See Rashidian, in press, for a brief description.

[2] It is worth noting that the concept of "garden" or "paradise" as a continuous ideological element of landscape transformation since the early first millennium BCE (Novák, 2002) is linked to the *Dastgerd* concept in the Late Antiquity (Gignoux, 1994), yet often neglected in the former discourse (Canepa, 2017; Canepa and Hardy, 2018).

[3] We presented this idea in a recent publication (Hauser *et al.*, 2023). G. Labisi has also elaborated on the architectural elements of a *Dastgerd* and the historical evidence for such a settlement type in a separate paper currently in press (Labisi, in press). The author has discussed this idea from a landscape perspective with reference to further cases with similar elements in a separate paper titled "The Landscape Elements of a Dastgerd according to the Bozpar Valley and Similar Case Studies in the Iranian Highlands", currently under review by Parthica.

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