Aqaba-Amman Water Desalination and Conveyance National (AAWDC) Project 2025 Environmental and Social Impact Assessment

Chapter 4: Project Alternatives

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4 Project Alternatives

4.1 Introduction

The Aqaba-Amman Water Desalination and Conveyance (AAWDC) Project (the Project) was initially conceived by the Jordanian Ministry of Water and Irrigation (MWI) with early concept design and technical feasibility studies completed in 2018. In 2019, the MWI issued a request for support to the United States Agency for International Development (USAID). USAID assigned a team of consultants to work with the Government of Jordan and MWI to provide assistance during the tendering for the Project and signature of the Project agreements with the Build Own Operate Transfer (BOT) Contractor. The 2022 concept design was completed for tendering purposes. An Environmental and Social Impact Assessment (hereafter "the 2022 ESIA") was prepared and approved by the Jordanian Ministry of Environment (MOEnv), and the Aqaba Special Economic Zone Authority (ASEZA) (refer to Chapter 1 Section 1.3[1] (Tetra Tech, 2022).

Prospective BOT Contractors submitted their initial proposals in response to the tender request in December 2023. These proposals were further refined in August 2024 and included design optimisations resulting in changes to the initial 2022 concept design. The Consortium of Meridiam and Suez with their Contractors (Engineering, Procurement, and Construction (EPC) Contractors and Operation and Maintenance (O&M) Contractors) were subsequently appointed as the BOT Contractor in September 2024 and have been progressing the Project design under a Limited Notice to Proceed (LNTP) Instruction. The LNTP programme is planned to extend until Q1 2026 prior to the commencement of Project detailed design and construction activities.

This Chapter of the 2025 AAWDC Project ESIA presents an overview of the key alternative development and design options that have been considered by the Project to date and describes how the mitigation hierarchy and stakeholder concerns have informed the design. Design refinement is ongoing under the LNTP scope and may result in changes to the design. Where these are reasonably known they have been described in this Chapter along with the potential for impact, notably the option of using the existing Aqaba Power Station lagoon for intake which has the potential to further reduce marine related impacts. Furthermore, stakeholder consultation will be ongoing as the design progresses which may also result in additional design refinements as well as detailed surveys to be undertaken prior to construction as described within Chapter 9. In the event that changes to the reference design are identified by the Project, the ESIA Management of Change will be implemented to review and, where necessary, assess potential changes in impacts and associated mitigation and management measures.

4.2 Jordan's Water Context and the Need for the Project

4.2.1 Current and Forecast National Water Demand

Jordan is classified as a semi-arid to arid region and is one of the most water-poor countries in the world, with only 61 cubic meters of renewable freshwater available per capita per year as of 2021. As stated in the Jordan National Water Strategy 2023 – 2040 (MWI, 2023), this is significantly below the internationally recognised absolute water scarcity line of 500 cubic metres per capita annually. The

[1] The 2022 ESIA was subsequently updated in January 2025 to include a change in conveyance routing – refer to Section 4.3.4.2 below.

country's water demand is driven by rapid population growth, economic development, and the need to provide safe drinking water.

The population of Jordan is expected to grow from 11 million in 2021 to 16.8 million by 2040 (MWI, 2023), further exacerbating the water demand. The National Water Strategy 2023 – 2040 projects that the total water demand will increase from 1,486 million cubic metres (MCM) in 2021 to 2,013MCM by 2040. This includes a significant rise in municipal water demand, which is expected to grow from 682MCM in 2021 to 991MCM by 2040.

4.2.2 Current Water Sources

Water supplies in Jordan derive from three main sources: 27 – 30% from surface water, 56-59% from groundwater and 14-15% from treated wastewater (MWI, 2023 and American Journal of Water Resources, 2022). Other unconventional resources include small scale brackish and seawater water desalination. In 2021, seawater desalination accounted for 0.06% of Jordan's water supply and was being produced and consumed primarily by industrial users in Aqaba.

Surface water resources in Jordan are limited and highly variable due to the country's semi-arid to arid climate. Major sources include the Jordan River, Yarmouk River, and Zarqa River, although inflows are significantly reduced due to upstream abstraction by neighbouring countries. Jordan's 13 main dams provide 280MCM of water storage, but this capacity is shrinking due to sedimentation build-up (MWI, 2023).

Groundwater, providing more than half of Jordan's annual supply (619MCM in 2021), is supplied from renewable aquifers (450MCM in 2021) and non-renewable resources in the Disi and Jafer Basins (169MCM in 2021). As reported within Jordan's National Water Strategy (MWI, 2023), the safe and sustainable extraction rate from renewable groundwater is estimated to be about 280MCM annually and current extraction rates are currently well above this rate.

Treated wastewater has become an increasingly important source, especially for irrigation. Advanced wastewater treatment technologies have significantly increased the use of reclaimed water, with more than 90% of Jordan's reclaimed water being used, mostly for irrigation, which is the highest water consuming sector in the country. Municipal supply is primarily from groundwater, with 70% of drinking water deriving from groundwater supplies (MWI, 2023).

4.2.3 Challenges

There is a significant and growing gap between existing water resources and demand within Jordan, which is driven by a number of challenges. The reliance on groundwater resources has led to overextraction from key aquifers such as Disi and Azraq. This has led to declining water tables and deteriorating water quality and has been further compounded by climate-related factors such as reduced rainfall, rising temperatures, and prolonged droughts, all of which further reduce natural aquifer recharge rates. The Jordanian Government have sought to address this through the development and implementation of successive National Water Strategies since 1998, significant investment in conventional and nonconventional water resources and technologies and active and sustained promotion of water efficiency, re-use and conservation practices. However, the water demand-supply gap has continued to widen despite these measures.

The situation has been further exacerbated by demographic and economic pressures. Rapid urbanisation and economic growth have intensified domestic and industrial water demand, particularly in major cities and industrial zones. Demand has been continuously increasing due to this population growth and the periodic influx of refugees fleeing instability in some neighbouring countries. In addition, demand has increased for agriculture and crops, where there has been a sustained year-on-year increase in irrigated land under cultivation since the 1980s, increasing the stress on existing resources (MWI, 2023). Initiatives such as increasing irrigation efficiency and wastewater re-use in the agriculture sector, rainwater harvesting and ecosystem-based approaches should be promoted, but in Jordan they cannot deliver the volume and consistency of supply required in the short to medium term.

The challenges of long-term water security and security of supply as noted within the National Water Strategy 2023 – 2040 include:

- "*Additional reliance on purchasing water from international sources has been necessary during recent years, increasing the vulnerability of supply options*
- *The need for all parties to abide by the concluded transboundary water agreements*
- *Challenges continue in abiding by regional water agreements that secure Jordan's rights to shared water resources*."

These transboundary challenges have, in part, been demonstrated through the Red Sea–Dead Sea Conveyance (RSDSC) project initially conceived in the 1960s to provide drinking water to Jordan and the Palestinian territories. The project progressed under various phases of development with agreements in place, a design and route determined and assessed and funding in place from commercial sources, including debt and equity and international financing. However, due to various delays and ultimately a lack of support from transboundary partners, the project was formally abandoned in 2021. The concept of a desalination and conveyance scheme was, however, retained in Jordan's strategic approach to addressing the growing water demand.

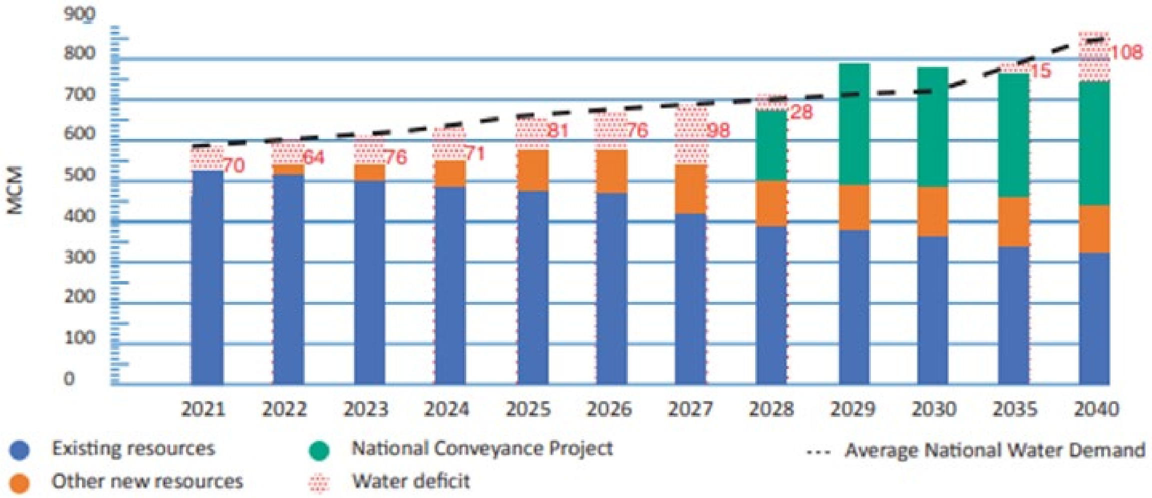
4.2.4 Need for, and Benefits of, the AADWCP

The AAWDC Project (also known as the National Conveyance Project) was conceived as a major infrastructure initiative designed to address the challenges discussed in Section 4.2.3 above and builds on the earlier abandoned RSDS Project and as well as other national conveyance schemes. This includes the Disi Conveyor, which commenced operation in 2013 and involves pumping and conveying groundwater from the Disi aquifer in Southern Jordan to Amman.

Figure 4-1 shows the forecast demand and supply estimates for municipal water as presented in the Jordan National Water Strategy 2023-2040 (MWI, 2023), including the forecast supply from the National Conveyance Project[2].

[2] It should be noted that the National Water Strategy was prepared in 2023 and at the time the anticipated start of National Conveyance Project operations was 2028; this is now projected to be 2030.

Figure 4-1: Demand and Supply Projection for the Municipal Sector (Drinking Water) (National Water Strategy 2023-2040) (MWI, 2023)



As stated within the Jordan National Water Strategy 2023-2040 (MWI, 2023), the AAWDC Project is designed to be implemented in combination with sustainable management of renewable freshwater across Jordan to not only halt water supply deterioration, but to also enable restoration of groundwater resources.

The key benefits of the Project can be summarised as follows:

- Reduced reliance on over-extracted groundwater
- Protection of aquifers from further deterioration
- Improvement in groundwater quality
- Relaxed pressure on existing freshwater supplies
- Expansion of treated wastewater for reuse, particularly for irrigation
- Modernisation and improved management of the water network
- Provision of long-term water supply security
- Reduced reliance on regional water agreements
- Reduced reliance on international water sources

The project is central to achieving Jordan's long-term development objectives outlined in the National Water Strategy 2023–2040, as well as the Sustainable Development Goals (SDGs) that Jordan is committed to. None of the benefits described above would be realised if the Project does not go ahead i.e. under the "No Development" concept.

