In association with:-

Tractebel Engineering Suez & KEMA

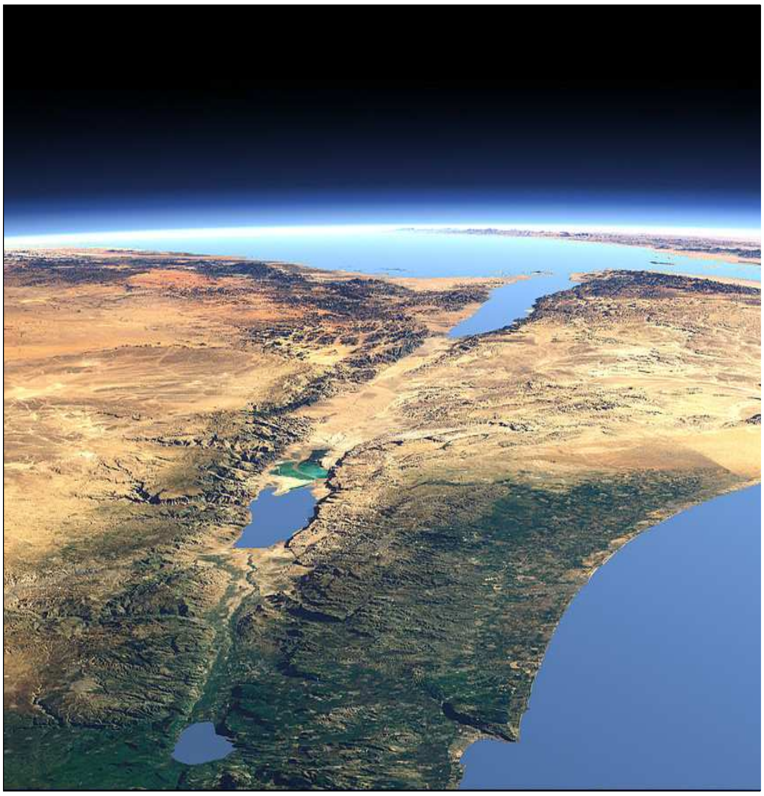
COYNE ET BELLIER
Bureau d'ingénieurs Conseils

RED SEA - DEAD SEA WATER CONVEYANCE STUDY PROGRAM

FEASIBILITY STUDY

Options Screening and Evaluation Report

Executive Summary



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1. Introduction

1.1 The Terms of Reference for the Red Sea Dead Sea Water Conveyance Feasibility Study require the Consultant to consider three scenarios as follows:-

No Project – make projections on the continued decline of the Dead Sea in the event there is no project and evaluate the environmental, social and economic impacts of this continued decline.

Base Case – examine options for transfer of Red Sea water to the Dead Sea to stabilise the Dead Sea at a target level and target year to be determined, prepare preliminary designs, prepare cost estimates and evaluate the environmental, social and economic impacts of the proposed solution.

Base Case Plus – as for the Base Case but also including provision of hydro power generation, desalination and transmission of potable water to Jordan, Israel and Palestinian Authority.

1.2 The Base Case and Base Case Plus scenarios potentially encompass an extremely wide range of options for the volumes of water to be transferred, the flow rates, the Dead Sea target year and level and hence the project configurations and design details.

1.3 The purpose of this Options Screening and Evaluation Report is to identify the range of options and to carry out a relatively coarse screening exercise to narrow down the range of options to a reasonable number for which the preliminary designs, costs and environmental, social and economic impacts will be evaluated in the subsequent Sub-Studies process.

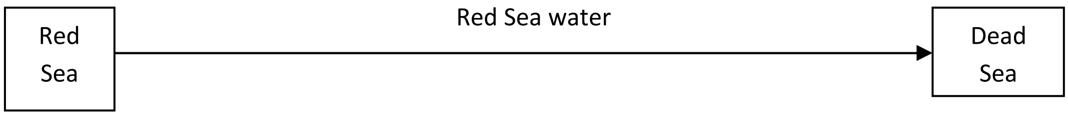
1.4 Whilst relative environmental impacts of the different options reviewed have been considered at a high level in the options screening and evaluation process no detailed environmental impact assessment has been carried out at this stage. An evaluation of the environmental and social impacts will be made during the next stage of the Study Program.

1.5 The “No Project” scenario is not addressed in this report.

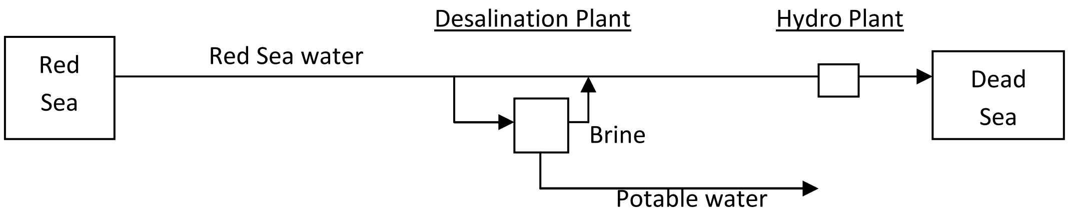
2. Red Sea Water Abstraction and Transfer Rates and Dead Sea Target Levels and Target Years

2.1 The basic flows associated with the various project options for the Base Case and Base Case Plus scenarios can be summarised as follows:-

2.1.1 Base Case



2.1.2 Base Case Plus (High level Desalination Plant)



2.1.3 Base Case Plus (Low Level Desalination Plant)

2.2 A water mass balance model has been developed for the Dead Sea incorporating the following parameters:-

Inflows

- Direct precipitation
- Surface run off including flash floods and irrigation return flows
- Return flow from chemical industry
- Ground water depletion
- Reject brine from RSDSP
- Red sea water from RSDSP

Outflows

- Evaporation
- Chemical industry abstractions
- Ground water replenishment

2.3 The most critical and most complex parameters in the establishment of the Dead Sea water mass balance model, for which no direct measurements are available, are evaporation and ground water depletion / replenishment. These have been dealt with as follows:-

2.3.1 Evaporation – an energy mass balance sub-module has been incorporated into the water mass balance model which simulates both meteorological and hyper-saline thermo-physical conditions to determine evaporation on the basis of an energy mass balance.

2.3.2 Ground Water – the model was initially run using historic records of the Dead Sea level with ground water depletion as the residual unknown. Ground water depletion equations were then derived and the model was re-run incorporating the ground water depletion equations and with Dead Sea level as the residual unknown to check that it accurately replicated historic Dead Sea water levels.

2.4 The water mass balance model has been checked and calibrated by running the model using historic data to predict the Dead Sea levels for the 10 year period from the date of the Pre Feasibility study up to the present time. The results of this model run show a good correlation with the known actual decline in the level of the Dead Sea during this time.

