



EXECUTIVE SUMMARY

The aflaj waterworks of Ras Al Khaimah are a testament to human ingenuity, yet they have largely been abandoned due to declining water tables, waning date palm cultivation, and lack of maintenance. Due to the extraordinary communal efforts that once went into creating and maintaining these systems, the aflaj should be inventoried in greater detail, incorporated into the existing heritage management and tourism frameworks, reactivated when possible in conjunction with contemporary solutions for date palm irrigation, and leveraged as public-facing sites broadcasting the importance of judicious management of water resources.

The Aflaj Waterworks of Ras Al Khaimah: Current Conditions and Prospects for Conservation

William Reynolds, Columbia University Graduate School of Architecture, Planning, and Preservation

Introduction

The heritage of Ras Al Khaimah in the United Arab Emirates (UAE) is often striking. From the hand-hewn coral blocks of Al Jazeera Al Hamra to the earthen ramparts of Dhaya Fort, from the dense cluster of mid-century houses in the urban core to the farj scattered sparsely on the slopes of the Ru'us al Jibal, the emirate's past remains visible even to casual observers watching the scene pass by quickly through the tinted windows of airconditioned cars.

At the same time, some of the most remarkable historic systems in the UAE remain relatively difficult to appreciate, because much of their ingenuity lies underground. These are the aflaj waterworks (singular felaj), which were once the most important feature of every grove and garden in Ras Al Khaimah, though they have lately suffered a significant decline. Within living memory, the ground water resources that once fed these irrigation systems have been largely exhausted and the down stream cultivation of date palms has waned. Once considered to be such vital infrastructure that every community member spent either time or money to keep them running properly, the aflaj have been neglected, and their existence is beginning to be forgotten.

Nevertheless, dormant or abandoned aflaj systems remain legible, and in certain cases, they remain in use. The present description of these waterworks in Ras Al Khaimah results from a rapid survey conducted in early 2018. Though far from comprehensive, this survey identified some of the most complete examples of traditional aflaj that remain in the emirate. Following a summary of these survey results, this paper describes the current challenges facing the aflaj as well as future prospects for their conservation.

Given their important historical role and their general proximity to other recognized historic resources, there is a strong rationale to protect and restore some of the remaining aflaj, incorporating them into plans for local economic and touristic development in the more rural areas of Ras Al Khaimah, much as they have been in neighboring Oman. Beginning in the late 1990's the Omani government mounted a campaign to document and preserve aflaj throughout their country, resulting in the inscription of these sites on the UNESCO World Heritage List, ongoing community development projects in rural areas, and a sustained sense of connection between Omanis and their aflaj. Building on the ongoing historic resource survey conducted by the Department of Antiquities and Museums, Ras Al Khaimah is well positioned to pursue a similar path.

At the same time, conserving the waterworks without careful consideration of the associated date palm groves would be, quite literally, fruitless. Any effort to preserve these ingenious waterworks must consider the aflaj and their dependent palm groves

as a single system, a human-driven microclimate that will only thrive when both biological and cultural elements are supported equally. Documenting and preserving the aflaj offers an opportunity to identify and protect the rare date cultivars still found in Ras Al Khaimah, strengthen local date production, create signature experiences around date tourism, and pioneer new techniques to manage scarce water resources. Such an approach provides many opportunities for Ras Al Khaimah to invest in its most important resources: ingenuity and communal problem solving, characteristics that have long sustained Ras Al Khaimah and which will continue to help it flourish.

Description of Resources

While the origins of date palm agriculture and its associated irrigation systems in the Gulf are not yet known with precision, they have clearly been a part of the economy for at least several thousand years. Some of the earliest evidence for date palm cultivation has been found in the UAE. Carbonized date pits or impressions of date palm fronds on mud brick have been recovered at the Neolithic site of Dalma 11 (5290-4940 BC), the Bronze Age site of Umm an-Nar (2700-2200 BC), and the Iron Age site of Muweilah (800-600 BC) (Tengberg, 2012). Dates appear to have been an important part of the ancient life of the Emirates just as they are an important part of life today.

In order to produce dates in larger quantities, moving towards active cultivation rather than harvesting of fruit from wild date trees, it was necessary to capture scarce water resources and redirect them to nourish the palm groves. The waterworks, aflaj, that accomplished this feat are challenging to date because they are rarely associated with carbonized remains or ceramics, though in the region of Al Ain, the Al Hili, and the Ras Al Khaimah aflaj systems are both thought to be at least 3,000 years old (Tikriti, 2002). These two lines of evidence, the presence of dates at a number of ancient sites covering a range of time and geography, and the early date of sophisticated waterworks. Both point towards a lasting pattern of judicious resource management, and a close relationship between date palm groves and their human stewards, which began millennia ago and endured largely unchanged until recent memory.

The three-tier ecosystem of a date palm grove is remarkable first and foremost for its productivity, with a date palm canopy providing shade and a wind break for a relatively humid environment below, where fruit trees are able to thrive in the dappled sun under the palm canopy and vegetables and greens grow at ground level. This is an ecosystem very much influenced by humans, for its rich production would not generally be possible without an ingenious system of waterworks

