Red Sea–Dead Sea Water Conveyance Study Program

Study of Alternatives

Preliminary Draft Report

EXECUTIVE SUMMARY

AND

MAIN REPORT

September 28, 2012

Prepared by

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Currency Equivalents
(as of September 28, 2012)

US Dollar (USD) 1 = New Israeli Shekel (NIS) 3.89
NIS 1.0 = USD 0.26

USD 1 = Jordanian Dinar (JD) 0.71
JD 1 = USD 1.41

ABBREVIATIONS AND ACRONYMS

APC	Arab Potash Company
BCM	billion cubic meters
Capex	Capital expenditure
CEHA	World Health Organisation Centre for Environmental Health Activities (CEHA)
DS	Dead Sea
DSMS	Dead Sea Modeling Study
DSW	Dead Sea Works
ERM	Environmental Resources Management
ESA	Environmental and Social Assessment
FoEME	Friends of the Earth Middle East
GSI	Geological Survey of Israel
GWh	Gigawatt hour
HLGT	High Level Gravity Tunnel
IWMI	International Water Management Institute
JD	Jordanian Dinar
JIIS	Jerusalem Institute for Israel Studies
JRSP	Jordan Red Sea Project
JVA	Jordan Valley Authority
km	Kilometer
km^2	square kilometers
LJR	Lower Jordan River
LLGT	Low Level Gravity Tunnel
M	Meter
m^3	cubic meter
Mbsl	meters below sea level
MCM	million cubic meters
MCM/y	million cubic meters per year
MDS	Mediterranean Sea-Dead Sea
Mwh	Megawatt hour

NATO	North Atlantic Treaty Organization
NIS	New Israeli Shekel
NPV	Net Present Value
Opex	Operational expenditure
PL	Pipe Line
PPL	Phased Pipe Line
RSDS	Red Sea Dead Sea
SoA	Study of Alternatives
ToR	Terms of Reference
US$	US Dollar
WHO	World Health Organisation

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RED SEA–DEAD SEA WATER CONVEYANCE STUDY PROGRAM

EXECUTIVE SUMMARY

1. OVERVIEW OF THE STUDY OF ALTERNATIVES

Objective of the Study of Alternatives. The objective of the Study of Alternatives is to provide decision makers, stakeholders and the public at large with a comparative analysis of alternatives to the Red Sea–Dead Sea Water Conveyance as described in the Feasibility Study prepared by Coyne et Bellier (2012), "Red Sea–Dead Sea Water Conveyance Study Program – Draft Final Feasibility Study Report – Summary of Main Report." The Study of Alternatives has not been designed nor does it intend to provide a recommended course of action for the Beneficiary Parties and/or other stakeholders.

The alternatives to the Red Sea–Dead Sea Water Conveyance include the "No Action" or "No Project" alternative and other alternatives that either fully, partially or in combination address the following objectives adopted by the Beneficiary Parties – Israel, Jordan and the Palestinian Authority – for the Red Sea–Dead Sea Water Conveyance Study Program (the Study Program):

- Save the Dead Sea from environmental degradation;
- Desalinate water / generate energy at affordable prices for Israel, Jordan and the Palestinian Authority; and
- Build a symbol of peace and cooperation in the Middle East.

The Study of Alternatives reviews the wide range of alternatives that have been put forward to address these issues by a variety of parties over recent decades. It describes them in a standardized manner, identifies their pros and cons and shows how they compare with both the Red Sea–Dead Sea Water Conveyance and with each other. It should be recognized that these alternatives have been subject to highly variable levels of examination concerning their technical, economic, environmental and social feasibility.

Three Key Elements. The Red Sea–Dead Sea Water Conveyance involves transferring up to 2,000 million cubic meters (MCM) per year of sea water about 180 km, from the Red Sea to the Dead Sea. When fully built, the conveyance scheme would include three elements that aim to:

- *Transfer Water* – Stabilize the Dead Sea water level utilizing up to 1,200 MCM/year of brine resulting from the desalination process;[1]
- *Desalinate Water* – Provide up to 850 MCM/year of potable water, to be shared among the three Beneficiary Parties; and
- *Generate Power* – Generate hydropower to lower the operational cost.

The Red Sea–Dead Sea Water Conveyance would use the elevation difference between the Red Sea and Dead Sea to generate hydropower, thereby lowering the cost of brine discharge and desalination.

Red Sea–Dead Sea Water Conveyance Study Program. The Study of Alternatives is one part of the Study Program, which also includes the following complementary studies:

[1] 1,200 MCM/year is the minimum required initially to stabilize the level of the Dead Sea, but may have to increase as: 1) the desalination capacity is increased up to 850 MCM/year; 2) the salinity of the Dead Sea changes over time, affecting evaporation rates; and 3) climate change has an effect on evaporation rates.

- Red Sea–Dead Sea Water Conveyance Study Program, Feasibility Study Report (Coyne et Bellier);
- Red Sea–Dead Sea Water Conveyance Study Program, Environmental and Social Assessment (ERM);
- Red Sea–Dead Sea Water Conveyance Study Program, Dead Sea Study (Tahal Group); and
- Red Sea–Dead Sea Water Conveyance Study Program, Red Sea Study (Thetis).

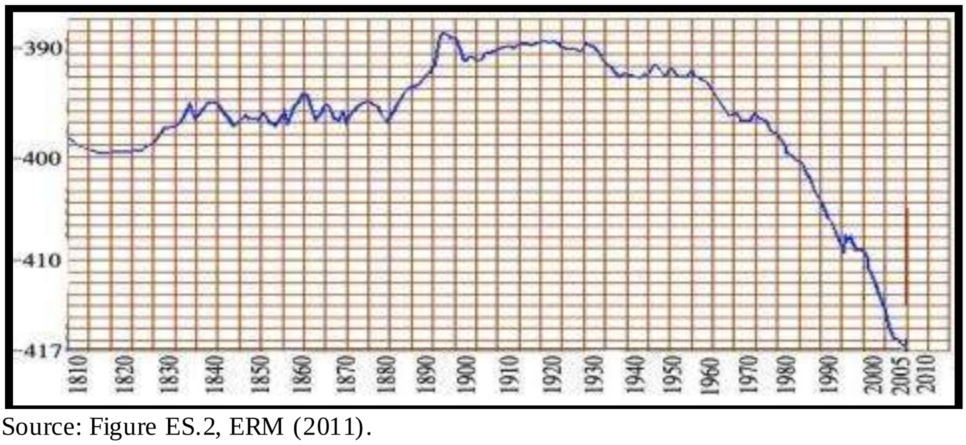
Information on the Study Program, including the Terms of Reference (TOR), draft reports and the public consultation record can be found on this website: www.worldbank.org/rds.

Connecting Two Seas. Connecting the two seas is not a new idea. A possible inter-basin transfer has been studied in many forms since the mid-1800s. The more than 400-meter difference in elevation between the Mediterranean Sea or the Red Sea and the Dead Sea has long been enticing because of the gravity flow advantage and the considerable potential for hydropower generation. The catchment area of the Dead Sea is shown in Map 1a and the associated elevation profile is shown in Map 1b. As unit prices for desalination have dropped in recent years, combining the transfer with desalination for domestic uses has become increasingly relevant to the Beneficiary Parties. As 60 to 70 percent of domestic water can be reused after suitable treatment (Cohen et al, 2008), the desalinated water will indirectly increase the potential supply of water available for restoration of the Dead Sea in conjunction with restoration of the Lower Jordan River.

A Complex Situation. Reversing the long-term environmental degradation of the Dead Sea from the reallocation of surface and ground water for agricultural, municipal, industrial and tourism purposes is a major challenge to Israel, Jordan, and the Palestinian Authority. Reversing the trend is made more complex by the significant consumption of Dead Sea water to support economically important chemical industries in Israel and Jordan. With no action the sea level is expected to drop by another 150 m until it will stabilize as a much smaller water body at a level of about 543 m below sea level (mbsl) by the mid-22nd century (Coyne et Bellier, 2010).

Rapid Rate of Decline. Since the 1960s the level of the Dead Sea has dropped by more than 30 m and today it stands at 426 mbsl (July 2011, Arab Potash Company and Dead Sea Works records). The Dead Sea is currently declining by more than a meter a year (see Figure ES.1). Stabilizing at the current level requires additional water inflow of 700-800 MCM/year and stabilizing at 410 mbsl requires over 1,000 MCM/year (Ministry of the Environment, the Geological Survey of Israel and the Jerusalem Institute for Israel Studies, 2006; Coyne et Bellier, 2010).

Figure ES.1: Drop of the Dead Sea Level (meters below sea level vs. time in years)

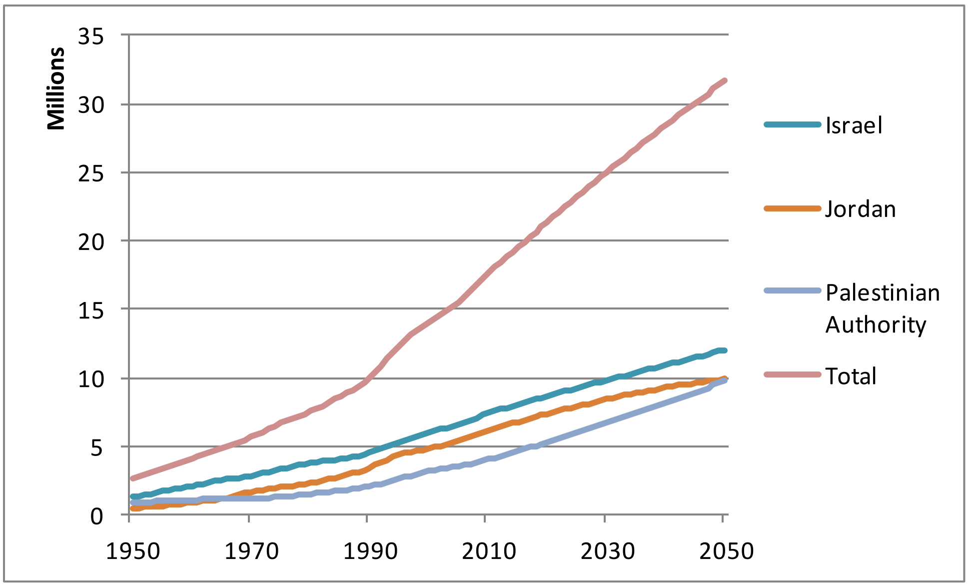


Source: Figure ES.2, ERM (2011).

Impacts of Decline on the Shoreline. Decline to date has included a significant retreat of the shoreline, especially on the northern Dead Sea, and development of steeper slopes on the western and eastern shores. Changes on the southern shore from the decline in sea level are less obvious because of the large scale conversion of the area into evaporation ponds for use in the chemical industries. In the future a major feature of the decline in sea level will be the increasingly steep shorelines especially on the western and eastern shores. In addition, the southern shoreline will also retreat significantly in the future, reducing the bay to the east of the Lisan Peninsula to a dry seabed (see Map 2). The decline has also resulted in the formation of a large number of sink holes around the Dead Sea that present a hazard to humans, natural habitats and commercial uses. The sink holes have damaged infrastructure and agricultural lands and restricted land use. It is anticipated that the ongoing decline of the Dead Sea will result in continued land surface stability problems.

Water Availability and Population Growth. The need to increase the supply of potable water in the region is unavoidable and stems from the gap between the water supplies available from natural sources and the basic needs of the growing population. Figure ES.2 depicts the population trends and projections of the three Beneficiary Parties between 1950 and 2050.

Figure ES.2: Population (million) Trends and Projections for Israel, Jordan and the Palestinian Authority for the Period 1950–2050



Source: United Nations, Department of Economic and Social Affairs, Population Division: World Population Prospects DEMOBASE extract, 2011.

The sustainable quantity of natural water[2] available through average annual recharge in the basins of Israel, Jordan and the Palestinian Authority is about 2,600 MCM/year on average: 1,700 MCM/year in Israel and the Palestinian Authority (Israel Hydrology Service, 2007; Weinberger et al, 2012); and 933 MCM/year in Jordan (Water for Life, Jordan's Water Strategy, 2008-2022). The population of the three parties combined is currently about 18 million and is expected to exceed 30 million by 2050. Per capita water available from natural sources was 139 m^3 per person per year in 2010 and could go as low as 80 m^3 per person per year by 2050, whereas the quantity of water deemed necessary to meet "basic human needs" is about 100 m^3 per person per year (Gleick, 1996). From 2030 onwards, therefore, the average annual recharge in the water basins of Israel, Jordan and the Palestinian

[2] *Natural water* is the water which derives from rainfall both local and that flowing from other parts of river basins. It is evident in surface and groundwater flows and storages. Its withdrawal for use by the economy and by society can be supplemented with recycled municipal water and manufactured – desalinated – water.

Authority will not meet even the basic human needs of the existing population. This is without taking into account the water needs for industrial, agricultural and environmental purposes.

Causes of Decline. The level of the Dead Sea has declined because the historical annual Jordan River flow of about 1,300 MCM/year has been progressively reduced by water consumption – mainly by Israel, Jordan and Syria (Courcier et al, 2005, Beyth 2006). This upstream diversion came in response to mounting demand for water since the 1950s. The main drivers were the allocation of potentially potable water, first to irrigation and secondly to provide the water services of the growing populations. The demand for potable water will continue to increase for municipal and industrial uses. But the allocation of high quality natural water to irrigation will decline at the rate at which water demand management measures and water reuse technologies can be introduced. These processes of both growth in demand and the adoption of measures to more efficiently use water will intensify in the future. The decline is also caused by significant consumption of Dead Sea water as a raw material for the large evaporation based chemical industries in Israel and Jordan at the southern end of the Sea, which produce potash, magnesium, manganese and bromide. The net amount of Dead Sea water used per year by the chemical industries is estimated at 262 MCM (Zbranek, 2012).


IBRD 38932R
RED SEA-DEAD SEA
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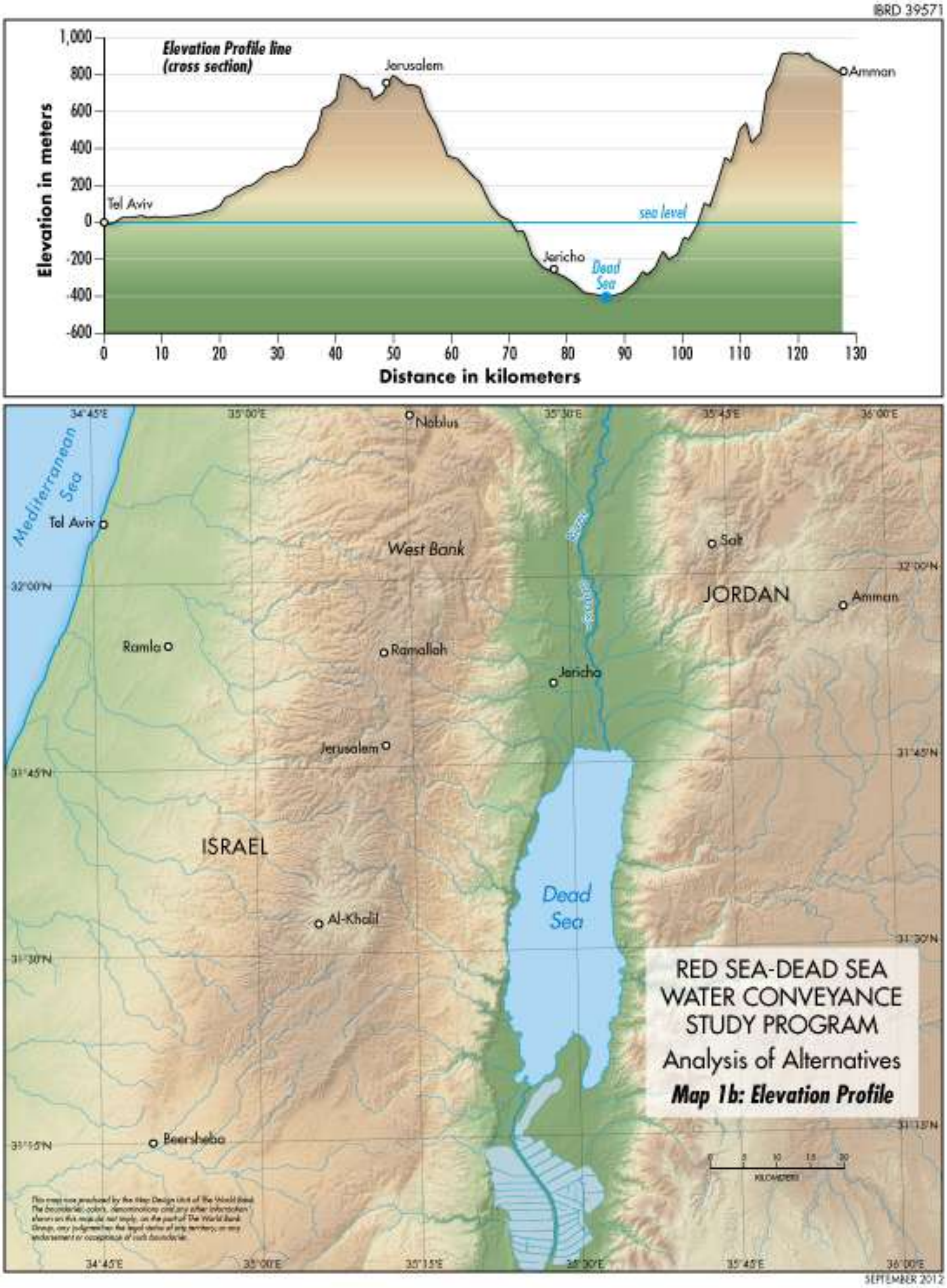
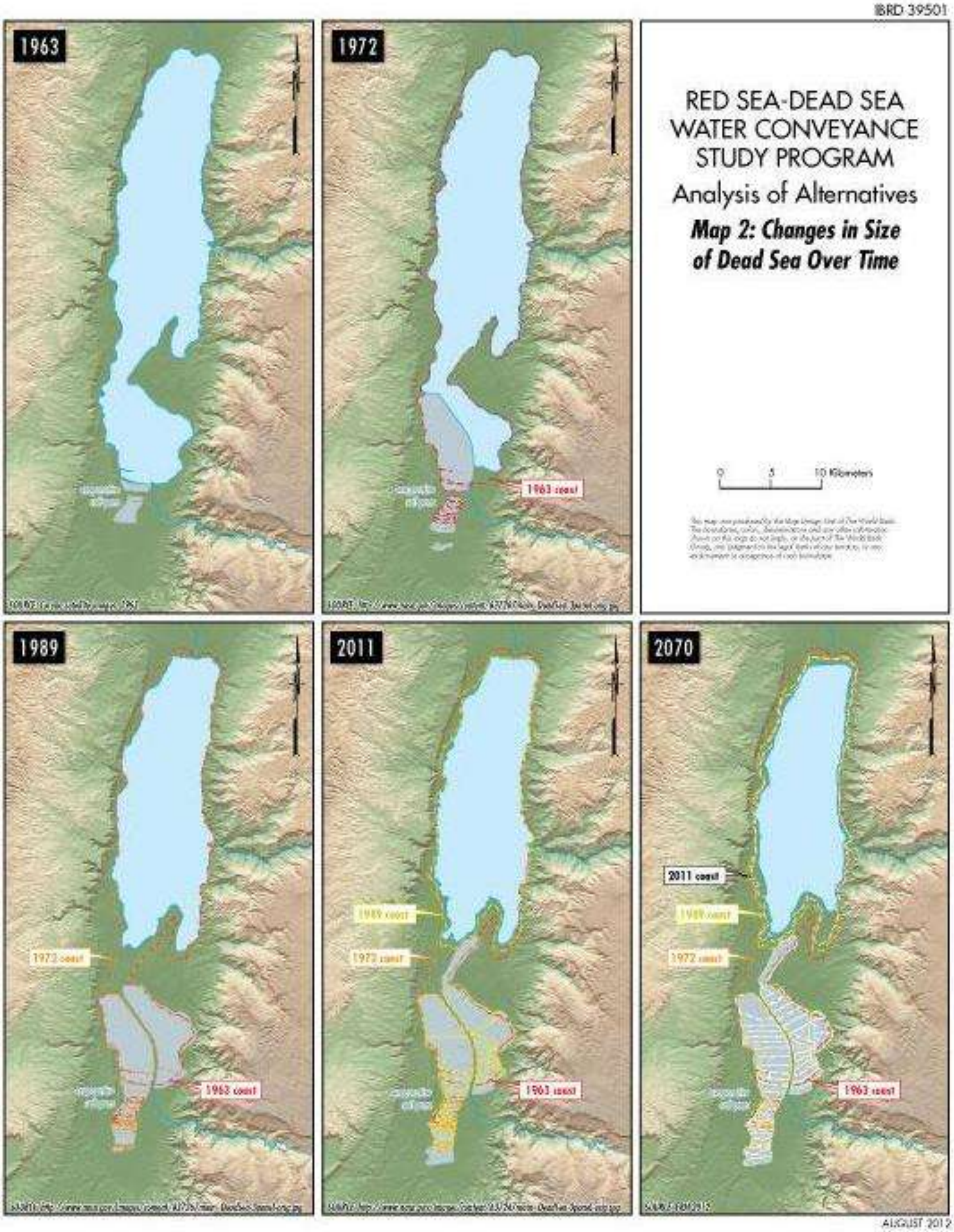
Analysis of Alternatives
Map 1a: Dead Sea Catchment Area
DEAD SEA CATCHMENT AREA
PRIMARY WADIS AND RIVERS
SECONDARY WADIS AND RIVERS
EVAPORATION PANS
MAIN CITIES AND TOWNS
Mediterranean Sea
Sidon
Damascus
Tyre
Al-Qunaytirah
Haifa
Lake Tiberias
Nazareth
Al-Suwayda
Dar'a
Irbid
Netanya
Al-Mafraq
Nablus
AMMAN UPLANDS
Al-Zarqa
Tel Aviv
Salt
HEBRON &
Ramla
Ramallah
Amman
Jericho
Jerusalem
Bethlehem
Madaba
JERUSALEM
Dead Sea
Gaza
Hebron
UPLANDS
Beersheba
Arad
Al Kerak
Dimona
Zin
NEGEV
UPLANDS
DEAD SEA CATCHMENT
SOUTH
JORDAN
Ma'an
UPLANDS
Petra
Elat
Aqaba
Gulf of Aqaba
0 10 20 30 Kilometers
0 10 20 30 Miles
SEPTEMBER 2012



IBRD 39571
Elevation Profile line (cross section)
Elevation in meters
Distance in kilometers
Tel Aviv
Jerusalem
Jericho
Dead Sea
Amman
sea level
Mediterranean Sea
West Bank
JORDAN
ISRAEL
Nablus
Salt
Ramla
Ramallah
Al-Khalil
Beersheba
RED SEA-DEAD SEA WATER CONVEYANCE STUDY PROGRAM
Analysis of Alternatives
Map 1b: Elevation Profile
SEPTEMBER 2012


IBRD 39501
1963
1972
RED SEA-DEAD SEA
WATER CONVEYANCE
STUDY PROGRAM
Analysis of Alternatives
Map 2: Changes in Size
of Dead Sea Over Time
0
5
10 Kilometers
1963 coast
1989
2011
2070
1972 coast
1989 coast
2011 coast
AUGUST 2012

Scope of the Study of Alternatives

The Study of Alternatives compares alternative options to the Red Sea–Dead Sea Water Conveyance, outlining the extent to which they meet the objectives above. Alternatives are also evaluated in terms of their economic, environmental and social impacts.

The Study of Alternatives Team has examined a range of measures that have been proposed to: (i) address the decline of the Dead Sea; and (ii) reduce the scarcity of potable water in the region. The alternatives that have been considered in this study are presented in Box ES.1 below:

Box ES.1: Alternatives Considered

No Action – NA1 - Analysis as provided by the Consultant for the Environmental and Social Assessment

Red Sea–Dead Sea Water Conveyance–(Base Case - BC) BC1/BC2 - Description and Analysis as provided by the Consultant for the Environmental and Social Assessment

Lower Jordan River Options (FL)

- FL1 - Full Restoration of Historic Lower Jordan River Flow Levels
- FL2 - Partial Restoration of Historic Lower Jordan River at a Variety of Flow Levels

Water Transfer Options (TR)

- TR1 - Transfer of Mediterranean Sea Water to Dead Sea
- TR2- Transfer of Water from Turkey by pipeline
- TR3- Transfer of Water from the Euphrates River Basin by pipeline

Desalination Options (DS)

- DS1 - Desalination of Mediterranean Sea Water on the Mediterranean Coast with Transfer to the Lower Jordan River and Dead Sea Region
- DS2 - Transfer of Mediterranean Sea Water to the Jordan Valley for Local Desalination and Use in Lower Jordan River and Dead Sea Region
- DS3 - Increased Desalination of Mediterranean Sea Water on the Mediterranean Coast with Transfer for Use by the Three Beneficiary Parties to Reduce Water Demand from Lower Jordan River
- DS4 - Desalination of Red Sea Water at the Gulf of Aqaba/Eilat with Transfer for Use by the Three Beneficiary Parties to Reduce Water Demand from Lower Jordan River

Technical and Water Conservation Options (TC)

- TC1- Changes of Technology Used by the Dead Sea Chemical Industry
- TC2 - Increased Water Conservation in the Lower Jordan Basin
- TC 3 - Increased Use of Treated Wastewater and Greywater
- TC4 - Changes in Crop Types and Cultivation Methods

Additional Alternatives Identified by the Consultants (AA)

- AA1 - Selling Electricity to Israel and Pumped Storage
- AA2- Transfers by Tanker, Bag and Submarine Pipeline from Turkey
- AA3 - Submarine Pipelines associated with Oil and Energy Conveyance–Medstream

Combination of Alternatives (CA) – Examination of a Range of Combinations of Alternatives to Assess the Benefits of Such an Approach – the combinations below were identified by the consultants during preparation of the Study

- CA1 - Desalination at Aqaba and Mediterranean Sea, water importation from Turkey and water recycling and conservation
- CA2 - Decreased chemical industry water extraction and decreased irrigation through cropping and other agronomic changes
- CA3 - Aqaba desalination plus decreased use from the chemical industries, plus increases in recycled water for irrigation
- CA4 - Reduced extractions from the Jordan River, plus Aqaba regional desalination and decreased irrigation use though agronomic changes

The Red Sea–Dead Sea Water Conveyance is the baseline case to which other alternatives are compared. The alternatives are evaluated according to their economic, environmental and social impacts vis-à-vis the previously mentioned objectives. The environmental goal of Dead Sea stabilization has a public good nature while increasing the supply of potable water is of a public utility (commercial) nature to address basic human needs. These features affect the costs and benefits associated with each goal.

Alternatives may involve: (i) transfers of brine, high quality natural water and desalinated water from sources within and outside the territories of the Beneficiary Parties; and (ii) regulatory and demand management measures in the Beneficiary Parties in irrigated agriculture, in the Dead Sea chemical industries and in municipal water uses. It is important to note that the generation of hydropower is not an option for a number of the alternatives considered in this report.

When appropriate (e.g., for the Red Sea–Dead Sea and the Mediterranean Sea–Dead Sea alternatives), and in accordance with the study's main objectives, the cost evaluation for an alternative is divided between the cost of brine/seawater discharge to the Dead Sea and the cost of potable water in Amman. The cost allocation methodology is shown in Box ES.2.

Box ES.2: Methodology for Cost Evaluation of Brine/Seawater and Potable Water

- ***Cost of brine/seawater discharge to Dead Sea:*** The cost of brine/seawater discharge to the Dead Sea is the cost of a project whose sole purpose is to stabilize the Dead Sea water level at about 410 meter below sea level. Saving the Dead Sea would involve the conveyance of over 1 billion m^3 per year of seawater from the Red Sea or the Mediterranean Sea to the Dead Sea and exploit the elevation difference to generate hydropower.
- ***Cost of potable water in Amman:*** The cost of potable water in Amman (or in any other location) consists of the added cost due to: (i) the conveyance of the additional volume of water needed for desalination from the source (the Red Sea or Mediterranean Sea) to the desalination plant (if desalination is performed near the Dead Sea); (ii) desalination; and (iii) conveyance of the desalinated water to Amman, or other locations
- ***Unit cost:*** The cost of Dead Sea stabilization is provided in US$ per year units and the cost of potable water in Amman in US$ per m^3 units. To obtain the cost of Dead Sea stabilization in US$ per m^3 units requires dividing the annual cost of the Dead Sea stabilization by the quantity of water discharged. Due to the proposed phasing of the volume of water to be discharged, the resulting figures would correspond to the cost of discharged water at the completion of the final phase. The modifier "break-even cost," is the point where the price charged for potable water in Amman would cover the supply cost. The supply cost involves conveyance from the source to the desalination plant, desalination and conveyance of the desalinated water to Amman.

The economic, cost and water data is explained in Box ES.3 below.