2.5 A chloride balance has been carried out by comparing the net inflow and outflow of chlorides in the elements of the water balance with the known changes in the concentration of chloride in the Dead Sea water to provide a further "order of magnitude" check on the water mass balance model.

2.6 Based on the provisions of the Terms of Reference a single desalination plant with an ultimate design capacity in the order of 800 Mm^3/year is considered in the Base Case Plus scenario.

2.7 The initial demand for desalinated water from the project at start up and the build up of this demand with time up to the ultimate capacity of the desalination plant are required for the following purposes:-

- To determine the initial capacity for the first phase of the desalination plant.
- To determine the timing and sizing of the subsequent phased developments of the desalination plant.
- To determine the volume of water discharged to the Dead Sea over time in the Base case Plus scenario and the changes in relative quantities of Red Sea water and reject brine comprising this discharge.
- To establish the target year at which any given target level will be reached.

2.8 Detailed water demand projections through to year 2070 have been developed for Jordan using data provided by the relevant Jordanian authorities and an assessment has been made on how much of this demand will be served from the Red Sea - Dead Sea Project.

2.9 Analysis shows that, compared to alternative options, it will not be economically viable to pump water to high elevation demand centres in Israel and the Palestinian Authority from the Red Sea Dead Sea Project. Assumptions have therefore been made that these high elevation demand centres in Israel and Palestinian Authority will be provided with water from already planned desalination plants on the Mediterranean coast. A provision has been made in the assessment of demand for potable water from the project to supply low elevation demand centres in Israel and Palestinian Authority in the Jordan Valley, the Arava Valley and adjacent to the Dead Sea.

2.10 The final allocation between the Beneficiary Parties of the total potable water available from the Red Sea – Dead Sea Project has not yet been determined. In the meantime, in order to progress the Feasibility study, it is proposed to adopt the following water demand projections for the project. This provides scope to increase the initial allocations to the Palestinian Authority and Israel as and when the beneficiary Parties agree the allocation of the total available potable water.

Beneficiary Party	Potable Water Supplied from the Project Million m^3/year				
	2020	2030	2040	2050	2060
Jordan	220				
Israel	60				
Palestinian Authority	30				
Total	**310**	**410**	**540**	**670**	**850**

2.11 A range of target levels from -433m (the projected Dead Sea water level at the date when the project will be commissioned) to -395m (the Dead Sea water level prevailing around 1960 prior to the onset of the current dramatic decline) has been examined for both the Base Case and Base Plus scenarios. It is evident that a target level above this upper elevation would have significant impacts on existing infrastructure. It should also be noted that any target level higher than -406m creates substantial technical and commercial issues for the chemical abstraction industry.

2.12 A range of Red Sea water abstraction and transfer rates from 1,000 Mm^3/year (the minimum flow required under the Base Case to achieve the lowest target level considered) up to 2,000 Mm^3/year (the maximum flow set out in the ToR for the Base Case Plus scenario) has been considered.

2.13 In order to stabilise the Dead Sea at a target level in the Base Case scenario it is necessary to reduce the rate of abstraction and transfer from the Red Sea when the Dead Sea target level is reached for all Red Sea water abstraction and transfer rates above 1,000 Mm^3/year. This effectively means that there is a significant redundancy in the capacity of the Red Sea water intake, pumping and conveyance system after the target level has been achieved in most Base Case project configurations.

2.14 Using the Dead Sea water mass balance model and the water demand projections the dates (target year) at which the range of target levels will be achieved for each of the Red Sea water abstraction and transfer rates considered have been determined.

2.15 The following selection criteria are proposed to establish the combination of Red Sea water abstraction rate and Dead Sea target level and target year that will be evaluated in the sub-study phase of the program:-

- *Stabilisation of the Dead Sea at the target level should be achieved within 25 years of commissioning the project in both the Base Case and Base Case Plus scenarios.*
- *In the Base Case Scenario, for the selected target level, the lowest Red Sea water abstraction and transfer rate that will achieve an acceptable target year will be the preferred option.*
- *In the Base Case Plus scenario, for any given Red Sea water abstraction and transfer rate, there are two competing criteria. It is possible to maximise the ultimate capacity of the desalination plant by constraining the target level or it is*

possible to maximise the target level at the expense of a reduced ultimate capacity of the desalination plant. The preferred option will be that which maximises the ultimate capacity of the desalination plant.

2.16 Based on the above selection criteria the following cases have been considered in this Options Screening and Evaluation process:-

Selected Base Case Scenarios

Case	System Capacity	Target Level	Target Year	Redundancy Capacity After target Level is Reached
BA433	1,000 million m^3/year	-429m	2039	12%
BD415	1,500 million m^3/year	-415m	2042	41%
BG403	2,000 million m^3/year	-403m	2044	48%

Selected Base Case Plus Scenario

Case	Red Sea Abstraction	Target Level	Target Year	Ultimate Desalination Capacity
PG417	2,000 million m^3/year	-412m	2038	875 million m^3/year

3. Overview of System Configuration Options Considered

3.1 There are a number of alternative potential locations and configurations for each of the components making up the overall Red Sea Dead Sea Project. This in turn leads to a very wide range of permutations that are possible for the overall system configuration. The variables, options and permutations considered are summarised as follows:-

Range of Project Configuration Options Considered

System Component	Variable	Options
Red Sea Intake	Intake Location	Three sites on north coast, east coast and west coast of Gulf of Aqaba / Eilat.
	Intake Capacity	Three flows of 1,000, 1,500 and 2,000 Mm^3/year.
	Intake Type	Three generic design types: open channel, enclosed lagoon and submerged offshore intake.
	Intake Channel	Various combinations of canal, buried box culvert and pipe.
Pumping Station	Location	Two possible locations associated with the north coast intake. One location associated with the east coast intake location.
	Capacity	Three pumping capacities corresponding to the three intake capacities.
	Pumping Head	Two pumping heads corresponding to the conveyance nominal elevations of +130m and +220m
	Riser Mains	Two alternative riser main routes from the northern pump station and a single route from the eastern location. Alternative configurations in tunnel or pipeline.
Water Conveyance	Elevation	A range of three elevations (00m, +130m and +220m)in tunnel and two elevations (+220m and +280m) in pipeline.
	Alignment	A total of four different tunnel alignment routes and three different pipeline alignment routes.
	Capacity	Three water conveyance capacities corresponding to the three Red Sea intake capacities.
	Configurations	A range fifteen configurations comprising various combinations of tunnel, open canal and pipeline encompassing each alignment option and each elevation.