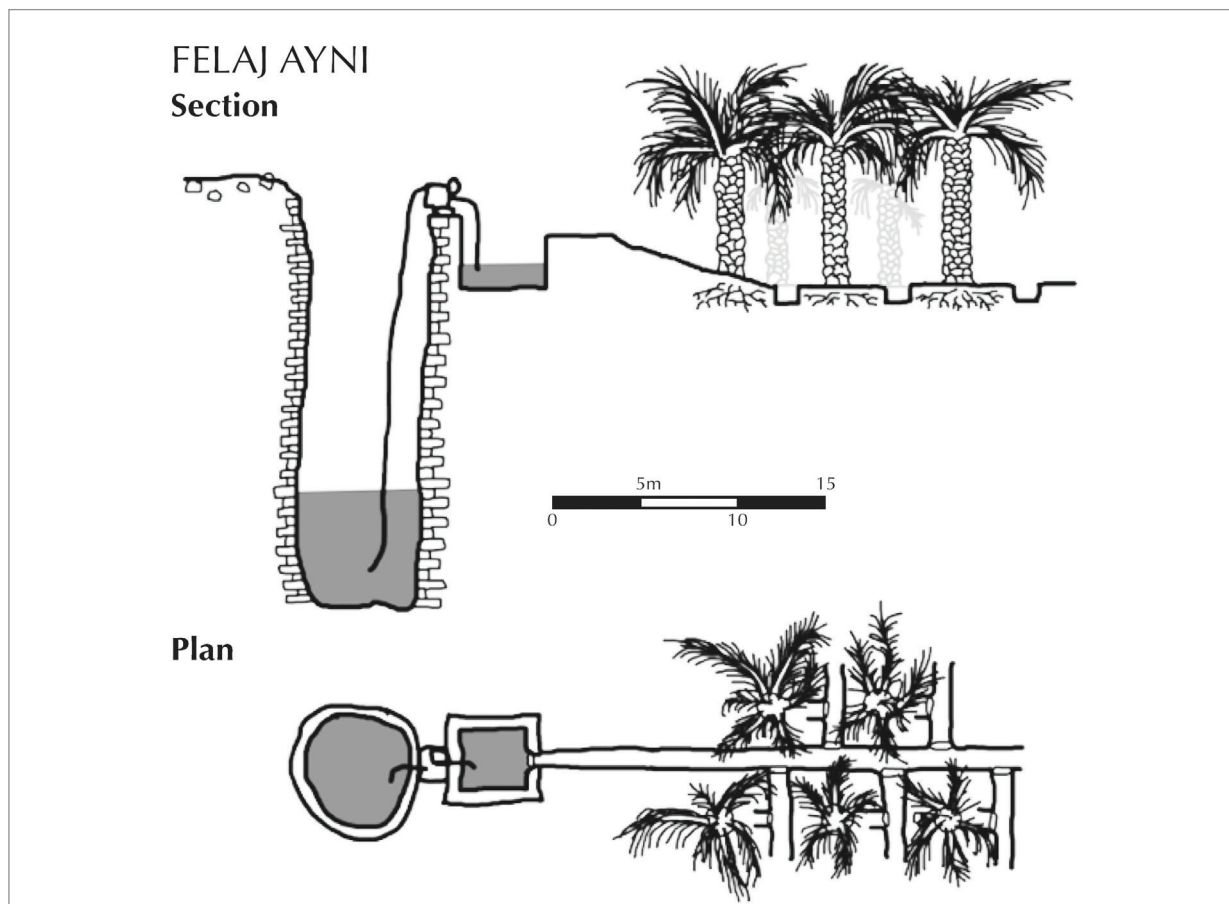


Figure 1. Section and plan of a typical felaj ayni system.

to collect and manage the flow of scarce surface and groundwater towards these palm groves.

The creation and maintenance of such ingenious irrigation systems required enough labor and expertise that it could only be managed communally. Due to the importance of such work, as well as its predictable daily and seasonal rhythm, water management can be considered as a central force that governed Emirati society prior to the discovery of oil (Lancasters, 2011).

In Ras Al Khaimah, as elsewhere in the UAE and Oman, the aflaj waterworks can be classified into three categories: the felaj ayni, the felaj ghali, and the felaj daoudi. These three systems employ different strategies to capture scarce ground and surface water and redirect it and apportion it through a system of channels to an area of agricultural use. This "splitting of the whole into parts" is what gave the name "felaj" to these systems. All of these waterworks are inextricably linked to the date palm groves.

In the case of a felaj ayni, ground water collects in a well and is then lifted to the surface. Historically, water was lifted using a mechanical hoist driven by a donkey or bull, but it is now lifted with a hose attached to a motorized pump. At the surface, the water enters a system of channels and flows with gravity to be distributed throughout the network, nourishing date palm groves that are generally

immediately adjacent to the well (see Figure1). At the time of this study, these felaj remain the most pervasive, with active systems or visible remnants in Al Qir, Ghalilah, Dhaya, Shimal, Felaya, Khatt, Masafi, Al Khari, and likely many other places besides. Given their dependence on near-surface aquifers that could be accessed through wells dug by hand, the felaj ayni have been particularly vulnerable to declining water tables.

The second variety of waterwork, the felaj ghayli, is a system in which water is retained behind a small catchment dam at the bottom of a wadi or in which periodic flood waters are simply redirected from the wadi bed into a small channel leading to a nearby agricultural plot (see Figure2).. In the case of a dam, a gate is periodically opened to allow the flow to pass into a system of channels. These systems are less common because they were only possible to establish under favorable circumstances in which a wadi had periodic flow with enough volume to fill the dam without destroying it, and the distance between the catchment point and the date palm groves was relatively small, generally less than half a kilometer. Active systems or visible remnants of felaj ghali were recorded at Shawka, in the hills between Ashashah and Asimah, and in Wadi Naqab, and it is likely that these systems can be identified in other locations as well. The felaj ghali systems work best in the rare instances in

