Fighting Drought With Flood Reviving Ancient Strategies To Tackle Water Scarcity In Flood-Prone Arid Regions

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INTRODUCTION

Rainfall, temperature alterations, and being located in an arid/semi-arid climate zone[1] have limited Iran's renewable water supply which led to the water stress and droughts that would continue in the future[2] . However, paradoxically some regions like Ahvaz City[3] , suffer from floods[4] , one of which was the 2019 flood that caused infrastructural damages[5] and ruined rural areas[6] (Fig. 1).

Khuzestan Province flood maps[7] and drought maps[8] indicate that Ahvaz is located in the hazardous flood zone[9] (Fig. 1-b), and also in the worst drought zone[1] (Fig. 1-d), which is supported[2] by predictive climate maps[10] . Additionally, anthropogenic impacts of development like continuous short-sighted unsustainable solutions[11] depleted the reserve and created food and social insecurity[12].

The flood-drought paradox in this province seems unorthodox considering its rich water management[13] history where residents protected their urban ecosystem[14] by utilizing schemes such as Qanat[15], Ab-Anbar[16] , Gourab[17] , and flood barriers[18] . These ancient methods stemmed from Persian beliefs[19] toward water sanctity manifesting as praying rituals[20] near water bodies similar to the Mexica-Nahua culture[21] .

Moreover, outside forces and governmental decisions made people socially passive[22] toward resources governance[23]. The timeline in Fig. 2 reveals the historical turning points that led to the current situation.

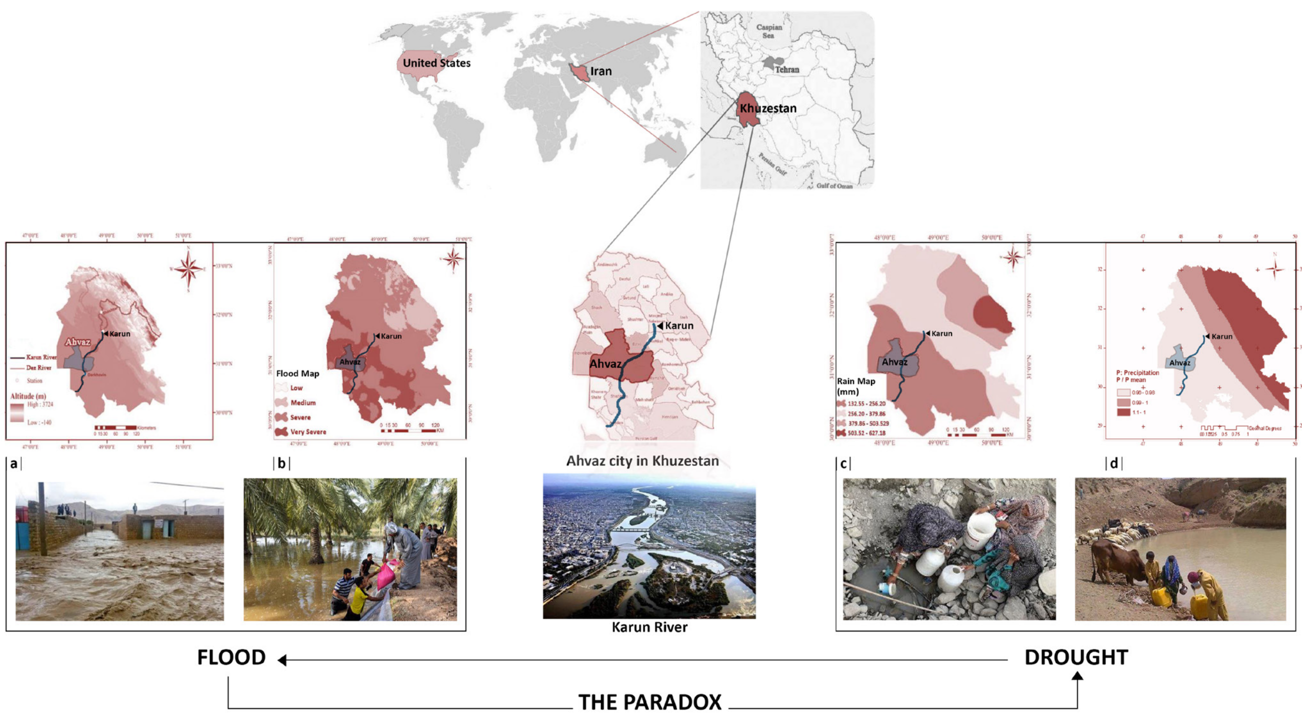

Figure 1. Khuzestan Province and Ahvaz City climactic maps. Author.

a) Elevation[8], b) Flood zones[8], c) Rainfall zones[8], d) Drought returns zones (for every two-year return period)[1]