System Component	Variable	Options
Desalination Plant	Location	Two possible high elevation sites and one possible low elevation site adjacent to the hydro facility.
	Capacity	A single ultimate design capacity of circa 800 Mm3/year of potable water with staged development to match potable water demand growth.
	Pre-treatment	Membrane filtration Media filtration Dissolved air flotation
	Process Tech.	Multi stage Flash (MSF) Multi Effect Distillation (MED) Seawater Reverse Osmosis (SWRO).
	Post treatment	Re-mineralisation Disinfection
Hydro Facility	Location	One single location to optimise the available head.
	Head	Three heads corresponding to the nominal conveyance elevations.
	Flow	Four flow rates – two for each desalination plant configuration
	Turbines	Francis and Pelton types
Dead Sea Discharge Works	Discharge Alignment	Four alignments: At the south end of the dead sea via the Truce Canal; northward up the west coast; northwards up the east coast and by marine pipeline within the body of the Dead Sea.
	Discharge Location	A number of locations are considered at the south end of the Dead Sea and northwards along the east shoreline.
	Discharge type	To be determined later.
Dead Sea Restitution	Target Level	A range from -433m (the level prevailing when the project is expected to be commissioned) to -395m (the level prevailing in 1960 before the current dramatic decline).
	Target Year	A range from year 2020 (only possible for a target level of -433m) to year 2050.
Potable Water Transmission	Jordan	A single terminal point in the Greater Amman area. Two alternative pipeline routes from the desalination plant to a single terminal location in Amman.
	Israel	A single pipeline route and a single size of pipe with a capacity of 60 Mm3/year to serve low elevation demand centres in the Arava Valley and adjacent to the Dead Sea.
	Palestinian Authority	Three alternative pipeline routes from the desalination to low elevation demand centres in the Jordan Valley. Initial capacity 30 Mm3/year with facility for further expansion.

4. Red Sea Intake Works

4.1 Three generic types of intake works have been considered as follows:-

- A submerged offshore intake
- A closed lagoon formed by breakwater with embedded pipes
- An open channel intake

4.2 A subjective relative rating of the benefits and environmental impacts of each type of intake has been carried out for each intake location considered and for the full range of intake flow rates considered and it is concluded that a submerged offshore intake is the preferred solution in all cases for a combination of construction, environmental and operational reasons.

4.3 Three intake locations have been identified and investigated as follows:-

- On the Israeli west coast of the Gulf of Aqaba / Eilat approximately 4km south of Eilat.
- On the Jordanian north coast of the Gulf of Aqaba / Eilat between the Jordanian / Israeli border and the boundary of the Ayla Project development.
- On the Jordanian east coast of the Gulf of Aqaba / Eilat approximately 5.5km south of Aqaba.

4.4 Due to lack of availability suitable sites a west coast intake would have to be located between two active oil terminals which in turn are adjacent to resort hotels and marine nature parks. It has been determined that this location would result in the greatest social and environmental impact and would also carry the risk of contamination and pollution arising from the oil terminals. A further disadvantage of this site is that the associated conveyance route would cross the border at some point south of Aqaba / Eilat that would undoubtedly give rise to administrative issues during construction.

4.5 The northern intake site would result in the shortest conveyance alignment and is the location preferred by the Pre Feasibility Study. However, there are major challenges associated with this site as follows;-

1) the site is bounded to the west by the Jordan / Israel border, to the east by the Ayla Development and to the north by Aqaba Airport. These constraints result in a very restricted site and these restrictions, combined with the site topography and geology, will necessitate complex, difficult and costly construction techniques.
2) The northern intake site also straddles the discharge route of major flash flood discharges from Wadi Yutum which are estimated to be in the order of 1,500 m^3/second for a 1:100 year flood event. Given the site constraints referred to in 4.5 above it will be almost impossible to re-route these flood flows away from the works or to design adequate flood protection defences for any permanent surface facilities.
3) Perhaps most significantly the northern intake site is extremely close to a branch of the Arava Main Transform fault which is an active seimic feature with an estimated annual average slip rate of 1mm/year that poses a very real threat to the long term integrity of the works.

4.6 The eastern intake location is on the site of an existing small thermal power station which is due to be decommissioned. The selection of this site would result in an increase of 5km in the length of the conveyance compared to the northern intake location but has the following benefits in comparison to the northern location:-

- Site is of adequate size and is already developed.
- The shore shelves relatively steeply allowing an offshore submerged discharge to be constructed at adequate depth close to the shoreline.
- There are no physical, topographical, geological or hydrological constraints similar to those described for the northern site.
- It will be possible to adopt conventional designs and construction methodologies with minimum impact on the surrounding developments.

4.7 From a technical perspective the eastern intake is the preferred location for a combination of risk, design, construction, operational and social / environmental impact reasons. The economic comparison of alternative intake sites in terms of the comparative NPV for the different project configurations considered is summarised in paragraph 13 below.

5. Pumping Station and Pumping Configuration

5.1 Two alternative pumping station locations have been considered associated with the northern intake site. Issues of flood hydrology combined with the difficult terrain that would have to be traversed by the riser mains renders the location PS2, which is closest to the intake, unsuitable. Location PS1, some twelve km inland, and sited to the north west of Aqaba airport, is therefore the preferred option for a pump station associated with the northern intake.

5.2 As noted above with respect to the intake works the northern intake and its associated works are situated in very close proximity to the line of the Araba Fault. This is a major and active fault with an estimated average slip rate of around 1mm/year. Seismic risk analysis shows that there is a significant risk of substantial, or even catastrophic, failure of any works on this location within the projected operating life time of the project.

5.3 A single pumping station location has been considered in association with the eastern intake location. This pump station is located very close to the shoreline which results in a short and simple intake channel when compared to the northern site.

5.4 The terrain and geology at the eastern intake are more favourable than the corresponding conditions at the northern intake which results in less excavation being required with easier and less costly construction for a pump station at this location.

5.5 As can be seen from the table below the annual energy requirements for a pumping station at the eastern intake is significantly less than that for the northern intake for all pumping heads and flow rates considered. This difference is due to the respective lengths, types and configurations of the associated riser mains.

Conveyance Elevation	Flow Rate Mm3/year	North Intake Pump Station	East Intake Pump Station
130m	2,000	971 GWh/Year	905 GWh/Year
130m	1,500	729 GWh/Year	679 GWh/Year
130m	1,000	500 GWh/Year	453 GWh/Year
220m	2,000	*1,558 GWh/Year or 1,566 GWh/Year	1,483 GWh/Year
220m	1,500	*1,170 GWh/Year or 1,176 GWh/Year	1,112 GWh/Year
220m	1,000	*795 GWh/Year or 799 GWh/Year	741GWh/Year

*Varies according to conveyance alignment

5.6 Based on technical power demand considerations the east intake pump station is the preferred pump station location. The economic comparison of alternative pump station locations in terms of the comparative NPV for the different project configurations considered is summarised in paragraph 13 below.