4.3 Design Development and Alternatives Considered

4.3.1 Project Components and Evaluation Criteria

The development of the AAWDC Project concept design has focused on the identification and evaluation of alternatives associated with the following project components:

- Marine Intake and Outfall Infrastructure
- Desalination Plant
- Conveyance System
- Power Supply and Renewable Facility

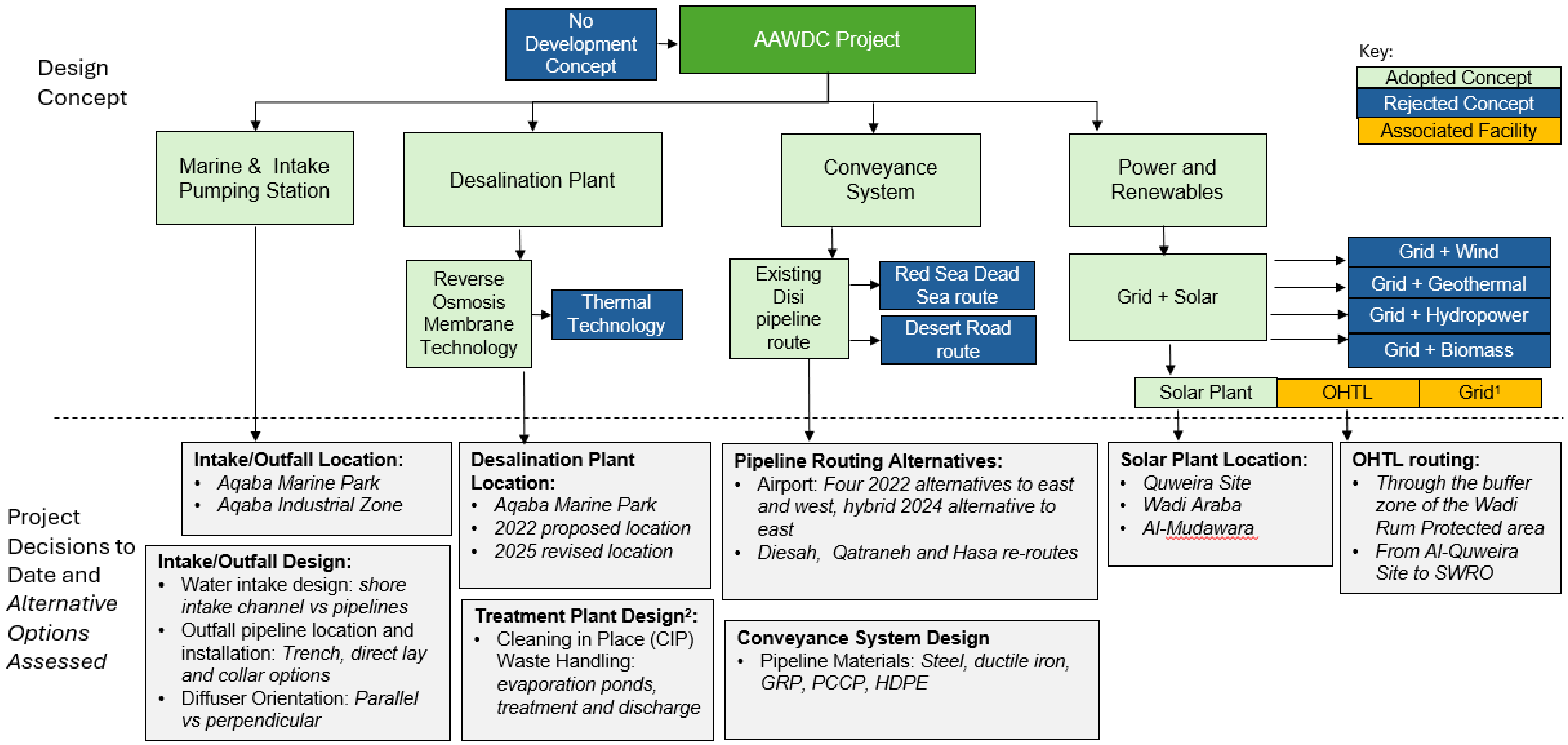
Options considered have included location and routing options, and design and technology alternatives. Evaluation of these options have taken into account the overarching Project objectives as discussed within Section 4.2.4 above.

Figure 4-2 below provides an overview of the key design decisions and alternative options considered by The Project for each of the Project components. Comparative assessment of alternative options described within this Chapter has been carried out using the evaluation criteria as set out in Table 4-1. The comparative assessment is qualitative except where quantitative data is available, e.g. footprints, dimensions, material, waste or emission estimates.

Table 4-1: Evaluation Criteria Used in Comparative Assessment of Alternative Options

Evaluation Criteria	Aspects Considered
Technical Feasibility	Complexity, constructability, operability, schedule, technical safety and geographic constraints e.g. proximity to existing infrastructure, land availability
Economic Feasibility	Cost, ability to meet Project's economic targets
Environmental	Biodiversity (including ecosystem services), air quality, noise, GHG, climate change, hydrology and flood risk, energy efficiency, climate and greenhouse emissions, soil and water quality, waste generation, material use, transboundary and cumulative aspects
Social	Community disturbance, livelihood and resettlement aspects, community health and safety, cultural heritage, tribal rights, landscape and visual, public perception, infrastructure and services aspects

Figure 4-2: Summary of Key Project Decisions and Alternatives Options

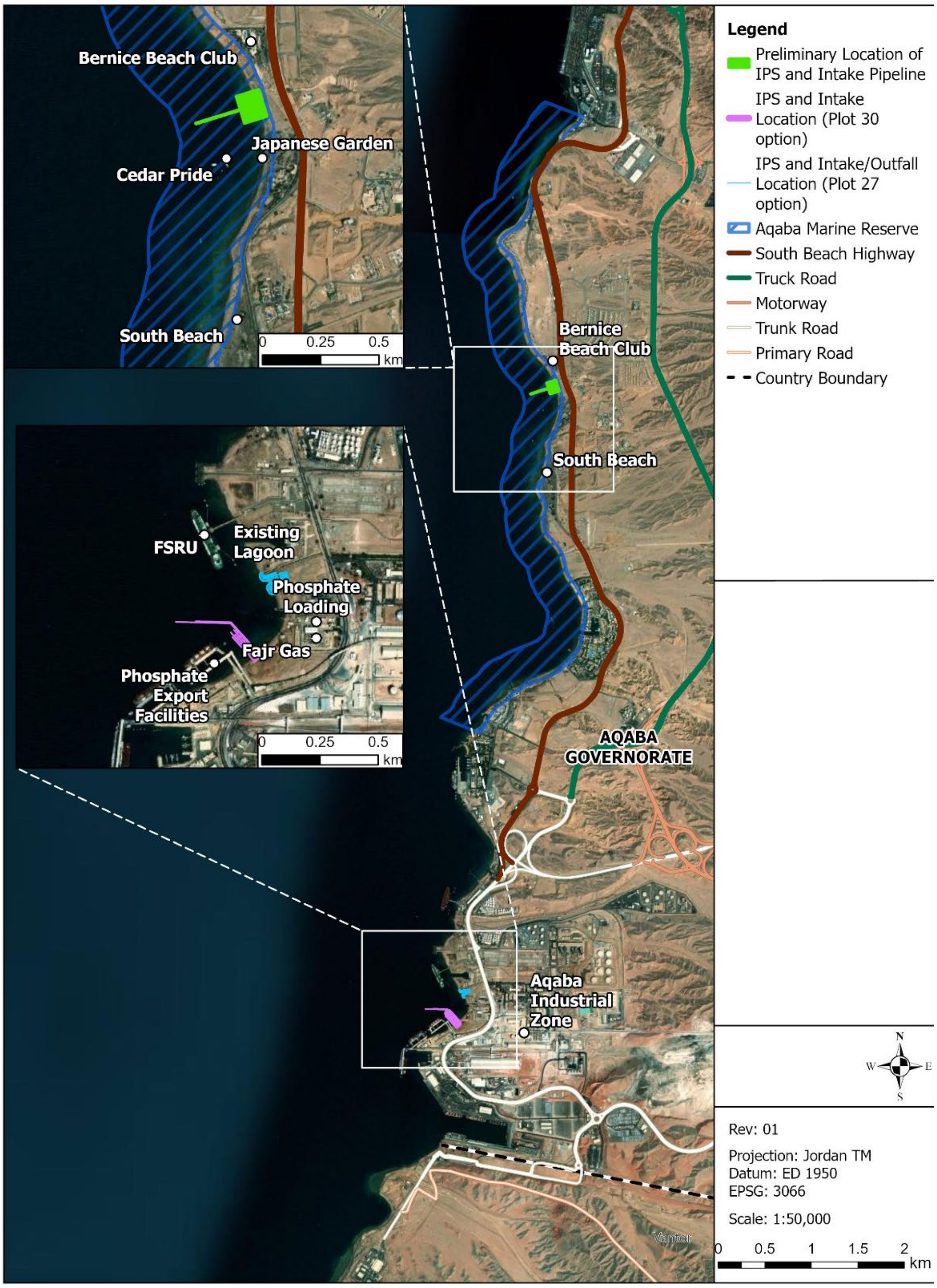


4.3.2 Marine and Intake Pumping Station

4.3.2.1 Location of Seawater Intake and Brine Outfall

Two areas along the coastline were initially evaluated for siting the intake and outfall facilities during initial concept development. These locations are shown in Figure 4-3.

Figure 4-3: Alternative Intake and Outfall Infrastructure Locations



The initial location considered for the proposed intake and outfall facilities was based on feasibility studies undertaken in 2018 (as reported within the 2022 ESIA (Tetra Tech, 2022)) and included siting the Intake Pumping Station (IPS) on an area of land located between the Bernice Beach Resort facilities to the north and the Japanese Garden snorkeling site to the south. The proposed intake and outfall pipelines extended into the sea from this location. As shown within Figure 4-3 the pipeline location for this option is within the protected area of Aqaba Marine Park.

From an environmental and social perspective, the option was not deemed acceptable. Installation and presence of the pipelines within the Aqaba Marine Park would have the potential for significant impacts on the important ecosystem and habitats within the Park both during construction and operation. Construction of the pipelines would potentially require trenching with potential for impacts to seabed flora and fauna within the Marine Park. In addition, the Project would likely interfere with recreational activities by the marine park users, e.g. diving, and affect the associated tourism-related revenue for the duration of the marine construction period. The Aqaba Marine Park and the associated eco-tourism it attracts is an important source of employment and income within the area alongside small-scale fisheries (for local supply) and maritime operators who rely on healthy marine ecosystems for their income.

This location was therefore rejected and the Project focused on feasible options for the siting of the IPS and the intake and outfall infrastructure to the south of the Aqaba Marine Reserve between, and including, the Aqaba Thermal Power Station intake lagoon and the phosphate export facility (see Figure 4-3). Technically, this location is constrained by the existing surrounding infrastructure, which includes the phosphate facility operations to the south and an existing subsea gas pipeline (and associated safety exclusion zone) but the environmental and social constraints associated with the Aqaba Marine Reserve location are avoided. Table 4-2 shows the summary of the comparative assessment of the two locations.

Table 4-2: Summary of Comparative Assessment of Seawater Intake and Outfall Locations

Assessment Criteria	Seawater Intake and Outfall Locations	
	Alternative 1: Aqaba Marine Reserve	Alternative 2: Aqaba Industrial Zone
Technical Feasibility	🔴	🟢
Economic Feasibility	🟠	⚪
Environmental	🟠	⚪
Social	🟠	⚪

Key:

Neutral (no differentiators)	Barriers to progress	Weakness	Limitations	Beneficial	Not applicable to this decision
🟡	🔴	🟠	⚪	🟢	N/A

4.3.2.2 Marine Intake Design

The Project has considered several alternative means of seawater intake, using either marine pipelines or a concrete shore intake channel. The two key options considered comprise:

- **Alternative 1: Intake Pipelines Equipped with Intake Towers and IPS at Plot 30:** This option considered either two or four intake pipelines laid on the seabed within a trench, backfilled and provided with appropriate protection against scour and wave action, connected to intake tower structures offshore and a new Intake Pumping Station (IPS) located within "Plot 30" at the shoreline (see Figure 4-3).

The design of towers being considered under this option assumed:

- Structures constructed in precast marine concrete/ glass reinforced plastic (GRP) and placed on a prepared granular foundation
- Towers located at approximately 100m offshore and positioned in waters deeper than 11 meters LAT (Lowest Astronomical Tide) to ensure they remained submerged
- Equipped with glass reinforced plastic (GRP) mesh bar screens (75mm x 75mm) to prevent intake of large debris and marine life
- Ensure a maximum intake velocity of 0.15–0.20 m/s to minimise fish entrainment
- Routine maintenance by divers and Remotely Operated Vehicles (ROV) supplemented with an air burst system to prevent jellyfish intrusion during seasonal blooms and an intermittent (shock) chlorination system to mitigate for biofouling

The design of pipelines being considered under this option assumed:

- Either two or four High Density Polyethylene (HDPE) pipelines connecting the offshore intake towers to the IPS, each with an external diameter of approximately 2300mm and ranging between 130-150m in length
- Installed within a shared trench extending from the shoreline to the intake towers
- Water velocities within the intake pipelines maintained above 0.8m/s to minimise settlement and macro-fouling up to a maximum rate of 2.5m/s

Construction of the towers and pipelines would require trenching and dredging in the nearshore and deeper waters to enable installation of the intake infrastructure with side casting of dredged material anticipated prior to backfilling and laying of rock amour following wave action and scour.

- **Alternative 2: Concrete Shore Intake Channel and IPS at Plot 27:** This option assumes construction of a new concrete intake lagoon provided with revetment structures for erosion protection within the intertidal area adjacent to a new IPS located within "Plot 27" (see Figure 4-3).

  The design of the intake lagoon assumes the following:

  - A bubble curtain installed at the mouth of the lagoon to reduce the potential entrainment of suspended and floating material
  - A fish recovery and return system will be used to recover a fish or other fauna that passes through the bubble curtain and automatically and reliably filter incoming water and discharge recovered marine life and debris into the appropriate handling trough and returned outside of the lagoon
  - A two-stage screen that will include a 50mm coarse and 5mm fine mesh

The key differentiators between the two options from an environmental impact perspective relate to the potential for impacts to the water column including turbidity effects from dredging/trenching, and seabed impacts from construction activities including the direct physical impacts to habitats from trenching (and side casting for Alternative 1) from suspended and settled sediments and from operational impacts associated with abstraction.