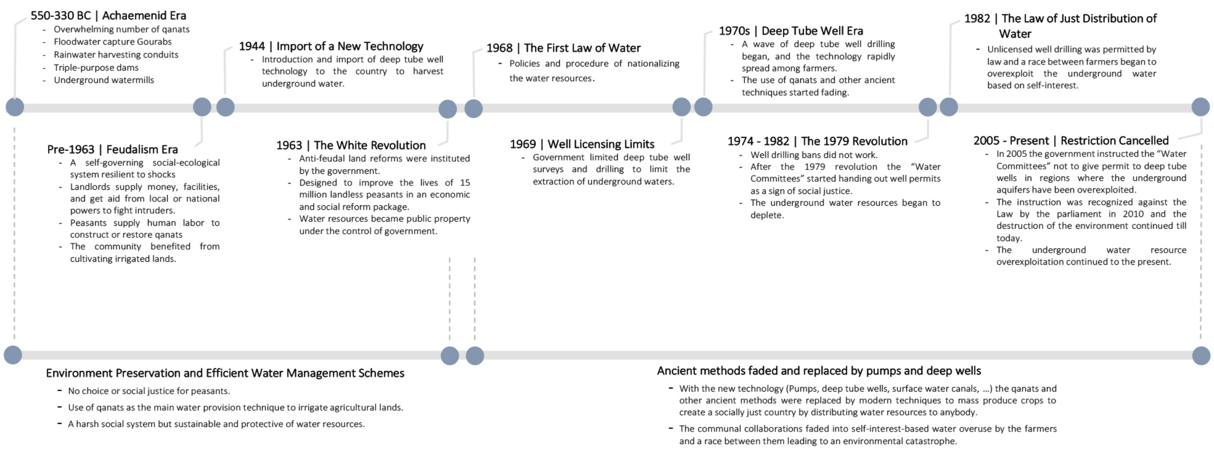

Figure 2. Historical timeline of governmental decisions affecting groundwater depletion[24]. Author.

PROBLEM STATEMENT AND APPROACH

How can we address the flood-drought paradox through design with a non-governmental, independent approach?

The study applies the theory of norm shift[25] and employs the local ancestral expertise in water management and preservation. Such a paradigm shift has two aspects: efficient use of water resources, or "Natural Capital", and increasing villagers' awareness, or "Social Capital", of effective ancient or modern water management techniques.

The new norm mobilizes citizens to develop a bottom-up, self-reliant approach to the socio-cultural and environmental issue by active participation. They will be able to create a sustainable living system[26] using local materials and vernalar architecture. Based on a careful study of the site's micro-topography, a drainage network is designed to control the detention and retention of floodwater in agricultural lands by employing the ancient water collection method (Gourab) (Fig. 5) and the preservation method of Ab-Anbar / Badgir[27] (Fig. 3).

The considered subterranean water reservoirs (Ab-Anbars) in the designed cistern complex provide year-round potable water and a community oasis where a comfortable microclimate is produced. The outcome heals human-induced environmental damage by promoting local expertise and enabling natural capital.

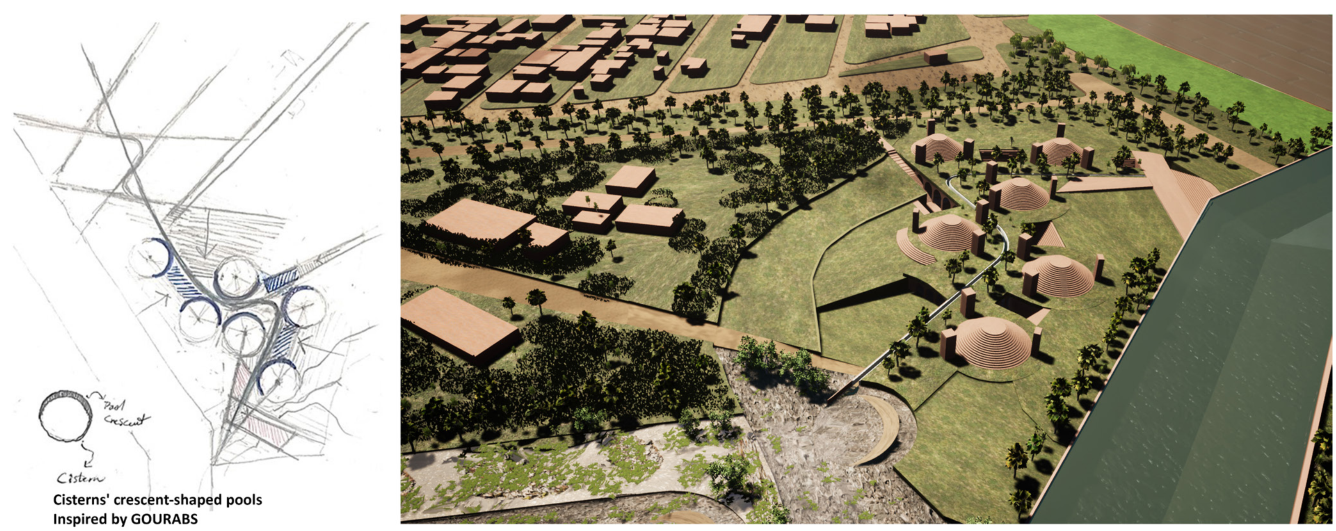

Figure 3. Design of the Cistern (Ab-Anbar/Badgir) Complex. Author.

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RESULT

The project proposes floodwater diversion and collection at the target village (Maksar-Biyuz). The topography and slope analysis reveal the flood breaching behavior from the Karun River levee (Point A) toward the village's agricultural lands[29] which covers all the neighboring lowlands (Fig. 4).
To control and direct breaching water, the existing drainage canal (Fig. 4) will be modified and applied to collect water.