6. Water Conveyance System

6.1 A wide range of potential water conveyance configurations in various combinations of tunnel, pipeline and canal have been considered. In total the following fifteen alternative water conveyance configurations have been reviewed and evaluated.

Case	High Point Elevation	Alignment Route	Intake Site	Configuration
0.1	00m	1	East	All tunnel
0.2	00m	2	North	All tunnel
130.1	130m	1	East	Tunnel / Canal
130.2	130m	2	North	Tunnel / Canal
220.1	220m	1	East	Tunnel / Canal
220.2	220m	2	North	Tunnel / Canal
220.3	220m	3	North	Tunnel / Canal
220.4	220m	4	North	Tunnel / Canal
220.1 / -100	220m	1	East	Tunnel / Canal / Pipeline/ 2HPP
220.2 / -100	220m	2	North	Tunnel / Canal / Pipeline / 2HPP
220.3 / -100	220m	3	North	Tunnel / Canal / Pipeline / 2HPP
220.4 / -100	220m	4	North	Tunnel / Canal / Pipeline / 2HPP
P1	280m	T1	North	All pipeline
P2	280m	T2	North	All pipeline
P3	220m	T3	North	All pipeline

6.2 These alternative configurations have been selected on the basis of two principal characteristics as follows:-

Elevation

The elevation of the water conveyance is significant for a number of reasons the principle being:-

- In simplistic terms the lower the elevation the greater the proportion of the conveyance configuration that will be in tunnel and conversely the higher the elevation the greater the proportion in canal or pipeline. This has a significant bearing on constructability, construction schedule, capital cost, maintainability and socio-environmental impacts.
- The elevation of the conveyance has a very significant impact on the pumping requirements, on the hydrostatic head available to generate hydro power and on the energy available to support the desalination process. Thus it has a significant bearing on both capital and operating costs.
- It is necessary to determine the elevation that provides the most favourable combination of construction and life cycle operating costs.

Alignment

Again in simplistic terms the shorter the alignment the lower the overall capital cost. However, there are a wide range of parameters that have been considered and that have a bearing on the selection of the actual alignments. These include:-

- Existing infrastructure and developments
- Topography
- Geology, Hydrogeology and Seismicity
- Presence of Nature reserves, archaeological sites and the like.

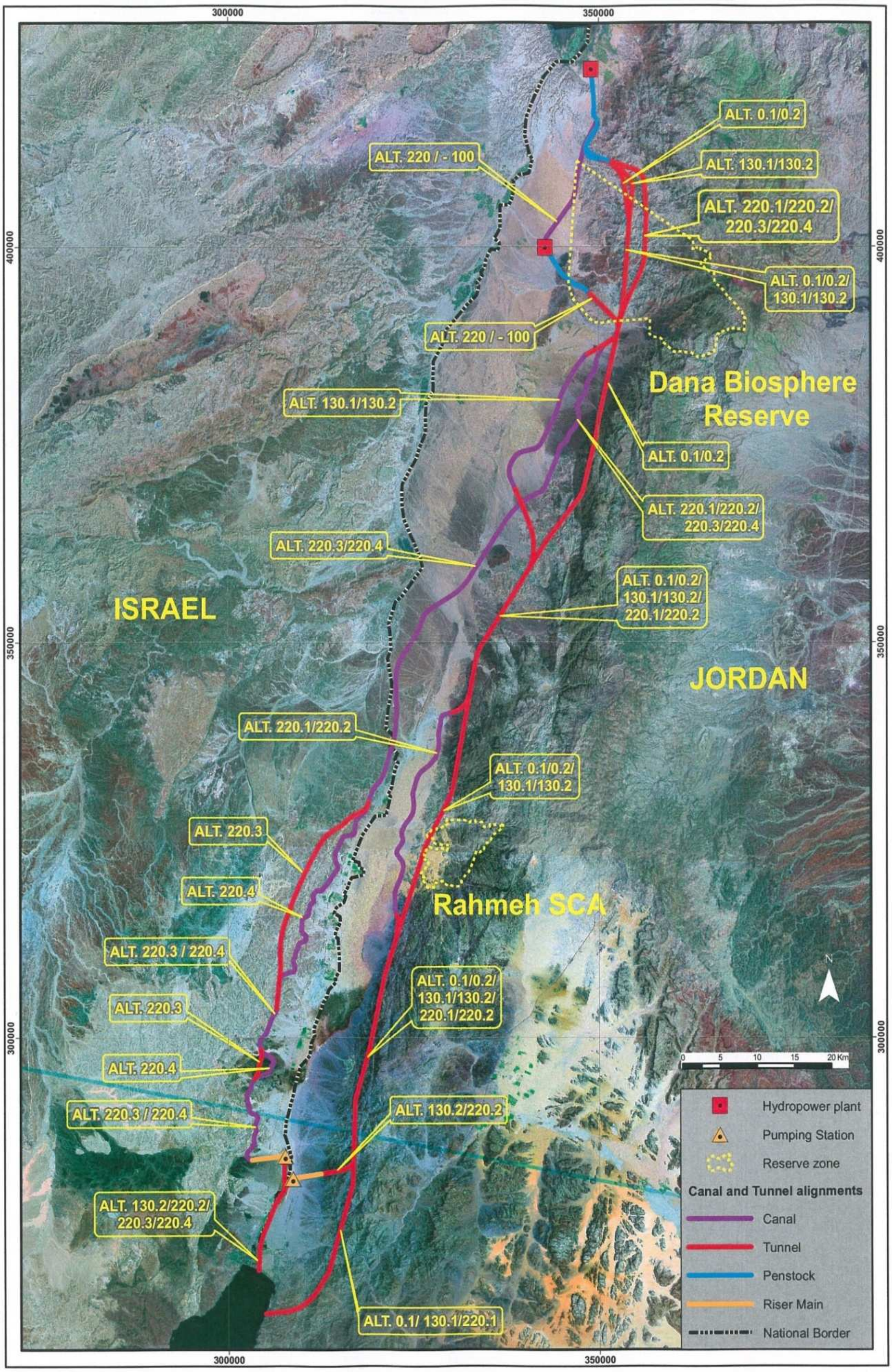
These issues have all had a significant bearing on the selection of the alignment routes considered which are indicated in the plan set out on the following page. However the overwhelmingly dominant consideration that has determined the alignment of each option is seismicity and the presence of major active fault zones.