Box ES.3: Economic, Cost and Water Data

- ***Economic and cost data*:** The cost calculations of the Red Sea–Dead Sea and Mediterranean Sea–Dead Sea alternatives are based on Coyne et Bellier's up-to-date data. In several places in the Study of Alternatives, results of earlier studies, which are based on now outdated economic and cost data, are reported.
- ***Water data*:** Data on water resources in the Middle East in general and the Jordan River basin in particular have expanded considerably in recent years, as data sources flourish and multiply by the week. In this report, the Study of Alternatives Team makes a clear distinction between official and unofficial sources. Official data sources include Israel's Hydrological Service, Israel's Water and Sewage Authority, Geological Survey of Israel, Kinneret Limnological Laboratory, Israel Oceanographic & Limnological Research, Israel's Central Bureau of Statistics, Mekorot, Jordanian Ministry of Water and Irrigation, Water Authority of Jordan, Jordan Valley Authority, and the Palestinian Water Authority. Unofficial data sources include FoEME reports, GLOWA Project, SMART Project, MED EUWI Dialogues and SWIM Demo Project. Analyses and assessments in the Study of Alternatives are based solely on data obtained from official sources.

2. PRINCIPAL FINDINGS AND CONCLUSIONS

No Action Alternative (NA1)

There will be economic, environmental and social costs associated with not remedying the decline of the Dead Sea and the imminent deficit of potable water in Jordan. A study by Becker and Katz (2009) estimated the No Action cost in the range of US$73–US$227 million a year. These estimates are based on willingness to pay by the local population to preserve the Dead Sea. However, the unique characteristics of the Dead Sea imply that the benefit of its preservation extends beyond the region and includes the international community as a whole. The total benefit of preventing the decline of the Dead Sea is therefore likely to be larger than the above range.

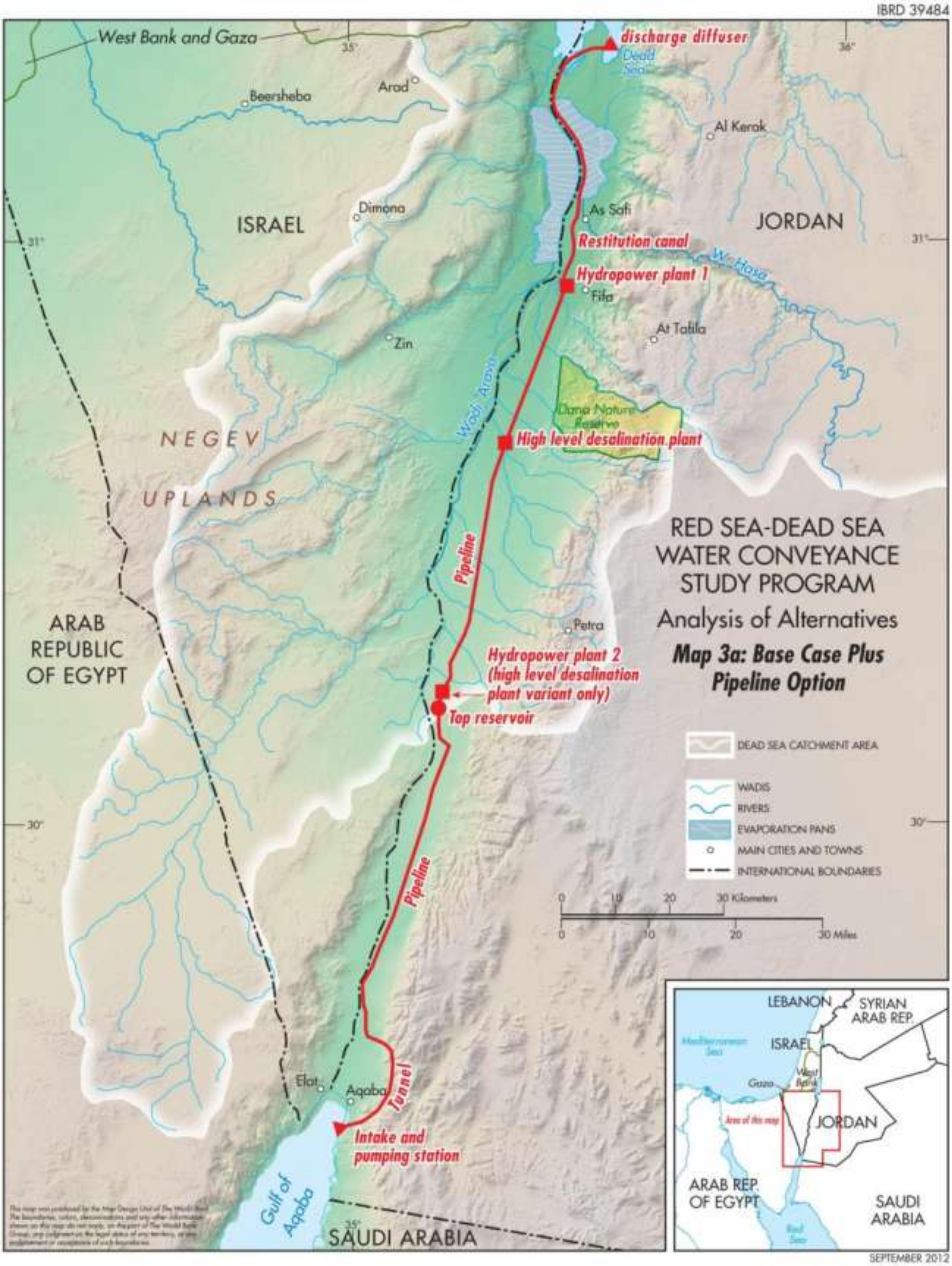
The No Action alternative will lead Jordan to seek other ways to increase the supply of potable water. The most likely course of action is to desalinate in Aqaba and convey the desalinated water to Amman, possibly expanding the Disi–Amman pipeline (currently under construction) for water conveyance. The cost of conveyance from Disi to Amman – about 325 km with a significant change in elevation en route requiring pumping – is estimated at US$1.1/$m^3$. The distance from Aqaba to Disi is about 70 km and the elevation in the Disi area is 800 m, implying an additional conveyance cost from Aqaba to Disi of at least US$0.4/$m^3$. Adding the cost of desalination (US$0.5/$m^3$) gives a figure above US$2/$m^3$ as the cost of desalinated Aqaba water in Amman. This cost is substantially larger than comparable costs of other alternatives.

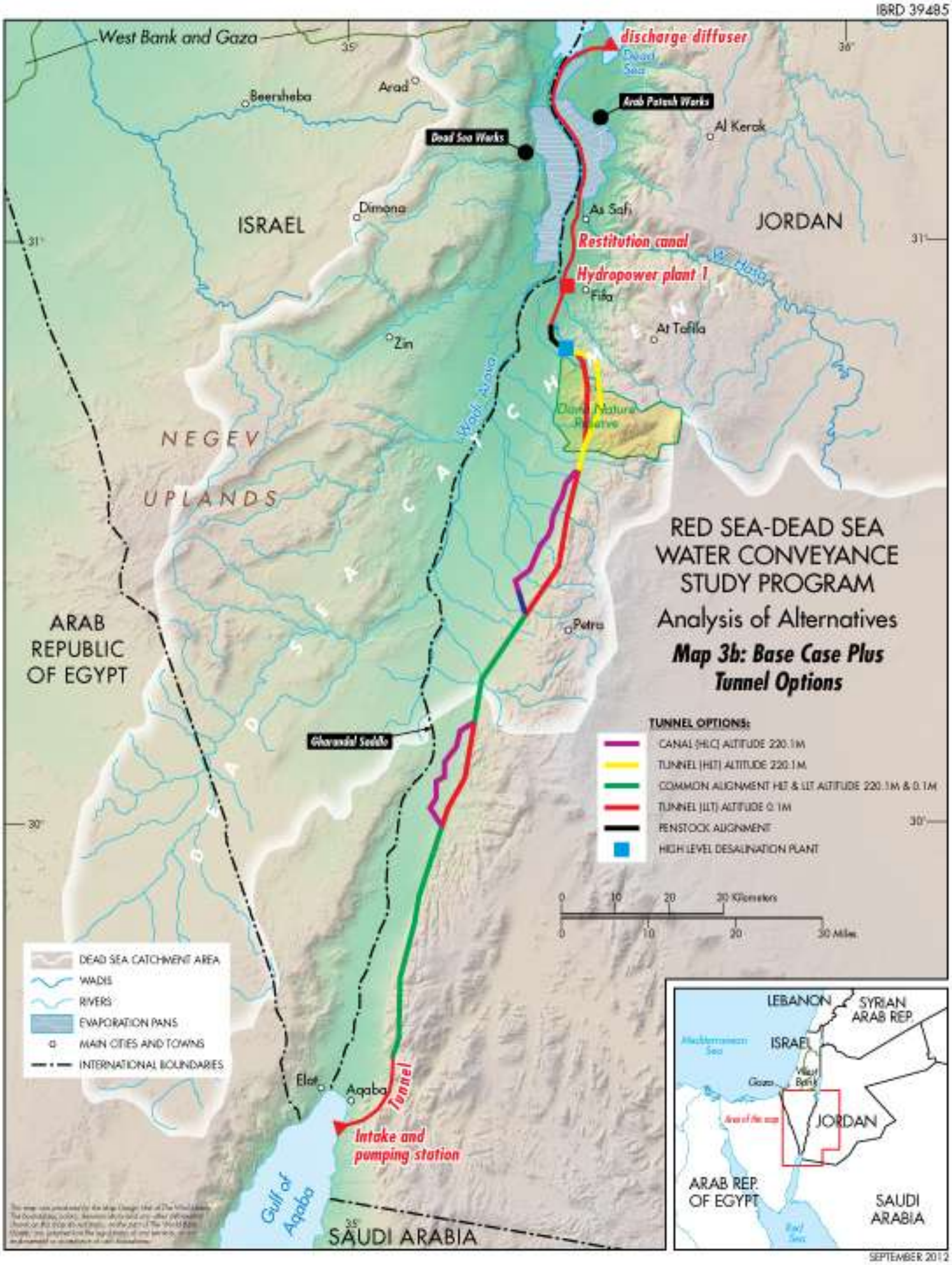
Impacts of the No Action Alternative. The progressive decrease in sea level has resulted in a retreat of the shoreline and dehydration of the shallow Southern Basin. Sinkholes, mud flats, steep slopes, and earthquake-associated landslides have developed. Terrestrial and aquatic ecosystems, infrastructure, tourism activities, neighbouring settlements and the chemical industry have been affected. Irreversible damage has also been caused to the shore habitat and to unique species. The ecology of the lakeside oases is of both local and global importance. Not taking any measures to change the situation will cause the continued deterioration of the Dead Sea and its environment.

Red Sea–Dead Sea Water Conveyance (BC1/BC2- see Maps 3A and 3B)

The cost of seawater-brine discharged in the Dead Sea depends on the chosen project option, varies along the project stages and is sensitive to economic parameters such as the rate of interest and electricity tariffs. Average annual costs after project completion (at full capacity) ranges between US$58 million and US$344 million. The cost of water in Amman after project completion (full capacity) ranges between US$1.1/$m^3$ and US$1.5/$m^3$.

The key environmental and social issues associated with the Base Case center around the effects on the water bodies at either end of the conveyance, the rare and/or fragile aspects of the desert ecosystems, the cultural heritage and disturbances to those communities that live in and around the Wadi Araba/Arava Valley. An issue of potentially major concern to the environmental and social acceptability of the Red Sea – Dead Sea Water Conveyance is the risk that the influx of seawater and reject brine into the Dead Sea will cause changes to the appearance and water quality of the Dead Sea such that its value as a heritage site of international importance will be damaged.


IBRD 39484
West Bank and Gaza
Arad
Beersheba
Al Kerak
discharge diffuser
Dead Sea
Dimona
ISRAEL
As Safi
JORDAN
Restitution canal
W. Hasa
Hydropower plant 1
Fifa
At Tafila
Zin
Wadi Araba
Dana Nature Reserve
High level desalination plant
NEGEV
UPLANDS
RED SEA-DEAD SEA
WATER CONVEYANCE
STUDY PROGRAM
Analysis of Alternatives
Map 3a: Base Case Plus
Pipeline Option
Pipeline
Petra
ARAB
REPUBLIC
OF EGYPT
Hydropower plant 2
(high level desalination
plant variant only)
Top reservoir
DEAD SEA CATCHMENT AREA
WADIS
RIVERS
EVAPORATION PANS
MAIN CITIES AND TOWNS
INTERNATIONAL BOUNDARIES
0 10 20 30 Kilometers
0 10 20 30 Miles
Pipeline
Tunnel
Elat
Aqaba
Intake and
pumping station
Gulf of Aqaba
SAUDI ARABIA
LEBANON
SYRIAN
ARAB REP.
ISRAEL
Gaza
West Bank
JORDAN
ARAB REP.
OF EGYPT
SAUDI
ARABIA
SEPTEMBER 2012


IBRD 39485
West Bank and Gaza
discharge diffuser
Dead Sea
Arab Potash Works
Dead Sea Works
Beersheba
Arad
Al Kerak
Dimona
As Safi
ISRAEL
JORDAN
Restitution canal
Hydropower plant 1
Fifa
At Tafila
Zin
Wadi Araba
Dana Nature Reserve
NEGEV
UPLANDS
DEAD SEA CATCHMENT
RED SEA-DEAD SEA
WATER CONVEYANCE
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Map 3b: Base Case Plus
Tunnel Options
Petra
ARAB
REPUBLIC
OF EGYPT
Gharandal Saddle
TUNNEL OPTIONS:
CANAL (HLC) ALTITUDE 220.1M
TUNNEL (HLT) ALTITUDE 220.1M
COMMON ALIGNMENT HLT & LLT ALTITUDE 220.1M & 0.1M
TUNNEL (LLT) ALTITUDE 0.1M
PENSTOCK ALIGNMENT
HIGH LEVEL DESALINATION PLANT
0 10 20 30 Kilometers
0 10 20 30 Miles
DEAD SEA CATCHMENT AREA
WADIS
RIVERS
EVAPORATION PANS
MAIN CITIES AND TOWNS
INTERNATIONAL BOUNDARIES
Elat
Aqaba
Tunnel
Intake and
pumping station
Gulf of Aqaba
SAUDI ARABIA
LEBANON
SYRIAN ARAB REP.
ISRAEL
JORDAN
ARAB REP. OF EGYPT
SAUDI ARABIA
SEPTEMBER 2012

Lower Jordan Options (FL1/FL2 – see Map 4)

Restoring the Lower Jordan River is a desirable goal with high environmental, historical and cultural values. Full restoration to historical flows would also address the first objective of saving the Dead Sea but is not economically or socially feasible at this time. Full restoration of the water flow (of over 1,000 MCM/year) based on recycled water will become feasible in the long run, as the supply of potable water increases to meet the needs of the growing population.

In the short and medium term, partial restoration of the Lower Jordan River should be seriously considered as a priority for water resources and environmental management in combination with partial restoration of the Dead Sea or increased supply of potable water to Amman and other areas. Partial restoration of the ecological services of the Lower Jordan River would aim to ensure a minimum environmental flow to rehabilitate some of the aquatic ecological diversity of the river. The partial restoration of Lower Jordan River flows, over a two decade term, could possibly contribute 40 percent to the quantity of water needed to stabilizethe Dead Sea level. Engagement and cooperation on the part of the Beneficiary Parties would also be enhanced. The main sources of water to achieve partial restoration would be: use of recycled wastewater, limited releases of water from Lake Tiberias (see Box ES.4); and transfer of desalinated water from the Mediterranean Sea associated with the conveyance of potable water to Amman.

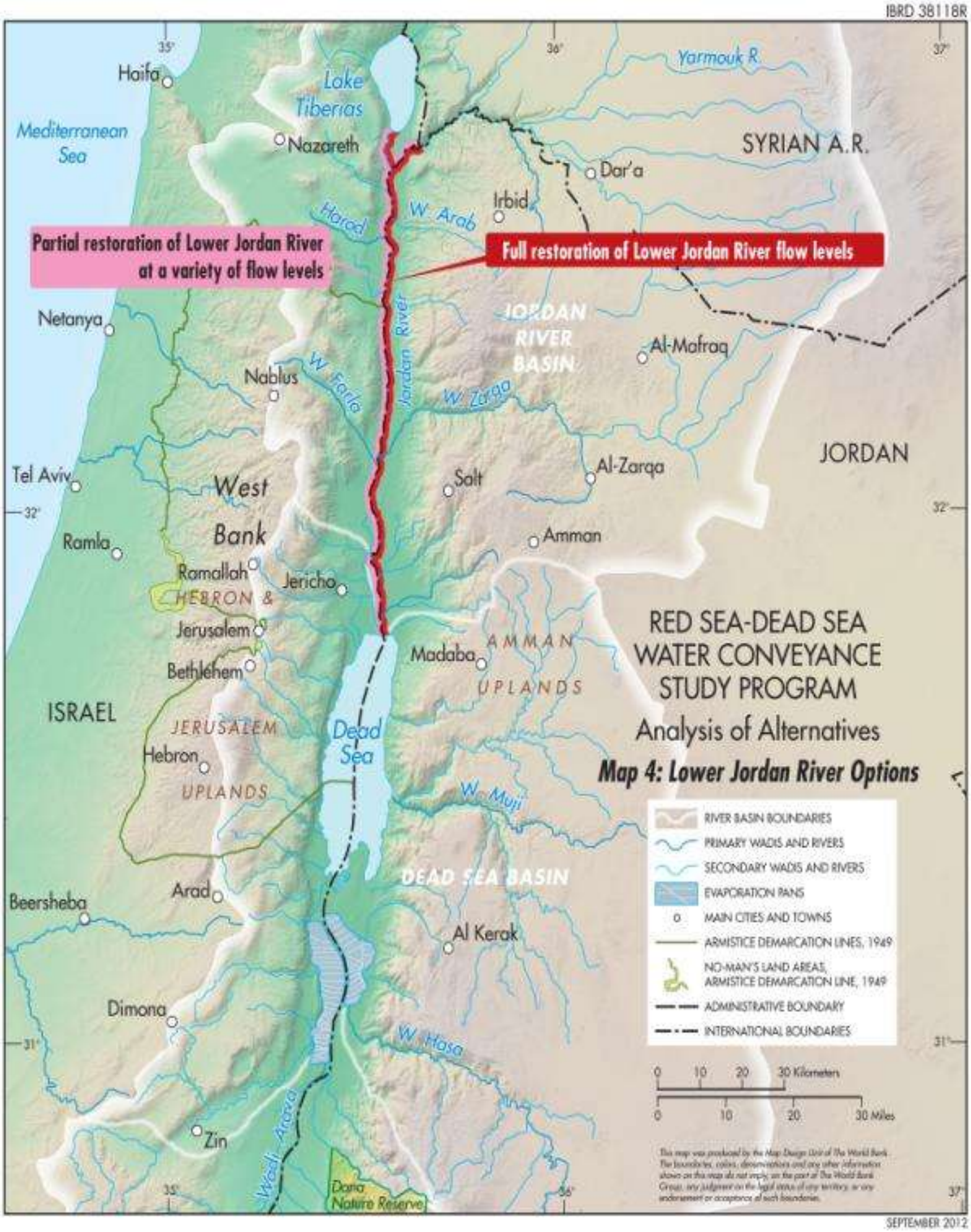
It is the view of the Study of Alternatives Team that the use of potable water – from Lake Tiberias, from desalination plants or from other sources of natural potable water – for Dead Sea stabilization purpose would not be a viable or desirable strategy as long as the Beneficiary Parties experience acute shortages of potable water.

Box ES.4: Lake Tiberias: Water Balance and Allocations

Lake Tiberias, also known as Lake Kinneret or the Sea of Galilee, is a fresh water lake located at the lower end of the upper Jordan River (see Map 1a). Its many uses include recreation, fishing and a source of water supply to nearby towns and villages and to the Israeli National Water Carrier. During the period 1973 – 2009, the average annual recharge (total water inflow, including direct rainfall) of Lake Tiberias was 581 MCM, with a standard deviation of 258 MCM (Weinberger et al, 2012). The lake loses 249 MCM/year to evaporation (op. cit.), leaving an average net water balance of 332 MCM/year with high fluctuations. The allocation of this water volume is as follows:

- *Releases to towns and villages surrounding the lake* – 40 MCM/year. This quantity will increase with population growth and is expected to reach 50 MCM/year in a decade or two.
- *Releases to Jordan (in fulfillment of the 1994 Peace Agreement)* – 50 MCM/year.
- *Additional water committed to Jordan* (in a preliminary framework recently agreed by Israel and Jordan) – 50 MCM/year.
- *Lower Jordan River restoration* – between 20 and 30 MCM/year (a decision has been made and implementation will begin as soon as the Bitania sewage treatment facility is completed and its water replaces Lake Tiberias water used for irrigation).
- *Israel's National Water Carrier* – the balance of 152 MCM/year on average (obtained by subtracting from 581 the sum of 249+50+50+50+30) will be available for pumping to Israel's National Water Carrier.
- *Water balance:* In the future, as Israel increases its desalination capacity (see Israel Water and Sewage Authority, 2011), the need to pump Lake Tiberias water to the Israeli National Water Carrier will decrease and the allocation to Lower Jordan River restoration and to Jordan will accordingly increase.

A feasible source for augmenting Lower Jordan River flow to support restoration would be recycled water. The growing population will gradually increase the potential supply of recycled water. Implementing any alternative that brings in additional potable water will indirectly contribute to the feasibility of Lower Jordan River restoration by increasing the potential supply of recycled water. Every m^3 of added potable water will enable additional uses that when combined account for more than 1.5 m^3 of water.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RED SEA-DEAD SEA
WATER CONVEYANCE
STUDY PROGRAM
Analysis of Alternatives
Map 4: Lower Jordan River Options
Partial restoration of Lower Jordan River
at a variety of flow levels
Full restoration of Lower Jordan River flow levels
Mediterranean Sea
Lake Tiberias
Dead Sea
SYRIAN A.R.
JORDAN
ISRAEL
West Bank
JORDAN RIVER BASIN
DEAD SEA BASIN
AMMAN UPLANDS
JERUSALEM UPLANDS
HEBRON &
Haifa
Nazareth
Dar'a
Irbid
Netanya
Al-Mafraq
Nablus
Tel Aviv
Salt
Al-Zarqa
Ramla
Amman
Ramallah
Jericho
Jerusalem
Madaba
Bethlehem
Hebron
Arad
Beersheba
Al Kerak
Dimona
Zin
Yarmouk R.
Harod
W. Arab
Jordan River
W. Faria
W. Zarqa
W. Mujib
W. Hasa
Wadi Arava
Dana Nature Reserve
RIVER BASIN BOUNDARIES
PRIMARY WADIS AND RIVERS
SECONDARY WADIS AND RIVERS
EVAPORATION PANS
MAIN CITIES AND TOWNS
ARMISTICE DEMARCATION LINES, 1949
NO-MAN'S LAND AREAS, ARMISTICE DEMARCATION LINE, 1949
ADMINISTRATIVE BOUNDARY
INTERNATIONAL BOUNDARIES
0 10 20 30 Kilometers
0 10 20 30 Miles
SEPTEMBER 2012

Water Transfer Options

Transfer of Mediterranean Sea Water to Dead Sea (TR1.1 - TR1.4 – see Maps 4 and 5)

Two Mediterranean Sea–Dead Sea project alignments–southern A and B and northern–are considered. These include Mediterranean Sea–Dead Sea Southern A – Ashkelon to North Dead Sea (Low Level Tunnel) (TR1.1) and a Phased Pipeline option (TR1.2) which both use the Southern A alignment. The northern alignment includes two options: Mediterranean Sea– to Naharayim-Bakura – with hydropower (TR1.3) and without hydropower (TR1.4). In reviewing the Southern A and Southern B alignments and their associated costs, the Study of Alternatives Team concluded that since the Southern A alignment delivers water to the northern edge of the Dead Sea it would be able to provide water at a lower cost to Amman and to other areas with significant water demand. The Southern B alignment was found to be more costly than other similar alternatives. Consequently, the southern Mediterranean Sea–Dead Sea alignment B has been screened out and this study considered only the Southern A –TR1.1 and TR1.2 as southern options.

The course of the southern Mediterranean Sea–Dead Sea alignment intersects the southern structures of the mountain aquifer and the exact route should be determined in order not to harm this sensitive and important water source. The high surface elevation of the southern Mediterranean Sea–Dead Sea alignment renders a phased pipeline option (as an integrated component) not feasible economically.

A pilot project to test the mixing of Mediterranean Sea and Dead Sea waters would have to be constructed separately and this will increase the cost. The actual route may be longer and/or deeper, with potentially substantial cost impacts. Further cost analysis would be needed after an exact route has been determined.

The Low Level Gravity Tunnel of the Red Sea–Dead Sea Base Case Plus would deliver potable water at \$1.11-1.24/m^3. The Base Case Plus Red Sea–Dead Sea Phased Pipeline is estimated at \$1.33-1.50/m^3. Potable water delivered by the Mediterranean Sea–Dead Sea Southern A – Low Level Gravity Tunnel would deliver equivalent water at \$0.85-\$ 0.93/m^3 (see Main Report, Section 6 and Table 6.2). The Mediterranean Sea–Dead Sea alternative would deliver water at 86 percent of the best Red Sea–Dead Sea Tunnel alternative and at 65 percent of the cost of water via the Red Sea–Dead Sea Phased Pipeline.

However, these costs do not include the cost of a pilot project to test the mixing of Mediterranean Sea and Dead Sea waters. Since the southern Mediterranean Sea–Dead Sea alignment cannot accommodate a pilot project as an initial – integrated – phase, a pilot will be constructed independently of the project and this will increase the cost of the potable water and the seawater/brine discharges into the Dead Sea. These additional costs will depend on the scale of the pilot and could be substantial.

A northern alignment that could be used to transfer Mediterranean Sea water to the Dead Sea is not considered feasible because its course would pass through fertile valleys that overlay sensitive aquifers. This alignment would entail serious environmental risks associated with conveying salt water across tracts where groundwater is used to provide domestic and industrial water and some vital complementary irrigation services. Given this concern, the northern alternatives (TR1.3 and TR 1.4) involve an approach that includes desalination undertaken on the Mediterranean coast with freshwater being transferred to Amman and other areas by a pipeline.

The eastern outlet of the northern Mediterranean Sea–Dead Sea route would be near Naharayim–Bakura, at the confluence of the Yarmouk and Jordan Rivers. From Naharayim–Bakura the water could be conveyed straight to Amman, by expanding existing conveyance infrastructure, or it could flow along part of the Lower Jordan River, and then be captured, treated and conveyed to Amman. The northern Mediterranean Sea–Dead Sea alignment delivers potable water to Amman at costs between US\$1.14/m^3 and US\$1.38/m^3, which compares favourably with the Red Sea–Dead Sea costs of US\$1.11/m^3–US\$1.5/m^3.

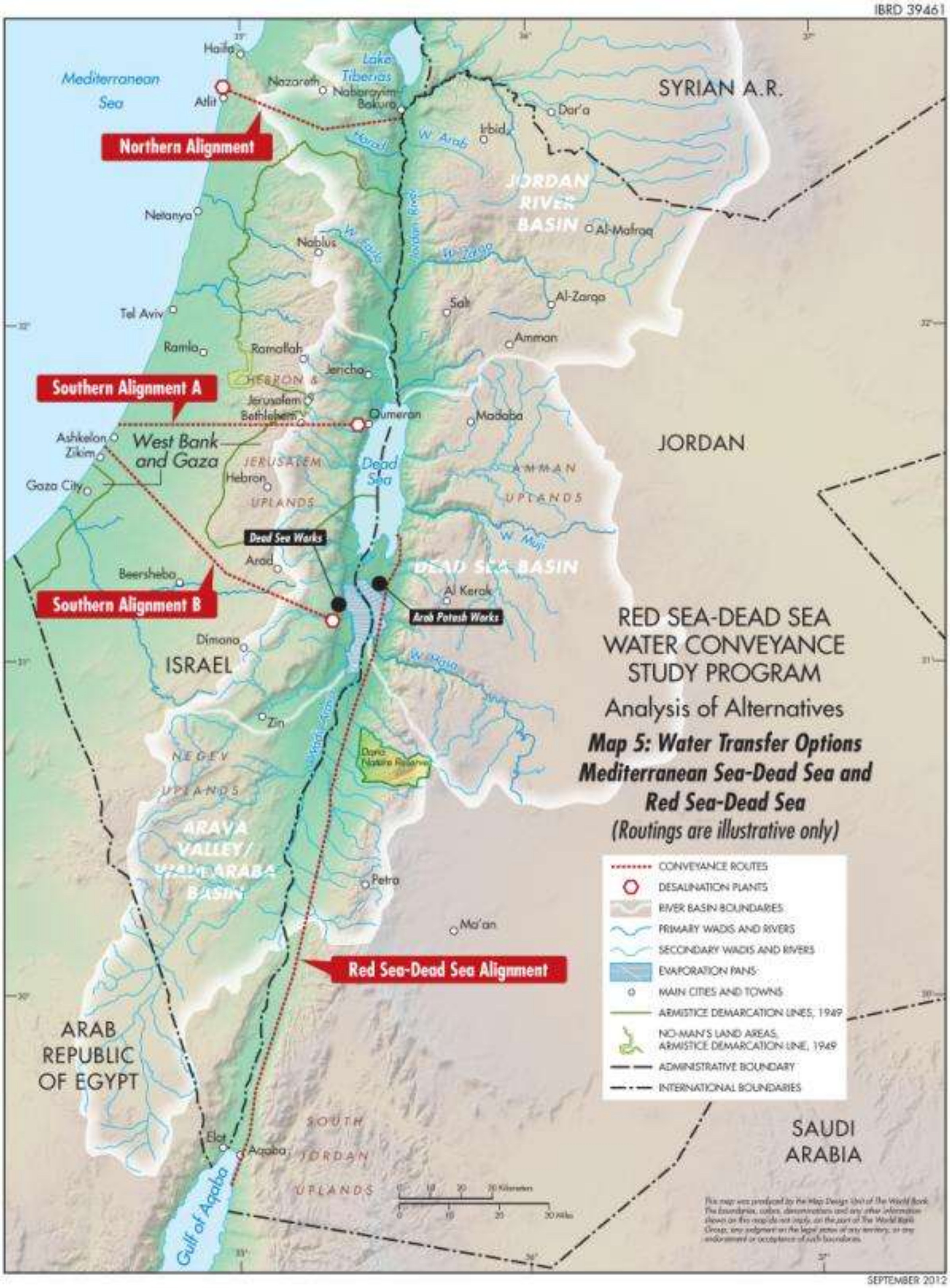
Transfer of Water from Turkey by Land Pipeline (TR2 – see Map 6)
The reliability of supplies of potable water in Turkey is the key issue. Nearly twenty years ago, when a version of a Seyhan-Ceyhan sourced Peace Pipeline was being proposed, it was assumed that there would be 2 BCM/year of reliably available water in the Seyhan-Ceyhan Rivers–near the city of Adana in southeastern Turkey (see Map 6). Transfer of 2 BCM/year of water annually would have been sufficient to address two of the Study Program objectives described above. However, 2 BCM/year are no longer available in the opinion of Turkish officials and scientists who met with the Study of Alternatives Team.