Based on previous floods[30] and the base flow rate of the Karun River[31] , the average flood volume reaching the village is estimated to be 24,180,000 m^3.
The topographic analysis indicated that 5,250,000 m^2 of lowland (below the flood elevation) are available for water collection. If 0.5 meters is considered the average depth of collected water, 2,625,000 m^3 can be captured (Fig. 4).

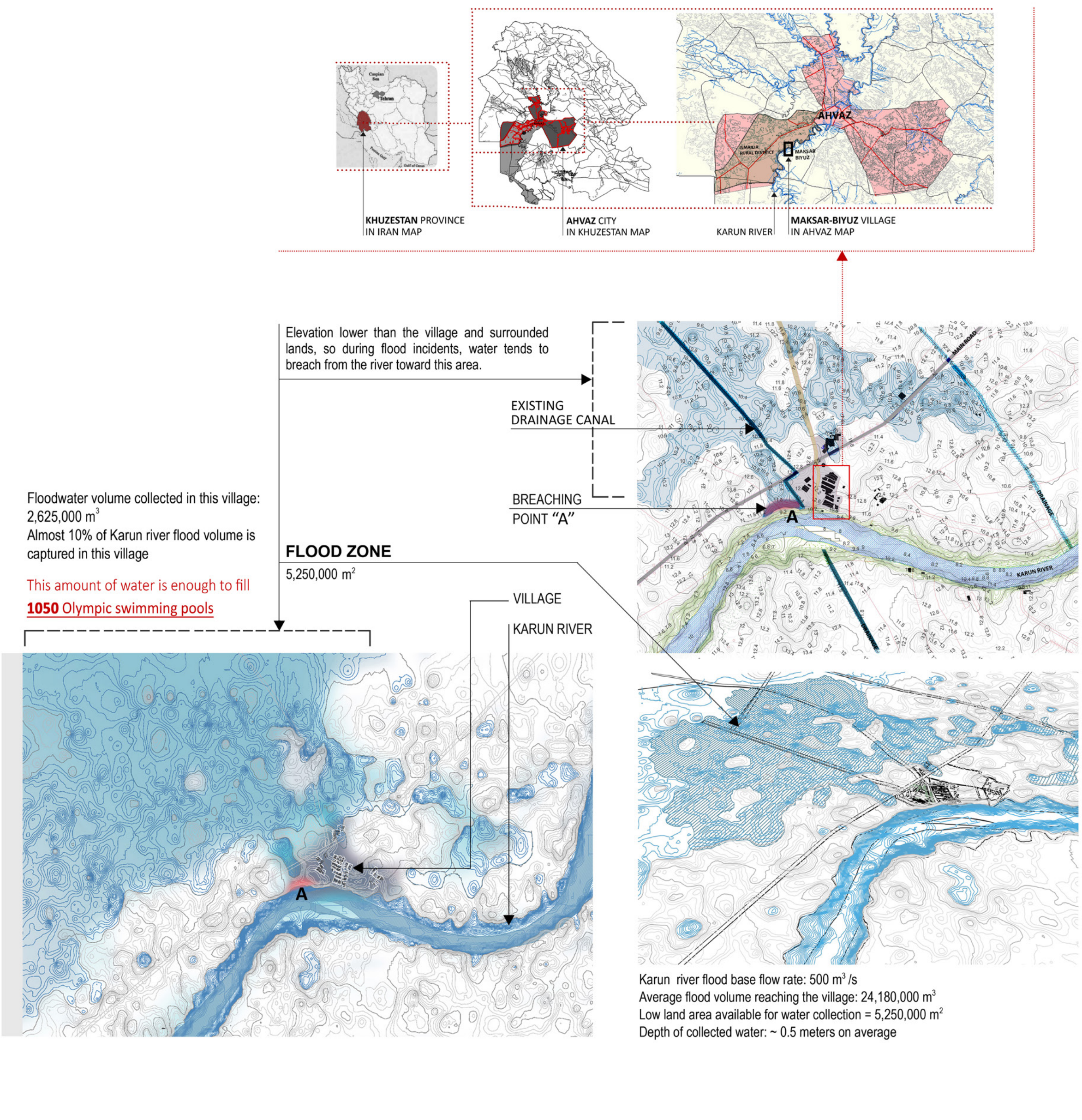


Figure 4. Flood zone based on the topography analysis of the Maksar-Biyuz village. Author.