6.3 It is an established fact that the project lies within an active seismic zone with a high risk that a major seismic event will take place within the operating life of the project. Faulting and seismicity are therefore the most significant factors in determining the technical feasibility of any configuration and alignment considered. Two major faults are recognised – the Arava Main Transform fault and the Aqaba–Gharandal fault together with a numerous other lesser associated faults.

- The Arava Main Transform fault is an active fault with an average slip rate estimated to be in the order of 1mm/year which runs through the northern intake site and very close to the possible conveyance alignments associated with the northern intake for some 16km inland from the Gulf of Aqaba / Eilat.
- The Aqaba-Gharandal fault is a major and active strike-slip fault with an estimated lateral slip rate of 4mm/year. This fault is present throughout the length of the Wadi Araba / Arava Valley and is particularly close to the possible water conveyance alignments in the north of the Wadi Araba / Arava Valley.

As noted in paragraph 4.5(3) above the presence of the Arava Main Transform fault is a very significant concern mitigating against the selection of the northern intake and it is also a major concern with regard to the long term integrity of any conveyance alignment from the northern intake. The Aqaba-Gharandal fault has a major bearing on the alignments of all conveyance options considered. The alignments have been selected to minimise the number of fault crossings, to cross the fault at right angles where crossings cannot be avoided and to keep as much distances as is practicable from the fault when running parallel to it. It is also relevant that circular tunnels excavated in rock are recognised to have the best earthquake resistance of all man-made structures, in that in a seismic event they tend to follow the rock mass wave like deformation. The consequences of any major fault movements are therefore likely to be much more serious with respect to a water conveyance by canal or pipeline than for a tunnel.

6.4 The other major technical concern with respect to the selection of the water conveyance configuration to be adopted is the risk of leakage of saline water contaminating the groundwater aquifer. This is not considered to be an issue for the zero elevation tunnel alignment option as this alignment is almost exclusively in crystalline rock beneath the main aquifer. However the high level tunnel/canal and pipeline alignments are either within or above the main aquifers and thus any leakage could potentially contaminate the aquifer(s). Reliable waterproofing systems are available for both tunnels and canals, designs can be developed to capture and contain leakage within the structures and sophisticated leak detection and control systems can be provided. These measures will provide adequate mitigation for any small and medium scale leakage. Provisions can also be made to detect and shut down the system whilst minimising total water loss in event of a major or catastrophic failure. However, as noted above this latter risk is greater for canals and pipelines than it is for tunnels.



Plan Showing the Tunnel / Canal Water conveyance Configurations Considered.

6.5. An initial technical evaluation of the fifteen alternative configurations tabulated above results in the following conclusions:-

- Option 220.4 has significant disadvantages compared to Option 220.3 and no advantages and therefore Option 200.4 has not been considered further.
- Due to the need to avoid the Dana reserve a 10km length of all the 220/-100 configurations runs parallel to, and very close to the Aqaba-Gharandal fault. This close proximity to such a major fault is considered to present an unacceptable risk to the long term integrity of the work and this suite of alternatives has not been considered further.
- The evaluation has demonstrated that the three all pipeline options have similar construction costs but that Option T1 results in the most favourable net energy balance and has significant benefits and few disadvantages when compared to the other all pipeline options. Hence Options T2 and T3 have also been discarded at this stage.

6.6 A total of six water conveyance configurations have been carried forward to the economic analysis process that is summarised in Section 13 of this Executive Summary and is presented in full detail in Section 12 of the Main Report.

6.7 Of the six water conveyance configurations carried forward for economic evaluation the technical evaluation shows that there are significant technical advantages for those configurations at elevation 00. A preliminary appraisal of the social and economic impacts also suggests that configurations at this elevation will have the least social and environmental impacts.

7. Desalination Plant

7.1 The desalination plant with a capacity of circa 800 Mm3/year is considered in accordance with the requirements of the Terms of Reference. It should be noted that this will be, by a substantial margin, the largest desalination plant in the world.

7.2 Conventional and emerging desalination technologies have been reviewed and it is considered that due to the size of the plant and the system configuration only the Seawater Reverse Osmosis (SWRO)process would be appropriate in this case.

7.3 Three basic configurations have been considered for the desalination process as follows:-

(1) A high level desalination plant with reject brine led back into the penstock feeding the hydro power facility. This configuration mimimises the pumping head for delivery of potable water to the main demand centres. However the downside is that it also greatly reduces the available hydrostatic head to drive the reverse osmosis desalination process.

(2) A low level desalination plant operating in parallel with the hydro facility. This allows the maximum hydrostatic head to be utilised to drive the reverse osmosis process and minimises the energy requirements for the desalination process. However this configuration results in a reduced flow of water available for hydro power generation.

(3) A low level desalination plant operating in series with, and downstream of the hydro power facility. This configuration maximises the water available for generation of hydro power but means that there is no hydrostatic pressure to assist the reverse osmosis process.

An initial appraisal shows that both construction costs and the net energy balance of configuration three is unfavourable compared to the other two possible configurations for all combinations of water flow rates and conveyance elevations considered. For that reason, the configuration 3 has not been considered further.

7.4 It is estimate that a desalination plant of this size including pre and post treatment facilities will require a plot of some 50 ha in area. Three locations have been identified where a suitable platform of this size could be developed:-

(1) A low level site adjacent to the site identified for the hydro power facility. This is located at the southern end of the Dead Sea immediately to the south of the Arab Potash Company's solar evaporation ponds close to the Jordanian village of Fifa.

(2) Two high level sites, one about 8km south east of the hydro power facility and one about 13km south of the hydro power facility.

7.5 Pre-treatment options have been reviewed. Final decisions on the pre-treatment will be determined at the next stage of the Study Program but it seems likely that two stage gravity media filtration will be adopted with the possible addition of dissolved air flotation.

7.6 Post-treatment options have been reviewed. Final decisions on the post-treatment will also be determined at the next stage of the Study Program. It is likely that the final post-treatment process will consist of re-mineralisation using carbonate and disinfection by chlorine dosage.

8. Hydro Power Facility

8.1 A single location has been identified for the hydro power facility with the aim of optimising the head available for the generation of power. The selected site is immediately to the south of the Arab Potash Company's solar evaporation ponds and close to the Jordanian village of Fifa.

8.2 The water flow rate available for the generation of hydro power will vary dependent on which of the two desalination plant configurations is adopted. In both cases the available flow rate will also decrease with time as the output of the desalination plant increases to match growing demand for potable water. It has been determined that for all the combinations of flow rates and heads considered the optimum solution will be to install the maximum generating capacity consistent with the flow rates available for power generation in the early years of operation.

8.3 Details of the hydro power facility characteristics and layout are not necessary for the options screening and evaluation process and have not been determined at this stage of the Study Program. However it is likely that the final figuration will adopt pelton wheel turbines in order to minimise hydraulic surge and transient effects.