With respect to dredging and trenching, a review of the seabed habitat types that would be potentially directly affected by the construction activities for Alternatives 1 and 2 was undertaken as presented in Table 4-3. These estimates include the areas by both intake and outfall construction works (see Section 4.3.2.3 below regarding outfall options). For Alternative 1 the estimate includes the entire area that would be trenched to install the pipelines and tower structures. For Alternative 2 the estimate includes the area required for trenching, construction of a temporary jetty and an anchoring area to support trenching as well as the lagoon structure installation.

Table 4-3: Quantification of the Marine Construction Affected Area within the Study Area for Alternatives 1 and 2

Habitat type	Coral cover	Depth range	Total reported in the Study Area m^2	Total area m^2 affected by construction Alternative 1	Total area m^2 affected by construction Alternative 2
Shallow Intertidal Areas	10%	0-5m	48,841	5460	754
Patch Reef and Shallow Seagrass	10%	5-15m	119,648	7107	491
Fringing Coral Reef	40%	15-35m	204,822	3045	396
Mixed Reef and Sediment	15%	35-75	153,756	9167	752
Deep Sand and Isolated Reef Outcrops	15%	75-150+m	225,372	16530	253
			Total:	5,460	2,646

Table 4-3 shows a significantly reduced area of direct impact for the Alternative 2 intake channel option. For Alternative 1 while the disturbance would be essentially temporary, a loss of approximately 11,000m^2 of benthic habitat that supports coral and seagrass is predicted with recovery uncertain and the potential for permanent alteration of substrate type as a result of changes in sediment due to the dredging activity. For Alternative 2 the area affected by the permanent infrastructure will be located within shallow waters adjacent to the shoreline. The lagoon seawall itself will provide suitable substrate for coral, giant clam and fish habitat with the potential for translocation of coral and giant clams in water depths of less than 35m by divers thus mitigating for impact to Critical Habitat and Priority Biodiversity Features known to be present in the Study Area. This includes coral reef and seagrass, giant clam and teleosts fish (Humphead wrasse (*Cheilinus undulatus*), Sky emperor (*Lethrinus mahsena),* Red Sea coral grouper *(Plectropomus marisrubri).*

With regard to effects from turbidity on pelagic species such as plankton, fish, turtles and cetaceans in the water column and to benthic habitats due to smothering, modelling was undertaken to assess the potential impacts associated with Alternative 1. The modelling results predict that the total area of benthic habitat impacted by sediment deposition during side casting will extend 1.2km from the location of side casting. Turbidity impacts in the water column and smothering effects on benthic habitats will be temporary and occur during dredging activities, which are anticipated to occur over approximately 30 operational days. The total area of water column impacted by increased turbidity was predicted to extend over an area of approximately 45,000m^2. In addition, risk of sediment contamination remobilisation was also identified based on potential for existing Polycyclic Aromatic Hydrocarbons (PAH) contamination across the Study Area. For Alternative 2 the Project would use appropriately designed turbidity curtains around the area to be trenched. As a result, assuming effectiveness is confirmed throughout operation, turbidity impacts would be avoided.

Operationally the effects of abstraction were considered for both alternatives. For Alternative 1 while the intake tower design incorporates mesh bars to mitigate for entertainment of larger marine life, there is potential for entrainment of coral larvae, seagrass that pollinate through the water column (which includes most species in the Gulf of Aqaba), and bivalves (specifically the giant clam) that trigger critical habitat is of primary concern. While the low intake velocity provides some mitigation there is still potential for effects to these receptors and potential for wider impact to seagrass and coral habitats due to effects on coral larvae and seagrass pollen or seeds in the area affected by the abstraction. For Alternative 2 the lagoon design includes a bubble curtain would provide a barrier to the majority of the seagrass pollen or seeds if present, as well as coral larvae and clam gametes. Modelling was undertaken to assess the increase in current velocity associated with the lagoon abstraction and hence the potential for effects to pollen, seeds, larvae and gametes that pass through the curtain with effects assumed to be either negligible or relatively minor (based on reduced reproductive success) (refer to Chapter 9 for further details).

From an economic, social and technical feasibility perspective there were no significant differentiators between the options while from the analysis presented above there was a clear preference for Alternative 2 given the benefit in reductions to potential impacts, specifically to Critical Habitat and Priority Biodiversity Features. This option was therefore adopted as the intake reference case. The comparative assessment between the two options is provided in Table 4-4 below.

Table 4-4: Summary of Comparative Assessment of Intake Design Options

Assessment Criteria	Intake Design Options	
	Alternative 1: Intake Pipelines (Plot 30)	Alternative 2: Intake Channel (Plot 27)
Technical Feasibility	🟡	🟡
Economic Feasibility	🟡	🟡
Environmental	🟠	🟢
Social	🟡	🟡

Key:

Neutral (no differentiators)	Barriers to progress	Weakness	Limitations	Beneficial	Not applicable to this decision
🟡	🔴	🟠	⚪	🟢	N/A

4.3.2.3 Marine Outfall Design and Diffuser Orientation Alternatives

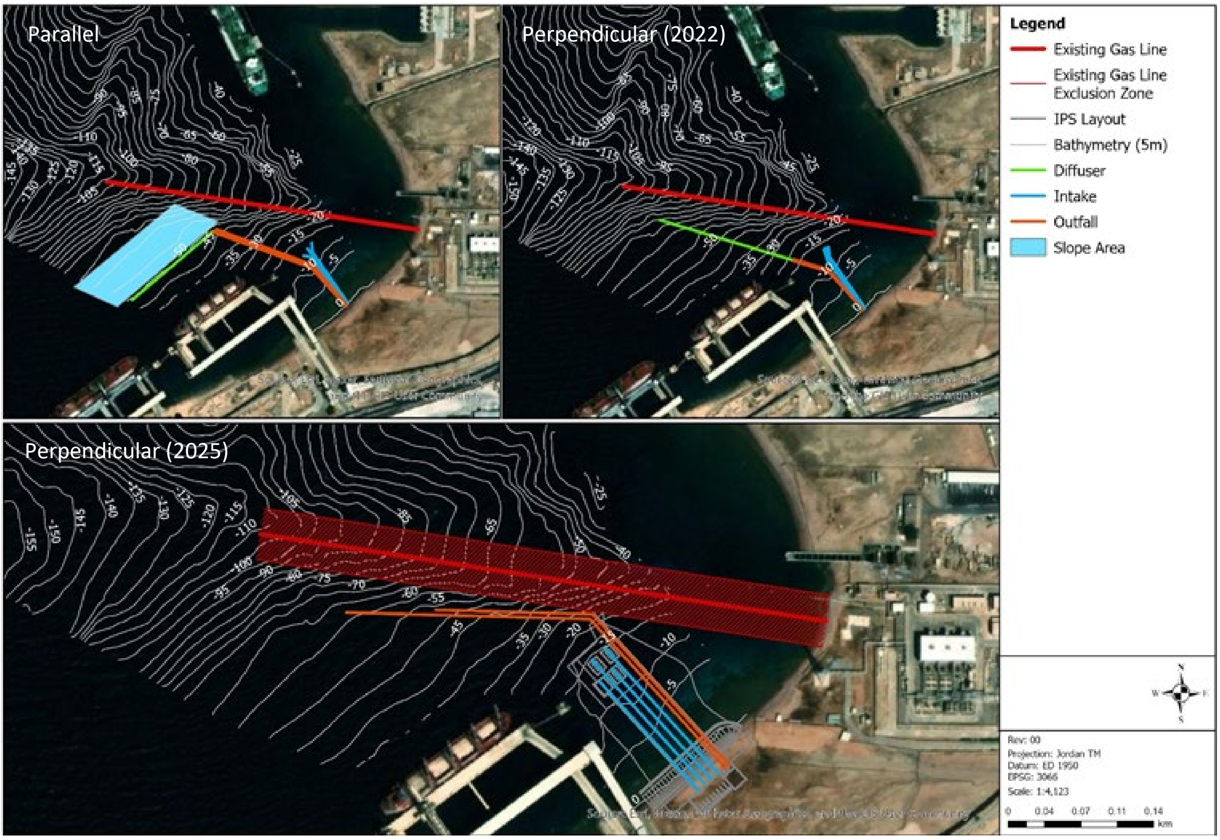
Diffuser Orientation

As reported within the 2022 ESIA, early concept design development included a number of studies considering the outfall diffuser design. The purpose of the diffuser is to promote the rapid and efficient mixing and dilution of the brine effluent discharge to sea, ensuring that applicable environmental standards are met in the receiving environment. During early design, following the selection of the intake and outfall location (see Section 4.3.2.1), the Project considered two diffuser orientations: an initial option being parallel to the coastline and an alternative running perpendicular to the coastline as shown in Figure 4-4. The same design of the diffuser, including the number and orientation of ports, was assumed for both orientations. The studies undertaken identified the following:

- **Diffuser orientation parallel to shore** – the initial diffuser alignment assumed the diffuser located on the seabed at the 50m depth contour to enable uniform flow from each port, a diffuser length of approximately 300m and port discharge velocity of ~6.5m/s. The alignment parallel to the coastline positions the diffuser towards the edge of a steep slope on the seabed and would require the excavation of a significant platform area to stabilise the diffuser and associated cost. This introduces constructability issues as well as stability risks in the event of any seismic activity and subsequent slope movement. Furthermore, the positioning of the diffuser directly under vessels manoeuvring at the adjacent phosphate berth exposes the diffuser to risks of accidental damage, including a possible impact from an anchor dropped in the event of vessel emergency
- **Diffuser orientation perpendicular to shore** – the proposed alternative perpendicular alignment requires a shorter overall diffuser length and offers improved constructability, and reduced construction impacts as compared to the parallel alternative. The alignment also mitigates seismic risks and moderately increases the distance of the diffuser from the adjacent phosphate berth to lower associated vessel risks. This alternative was adopted within the design assessed in the 2022 ESIA (Tetra Tech, 2022)

While the 2022 ESIA reported that the hydrodynamic modelling undertaken for both options predicted compliance with the environmental discharge standards adopted at the time, a difference in performance for the perpendicular orientation as compared to the parallel orientation (specifically for low flow discharge conditions), was noted. Further work was subsequently undertaken in 2023 to evaluate the outfall and diffuser design based on an updated design, which considered a revised layout for the intake and outfall pipelines (see Figure 4-4). The study used MIKE 3 and CORMIX software to assess recirculation and dilution effects respectively to confirm near field dispersion and dilution effects of the diffuser and compliance with the environmental discharge standards as stated in the 2022 ESIA (Tetra Tech, 2022). The modelling considered four scenarios, representing parallel and perpendicular current directions relative to the diffuser and two outfall flowrates. For the cases modelled, it was concluded that the excess salinity concentration showed rapid decrease after the discharge, reducing from 45 PSU to close to 2% of ambient salinity within the 100m radius for all cases. This was consistent with the modelling presented in the 2022 ESIA (Tetra Tech, 2022). The modelling was repeated in 2025 based on the same diffuser design for the outfall pipeline located at Plot 30 and taking into account updated discharge characteristics for the reference case design (refer to Chapter 9) confirming similar results with respect to the 2% excess salinity threshold at the edge of the mixing zone.

Figure 4-4: Alternative Brine Outfall Diffuser Orientations



In overall terms, the alternative arrangement of the diffuser orientation perpendicular to the coastline was favoured over a parallel orientation due to the lower construction impacts and operational risks as summarised in Table 4-5.

Table 4-5: Summary of Comparative Assessment of Diffuser Orientation Options

Assessment Criteria	Diffuser Orientation Options	
	Alternative 1: Parallel to Shore	Alternative 2: Perpendicular to Shore
Technical Feasibility	Weakness (orange)	Neutral (yellow)
Economic Feasibility	Weakness (orange)	Neutral (yellow)
Environmental	Weakness (orange)	Limitations (light)
Social	Limitations (light)	Neutral (yellow)

Key:

Neutral (no differentiators)	Barriers to progress	Weakness	Limitations	Beneficial	Not applicable to this decision
(yellow)	(red)	(orange)	(light)	(green)	N/A

Outfall Pipeline Installation Alternatives

In parallel with the options considered for the intake as discussed in Section 4.3.2.2 above, the Project also considered a number of alternatives for the outfall pipeline including two options at Plot 30 and Plot 27 (in each case assuming the same diffuser type and design fitted to the outfall to aid dispersion). The key differentiator between the options considered focused on the method of installation. For Alternative 1 the marine outfall system located at Plot 30 comprised two outfall pipelines (approximately 435m and 350m respectively) laid on the seabed parallel to and within a common trench with the intake pipelines up to the intake towers and then deviating and extending to a maximum water depth of -60m MSL where they would lay directly on the seabed. The extent of dredging required for this alternative is included within the estimates provided in Table 4-3 above. For Alternative 2 the outfall pipeline would be laid within a nearshore trench up to -10m MSL water depth and then laid directly on the seabed stabilised by concrete ballast collars spaced at 5m intervals. The trench would be constructed from a temporary jetty and equipped with sediment curtains that would remain in place until all sediment generating activities are completed, i.e. post backfilling and reinstatement. Materials from the trenching activities will be transferred to shore and then returned to the trench for backfilling, avoiding the side casting activities associated with Alternative 1. The extent of trenching and area of seabed affected for Alternative 2 is included within the estimates provided in Table 4-3 above.