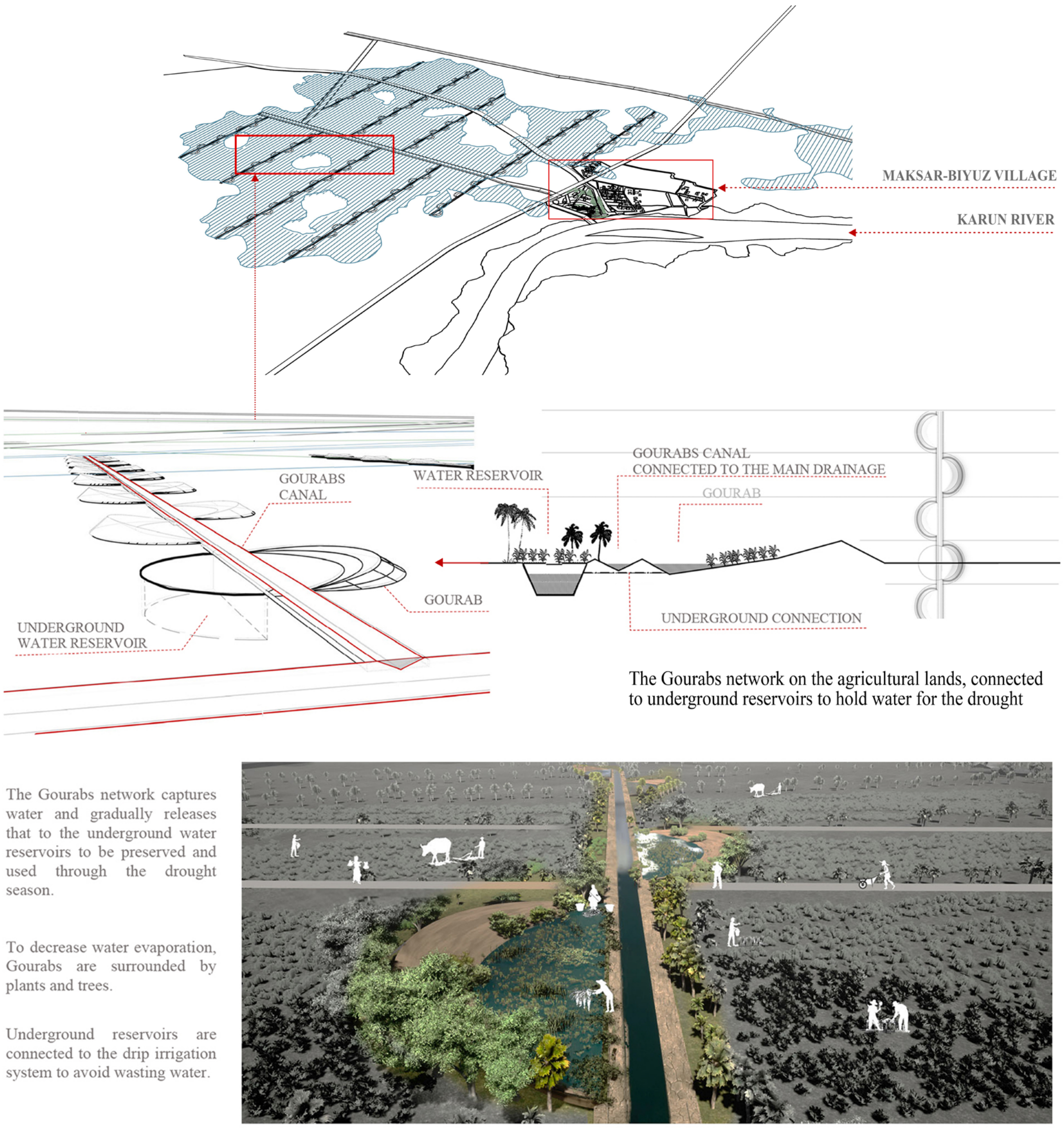


Figure 5. Gourabs Network based on the flood zone in agricultural lands for flood control and water collection. Author.

Accordingly, almost 10% of the total flood volume can be detained in this village. Therefore, if 10 other neighboring villages implement similar practices, the flooding issue will be controlled in this district. Irrigation Water for Agriculture: The project includes constructing a network of Gourabs on the village's agricultural lands by the villagers with local methods[32] and labor[33] to collect floodwater and detain it inside underground reservoirs for drought periods (Fig. 5-6). Potable Water for Residents: Since the villagers have been suffering from a severe drought and using contaminated water[34], another goal of this design is to find a solution for the potable water scarcity of the village. In this regard, several cisterns are considered (Fig. 7-8) to hold clean water underground based on the ancient water management method[35] (Ab-Anbar) which is a combination of cisterns and wind-catchers that creates thermal comfort inside the complex with cool humid air (Fig. 8).