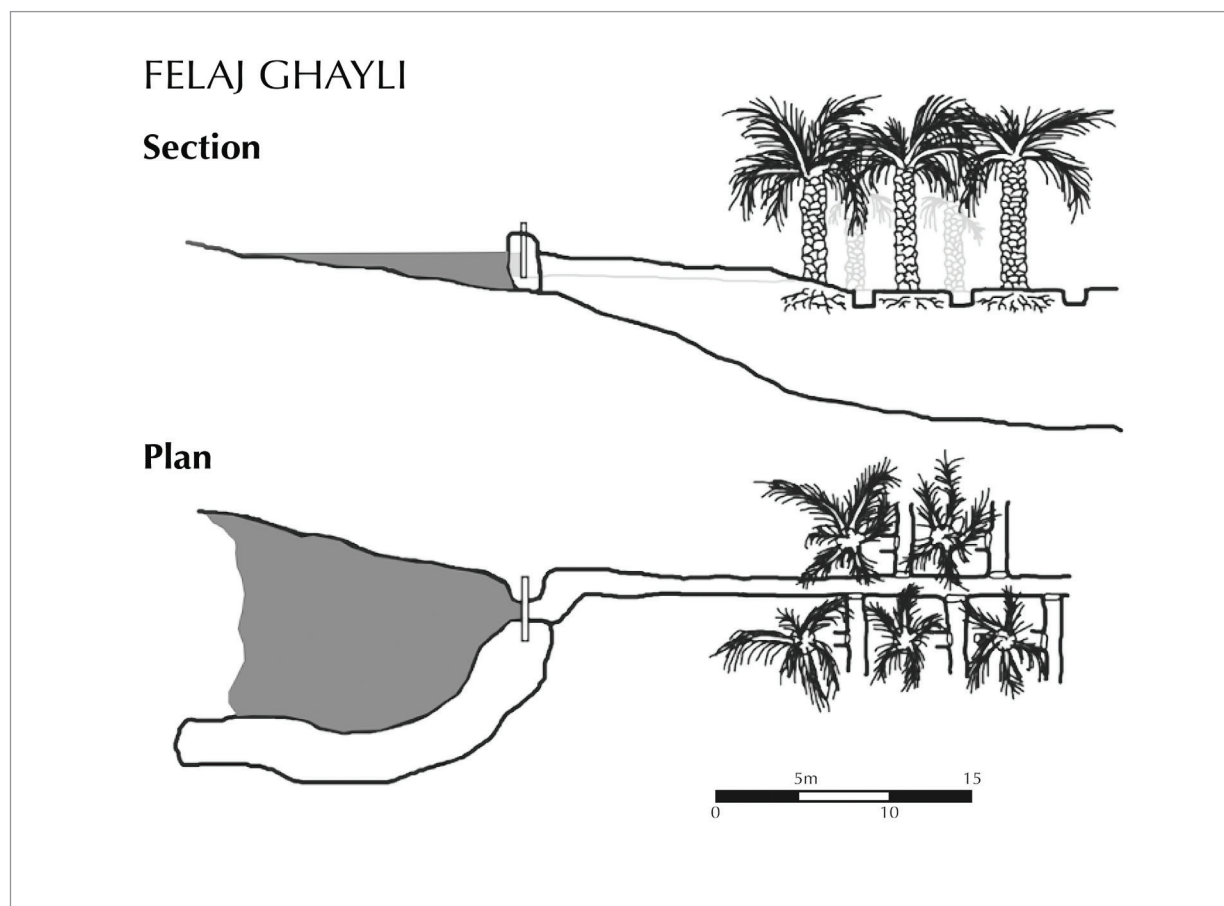


Figure 2. Section and plan of a typical felaj ghayli.

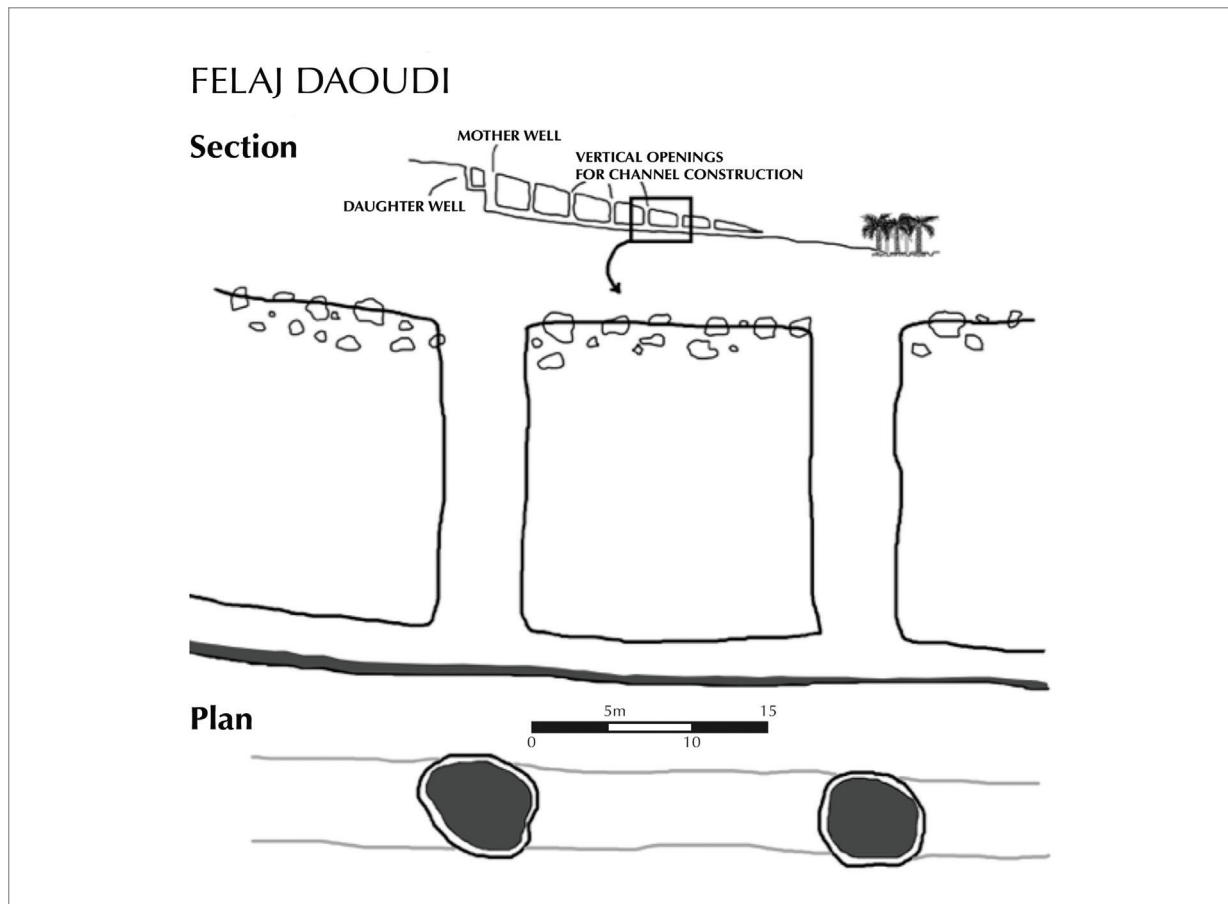


Figure 3. Section and plan of a typical felaj daoudi.

which there is sustained or permanent flow in a wadi (as is the case below the Shawka dam), but also depend on a seasonal sayl, or flood.