As described with Section 4.3.2.2 above, the reduced footprint of trenching associated with Alternative 2 along with the benefits of being able to significantly reduce the potential for sediment transfer and the resulting effects to the water column and benthic habitat through use of sediment curtains make this the preferred option from an environmental perspective. From an economic, social and technical feasibility perspective there were no significant differentiators between the options and Alternative 2 was therefore adopted as the outfall reference case. The comparative assessment between the two options is provided in Table 4-6 below.

Table 4-6: Summary of Comparative Assessment of Intake Design Options

Assessment Criteria	Intake Design Options	
	Alternative 1: Intake Pipelines (Plot 30)	Alternative 2: Intake Channel (Plot 27)
Technical Feasibility	●	●
Economic Feasibility	●	●
Environmental	●	●
Social	●	●

Key:

Neutral (no differentiators)	Barriers to progress	Weakness	Limitations	Beneficial	Not applicable to this decision
●	●	●	●	●	N/A

4.3.2.4 Marine Intake and Outfall Ongoing Design Refinements

As part of the ongoing design refinements the option of using of the Aqaba Thermal Power Station intake lagoon for intake for AAWDC Project is being further investigated. Discussions have been ongoing with CEGCO and other stakeholders to examine the potential feasibility of using the lagoon for AAWDC Project intake. The advantage of this option is that it is anticipated to avoid the majority of construction and installation impacts in the marine environment associated with an intake pipeline or channel option. Under this scenario it is likely that the Project intake pumping facilities would relocate to the vicinity of the lagoon (either new facilities or use of the existing CEGCO intake facilities).

In the event this option is shown to be feasible and are adopted within the design basis, an assessment of the change in environmental impacts would be undertaken in accordance with the Management of Change Process (see Chapter 5). It is anticipated however that this option, if found to be feasible, would be beneficial in terms of environmental impact for the reasons described above.

4.3.3 Desalination Plant

4.3.3.1 Desalination Plant Design Concept

The two main desalination concepts that are used globally for industrial scale desalination can be broadly classified as either thermal or membrane type technologies (Texas Water Development Board, 2004). Both require energy to produce fresh water, with thermal technologies using a combination of heat (to initially vaporise seawater into distillate) and electrical energy whilst membrane technologies rely on electrical energy only.

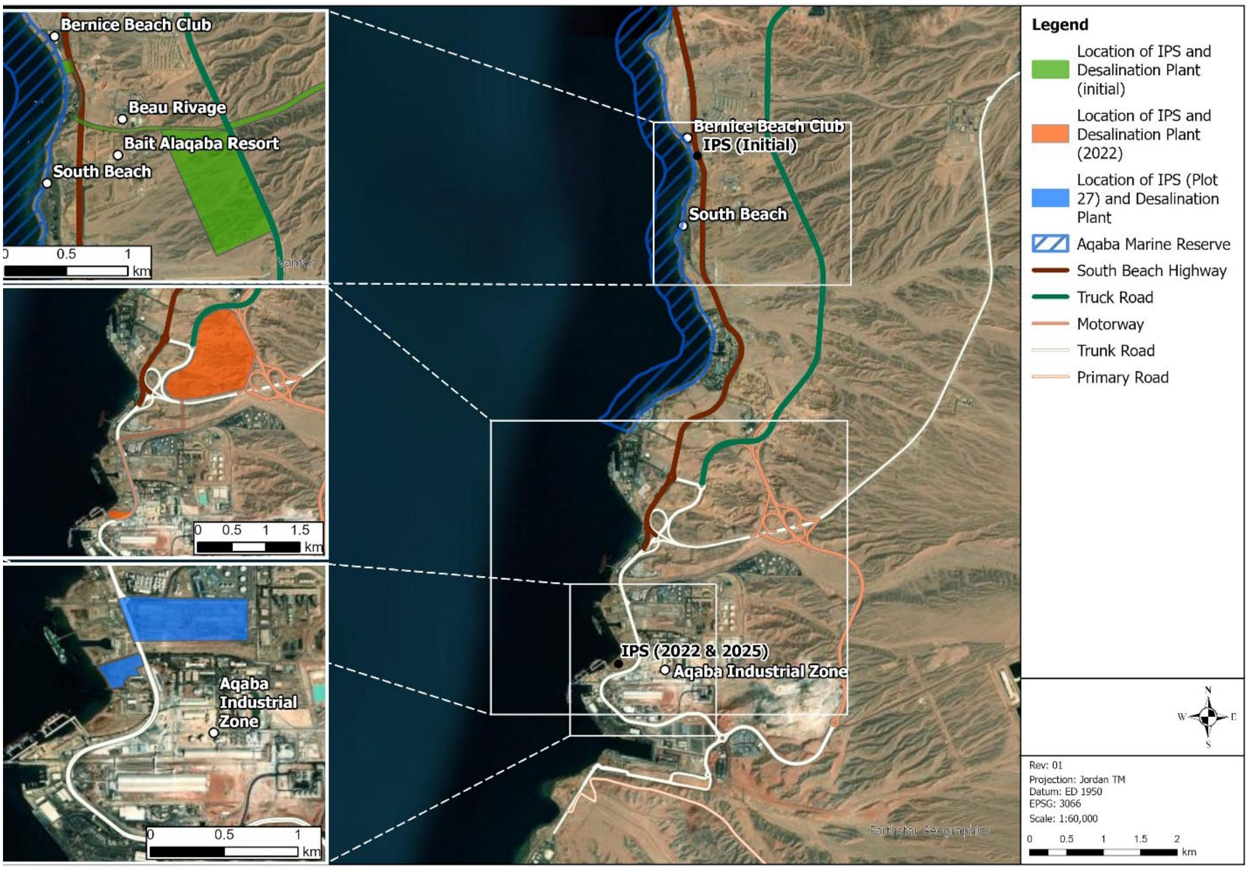
Thermal technologies have been historically used across the Middle East as the high salinity of the seawater of Arabian Gulf and Red Sea have precluded the use of membrane technology. However, these limitations have been addressed through more advanced and efficient membrane technology and the use of reverse osmosis (RO) techniques, which reduce both the process energy demand and the extent of fouling as compared to older membrane technologies (IRENA, 2016). In addition, benefits in performance have been achieved through the routine use of energy recovery devices as part of RO plant technology. When thermal desalination technology alone (i.e. without the inclusion of heat recovery technology) is compared to current RO technology, the latter is significantly less energy intensive. Globally RO accounts for about 69% share of installed desalination capacity and is a proven and reliable technology (Eke, J., *et al,* 2020). While there are a number of other common forms of membrane-based desalination available such as electrodialysis, these are typically used for treating brackish water rather than seawater (Texas Water Development Board, 2004).

On the basis of proven performance and reliability including higher energy efficiencies, RO technology was selected as the design concept for desalination and no further assessment of desalination plant technology types was undertaken.

4.3.3.2 Desalination Facility Location Alternatives

The three locations have been evaluated to date for siting the desalination plant. These locations are shown in Figure 4-5 below.

Figure 4-5: Alternative Desalination Plant Locations



As reported within the 2022 ESIA (Tetra Tech, 2022) during the initial phase of AAWDC Project development, locations for the siting of the desalination plant were investigated by a committee formed by His Excellency the Minister of Water and Irrigation and a location selected. This original site (refer to Figure 4-5) was ultimately disregarded due to its location within the vicinity of the Aqaba Marine Park (see Section 4.3.2.1 above). Consequently, two further site locations were investigated within the Aqaba Industrial Zone. In both cases the need for a new substation facility (to be constructed and subsequently operated by NEPCO) to be located nearby to provide power to the Project facilities was factored into the site selection.

The location initially considered and assessed within the 2022 ESIA (refer to Figure 4-5) was an undeveloped “greenfield” area totalling 113 hectares (ha), of which 35 ha was allocated for the construction of the desalination plant facilities. From a technical perspective the site was considered suitable in terms of access, safety and logistics, however the topography of the land meant that significant ground engineering and civil works were required to provide level areas (requiring the construction of platforms) to locate the desalination plant facilities. In addition, the site is traversed by power lines and two seasonal wadis, which effectively sub-divide the site. Environmentally the site is not located in or adjacent to any protected areas however the significant groundworks and associated plant use contributes to construction phase emissions, and the presence of the wadis contribute to the potential for surface water impacts. At a distance of approximately 400m from the shoreline, impacts to the marine environment are avoided however at an elevation of approximately 110m above sea level (and a distance of 3.5km to the intake pumping station) there is a greater pumping requirement as compared to a sea level location, which results in greater power requirements (and associated emissions) as well as cost. The identification of a more suitable site closer the intake pumping station was highlighted as a key optimisation during the EPC tender process and resulted in the identification of a new brownfield site located in the centre of the Aqaba Industrial Zone (see "Location of IPS and Desalination Plant (2025) within Figure 4-5).

The brownfield site identified for the desalination plant is approximately 300m inland from the coast and is bordered by the Ports Highway (Highway 47) to the immediate west and by industrial facilities to the north, south and east including the Aqaba Thermal Power Station. The site, covering an area of approximately 27 ha, was previously occupied by a timber processing and manufacturing facility and requires significantly less ground engineering and civil works as compared to the previous "greenfield" alternative. Operational pumping requirements and hence power demand is significantly less given the shorter distance to the intake pumping station and lower elevation of the site**.** The disadvantage of the site is the smaller footprint available as compared to the previous site assessed in the 2022 ESIA and the added complexity of utilities and services in the vicinity (including a utilities pipeline corridor to the south of the site).

A summary of comparative assessment of the desalination plant location alternatives is provided within Table 4-7 below.

Table 4-7: Summary of Comparative Assessment of Desalination Plant Location Alternatives

Assessment Criteria	Desalination Plant Alternative Locations		
	Alternative 1: Adjacent Aqaba Marine Park	Alternative 2: 2022 Greenfield Site	Alternative 3: 2025 Brownfield Site
Technical Feasibility	🟡	🟠	🟢
Economic Feasibility	🟡	⚪	🟢
Environmental	🔴	🟡	🟢
Social	🔴	🟡	🟡

Key:

Neutral (no differentiators)	Barriers to progress	Weakness	Limitations	Beneficial	Not applicable to this decision
🟡	🔴	🟠	⚪	🟢	N/A

4.3.3.3 Cleaning in Place Waste Alternatives

Chemical cleaning-in-place (CIP) of the RO membranes is a routine maintenance activity regularly carried out within the desalination plant RO system to remove biofouling and ensure effective membrane performance. It is estimated that each RO rack undergoes CIP approximately 2-3 times a year. The process, including planned chemical use, is described in more detail within Chapter 5 The CIP process produces inorganic and organic waste streams, with the latter containing the organic cleaning chemicals (including citric acid and biocide) used in the CIP process. The Project has considered the options for the handling and disposal of the CIP organic waste stream through the concept design development, assuming the waste stream is first neutralised using chemicals (e.g. sulphuric acid and sodium hydroxide). Initially the option of routing the neutralised organic CIP waste streams from the RO system to onshore site-based evaporation ponds was considered. This option assumed the construction of two lined (i.e. impermeable) evaporation ponds with a combined storage capacity of approximately 2,800m^3 to be located within the desalination plant site area. The use of evaporation would have the benefit of avoiding a liquid waste stream or potential discharge however this option will result in the generation of potentially contaminated sludge requiring handling and disposal via a licensed waste disposal facility. This would be additional to the non-hazardous sludge routinely generated by the desalination plant operations. Ultimately on the basis of cost and the site area constraints associated with the 2024 brownfield site selected (see Section 4.3.3.2 above) this option was not taken forward.