The cost estimates in pre-feasibility studies of previously proposed land pipelines are not robust nor are they up-to-date. At this point the costs of delivering potable water by land from Turkey would not seem to be competitive with well installed and managed desalination systems located in the Beneficiary Parties.

The environmental risks and impacts of water piped from Turkey would be low as the water being conveyed would be high quality water rather than sea water or brine. Social impacts would need to be carefully evaluated given the diversity of settlement patterns and land use along the alignment. Measures would also need to be taken to avoid or minimize potential impacts to cultural heritage along the alignment. Cumulative impacts would exist from the transfer of water from the Seyhan and Ceyhan Rivers ecosystems downstream of the point from which water is withdrawn and extend to the Mediterranean coastal zone. Management of potential environmental and social impacts would require actions to be taken by Turkey, Syria and Jordan within their respective territories.

Transfer of Water from the Euphrates River (TR3 – see Map 6)
A structure to convey reasonably high quality water from the Euphrates River in Iraq would be technically and economically feasible. But the volume of water – 160 MCM/year proposed in studies undertaken in the 1990s – would be too small even to address the volumes of potable water needed in the Jordan Basin. Water from the Euphrates River would not address Dead Sea restoration and could only provide supplemental potable water supply for Jordan. Today, Iraq cannot spare any water from the Euphrates River as the flow has been significantly reduced as a consequence of water abstraction from the river in Turkey, Syria and Iraq.

A Euphrates River pipeline from Iraq would be technically feasible. Its water would be lower cost than water conveyed from Turkey and competitive with desalinated water delivered to Amman by a Red Sea–Dead Sea Water Conveyance. Its direct social impacts in Iraq would be limited as the alignment has very few settlements while in Jordan there is extremely limited settlement along the alignment until it reaches the Amman urban area. Measures would need to be taken in both Iraq and Jordan to avoid or minimize potential impacts on cultural heritage along the alignment. Cumulative impacts would exist from the transfer of water from the Euphrates ecosystem downstream of the point from which water is withdrawn. In Jordan there could be positive impacts as there would be more potable water available to users and a potential for introduced water to partially reflow into the Dead Sea basin.



IBRD 39461
RED SEA-DEAD SEA
WATER CONVEYANCE
STUDY PROGRAM
Analysis of Alternatives
Map 5: Water Transfer Options
Mediterranean Sea-Dead Sea and
Red Sea-Dead Sea
(Routings are illustrative only)
Northern Alignment
Southern Alignment A
Southern Alignment B
Red Sea-Dead Sea Alignment
Dead Sea Works
Arab Potash Works
Mediterranean Sea
SYRIAN A.R.
JORDAN
ISRAEL
West Bank and Gaza
ARAB REPUBLIC OF EGYPT
SAUDI ARABIA
JORDAN RIVER BASIN
DEAD SEA BASIN
Lake Tiberias
Dead Sea
Gulf of Aqaba
CONVEYANCE ROUTES
DESALINATION PLANTS
RIVER BASIN BOUNDARIES
PRIMARY WADIS AND RIVERS
SECONDARY WADIS AND RIVERS
EVAPORATION PANS
MAIN CITIES AND TOWNS
ARMISTICE DEMARCATION LINES, 1949
NO-MAN'S LAND AREAS, ARMISTICE DEMARCATION LINE, 1949
ADMINISTRATIVE BOUNDARY
INTERNATIONAL BOUNDARIES
SEPTEMBER 2012


IBRD 38119R
TURKEY
Adana
Aleppo
Transfer of water from Seyhan and Ceyhan Rivers in Turkey by pipeline
CYPRUS
SYRIAN ARAB REP.
LEBANON
Beirut
Mediterranean Sea
Damascus
IRAQ
Haifa
Northern Alignment
Transfer of water from the Euphrates River in Iraq by pipeline
Tel Aviv
Amman
West Bank and Gaza
Transfer of Mediterranean Sea water to Dead Sea Northern and Southern Alignments
Southern Alignments
ISRAEL
Dead Sea
JORDAN
ARAB REP. OF EGYPT
Transfer of Red Sea water to Dead Sea
RED SEA-DEAD SEA WATER CONVEYANCE STUDY PROGRAM
Analysis of Alternatives
Map 6: Water Transfer Options
(Routings are illustrative only)
SAUDI ARABIA
0 100 200 300 Kilometers
0 100 200 Miles
SEPTEMBER 2012

Desalination Options (DS1-DS4 – see Map 7)

Background for Desalination Alternatives (DS1-DS4). By 2014 Israel plans to have a desalination capacity of about 600 MCM/year. By 2020 the plan is to add an additional desalination capacity of 150 MCM/year that would bring the total capacity to 750 MCM/year. Israel plans to reach a total desalination capacity of up to 1,500 MCM/year by 2050 (Water and Sewage Authority, 2011). With support from the Union for the Mediterranean, the Palestinian Authority is examining the technical and financial feasibility of a desalination facility in Gaza capable of supplying up to 55 MCM/year. The cost of desalination in Israel ranges between US$0.7/$m^3$ in the Ashkelon desalination plant and US$0.54/$m^3$ in the Soreq plant (currently under construction), which can be used as a benchmark for any of the desalination options described below.

Desalination of Mediterranean Sea Water on the Mediterranean Coast with Transfer to the Lower Jordan River and Dead Sea Region (DS1)

This alternative involves increasing desalination capacity on the Mediterranean coast in northern Israel. Brine produced during the desalination process would be returned to the Mediterranean Sea and desalinated water would be distributed to the Beneficiary Parties and the Jordan River. Partial restoration of the Lower Jordan River using desalinated water is possible to a limited extent if implemented in conjunction with the goal of increasing the supply of potable water in Amman (see the northern alignment of Transfer from the Mediterranean Sea to the Dead Sea, TR1.3 and TR 1.4, above). It is the view of the Study of Alternatives Team that the use of potable water – from Lake Tiberias, from desalination plants or from other sources of natural potable water – for Dead Sea stabilization purpose would not be a viable or desirable strategy as long as the Beneficiary Parties experience acute shortages of potable water.

Transfer of Mediterranean Sea Water to the Jordan Valley for Local Desalination and Use in Lower Jordan River and Dead Sea Region (DS2)

This alternative is similar to DS1 except that the seawater extracted from the Mediterranean coast is transferred inland by pipeline/tunnel/channel for desalination in the Jordan Valley. The brine from this process would then be transferred by pipeline (or channel) to the Dead Sea. The Samuel Neaman Institute examined an option consistent with this alternative. It involved transferring 2,000 MCM/year of sea water from the Mediterranean south of Haifa to the Naharayim–Beit She'an area. This would produce 800 MCM/year of high quality desalinated water that could be supplied to Jordan. The brine from the process (1,200 MCM/year) would be transferred to the Dead Sea by canal or pipeline. This process would involve transferring seawater and brine across aquifers that are used for provide potable water so the alternative would present considerable environmental risk. Total net running costs were estimated at US$875 million per year and the total investment cost at US$5,710 million.

In the view of the Study of Alternatives Team, this alternative is problematic because the course of the water conveyance would pass through fertile valleys that overlay sensitive aquifers, thus entailing environmental risks associated with conveying salt water across tracts where groundwater is used to provide domestic and industrial water and some vital complementary irrigation services.

Increased Desalination of Mediterranean Sea Water on the Mediterranean Coast with Transfer for Use by the Three Beneficiary Parties to Reduce Water Demand from Lower Jordan River (DS3)

This alternative would involve increasing desalination capacity on the Mediterranean coast of Israel and Gaza by constructing new desalination plants and the upgrade of existing plants. This alternative overlaps with other desalination alternatives discussed above. Israeli authorities are considering plans to increase desalination capacity along the Mediterranean coast to 1.5 BCM /year by the year 2050 to meet the domestic water needs in Israel and the Palestinian Authority. This quantity could be increased to meet some of the urban water needs of Jordan as well, both (i) by reducing the pumping from Lake Tiberias to the Israeli National Water Carrier and accordingly increasing the allocation of Lake Tiberias water to Jordan, and (ii) by transferring water desalinated near Haifa to Amman via Naharayim-Bakura (see the northern alignment of the Mediterranean Transfer Alternative TR.3, TR.4 above). In addition, the Palestinian Authority is working with the European Union and other donors for the development of a 55 MCM/year desalination plant in Gaza (Secretariat of the Union for the

Mediterranean, 14 May 2011).

Desalination of Red Sea Water at the Gulf of Aqaba/Eilat with Transfer for Use by the Three Beneficiary Parties to Reduce Water Demand from Lower Jordan River (DS4)
This alternative would involve either: (i) establishing desalination capacity on the shore of the Gulf of Aqaba/Eilat and transferring desalinated water from the Red Sea coast to the three Beneficiary Parties, and would include brine transfer to the Dead Sea; or (ii) transferring sea water to the Dead Sea for desalination and sharing the desalinated water among the Beneficiary Parties.

The cost of desalination in Aqaba and conveyance to Amman is about US$2 per m^3 under this approach. The cost of desalination in Aqaba and conveyance to the densely populated areas of Israel and the Palestinian Authority would be about the same. This US$2 per m^3 cost would be considerably larger than the cost of desalination along the Mediterranean Sea and conveyance to the three Beneficiary Parties or the cost of the Red Sea–Dead Sea Water Conveyance. This alternative would provide an appropriate approach to increase the supply of potable water in the Aqaba/Eilat region.

Jordan Red Sea Project (Not Included in the Terms of Reference)
The Jordan Red Sea Project is an alternative that was not included in the Terms of Reference for the Study of Alternatives, but it has become a well known alternative in the last two years. This alternative would be a “Jordan only” initiative and would not involve Israel or the Palestinian Authority (see Box 4.1 in Main Report). It would consist of 5 phases and ultimately would aim to abstract 2,150 MCM/year of seawater from the Gulf of Aqaba, partially desalinate this volume to produce 80 MCM/year of potable water in the Aqaba area, and then convey the remaining seawater and brine by pipeline for desalination at the Dead Sea in order to produce a further 850 MCM/year of potable water. A total of up to 1,220 MCM/year would be discharged to the Dead Sea. Phase I, possibly for completion in 2018, would produce 250 MCM/year of desalinated water and 190 MCM/year of Dead Sea discharge.

Technical and Water Conservation Options (TC1-TC4)

Change of Technology Used by the Dead Sea Chemical Industry (TC1)
The Study of Alternatives Team is unaware of any new technologies being used to significantly reduce the water consumption per ton of produced potash by the Dead Sea chemical industries. Because neither of the industries in Israel or in Jordan is currently required to pay for their consumption of water from the Dead Sea, there are no incentives in place to develop or adopt more efficient water using technologies. A mechanism of resource use fees, proportionate with their water consumption, should be considered to create such an incentive.

A Friends of the Earth Middle East study (FoEME, 2012) has reported that there is international research being carried out to increase water use efficiency at the Dead Sea chemical companies. The study also strongly recommended the introduction of metering to record water use to which a charge for water could be related (see Box 9.1).

Increased Water Conservation in the Lower Jordan River Basin (TC2)
In 2010, Israel’s agriculture, industrial and environmental sectors used 664.3 MCM of marginal water (recycled, saline and flood), of which 416.8 MCM came from sewage treatment plants – recycled water. Jordan currently recovers about 84 MCM/year. As urban water consumption increases within all three Beneficiaries, the potential for expanded wastewater treatment increases. Over the period 2007-2009, the Israeli Water Authority increased the water tariffs for domestic and industrial users in Israel. Data from the Israeli Water Authority (Israeli Water Authority 2012) estimate that the recent reduction in domestic consumption in Israel following the increases in tariffs brought an annual reduction in use of over 10 percent, about 100 MCM annually. This volume is equivalent to a large scale desalination plant or two-thirds of the net volume required annually to operate the Dead Sea Works and is approximately the net amount of Dead Sea water used annually by the Arab Potash Company. This recent experience demonstrates the importance of water pricing. When set properly, and introduced carefully, water prices generate the right incentives to use water efficiently and minimize the unaccounted water losses that result from badly maintained infrastructure. It is clear that there is considerable scope for further conservation.

Increased Use of Treated Wastewater and Greywater (TC3)

Water could be conserved in the municipal, industrial and domestic sectors through the increased use of treated wastewater. For example, in Israel the use of fresh/potable water in irrigation has been reduced from 896.8 MCM in 1995 to 490.7 MCM in 2008 (see data on website of Israel's Water Authority) – a reduction of almost 50 percent – and the allocations of natural water to irrigation will continue to decline. This volume is significant in any policy that aims to secure water and the sustainability of the environmental services of water in the Jordan Basin.

The re-use of water in the municipal (gardening), industrial and domestic (greywater) sectors is also water conserving. The achievements in installing these technologies and related regulatory regimes in the Beneficiary Parties are impressive in global terms. It is increasingly recognized that one cubic meter of water utilized in high value activities should be counted as 1.5–1.7 cubic meters as a consequence of re-use (Cohen et al, 2008). This principle applies to any water produced by a Red Sea–Dead Sea desalination plant and all the desalination plants associated with other alternatives.

Changes in Crop Type and Cultivation Methods (TC4)

This alternative aims to reduce the amount of high value potable water allocated to watering low value crops. Water savings would be achieved by modifying cropping patterns and changing tariff thresholds. The potential for water conservation in the irrigation sectors of the three Beneficiary Parties is currently substantial (see Gafny et al, 2010 and Gorskaya et al, 2010). The shift from fresh water irrigation farming to an irrigation sector based on recycled water is quite involved, entailing changes in crop mix, cultivation methods as well as improved marketing. In Israel, there has been a successful shift driven by water allocation measures based on quotas and pricing. First, the price of irrigation water has been gradually increased and water quotas reduced to reflect the scarcity of natural water. Secondly, the supply of recycled water has been steadily increased, as all residential sewage is collected and treated and the recycled water is conveyed to irrigated areas. This ongoing process has been facilitated, subsidized and regulated by the government.

The Israeli experience shows that the gradual implementation of water re-allocation policies can be highly effective and can increase the efficient use of scarce water. These measures have been based on quotas and pricing coupled with accessible extension services. They have helped farmers make the necessary transition to changing their crop mix and their cultivation and irrigation methods.

Additional Alternatives Identified by the Consultants (AA1-AA3)

The following additional alternatives are discussed that provide partial contributions to meeting the objectives of the Study Program:

Selling Electricity to Israel and Pumped Storage (AA1)

This alternative would be undertaken in addition to the Red Sea–Dead Sea Water Conveyance (BC1, BC2) to put in place infrastructure and international management contracts that would enable the use of pumped storage in Israel or Jordan to generate electricity. The Red Sea–Dead Sea Water Conveyance and the alternatives that would involve lifting and conveying water over long distances, such as the Mediterranean Sea–Dead Sea alternatives, would be subject to the cost of energy. As the Red Sea–Dead Sea Water Conveyance and the other conveyance alternatives would require more energy for operation than they would generate from associated hydropower installations there is a big incentive to examine the economic impact of selling project electricity during periods when the tariffs would be high in Israel and using electricity from the grid when the tariffs are low.

Transfers by Tanker, Bag, Submarine Pipeline from Turkey (AA2)

This alternative involves water conveyance from the Seyhan and Ceyhan Rivers and/or from the Manavgat area in Turkey by means of tankering, floating bags or sub-marine pipeline. Turkey is very interested to sell potable water to recover some or all of the costs from its major investment in the facilities at Manavgat. The volumes of water available from the Manavgat River – with an annual average river flow of over 4 BCM/year (DSI, 1999) and an existing export facility capacity of 400 MCM/year – would be significant to meet potable water demands.

Major uncertainties have emerged concerning the availability of sufficient quantities of water from Seyhan-Ceyhan Rivers, which had been a prominent potential source in the past. The sea-borne conveyance of water by tanker, bag or submarine pipeline from Turkey would not address the stabilization of the Dead Sea; however, it could provide an incremental supply of high quality potable water that would indirectly contribute to Lower Jordan River restoration and Dead Sea stabilization via reuse of more than 50 percent of the imported water.

Submarine Pipelines Associated with Oil and Energy Conveyance-Medstream (AA3)
Water would be one of the resources conveyed by the Medstream Submarine Pipeline from Turkey. The volumes of water to be conveyed have not been firmly established. The volumes would not be sufficient to restore the Dead Sea. They would contribute to the regional demand for potable water.

Combination of Alternatives (CA1-CA4)

The Terms of Reference require that "a range of combinations of alternatives be examined to assess the benefits of such an approach." The study examines four of a potentially very large number of combined alternatives. These alternatives include:

Combination No. 1. Desalination at Aqaba and Mediterranean Sea, Water Importation from Turkey, and Water Recycling and Conservation (CA1)
This combination of alternatives takes a longer perspective of at least three or more decades and could be implemented incrementally by the Beneficiary Parties. An incremental approach has a number of advantages. First, it can be flexible and responsive especially to technological advances. Secondly, the approach would usually be more fundable than one that would require a very big up-front investment.

Thirdly, it addresses both the objective of restoring the Dead Sea and the objective of providing potable desalinated water for use mainly in Amman. Fourthly, it has the potential to do so without the need for a major sea to sea conveyance. Fifthly, and very importantly, it would also avoid the risks of mixing Red Sea or Mediterranean Sea waters with Dead Sea water. Last, it would avoid the expensive pilot study that would be a necessary to undertake in advance of proceeding to a full scale sea to sea conveyance of water.

At the same time this alternative would certainly require, and could promote, close and sustained cooperation between the Beneficiary Parties via a suite of complementary planning, management and investment actions.

Recent experience in Israel has demonstrated that municipal and industrial water can be effectively recycled to provide strategic volumes of water suitable for irrigation and environmental restoration purposes. It is anticipated here that over a period of three or more decades the same policies could be implemented in Jordan. Jordan currently recovers about 84 MCM/year from the treatment of wastewater and uses this water to supplement its water supply principally for the irrigation of suitable crops. It is estimated by the Study of Alternatives Team that three to four decades from now, the total allocation of water for urban water consumption in Jordan will be about 1.2 BCM/year. This would consist of the following:

- ***Natural water –*** use of existing water allocation in Jordan. 350 MCM of the existing river water allocation (Jordan Water Strategy JWS, 2008-2022);
- ***Reallocated water –*** reallocation of water from irrigation to urban use in Jordan. 300 MCM/year that would be re-allocated from irrigation to urban use;
- ***Water from improved management in Jordan*** – technical measures and water user behavior changes – including reduced leakage and unaccounted water (loss) by the implementation of technical measures and the introduction of appropriate water tariffs and other conservation incentives; 100 – 200 MCM/year.

- ***New water in Jordan***:
  - *Additional water* from Lake Tiberias (100 - 200 MCM/year), desalination in Aqaba 100 MCM/year), desalination along the northern Mediterranean coast, and/or water importation from Turkey -Manavgat (400 MCM/year); and
  - *Recycling urban water.* 60 percent of the total annual urban allocation of 1.2 BCM could be recycled to generate 720 MCM/year of treated water.

Under this combined alternative it would be possible to meet the potable water needs of Jordan and stop the decline of the Dead Sea by partially restoring the flow of the Lower Jordan River. The following measures would have to be implemented in order to gain the acceptance of irrigators in Jordan: 300 MCM/year of the 720 MCM/year of recycled water would be allocated to irrigation in Jordan to replace the natural water that would be taken away from the irrigation sector for urban uses. The remaining water – about 400 MCM/year – would be available for the restoration of both the Lower Jordan River and the Dead Sea.

A similar approach in Israel and the Palestinian Authority would provide an additional supply of recycled water of about 600 MCM/year over and above recycled water allocated for irrigation. This water could be used for the restoration of the Lower Jordan River and the Dead Sea after future demands for irrigation water have been satisfied.

In about 30–40 years, the residual supply of recycled water – net of the recycled water allocated for irrigation – would potentially provide about 800-1,000 MCM/year of recycled water for environmental restoration. These changes in water use could be incrementally achieved and would provide sufficient water to restore the lower Jordan River and stabilize the level of the Dead Sea above its current level.

Combinations No. 2. Decreased Chemical Industry Water Extraction and Decreased Irrigation through Cropping and Other Agronomic Changes (CA2)
This combined alternative would result from reductions of water used in the Dead Sea chemical industries. The Israeli experience shows that significant volumes of natural water can be saved in both irrigation and municipal and industrial uses. This combination was chosen for analysis because: (i) the chemical companies would likely lower the Dead Sea extractions if a per cubic meter fee for Dead Sea water was assessed; and (ii) cropping pattern reform has been under discussion in the region for some time and the arguments and alternatives are familiar, even if difficult.

Combinations No. 3. Aqaba Desalination Plus Decreased Use from the Chemical Industries, Plus Increases in Recycled Water for Irrigation (CA3)
This combination of alternatives was chosen for analysis because: (i) a desalination plant has been discussed under both the Red Sea–Dead Sea Study Program and the Jordan Red Sea Project; (ii) the cold crystallization process (or another process) now being implemented by the potash companies may prove possible to make more efficient over the short term; and (iii) there is already substantial use of recycled water for irrigation in both Israel and Jordan and it appears at least possible that an even larger increase in the use of this resource is feasible.

Combination No. 4. Reduced Extractions from the Jordan River, plus Aqaba Regional Desalination and Decreased Irrigation Use though Agronomic Changes (CA4)

- This combination of alternatives was chosen for analysis because: (i) reduced extractions from the Lower Jordan River could be accomplished through a variety of measures including cropping/agronomic changes, increased use of recycled water or irrigation technology changes; and (ii) a desalination plant in the Aqaba area is under discussion as part of the proposed Jordan Red Sea Project.

The combination alternatives CA2-4 could make some, but not strategic, contributions to the provision of potable water and/or water for environmental purposes. If all the elements of the combination alternatives were implemented 100-200 MCM/year of high quality water could be added, more than 200 MCM/year of re-used effluent could be devoted to irrigation and about the same quantity of water could be devoted to the environmental services of water – such as restoring the flows of the Lower Jordan and the level of the Dead Sea (see Table ES.1). These are all significant alternatives in a two decade perspective; however, they would not provide longer-term reliability of water.

3. Comparative Review of Alternatives

A Framework for Review of Alternatives. A comparative review of the wide range of alternatives that have been considered in the Study of Alternatives is provided below. It enables broad comparisons of individual and combined options in a form helpful to decision makers and the public. The Study of Alternatives is designed to evaluate and compare the various alternatives according to the following criteria:

- Dead Sea stabilization or restoration;
- Production of new potable water to be shared in the Region;
- Demonstrated cooperation among the Beneficiary Parties;
- Costs of construction and operation; and
- Potential environmental and social impacts.

The capacity of the alternatives to produce hydropower is not given significant weight as the Red Sea – Dead Sea Water Conveyance and nearly all the potential alternatives are require more energy than they produce.

Up to this point the analysis has been carried out according to the structure set out in the Terms of Reference. The comparative review of alternatives in this section has adopted a simplified classification of the alternatives. The classification is twofold, based on the extent to which an alternative or a combined alternative either comprehensively addresses the three objectives of the Red Sea–Dead Sea Water Conveyance, or only partially addresses them. As the analysis progressed it became clear that the partial alternatives all had the characteristic of providing incremental solutions. This second class of alternatives is referred to as both partial and incremental alternatives.

The Alternatives

No Action Alternative. The no action alternative is described in detail in both the Feasibility Study (Coyne et Bellier, 2012) and the Environmental and Social Assessment Study (ERM, 2012). Both conclude that this scenario involves substantial and adverse changes to the Dead Sea and its surrounding environment. By the year 2070 the area of the Dead Sea would decrease by an additional 16 percent, or a cumulative decrease of 40 percent from the level in the early 1900s. Under this alternative, the chemical industries would also eventually go out of business incurring another substantial reduction in regional GDP. If the chemical industries halt production within the next few decades, then the Dead Sea would eventually stabilize under the no action alternative at about minus 515 mbsl, or almost 100 meters lower than today's level.

Comprehensive Alternatives. Two alternatives and one combination of alternatives have been identified that would comprehensively address all the five criteria described above. These are:

- BC1 – Red Sea–Dead Sea Water Conveyance Base Case Plus;
- TR1 – The Mediterranean Sea–Dead Sea Water Conveyance – Southern A; and

- CA1 – Combination No.1 Desalination at Aqaba and Mediterranean Sea, Water Importation from Turkey and Water Recycling and Conservation.

The Mediterranean Sea–Dead Sea Conveyance addresses all the key technical features and is anticipated to have a lower cost; however, it may prove to be significantly more challenging to set in place the necessary multiple cooperative agreements necessary to gain support for and implement this alternative. It should be noted that the first two alternatives above are anticipated to need a pilot program to physically test the mixing of either Red Sea or Mediterranean Sea waters with Dead Sea waters, which would require significant expenditures and adequate time to conduct and evaluate. An advantage of the Red Sea–Dead Sea Phased Pipeline (PPL) Alternative over the Mediterranean Sea–Dead Sea southern alignment (Gravity Tunnel) is that the former could accommodate a pilot as an integrated phase whereas for the latter a pilot must be constructed independently of this alternative. The added pilot cost could therefore be much larger for the Mediterranean Sea–Dead Sea Southern alignment than for the Red Sea–Dead Sea PPL project. Even with the added pilot cost, the cost of seawater/brine discharge into the Dead Sea and of desalinated water in Amman is likely to be considerably smaller for the Mediterranean Sea–Dead Sea southern alignment than for the Red Sea–Dead Sea Phased Pipeline.

Non-Comprehensive Alternatives. Nineteen alternatives were also examined that do not comprehensively meet the five criteria described above. They include those identified in previous studies, raised by other parties or proposed by the Study of Alternatives Team, along with combinations of the above. Information available for these alternatives is sometimes limited and often dated. However, it is worth noting that many of these “non-comprehensive” alternatives may be more technically and economically attractive for investors and easier for the parties to implement.

Comprehensive Alternatives – Red Sea–Dead Sea Water Conveyance (BC1), Mediterranean–Dead Sea Conveyance (TR1) and Combination Alternative No. 1 (CA1)

Both the Red Sea–Dead Sea Water Conveyance Base Case Plus and the Mediterranean–Dead Sea Conveyance Southern A alternatives would be iconic hydraulic infrastructure projects of regional and global significance. Both would address the first three criteria identified above. They would restore the level of the Dead Sea without imposing unacceptable ecosystem costs except for the uncertainty of impacts on the Dead Sea consequent on the importation and mixing of alien brine from Red Sea or Mediterranean Sea water. The precautionary option of progressive development of the comprehensive alternatives via pilot phases would add significantly to the capital costs for both alignments. Both conveyances would enable the delivery of potable water to the Beneficiary Parties. Both conveyances would also require and enhance cooperation.

Potable water from the Red Sea–Dead Sea Low Level Gravity Tunnel would be \$1.11-1.24/m^3 or \$1.33-1.50/m^3 by the Red Sea–Dead Sea Phased Pipeline. Potable water delivered by the Mediterranean Sea – Dead Sea conveyance would be \$0.85-\$0.93/m^3. The Mediterranean Sea–Dead Sea alternative would deliver water at 86 percent of the best Red Sea–Dead Sea LLGT alternative and at 65 percent of the cost of water via the Red Sea–Dead Sea Phased Pipeline. The comprehensive alternatives require land for water-handling plants, desalination and hydropower plants and, in the case of the pipeline options, land for the conveyance structures. The construction phase would be locally disruptive in all cases, yet long-term negative environmental impacts would be modest after mitigation. Social impacts would not be significantly negative after mitigation.