The third and most sophisticated type of waterwork is the felaj daoudi. The system originates at a mother well, often connected to several smaller daughter wells nearby. Leading from this source is a subterranean graded channel. Vertical shafts spaced approximately 10–20m apart connect to the subterranean channel and provided both the means for excavating the channel as well as a means to access it for regular maintenance (see Figure 3).

In a felaj daoudi, water from the source wells flows along the channel, eventually surfacing and flowing through a brachiated network to various date palm groves. In Ras Al Khaimah, the felaj daoudi were excavated into the consolidated gravels found in the bed of large wadis with seasonal flow or in the depositional alluvial fans found at the mouth of such wadis. The present survey recorded visible remnants or actively maintained felaj daoudi in Felaya, Khatt, Munay, Howailat, Nusarah, and Rafaq. Given that these felaj daoudi depend on near surface aquifers at the mother well in addition to rainfall concentrated in and percolating through the gravels, they have fallen into disuse as aquifers have been depleted and a period of prolonged drought continues.

Some of the felaj daoudi observed in southern Ras Al Khaimah, such as Nusarah and Rafaq, had their vertical shafts intentionally filled with larger rocks topped with gravel (see Figure 4). In all such cases, a significant portion of their channel was located directly beneath the bed of the wadi, and therefore they were prone to getting clogged with debris swept into the vertical shafts during the time of the seasonal sayl. The vertical shafts were plugged with preventive fill, with loose joints in the bottom-most layers, permitting water to pass along the horizontal channel below the surface.

Changing Conditions

Currently, aflaj systems throughout Ras Al Khaimah are in serious decline and so too are their dependent palm groves. From a vantage point straddling an abandoned felaj system, it is obvious that its wells and channels are dry or that they have been allowed to fill up with debris or collapse. Yet, from the vantage point of space, the impressive scale of this decline is easier to appreciate.

The decline of the formerly verdant palm groves of Shimal is a particularly egregious example, but similar deterioration is evident throughout much of Ras Al Khaimah. Once verdant palm groves have turned into gray husks, gradually blowing away with the wind. Functional examples of all three types of felaj have become less

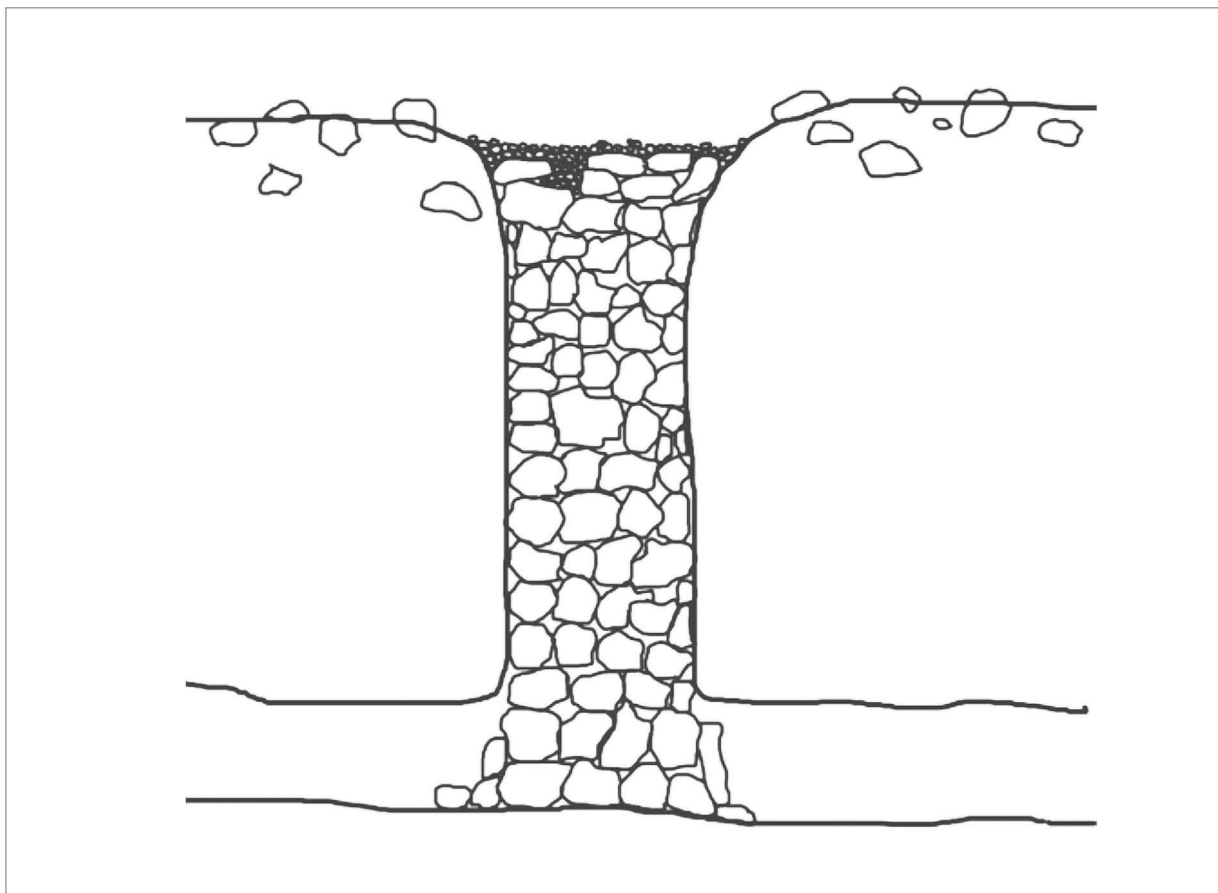


Figure 4. Section of a felaj daoudi in southern Ras Al Khaimah, such as the one found in Nusarah.

common in Ras Al Khaimah; many of the wells feeding the felaj ayni have run dry, the seasonal rains feeding the felaj ghayli have become less frequent, and the felaj daoudi have stopped flowing.