The key alternative option assumes the use of cartridge filtration in the CIP system to remove particulates from the CIP organic waste stream prior to neutralisation. The neutralised intermittent waste stream is then sent to the desalination plant equalisation tank where it mixes with RO brine and other effluents from the solids treatment system and is diluted prior to discharge within a combined discharge effluent stream (see Chapter 5). This option represents a technically feasible alternative (unlike the previous pond option) due to the lower footprint required and lower cost and has been adopted into the design basis. Modelling of the discharge from the desalination plant (both with and without the CIP waste stream) is presented within Chapter 9 and shows no significant difference in the quality of the discharge when the CIP waste stream is present. The use of 2-2 dibromo-3-nitrilopropionamide (DBNPA) during Cleaning in Place (CIP), which will be neutralised prior to discharge, is not expected to result in any significant impacts and The assessment of other inorganic components within the effluent discharge under routine and non-routine discharge conditions (i.e. with and without the neutralised Cleaning-In-Place effluent), aside from iron (which is introduced as part of desalination process as a coagulant, were predicted to be below the relevant mixing zone criteria well within the mixing zone edge.

Table 4-8 below summarises the comparative assessment of the above CIP waste disposal options.

Table 4-8: Summary of Comparative Assessment of Cleaning-In-Place Waste Alternatives

Assessment Criteria	Cleaning In Place Waste Alternatives	
	Alternative 1: Evaporation Ponds	Alternative 2: Treatment and Discharge
Technical Feasibility		
Economic Feasibility		
Environmental		
Social		

Key:					
Neutral (no differentiators)	Barriers to progress	Weakness	Limitations	Beneficial	Not applicable to this decision N/A

4.3.4 Conveyance System Alternatives

4.3.4.1 Conveyance Routing Concept

Initial conveyance routing analysis was undertaken to determine a routing concept to convey the desalinated water from the intake and desalination facilities in Aqaba to the existing reservoirs of Abu Alanda and Al Muntazah near Amman. The development of the concept was driven by the following key design requirements:

- Minimise the degree of pumping required (i.e. pump head) and power requirements
- Minimise the total length of the pipeline
- Achieve minimal disruption to existing roads and services
- Ensure sufficient accessibility for construction and maintenance

In addition, the concept development considered the need to minimise impacts to communities as far as possible, minimise changes to land use, minimise environmental impacts (e.g. through avoidance of protected areas) and make use of existing land ownership, access and agreements in place as well as current understanding of the presence of utilities and services with a focus on optimising schedule and cost. As such, an early concept decision was made to take advantage of the existing Disi Conveyor Right of Way (RoW) and follow this route as far as practicable. The Disi Conveyor is owned and operated by MWI and began operation in 2013. Conceptual routing studies confirmed that the AADWC Project route could be laid parallel adjacent to the Disi Conveyor route for around 300km (approximately 70% of the entire route) enabling the key design criteria to be achieved. Part of the routing concept also included a small part of the alignment on private land and sections on public roads including a section along the Desert Highway. Conceptual studies considering a route with a greater degree of alignment with the Desert Highway, however, identified a sharply inclined section of approximately 5km in length equating to an elevation change of approximately 500m. This section was deemed to contribute to a significantly increased overall power and pump head requirement and made the design hydraulically and economically very challenging. As such the option of increased alignment with the Desert Highway was rejected. Similarly, the option of using the route that was identified for the RSDSC project (see Section 4.2.3 above) was not pursued. This was due to concerns around security and potential political risks associated with the route which had been previously selected for the RSDSC project at a time when the transboundary support had initially been in place. As discussed in Section 4.2.3, this support was subsequently withdrawn and the project abandoned.

4.3.4.2 Routing Alternatives Around Queen Alia International Airport

As reported within the 2022 ESIA (and the subsequent 2025 update) during concept design development alternative alignments were considered in the South Amman area adjacent to Queen Alia International Airport (QAIA) and Al Jeza municipality to ensure that the selected pipeline alignment is optimised in terms of costs, ease of construction, reduced interference with other existing services and reduced impact on the commercial activities in the area during construction. To achieve these objectives, four alternative alignments were considered (refer to Figure 4-6). The alternatives were assessed taking into account the length of the routes, the degree of land acquisition and expropriation required for each route, the utilities, services and other constraints (including the Hijaz Railroad, local roads and highways and the building, structures and businesses) known to be present along the proposed alignment. On the basis of the assessment undertaken the Alternative 2 route was selected.

Subsequently the decision was taken by MWI to relocate the ADC pumping station (PS ADC), which is to the north of the QAIA, to a site which is owned by the Water Authority of Jordan. As a result, a further revision to the routing alignment around the QAIA has been determined as shown in Figure 4-6 following part of the previous Route 1 and 2 alignment options. This route has been determined using the same objectives as the original alternative routes but taking into account the relocated PSADC site.

Figure 4-6: Routing Alternatives Around Queen Alia International Airport

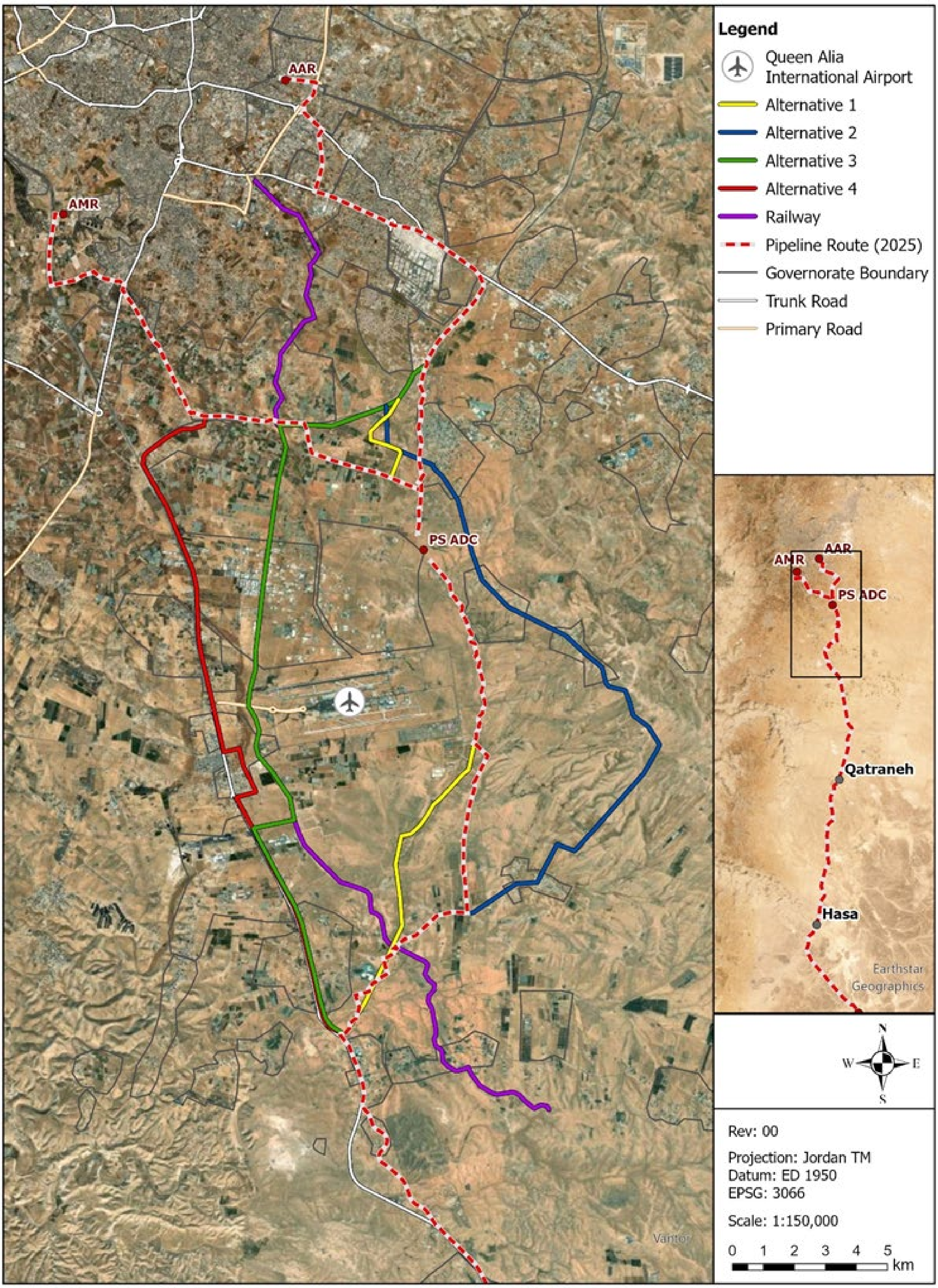


Table 4-9 below presents a comparative summary between the routing alternatives around QAIA. The 2025 alternative is not ranked as this option is not comparable given the PS ADC location change, which significantly influenced the final routing decision.

Table 4-9: Summary of Comparative Assessment of Routing Alternatives Around QAIA

Assessment Criteria	Routing Alternatives Around QAIA				
	2022 Route 1	2022 Route 2	2022 Route 3	2022 Route 4	2025 Route
Technical Feasibility	[Weakness]	[Limitations]	[Neutral]	[Limitations]	N/A
Economic Feasibility	[Neutral]	[Limitations]	[Weakness]	[Limitations]	N/A
Environmental	[Neutral]	[Neutral]	[Neutral]	[Neutral]	N/A
Social	[Neutral]	[Neutral]	[Neutral]	[Weakness]	N/A

Key:

Neutral (no differentiators)	Barriers to progress	Weakness	Limitations	Beneficial	Not applicable to this decision
[yellow circle]	[red circle]	[orange circle]	[peach circle]	[green circle]	N/A

4.3.4.3 Conveyance Pipeline Material Alternatives

The conveyance pipeline material alternatives considered by the Project include Steel, Ductile Iron (DI), Glass Reinforced Plastic (GRP) and Pre-stressed Concrete Cylinder (PCCP). The materials were analysed based on cost, market availability, strength, durability, ease of repair and possibility of partly manufacturing in Jordan. As reported in the 2022 ESIA (Tetra Tech, 2022) global warming potential (GWP) of the options was also considered based on life cycle analysis of the materials. In summary, the materials analysis concluded the following:

- **Steel Pipe:** typically selected for high-pressure water conveyance systems (i.e. where the static head exceeds 16 bars) due to their high strength, durability and leak-free welded joints. This is considered highly advantageous over pipeline materials which use mechanical joints to connect pipe sections. Steel pipe also offers the potential benefit of partial local manufacturing in Jordan. Steel pipe is, however, the most expensive material option, albeit the costs are partially offset by the ability to operate the conveyance pipeline at higher pressures with a reduced number of booster stations and break pressure tanks. Steel pipe also carries a long-term risk of internal epoxy lining failure and corrosion after the initial guarantee period, which could lead to complex repair and maintenance and subsequent operational downtime. Steel manufacture is energy intensive, incurring a higher Global Warming Potential (GWP) than non-ferrous pipe materials during the production phase
- **Glass Reinforced Plastic (GRP) Pipe -** typically used for lower pressure freshwater, seawater, and brine systems due to their high corrosion resistance and lower cost. Operating at a lower pressure would necessitate additional booster stations and break pressure tanks along the water conveyance route. Whilst current international standards account for a 50-year design life, GRP pipelines long-term field performance beyond 30 years is less documented. Standard mechanical (socket spigot) joints are also seen as potential leak points. GRP pipelines have been considered within a hybrid Steel/ GPR conveyance system design of 250km high pressure steel pipe and 202km lower pressure GRP Pipe. The GRP pipe sections would incorporate restrained (effectively

welded) joints on 20% of the length to prevent leaks. GRP manufacture is moderately less energy intensive than ferrous metal pipe materials during the production phase

- **Ductile Iron (DI) Pipe** - considered uncompetitive for the main water conveyance pipeline system as DI pipe cannot meet the capacity requirement without the installation of 2 separate pipelines which would result in a larger, more disruptive construction footprint. DI pipe cannot be manufactured locally which incurs high shipping costs and requires additional corrosion protection in the form of external tape wrapping and internal alumina cement, making it significantly more expensive than the alternatives. DI manufacture is energy intensive, incurring a higher Global Warming Potential (GWP) than non-ferrous pipe materials during the production phase
- **Pre-stressed Concrete Cylinder (PCCP) Pipe** - deemed unsuitable due to a high corrosion risk, excessive weight that complicates handling and repair, a higher number of potential leak points compared to GRP, and the need for additional lining that would make them commercially unviable. Relative to the other pipeline materials considered, concrete pipe manufacture is less energy intensive, however it has a higher eco-toxicological impact due to the heavy metal and toxic inorganic compounds found in cement (primary raw material used in concrete)

The two viable material options carried forward from the assessment were steel and hybrid steel and GRP with the final decision taken to select steel on the basis of performance and technical feasibility. The comparative assessment between the material options is shown in Table 4-10 below.