From a cost standpoint, the Mediterranean Sea–Dead Sea Conveyance would be the preferred alternative. The region’s immediate need to augment potable water supplies could encourage the required tri-lateral cooperation to put this into place. The significant environmental and social impacts of the two comprehensive alternatives, subject to a successful pilot of the impacts of Dead Sea mixing, could be mitigated. However, and even with appropriate mitigation measures, during construction there would be short term major environmental and social impacts. With proper mitigation and competent management, there would be minimal but permanent post construction environmental and social impacts. See Tables ES.3 and ES.4 below.

One of the Combination Alternatives (CA1) addresses all three objectives – it would save the Dead Sea, meet potable water needs and promote cooperation. Combination CA1 proposes desalination at Aqaba and at the Mediterranean Sea, water importation from Turkey, and substantial water recycling and conservation. The time scale of this alternative would be three or more decades. But this period is only somewhat longer than the time required to prepare, complete pilot studies, plan and construct the Red Sea – Dead Sea Water Conveyance. The regional cooperation aspects of this alternative, are, of course, particularly complex and challenging. In addition, the long-term availability of the large-scale importation of water from Turkey would need to be confirmed.

Non-Comprehensive Alternatives

While none of the non-comprehensive alternatives in this report would totally restore the level of the Dead Sea to the target level of about 416 meters below sea level, they could nevertheless play an incremental role in stabilizing it above its current level. They represent measures that taken individually or alone could have a positive incremental impact on the condition of the Dead Sea. Two of the technical and water conservation options – TC1, changes in technology of the Dead Sea industries and TC2, increased water conservation in the Lower Jordan – if effectively managed, would deliver additional volumes of water to the Dead Sea but the volumes would have insignificant restoration impacts. The same is the case for the Combined Alternatives, which would include: in the case of CA2 reduced water use by the chemical industries and decreased irrigation; in CA3 reduced water use by the chemical industries and increased recycled water; and in CA4 reduced use of Jordan water and reductions in use of water for irrigation. Again the volumes of water that would potentially flow to the Dead Sea would have negligible impact on Dead Sea levels.

Many of the non-comprehensive alternatives could play a very significant role in providing additional potable water to be shared in the region by making incremental improvements in the availability of potable water. All of the desalination options would provide additional potable water via projects where the construction costs and the costs per cubic meter of potable water would be in line with the current state-of-the-art desalination plants. Since the inception of the Red Sea–Dead Sea Study Program, Israel has installed or has under construction desalination capacity of 600 MCM/year. A total capacity of 750 MCM/year is planned to be installed by 2020. But other sources of desalinated water would have to be mobilized over the longer term.

Estimates of the costs of the non-comprehensive alternatives are inadequate to enable precise comparison. However, as they mainly comprise proposed projects that would deliver desalinated water from state-of-the-art plants where the costs of desalinated water are well known, it can be assumed that the capital costs of the proposed desalination plants and the prices of the potable water produced would be acceptable to funders.

The "after mitigation" environmental and social impacts of the non-comprehensive alternatives would be at worst moderate. In many cases, an alternative would improve the current situation. However, as with the comprehensive alternatives, during the construction of many of the non-comprehensive alternatives there would be major short-term environmental and social impacts. Even with proper mitigation and competent management, for most alternatives there would be minimal but permanent post construction environmental and social impacts.

Cooperation: Important for the Beneficiary Parties, Funders, Donors and Investors

Political Acceptability Is Beyond the Scope of the Study of Alternatives. It is beyond the scope of the Study of Alternatives to assess political acceptability of various alternatives on an individual or comparative basis. In the end it is the Beneficiary Parties that will need to make their own assessments and decisions concerning the complex political issues that would need to be addressed to proceed with the Red Sea–Dead Sea Water Conveyance, other individual alternatives or a combination of alternatives. The outcome of such processes will determine in part how much the Study Program is able to "build a symbol of peace and cooperation in the Middle East."

The Study Program – A Reflection of Cooperation. The Study Program reflects the sustained existence of a cooperative platform established by the Beneficiary Parties to examine potential options to address the challenges of managing the Dead Sea, generating hydropower and producing additional potable water through desalination. The Study of Alternatives expands this process by looking at a range of alternatives beyond the Red Sea–Dead Sea Water Conveyance. Going forward the Beneficiary Parties will need to redefine and renew their platform for cooperation, demonstrating to potential donors and investors, as well as other stakeholders, that there is a long-term commitment to the cooperative management and investment actions that would need to be undertaken.

Importance of Cooperative Frameworks. The Beneficiary Parties will need a variety of cooperative frameworks between governments and/or inter-governmental agreements in order to move from planning to action on the ground to address the diverse challenges of managing the Dead Sea. Such agreements would be required for the development, construction and operation of the infrastructure interventions proposed in many of the alternatives considered in the Study of Alternatives. Mobilization of resources from both public and private sources will require clear and formal arrangements and in many cases, such arrangements will need to be transparent in nature and accessible by investors, donors and the public.

Need for Significant and Sustained Cooperation. All the alternatives examined in this Study of Alternatives would require significant and sustained cooperation among the Beneficiary Parties. The three comprehensive alternatives would promote the deepest cooperation. The international funding bodies that may be called upon to fund the alternatives would require agreement of all the Beneficiary Parties, especially for any alternative that would bring about discharges of brine into the Dead Sea or any projects that would involve moving brine or potable water across the territory of one Beneficiary Party to another.

Elements of Successful Cooperation. Large complex programs of action such as those under consideration require the development of a shared vision among the cooperating parties and key stakeholders that allows for a sustained approach to meeting long-term objectives. The success of cooperation rests on a variety of elements, including: a public commitment to cooperate on a sustained basis; development of a framework for cooperation; and the ability of cooperating parties to adapt to changes that may occur. Beyond these features, in the context of the Dead Sea it would be necessary for the cooperating parties to make use of new management approaches as they evolve, effectively adopt and successful use policy and economic instruments including economic incentives; and have a willingness to apply new technologies and methods at a variety of levels and for diverse purposes.

Approach Used in the Study of Alternatives. The methodology adopted in the Study of Alternatives has been to examine the options on the assumption that the concerned parties will be willing to cooperate to implement them. At the same time, it is necessary to recognize that there are significant risks that some or all parties may not be willing to be cooperative on a sustained basis or at all. These risks to cooperation increase with the number of parties involved, the complexity of actions requiring cooperation and the funding needs for investment and operating costs. The Study of Alternatives Team, in the analysis of alternatives and their comparative review has provided comments concerning these factors in the text and the tables of pros and cons. This has allowed the Team to highlight both the challenges and the opportunities for cooperation associated with a range of alternatives.

Environmental, Social and Cultural Heritage Impacts and Risks

Environmental, Social and Cultural Heritage Impacts and Risks. All alternatives, including the "No Action" alternative, present potential positive and negative environmental, social and/or cultural heritage impacts of varying types and significance. Table 2.1 in the main report provides a summary of the studies prepared for potential alternatives over the years. The level of information on environmental, social and cultural heritage aspects of these alternatives is highly variable in nature, ranging from detailed impact assessment studies that have been subject to public consultation and disclosure through studies that only give consideration to engineering and economic aspects.

The potential impacts and risks from the alternatives are summarized in Table ES.3, which provides a broad comparison of all alternatives from a variety of perspectives. This table is complemented by Tables ES.4 and ES.5, which provide an overview of the spatial distribution and magnitude of environmental and social issues whose zones of influence are shown in Map 8. These tables use the same qualitative rating approach as was adopted by ERM (2012) for the Environmental and Social Assessment of the Red Sea – Dead Sea Water Conveyance (Box ES.5).

A Variety of Locations and Types of Impacts. As illustrated in Map 9, some alternatives under consideration have potential impacts that may occur over large areas with significant differences in environmental or social conditions. The potential impacts of other alternatives may be more localized. The types of impacts and risks include direct impacts associated with the action, as well as indirect impacts that may be caused or induced by the action. In addition, consideration needs to be given in the selection of an alternative or a combination of alternatives to the potential cumulative impacts of the proposed action with other planned or anticipated actions that may occur in the area of influence, including the need for associated infrastructure and other types of facilities. It should be noted that most alternatives involving construction of infrastructure can provide significant flexibility at the local level in terms of siting facilities, such as desalination plants, or alignment, such as for pipelines. This flexibility allows for development of designs that avoid or reduce impacts on the environment, people and cultural heritage.

An Opportunity for Positive Impacts. Implementation of comprehensive, partial or combination alternatives have the potential to provide positive impacts including: (i) protection and restoration of a global public good by enhancing the status of the Dead Sea; (ii) increasing the availability and reliability of available water to Israel, Jordan and the Palestinian Authority; and (iii) providing opportunities for sustained cooperation between the Beneficiary Parties for resource management and social development. Measures to address the decline of the level of the Dead Sea are also anticipated to reduce the ongoing physical degradation of the areas adjacent to the shoreline, which suffer from land subsidence and the development of sinkholes. Not taking action to address the issue of improving the management and status of the Dead Sea in a timely manner presents a range of risks that need to be recognized when considering alternatives individually or in combination. It is also worth noting that many management related actions with limited impacts and risks could be taken that would partially contribute to both improving the Dead Sea and increasing water supply in the medium and long term.

Potential Modification of Ecosystems. Many of the alternatives reviewed in this study, including the Red Sea–Dead Sea Water Conveyance, Mediterranean Sea–Dead Sea water conveyance options and proposals for transfer of water from Turkey and Iraq would result in direct and indirect modification of ecosystems. The most complex potential impact would be the outcome of mixing variable amounts of Red Sea or Mediterranean Sea water and brine from desalination operations with the water in the Dead Sea. While this has been subject to a number of studies, including a major modeling study by Tahal (2011), given the major impacts and risks associated with these interventions, additional studies, including a physical pilot, are needed before any of these alternatives should move forward. In this regard, special consideration needs to be given to the impact on the chemical and tourism industries from changes in the composition of the water in the Dead Sea. The transfer of fresh water from external sources, such as Turkey or Iraq, using pipelines, tankers or other methods would also have impacts on the ecology of the river channel from which the water is abstracted and further downstream in coastal zones, by reducing the flow of water. In contrast, measures that facilitate the improvement of the quantity and quality of the water flows into the Lower Jordan River would support restoration of both the river and the Dead Sea.

Use of Desalination. With proper site selection and careful design of intakes, the physical and ecological impacts from large scale abstraction of sea water from either the Red Sea or the Mediterranean Sea should be able to be successfully managed. At the same time, desalination facilities require significant land whether they are located on the limited coastal zone of the Beneficiary Parties or at an inland site. Further, desalination requires significant amounts of energy, with associated impacts from generation, and involves the use of membranes and other materials that then need to be disposed of properly. The management of brine generated from the proposed desalination plants varies widely among alternatives, with some using the brine as a resource to recharge the Dead Sea and others disposing of it in the Mediterranean Sea. In the case of the Mediterranean Sea, impacts would vary depending on the sensitivity of the coastal and offshore environment at the proposed location and the design used for brine discharge. The impacts associated with alternatives involving desalination will vary depending on the sites for the intake, plant and discharge. The impacts from operation of the facilities should be generally viewed as directly proportional to the size and technology adopted for the plant(s).

Fresh Water, Sea Water and Brine Conveyance. The transfer of sea water, brine or freshwater through tunnels or pipelines presents potential impacts during construction and operation. The most important issue has been the need to properly assess seismic and other types of geological risks associated with construction and operation of pipelines and tunnels given the concern about their rupture and release of sea water or brine into heavily used aquifers. A concern raised by some parties has been the disruption of biological corridors during the construction period of pipelines and during operation if they are not buried. An additional concern has been impacts on local habitats from the disposal of tunnel excavation waste material. In addition, these investments will require involuntary resettlement and land acquisition that will vary in proportion to the length and alignment of the pipeline, as well as land for disposal of excavated material in the case of tunnels. Risks to cultural heritage also need to be addressed using field based surveys and chance find procedures. These issues under normal circumstances can be addressed by careful selection of the alignment to minimize or avoid impacts, the adoption of designs that provide for significant protection from leakage, and careful construction supervision, including environmental and social monitoring.

Water Management Measures and Use of Economic Incentives. Alternatives under review individually or in combination with others include measures for water conservation, increased use of treated wastewater and greywater, changes in crop types and use of economic incentives. These alternatives present actions that, if taken, could have positive impacts on the use of water resources, regardless of whether measures to manage the Dead Sea are included. The conservation of water and the expanded use of treated wastewater provide opportunities for enhanced surface and groundwater availability and quality. Changes in crop types and irrigation methods can also support a better water balance. The most significant potential benefits over the medium and long term, if successfully adopted and implemented, may result from the use of economic incentives to promote the conservation and more efficient use of water and Dead Sea brine. This would contribute to reduced use of water and brine allowing for a more stable Dead Sea and improvements in the Lower Jordan River.

Increasing the Availability and Reliability of Water. Numerous alternatives focus on supporting actions to increase the water available to the Beneficiary Parties. These alternatives include the creation of natural water through water transfers from outside sources such as Turkey and Iraq, while others focus on manufacturing water from desalination. There are major social benefits from increased availability of additional freshwater in the future including access to high quality water for domestic consumption as well as in the rapidly expanding tourism sector. Creating this new water, hence changing the water balance, creates important opportunities for economic activities and frees up lower quality water for other types of uses. Many remain concerned that there is a risk that additional water reduces incentives to increase water use efficiency; to avoid such an outcome would require a well planned outreach program and careful monitoring.

Diverse Social Impacts and Risks. The alternatives reviewed in the Study present diverse direct and indirect social impacts and risks. Consideration of social issues is an important element in determining the potential benefits and viability of an alternative and special consideration should be given to the differential impact on women, the needs of disadvantaged groups and social equity. While broad views of the potential social impacts of alternatives have been provided in Table 13.5, these issues can only be effectively assessed in detail at the project level using qualified social scientists working at the field level and engaging with communities.

Involuntary Resettlement and Land Acquisition. A major issue with a number of the alternatives under consideration, especially the water transfer and desalination alternatives, is the anticipated need for involuntary resettlement and land acquisition. While the government in many instances is the formal owner of the land, recognition needs to be given to often long established informal use of these lands by local communities and in some cases nomadic populations. Some alternatives, particularly those concerning conveyance from the Mediterranean Sea to the Dead Sea, pass through areas on the coast and inland that are heavily populated, in contrast to the sparse population living between the Red Sea and the Dead Sea, with the exception of the Aqaba/Eilat region. Implementing alternatives in more densely settled areas should be anticipated to be more complex in their planning and permitting, and more expensive with regard to compensation for land, structures and other losses. In all cases, it would be important to have site specific resettlement and land acquisition plans developed on the basis of a social assessment and consultation process and including a grievance mechanism to address disputes.

Regional Development and Employment. Alternatives that have been reviewed have a potential to support regional development, including tourism development, and generate employment during construction and operation. Potential benefits for tourism, especially at the Dead Sea, include improved conditions that lead to an incremental reversal of the decline of this unique resource. In contrast, significant adverse impacts could result from the discharge of brine into the Dead Sea without adequate knowledge regarding the potential for an aesthetically adverse reaction, which would lessen the amenity value of the region and reduce tourist interest. While local employment opportunities will be created by alternatives that involve construction activities, it will be important to manage public expectations in this regard. Construction activities as proposed would require a large number of workers during the construction and commissioning phases but would have limited needs for longer term employment during operations. All alternatives that involve construction will need to carefully manage the potential influx of foreign workers and associated risk of social conflict. In addition, induced environmental and social impacts, such as informal settlement adjacent to construction sites, presents a challenge that will need to be analyzed and controlled on a case by case basis.

Management of Health and Safety. All alternatives that involve building will require measures to manage the construction phase impacts and provisions to address the health and safety of local communities and workers (World Bank Group, Environment, Health and Safety Guidelines, 2007). Common problems include construction related impacts from nuisances and disturbances such as noise, vibration and dust that need to be carefully monitored and controlled by the government, contractors and others. Measures would also need to be taken to address health and safety of workers as a key element of planning and oversight during the construction period to protect them and others from a range of risks. All construction related activities should include provisions for the management of risk associated with HIV/AIDs. Potential impacts to health and safety should be anticipated to be proportional to the size of the construction program and the complexity of operating facilities that may be built to implement an alternative.

Cultural Heritage – A Special Issue. The protection and conservation of cultural heritage is a special issue that needs to be given significant consideration in the development and implementation of nearly every alternative reviewed in this study. This is a concern that is highly site specific and requires the conduct of field based surveys by qualified parties to determine the potential impacts and risks to cultural resources (World Bank 2009). While the importance of cultural heritage in the region is widely recognized it has not been a significant factor when parties have proposed and developed alternatives in the past. The Red Sea–Dead Sea Water Conveyance included the conduct of this type of survey as part of the Environmental and Social Assessment (ERM 2011). Other alternatives, to the knowledge of the Study of Alternatives Team, have not undertaken the field based surveys which would be needed to fully assess their potential impacts. Use of properly supervised "chance find procedures" would be needed, given the high concentration of cultural resources, both known and unknown, in areas where alternatives that involve construction or other activities would result in changes to the surface and immediate subsurface of land.

A Need for Management, Mitigation and Monitoring. A decision to proceed with one or more of the alternatives by the Beneficiary Parties would require development and implementation on a project specific basis of a robust and properly funded environmental and social management plan. The plan would be used to integrate these concerns into design, implementation and operation of the project or projects. This would include specific provisions for addressing these issues in the project budget and integrating key measures into the implementation schedule. Provisions should be included for implementation and monitoring of various types of measures for management and mitigation of potential adverse impacts by government agencies with specialized capacities. Where appropriate, use should be made of third party monitoring, which is an emerging good practice for complex projects.

Continued Use of an Independent Panel of Experts. Consistent with established international good practice, the use of an independent Panel of Experts should be continued if a decision is made by the Beneficiary Parties to proceed with further development and/or implementation of the alternatives reviewed in this study. The use of a Panel of Experts would be beneficial to all stakeholders given the complexity of the actions proposed under nearly all of the alternatives and the sensitive environmental and social setting and extensive cultural heritage in the region.

Comparative Tables

Table ES.1 – Summary Comparison by Selected Cost Criteria. The table compares each alternative against selected criteria in the Terms of Reference for the Study of Alternatives. It also calculates the cost of potable water in Amman for alternatives where such a calculation was possible. In addition, it shows a judgment in the form of a “Viability Assessment” for each element of the table which represents the subjective view of the Study of Alternatives Team on the difficulty of realization of this alternative.

Table ES.2 – Water Conveyance for Dead Sea Stabilization Only. The table provides a physical and cost description of the nine Dead Sea “stabilization only” alternatives. It includes the estimated construction costs and electricity potential for each option and an indication of the elevation profile.

Table ES.3 – Comparison of Alternatives. The table provides the reader with a visual presentation to compare each alternative as follows: (i) whether or not it can address the three Study Program objectives; (ii) an indication of its capital cost and energy requirements; and (iii) its potential environmental and social impacts both before and after mitigation measures.

Table ES.4 – Spatial Distribution and Magnitude of Potential Environmental Impacts. The table is organized by geographical location (see Map 8) and is designed to provide the reader with a visual representation of the potential environmental impacts and risks of the various alternatives. For example looking at the Dead Sea Coast, nearly all the alternatives, with the exception of the No Action alternative, would have a positive impact on this highly sensitive area.

Table ES.5 – Spatial Distribution and Magnitude of Potential Social Impacts. The table is organized by geographical location (see Map 8) and is designed to provide the reader with a visual representation of the potential social impacts and risks of the various alternatives. For example the “No Action” alternative has a major social impact on the Dead Sea Coast and Dead Sea. In contrast for many alternatives the social impact would be moderate or slight/none.

The assessment methodology is outlined in Box ES.5 below.

Box ES.5: Impact Assessment Methodology

Key: ● = positive; O= slight/none; ● = moderate; ● = major

The Study of Alternatives Team has reviewed the potential environmental and social impacts from the proposed alternatives, using the approach adopted by ERM for the Environmental and Social Assessment prepared for the Red Sea – Dead Sea Water Conveyance Study Program and providing ratings for both before and after adoption of mitigation measures.

The assessment has addressed impacts with different temporal characteristics (permanent impacts, temporary impacts, long-term impacts) and both routine impacts and non-routine impacts (i.e., those arising from unplanned or accidental events or external events).

Induced impacts, for example those caused by stimulating other developments to take place are also considered in the assessment, as are cumulative impacts with other developments taking place in the area at the same time.

The definition of these degrees of significance has been expressed in terms of design response as follows:

- Critical: the effect on a sensitive receptor is so severe as to be unacceptable (either because it breaches standards or norms relating to human health and livelihood, or causes irreversible damage to a valuable asset or resource) and mitigation is unlikely to change this;
- Major: the effect on a sensitive receptor must be mitigated, either because it breaches relevant standards, norms, guidelines or policy, or causes long-lasting damage to a valuable or scarce resource;
- Moderate: the effect on a sensitive receptor is either transient or mainly within currently accepted standards, etc., but should be mitigated to ensure that the effect does not become significant by virtue of cumulation or poor management;
- Slight/none: the effect is temporary, of low magnitude, within accepted standards etc, and of little concern to stakeholders; and
- Positive: The effect on the sensitive receptors is to improve their current state.

The Study of Alternatives Team, for the sake of consistency, has used the same approach to significance adopted for the Environmental and Social Assessment. As stated in the ESA, since there is no statutory or agreed definition of significance, for the purposes of this assessment, the following practical definition is used:

"An impact is significant if, in isolation or in combination with other impacts, it should, in the judgment of the Environmental and Social Assessment team, be reported in the Environmental and Social Assessment Report so that it can be taken into account in the decision on whether or not the Scheme should proceed and if so under what conditions."

Table ES.1: Alternatives Compared by Selected Cost Criteria (% is assumed annual cost of capital)

Alternative	Case	Comments	Potable Water in Amman: Quantity satisfies demand schedule?	Potable Water in Amman: Cost (>2060) (US$/m^3)	Water Discharge in the Dead Sea: Quantity sufficient to stabilize Dead Sea water level?	Water Discharge in the Dead Sea: Annual cost (US$million)	Viability Assess-ment*
No Action NA1			NA	> 2	No	NA	High
Red Sea - Dead Sea Water Conveyance	Low Level Gravity Tunnel BC1	High Level Desalination and Hydropower Generation for a range interest rates	Yes	1.11 (4%) - 1.24 (6%)	Yes	58 -- 226	Medium/ High
	Phased Pipe Line BC2		Yes	1.33 (4%) - 1.50 (6%)	Yes	114 -- 247	High
Lower Jordan River Restoration	Full and Partial FL1/FL2	Releases from Lake Tiberias	No	Added cost: 0.38	No	NA	High
		North Mediterranean Sea – Dead Sea	No	Added cost: 0.5 - 0.75	No	NA	Medium
		Recycled Wastewater	No	NA	No	NA	High
Water Transfer Options	From Mediterranean to Dead Sea TR1.1 – TR1.4	Southern A - Ashkelon–North Dead Sea, low level desalination and hydropower	Yes	0.85 (4%) - 0.93 (6%)	Yes	-60 (2%) to 99 (6%)	Medium/ High
		Southern A - Ashkelon–North Dead Sea, low level desalination and hydropower (Phased)	Yes	0.85 (4%) - 0.93 (6%)	Yes	-38 (2%) to 148 (6%)	Medium
		Northern - Atlit to Naharayim-Bakura with hydropower		1.14 (6%)	No	NA	Medium
		Northern -Atlit to Naharayim-Bakura without hydropower	Yes	1.38 (6%)	No	NA	Medium
	Major Pipelines TR2	From Turkey Seyhan-Ceyhan Rivers	Not certain	NA	No	NA	Low
		From Iraq–Euphrates River	No	NA	No	NA	Low
	TR3						
Desalination Options	Mediterranean Sea Water on Mediterranean Coast with Transfer to Lower Jordan River and Dead Sea Region DS1		Yes	?	No	NA	Medium
	Transfer of Mediterranean Sea Water to Jordan Valley for Local Desalination and Use in Lower Jordan River and Dead Sea		Yes	?	No	NA	Medium

Alternative	Case	Comments	Potable Water in Amman Quantity satisfies demand schedule?	Cost (>2060) (US$/m^3)	Water Discharge in the Dead Sea Quantity sufficient to stabilize Dead Sea water level?	Annual cost (US$million)	Viability Assess-ment*
	Region DS2						
	Increased Desalination Med Sea Water on Mediterranean Coast with Transfer for Use by Three Beneficiary Parties to Reduce Water Demand from Lower Jordan River DS3		Yes	?	No	NA	Medium
	Red Sea Water at Gulf of Aqaba/Eilat with Transfer for Use by the Three Beneficiary Parties to Reduce Water Demand from Lower Jordan River DS4		Yes	?	No	NA	Medium
Technical Conservation options	Chemical Industries TC1	Arab Potash Company Dead Sea Works	No	?	No	NA	Medium
	Increased conservation and use of treated wastewater and greywater in agriculture TC2		No	?	No	NA	High
	Changes in crop types and cultivation methods TC3		No	?	No	NA	Medium
Additional Alternatives Identified by Study Team	Selling electricity to Israel based on Israeli peak-load pricing with and without storage AA1	See Main Report, Section 11 – Costs Vary According to Assumptions Used	Yes	\$1.11-\$1.50	Yes	58-247	Medium
	Tankering and Bags AA2	From Manavgat or Seyhan-Ceyhan Rivers in Turkey	No	1.5 - 4.5	No	NA	Low
	Transfer by Underwater Marine Pipeline (Medstream)AA3		Not Certain	?	No	NA	Low
Combination Options	No. 1. Desalination at Aqaba and Mediterranean Sea, water importation from Turkey and water recycling and conservation	Would require close and sustained cooperation between the Beneficiary Parties concerning planning, investment and management actions	Potentially	?	Partially	NA	Low/ Medium
	No. 2. Decreased chemical		No	?	No	NA	Low

Alternative	Case	Comments	Potable Water in Amman: Quantity satisfies demand schedule?	Potable Water in Amman: Cost (>2060) (US$/m^3)	Water Discharge in the Dead Sea: Quantity sufficient to stabilize Dead Sea water level?	Water Discharge in the Dead Sea: Annual cost (US$million)	Viability Assess-ment*
	industry water extraction and decreased irrigation through cropping and other agronomic changes CA1						
	No. 3. Aqaba desalination plus decreased use from the chemical industries, plus increases in recycled water for irrigation CA2		No	?	No	NA	Low
	No. 4. Reduced extractions from the Jordan River, plus Aqaba regional desalination and decreased irrigation use though agronomic changes CA3		No	?	No	NA	Low

* ***Viability Assessment Ranking***

High The alternative can be realized/constructed through determined cooperation efforts and the application of moderate mitigation measures.

Medium The alternative can be realized/constructed through very determined and sustained cooperation efforts plus the application of significant environmental and social mitigation measures.

Low The level of cooperation effort, and/or the environmental and social costs, required to realize/construct the alternative are so significant that it makes the alternative very unlikely to be undertaken.

Table ES.2: Water Conveyance for Dead Sea Stabilization Only (quantity, length, effective elevation, power generation, capital cost) does not include added costs associated with desalination

			Quantity of Water (MCM)[1] (Q)	Total Length of the Water Conveyance (km)	Effective Elevation (m) (h)	Power Generation (GWh/year)[2]	Power Generation (MW)	Construction (Capital) Cost (Billion US$)
Red Sea-Dead Sea Water Conveyance	Low Level Gravity Tunnel (LLGT)		Unlimited	180	390	1911	218	5.80
	Phased Pipeline (PPL)		Unlimited	180	324	1588	181	3.43
Mediterranean Sea –Dead Sea Water Conveyance	Southern Alignment (A)	Low Level Gravity Tunnel	Unlimited	90	--	--	--	3.67
		Phased Pipeline	Unlimited	90	145	711	81	3.05
	Southern Alignment (B)	Phased Pipeline	Unlimited	90	238	1166	133	3.3
	Northern Alignment Phased Pipeline	With Hydropower	Unlimited	65-70	220	1078	123	1.69 [3]
		Without Hydropower	Unlimited	65-70	220	--	--	1.69 [3]
Transfer of Water from Seyhan and Ceyhan Rivers in Turkey by Pipeline			400	800	>1500 Cumulative[4]	nil	nil	5.00 [5]
Transfer of Water from the Euphrates River in Iraq by Pipeline			160	600	500	nil	nil	not available

[1]Quantity of Water Assumed 2000 MCM/yr i.e., flow rate of ≈ 63.0 m^3/s.
[2]Power (W) = ρ*Q*h*g (ρ is the density of water, Q is the flow rate of water in m3/sec, h is the height difference in m, and g is 9.8 m/s2. The actual hydropower is about 90% of the theoretical value).
[3]Construction cost for conveyance from Atlit to Naharayim-Bakura.
[4] This alignment would require many pumping lifts.
[5] 1992 costs from: Gruen, G. E., 1994, Contribution to water imports to Israeli-Palestinian-Jordanian Peace, Shuval, H. and Isaac, J., *Water & peace in the Middle East,* Proceedings of the first Israeli-Palestinian conference on water resources, held in Zurich in 1992, Amsterdam: Elsevier, pp 273-288.