Though the ultimate cause for the decline of a given felaj system and its dependent groves requires a specific investigation, there are several common factors that frequently operate in concert with each other: declining water tables, prolonged drought, changing land use, and lack of maintenance.

In general, the UAE has been using groundwater reserves faster than the ambient recharge rate from rainfall, and groundwater levels continue to drop so precipitously that all aquifers in the UAE may be depleted by 2030 (Shahin & Salem, 2015). Meanwhile, the domestic per-capita water consumption of 353 L/day (Ministry of Environment and Water, n.d.) exceeds that of larger nations such as the United States and Japan, suggesting that demand remains abnormally high. In this context, it is not surprising that many wells feeding felaj ayni and felaj daoudi have run dry. While it may be possible to dig a deeper well in some cases to reactivate the system, it is likely that many aquifers have already been depleted.

Prolonged drought has also played a role. At the time of this survey, it had been four years since the last

strong sayl (~40mm of rain in a month in early 2014) and twenty years since there was a sayl resulting from more than 60mm of rain in a month (World Bank, 2015). Those knowledgeable about the history of individual felaj systems bemoaned the lack of strong seasonal rains, which has rendered the remaining felaj ghayli less practical and rendered most of the remaining felaj daoudi unusable. This change has been building slowly, and the mother and daughter wells at the headwaters of the felaj daoudi of Munay began to run dry around 1995. Nevertheless, it recently passed another milestone of severity, as the felaj daoudi in Howailat and Rafaq stopped flowing three to five years ago (Abu Hammad al Rafqui, personal communication, 2018). The Intergovernmental Panel on Climate Change predicts that probability of drought will continue to increase throughout the UAE, and that rainfall may decrease by 15–20% over the next 50 years. Due to climate change, this trend of water scarcity may only intensify (IPCC, 2014).

Land use has also changed. Urbanization in areas like Shimal and Felaya has encroached on the footprint of what once were thriving palm groves supporting thousands of people (see Figure 5). In many cases, increasing urbanization has been accompanied with the digging of additional wells, depleting ground water resources even faster. In certain cases, like the felaj daoudi at Khatt, the installation of a single new well



Figure 5. Landsat imagery of the decline of aflaj-fed palm groves in Shimal and Felaya areas of Ras Al Khaimah in 1986 and 2016 (GoogleEarth, 2016).

associated with the Golden Tulip Khatt Spring Resort and Spa appears to have a dramatic impact on the existing felaj. The infrastructure of the waterworks remain in the same location as described in the maps of the community created by the German ethnographer Walter Dostal in the mid-1980's (Dostal, 1985), but they are now dry. Following the expansion of the resort and the increase of the use of the spring water for its spa approximately a decade ago, water no longer flowed reliably into the private and public bathing facilities in Khatt, let alone the nearby palm groves dependent on this water (personal communication, Walid Abd al Karim, 2018).

All felaj require regular maintenance to function. Since the main infrastructure of these systems were always held in common trust, maintenance was traditionally a communal activity. The aflaj have become more vulnerable as changing priorities on the part of individuals and changing administrative structures on the part of the state have led to the decline of communal maintenance activities. Nevertheless, resuming maintenance and cleaning out blocked felaj channels can sometimes restore water flow. At the Sa'ra felaj daoudi in Buraimi, Oman, a group of volunteers managed to clear and re-stabilize the underground channels of the felaj, restoring regular, natural flow to the system after it had been dry for 15 years (Oman Channel, 2017). In Ras Al Khaimah, recent efforts on the part of the Ministry of Agriculture to repair the felaj daoudi at Rafaq and Howailat are commendable, but their channels still do not flow with the volumes they once did, and they were entirely dry at the time of this survey. It may be that efforts to restore their channels arrived too late.

Rationale and Recommendations for Conservation

Several steps should be taken to ensure further protection of the aflaj of Ras Al Khaimah and their associated palm groves including: more comprehensive inventory, extending the boundaries of existing historic sites to include more aflaj, researching and protecting the biodiversity of rare date cultivars, incorporating the aflaj into public education, and renewing a commitment to the values that have long sustained these waterworks. The following sections outline these opportunities in greater detail.

Inventory and Recognition as Historic Resources

While the decline in aflaj is clear, it remains difficult to describe the full extent of loss because a complete inventory of these systems has not been made in Ras Al Khaimah. In Oman, the Ministry of Water Resources undertook the National Aflaj Inventory Project, identifying and documenting over 4000 aflaj around the country (Ministry of Water Resources, 1997), a process that assisted the government in its nomination of these systems to the UNESCO World Heritage List. Following this baseline study, the Omani Ministry of Regional Municipalities and Water Resources recently pursued a follow up survey 20 years after the original. Approximately one quarter of the aflaj had dried up during this time (Muscat Daily, 2017). Documenting the nature and severity of this decline over time has enabled the Omani government to mobilize resources to protect their remaining aflaj, thereby strengthening the communities that depend on these water systems and groves.



Figure 6. Deterioration of felaj channels and the death of palm groves goes hand in hand.