8.4 The effects of the net project power balance for the various project configurations on the overall project NPV for each project configuration considered is summarised in paragraph 13 below and is presented in detail in Section 12 of the main report.

9 Potable Water Transmission to Jordan

9.1 Substantial data has been obtained with respect to water resources, water usage and water master planning in Jordan. Using the data obtained low, medium and high scenario water demand and water deficit projections have been developed for the whole of Jordan, for the North Eastern area of Jordan (Amman, Zarqa, Madaba, Karak, Balqa, Irbid, Marfaq, Jarash and Ajlun) and for the Greater Amman area (Amman, Zarqa, Madaba and Karak). The medium scenario projections of water deficits are as follows:-

Projected Water Deficits in Jordan (Medium Scenario)

Region	Million m^3/Year				
	2020	2030	2040	2050	2060
Jordan	611	642	643	687	735
North East Jordan	560	591	593	637	686
Greater Amman	176	247	294	370	446

9.2 Having conveyed Red Sea water to a desalination plant at the south end of the Dead Sea it will not then be economical to supply desalinated water from the Red Sea – Dead Sea project to regions in the south and east of Jordan. In any case a large proportion of the projected water deficits occur in the Greater Amman area and the north east of Jordan.

9.3 Furthermore a substantial portion of the water deficits in Jordan as a whole and in the north east region are attributable to agricultural demand. It is unlikely that the international funding community will finance a project to utilise desalinated water directly for agricultural purposes. However, the water deficits for the Greater Amman area can be largely attributed to growth in domestic and industrial demand.

9.4 It is proposed that potable water from the project will be used to address the total projected water deficit for the Greater Amman area up to the year 2060 plus a further smaller amount to augment domestic supply in adjacent governorates as follows:-

Potable Water Supply to Jordan	Million m^3/year				
	2020	2030	2040	2050	2060
Total Greater Amman Water Deficit	176	247	294	370	446
Additional Domestic Supply to Neighbouring Governorates	50	61	75	92	113
Total Potable Water Supply to Jordan	226	308	369	462	559

9.5 Three alternative water transmission pipeline routes from the desalination plant, passing through Karak and Madaba governates to a single terminal reservoir on the outskirts of Amman have been considered. In all cases the pipeline routes traverse steep and rugged terrain as they rise up the escarpment from the rift valley to the highland plains to the south of Amman.

9.6 The main difference between the three identified alignments is the route up the eastern escarpment of the Wadi Araba / Arava valley. Once the plateau has been reached all three alignments follow a similar route to Amman roughly parallel to the Desert Highway. The main criteria for selection of the preferred water transmission pipeline alignment is the steepness of the terrain and the consequent difficulties of construction and the respective energy requirements for pumping. Based on these criteria the preferred pipeline route is the most southerly route up the escarpment although it is neither the shortest route nor that with the lowest energy requirements for pumping. A more detailed analysis including an economic evaluation to verify the optimum route will be carried out in the next stage of the Study Program.

10 Potable Water Transmission to Israel

10.1 Only very limited data has been obtain regarding water demands, water supply, water master planning and cost of water in Israel. It has not been possible to make any realistic assessment of water demand projections.

10.2 All of the main domestic and industrial water demand centres in Israel are in the western and central areas of the country, at or above sea level. The long run marginal cost of supplying these demand centres from desalinations plants already planned for development on the Mediterranean coast will always be less than the cost of water pumped up from the Red Sea - Dead Sea Project desalination plant which will be at an elevation of around either -350m or -150m.

10.3 It has been advised on a number of occasions during the Study Program to date that Israel will only take a relatively small quantity of potable water from the Red Sea-Dead Sea Project to service demand in the vicinity of the Dead Sea and the northern Arava Valley. A figure of 60 million m3/year has been quoted.

10.4 For purposes of the Feasibility Study a single transmission pipeline with a capacity of 60 million m^3/year will be considered linking the Red Sea-Dead Sea Project desalination plant to demand centres along the western shore of the Dead Sea and the northern Arava valley from Ein Gedi in the north to Ein Khatseva in the south with a spur line up to the municipality of Arad at an elevation of +500m close to the southern end of the Dead sea. ***This represents a very preliminary proposition and will be subject to review and change as and when the Beneficiary Parties determine the sharing of the potable water output from the project.***

11 Potable Water Transmission to Palestinian Authority

11.1 Some data has been obtained on water resources in Palestinian Authority but it has not been possible to obtain any information on water demands or water master planning.

11.2 At this stage in the study program there has been no consideration as to the final division of the ultimate potable water capacity of the project between the Beneficiary Parties and hence the ultimate volume of potable water available for transmission to Palestinian Authority is not yet known.

11.3 Similarly to the discussion with regard to water supply to Israel in Section 10 above, the long run marginal cost of supplying high elevation demand centres from desalinations plants already planned for development on the Mediterranean coast will always be less than the cost of water pumped up from the Red-Sea Dead Sea Project desalination plant which will be at an elevation of around either -350m or -150m.

11.4 Jericho and other communities in the Jordan Valley constitute a significant area of water demand at low elevations within the Palestinian Authority and it would be reasonable to supply these areas with desalinated water from the Red Sea – Dead Sea Project.

11.5 The current population on the West Bank living at elevations of 0m and below is estimated to be in the order of 50,000 persons. Adopting a continued population growth rate of 3.5% per annum and an ultimate per capita consumption of 130 litres/person/day the water demand in 2020 would be 3.6 million m^3/year growing to some 10 million m^3/year by 2060.

11.6 As the peace process develops it is anticipated that the natural population growth will be enhanced by returning refugees and that the Jordan Valley area of the West Bank will become a focus for development.

11.7 For the purposes of the Feasibility Study a single potable water transmission pipeline from the Red Sea – Dead Sea Project to Jericho with a capacity of 30 million m3/year will be adopted with the provisions for significant expansion. ***This represents a very preliminary proposition and will be subject to review and change as and when the Beneficiary Parties determine the sharing of the potable water output from the project.***

12 Discharge to the Dead Sea

12.1 There are potentially three discrete water streams to be discharged to the Dead Sea as follows:-

- Reject brine from the desalination plant
- Discharge from the hydro facility tail race
- Red Sea water by-passing the desalination plant and hydro facility

All of these streams will be brought together immediately downstream of the desalination plant and hydro facility and transferred to the Dead Sea by means of a single discharge conveyance.

12.2 The Dead Sea discharge conveyance will be designed with the capacity to convey the total Red Sea water abstraction and transfer flow to the Dead Sea in the event that it is required to shut down the desalination plant operations suddenly and unexpectedly.