Table 4-10: Summary of Comparative Assessment of Conveyance Pipeline Material Alternatives

Assessment Criteria	Conveyance Pipeline Material Alternatives			
	Steel	Ductile Iron	GRP	PCCP
Technical Feasibility	Beneficial	Barriers to progress	Weakness	Barriers to progress
Economic Feasibility	Weakness	Weakness	Beneficial	Barriers to progress
Environmental	Limitations	Weakness	Limitations	Weakness
Social	Beneficial	Limitations	Limitations	Limitations

Key:

Neutral (no differentiators)	Barriers to progress	Weakness	Limitations	Beneficial	Not applicable to this decision N/A

4.3.4.4 Routing Optimisation and Re-Routes

One of the key focus areas of the route optimisation work being completed under the LNTP programme is the identification of any significant constraints necessitating re-route of major sections of the conveyance pipeline. Detailed analysis has been undertaken by the conveyance EPC contractor informed by mapping, physical ground truthing, secondary data sources and meetings with stakeholders including MWI to determine:

- Areas with significant presence of utilities, buildings, structures, housing, businesses, roads, geological features etc
- Locations requiring crossing of populated areas where there is high potential for disturbance

- Potential for use of alternative construction techniques or methodologies to manage the constraints and the associated impacts
- Re-routing options that represent feasible solutions to manage the constraints and constructability challenges while minimising both environmental and social impacts including land take, use of private land and change of land use

The re-routes to date have focused on urban locations specifically in the vicinity of Diesah, Qatraneh and Hasa villages. An overview of these re-routes is provided below.

Diesah Village

A section of 41km in the vicinity of Diesah village was identified as representing a major challenge from constructability, safety, schedule, and social impact perspectives. This section runs parallel to a new road, HV towers, and electrical substations; through Diesah's main commercial and residential street; and through pivot irrigation farms. Existing underground pipelines and services, electricity and light poles, high voltage towers, telecommunication towers, an electricity substation, roads, railway, businesses and private facilities represent a constraint to the use of cranes and equipment needed to lower the pipelines into the ground, and in some cases are located within the zone required for pipeline construction and access.

In Diesah village itself there is very little working space available between the existing properties either side of the highway which results in high risk to the existing structures.

An alternative route ("Northern Desert Route") has been identified to pass outside the newly constructed road and Diesah village's main road, along the northern side of Diesah village in the open desert area parallel to the HV towers located in the north side of the town. The original and revised Northern Desert Route is shown in Figure 4-7.

This revised route avoids the above mentioned obstacles and minimises the construction and operational challenges associated with the current alignment. The benefits of this route include the reduction in nuisance impacts to the Diesah residents given the distance of the route from the centre of the village and avoidance of potential physical impacts to businesses and residences.

Key advantages of the revised route can be summarised as follows:

Technical Feasibility, Safety and Schedule:

- Easier mobilization and manoeuvring of construction equipment in the open desert area
- Increased space for crane operations, pipe storage, and backfill material staging
- Improved safety, with minimal interaction with residents, pedestrians, and public infrastructure
- Lower risk of damage to existing utilities, roads, and electricity infrastructure
- Potentially faster construction due to fewer constraints and operational interruptions

Cost:

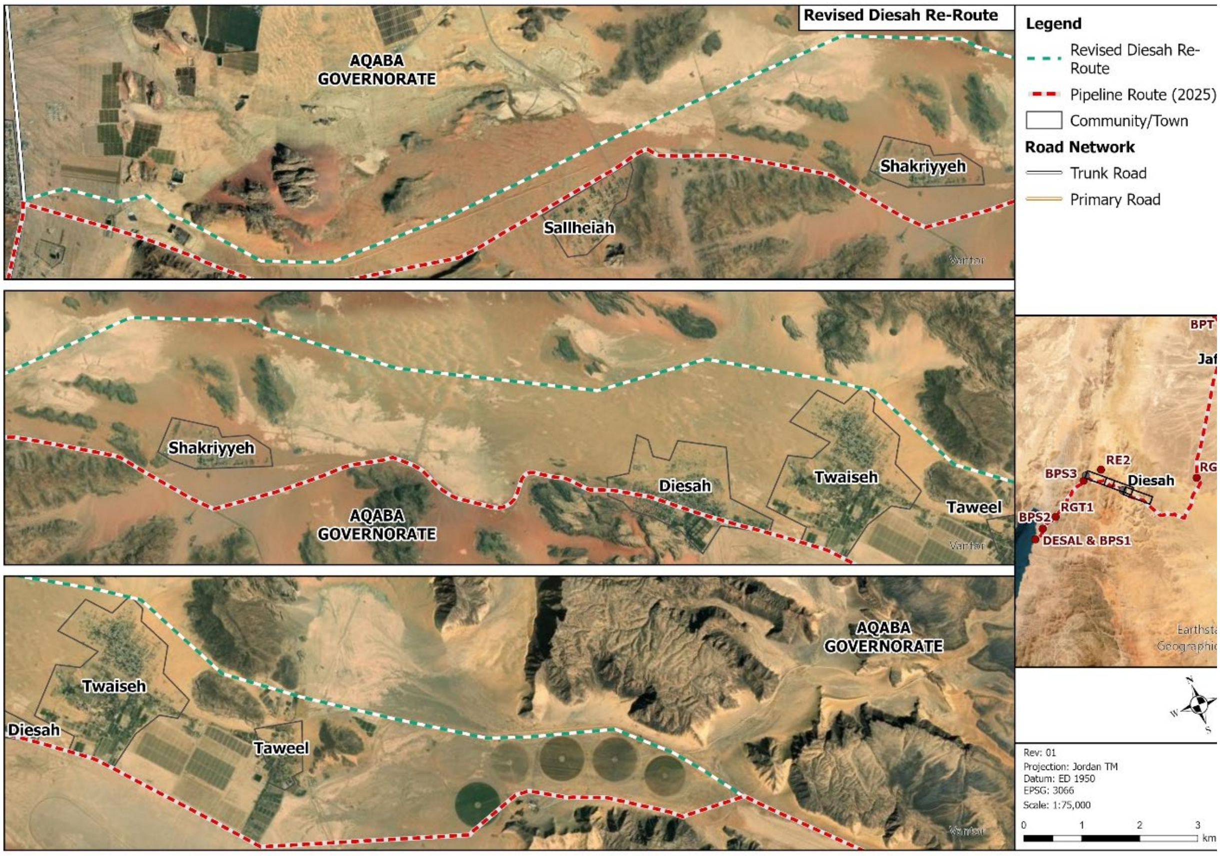
- Reduced risk of incurring extra costs associated with potential claims for compensation and delays

Environmental and Social:

- Reduced noise and local air quality impacts on residential and commercial receptors
- Reduced disruption to agricultural and urban areas
- Reduced impact on traffic and local businesses
- It is estimated that the revised routing would protect circa 40-50 properties from damage or destruction

The revised route aligns with the outcome of the stakeholder engagement undertaken with key Diesah stakeholders where concerns were raised around potential for significant disturbance to businesses, residential locations, tourism activity and create access restrictions. The stakeholders consulted recommended a re-route to the north of the village to address these issues (refer to Chapter 8 of this ESIA for more detail).

Figure 4-7: Diesah Village – Original Route and Revised "Northern Desert Route"



Qatraneh Village

A section of 13km in the vicinity of Qatraneh village was identified as representing a challenge from both constructability, safety and social impact perspectives. Main challenges associated with this routing include the following:

- The pipeline is forced into a narrow corridor already occupied by the Disi Line, electrical poles, and other utilities which impacts safe and efficient construction
- There is limited space for crane operations, pipe storage, and backfill material storage
- The alignment passes directly in front of shops, houses, and commercial facilities, posing major disturbance to local residents
- Increased safety concerns due to proximity of construction works to residents, pedestrians and ongoing traffic
- Increased environmental and social impacts, including dust, noise, and potential disruption to local businesses
- Potential impact on schedule as work may be restricted to certain hours during the day to minimize public disturbance

An alternative route outside the village has been identified where the pipeline is moved into an open corridor, utilizing open desert and away from the congested Disi Line utility corridor and associated constraints. The original and revised routes are shown in Figure 4-8.

In addition to improved technical feasibility and constructability, the benefits of this re-route include the reduction in nuisance impacts to the Qatraneh residents and businesses, given the distance of the revised route from the centre of the village.

Key advantages of the revised route can be summarised as follows:

Technical Feasibility, Safety and Schedule:

- Easier mobilization and manoeuvring of construction equipment in the open desert area
- Elimination of all interfaces with the Disi Line, power poles, underground utilities which removes the risk of service interruption
- Improved public and workforce safety due to work being carried out away from live traffic or densely populated areas
- Ample workspace allows for standard, fast-paced desert pipeline construction methods protecting project schedule

Cost:

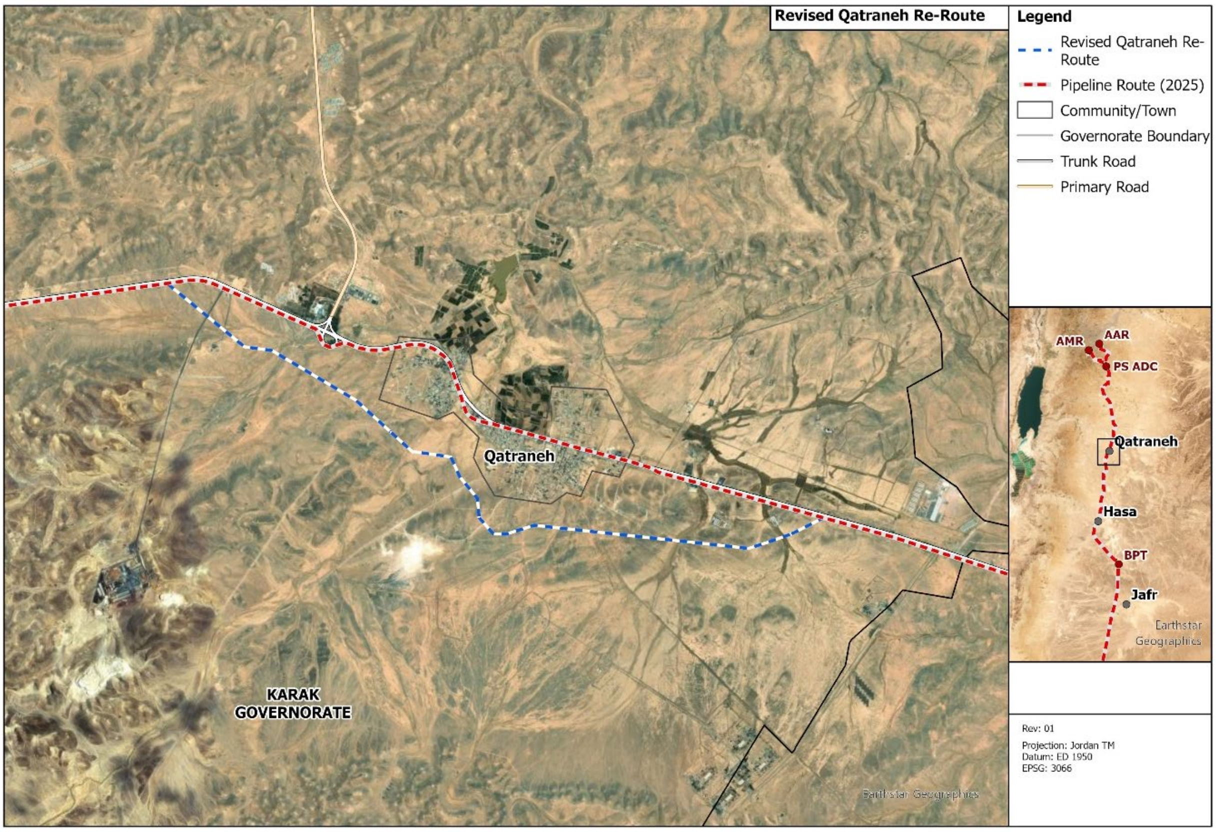
- Reduced risk of incurring extra costs due to potential for compensation, delays and claims

Environmental and Social:

- Reduced noise and local air quality impacts on residential and commercial receptors
- Reduced disruption to traffic and local businesses
- It is estimated that circa 60 properties will be saved from damage or destruction

This re-route is aligned to the concerns that were raised by communities during the stakeholder engagement around potential for significant community disturbance, impeded access and significant disruption to traffic on the Desert Highway, and their request for bypasses around Qatraneh (refer to Chapter 8 of this ESIA for more detail).