Table ES.3: Comparison of Alternatives

Key: ✗ No; ✓ Yes; $ Billion USD; ⚡ Gigawatt hour; 🟢 = positive; O= slight/none; 🟠 = moderate; 🔴 = major

Alterna-tive Code	Alternative name	Stabilizes level of Dead Sea	Provides water for three benefi-ciaries	Gener-ates hydro-power	Promotes regional cooperation	Capital cost billions USD $	Net energy requirement GWH/yr	Environmental impact		Social impact	
								Before mitigation	After mitigation	Before mitigation	After mitigation
A – No Action											
NA1	No Action	✗	✗	✗	✗	cost of damage to infrastructure and tourism		🔴		🔴	
B – Red Sea–Dead Sea Water Conveyance											
BC1	Base case plus – Low Level Gravity Tunnel (LLGT)	✓	✓	✓	✓	$$$$$ $$$$$	⚡⚡⚡⚡ ⚡⚡	🔴	🟠/🔴	🟠	🟠
BC2	Base case plus – Phased Pipeline (PPL)	✓	✓	✓	✓	$$$$$ $$$$$	⚡⚡⚡⚡ ⚡⚡	🔴	🟠/🔴	🟠	🟠
C – Lower Jordan River Restoration – Partial Restoration of Jordan River Flows											
FL1	Full restoration of historic Jordan River flow levels	✗	✗	✗	✓	not known; but costly	⚡⚡	🔴	🟢	🔴	🟠
FL2	Partial restoration of historic Jordan River flow levels	✗	✗	✗	✓	$$	⚡⚡	🔴	🟢	🔴	🟠
D – Water Transfer Options											
TR1.1	Transfer of Mediterranean Sea water to the Dead Sea – Southern A (Low Level Tunnel)	✓	✓	✓	✓	$$$$$	⚡⚡⚡⚡ ⚡	🔴	🟠	🟠	🟢
TR1.2	Transfer of Mediterranean Sea water to the Dead Sea – Southern B (Phased Pipeline and Gravity Tunnel)	✓	✓	✓	✓	$$$$$	⚡⚡⚡⚡	🔴	🟠	🟠	🟢
TR1.3	Transfer of Mediterranean Sea water to the Dead Sea – Northern with hydropower	✗	✗	✓	✓	$$$$$	⚡⚡⚡	🔴	🟠	🟠	🟠

Alterna-tive Code	Alternative name	Stabilizes level of Dead Sea	Provides water for three benefi-ciaries	Gener-ates hydro-power	Promotes regional cooperation	Capital cost billions USD $	Net energy requirement GWH/yr	Environmental impact		Social impact	
								Before mitigation	After mitigation	Before mitigation	After mitigation
TR1.4	Transfer of Mediterranean Sea water to the Dead Sea – Northern without hydropower	✗	✗	✗	✓	$$$$	⚡⚡⚡⚡	🔴	🟠	🟠	🟠
TR2	Transfer of water from Turkey by pipeline (Peace Pipeline)	✗	✓	✗	✓	$$$$$$	⚡⚡⚡⚡⚡	🔴	🟠	🔴	🟠
TR3	Transfer of water from the Euphrates River Basin by pipeline	✗	✓	✗	✗	$$$$	⚡⚡⚡	🔴	🟠	🔴	🟠
E - Desalination Options											
DS1	Samuel Neaman Institute MD-1 alignment - Desalination of Mediterranean Sea Water on the Mediterranean Coast with Transfer to the Lower Jordan River and Dead Sea Region	✓	✓	✓	✓	$$$$$$	⚡⚡⚡⚡⚡⚡⚡	🔴	🟠/🔴	🔴	?
DS2	Samuel Neaman Institute MD-2 alignment - Transfer of Mediterranean Sea Water to the Jordan Valley for Local Desalination and Use in Lower Jordan River and Dead Sea Region	✓	✓	✗	✓	$$$$$$	⚡⚡⚡⚡⚡	🔴	🟠	🟠	🟢
DS3	Increased Desalination of Mediterranean Sea Water on the Mediterranean Coast with Transfer for Use by the Three Beneficiary Parties to Reduce Water Demand from Lower Jordan River	✗	✓	✗	✓	$$$	⚡⚡⚡⚡	🔴	🟠	🔴	🟠
DS4	Desalination of Red Sea Water at the Gulf of Aqaba/Eilat with Transfer for Use by the Three Beneficiary Parties to Reduce Water Demand from Lower Jordan River	Partial but not sufficient	✓	✗	✓	$	⚡⚡⚡	🔴	🟠	🟠	🟢
F - Technical and Water Conservation Options											
TC1	Changes of technology used by the Dead Sea Chemical Industry	Partial but not	✗	✗	✓	Unknown	Unknown	🔴	🟠	🔴	🟢

Alterna-tive Code	Alternative name	Stabilizes level of Dead Sea	Provides water for three benefi-ciaries	Gener-ates hydro-power	Promotes regional cooperation	Capital cost billions USD $	Net energy requirement GWH/yr	Environmental impact: Before mitigation	Environmental impact: After mitigation	Social impact: Before mitigation	Social impact: After mitigation
		sufficient									
TC2	Increased water conservation in the Lower Jordan River Basin	✗	✓	✗	✓	Unknown	Unknown	🔴	🟠 / 🟢	🟠	🟠
TC3	Increased use of wastewater and grey water	✗	✓	✗	✗	Unknown but substantial	Unknown	🔴	🟠 / 🟢	🔴	🟢
TC4	Changes in crop types and cultivation methods	✗	✓	✗	✗	Unknown but substantial	Unknown	🟠	🟠 / 🟢	🟠	🟠
G - Additional Alternatives Identified by the Study of Alternatives Team											
AA1	Selling electricity to Israel and pumped storage	✓	✓	✓	✓	$$$$$$ $$$$$	⚡⚡⚡⚡⚡ ⚡	🔴	🟠 / 🔴	🟠	🟠
AA2	Transfers by Tanker and Bags	✗	✓	✗	✓	$	⚡	🟠	🟢	🟢	🟢
AA3	Transfers by Sub-marine Pipeline from Turkey	✗	✓	✗	✓	$$$$$$	⚡⚡⚡⚡⚡	🟠	🟠	🟢	🟢
H - Combination of Alternatives											
CA1	Desalination at Aqaba and Mediterranean Sea, water importation from Turkey, and water recycling and conservation	✓	✓	✗	✓	Unknown but substantial	⚡⚡⚡⚡⚡	🔴	🟢	🟠	🟢
CA2	Decreased chemical industry water extraction and decreased irrigation through cropping and other agronomic changes	Partial but not sufficient	✓	✗	✓	Unknown but substantial	Unknown but substantial	🟠	🟠 / 🟢	🟠	🟠
CA3	Aqaba desalination plus decreased use from the chemical Industries, plus increases in recycled water for irrigation	Partial but not sufficient	✓	✗	✓	$$	⚡⚡	🔴	🟠	🔴	🟠
CA4	Reduced extractions from the Jordan River, plus Aqaba desalination and decreased irrigation use though agronomic changes	Partial but not sufficient	✓	✗	✓	$$	⚡⚡	🔴	🟠	🔴	🟠

Table ES.4. Spatial Distribution and Magnitude of Potential Environmental Impacts

Key: ● (green) = positive; O= slight/none; ● (orange) = moderate; ● (red) = major

Alternative Code	Alternative	Red Sea – Dead Sea Area: Red Sea	Red Sea Coast	Wadi Araba/Arava Valley	Desalina-tion Plant and Hydro-power Plant	Chemical Industries	Dead Sea Coast	Dead Sea	Desali-nated Water Conveyance	Other Areas: Lower Jordan River	Eastern Medi-terranean Sea	Eastern Medi-terranean Coast	Transfer Eastern Med to Dead Sea	Comments
Relative Sensitivity of Area (Low, Medium, High)		**M**	**M**	**H**	**M**	**H**	**M**	**H**	**M**	**H**	**M**	**M**	**H**	
A – No Action														
NA 1	No Action	O	O	O	O	moderate	major	major	O	moderate	O	O	O	
B – Red Sea -- Dead Sea														
BC1	• Low Level Gravity Tunnel (LLGT)	moderate	moderate	major	moderate	moderate	positive	major	moderate	O	O	O	O	High Level Elevation Desalination and Hydropower Facilities
BC2	• Phased Pipeline (PPL)	moderate	moderate	moderate	moderate	moderate	positive	major	moderate	O	O	O	O	
C – Lower Jordan River Restoration – Partial Restoration of Jordan River Flows														
FL1	• Releases from Lake Tiberias	O	O	O	O	O	positive	positive	O	positive	O	O	O	
FL2	• Production and Transfer of Desalinated Water from Mediterranean Sea	O	O	O	O	O	positive	positive	positive	positive	moderate	moderate	moderate	
FL3	• Recycled Treated Wastewater	O	O	O	O	O	O	positive	O	positive	O	O	O	
	D – Water Transfer Options													
TR1.1	*From Mediterranean to Dead Sea* • Southern A - Ashkelon to Northern Dead Sea (Low Level Tunnel)	O	O	moderate	moderate	moderate	positive	major	positive	O	moderate	moderate	major	Low Elevation Desalination and Hydropower Facilities
TR1.2	• Southern A - Ashkelon to Southern Dead Sea (Phased Pipeline and Gravity Tunnel)	O	O	moderate	moderate	moderate	positive	major	positive	O	moderate	moderate	major	Phased Low Elevation Desalination and

Alternative Code	Alternative	Red Sea – Dead Sea Area								Other Areas				Comments
		Red Sea	**Red Sea Coast**	**Wadi Araba/Arava Valley**	**Desalination Plant and Hydro-power Plant**	**Chemical Industries**	**Dead Sea Coast**	**Dead Sea**	**Desalinated Water Conveyance**	**Lower Jordan River**	**Eastern Mediterranean Sea**	**Eastern Mediterranean Coast**	**Transfer Eastern Med to Dead Sea**	
Relative Sensitivity of Area (Low, Medium, High)		**M**	**M**	**H**	**M**	**H**	**M**	**H**	**M**	**H**	**M**	**M**	**H**	
														Hydropower Facilities
TR1.3	• Northern A - Atlit to Naharayim-Bakura – with hydropower	**O**	**O**	**O**	🟠	🟠	🟢	🔴	🟢	🟢	🟢	🟠	🔴	With Hydropower
TR1.4	• Northern B - Atlit to Naharayim-Bakura – without hydropower	**O**	**O**	**O**	🟠	🟠	🟢	🔴	🟢	🟢	🟢	🟠	🔴	Without hydropower
TR2	*Pipelines* • From Turkey Seyhan-Ceyhan Rivers	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**	🟢	🟠	🔴	🟠	Turkish authorities indicate that proposed withdrawal was not feasible due to inadequate quantities of water Proposed to provide fresh water for drinking water purposes only
TR3	• From Iraq – Euphrates River	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**	This is an old proposal; water from the Euphrates does not appear to be available at this time. Proposed to provide fresh water for drinking water purposes only
E – Desalination Options														
DS1	• Desalination of Mediterranean Sea Water on the Mediterranean Coast with	**O**	**O**	**O**	**O**	**O**	**O**	**O**	🟠	**O**	🟠	🟠	🟠	Desalination to occur on Med.

Alternative Code	Alternative	Red Sea – Dead Sea Area								Other Areas				Comments
		Red Sea	Red Sea Coast	Wadi Araba/Arava Valley	Desalination Plant and Hydro-power Plant	Chemical Industries	Dead Sea Coast	Dead Sea	Desalinated Water Conveyance	Lower Jordan River	Eastern Mediterranean Sea	Eastern Mediterranean Coast	Transfer Eastern Med to Dead Sea	
Relative Sensitivity of Area (Low, Medium, High)		**M**	**M**	**H**	**M**	**H**	**M**	**H**	**M**	**H**	**M**	**M**	**H**	
	Transfer to the Lower Jordan River and Dead Sea Region													Coast
DS2	• Transfer of Mediterranean Sea Water to the Jordan Valley for Local Desalination and Use in Lower Jordan River and Dead Sea Region	**O**	**O**	**O**	**O**	**O**	**O**	🔴	🟠	🟢	🟠	🟠	🔴	Desalination plant located north of Dead Sea
DS3	• Increased Desalination of Mediterranean Sea Water on the Mediterranean Coast with Transfer for Use by the Three Beneficiary Parties to Reduce Water Demand from Lower Jordan River	**O**	**O**	**O**	**O**	**O**	**O**	**O**	🟢	**O**	**O**	🟠	🟢	
DS4	• Desalination of Red Sea Water at the Gulf of Aqaba/Eilat with Transfer for Use by the Three Beneficiary Parties to Reduce Water Demand from Lower Jordan River	🟠	🟠	🟠	🟠	🟠	🟢	🟢	🟠	🟢	**O**	**O**	**O**	
F – Technical and Water Conservation Options														
TC1	• Potash Industries New Technologies	**O**	**O**	**O**	**O**	🟢	🟢	🟢	**O**	**O**	**O**	**O**	**O**	
TC2	• Increased Water Conservation in the Lower Jordan River Basin	**O**	**O**	**O**	**O**	🟢	🟢	🟢	**O**	🟢	**O**	**O**	**O**	
TC3	• Increased Use of Treated Wastewater and Grey Water	**O**	**O**	**O**	**O**	**O**	🟢	🟢	**O**	🟢	**O**	**O**	**O**	
TC4	• Changes in Crop Types and Cultivation Methods	**O**	**O**	🟢	**O**	**O**	🟢	🟢	**O**	🟢	**O**	**O**	**O**	

Alternative Code	Alternative	Red Sea – Dead Sea Area								Other Areas				Comments
		Red Sea	Red Sea Coast	Wadi Araba/Arava Valley	Desalination Plant and Hydro-power Plant	Chemical Industries	Dead Sea Coast	Dead Sea	Desalinated Water Conveyance	Lower Jordan River	Eastern Medi-terranean Sea	Eastern Medi-terranean Coast	Transfer Eastern Med to Dead Sea	
Relative Sensitivity of Area (Low, Medium, High)		**M**	**M**	**H**	**M**	**H**	**M**	**H**	**M**	**H**	**M**	**M**	**H**	
G – Additional Alternatives Identified by Study Team														
AA1	• Selling electricity to Israel based on Israeli peak-load pricing with and without storage	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**	See section 11
AA2	• Transfers by tanker, bag and sub-marine pipeline from Manavgat in Turkey	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**	🟠	🟠	🟠	For drinking water purposes
AA3	• Sub-marine pipelines associated with oil and energy conveyance-Medstream	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**	🟠	🟠	🟠	🟠	For drinking water purposes; Impacts shared with energy and oil services; small water volume
H – Combination of Alternatives														
CA1	• No. 1. Desalination at Aqaba and Mediterranean Sea, water importation from Turkey and water recycling and conservation	🟠	🟠	🟠	🟠	🟠	🟢	🟠/ 🟢	🟠	🟢	🟢	🟠	🟠	
CA2	• No. 2. Decreased chemical industry water extraction and decreased irrigation through cropping and other agronomic changes	**O**	**O**	**O**	**O**	🟠	🟢	🟢	**O**	🟢	**O**	**O**	**O**	
CA3	• No. 3. Aqaba desalination plus decreased use from the chemical industries, plus increases in recycled water for irrigation	🟠	🟠	🟠	🟠	**O**	🟢	**O**	🟠	**O**	**O**	**O**	**O**	Desalination facility located at Aqaba on Red Sea
CA4	• No. 4. Reduced extractions from the Jordan River, plus Aqaba regional desalination and decreased irrigation use though agronomic changes	🟠	🟠	🟠	🟠	🟠	🟠	**O**	🟠	🟢	**O**	**O**	**O**	

Table ES.5. Spatial Distribution and Magnitude of Potential Social Impacts

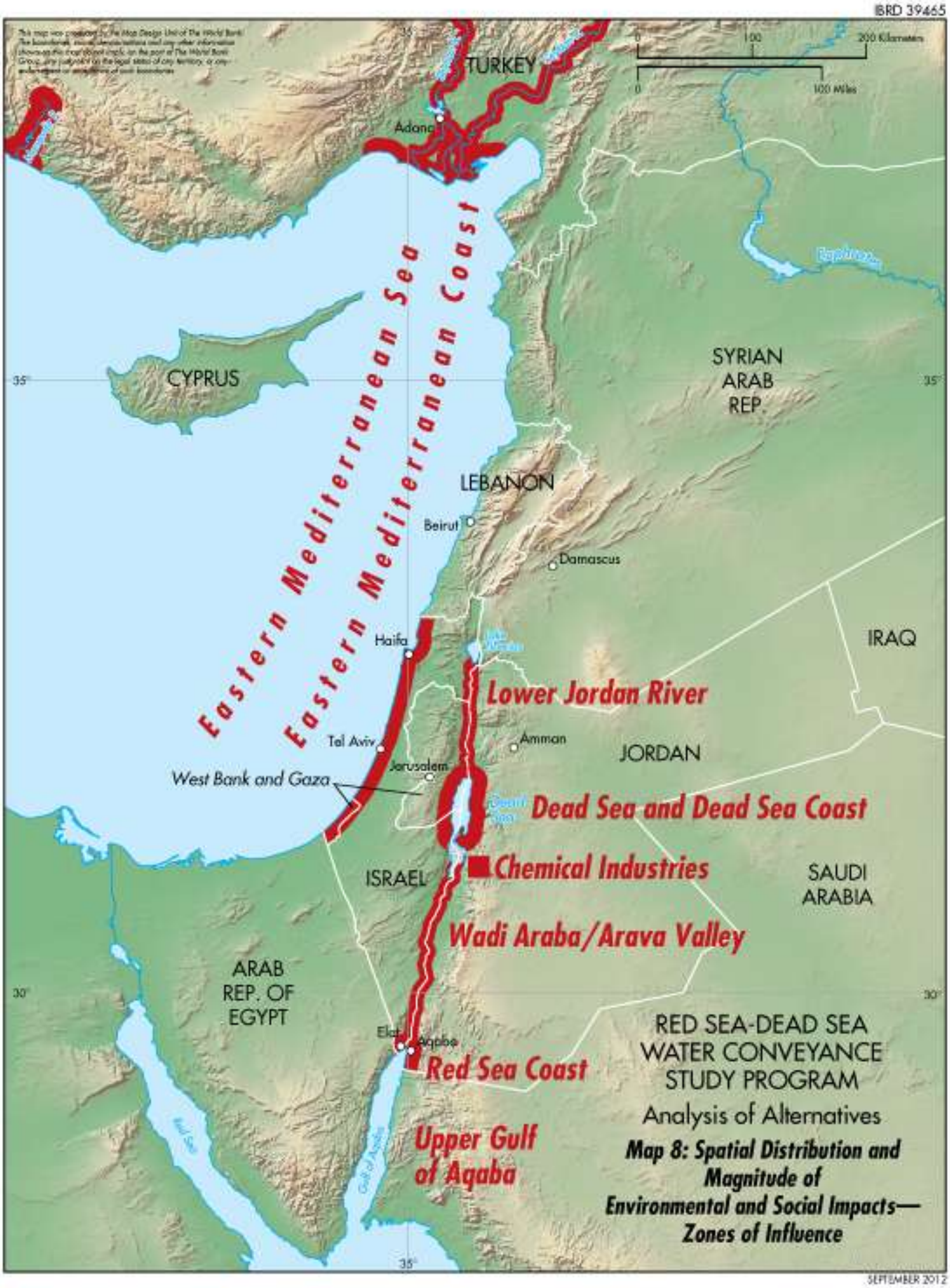
Key: 🟢 = positive; O= slight/none; 🟠 = moderate; 🔴 = major

Alternative Code	Alternative	Red Sea – Dead Sea Area								Other Areas				Comments
		Red Sea	**Red Sea Coast**	**Arava Valley/ Wadi Araba**	**Desalina-tion Plant and Hydro-power Plant**	**Chemical Industries**	**Dead Sea Coast**	**Dead Sea**	**Desali-nated Water Conve-yance**	**Lower Jordan River**	**Eastern Medi-terranean Sea**	**Eastern Medi-terranean Coast**	**Transfer Eastern Med to Dead Sea**	
Relative Sensitivity of Area (Low, Medium, High)		**M**	**M**	**H**	**M**	**H**	**M**	**H**	**L**	**H**	**L**	**M**	**H**	
A – No Action														
NA1	No Action	**O**	**O**	**O**	**O**	🟠	🔴	🔴	**O**	**O**	**O**	**O**	**O**	
B – Red Sea -- Dead Sea														
BC1	• Low Level Gravity Tunnel (LLGT)	🟠	🟠	🔴	🟢	🟠	🟢	**O**	🟢	**O**	**O**	**O**	**O**	High Level Elevation Desalination and Hydropower Facilities
BC2	• Phased Pipeline (PPL)	🟠	🟠	🟠	🟢	🟠	🟢	**O**	🟢	**O**	**O**	**O**	**O**	
C – Lower Jordan River Restoration – Partial Restoration of Jordan River Flows														
FL1	• Releases from Lake Tiberias	**O**	**O**	**O**	**O**	**O**	**O**	🟢	**O**	🟢	**O**	**O**	**O**	
FL2	• Production and Transfer of Desalinated Water from the Mediterranean Sea	**O**	**O**	**O**	**O**	**O**	🟢	🟢	**O**	🟠	🟠	🟠	🟠	
FL3	• Recycled Treated Wastewater	**O**	**O**	**O**	**O**	**O**	**O**	🟢	**O**	🟢	**O**	**O**	**O**	
D – Water Transfer Options														
TR1.1	*From Mediterranean to Dead Sea* • Southern A - Ashkelon to North Dead Sea (Low Level Gravity Tunnel)	**O**	**O**	**O**	**O**	**O**	🟠	🔴	**O**	**O**	**O**	🟠	🔴	Low Elevation Desalination and Hydropower Facilities
TR1.2	• Southern B - Ashkelon to North Dead Sea (Phased Pipeline and Gravity	**O**	**O**	**O**	**O**	**O**	🟠	🔴	**O**	**O**	**O**	🟠	🔴	**Phased** Low Elevation Desalination

Alternative Code	Alternative	Red Sea – Dead Sea Area								Other Areas				Comments
		Red Sea	**Red Sea Coast**	**Arava Valley/ Wadi Araba**	**Desalination Plant and Hydro-power Plant**	**Chemical Industries**	**Dead Sea Coast**	**Dead Sea**	**Desalinated Water Conveyance**	**Lower Jordan River**	**Eastern Mediterranean Sea**	**Eastern Mediterranean Coast**	**Transfer Eastern Med to Dead Sea**	
Relative Sensitivity of Area (Low, Medium, High)		**M**	**M**	**H**	**M**	**H**	**M**	**H**	**L**	**H**	**L**	**M**	**H**	
	Tunnel)													and Hydropower Facilities
TR1.3	• Northern A - Atlit to Naharayim-Bakura – with hydropower	**O**	**O**	**O**	🟠	🟠	🟢	🟢	🟢	🟢	🟠	🟠	🔴	With Hydropower
TR1.4	• Northern B - Atlit to Naharayim-Bakura – without hydropower	**O**	**O**	**O**	🟠	🟠	🟢	🟢	🟢	🟢	🟠	🟠	🔴	Without hydropower
TR2	*Pipelines* • From Turkey Seyhan-Ceyhan Rivers	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**	🟢	🟢	🟢	**O**	Proposed to provide fresh water for drinking water purposes only
TR3	• From Iraq – Euphrates River	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**	
E – Desalination Options														
DS1	• Desalination of Mediterranean Sea Water on the Mediterranean Coast with Transfer to the Lower Jordan River and Dead Sea Region	**O**	**O**	**O**	🟠	🟢	🟢	🟢	🟠	🟢	🟠	🟠	🟠	Desalination to occur on Med. Coast
DS2	• Transfer of Mediterranean Sea Water to the Jordan Valley for Local Desalination and Use in Lower Jordan River and Dead Sea Region	**O**	**O**	**O**	🟠	🟢	🟢	🟢	🟠	🟢	🟠	🟠	🔴	Desalination plant located north of Dead Sea
DS3	• Increased Desalination of Mediterranean Sea Water on the Mediterranean Coast with Transfer for Use by the Three Beneficiary Parties to Reduce Water Demand from Lower Jordan River	**O**	**O**	**O**	🟠	🟢	🟢	🟢	🟠	🟢	🟠	🟠	🟠	
DS4	• Desalination of Red Sea Water at the Gulf of Aqaba/Eilat with Transfer for Use by the Three Beneficiary Parties to Reduce Water Demand from Lower Jordan River	🟠	🟠	🟠	🟠	🟠	🟢	🟠	🟠	**O**	**O**	**O**	**O**	

Alternative Code	Alternative	Red Sea – Dead Sea Area								Other Areas				Comments
		Red Sea	Red Sea Coast	Arava Valley/ Wadi Araba	Desalina-tion Plant and Hydro-power Plant	Chemical Industries	Dead Sea Coast	Dead Sea	Desali-nated Water Conve-yance	Lower Jordan River	Eastern Medi-terranean Sea	Eastern Medi-terranean Coast	Transfer Eastern Med to Dead Sea	
Relative Sensitivity of Area (Low, Medium, High)		**M**	**M**	**H**	**M**	**H**	**M**	**H**	**L**	**H**	**L**	**M**	**H**	
F – Technical and Water Conservation Options														
TC1	• Potash Industries new technologies	**O**	**O**	**O**	**O**	🟠	🟢	🟢	**O**	**O**	**O**	**O**	**O**	
TC2	• Increased Water Conservation in the Lower Jordan River Basin	**O**	**O**	🟢	**O**	**O**	🟢	🟢	**O**	**O**	**O**	**O**	**O**	
TC3	• Increased Use of Treated Wastewater and Grey Water	**O**	**O**	**O**	**O**	**O**	🟢	🟢	**O**	🟠	**O**	**O**	**O**	
TC4	• Changes in Crop Types and Cultivation Methods	**O**	**O**	**O**	**O**	**O**	🟢	🟢	**O**	🟠	**O**	**O**	**O**	
G – Additional Alternatives Identified by Study Team														
AA1	• Selling electricity to Israel based on Israeli peak-load pricing with and without storage	**O**	**O**	🟠	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**	See report
AA2	• Transfers by tanker, bag and sub-marine pipeline from Manavgat in Turkey	**O**	**O**	**O**	**O**	**O**	🟢	🟢	**O**	**O**	🟠	🟠	🟠	For drinking water purposes
AA3	• Sub-marine pipelines associated with oil and energy conveyance-Medstream	**O**	**O**	**O**	**O**	**O**	**O**	**O**	🟠	**O**	🟠	🟠	🟠	For drinking water purposes; Impacts shared with energy and oil services
H – Combination of Alternatives														
CA1	• No. 1. Desalination at Aqaba and Mediterranean Sea, water importation from Turkey and water recycling and conservation	🟠	🟠	🟠	🟠	🟠	🟢	🟢	🟠	🟢	🟠	🟠	🟠	
CA2	• No. 2. Decreased chemical industry water extraction and decreased irrigation through cropping and other agronomic changes	**O**	**O**	**O**	**O**	🔴	🟢	🟠	**O**	🟠	**O**	**O**	**O**	

Alternative Code	Alternative	Red Sea – Dead Sea Area								Other Areas				Comments
		Red Sea	**Red Sea Coast**	**Arava Valley/ Wadi Araba**	**Desalina-tion Plant and Hydro-power Plant**	**Chemical Industries**	**Dead Sea Coast**	**Dead Sea**	**Desali-nated Water Conve-yance**	**Lower Jordan River**	**Eastern Medi-terranean Sea**	**Eastern Medi-terranean Coast**	**Transfer Eastern Med to Dead Sea**	
Relative Sensitivity of Area (Low, Medium, High)		**M**	**M**	**H**	**M**	**H**	**M**	**H**	**L**	**H**	**L**	**M**	**H**	
CA3	• No. 3. Aqaba desalination plus decreased use from the chemical industries, plus increases in recycled water for irrigation	🟠	🟠	🟠	🟠	🟢	🟢	🟢	🟢	🟢	**O**	**O**	**O**	Desalination facility located at Aqaba on Red Sea
CA4	• No. 4. Reduced extractions from the Jordan River, plus Aqaba regional desalination and decreased irrigation use though agronomic changes	🟠	🟠	🟠	🟠	🟠	🟠	🟠	🟠	🟠	**O**	**O**	**O**	


IBRD 39465
TURKEY
Adana
CYPRUS
SYRIAN ARAB REP.
LEBANON
Beirut
Damascus
IRAQ
Haifa
Tel Aviv
Jerusalem
Amman
JORDAN
West Bank and Gaza
ISRAEL
SAUDI ARABIA
ARAB REP. OF EGYPT
Elat
Aqaba
Eastern Mediterranean Sea
Eastern Mediterranean Coast
Lower Jordan River
Dead Sea and Dead Sea Coast
Chemical Industries
Wadi Araba/Arava Valley
Red Sea Coast
Upper Gulf of Aqaba
RED SEA-DEAD SEA WATER CONVEYANCE STUDY PROGRAM
Analysis of Alternatives
Map 8: Spatial Distribution and Magnitude of Environmental and Social Impacts—Zones of Influence
SEPTEMBER 2012

4. SUMMARY OF STAKEHOLDER CONSULTATIONS

[to be drafted after stakeholder consultations]

Red Sea–Dead Sea Water Conveyance Study Program

Study of Alternatives

Preliminary Draft Report

MAIN REPORT

September 28, 2012

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1. INTRODUCTION

Objective of the Study of Alternatives. The objective of the Study of Alternatives is to provide decision makers, stakeholders and the public at large with a comparative analysis of alternatives to the Red Sea–Dead Sea Water Conveyance as described in the Feasibility Study prepared by Coyne et Bellier (2012), "Red Sea–Dead Sea Water Conveyance Study Program – Draft Final Feasibility Study Report – Summary of Main Report." The Study of Alternatives has not been designed nor does it intend to provide a recommended course of action for the Beneficiary Parties and/or other stakeholders.