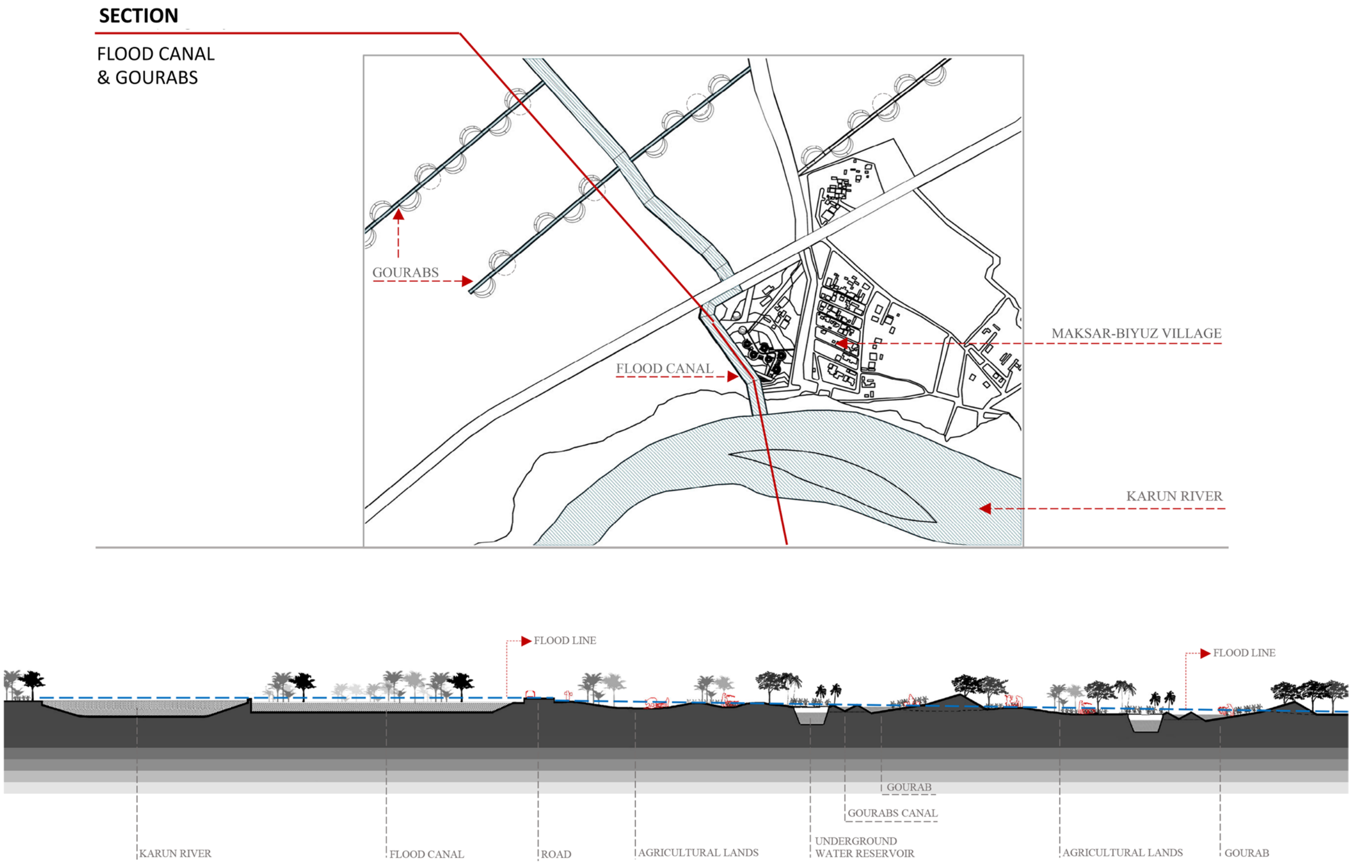


Figure 6. Flood canal and Gourabs section. Author.

The designed cistern complex (Fig. 3) would provide clean water for the villagers who believe in the sanctity of water and act as an oasis for social gatherings and daily rituals (Fig. 8-10). The structure would be built based on the local methods of cistern construction[36] and will be located close to the village for convenience and near the path of water for maximum collection. Based on the village population, 464 persons, and the annual potable consumption which is almost 17,000 m^3, six cisterns are considered for the year-round water demand.

Social Implications of Water: The proposed solution encopasses ancient collaborative communal construction methods that people are familiar with and would be an applicable approach for the residents.
Cisterns and Gourabs will be constructed one at a time to demonstrate the effectiveness of the approach, gradually realizing the full scope[37].
The construction and usage of the cistern complex both are in line with the traditional rituals of the local people acting as a purpose to alleviate their flood-drought problem as well as creating an active, participating, and caring community toward their limited environmental resources by a gradual shift in the social interactions of the people.