Such an inventory effort in Ras Al Khaimah would not begin from scratch. The Department of Antiquities and Museums has already identified 190 sites as part of their mandate to protect historic resources (Hilal, 2015). In a number of cases, aflaj and groves are in close proximity to other historic resources that have already been inventoried. This is particularly true of the felaj daoudi in Khatt and Rafaq, as well as the felaj ayni near Burj Shimal and Dhaya. Boundaries which have already been defined to protect other nearby resources might be expanded to protect portions of the felaj, recognizing them as historic

resources that are also worth protecting. It may be that such efforts can find common cause with the Ministry of Agriculture, given their work on felaj restoration or improvement projects in recent years.

Additional Protection for Rare Date Cultivars

Ultimately, the aflaj and the date palms are so connected that any work to inventory, protect, or restore the man-made aspects of this system must consider the health of the biological components as well, and should include



Figure 7. The Rafaq felaj, though recently improved with government support, remained dry at the time of this survey.

biologists and farmers knowledgeable about varieties of date palm in addition to archaeologists and cultural heritage specialists. Collectively, these resources quite literally embody the aspiration for a "living heritage" (MacLean, 2018) in Ras Al Khaimah, as opposed to preserving historic sites that are no longer actively used and enjoyed by the community or are artificial replicas. The aflaj and their groves can only be sustained through ongoing attention and investment, generation after generation. In return, the community receives not only the fruits of this effort (dates, as well as other fruits, vegetables, and greens grown in the grove) but also the dividends of the process itself, which takes the form of social bonds strengthened through the collective management of a complex system and scarce resources.

In 2015, the Food and Agriculture Organization (FAO) of the United Nations inscribed Al Ain and Liwa Oases in Abu Dhabi as "globally important agricultural heritage sites," citing their quality as repositories of genetic resources, including at least 200 cultivars of date palm, providing a shelter for both biodiversity and cultural heritage (FAO, 2015). This recognition from the FAO points towards a complementary approach for protecting the aflaj and associated groves: the natural resources supported by the aflaj are at least as important as the waterworks themselves.

While most of the remaining palms under cultivation in Ras Al Khaimah produce well-known varieties of dates like *khalas*, *lulu* and *sukari*, it is likely that rare and potentially undocumented strains of date palm continue to grow, particularly in the oldest groves associated with felaj systems. While their dates may not be as sweet as the most popular varieties, they may have other positive attributes including disease resistance or drought tolerance that could be used to strengthen palms sold commercially both in the Emirates and beyond.

With more than 40 million trees, the Emirates has the largest number of date palms of any country in the world, and yet its production of dates generally lags behind other countries such as Egypt, Iran, Algeria, Saudi Arabia, Iraq, and Pakistan, as it did in 2017 (FAO, 2017). This difference between potential and actual production is attributed to a lack of disease and pest control (particularly the ongoing infestation of the Red Palm Weevil), poor management of water resources, and a lack of investment in staffing, harvesting, packing, and processing (El-Juhany, 2010). Identifying and protecting rare date varieties that are more resilient under the attack of the Red Palm Weevil, or able to grow and produce fruit with less water, will contribute to solving these persistent problems.

The biodiversity of rare date palm cultivars in Ras Al Khaimah should be better documented. Since 1989, United Arab Emirates University has hosted a Date Palm Tissue Culture Laboratory, part of its Date Palm Research and Development Unit, which is largely focused on mass

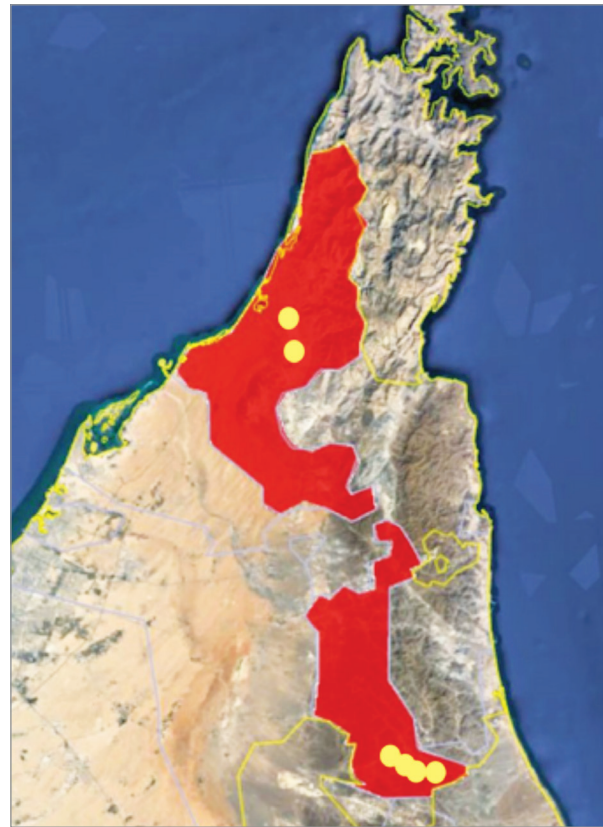


Figure 8. Map of the relative position of felaj daoudi in Ras Al Khaimah documented during this survey.

cloning and propagation of popular date cultivars for commercial purposes. Many of these cultivars originated in other countries like Saudi Arabia, Iraq, and Oman and have since become commercially successful in the UAE (UAEU, 2018). Yet Ras Al Khaimah and the UAE currently lack a comprehensive repository of Emirati date palm germplasm for research purposes, in the style of the National Date Palm Germplasm Repository maintained by the United States Department of Agriculture (Krueger, 2015). If samples from date palms were collected in conjunction with an inventory of existing aflaj systems in Ras Al Khaimah, this would be the first step towards such a repository that could strengthen desirable characteristics in date palms around the country.

Given declining water tables and the uncertain future of many aflaj, it may not be possible to protect rare trees where they stand. Moving them is preferable to watching them perish. One notable effort along these lines is the work of the Dhaya Rest House to identify rare date varieties from the declining groves of Shimal, negotiate with their owners to uproot them, and replant them in the thriving groves of Dhaya. By opening the Dhaya groves to the public, this work has preserved a more genetically diverse date crop for the future, featuring 55 different varieties of dates, and serves as a strong example of the authentic tourism sought by the Ras Al Khaimah Tourism Development Authority (RAK TDA, 2016).