The alternatives to the Red Sea–Dead Sea Water Conveyance include the "No Action" or "No Project" alternative and other alternatives that either fully, partially or in combination address the following objectives adopted by the Beneficiary Parties – Israel, Jordan and the Palestinian Authority – for the Red Sea–Dead Sea Water Conveyance Study Program (the Study Program):

- Save the Dead Sea from environmental degradation;
- Desalinate water / generate energy at affordable prices for Israel, Jordan and the Palestinian Authority; and
- Build a symbol of peace and cooperation in the Middle East.

The Study of Alternatives reviews the wide range of alternatives that have been put forward to address these issues by a variety of parties over recent decades. It describes them in a standardized manner, identifies their pros and cons and shows how they compare with both the Red Sea–Dead Sea Water Conveyance and with each other. It should be recognized that these alternatives have been subject to highly variable levels of examination concerning their technical, economic, environmental and social feasibility.

Three Key Elements. The Red Sea–Dead Sea Water Conveyance involves transferring up to 2,000 million cubic meters (MCM) per year of sea water about 180 km, from the Red Sea to the Dead Sea (see Box 1.1). When fully built, the conveyance scheme would include three elements that aim to:

- *Transfer Water* – Stabilize the Dead Sea water level utilizing up to 1,200 MCM/year of brine resulting from the desalination process;
- *Desalinate Water* – Provide up to 850 MCM per year of potable water, to be shared among the three Beneficiary Parties; and
- *Generate Power* – Generate hydropower to lower the operational cost.

The Red Sea–Dead Sea Water Conveyance would use the elevation difference between the Red Sea and Dead Sea to generate hydropower, thereby lowering the cost of brine discharge and desalination.

Red Sea–Dead Sea Water Conveyance Study Program. The Study of Alternatives is one part of the Study Program, which also includes the following complementary studies:

- Red Sea–Dead Sea Water Conveyance Study Program, Feasibility Study Report (Coyne et Bellier);
- Red Sea–Dead Sea Water Conveyance Study Program, Environmental and Social Assessment (ERM);
- Red Sea–Dead Sea Water Conveyance Study Program, Dead Sea Study (Tahal Group); and

- Red Sea–Dead Sea Water Conveyance Study Program, Red Sea Study (Thetis).

Information on the Study Program, including the Terms of Reference (TOR), draft reports and the public consultation record can be found on this website: www.worldbank.org/rds.

Connecting Two Seas. Connecting the two seas is not a new idea. A possible inter-basin transfer has been studied in many forms since the mid-1800s. The more than 400-meter difference in elevation between the Mediterranean Sea or the Red Sea and the Dead Sea has long been enticing because of the gravity flow advantage and the considerable potential for hydropower generation. The catchment area of the Dead Sea is shown in Map 1a and the associated elevation profile is shown in Map 1b.. As unit prices for desalination have dropped in recent years, combining the transfer with desalination for domestic or agricultural uses has become increasingly relevant to the Beneficiary Parties. As 60 to 70 percent of domestic water can be reused after suitable treatment (Cohen et al, 2008), the desalinated water will indirectly increase the potential supply of water available for restoration of the Dead Sea in conjunction with restoration of the Lower Jordan River.

A Complex Situation. Reversing the long-term environmental degradation of the Dead Sea from the reallocation of surface and ground water for agricultural, municipal, industrial and tourism purposes is a major challenge to Israel, Jordan, and the Palestinian Authority. Reversing the trend is made more complex by the significant consumption of Dead Sea water to support economically important chemical industries in Israel and Jordan. With no action the sea level is expected to drop by another 150 m until it will stabilize as a much smaller water body at a level of about 543 m below sea level (mbsl) by the mid-22nd century (Coyne et Bellier, 2010).

Rapid Rate of Decline. Since the 1960s the level of the Dead Sea has dropped by more than 30 m and today it stands at 426 mbsl (July 2011, Arab Potash Company and Dead Sea Works records). The Dead Sea is currently declining by more than a meter per year (see Figure 1.1). Stabilizing at the current level requires additional water inflow of 700-800 MCM/year and stabilizing at 410 mbsl requires over 1,000 MCM/year (Ministry of the Environment, the Geological Survey of Israel and the Jerusalem Institute for Israel Studies, 2006; Coyne et Bellier, 2010).

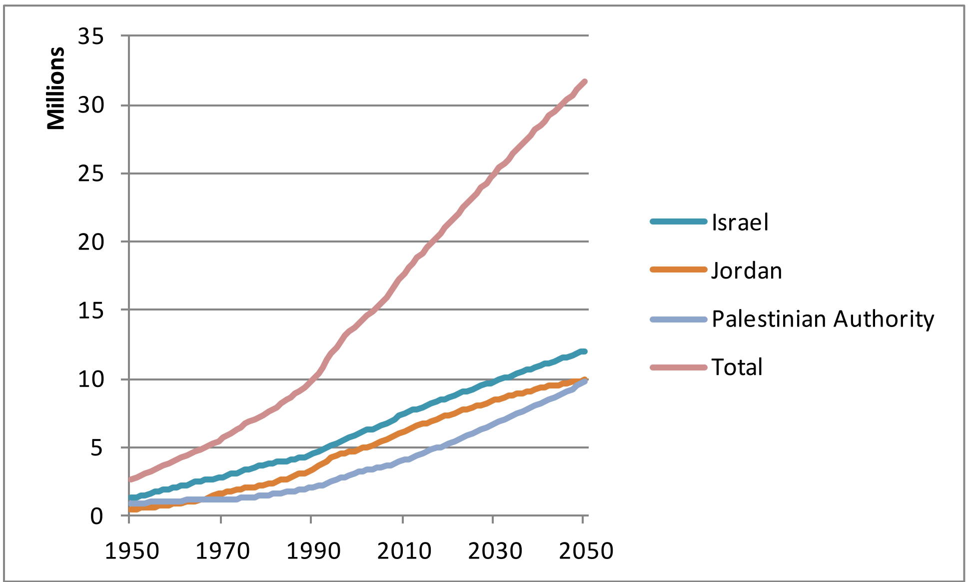
Figure 1.1: Drop of the Dead Sea Level (meters below sea level vs. time in years)

Source: Figure ES.2, ERM (2011).

Impacts of Decline on the Shoreline. Decline to date has included a significant retreat of the shoreline, especially on the northern Dead Sea, and development of steeper slopes on the western and eastern shores. Changes on the southern shore from the decline in sea level are less obvious because of the large scale conversion of the area into evaporation ponds for use in the chemical industries. In the future a major feature of the decline in sea level will be the increasingly steep shorelines especially on the western and eastern shores. In addition, the southern shoreline will also retreat significantly during the future, reducing the bay to the east of the Lisan Peninsula to a dry seabed. The decline has also resulted in the formation of a large number of sink holes around the Dead Sea that present a hazard to humans, natural habitats and commercial uses. The sink holes have damaged infrastructure and agricultural lands and restricted land use. It is anticipated that the ongoing decline of the Dead Sea will result in continued land surface stability problems.

Water Availability and Population Growth. The need to increase the supply of potable water in the region is unavoidable and stems from the gap between the water supplies available from natural sources and the basic needs of the growing population. Figure 1.2 depicts the population trends and projections of the three Beneficiary Parties between 1950 and 2050.

Figure 1.2: Population (million) Trends and Projections for Israel, Jordan and the Palestinian Authority for the Period 1950–2050



Source: United Nations, Department of Economic and Social Affairs, Population Division: World Population Prospects DEMOBASE extract, 2011.

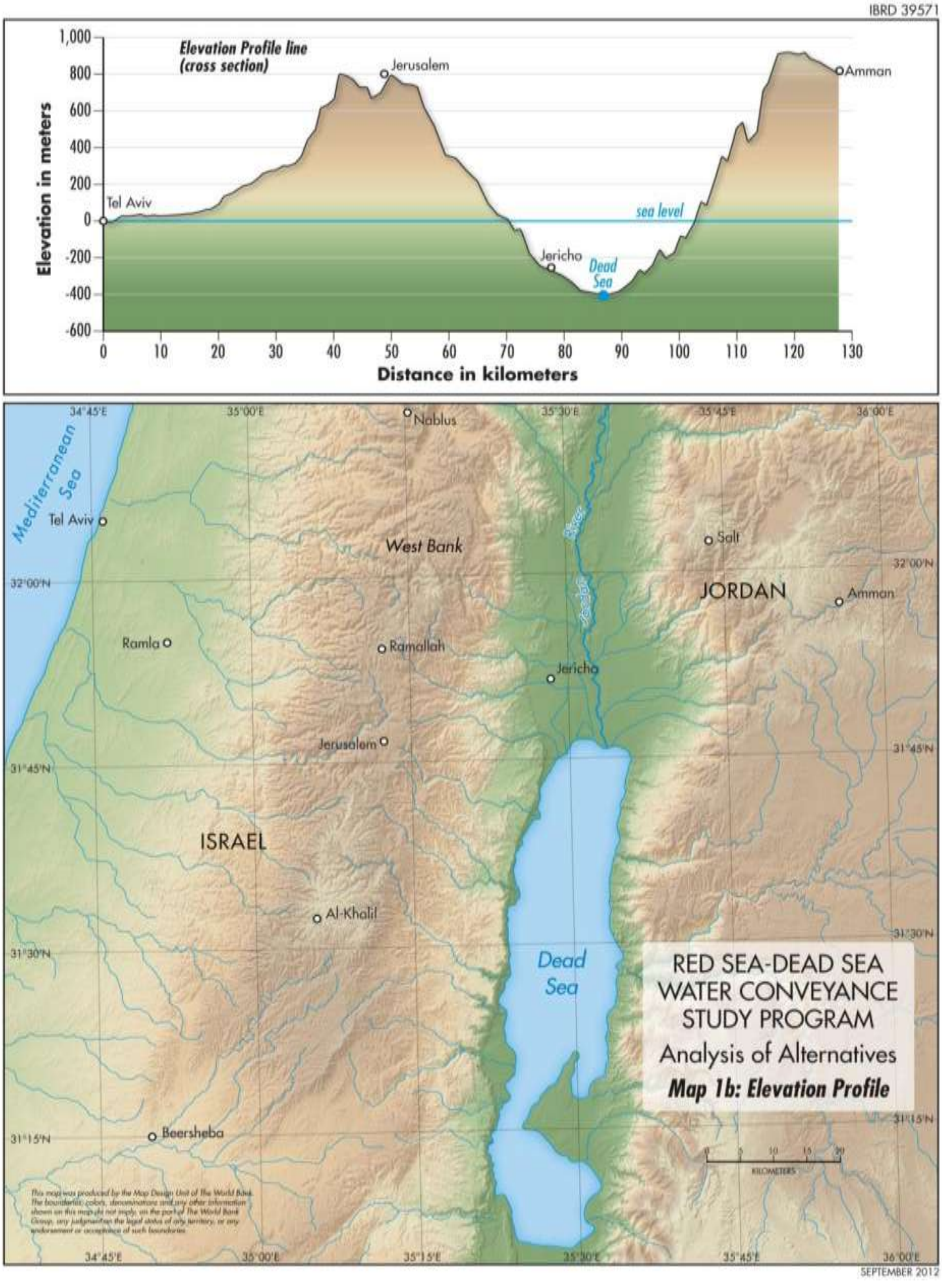
The sustainable quantity of natural water[3] available through average annual recharge in the basins of Israel, Jordan and the Palestinian Authority is about 2,600 MCM/year on average: 1,700 MCM/year in Israel and the Palestinian Authority (Israel Hydrology Service, 2007; Weinberger et al, 2012); and 933 MCM/year in Jordan (Water for Life, Jordan's Water Strategy, 2008-2022). The population of the three parties combined is currently about 18 million and is expected to exceed 30 million by 2050. Per capita water available from natural sources was 139 m^3 per person per year in 2010 and could go as low as 80 m^3 per person per year by 2050, whereas the quantity of water deemed necessary to meet "basic human needs" is about 100 m^3 per person per year (Gleick, 1996). From 2030 onwards, therefore, the average annual recharge in the water basins of Israel, Jordan and the Palestinian Authority will not meet even the basic human needs of the existing population. This is without taking into account the water needs for industrial, agricultural and environmental purposes.

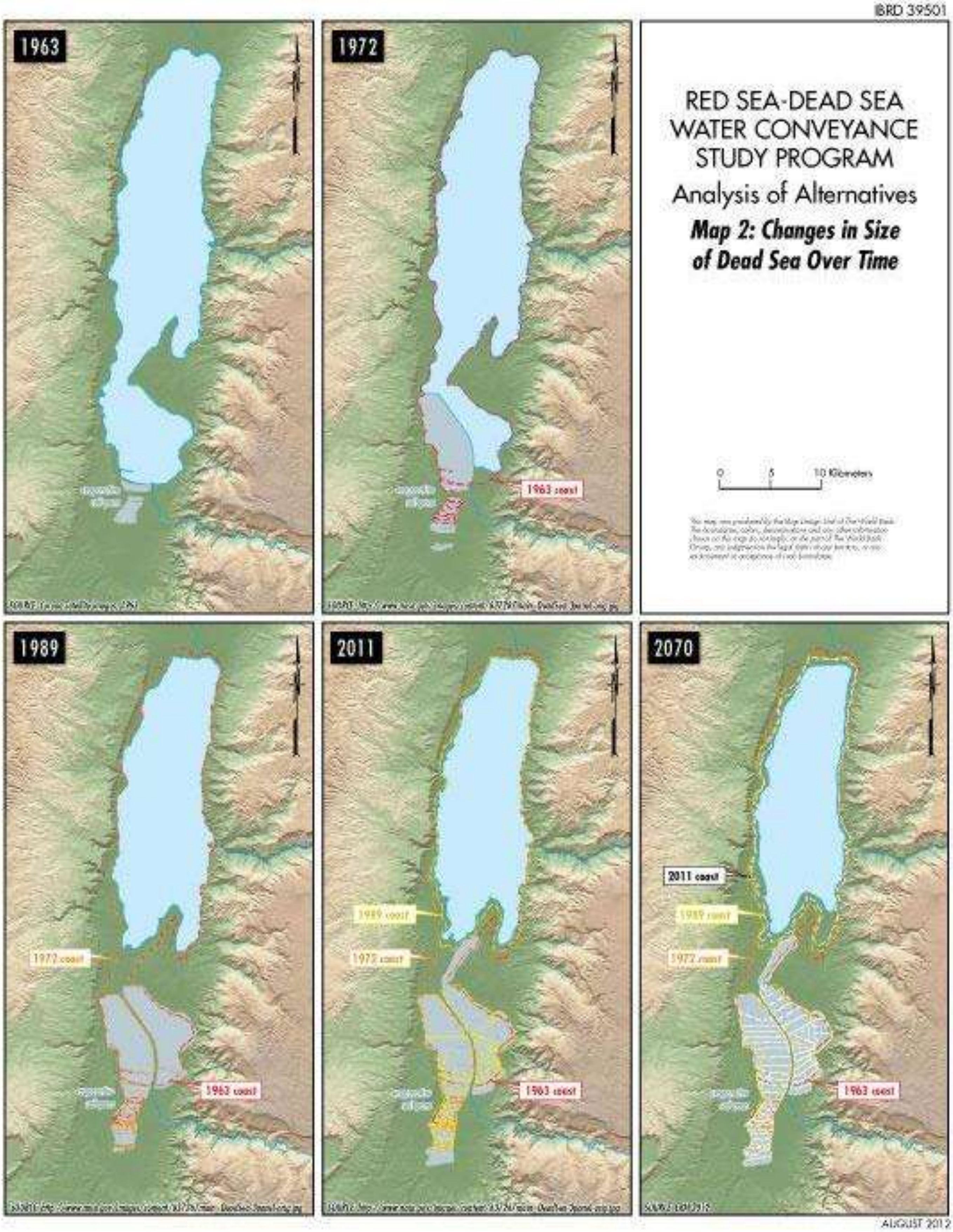
Causes of Decline. The level of the Dead Sea has declined because the historical annual Jordan River flow of about 1,300 MCM/year has been progressively reduced by water consumption – mainly by Israel, Jordan and Syria (Courcier et al, 2005, Beyth 2006). This upstream diversion came in response to mounting demand for water since the 1950s. The main drivers were the allocation of potentially potable water, first to irrigation and secondly to provide the water services of the rapidly growing populations. The demand for potable water will continue to increase for municipal and industrial uses. But the allocation of high quality natural water to irrigation will decline at the rate at which water demand management measures and water reuse technologies can be introduced. These processes of

[3] *Natural water* is the water which derives from rainfall both local and that flowing from other parts of river basins. It is evident in surface and groundwater flows and storages. Its withdrawal for use by the economy and by society can be supplemented with recycled municipal water and manufactured – desalinated – water.

both growth in demand and the adoption of measures to more efficiently use water will intensify in the future. The decline is also caused by significant consumption of Dead Sea water as a raw material for the large evaporation based chemical industries in Israel and Jordan at the southern end of the Dead Sea, which produce potash, magnesium, manganese and bromide. The net amount of Dead Sea water used per year by the chemical industries is estimated at 262 MCM (Zbranek, 2012).


IBRD 38932R
RED SEA-DEAD SEA
WATER CONVEYANCE
STUDY PROGRAM
Analysis of Alternatives
Map 1a: Dead Sea Catchment Area
DEAD SEA CATCHMENT AREA
PRIMARY WADIS AND RIVERS
SECONDARY WADIS AND RIVERS
EVAPORATION PANS
MAIN CITIES AND TOWNS
Sidon
Damascus
Tyre
Al-Qunaytirah
Haifa
Lake Tiberias
Nazareth
Yarmouk R.
Al-Suwayda
Dar'a
Irbid
Netanya
Al-Mafraq
Nablus
AMMAN UPLANDS
Tel Aviv
Salt
Al-Zarqa
Mediterranean Sea
HEBRON & JERUSALEM UPLANDS
Ramla
Ramallah
Amman
Jericho
Jerusalem
Bethlehem
Madaba
Dead Sea
Hebron
Gaza
Beersheba
Arad
Al Kerak
Dimona
Zin
NEGEV UPLANDS
DEAD SEA CATCHMENT
SOUTH JORDAN UPLANDS
Petra
Ma'an
Elat
Aqaba
Gulf of Aqaba
0 10 20 30 Kilometers
0 10 20 30 Miles
This map was produced by the Map Design Unit of The World Bank. The boundaries, colors, denominations and any other information shown on this map do not imply, on the part of The World Bank Group, any judgment on the legal status of any territory, or any endorsement or acceptance of such boundaries.
SEPTEMBER 2012


IBRD 39571
Elevation Profile line (cross section)
Elevation in meters
Distance in kilometers
Tel Aviv
Jerusalem
Amman
Jericho
Dead Sea
sea level
Mediterranean Sea
Nablus
West Bank
Salt
JORDAN
Ramla
Ramallah
Jericho
Jerusalem
ISRAEL
Al-Khalil
Beersheba
RED SEA-DEAD SEA WATER CONVEYANCE STUDY PROGRAM
Analysis of Alternatives
Map 1b: Elevation Profile
SEPTEMBER 2012


IBRD 39501
1963
1972
RED SEA-DEAD SEA
WATER CONVEYANCE
STUDY PROGRAM
Analysis of Alternatives
Map 2: Changes in Size
of Dead Sea Over Time
1963 coast
0 5 10 Kilometers
1989
2011
2070
2011 coast
1989 coast
1972 coast
1963 coast
AUGUST 2012

Changes in Water Use. The three Beneficiary Parties have very different economies from those that existed in the 1950s. Integral to this economic and social transformation has been the increased use of natural water, recycled water and recently of manufactured water from desalination, along with intensified use of both surface water and groundwater from all sources. Without these interventions in the hydrology of the Jordan Basin during the past six decades, the living standards of the 18 million current inhabitants of the region would be low, with poor socio-economic conditions and limited opportunities for future economic development.

Regional Challenges. There have been impressive socio-economic developments over the past six decades in the region–some are globally exceptional. The decline of the Dead Sea and the current and future water shortages are challenges that must be addressed regionally. The need for cooperation in solving these problems is reflected in the Red Sea–Dead Sea Water Conveyance and its alternatives. A project at the scale and complexity being considered, whether the Red Sea–Dead Sea Water Conveyance or an alternative, requires sustained cooperation and presents significant opportunities for further and enhanced cooperation among the three Beneficiary Parties in the future.

Cooperation – Difficult but Necessary. One of the objectives of the Red Sea–Dead Sea Water Conveyance initiative is to develop and build on the cooperative engagement that launched, subsequently developed and is advancing the Study Program activities. The prime cooperative scope has involved the engagement of the three Beneficiary Parties. The analysis in the Study of Alternatives has focused on this trilateral level of regional cooperation between the three Beneficiary Parties. The Study Program, through the Study of Alternatives, has also examined alternatives that included potential water transfers from Turkey and Iraq. In the immediate and longer term, the increasing scarcity of water resources will place greater emphasis on increased cooperation on the regional scale.

Box 1.1: How Much Water Is Enough?

The current phase of international engagement with the Red Sea–Dead Sea Water Conveyance concept has lasted over a decade, since a prominent launch at the United Nations sponsored World Summit on Sustainable Development in Johannesburg during 2002. But late 1990s' assumptions of the scale and contribution of the project have been overtaken. Ten years is a long time in the recent history of water demand in the region, and a very long time in the history of new water technologies. Consumer expectations regarding the reliability of domestic water services have also been transformed, as have those of society with respect to environmental stewardship. Since then, it has been shown that leaks could be fixed and that high volumes of desalinated water are affordable.

The answer to the question 'how much water is enough' to address the decline in the level of the Dead Sea is the same in 2012 as it was in the 1970s: a volume of 1.1/1.2 BCM/year – equivalent to the historic flow of the Lower Jordan. However, the question 'how much high quality domestic water is enough' is perceived to be very different in 2012 than it was just a decade ago. A volume of 100 MCM/year was a large number as recently as the late 1990s. At that time economists influenced the highly sensitive discussion on how to deal with the scarcity of natural (renewable blue) water. They successfully kept the idea of mobilizing high volumes of expensive new water off the agenda, insisting that there were still water efficiency battles to be won.

The first decade of the 21st century could not have been more different in Israel from what was anticipated as recently as 1998. One hundred MCM/year of high quality water is no longer a big number. Policies and projects in the Beneficiary Parties now have to deliver at least 500 MCM/year of high quality water. This number fits well into the Red Sea–Dead Sea Water Conveyance scenario. The conveyance could deliver as much as 850 MCM/year, and would have the capacity to deliver such volumes incrementally.

The ability to mobilize annual volumes of even 500 MCM/year of high quality water seriously tests the capacities of alternatives to the Red Sea–Dead Sea Water Conveyance. The option of conveying high quality water via the long proposed Peace Pipeline from the Seyhan and Ceyhan Rivers in southern Turkey has been re-evaluated and is no longer regarded as a long-term secure source of water. Meanwhile Israel's experiments since 2002 with recycling and desalination have shown that it is possible to manufacture 600 MCM/year – which will become 750 MCM/year – of affordable high quality water – but with the use of fossil fuel based technology. At the same time it has pushed the volumes of municipal water recycled up to 700 MCM/year, with 1,000 MCM/year in sight in the future. These very large numbers challenge the relatively small volumes of water that would be produced by many of the alternatives examined in this Study of Alternatives – even when combined.

2. METHODOLOGY

Evaluation Methodology. The alternatives are evaluated according to their technical feasibility, economic costs, and potential environmental and social impacts with regard to the three objectives of the Study Program as noted earlier:

- Saving the Dead Sea from environmental degradation;
- Desalinating water and generating energy at affordable prices for Israel, Jordan, and the Palestinian Authority; and
- Building a symbol of peace and cooperation in the Middle East.

The first objective is environmental, hence of a global public good nature; the second is of a public utility nature with potential commercial aspects; and the third relates to regional cooperation and economic development. These features bear on the cost of capital and the operational costs for each of the first two objectives, and therefore on the costs of water discharged to the Dead Sea and of potable water delivered to Amman and other places to which desalinated water could be distributed. The costs associated with regional cooperation are not estimated; however, these efforts require the significant commitment of experienced and skilled human resources from the Beneficiary Parties to maintain current levels of cooperation and to potentially expand them into new areas.

Alternatives to be Evaluated. The Study of Alternatives examines a range of measures that have been proposed to address the decline of the Dead Sea (see Box 2.1). The alternatives have been labeled with abbreviations to facilitate their identification in the various sections of text and tables in which they appear throughout the document.

Box 2.1: Alternatives to be Examined under the Terms of Reference

No Action – NA1 - Analysis as provided by the Consultant for the Environmental and Social Assessment

Red Sea–Dead Sea Water Conveyance–(Base Case - BC) BC1/BC2 - Description and Analysis as provided by the Consultant for the Environmental and Social Assessment

Lower Jordan River Options (FL)

- FL1 - Full Restoration of Historic Lower Jordan River Flow Levels
- FL2 - Partial Restoration of Historic Lower Jordan River at a Variety of Flow Levels

Water Transfer Options (TR)

- TR1 - Transfer of Mediterranean Sea Water to Dead Sea
- TR2 - Transfer of Water from Turkey by pipeline
- TR3 - Transfer of Water from the Euphrates River Basin by pipeline

Desalination Options (DS)

- DS1 - Desalination of Mediterranean Sea Water on the Mediterranean Coast with Transfer to the Lower Jordan River and Dead Sea Region
- DS2 - Transfer of Mediterranean Sea Water to the Jordan Valley for Local Desalination and Use in Lower Jordan River and Dead Sea Region
- DS3 - Increased Desalination of Mediterranean Sea Water on the Mediterranean Coast with Transfer for Use by the Three Beneficiary Parties to Reduce Water Demand from Lower Jordan River
- DS4 - Desalination of Red Sea Water at the Gulf of Aqaba/Eilat with Transfer for Use by the Three Beneficiary Parties to Reduce Water Demand from Lower Jordan River

Technical and Water Conservation Options (TC)

- TC1- Changes of Technology Used by the Dead Sea Chemical Industry
- TC2 - Increased Water Conservation in the Lower Jordan Basin
- TC3 - Increased Use of Treated Wastewater and Greywater
- TC4 - Changes in Crop Types and Cultivation Methods

Additional Alternatives Identified by the Consultants (AA)

- AA1 - Selling Electricity to Israel and Pumped Storage
- AA2 - Transfers by Tanker, Bag and Submarine Pipeline from Turkey
- AA3 - Submarine Pipelines associated with Oil and Energy Conveyance–Medstream

Combination of Alternatives (CA) – Examination of a Range of Combinations of Alternatives to Assess the Benefits of Such an Approach – the combinations below were identified by the consultants during preparation of the Study

- CA1 - Desalination at Aqaba and Mediterranean Sea, water importation from Turkey and water recycling and conservation
- CA2 - Decreased chemical industry water extraction and decreased irrigation through cropping and other agronomic changes
- CA3 - Aqaba desalination plus decreased use from the chemical industries, plus increases in recycled water for irrigation
- CA4 - Reduced extractions from the Jordan River, plus Aqaba regional desalination and decreased irrigation use though agronomic changes

Evaluating Costs and Benefits. The Dead Sea is a natural and historical site of global uniqueness. Its preservation or conservation, therefore, is valuable to the international community as a whole. This feature is important for the evaluation of the costs and benefits of stabilizing the Dead Sea water level. Whenever feasible, monetary costs and benefits will underlie evaluations and recommendations. When quantifying costs and benefits is impossible or highly imprecise, which is often the case for environmental and social impacts, qualitative indexes will be used.