12.3 The least cost solution will be to discharge water to the southern end of the Dead Sea via the existing Truce Canal as was envisaged in the Pre Feasibility Study. However there are concerns that this may have a serious impact on the operations of the chemical industry. Preliminary results suggest that the mixing and layering dynamics will be confined to a zone no more than 50 metres deep on the surface of the Dead Sea. If this is correct it may be possible for the chemical industry to avoid any impact to their operations by changing their intake arrangement to draw water from below this level. None the less, the project discharge will have to be located sufficiently distant from the chemical industry intake to avoid a short circuit in the flow developing whereby the project discharge water is sucked directly into the chemical industry intakes. A project discharge into the bay to the east of the Lissan Peninsula may provide adequate separation and this location has the added advantage of being remote from the tourist developments on both sides of the Dead sea. The alternative would be to move the discharge to the northern end of the Dead Sea away from the chemical works.

12.4 The alternative option of moving the discharge works to the north of the Dead Sea away from the chemical industry operations is technically difficult and is probably prohibitively expensive.

12.5 The dynamics and impacts of mixing Red Sea water and Dead Sea water will only be understood and evaluated after oceanographic and water mixing studies together with development of dynamic hydro-chemical modelling of the Dead Sea have been completed by a specialised institution under the "Additional Studies" program. The results of this work will not be known until the second half of 2010. Conclusions cannot be drawn and recommendations cannot be made on the preferred location or type of discharge or on the environmental impacts of mixing Red Sea and Dead Sea water until these studies are completed.

12.6 In order to progress the Feasibility Study in the absence of the results of the specialised study on this subject a discharge alignment via the Truce Canal and thence across the Lissan Peninsula to a discharge to the bay on the eastern side of the peninsula will be adopted pending the results of the "Additional Studies".

13 Cost Analysis

13.1 A set of aggregate unit rates for the main construction activities has been developed using actual rates from other similar types of project and locations. The rates have been converted to US $ and have been updated to December 2008 prices using appropriate indices and adjustment factors.

13.2 A set of unit rates for tunnel excavation and lining have been developed in a similar manner based on actual costs of tunnels recently constructed in similar rock types and geological conditions. Adjustments and additions have been made to reflect the conditions that are expected to be encountered in the execution of the Red Sea - Dead Sea Project.

13.3 The project configurations to be evaluated present a very wide range of possible water discharge rates and heads available for generation of hydro electricity. A suite of graphs have been developed showing the unit cost per kW of installed capacity for a range of discharges and a range of heads.

13.4 Using the unit rates developed as described above the capital cost of constructing the various project configurations carried forward to the economic comparison process have been determined.

13.5 Net Present Values have been determined for the selected configurations using a discount rate of 10%, a construction period of six years, lifecycle operating costs over a period of 50 years and energy costs of US $60 per MWh. The sensitivity of NPV to energy costs used has also been tested over a range of energy costs.

13.6 A comparison of the capital costs of the alignments at all three elevations from the eastern intake with the corresponding alignments from the northern intake shows that there is a marginal capital benefit (circa US$70 million) associate with the northern intake. However this will be largely offset by higher pumping costs for the northern intake over the operating lifecycle of the project effectively rendering both options economically similar. It is therefore concluded that due to better site conditions, less complex construction and greatly reduced seismic risk the eastern intake is the preferred option.

13.7 Base Case

13.7.1 A comparison of the Net Present Values has been carried out for the three conveyance alignment configurations based on the eastern intake and also for the pipeline alignment associated with the northern intake and on the intermediate Base Case flow rate of 1,500 million m^3/year. Sensitivity of the NPV to energy costs has been tested using three different energy costs. The conclusion is that the NPV of a project configuration with a water conveyance level of 00m is some $500 million less than that for water conveyance levels of 130m and 220m and some $1,000 million less than the pipeline option.

Configuration =	00.1	130.1	220.1	Pipeline
Capital Cost	$4,149 million	$4,175 million	$3,940 miilion	$4,009 million
Annual Pumping Energy	0	679 GWh	1,112 GWh	1,545 GWh
Construction Cost	$4,149 million	$ 4,175 million	$3,940 million	$4,009 million
NPV (energy = $60/MWh)	$6,029 million	$6,520 million	$6,468 million	$6,872 million
NPV (energy = $45/MWh)	$6,029 million	$6,409 million	$6,286 million	$6,619 million
NPV (energy = $75/MWh)	$6,029 million	$6,631 million	$6,650 million	$7,125 million

Note: These are comparative costs only. The cost of some elements common to all configurations are not included.

13.7.2 It can safely be assumed that the relative costs and relative NPV values will be similar for the other two flow capacities considered, namely 1,000 and 2,000 Mm^3/year.

13.7.3 The preferred configuration for the Base Case on the basis of economic parameters as well as technical considerations is a gravity flow water conveyance tunnel at an elevation of 00m from the eastern intake. As has also been noted elsewhere this is likely to be the least environmentally intrusive configuration.

13.8 Base Case Plus

13.8.1 In the first instance screening of the alternative configurations for the Base Case Plus scenario has been carried out by repeating the above evaluation for the Base Case but with the addition of the cost of a hydro power plant and the value of the energy generated. The cost of a desalination plant has not been included as this cost is common to all configurations. This evaluation gives broadly similar results to that for the base case and shows that the most favourable Base Case Plus configurations are 00.1 and 220.1.

13.8.2 A detailed NPV has been developed for both the Base Case Plus configurations 00.1 and 220.1 which shows that there is less than 3% difference in cost between the respective NPVs of these two options:-

	Alternative 0.1	Alternative 220.1
Construction cost (1)	5,210.5 MUSD	4,848.6 MUSD
Annual energy demand of the pumping station	0	1,483 GWh
Energy generated annually at the hydropower plant	1,129 GWh - 797 GWh (2)	1,996 GWh - 1,409 GWh (2)
Annual energy demand to raise the desalinated water by 220 m	201 GWh- 536 GWh (2)	0
Net Present Value ($60 /MWh) (3)	7,134 MUSD	6,892 MUSD
Net Present Value ($45 /MWh) (3)	7,268 MUSD	6,960 MUSD
Net Present Value ($75 /MWh) (3)	7,001 MUSD	6,825 MUSD

Note: (1) The cost of the desalination plant is not included.
(2) The first figure corresponds to the commissioning year of the project and the second figure to the year when the ultimate desalination capacity is installed.
(3) The values of 60, 45 and 75 USD/MWh correspond to the cost of energy.

13.8.3. The preferred configuration for the Base Case Plus on the basis of economic parameters as well as technical considerations is either a gravity flow water conveyance tunnel at an elevation of 00m from the eastern intake or a pumped conveyance from the eastern intake at an elevation of 220m. The estimated NPV for these two configurations is too close to determine the preferred solution with the current level of detail and both options will be carried forward to the next stage of the Study Program.