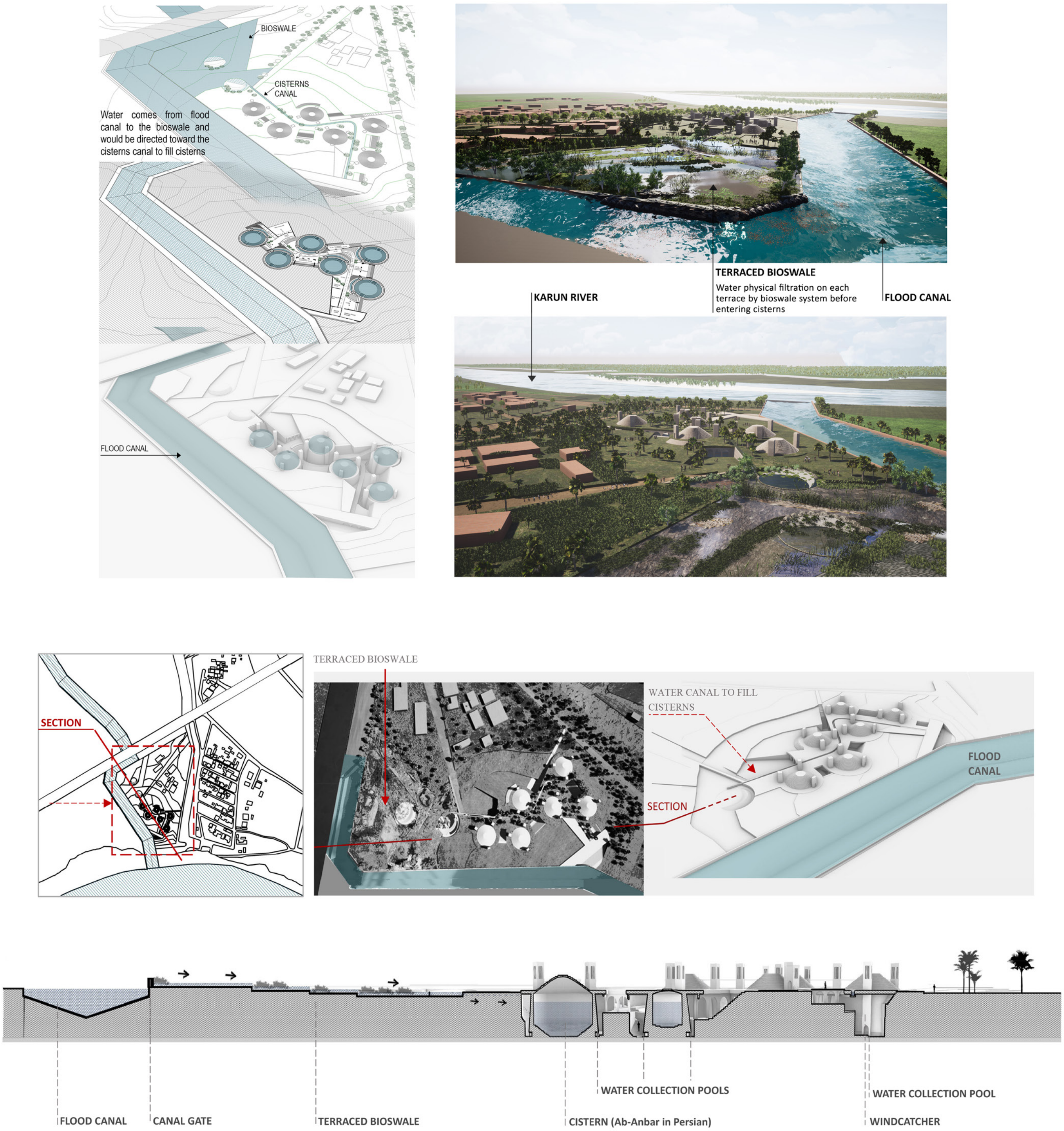
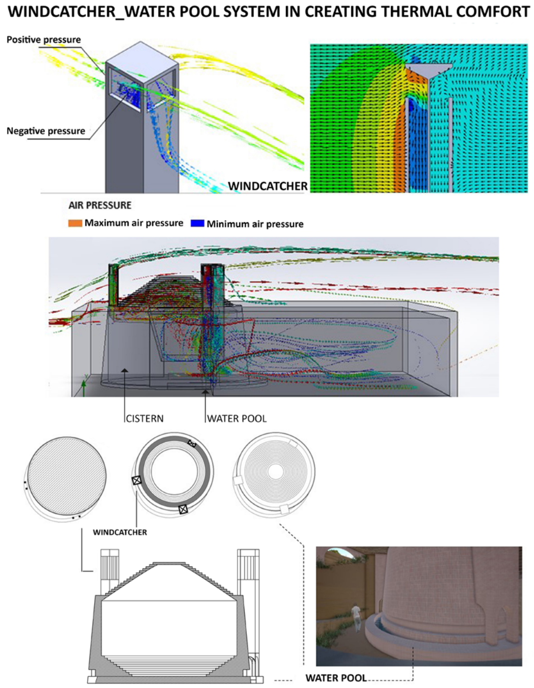
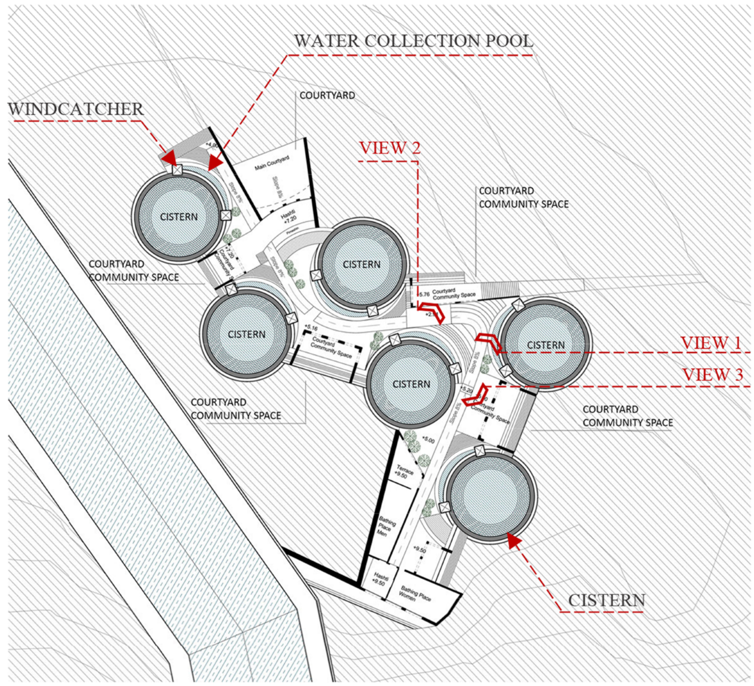


Figure 7. Directing floodwater from the Karun River toward the cisterns using the flood canal to preserve water for drought. Author.



|a| Windcatcher (Badgir) performs based on the concept of inducing positive and negative pressures and makes natural airflow. This flow passes over the water pools and becomes cool and humid creating thermal comfort underground.



|b|

VIEW 1
People are coming underground to the cistern's pool to collect water

VIEW 2
Shaded courtyard as a community space and one of entrances to the cistern complex

VIEW 3
Shaded courtyard as a community space

|c|

Figure 8. a) Cistern and windcatcher performance, b) Cistern complex underground plan, c)Interior perspectives. Author.