Public Education

Efforts to protect the aflaj of Ras Al Khaimah must be coupled with reconnecting these resources to the public. For many, the aflaj and groves no longer play a role in daily life, and date palm agriculture is no longer a significant source of income. The aflaj have been easy to neglect, and the dates that grow are too often left to rot on the tree. Elsewhere, there have been efforts to incorporate the aflaj into educational campaigns which might serve as a model for future similar work on the part of the Ministry of Education and the Department of Antiquities and Museums.

In Abu Dhabi, the aflaj were mentioned prominently within UNESCO's inscription of the Cultural Sites of Al Ain (United Arab Emirates, 2010), and their channels were recently restored prior to opening the groves to visitors. Spaces that had once been semi-private have been opened to the public, ensuring that residents, as well as tourists from around the world, have an opportunity to directly experience the marvel of a date palm oasis. Through the scale model of a felaj at the entrance, the interpretative content at the eco-center, signage throughout the groves, and the chance to watch actual felaj irrigating the palm groves, the Abu Dhabi Department of Culture and Tourism reinforces the fundamental importance of aflaj in a manner accessible to most visitors.

In Madha, the small exclave of Oman surrounded by the Emirate of Fujairah, the aflaj systems are thriving, with examples of felaj ayni, gheyli, and daoudi all connected to groves that are relatively well maintained. Given that the nearby aflaj of Masafi and Al Dhaid have been abandoned, the residents of Madha attribute their relative success in maintaining their aflaj to routine exposure through

local schools. As recently as the late 1970's, children were expected to contribute to the maintenance of the groves and aflaj, creating a direct, life-long connection to date palms.

With greater wealth and access to foreign workers, the children of Medha no longer contribute their labor, but they now attend annual field trips to visit the date palms in the center of their community. Through early and frequent exposure to the groves, and with the ongoing support and management of the Ministry of Regional Municipalities, Environment and Water Resources, residents are optimistic that their aflaj will avoid the fate of so many in the surrounding emirates.

Such efforts to strengthen public engagement could be adapted to the context of Ras Al Khaimah. The groves of Khatt offer an unusual opportunity given their proximity to the Khatt Dates Factory, which produces dates that are widely available in local groceries. For members of the public, the chance to experience the ingenuity of the aflaj, the growth of the palms, and the processing of dates would offer an unforgettable lesson that would be reinforced every time they return to the grocery store. Since many of the larger groves like Dhaya already have their own date processing facilities, this kind of experience could be available in multiple parts of Ras Al Khaimah rather than one dedicated center.

To counter the long term decline of the aflaj and their groves, the goals set should be ambitious: no child in Ras Al Khaimah should reach the age of ten without experiencing how a date grows and makes it to market, and every visitor who spends a night in a hotel in the emirate should be offered to taste a date grown in Ras Al Khaimah and offered the opportunity to join such a date tour.



Figure 9. The date palm groves of the Dhaya Rest House provide a refuge for rare date cultivars.

Evolution of a Traditional System

Among the most important aspects of the aflaj are the two core values that sustained them through time: ingenuity in creating complex systems to improve the quality of life in a harsh environment, and judicious collective management of scarce resources. These values can never be depleted, though the poor condition of the aflaj and associated palm groves in Ras Al Khaimah suggests that the commitment to these values stands to be renewed. Pursuing these values may result in an evolution of the system, incorporating new methods and materials to meet the same timeless objectives.

In many cases, the groundwater that once fed the aflaj may now be so depleted that it will only fully recharge over thousands of years. Before pursuing costly restoration efforts, it is worth evaluating water levels in any wells adjacent to a given irrigation system to approximate the remaining availability of subterranean water. It is also worth considering options to augment natural flow if necessary. In Al Ain, for example, the water coursing through the recently restored aflaj could only be sustained by supplementing natural flow with desalinated water from the Qidfa plant, as well as treated sewage effluent (Brook & al Houqani, 2006).

Declining groundwater resources also prompt rethinking traditional irrigation practices, such as flood irrigating plots surrounding individual date palm trees. Demonstrating the same ingenuity as those who first built the aflaj, the Green Coast Nursery of Fujairah has been working to develop modified irrigation systems that incorporate lengths of tubing and drip tape,

minimizing loss and ensuring that a precise amount of water is delivered directly to the roots of each date palm. Not only is this system easier to maintain than a typical felaj, it also enables a farmer to use only 2–4L of water per tree per day, compared to at least ten times that amount that would be used in flood irrigation at the end of a felaj.

Finally, communal management of scarce but vital water resources can and should endure. Over the past fifty years, the transition from a system of local maintenance and management of the aflaj to one of centralized state responsibility has failed to prevent their decline. Since 2001, Oman has closely associated the management of local municipalities with the management of water resources and the environment under the umbrella of a single ministry, offering one model for how administrative structure can further support the simultaneous protection of communities, water resources, waterworks, and palm groves.

The recent selection of the first Emirati astronauts to staff the International Space Station is a clear reminder of the level of ingenuity that the UAE offers. Nevertheless, meeting the severe demands of the coming century and a changing climate will require maximizing every possible benefit from the traditional human and biological systems that sustained people in a harsh environment prior to the oil economy. By supporting the exploration, protection and evolution of such systems, Ras Al Khaimah is well positioned to make such a sustainable contribution to the world.



Figure 10. The aflaj of Medha, Oman continue to thrive, while those in the surrounding Emirates have been largely neglected and have run dry.

Author Biography

William Reynolds is an adjunct assistant professor of historic preservation at the Columbia University Graduate School of Architecture, Planning, and Preservation, where his work focuses on the documentation of heritage sites and problems at the intersection of preservation, planning, and the protection of blended natural and cultural resources.