Range of Alternatives Considered. The list of alternatives covers a wide range of activities and includes options that are located in diverse physical, biological, socio-economic and administrative settings. The relevant literature and data, both formal and informal, are enormous and exist in many locations and in a wide variety of media. In this study, the focus is on recent literature and a comparative analysis of the alternatives (see Table 2.1). Data on costs for various types of technical options, such as pipelines and tunnels, provided by the staff of Coyne et Bellier, have made it possible to gain some understanding of the comparative costs of various alternatives using current unit costs. Earlier studies of specific alternatives, some of them in significant depth, were carried out in the 1980s and 1990s. With the start of the Study Program, there has been increased interest in this topic and possible alternatives proposed by the public, including applied research institutions and nongovernmental organizations (for example, see Boxes 6.1, 6.2 and 6.3 and Table 2.1).

Evaluation and Comparison of Costs. Costs of the Red Sea–Dead Sea Water Conveyance and other alternatives are evaluated and compared using the up-to-date data of Coyne et Bellier developed for the Feasibility Study, adapted for the different circumstances of the various alternatives. The alternatives are compared based on their performance vis-à-vis the two primary goals of stabilizing the Dead Sea level and increasing the supply of potable water. Consequently, the cost of each alternative is broken down into:

- Cost of brine and seawater discharge in Dead Sea; and
- Cost of desalination and conveyance to the consumption areas, including Amman.

The first cost component corresponds to the goal of stabilizing the Dead Sea water level and the second corresponds to the goal of increasing the quantity of potable water. Discussions of the methodology of the cost breakdown, cost data and calculations are presented in Box 2.2 and Appendix 2.

Box 2.2: Methodology for Cost Evaluation of Brine/Seawater and Potable Water

When appropriate (e.g., for the Red Sea–Dead Sea and the Mediterranean Sea–Dead Sea alternatives), and in accordance with the study's main objectives, the cost evaluation for an alternative is divided between the cost of brine/seawater discharge to the Dead Sea and the cost of potable water in Amman. The cost allocation methodology is as follows:

- ***Cost of brine/seawater discharge to Dead Sea:*** The cost of brine/seawater discharge to the Dead Sea is the cost of a project whose sole purpose is to stabilize the Dead Sea water level at about 410 meters below sea level. Saving the Dead Sea would involve the conveyance of over 1 billion m^3 per year of seawater from the Red Sea or the Mediterranean Sea to the Dead Sea and would exploit the elevation difference to generate hydropower.
- ***Cost of potable water in Amman:*** The cost of potable water in Amman (or in any other location) consists of the added cost due to: (i) the conveyance of the additional volume of water needed for desalination from the source (the Red Sea or Mediterranean Sea) to the desalination plant (if desalination is performed near the Dead Sea); (ii) desalination; and (iii) conveyance of the desalinated water to Amman or other locations.
- ***Unit cost:*** The cost of Dead Sea stabilization is provided in US$ per year units and the cost of potable water in Amman in US$ per m^3 units. To obtain the cost of Dead Sea stabilization in US$ per m^3 units requires dividing the annual cost of the Dead Sea stabilization by the quantity of water discharged. Due to the proposed phasing of the volume of water to be discharged, the resulting figures would correspond to the cost of discharged water at the completion of the final phase. The modifier “break-even cost,” is the point where the price charged for potable water in Amman would cover the supply cost. The supply cost involves conveyance from the source to the desalination plant, desalination and conveyance of the desalinated water to Amman.

Table 2.1: Red Sea–Dead Sea Water Conveyance Study Program
Study of Alternatives – Summary of Recent Studies (September 2012)

Alternative	Report Title	Consultant/ Sponsor	Date	Evaluation Level of Analysis 1=None / 5=Extensive			Public Consultation	Public Disclosure
				Engineering	Environ-mental	Social	Yes/No	Yes/No
Red Sea–Dead Sea	Feasibility Study	Coyne et Bellier	July 2012	5	4	3	Yes	Yes
	Environmental and Social Impact Assessment (ESA)	ERM	July 2012	1	5	5	Yes	Yes
	Red Sea Modeling	Thetis	Sep-2011	3	5	1	Yes	Yes
	Dead Sea Modeling	Tahal	Sep-2011	1	5	1	Yes	Yes
Lower Jordan River Restoration	Roadmap for Rehabilitation of the Lower Jordan River	DHV/FoEME	Nov-2011	1	3	1	No	Yes
	Environmental Flows Report for Rehabilitation of the Lower Jordan River	Gafny, et al/FoEME	2010	2	5	3	No	Yes
	Economic Analysis of Policy Options for Water Conservation in Jordan, Israel and Palestinian Authority	Gorskaya, et al/FoEME	2010	1	3	3	No	Yes
Water Transfer Options	Altering the Water Balance as a Means to Addressing Problems of the Dead Sea	Jerusalem Institute for Israel Studies	Dec-2011	2	1	1	No	Yes
	Reclaiming the Dead Sea: Alternatives for Action	Samuel Neaman Institute	Sep-2007	2	3	3	No	Yes
	Peace Pipeline from Turkey: Water Transfer from Seyhan and Ceyhan Rivers	Brown and Root	1980s	3	1	1	No	No
	Water Transfer from Euphrates River in Iraq	USAID	1980s	2	1	1	No	No
		Murakami	1995	2	1	1	No	Yes

Alternative	Report Title	Consultant/ Sponsor	Date	Evaluation Level of Analysis 1=None / 5=Extensive Engineering	Environ-mental	Social	Public Consultation	Public Disclosure
							Yes/No	Yes/No
		GTZ	1996, 1998	2	1	1	No	Yes
Desalination Options	Sea Water Desalination in Israel: Planning, Coping with Difficulties, and Economic Aspects of Long-term Risks	State of Israel Water Authority: Desalination Division	Oct-2010	4	3	3	No	Yes
	Reclaiming the Dead Sea: Alternatives for Action	Samuel Neaman Institute	Sep-2007	2	3	3	No	Yes
Technical Conservation Options	Salt Production from the Dead Sea Using Various Technological Options	Department of Chemical Engineering, Mutah University, Jordan	2005	5	2	1	No	Yes
	An Economic Assessment of Dead Sea Preservation and Restoration	NATO Science for Peace and Security Series C: Environmental Security	2009	Not infrastructure based alternative	3	5	No	Yes
	Wells and Canals in Jordan: Can Pricing Policies Regulate Irrigation Water Use?	IWMI	Dec-2007	Not infrastructure based alternative	3	5	No	Yes
	Irrigated Agriculture, Water Pricing and Water Savings in the Lower Jordan River Basin (in Jordan)	IWMI	2007	3	3	5	No	Yes
	Dealing with Closed Basins: The Case of the Lower Jordan River Basin	IWMI	2007	2	2	5	No	Yes
	Water Demand Management, Conservation and Pollution Control	WHO Regional Office for Eastern Med / CEHA	2001	2	2	2	No	Yes
	Dead Sea Chemical Industries Study	Zbranek/World Bank	August 2012	3	1	2	No	Yes

Alternative	Report Title	Consultant/ Sponsor	Date	Evaluation Level of Analysis 1=None / 5=Extensive			Public Consultation	Public Disclosure
				Engineering	Environ-mental	Social	Yes/No	Yes/No
Additional Options	Evaluating Water-Importation Options in Jordan: Opportunities and Constraints	Hussein, I., Al-Jayyomi, O.	1999	4	2	4	No	Yes
Combined Options	The Jordan River Basin: 3 Options for Satisfying the Current and Future Water Demand of the Five Riparians	Phillips, D.J.H, Jagerskog, A., Turton, A.	2009	3	2	5	No	Yes
	The Jordan River Basin: 4. Using the Trans-boundary Waters Opportunity Analysis to Enhance Economic Benefits	Phillips, D.J.H	2010	2	1	5	No	Yes
Options Outside the Terms of Reference	Jordan Red Sea Project Study Program	Jordan Ministry of Water and Irrigation	Ongoing	2	1	1	No	Yes

THE STUDY OF ALTERNATIVES PROCESS

Meetings and Field Visits. When studying the alternatives, the activities of the Study of Alternatives Team were guided by the Terms of Reference agreed by the Beneficiary Parties. Their research and evaluation was informed by a large number of meetings with the most senior officials in all three Beneficiary Parties responsible for water policy, with water managers, with water and environmental scientists and engineers and with representatives of applied research institutes, private sector and nongovernmental organizations. These parties drew the attention of the Team to the rich technical, economic, environmental and social documentation generated during the past decades.

Research Data Base. As part of the research for this report, the Study of Alternatives Team compiled a background documents data base of more than 500 items including journal articles, published and unpublished papers, reports, newspaper articles, web blogs and other material. The data base is on Excel and is organized by alternative. The material in the database is classified to match the alternatives reviewed in the Study of Alternatives. Persons interested in receiving a copy of the data base should contact Alexander McPhail at this email address: amcphail@worldbank.org. An overview of data sources is provided in Box 2.3.

Box 2.3: Economic, Cost and Water Data

- ***Economic and cost data*:** The cost calculations of the Red Sea–Dead Sea and Mediterranean Sea–Dead Sea alternatives are based on Coyne et Bellier's up-to-date data. In several places in the Study of Alternatives, results of earlier studies, which are based on now outdated economic and cost data, are reported.
- ***Water data*:** Data on water resources in the Middle East in general and the Jordan River basin in particular have expanded considerably in recent years, as data sources flourish and multiply by the week. In this report, the Study of Alternatives Team makes a clear distinction between official and unofficial sources. Official data sources include Israel's Hydrological Service, Israel's Water and Sewage Authority, Geological Survey of Israel, Kinneret Limnological Laboratory, Israel Oceanographic & Limnological Research, Israel's Central Bureau of Statistics, Mekorot, Jordanian Ministry of Water and Irrigation, Water Authority of Jordan, Jordan Valley Authority, and the Palestinian Water Authority. Unofficial data sources include FoEME reports, GLOWA Project, SMART Project, MED EUWI Dialogues and SWIM Demo Project. Analyses and assessments in the Study of Alternatives are based solely on data obtained from official sources.

Unique Circumstances. The study has been undertaken in the unique circumstances of the Beneficiary Parties. For example, the volumes of water available and being used are not agreed. Further, the three economies have very different capacities for investment to remedy the problems of water scarcity. It is also important to note that the Beneficiary Parties have been relating to each other in a cooperative mode of variable intensity for a number of decades in attempting to address complex shared water resources management and related economic, environmental and social issues and challenges.

3. NO ACTION ALTERNATIVE – NO PROJECT SCENARIO (NA1)

Description. The "No Project Scenario" is a projection of future conditions that would be likely to develop if no action were taken to address declining Dead Sea levels. The main anticipated effects are summarized in Table 3.1. Consistent with the Terms of Reference, this section of the analysis draws on the Environmental and Social Assessment prepared by ERM (2012).

Table 3.1: No Action Alternative–Pros and Cons (NA)

	PROS	CONS
Overview	• No direct capital costs or operation and maintenance expenditures • No large infrastructure investment needed • Short term increase in production of potash	• Does not address ongoing decline of sea level and associated degradation • Does not provide additional water and energy to the region
Technical	• No new construction undertaken	• No technical innovation
Economic and Financial	• Avoids medium and long-term impact on chemical companies from dilution of salinity in Dead Sea	• No new potable water for the region • Eventual closure of chemical companies • Need for continued expenditures to address damage to infrastructure from decline of sea level, including for transport, agriculture and tourism
Environmental and Social	• Avoids environmental and social impacts to Red Sea and Wadi Araba/Arava Valley from construction and operation of proposed water transfer	• Continued deterioration of Dead Sea environment • Reduced attractiveness of Dead Sea for tourism • Loss of freshwater springs and groundwater resources as a result of fresh/salt water intrusions
Other	• No need to compete for limited international funding	• Signal that Dead Sea and region–including Lower Jordan River environment–are not high priority ecological problem needing remediation at the global, regional and national level

Source: ERM, 2012, Table ES.3.

Outcomes from No Action. The No Action alternative entails a number of contemporary and future outcomes.

Changes in the Level of the Dead Sea. Currently, the Dead Sea and its shores are undergoing serious environmental damage as a consequence of the decline in the level of the Sea. Since more water is subtracted than renewed, there is a constant drop of sea level at a rate of over 1 m/year. See Figure 1.1 above.

Since the early 1960s the level of the Dead Sea has dropped by more than 30 m and today it stands at 426 m below sea level (July 2011, Arab Potash Company and Dead Sea Works records). It now has a surface area of less than 650 km^2. With no action the sea level is expected to drop by another 150 m until it will stabilize as a much smaller water body at a level of about 543 m below sea level by the year 2156 (Coyne et Bellier, 2010).

Assuming no major changes in freshwater inflows, and the potash industries continuing their planned production (these industry plans, and hence the 'no project' scenario, include a significant increase in production levels over the next decade or so – as discussed in Section A3.2.2 of the main ESA report (ERM, 2012)), it is estimated that the Dead Sea surface level will fall a further 45 m by 2070, with the surface area declining from 605 km^2 to 509 km^2. This is a drop of around 16 percent from the 2010 surface area, and means that the surface area in 2070 will be just over 60 percent of the pre-decline area of the northern basin. The projected difference in the surface area of the Dead Sea between 2010 and 2070, if no scheme goes ahead, is illustrated in Map 2. If the mineral extraction industries continue operations after 2070, the surface level will continue to fall at a rate of 1 to 1.2m/year, reaching a level of 550 meters below sea level by 2150. If the industries cease operations within the next few decades, the Dead Sea will stabilize naturally at a level of around 515 meters below sea level, about 300 years from now. In either case, with decreasing surface elevation, the area will continue to shrink beyond 2070.

Implications of Degradation. Not taking any measures to change the situation will cause the continued deterioration of the Dead Sea and its environment. These outcomes are already evident in the deterioration of existing infrastructures, in the trends of social and economic changes in the region and in the serious degradation of some elements of the environment in the Dead Sea region.

Impacts from Shoreline Retreat and Dehydration. The progressive decrease in sea level has resulted in a horizontal retreat of the shoreline and the almost total dehydration of the shallow Southern Basin. The exposure of the shore is associated with the development of sinkholes, mud flats, steep slopes, and earthquake-associated landslides. Serious damage has occurred impacting negatively the terrestrial and aquatic ecosystems, the hotels and related tourist activities, neighbouring settlements and the chemical industry. Damage to road, bridge and irrigation infrastructure is particularly evident. Further, extensive stretches of the shoreline are now “off limits” for safety reasons due to land subsidence (Israel Ministry of the Environment and the Jerusalem Institute, 2006).

Shoreline Habitats and Ecological Impacts. An additional problem related to the retreat of the level of the sea is the irreversible damage to the shore habitat and to unique species. The ecology of the lakeside oases is of both local and global importance. They serve as vital rest stops along bird migration routes, as well as a source of water and food for the birds and larger mammals of the Dead Sea region. The falling level of the Dead Sea also causes changes in the shore habitat, creating rapid flow gullies which overwhelm the normal pool embankments that sustain the ecology.

Costs of Not Addressing the Decline. There will be economic, social and environmental costs associated with not remedying the decline of the Dead Sea and the imminent deficit of potable water in Jordan. Not taking any measures to change the situation will cause continued deterioration of the Dead Sea and its environment. At this stage, cost estimates are based on limited data and on a set of variable assumptions. These are roughly estimated at about US$90 million per year (Samuel Neaman Institute, 2007).

A related study by Becker and Katz (2009) estimated the No Action cost in the range of US$73 - US$227 million a year. These estimates are based on willingness to pay by the local population to preserve the Dead Sea. However, the unique characteristics of the Dead Sea imply that the benefits of its preservation extend beyond the region and include the international community as a whole. The total benefit of preventing the decline of the Dead Sea is therefore likely to be larger than the above range.

Costs of Damage to Agriculture and Mineral Industries. The above estimates do not include the costs of potential damage to agriculture in the region and to the mineral extraction industries. Likewise, the damage to tourism underestimates actual costs when considering the economy of the tourist industries, in which huge investments have been made in facilities and infrastructure, and from which much employment and foreign currencies earnings are, and could be, generated.

Actions That May be Taken. Failing to carry out any of the alternatives considered does not mean that no action will be undertaken. Given the worsening water deficit in Jordan, as its population grows over time, Jordan will seek other ways to increase the supply of potable water.

4. RED SEA–DEAD SEA (RSDS) WATER CONVEYANCE – BASE CASE PLUS CONVEYANCE ALIGNMENTS (BC1/BC2)

Three Main Options. The Feasibility Study examined three main options for conveying Red Sea water about 180 km to the Dead Sea. The study labels the conveyance scheme options as the "Alternative Base Case Plus Conveyance Configurations" (see Maps 3a and 3b) and defines these as:

- A buried pipeline;
- A tunnel starting at 0 m elevation (the "low-level tunnel"); and
- A tunnel and canal system at 220 m elevation (the "high-level tunnel").

Buried Pipeline Option. The Buried Pipeline proposal incorporates a pumping station immediately adjacent to the eastern intake site just south of Aqaba on the Gulf of Aqaba. The pumped riser main comprises a short section of pressurized tunnel around the eastern and northern fringes of the city of Aqaba and a series of parallel pipelines from the downstream end of the tunnel to a regulating tank at a high point on the Gharandal Saddle, which marks the watershed between the Red Sea and Dead Sea water catchments. From the regulating tank, flow would be by gravity, again in a series of parallel pipelines, to the hydropower plant at the southern end of the Dead Sea. The pipelines' alignment is approximately parallel to the Israeli/Jordanian border, typically 5 km to 10 km east of the border, and crosses the Dead Sea road a number of times. The desalination plant for the high level desalination variant of this proposed configuration would be located on the pipeline alignment about 50 km north of the Gharandal Saddle. The high level desalination option would permit a second hydropower plant located about 300 meters north of the Gharandal Saddle. The desalination plant for the low level desalination variation would be located adjacent to the single hydropower plant.

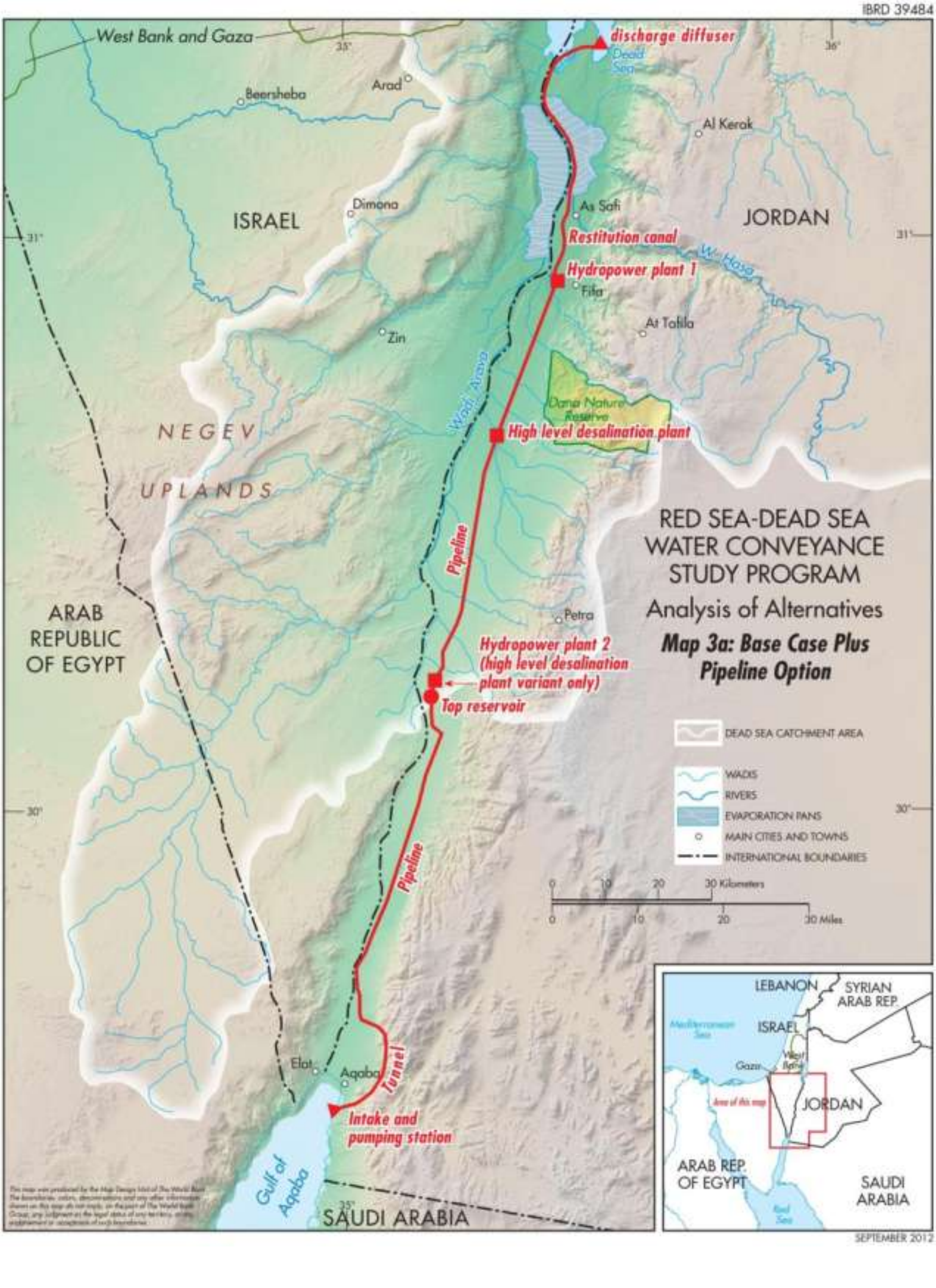
Low Level Tunnel Option. The proposed Low Level Tunnel alignment is located within the eastern escarpment of the Dead Sea rift valley. The tunnel would have an internal diameter of 8.3 m and would fall gently from the eastern intake to an outlet portal some 160 km north of the city of Aqaba. The proposed alignment is below the groundwater table over most of its length. From the tunnel outlet the conveyance would fall more steeply in buried steel penstocks 11 km long to a hydropower plant at the southern end of the Dead Sea. The desalination plant for the high level desalination variation of this configuration would be located at the tunnel outlet portal. The desalination plant for the low level desalination plant variation would be located at the downstream end of the penstocks adjacent to the hydropower plant.

The High Level Tunnel Option. The proposed High Level Tunnel incorporates a pumping station immediately adjacent to the eastern intake site just south of Aqaba on the Gulf of Aqaba. The proposed conveyance alignment rises sharply from the eastern intake pump station to a high point at an elevation of +220 m some 4.4 km from the eastern intake from where it falls gently in a sequence of tunnel and open canal sections to a tunnel outlet portal some 160 km north of the city of Aqaba. The tunnel sections would be located in the eastern escarpment of the Dead Sea rift valley and would generally be located above the groundwater table. The open canal sections of this proposed configuration lie within the Wadi Araba/Arava Valley at the toe of the eastern escarpment. From the tunnel outlet the conveyance would fall more steeply in buried steel penstocks 14 km long to a hydropower plant at the southern end of the Dead Sea. The desalination plant for the high level desalination variation of this configuration would be located at the tunnel outlet portal. The desalination plant for the low level desalination variation would be located adjacent to the hydropower plant.

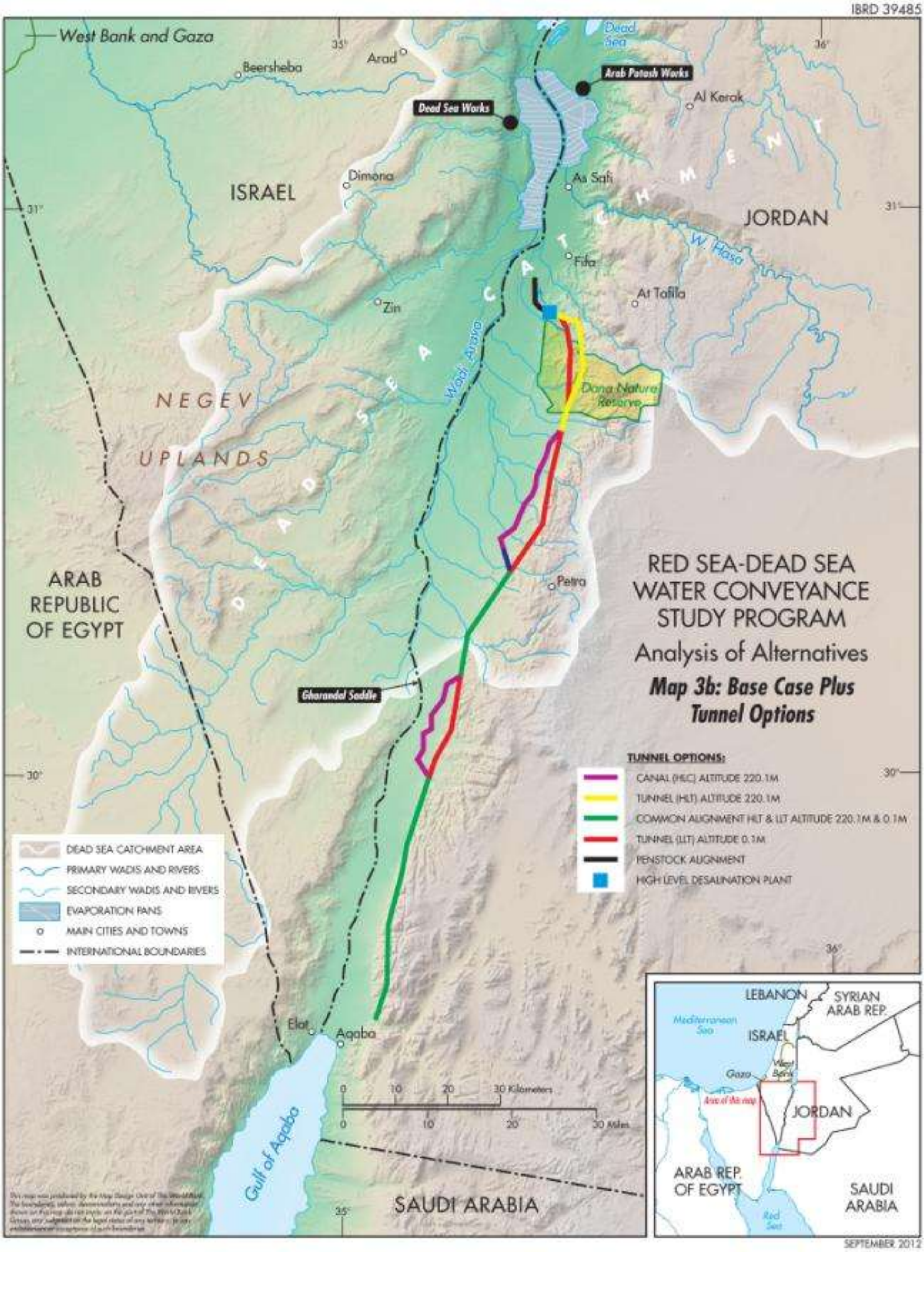
All three proposed conveyance options lie entirely within Jordanian territory. The main anticipated effects are summarized in Table 4.1.