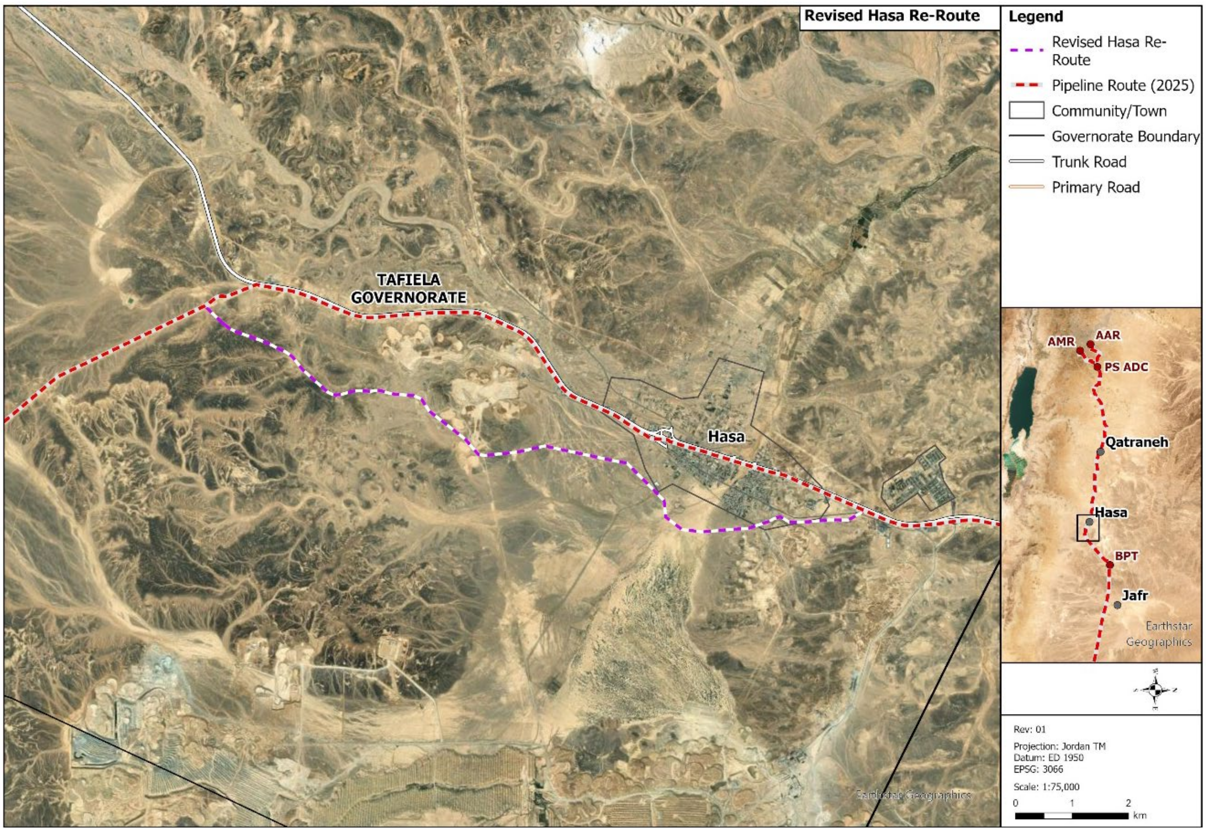
Figure 4-8: Original Route via Qatraneh and Revised Route via Open Desert



Hasa Village

Similar constraints have been identified for the section of the pipeline originally routed through Hasa village, resulting in the re-route of the section as shown in Figure 4-9 below. As in the case with the re-routing around Diesah and Qatraneh, the re-route around Hasa village resolves the constructability, safety, environmental and social constraints associated with the original alignment through the village, and addresses the concerns that were raised by communities during the stakeholder engagement (refer to Chapter 8 of this ESIA for more detail). The type and scale of obstacles, assets and properties avoided by the re-route is similar to Qatraneh.

Figure 4-9: Original Route via Hasa and Revised Route via Open Desert



A summary of comparative assessment of the original routing versus the revised routing around Diesah, Qatraneh and Hasa villages is presented in Table 4-11 below.

Table 4-11: Summary of Comparative Assessment of Original and Revised Routes

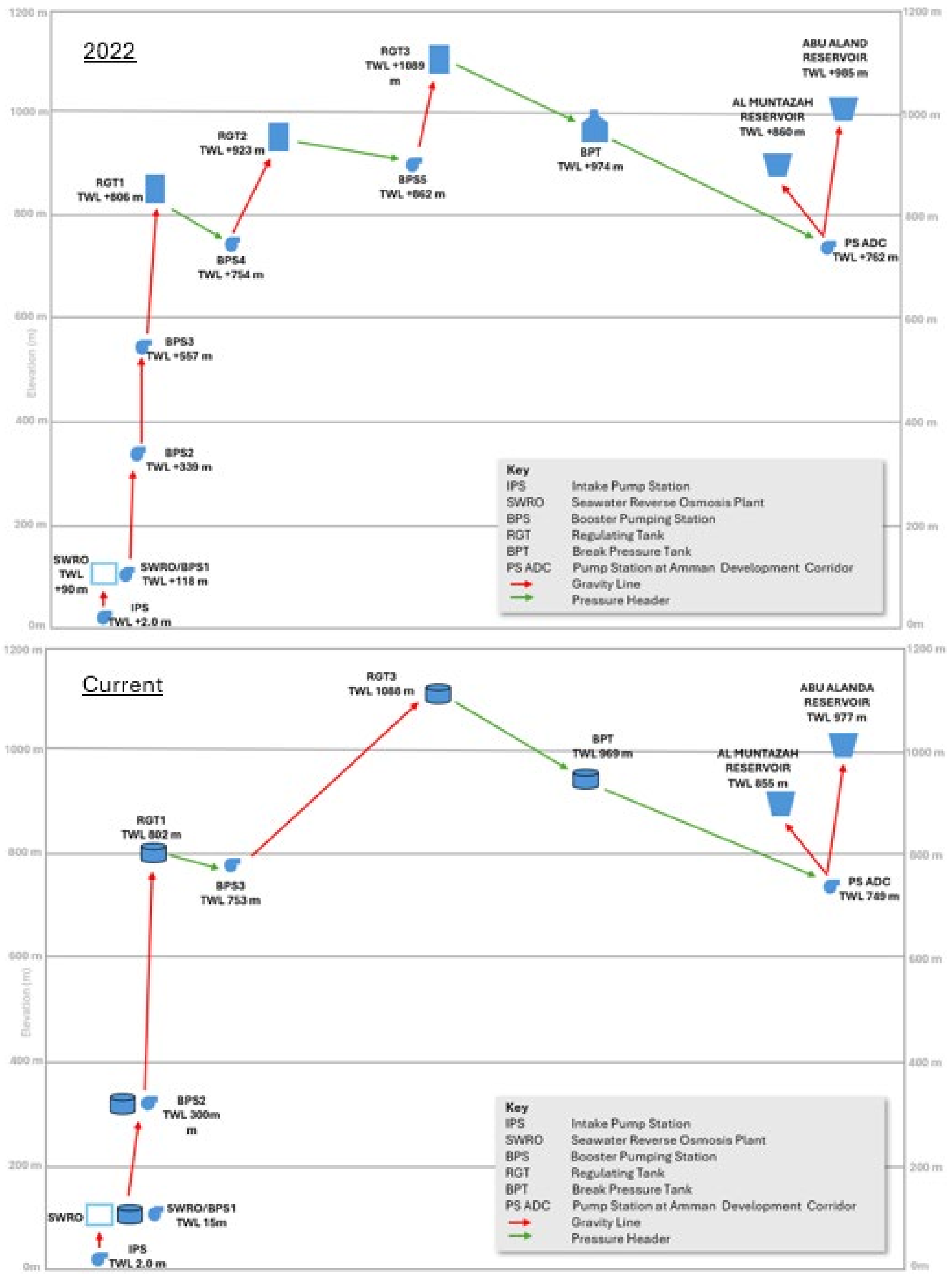
<table>
<tr><th colspan="2" rowspan="2">Assessment Criteria</th><th colspan="4">Routing</th></tr>
<tr><th colspan="2">Original Route</th><th colspan="2">Revised Route</th></tr>
<tr><td colspan="2">Technical Feasibility</td><td colspan="2">● (red)</td><td colspan="2">● (green)</td></tr>
<tr><td colspan="2">Economic Feasibility</td><td colspan="2">● (orange)</td><td colspan="2">● (green)</td></tr>
<tr><td colspan="2">Environmental</td><td colspan="2">● (orange)</td><td colspan="2">● (green)</td></tr>
<tr><td colspan="2">Social</td><td colspan="2">● (orange)</td><td colspan="2">● (green)</td></tr>
<tr><td colspan="6">Key:</td></tr>
<tr><td>Neutral (no differentiators)
● (yellow)</td><td>Barriers to progress
● (red)</td><td>Weakness
● (orange)</td><td>Limitations
● (light peach)</td><td>Beneficial
● (green)</td><td>Not applicable to this decision
N/A</td></tr>
</table>

4.3.4.5 Hydraulic Design Optimisation

One of the key areas identified for optimisation by the conveyance EPC was the overall hydraulic design of the conveyance system, with the adoption of an open rather than pressurised closed system (which was the original design as assessed within the 2022 ESIA). The effect of the change was to reduce the overall maximum operating pressure to 50 bar, thus enabling a reduction in pipeline diameters (by between 2 and 16 inches, depending on the pipeline section) and hence steel requirements (with a reduction of 7% by volume estimated). In addition, a further optimisation associated with the adoption of both fixed speed and variable speed pumps (previously all variable speed pumps were selected) at BPS1, BPS2 and BPS3 and station outlet control valves was introduced in the design to optimise the control of pumping stations, minimising pump starts and stops with the effect of minimising the requirement for intermediate storage through the system. The optimisation studies undertaken also resulted in changes to the above ground installation (AGI) requirements. Figure 4-10 below illustrates these changes by showing the comparison between the 2022 and optimised conveyance system schematic. The key changes can be summarised as follows:

- The location of BPS3 has shifted to upstream of Wadi Rum, to the location previously reserved for BPS 4. The requirement for additional booster pumping stations BPS4 and BPS 5 is removed from the design
- At the pipeline highpoint, located at approximately 804m above sea level (asl), upstream of BPS3, a reservoir has been introduced identical to the original design (at RGT1) to keep the system open. The requirement for RGT2 is removed from the design although RGT3 is retained
- The Break Pressure Tank (BPT) is retained and acts as a reservoir in the gravity section between RGT3 (the High Point Reservoir (HPR)) and PSADC
- The storage tanks previously located at BPS3 and PS ADC are removed from the design

Figure 4-10: 2022 and Current Conveyance System Schematics



The effect of the hydraulic system optimisation and decision to use of variable speed and fixed speed pumps at BPS1, BPS2 and BPS3 has resulted in a significant change to the volume of storage required through the system. A comparison between the storage requirements from the 2022 design and optimised design is provided in Table 4-12 below.

Table 4-12: Comparison Between Estimated Storage Tank Capacities (2022 vs Optimised Design)

Location	2022 Design Volume per Tank m3	Optimised Design Volume per Tank m3
BPS1	50,000	30,000
BPS2	21,000	30,000
RGT1	21,000	15,000
BPS3	19,000	-
BPS4	21,000	No longer within design
RGT2	18,250	No longer within design
BPS5	21,000	No longer within design
RGT3	21,000	-
BPT	21,000	20,000
PS ADC	19,000	-
Total	232,250	115,000
Total (including standby)	464,500	230,000

The reduction in the AGI requirements including the reduction on storage requirements represents significant cost savings but also savings in terms of material use and reduction in facility footprint; the removal of the RGT2, BPS4 and BPS5 facilities results in a reduction of approximately 10 ha alone and allows the potential environmental and social impacts that may otherwise have occurred at and in the vicinity of these locations due to AGI installation and operational activities to be avoided.

4.3.4.6 Conveyance System Ongoing Design Refinements

Further routing refinement of the conveyance pipeline will be ongoing through the LNTP programme as more information is made available from ongoing survey activities including topographic surveys, geotechnical investigations and light detection and ranging (LIDAR) surveys to establish ground and subsurface conditions (including locations of obstacles), engagement with and feedback from stakeholders including regulatory authorities, businesses, utility owners and local communities and through further detailed constructability reviews.

4.3.5 Power and Renewables

4.3.5.1 Power Supply Philosophy

Desalination and conveyance are, by nature, energy intensive and require a significant continuous and stable power supply to meet the electrical consumer demand of high-pressure pumps and other process equipment. At the early concept stage of the Project the decision was taken to source the required power from the Jordanian national grid, rather than a standalone site-based power generation facility, as the most energy efficient and cost-effective option.

There are significant benefits to using grid-based sources over conventional site-based power generation for a Project on this scale with its high continuous power demand. Primarily the national grid offers higher energy efficiency due to the size of power generation plant contributing towards the electricity supply compared with standalone power generators which are smaller, less efficient as they require costly idling capacity (spinning reserve) in the form of standby units. The grid can supply stable voltage and frequency that is better suited to electric motor driven high pressure pumps and removes, through added redundancy in electricity supply, a project risk associated with a single supply of power.