CONCLUSION

A universally applicable practice can be extrapolated from this study to alleviate the water shortage problem in flood-prone arid regions. It diverges from the conventional 20th-century engineering approach[38] where flood control is considered independently from drought resistance[39]. The limits are now obvious on the water cycle[40].

In contrast, the project proposes to "tame" the behavior of water by letting it follow its natural course. Instead of eliminating flood, the region will embrace it for a positive impact on agriculture, accumulating fertile soil and collecting floodwater to alleviate water shortage[41]. Such a scheme speculates an alternative low-tech, hi-impact strategy toward a sustainable built environment.

PROJECT

Figure 9. Cistern complex in Maksar-Biyuz village. Author.

Figure 10. Exterior perspectives of the cistern complex. Author.

ENDNOTES

1. Hadi Moazed et al., "Analysis of drought return periods in Khuzestan province, southwest of Iran," Journal of Food, Agriculture & Environment 10, no. 1 (2012): 642-645.
2. Karim C. Abbaspour et al., "Assessing the impact of climate change on water resources in Iran.," Journal of Water Resources Research 45, no. 10 (October 2009), W10434. https://doi.org/10.1029/2008WR007615.
3. Ahvaz City is the capital of Khuzestan Province (South East of Iran) where the Karun River, the largest river in the country, passes through the city.
4. The most recent flood happened in December 2021.
5. During the massive flood of 2019, although several large dams were built along the main rivers over the years, and even with flooding predictions that alerted people and authorities ten days prior to the flood, the disastrous incident happened anyway.
6. Yousef Rajabizadeh, Seyed Ali Ayyoubzadeh, and Mehdi Ghomeshi, "Flood Survey of Khuzestan Province in 97-98 and Providing Solutions for its Control and Management in the Future." Iranian Journal of Eco hydrology 6, no. 4 (2020): 1069-1084.
7. The study reveals that the southern and southwestern parts are in a very severe situation and the central (Ahvaz City and its rural areas) and southeastern parts are in a very hazardous condition, confirming the flood threats to regions affected by the 2019 flood.
8. For any drought investigation, drought maps are required. However, droughts are phenomena dependent on the location and regional context, therefore it is beneficial to develop drought maps that are derived from regional meteorological station-based indices. Data used in this study was based on annual and monthly average rainfall values at 16 synoptic stations in Khuzestan Province over 31 years.

   Steven M. Quiring, "Developing objective operational definitions for monitoring drought," Journal of Applied Meteorology and Climatology 48, no. 6 (June 2009): 1217-1229. https://doi.org/10.1175/2009JAMC2088.1.
9. Karim Solaimani and Shadman Darvishi, "Zoning and Monitoring of spring 2019 Flood Hazard in Khuzestan Using Landsat-8 Data," Iranian Journal of Eco hydrology 7, no. 3 (October 2020): 647-662. https://doi.org/10.22059/ije.2020.302703.1333.
10. Average annual rainfall in Khuzestan Province is in the range of 201-300 mm. The predictive maps indicate that for the periods

of 2013-2039 and 2073-2099 there would be no change or minor changes in the precipitation, a 0.01-10.0% increase, and a 10.01-20.0% increase, respectively. Both these changes would not make any substantial impacts on precipitation in the province.

11. Mohsen Maghrebi et al., "Iran's Agriculture in the Anthropocene," Journal of Earth's Future 8, no. 9 (September 2020). https://doi.org/10.1029/2020EF001547.

12. Nezam Asgharipour Dasht Bozorg et al., "Identification the traditional methods of rainwater harvesting in Khuzestan province," 6th national conference in rainwater catcher surfaces, Isfahan, Iran (2017).

13. Residents trapped rainwater or floodwater and reserved it for later use, especially during drought periods. They avoided transferring water on surfaces exposed to direct sunlight and used qanats as an underground conduit and Ab-Anbars as underground reservoirs.

14. During the Achaemenid era (550 – 330 BC) fertile lands of Medes, Khuzestan, and Pars irrigation and drainage systems were common features with an overwhelming number of qanats. There were wells wide in diameter serving as reservoirs that were filled by floodwater in winter and spring and used in other seasons. Clay and rocky gable roofs in the Persepolis were installed inside the walls to conduct rainwater to the underground conduits and cisterns. Ancient Persian water management methods were delicately defined to maximize efficiency. Dams were designed to deliver dual or even triple purposes (collection of water, acting as a bridge, harvesting energy from water in watermills).

    Andreas N Angelakis et al., *Evolution of Water Supply Through the Millennia* (London, IWA Publishing, 2012), 92-126.