14 Conclusions

14.1 In the absence of the proposed studies by specialised institutions it has not been possible at this stage in the Feasibility Study program to analyse the oceanographic, marine ecology or water mixing issues and impacts associated with the various options for the Red Sea intake works or the Dead Sea discharge works. As a result the following approach has been adopted in the Options Screening and Evaluation process:-

- Preliminary conclusions have been reached regarding the location and type of Red Sea intake based on engineering and economic grounds plus a professional judgement by the Study team of the likely environmental impacts. The environmental impacts of the options proposed in this report will have to be fully evaluated using appropriate scientific methods in the proposed Additional Studies program before any final recommendations can be confirmed.
- No recommendations are made in this report regarding the location or design of discharge works to the Dead Sea . The options are however identified. The influence of the different options on the mixing of Red Sea and Dead Sea water and how this impacts the nature and extent of the mixing plume and the chemistry, layering and micro-biology of the Dead Sea will have to be evaluated by an appropriate specialised institution under the proposed Additional Studies program before any conclusions can be drawn or recommendations made.

14.2 In this first pass screening and evaluation process the wide range of project configuration options set out in paragraph 3.1 above have been evaluated technically and a number of alternatives have been eliminated due to technical reasons. However, the majority of options are deemed at this stage to be technically feasible (subject to the provisos detailed in paragraph 14.1 above) and worthy of further consideration. A relative cost and discounted Net Present Value evaluation of these remaining options has then been carried out to establish a short list of those technically feasible options that are most attractive economically to be evaluated in more detail in the next stage of the Study Program.

14.3 The project configurations recommended to be carried forward for more detailed evaluation in the sub-studies phase of the overall study program are summarised as follows:-

Summary of Project Configurations to be Evaluated in Detail in Remainder of Study Program

Project Element	Base Case	Base Case Plus	
	Gravity Conveyance	Gravity Conveyance	Pumped Conveyance
Dead Sea Target Level	-428m / -426m	-412m	-412m
Dead Sea Target Year	2045 / 2070	2050	2050
Red Sea Water Abstraction Rate	1,000 million m^3/year	2,000 million m^3/year	2,000 million m^3/year
Intake Location	Eastern	Eastern	Eastern
Intake Type	Submerged bellmouth	Submerged offshore	Submerged offshore
Intake Channel	Short buried culvert or pipe	Short buried culvert or pipe	Short buried culvert or pipe
Pump Station Location	Not applicable	Not applicable	Eastern
Pump Station Capacity	Not applicable	Not applicable	2,000 million m^3/year
Pumping Head	Not applicable	Not applicable	Approximately 230m
Riser Mains	Not applicable	Not applicable	Steel lined tunnel or aerial penstocks
Water Conveyance – Nominal Elevation	00m	00m	+220m
Water Conveyance - Alignment	Eastern	Eastern	Eastern
Water Conveyance - Capacity	1,000 million m^3/year	2,000 million m^3/year	2,000 million m^3/year
Water Conveyance - Type	Tunnel – 161.5km long	Tunnel 161.5km long	Tunnel (111km) + Canal (57km)
Desalination Plant - Location	Not applicable	Zone A – Near Fifa village, or Zone C – South of Dana Reserve	Zone A – Near Fifa village, or Zone C – South of Dana Reserve
Desalination Capacity	Not applicable	Initial – circa 400 million m3/year Ultimate - 875 million m^3/year	Initial – circa 400 million m3/year Ultimate - 875 million m^3/year
Desalination Process	Not applicable	Seawater reverse osmosis	Seawater reverse osmosis
Desalination – Pre and Post Treatment	Not applicable	To be determined	To be determined
Hydro Power Facility - Location	Not applicable	South of Dead Sea near Fifa village	South of Dead Sea near Fifa village
Hydro Power Facility – Head	Not applicable	Circa 320m	Circa 545m
Hydro Power Facility – Flow Rate	Not applicable	Two alternative flows depending on desalination plant location. Both flows vary with time depending on water demands and desalination output.	Two alternative flows depending on desalination plant location. Both flows vary with time depending on water demands and desalination output.
Dead Sea Discharge - Capacity	1,000 million m^3/year	2,000 million m^3/year	2,000 million m^3/year
Dead Sea Discharge – Location	To be determined. Provisionally into the bay to the east of the Lissan Peninsula.	To be determined. Provisionally into the bay to the east of the Lissan Peninsula.	To be determined. Provisionally into the bay to the east of the Lissan Peninsula.
Dead Sea Discharge - Type	To be determined. Provisionally an open channel discharge.	To be determined. Provisionally an open channel discharge.	To be determined. Provisionally an open channel discharge.

Project Element	**Base Case**		**Base Case Plus**		
	Gravity Conveyance		**Gravity Conveyance**		**Pumped Conveyance**
Potable Water Transmission - Jordan	Not applicable		226 million m3/year at start up rising to 559 million m3/year in 2060. Delivered to a terminal service reservoir on the outskirts of Amman. Pipelines and pump stations to be developed in stages corresponding to growth in water demand.		226 million m3/year at start up rising to 559 million m3/year in 2060. Delivered to a terminal service reservoir on the outskirts of Amman. Pipelines and pump stations to be developed in stages corresponding to growth in water demand.
Potable Water Transmission - Israel	Not applicable		60 million m3/year delivered to low elevation demand centres in northern Arava and Dead Sea areas.		60 million m3/year delivered to low elevation demand centres in northern Arava and Dead Sea areas.
Potable Water Transmission – Palestinian Authority	Not applicable		Initially – 30 million m3/year delivered to low elevation demand centres in Jordan Valley. Expansion – to be determined.		Initially – 30 million m3/year delivered to low elevation demand centres in Jordan Valley. Expansion – to be determined.
Preliminary Estimate of Capital Cost	Approximately US$ 3,5 billion		Approximately US$ 7.5 billion		Approximately US$ 7.5 billion

Notes:-

(1) ***The above estimates of capital cost are very preliminary and will be subject to refinement and change as the Study Program progresses. It should also be noted that these cost estimates do not include the cost of water transmission pipelines to from the desalination plant to the potable water demand centres in the Beneficiary Party territories.***

(2) The selected Red Sea intake location and configuration remains to be validated during the specialised study of the Red Sea to be carried out under the Additional Studies.

(3) Water demand projections and sizing of the desalinated water transmission lines adopted are, at this stage, preliminary only for the purposes of determining project feasibility of the project. The final capacity of the water transmission systems will be dependent on how the Beneficiary Parties choose to allocate the supply of desalinated from the project between themselves.