The AAWDCP is required to meet MWI CO_2 emissions limits for every cubic metre of potable water delivered, therefore, the Project power supply includes a portion derived from a dedicated renewable energy source (discussed further under Section 4.3.5.2 below). A key MWI condition, on behalf of other electricity producers in Jordan, and a constraint on the type of renewable energy supply developed by the Project, is the need to comply with a 'zero feed-in' principle where power exports from the renewable energy facilities to the Jordanian national grid are prohibited.

Low carbon renewable energy capacity is growing in Jordan and is predicted to contribute 31% of Jordan's primary energy supply by 2030 (Salah., A., *et al*, 2023). The option of sourcing all power from renewable sources, however, was not studied in detail as the total AAWDCP power consumption is estimated at 2,606 GWh/y, which is not considered feasible to supply from a standalone renewable's development.

The Project power supply philosophy aligns with Jordan's National Water Strategy (MWI, 2023) which has several goals around increasing energy efficiency across the water sector and financial incentives to encourage this. The National Water Strategy notes that 'The water sector cannot achieve its own energy efficiency and renewable energy targets without the cooperation and support of an effective enabling environment from the energy sector'.

The electrical construction work required to connect the electricity grid with the AAWDCP facilities will be carried out by NEPCO, JEPCO and EDCO, all Jordanian Electricity Companies, under the supervision of the MWI. Construction of the transmission and distribution facilities will include new substations and transmission lines as described in Chapter 5 Section 5.3.5.

4.3.5.2 Renewable Concept

The MWI has set a cap of 3.2 kg $CO2_e$/ m^3 potable water for the Project which necessitates a renewable energy component to support the provision of electrical power to the desalination and water conveyance facilities instead of a complete reliance on the Jordanian national grid.

Renewable technologies relevant to Jordan include solar, wind, geothermal, biomass and hydropower however at the early concept design stage, the decision was taken to adopt solar photovoltaic (PV) power as the preferred renewable energy concept. The high solar irradiation levels (5.6 kWh/m^2/day – (Salah., A., *et al*, 2023)) in southern Jordan and associated energy yield, the availability of suitable areas of undeveloped, non-arable land and the lower CAPEX required for a large-scale installation make this option the most attractive. Other renewable supply options are less favourable due to the following:

- **Wind** - By their nature wind turbine developments require a larger footprint and offer a more intermittent power supply compared to solar PV. The Project requirement that self-generated RE shall not exceed at any time the total project consumption, i.e. no feed-in to the grid represents a constraint with respect to the supply profile. In addition, the locations in Jordan where preferrable conditions exist for wind power generation are at a significant distance from the AAWDC Project facilities (e.g. existing wind energy projects in Irbid, Tafilah and Ma'an regions). Hence significant works would be required to tie-in to any wind schemes in these locations. From an environmental perspective, potential sites proposed by MWI for Wind Projects are in a sensitive area for avifauna, along the Rift Valley-Red Sea flyway, and in or near several Important Bird Areas (IBAs)
- **Geothermal energy** – geothermal sources across Jordan have insufficiently high temperatures to support electricity generation (IRENA, 2021). The available geothermal resources are focused on the country's northeastern region and around the Dead Sea and tend to suit small scale applications
- **Biomass/ Bioenergy** – Jordan's arid climate and limited water resources restrict the ability to produce the feedstock necessary to develop biofuels (which contribute 0.1% of Jordan's total energy demand – Nahar Myyas, R., M., *et al,* 2023). Bioenergy resources in Jordan are mainly derived from municipal solid waste (MSW), with small scale Projects focused around Amman's waste management infrastructure
- **Hydropower** – lack of large water bodies such as major flowing rivers required to construct large scale hydro-electric power plant have limited hydropower investment in Jordan (Salah., A., *et al*, 2023). Whilst there is a small hydro-electric component (~6 MW) associated with the Aqaba Thermal Power Station (IFC, 2016), hydro-electric power generation typically requires significant elevation changes in order to support a major power plant which are not available in the Aqaba region

The solar PV concept was therefore selected with a solar PV plant adopted within the design to supply electricity to the Project desalination facilities and pump stations within the Aqaba Governate during daylight hours. The use of renewable energy power supply in combination with a Battery Energy Storage System (BESS) was not considered feasible from a land requirement, cost, and operational experience perspective. In addition to the large BESS capacity requirement, BESS introduces significant technical lifecycle risk on the long-term, as the effective lifetime of such equipment is not predictable. Replacement plans and costs would have a high degree of uncertainty, leading to higher water charge and more potential exposure to the grid.

4.3.5.3 Renewable Facilities Location Alternatives

During early concept design the feasibility of using land around the desalination plant to produce around 22 MW of solar power was examined, but this option was discounted due to lack of available sites. Three locations were subsequently considered for the siting of the Project renewable energy PV solar plant facilities as shown in Figure 4-11. These were selected from land areas under the Government of Jordan ownership that were considered technically suitable for the siting of the PV facilities and included:

- Alternative 1 Wadi Araba: To the north of the King Hussein International Airport, approximately 60km from the proposed desalination facilities. The site is owned by MWI/Jordan Valley Authority and had been allocated to the Project at the early concept stage. However, the site was associated with various challenges including security concerns due to its proximity to the international border with Palestine. The site was also located within the Qatar Nature Reserve
- Alternative 2 Al-Quweira: Approximately 60km from the proposed desalination facilities and approximately 5.5km from Al-Quweira village, located in the north of the Wadi Rum Protected Area buffer zone and to the north of the Hisma Basin–Rum Key Biodiversity Area (KBA). A number of other solar PV facilities are present within 2km of this location. The Al-Quweira site is located in a land use zone classified as "Medium Development: Limited to Non Consumptive Tourism"
- Alternative 3 Al-Mudawara: Located in the Maan Governate in a location immediately adjacent to the location of the initially planned Booster Pump Station 5 (BPS5) and approximately 90km from the proposed desalination facilities. Over the course of the design development the requirement for BPS5 was removed, and hence this location was significantly less attractive given the remoteness from the Project AGIs and the distance to the desalination facilities, and the option was eliminated from further consideration

Based on technical and economic feasibility as well as environmental and social aspects the Al-Quweira site (Alternative 2) was selected. Table 4-13 summarises the comparative assessment between the three locations[3].

Table 4-13: Summary of Comparative Assessment of Renewable Facility Location Alternatives

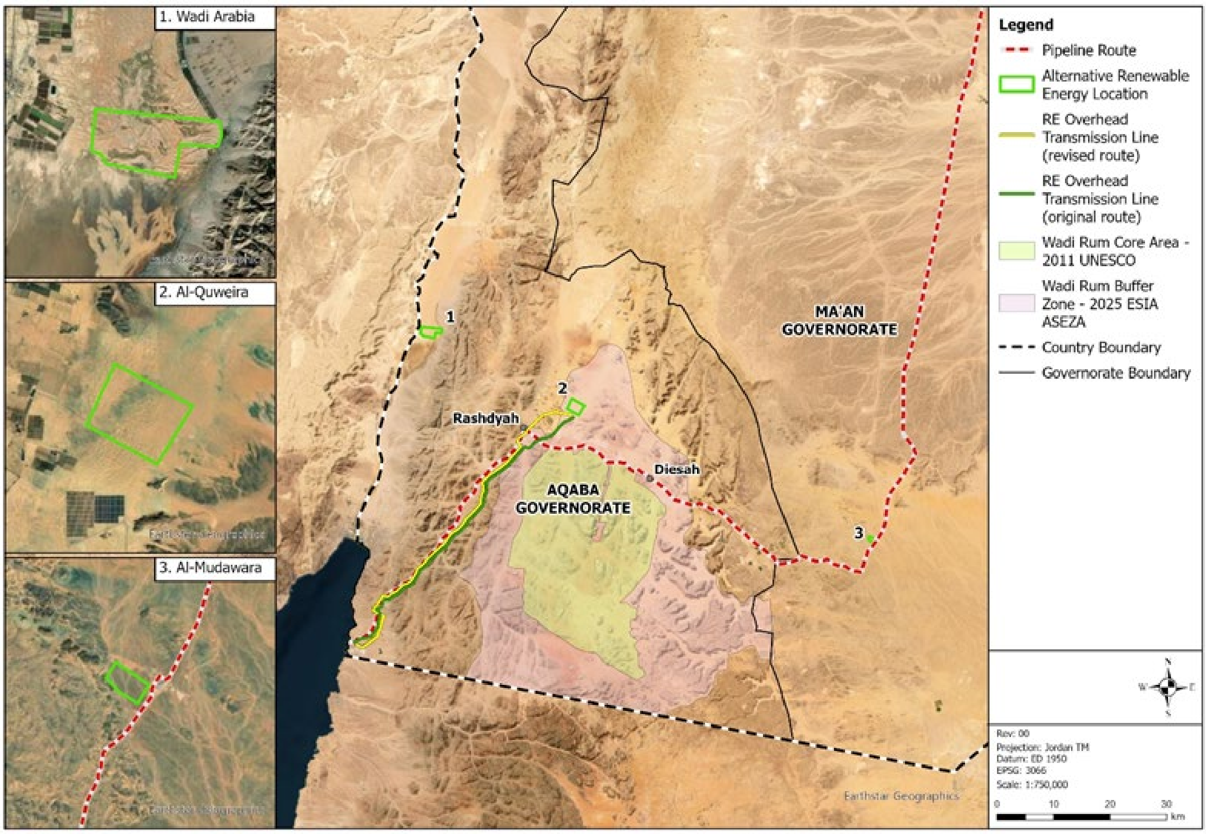
Assessment Criteria	Renewable Facility Location Alternatives		
	Alternative 1: Wadi Araba	Alternative 2: Al-Quweira	Alternative 3: Al-Mudawara
Technical Feasibility	🟠	🟡	N/A
Economic Feasibility	🟡	🟡	N/A
Environmental	🟠	🟡	N/A
Social	🟡	🟡	N/A

Key:

Neutral (no differentiators)	Barriers to progress	Weakness	Limitations	Strength	Not applicable to this decision
🟡	🔴	🟠	⚪	🟢	N/A

[3] Provisions around permitted development within the WRPA buffer zone are described in Chapter 2 of this ESIA

Figure 4-11: Alternative Renewable Energy Locations and OHTL Route Options



4.3.5.4 OHTL Routing Alternatives

The purpose of the OHTL is to provide a single power supply connection between the Project Solar PV Renewable Facility and the AAWDC Project desalination plant and Booster Pumping Stations. A standalone OHTL is necessary as transportation of the power load over the national grid is not permitted under the legal terms for the Project agreed with MWI. Adapting the existing electricity network to handle the additional load generated from the RE Plant (approximately 281MW AC) was considered to be more costly than constructing a dedicated transmission line. It introduces significant stability challenges, which require the deployment of complex and expensive mitigation technologies. Furthermore, reinforcement works was considered to require temporary interruption to the transmission network including the existing 132 kV Amman-Aqaba transmission line, potentially compromising the continuity of supply in the country. A standalone OHTL was therefore adopted into the design.

The OHTL for the Project is to be designed and built by NEPCO. The two routes that have been evaluated to date for the OHTL are shown in Figure 4-11. As reported within the 2025 Renewable Energy ESIA (Tetra Tech, 2025) NEPCO initially proposed an OHTL route that passed through the buffer zone of the Wadi Rum Protected Area. However, following engagement with ASEZA and the Wadi Rum Protected Area management, it was concluded that the most feasible option would be to reroute the OHTL to remain outside of the buffer zone. There are no other significant differentiators between the two routes as shown within Table 4-14. Both of the route options pass through the Rift Valley/Red Sea migratory flyway and partly overlaps with the Aqaba Mountains and Coast KBA/IBA. The potential for impacts to avifaunal is the same for both alternatives (impacts are further assessed within Chapter 9). The potential impacts of the OHTL on cultural heritage are also discussed within Chapter 9 with the requirements around buffer zones avoidance described in Chapter 2 Section 2.11.12.

Table 4-14: Summary of Comparative Assessment of OHTL Route Alternatives

Assessment Criteria	OHTL Route Alternatives	
	Alternative 1: Within Wadi Rum Buffer Zone	Alternative 2: Avoiding Wadi Rum Zone
Technical Feasibility	🟡	🟡
Economic Feasibility	🟡	🟡
Environmental	🟡	🟡
Social	🟠	🟡

Key:

Neutral (no differentiators)	Barriers to progress	Weakness	Limitations	Beneficial	Not applicable to this decision
🟡	🔴	🟠	⚪	🟢	N/A

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