References

- Brook, M. & al Houqani, H. (2006). "Current Status of Aflaj in the Al Ain Area, United Arab Emirates." Abu Dhabi: Environmental Agency Abu Dhabi.
- Dostal, W. (1985). *Egalität und Klassengesellschaft in Südarabien*. Horn: Horn Wien Berger, p. 352
- El-Juhany, L. (2010). "Degradation of Date Palm Trees and Date Production in Arab Countries: Causes and Potential Rehabilitation." *Australian Journal of Basic and Applied Sciences*. Vol. 4, No. 8: pp. 3998-4010.
- Food and Agriculture Organization of the United Nations. (2015). "Emirates' Date Palm Oases Recognized as Agricultural Heritage Sites." Retrieved from <http://www.fao.org/news/story/en/item/280343/icode/>
- Food and Agriculture Organization of the United Nations. (2017). *FAO STAT*. Retrieved from <http://www.fao.org/faostat/en/#data/QC>.
- Hilal, A, Kennet, D. & Humble, L. (2015). "Towards a Heritage Management Strategy for Ras al-Khaimah (UAE)." *Proceedings of the Seminar for Arabian Studies* Vol. 45, pp. 149-158.
- Intergovernmental Panel on Climate Change. (2014). *Fifth Assessment Report (AR5)*. Geneva, Switzerland.
- Krueger, R. (2015). "National Date Palm Germplasm Repository." *Plant and Animal Genome*. Vol. 1, p. 560.
- Lancaster, W. & Lancaster, F. (2011). *Honour is in Contentment: Life Before Oil in Ras Al-Khaimah (UAE) and Some Neighboring Regions*. Berlin: De Gruyter.
- MacLean, M. (2018). "Preserving and Promoting Ras Al Khaimah's Cultural Heritage." Ras Al Khaimah: Sheikh Saud Bin Saqr Al Qasimi Foundation for Policy Research.
- Ministry of Environment and Water, United Arab Emirates. (n.d.). "Green Economic Indicators." Retrieved from www.moccae.gov.ae/assets/download/7e8b4415/uaes-green-eco-indicators.aspx
- Ministry of Water Resources. (1997). *National Aflaj Inventory Project*. Muscat: Ministry of Water Resources, Sultanate of Oman.
- Muscat Daily. (2017, April 5). "MRMWR Survey Shows Over 1,095 Aflaj Have Dried Up." Retrieved from <https://muscatdaily.com/Archive/Oman/MRMWR-survey-shows-over-1-095-aflaj-have-dried-up-4zq2>
- Oman Channel. (2017, January 30). فلج صعراء بولاية البريمي بتدفق بعد انقطاع دام 15 عاما. Available at <https://www.youtube.com/watch?v=DpcgKJRcq6M>
- Ras Al Khaimah Tourism Development Authority. (2016). "Destination Ras Al Khaimah: A Three-Year Strategy for Growth and Development 2016-2019." Ras Al Khaimah: Ras Al Khaimah Tourism Development Authority.
- Shahin, S. & Salem, M. (2015). "The Challenges of Water Scarcity and the Future of Food Security in the United Arab Emirates (UAE)," *Natural Resources and Conservation*. Vol. 3, No. 1: pp. 1-6.
- Tenberg, M. (2012). "Beginnings and Early History of Date Palm Garden Cultivation in the Middle East." *Journal of Arid Environments*. Vol. 86 (2012), p. 139-147.
- Tikriti, W. (2011). "Archaeology of the Falaj: a Field Study of the Ancient Irrigation Systems of the United Arab Emirates." Abu Dhabi: Department of Historic Environment, Abu Dhabi Culture & Heritage.

United Arab Emirates. (2010). "The Cultural Sites of Al Ain (Hafit, Hili, Bidaa Bint Saud and Oases Areas): Serial Property Nomination File" Paris: World Heritage Center, UNESCO.

United Arab Emirates University. (2018). "Date Palm Culture in UAE." Al Ain: United Arab Emirates University. Retrieved from <https://www.uaeu.ac.ae/en/dvcrs/research/centers/dpdrud/datepalmculture.shtml>

World Bank Group. (2015). "Climate Change Knowledge Portal: United Arab Emirates." Retrieved from http://sdwebx.worldbank.org/climateportal/index.cfm?page=country_historical_climate&ThisRegion=Middle%20East&ThisCCode=ARE

The Sheikh Saud bin Saqr Al Qasimi Foundation for Policy Research Policy Paper Series is designed to disseminate ongoing research to individuals and institutions interested in the development of public policy in the Arab world. Findings and conclusions are solely those of the authors and should not be attributed to the Sheikh Saud bin Saqr Al Qasimi Foundation for Policy Research.

THE SHEIKH SAUD BIN SAQR AL QASIMI FOUNDATION FOR POLICY RESEARCH

DEVELOPING RESEARCH, SUPPORTING MINDS

Based in the emirate of Ras Al Khaimah, the Sheikh Saud bin Saqr Al Qasimi Foundation for Policy Research is a non-profit foundation that was established in 2009 under the patronage of His Highness Sheikh Saud bin Saqr Al Qasimi, United Arab Emirates Supreme Council Member and Ruler of Ras Al Khaimah. The Foundation has three broad functions:

- to inform policymaking by conducting and commissioning high quality research;
- to enrich the local public sector, especially education, by providing educators and civil servants in Ras Al Khaimah with tools to make a positive impact on their own society; and
- to build a spirit of community, collaboration, and shared vision through purposeful engagement that fosters relationships among individuals and organizations.

Visit www.alqasimifoundation.com to learn more about our research, grants, and programmatic activities.



SHEIKH SAUD BIN SAQR AL QASIMI
FOUNDATION FOR POLICY RESEARCH

P.O. Box 12050, Ras Al Khaimah, United Arab Emirates

Tel: +971 7 233 8060 | Fax: +971 7 233 8070

E-mail: info@alqasimifoundation.rak.ae | www.alqasimifoundation.com