    Seyed Mohammad Hashami, *Case History of Tabriz Water* (East Azerbaijan Province, Water and Wastewater Company, 2010)

15. Qanat is an invention of ancient Persian engineers that used gravitational force to harvest underground water beneath the elevated lands (mountains) toward low-elevated arid lands using a network of underground transfer tunnels.

16. Ab-Anbar /Ãb ænbÃr/ (cistern) is an ancient water storage system to keep the drinking water.

    Siamak Gholami et al., "Development of Ancient water storage systems namely Ab-Anbar by Evaluation, a Technical Method in Iranian deserts (By Environmental aspects structures)." Journal of Water and Environment, Iran University of Science and Technology, Tehran, Iran (May 2015).

17. Gourab /go:rÃb/ is an ancient crescent-shaped Persian surface water collection barrier that holds rain or flood water.

    Nezam Asgharipour Dasht Bozorg et al., "Identification the traditional methods of rainwater harvesting in Khuzestan province," 6th national conference in rainwater catcher surfaces, Isfahan, Iran (2017).

18. Nezam Asgharipour Dasht Bozorg et al., "Identification the traditional methods of rainwater harvesting in Khuzestan province," (2017).

19. There are cultural aspects to the issue that should not be ignored as water has always been a sacred part of their beliefs and daily routines. Ethnographically, the province has been home to three ethnicities of Bakhtiari Lors, Arabs, and Persians. Their ancestors never polluted water and respected it since they believed the god's wife "Anahita" was the protector of the water, they had many water rituals and some still do. Since Anahita is a woman, only women are allowed to carry water because of their pure souls and it should be done at sunrise since the sun is the element of light, life, and purity, and at night because of the Devil, carrying water is considered a sinful act.

20. They prayed beside waters coming out of the ground (Springs, wells, or underground waters) in a ritual as they thought it would be granted.

21. The Mexica-Nahua (Indigenous Americans) held a water ritual that was a ceremony where individuals honor water as a life-giving, spiritual force.

    Iyana Esters and Gabriel Kwan, "The water ritual," The water main (May 2019). https://www.thewatermain.org/blog/the-water-ritual#:~:text=The%20Indigenous%20Nahuatl%20water%20ritual,performing%20dances%20in%20the%20water.

22. Repercussions of political decision-making and political ecology parameters such as power relations, inequity, and corruption in top-down governmental regulations are the reasons behind such a change in social attitude that led to social passivity toward water resource preservation.

23. Ali Bagheri, S. Jalal Mirnezami and Ali Maleki, "Inaction of society on the drawdown of groundwater resources: A case study of Rafsanjan Plain in Iran," Journal of Water Alternatives 11, no. 3 (August 2019): 725-748.

24. Carl Folke et al., "Resilience thinking: Integrating resilience, adaptability and transformability," Journal of Ecology and Society 15, no. 4 (2010).

    Paul Ward English, Q*anats and lifeworlds in Iranian plateau villages* (Austin, Yale F&ES Bulletin, 1998): 187-205.

25. The gradual and phasing of the construction over a period of time, make it feasible and applicable since it requires a labor force from the village, gives the residents the time for becoming familiar with the techniques, and see these tools actually alleviate their water shortage problem, and gradually adapt themselves to the new method. Taking this path makes people aware of the ancient resiliency methods that would educate them as a community (promoting social capital) while leading them toward protecting their environmental ecosystem in the long run (promoting natural capital). This is how the concept of norm shift would be applied to this village that could put them on the track to sustainable development.

26. Erica Gies, "The Architect Making Friends With Flooding," MIT Technology Review (May 2021). https://www.technologyreview.com/2021/12/21/1041318/flooding-landscape-architecture-yu-kongjian/

27. Xiaogang He et al., "Climate-informed hydrologic modeling and policy typology to guide managed aquifer recharge," Journal of Science Advances 7, no. 17 (April 2021). https://doi.org/10.1126/sciadv.abe6025

28. Summer and fall 2021 brought deadly flooding to New York, New Jersey, Tennessee, Alabama, Germany, Belgium, India, Thailand, and the Philippines. At the same time drought, crop failures, and forest fires plagued the American West, Syria, Guatemala, Greece, and Siberia. Global economic losses from flooding rose from $500 million annually, on average, in the 1980s to $76 billion in 2020. When it comes to drought, more than 2 billion people around the world already live with severe or higher water insecurity. Researchers predict that as the climate continues to warm, two-thirds of the global population—more than 5.25 billion people—will experience progressively worse and more frequent drought conditions.

29. Liza Gross's article on California's increasing frequency of extreme drought and flooding under climate change, provided the first statewide analysis of the floodwater potentially available to restore depleted groundwater basins under future climate change scenarios. The increase in floodwater available to replenish over-drafted aquifers over the next 30 years, She found, would be enough to fill 192,000 Olympic swimming pools each year under an intermediate-emissions scenario, and 232,000 pools under a high-emissions scenario. Harvesting those high-water flows could help mitigate flood risk while boosting the state's dwindling groundwater supplies.

    Liza Gross, "How Capturing Floodwaters Can Reduce Flooding and Combat Drought," Inside Climate News (June 2021). https://insideclimatenews.org/news/08062021/california-agriculture-drought-climate-change-groundwater/

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