Table 4.1: Base Case Plus Conveyance Configurations–Pros and Cons (BC)

	PROS	CONS
Overview	• Two main goals met: • Restoration of level of Dead Sea • Provision of substantial volumes of high quality water • Global public good value of Dead Sea region maintained	• Major infrastructure with potentially environmentally negative consequences although most could be significantly mitigated • Risk of unknown consequences from mixing Red Sea and Dead Sea waters unless adequately studied and tested
Technical	• Use of proven technology–except with respect to mixing of Red Sea and Dead Sea waters	• Risk of impacts if proceeding with transfer of water from Red Sea to Dead Sea without adequate studies and testing • Risk of a seismic event, accident or intentional damage to infrastructure with environmental impacts
Economic and Financial	• Hydropower to offset partially energy requirements for desalination • Secure supplies of potable water for Amman and the Dead Sea Region areas • End to rising costs of repairs to road and other infrastructure caused by fall in level of Dead Sea	• High capital costs • High operational and maintenance costs • Significant outlays for energy
Environ-mental and Social	• Resolution of sink-hole problem associated with progressive regression of Dead Sea • Social amenity of secure potable water for decades for water users living at higher elevations in Jordan and elsewhere in all three Beneficiary Parties • Short-term increased employment during construction period • Limited increased employment from new jobs to operate and maintain the conveyance infrastructure	• Anticipated to require limited involuntary resettlement and some land acquisition • Large short-term negative environmental and social effects during construction, which can be mitigated • Possible significant effects on Dead Sea from mixing with Red Sea water and desalination brine • Carbon impact of power needed to run the scheme
Other	• Creation of strategically important infrastructure providing mutual and shared benefits reinforcing ongoing regional cooperation • Engagement of global interests and potential international funding to a global environmental and heritage project	• Infrastructure located in Jordan, raising the possible risk of, over time, non-cooperative interventions by one or more of Beneficiary Parties • Significant competition for available international funding with other essential priorities • May be more expensive than increments of combinations of alternatives



IBRD 39484
West Bank and Gaza
discharge diffuser
Dead Sea
Beersheba
Arad
Al Kerak
Dimona
ISRAEL
As Safi
JORDAN
Restitution canal
W. Hasa
Hydropower plant 1
Fifa
At Tafila
Zin
Wadi Araba
Dana Nature Reserve
NEGEV
High level desalination plant
UPLANDS
RED SEA-DEAD SEA
WATER CONVEYANCE
STUDY PROGRAM
Analysis of Alternatives
Map 3a: Base Case Plus
Pipeline Option
Pipeline
ARAB
REPUBLIC
OF EGYPT
Petra
Hydropower plant 2
(high level desalination
plant variant only)
Top reservoir
DEAD SEA CATCHMENT AREA
WADIS
RIVERS
EVAPORATION PANS
MAIN CITIES AND TOWNS
INTERNATIONAL BOUNDARIES
Pipeline
0 10 20 30 Kilometers
0 10 20 30 Miles
LEBANON
SYRIAN
ARAB REP.
ISRAEL
Gaza
JORDAN
Tunnel
Elat
Aqaba
Intake and
pumping station
ARAB REP.
OF EGYPT
SAUDI
ARABIA
Gulf of
Aqaba
SAUDI ARABIA
SEPTEMBER 2012


IBRD 39485
RED SEA-DEAD SEA
WATER CONVEYANCE
STUDY PROGRAM
Analysis of Alternatives
Map 3b: Base Case Plus
Tunnel Options
TUNNEL OPTIONS:
CANAL (HLC) ALTITUDE 220.1M
TUNNEL (HLT) ALTITUDE 220.1M
COMMON ALIGNMENT HLT & LLT ALTITUDE 220.1M & 0.1M
TUNNEL (LLT) ALTITUDE 0.1M
PENSTOCK ALIGNMENT
HIGH LEVEL DESALINATION PLANT
DEAD SEA CATCHMENT AREA
PRIMARY WADIS AND RIVERS
SECONDARY WADIS AND RIVERS
EVAPORATION PANS
MAIN CITIES AND TOWNS
INTERNATIONAL BOUNDARIES
West Bank and Gaza
Beersheba
Arad
Dead Sea
Arab Potash Works
Dead Sea Works
Al Kerak
Dimona
ISRAEL
As Safi
JORDAN
W. Hasa
Fifa
At Tafila
Zin
Wadi Araba
Dana Nature Reserve
NEGEV
UPLANDS
DEAD SEA CATCHMENT
ARAB REPUBLIC OF EGYPT
Petra
Gharandal Saddle
Elat
Aqaba
Gulf of Aqaba
SAUDI ARABIA
30 Kilometers
30 Miles
LEBANON
SYRIAN ARAB REP.
ISRAEL
Gaza
JORDAN
ARAB REP. OF EGYPT
SAUDI ARABIA
SEPTEMBER 2012

Location of Intake and Discharge Points. For each of the proposed conveyance options, the intake would be on the Jordan side of the Gulf of Aqaba, about 5 km south of the city of Aqaba, and from which 2,000 MCM/year of seawater would be extracted from the Red Sea. The desalination plant would operate by reverse osmosis and its capacity would be expanded in phases until eventually all the water would be desalinated. The outflow from the hydropower plant would continue in a series of buried pipes and open channels, and eventually be discharged to the Dead Sea.

Provision of Desalinated Water. Freshwater conveyances would be constructed to take the potable water from the desalination plant to different locations in Jordan, and also to as yet undetermined locations in Israel and the Palestinian Authority. For Jordan, the eastern freshwater line would rise up the escarpment in the Jordanian southern highlands, passing south of Tafila before turning north to follow the approximate line of the Desert Highway, terminating in the southern outskirts of Amman. A line (or lines) would cross the border to provide water to Israel (probably to tourism facilities and residential communities in the Dead Sea basin and/or Wadi Araba/Arava Valley) and to the Palestinian Authority (at locations to be determined).

Net Present Value. According to the Feasibility Study, the net present value of all three options is very similar when examined over 50 years with a 10 percent discount rate and including energy but not the other operating costs. The buried pipeline conveyance combined with a high level desalination plant is the recommended solution in the Feasibility Study. See Table 4.2 below, which shows the full cost of that option.

Table 4.2: Full Cost of the Pipeline with High Level Desalination Plant Configuration

Cost items	**CAPEX (MUSD)**	**Annual Operation and Maintenance costs (MUSD)**					**Average annual renewal costs (MUSD)**
		2020	**2030**	**2040**	**2050**	**2060**	
Intake works	23,00	/	/	/	/	/	/
Pumping station	230,94	/	/	/	/	/	1,51
Main water conveyance (tunnel and steel pipes)	4 689,98	132,91	132,91	132,91	132,91	132,91	1,04
Desalination facilities	2 436,85	120,11	146,66	180,72	223,08	277,91	19,27
Hydropower plants	241,38	6,23	6,23	6,23	6,23	6,23	2,21
Restitution canal	266,93	/	/	/	/	/	/
Connection to the transmission grid	265,56	5,31	5,31	5,31	5,31	5,31	0,80
Project Management	244,64	/	/	/	/	/	/
Institutional Structure	7,8	17,595	17,595	17,595	17,595	17,595	/
Sub-total	8 407,09	282,16	308,71	342,77	385,13	439,96	24,81
Water transmission line to Amman	2 015,74	84,43	106,68	127,67	159,82	192,29	3,49
Connection to the transmission grid	131,44	2,63	2,63	2,63	2,63	2,63	0,39
Project Management	64,42	/	/	/	/	/	/
Sub-total WTL to Amman	2 211,60	87,06	109,31	130,30	162,45	194,92	3,88
Total	**10 618,69**	**369,22**	**418,02**	**473,07**	**547,58**	**634,88**	**28,70**

Source: Coyne et Bellier, 2010, Table 24.8.1, Section 24, page 64
Note: A provision of 500 to 750 million US Dollars should be added to the Capital Expenditure (CAPEX) provided in the above table to cover the construction costs of the water transmission line to Israel and to the Palestinian Authority

Potential Environmental and Social Impacts. The key environmental and social issues associated with the Base Case center around the effects on the water bodies at either end of the conveyance, the rare and/or fragile aspects of the desert ecosystems, the archaeological heritage and disturbances to those communities that live in and around the Wadi Araba/Arava Valley. An issue of potentially major concern to the environmental and social acceptability of the Red Sea–Dead Sea Water Conveyance is the risk that the influx of seawater and reject brine into the Dead Sea will cause changes to its appearance and water quality such that its value as a heritage site of international importance will be damaged.

The main environmental and social risks associated with the Base Case, as identified by ERM (2012), are:

- Unanticipated or unexpectedly acute impacts on Dead Sea quality;
- Contamination of aquifers due to catastrophic failure of the saltwater conveyance;
- Large-scale regional public opposition with mobilization of international stakeholders;
- Impacts arising from poor construction practice coupled with inadequate supervision (waste disposal, health and safety, nuisances);
- Destruction or loss of archaeological and culturally significant sites;
- Community objections at worksites because of land disputes, migrant labor, social changes or accidents; and
- Disturbance to ecologically sensitive areas in the Wadi Araba/Arava Valley.

Beyond the Study Program: Proposed Jordan Red Sea Project. In addition to the Red Sea–Dead Sea Water Conveyance being examined by the Beneficiary Parties with support from the World Bank, another proposal is being examined by Jordan, which is called the Jordan Red Sea Project (see Box 4.1).

Box 4.1: The Jordan Red Sea Project (JRSP)

The Jordan Red Sea Project (JRSP) http://www.jrsp-jordan.com/ is a proposed water infrastructure and economic development project designed to assist the Hashemite Kingdom of Jordan to establish water independence through a long-term and stable potable water supply. This is not an alternative covered under the Terms of Reference for the Study of Alternatives; however, it is important for the reader to be aware of this ongoing initiative. The core project involves the financing, planning, design, construction, operation and maintenance of a water conveyance system from the Red Sea to the Dead Sea and to Amman with large scale desalination of seawater for Jordan and perhaps also for other regional governments. (See also Section 8 below.)

The JRSP is a Jordan only initiative, and does not involve Israel, the Palestinian Authority or the World Bank.

The JRSP has four primary objectives:

- Establish a secure and affordable water supply for Jordan;
- Save the Dead Sea from extinction;
- Support widespread economic growth; and
- Potentially provide water to the region.

The proposed JRSP involves a pipeline conveyance through the Wadi Araba/Arava Valley to transport about 2,000 MCM/year of sea water from Aqaba on the Red Sea to desalination and hydropower plants. The brine would be disposed of in the Dead Sea. This is a large project and the envisaged infrastructure includes:

- Seawater Pump Stations: One intake pump station that has eleven (11) pumps and two seawater booster pump stations that each have eleven (11) pumps;
- Seawater Pipelines: 525 kilometers of seawater intake, and seawater and brine conveyance pipelines (2.7 to 3.7 meter diameter);
- Freshwater Pipelines: 348 kilometers of freshwater conveyance pipelines (1.0 to 2.1 meter diameter);
- Desalination: Two desalination facilities, one for 80 MCM/year and another for 850 MCM/year; and

- Hydro-electric Power: Two seawater and one freshwater hydropower stations to produce approximately 180 MW of electrical energy per year (18 percent of the project's power requirements).

The Government of Jordan plans to contract a Master Developer that would be responsible for planning, developing, implementing and managing the JRSP. The JRSP water infrastructure capital and operational costs will exceed water related revenues that could be collected through conventional cost-recovery methods. The Master Developer would therefore implement a "development program" within Jordan in order to help repay project debt and provide a reasonable rate of return to project investors.

The development program centers on real estate and includes new cities, resorts and industrial development across Jordan. These include:

- South Amman City: High-density residential housing to accommodate a 30-year population growth of up to 1,000,000 people*;*
- South Dead Sea City: A mixed-use city featuring a JRSP-related industrial development zone with an adjacent residential community and commercial town center to support a 30-year population growth of up to 180,000 workers and residents*;*
- North Aqaba City: A new mixed-use city with technical and professional employment, a variety of workforce housing and a commercial town center to support a 30-year population growth of 40,000 people*;*
- Resorts: Five new resort properties with an assortment of amenities focused on the growing tourism and recreation industry. Resorts could be located near Aqaba, the south Dead Sea, Petra, Wadi Rum and other national park areas*;* and
- Gated Communities: 47,000 low density gated community luxury homes in multiple locations for 120,000 people.

The JRSP is anticipated to be divided into multiple phases, each assigned a freshwater amount to be delivered in a specific period of time. A phasing plan will allow manageable portions of the overall project to be planned, financed, designed, constructed, started, operated and maintained. Phase I envisages 210 MCM/year of desalinated water by 2018.

As of February 2012, two of the six short listed consortia have responded to the Government of Jordan's Master Developer request for proposals. These proposals are under evaluation and, according to media reports, the highest ranked proposal should be announced in November 2012 (e.g., see: http://jordantimes.com/red-sea-project-master-developer-to-be-chosen-in-april). The table below shows the major differences between the Red Sea–Dead Sea Water Conveyance Program and the JRSP.

	Red Sea–Dead Sea Water Conveyance Study Program	Jordan Red Sea Project
Focus	Tri-lateral	Jordan Only
Scope	Water Hydropower Save the Dead Sea Regional Cooperation	Water Hydropower Save the Dead Sea Real Estate and Other Economic Development
Desalination	850 MCM/year	930 MCM/year
Financing	Mostly Public Sector	Mostly Private Sector
Stage	Feasibility Studies completed late-2012	Master Developer award November 2012

5. LOWER JORDAN OPTIONS – FULL AND PARTIAL RESTORATION OF FLOWS (FL1/FL2) – see Map 4

The Jordan River Basin. The Jordan River drains a total area of about 18,000 km² (see Map 1a). Its three head water tributaries drain the Upper Jordan basin and flow southward into Lake Tiberias (see Box 5.1). These tributary rivers are the Hisbani, coming from Lebanon, the Banias, coming from the Golan Heights and the Dan, coming from the northern Hula Valley. The three tributaries contribute about 500 MCM/year on average, of which about 150–200 MCM/year are consumed (mostly for irrigation purposes) north of Lake Tiberias.

Box 5.1: Lake Tiberias: Available Water and Allocation

Lake Tiberias, also known as Lake Kinneret or the Sea of Galilee, is a fresh water lake located at the lower end of the upper Jordan River (see Map 1a). Its many uses include recreation, fishing and a source of water supply to nearby towns and villages and to the Israeli National Water Carrier. During the period 1973 – 2009, the average annual recharge (total water inflow, including direct rainfall) of Lake Tiberias was 581 MCM, with a standard deviation of 258 MCM (Weinberger et al, 2012). The lake loses 249 MCM/year to evaporation (op. cit.), leaving an average net water balance of 332 MCM/year with high fluctuations. The allocation of this water volume is as follows:

- *Releases to towns and villages surrounding the lake* – 40 MCM/year. This quantity will increase with population growth and is expected to reach 50 MCM/year in a decade or two.
- *Releases to Jordan* (in fulfillment of the 1994 Peace Agreement) – 50 MCM/year.
- *Additional water committed to Jordan* (in a preliminary framework recently agreed by Israel and Jordan) – 50 MCM/year.
- *Lower Jordan River restoration* – between 20 and 30 MCM/year (a decision has been made and implementation will begin as soon as the Bitania sewage treatment facility is completed and its water replaces Lake Tiberias water used for irrigation).
- *Israel's National Water Carrier* – the balance of 152 MCM/year on average (obtained by subtracting from 581 the sum of 249+50+50+50+30) will be available for pumping to Israel's National Water Carrier.
- *Water balance:* In the future, as Israel increases its desalination capacity (see Israel Water and Sewage Authority, 2011), the need to pump Lake Tiberias water to the Israeli National Water Carrier will decrease and the allocation to Lower Jordan River restoration and to Jordan will accordingly increase.

Lower Jordan River. The Lower Jordan River is the longest perennial river in this region, flowing about 220 km from Lake Tiberias to the Dead Sea. Over this distance the river descends from an altitude of 212 above sea level to 422 meters below sea level. Ten kilometers downstream of Lake Tiberias, the Lower Jordan River receives the water from its main tributary, the Yarmouk River. Historically, this river, coming from the southwestern part of Syria, contributed 460 MCM/year on average to the Lower Jordan River flow. Several temporary streams of lesser importance (side-wadis) and the larger Zarqa River in Jordan also feed the Lower Jordan River.

Historic and Current Flows. Up to the mid-20th century, the original flow of the Lower Jordan River into the Dead Sea varied between 1,100 and 1,400 MCM/year (Klein, 1998; Al-Weshah, 2000). Today, the average flow of the Lower Jordan River into the Dead Sea is estimated at 40 MCM/year (Tahal, 2011). Fresh water input to the Lower Jordan River between Lake Tiberias and the Dead Sea occurs only in periods of high rainfall. At other times, the flow is a combination of polluted water from sewers, agricultural uses, fish farms and saline springs.

Full and Partial Restoration Defined. A restoration of the Lower Jordan River consists of three main characteristics: flow, quality and timing. Full restoration to the situation prevailing up to the mid-20th century, at which time the Hula wetland was reclaimed and major diversions began, implies using the natural flows of the Jordan and Yarmouk Rivers, with their historic water quality and timing of flow.

Full restoration, according to Gafny et al (2010), corresponds to restoring the flow to 1,200 – 1,400 MCM/year. They conclude that "full restoration" quantities are beyond the ability of the region and, therefore, there is little likelihood that this can be realized or that it is necessarily desirable:

> "It is important to acknowledge that full restoration is seldom possible. Firstly, because of the on-going water shortage in the Lower Jordan River (Orthofer et al, 2007) the quantities and quality of the water required for full restoration are beyond the ability of the countries in the region. Secondly, our knowledge of what exactly [was] the original pre-perturbation condition is limited. Thirdly, such restoration would mean modifying the physical and biological character of the reach (channel form, biological communities) so that they replicate the original state. This would involve changing all of the inputs and outputs (water quality and quantity, sediment, and organisms) from upstream, downstream and the riparian zone, to the pre-perturbation state. Because of the connections between the LJR and its catchment, in most situations this would only be possible if the entire river network, and most of the catchment surface, would also be restored. Clearly, this will probably not be possible. Even if the attempt was made, the changes that have occurred over the last 100 years may have been great enough to alter the river irreversibly." (Gafny et al, 2010, pg. 55).

As the above quote clarifies, restoring the original natural flows is no longer feasible and this option is therefore not considered in the report. The term "full restoration" denotes the situation where the annual flow of the Lower Jordan River is brought back to the original average annual flow of above 1,000 MCM/year, while "partial restoration" denotes a situation where the annual flow is substantially below that rate.

The publication of the IHS report (Weinberger, 2012) further confirms that the availability of natural water in the Upper Jordan Basin has been declining and will continue to decline. The implication for the restoration of the Lower Jordan is that because the Upper Jordan will not be able to provide its historic flow, full restoration of the Lower Jordan would not be possible without new water from recycled sources.

FULL AND PARTIAL RESTORATION OF THE LOWER JORDAN RIVER FLOWS (FL1/FL2): THE VIEW OF THE STUDY OF ALTERNATIVES TEAM

Sources of Restoration Water. The use of potable water for environmental remediation in a region afflicted with acute water shortages is neither feasible nor desirable. The use of desalinated or imported water for river restoration is problematic for two additional reasons. First, this water is expensive and using it for environmental purposes raises severe cost-benefit, funding and water resource re-allocation issues (see Table 5.1). Second, desalination entails negative environmental impacts, by consuming significant amounts of energy, requiring the use of precious coastal areas for the siting of desalination facilities and their supporting infrastructure, and for the discharge of brine. The two effects – high cost and negative environmental impact – when combined render use of desalinated water unsuitable for most environmental remediation purposes. A strategy that assigns large volumes of natural or desalinated water for Lower Jordan River restoration is, therefore, not viable.

Use of Lake Tiberias Water for Partial Restoration. A limited quantity of Lake Tiberias water could be allocated to Lower Jordan River restoration. Israel recently announced that it will gradually release 30 MCM/year of Lake Tiberias water for that purpose. However, in light of Box 5.1 and the above discussion, the potential for this quantity to increase in the future is limited. Moreover, the use of Lake Tiberias water for Lower Jordan River restoration is expensive because this water could alternatively be used to increase the supply of potable water in Jordan, alleviating the water shortage in Amman. The alternative price of Lake Tiberias water allocated for Lower Jordan River restoration is therefore the price that Amman residents are willing to pay for this water.

Use of Natural or Desalinated Water for Partial Lower Jordan River Restoration in Conjunction with Supply of Water to Amman. Lake Tiberias water or desalinated water could be allocated to

Lower Jordan River restoration in conjunction with the objective of increasing the supply of potable water in Amman. This can be done as follows. The conveyance of Lake Tiberias water or of desalinated water from the northern alignment of the Mediterranean Sea–Dead Sea Alternative to Amman could include a flow along part of the Lower Jordan River. This option may be feasible only for the northern part of the Lower Jordan River, for example, up to the area near Beit She'an, and only if this part of the Lower Jordan River is kept free of any brackish (including recycled) water. In this way, Lake Tiberias water and desalinated water used for Lower Jordan River restoration should not be taken away from (would not compete with) the supply of water to Amman, but rather would serve both purposes: restoring the northern part of the Lower Jordan River and increasing the supply of potable water in Amman. The cost of using Lake Tiberias water and desalinated water for Lower Jordan River restoration in this way would consist only of the added cost due to water loss while the water flows along the Lower Jordan River and the added treatment cost due to this flow. This added cost is in the range of US\$0.1–US\$0.2/m^3 (see Box 6.1) and is much lower than the alternative cost had this water been used for Lower Jordan restoration and allowed to flow to the Dead Sea.

Use of Recycled Water: Full Restoration in the Long Run. The view of the Study of Alternatives Team is that recycled water will gradually become the most viable source of water for Lower Jordan River restoration and that in the long run this source could support full restoration of the River. This assessment is based on two observations. First, the population of the three Beneficiary Parties is expected to exceed 25 million by the year 2030 and 30 million by the year 2050 (see Figure 1.2). Second, the future universal implementation of water treatment in the three Beneficiary Parties means that 60-70 percent of domestic water will be available for reuse (Cohen et al, 2008). A domestic water consumption of about 100 MCM per person per year will generate 1.5–1.75 BCM/year and 1.8–2.1 BCM/year by 2030 and 2050, respectively. After allocating about 1,000 MCM/year of recycled water for irrigation (in the three Beneficiary Parties), the remaining supplies of recycled water will be about 600 MCM/year or 1,000 MCM/year in the year 2030 or 2050, respectively. These residual supplies of recycled water (over and above the allocation of recycled water for irrigation) could be exploited for Lower Jordan River restoration purposes. The growing population will increase the potential volume of recycled water supply and could, over the long term, make full restoration of the Lower Jordan River feasible. Implementing any alternative that brings in additional potable water to the Lower Jordan region for variable uses will indirectly contribute to the feasibility of Lower Jordan River restoration by increasing the potential supply of recycled water. Every new m^3 of manufactured water will enable uses that when combined account for about 1.6–1.7 m^3 of water (Cohen et al, 2008). The Combination Alternative CA1 proposed by the Study of Alternatives Team addresses this option.


IBRD 38118R
Haifa
Lake Tiberias
Mediterranean Sea
Nazareth
Yarmouk R.
SYRIAN A.R.
Dar'a
Irbid
Harod
W. Arab
Partial restoration of Lower Jordan River at a variety of flow levels
Full restoration of Lower Jordan River flow levels
Netanya
JORDAN RIVER BASIN
Al-Mafraq
Nablus
W. Farla
Jordan River
W. Zarqa
JORDAN
Tel Aviv
West Bank
Salt
Al-Zarqa
Ramla
Amman
Ramallah
Jericho
HEBRON &
Jerusalem
Madaba
AMMAN
UPLANDS
Bethlehem
RED SEA-DEAD SEA WATER CONVEYANCE STUDY PROGRAM
Analysis of Alternatives
Map 4: Lower Jordan River Options
ISRAEL
JERUSALEM
UPLANDS
Hebron
Dead Sea
W. Mujib
RIVER BASIN BOUNDARIES
PRIMARY WADIS AND RIVERS
SECONDARY WADIS AND RIVERS
EVAPORATION PANS
MAIN CITIES AND TOWNS
ARMISTICE DEMARCATION LINES, 1949
NO-MAN'S LAND AREAS, ARMISTICE DEMARCATION LINE, 1949
ADMINISTRATIVE BOUNDARY
INTERNATIONAL BOUNDARIES
DEAD SEA BASIN
Arad
Beersheba
Al Kerak
Dimona
W. Hasa
0 10 20 30 Kilometers
0 10 20 30 Miles
Zin
Wadi Arava
Dana Nature Reserve
SEPTEMBER 2012

Table 5.1: Cost Comparisons of Partial Restoration Options of the Lower Jordan River

Source	Potential quantity at source	Alternative price of water at the northern entrance(US$/m^3)	Cost of water for LJR restoration (US$/m^3)	Comments
Lake Tiberias	up to 100 MCM/y, but decreasing with population	0.4	0.1	By-product of potable water to Amman; can be used only for the northern part of the Lower Jordan River; 10% water loss along the Jordan River; additional treatment cost of US$0.1/m^3
Desalination or importation	Technically unlimited	0.75–1.5	0.17–0.24	
Recycled	Increasing with population	0–0.25	0	

FULL AND PARTIAL RESTORATION OF THE LOWER JORDAN RIVER FLOWS (FL1/FL2): A SURVEY OF NGO PROPOSALS

Full or Partial Restoration. A major question has been raised by a variety of stakeholders regarding the role that the alternative of a full or partial restoration of the Lower Jordan River may have in the restoration of the Dead Sea. Such an alternative would have a high, and likely positive, environmental and social impact on the river and its immediate environment (see Map 4). For example, see the recent reports by Gafny et al (2010), DHV (2011) and Gorskaya et al (2010), the findings of which are summarized in Box 5.2. Other initiatives for restoration and/or partial restoration of the Lower Jordan River, supported by the European Commission and Germany, are reviewed in Boxes 5.3, 5.4 and Box 5.5 takes note of a resolution by the United States Senate. The main anticipated effects of full restoration are summarized in Table 5.2 and partial restoration in Table 5.3.

Partial Restoration of the Historic Lower Jordan River Flow Levels (FL2)

Description. This is an outcome rather than an alternative in itself. The natural annual flow of the Lower Jordan River of about 1,300 MCM/year (Gafny et al, 2010) has been reduced by major diversion infrastructures in Israel, Jordan and Syria. Partial restoration would aim for a minimum environmental flow. According to Gafny et al (2010), the volume of water necessary for this would be 400 MCM/year, or one third of the former natural flow, with an annual small flood event of 4 MCM over 24 hours. FoEME proposes that the restoration of flows would be incremental and suggests that an initial target of 400 MCM/year could be increased to 600 MCM/year.

Ecological Services. Partial restoration of the ecological services of the Lower Jordan River would aim to ensure a minimum environmental flow to rehabilitate some of the aquatic ecological diversity of the river. The partial restoration of Lower Jordan River flows, over a two decade term, could possibly contribute 40 percent to the restoration of the Dead Sea level. There would be no contribution to the high quality water needs of the Beneficiary Parties; rather the contribution of this alternative would reside in restoration of environmental services. Engagement and cooperation on the part of the Beneficiary Parties would also be enhanced. Three main measures to achieve partial restoration would be considered: releases from Lake Tiberias; production and transfer of desalinated water from the Mediterranean Sea; and recycled wastewater.

Releases from Lake Tiberias. The inflow to Lake Tiberias in recent years has been about 800 MCM/year. During the same period annual evaporation from the lake is about 280 MCM/year. From this storage Israel's National Water Carrier transfers on average about 370 MCM/year to Israel's coastal users. About 90 MCM/year are used for local consumption and allocated to Jordan as agreed by Jordan and Israel in 1994. Outflow at the Degania Dam of high quality water varies greatly. High rainfall in 1991 caused a flow as high as the old flow of the river. The level of Lake Tiberias was also restored. However, every decade has seen a multi-year drought, when virtually only sewage has flowed in the Lower Jordan River.

Production and Transfer of Desalinated Water from the Mediterranean Sea. The alignment of the Northern Mediterranean Sea–Dead Sea Transfer (see section on Water Transfer Options below) would make it possible to produce and deliver volumes of desalinated water large enough to restore Lower Jordan flows. But the cost per cubic meter of desalinated water makes it a very unattractive option for river restoration.

Recycled Wastewater. Treating and recycling domestic and industrial water from urban centers is now a proven method of augmenting national water supplies in Israel. The location of major urban centers limits the potential for such water to be available for restoring the Lower Jordan River. Nearby Tiberias (40,000 inhabitants), Jericho (20,000) and Beit She'an (17,000) would not provide significant volumes. On the other hand, the populations of Greater Amman and other highland cities in Jordan are well located to deliver treated wastewater in significant volumes. Jerusalem could also contribute.

Partial Restoration of Flows. Limited empirical work has been done to study the feasibility of a partial restoration of flows to the Lower Jordan River. The most recent was Gafny et al (2010), who concluded that:

- The flow of the Lower Jordan River: 400 MCM/y, to be expanded to 600 MCM/year over time, is required for the river to function as a healthy ecosystem;
- One minor flood event is required annually to keep the river's salinity level to no more than 750 parts per million (ppm). This implies that primarily fresh water needs to be returned to the river and only the highest quality of effluents allowed (with effluents constituting no more than 25 percent of the Lower Jordan River's base flow); and
- Implementation of this strategy would restore the river's structure and function, restore stable communities of flora and fauna and achieve a "fair to high ecosystem integrity and health."

Box 5.2: Studies Commissioned by Friends of the Earth Middle East

Friends of the Earth Middle East (FoEME) is a tri-lateral (Israel, Jordan and Palestinian Authority) nongovernmental organization with the objective to promote cooperative efforts in order to protect shared environmental heritage. It also seeks to advance sustainable regional development in the Middle East. FoEME has recently commissioned two interrelated and technical reports on rehabilitation of the lower Jordan River:

- Towards a Living Jordan River: An Environmental Flows Report in the Rehabilitation of the Lower Jordan River (May 2010) by: Gafny, S.; Tolozi, S.; and Al Sheikh, B. (http://foeme.org/uploads/publications_publ117_1.pdf)
- Roadmap for Rehabilitation of the Lower Jordan Valley (November 2011) by DHV MED (http://foeme.org/uploads/13209208250~%5EUS$%5E~DHV_Full_Report_11.2011.pdf)

The May 2010 report (referred to as the Environmental Flows Report) was co-authored by three scientists. It concludes that the lower Jordan River requires 400 MCM/year, increasing by 50 percent over time (to 600 MCM/year), in order to restore a minimum environmental flow. One small flood event (4 MCM over 24 hours) per year is also required. According to this report, implementation of the strategy would reduce the lower Jordan's salinity to not more than 750 ppm, allowing the natural riparian plant community to recover and restore stable communities of flora and fauna (page 14). The report states that the average historic flow of the Jordan River is 1,300 MCM/year, thus a third of the historic flow is required for the minimum environmental flow.

The November 2011 report (referred to as the Roadmap Report) was authored by a scientist employed by DHV MED, an international consulting firm. This report builds on the conclusions of the Environmental Flows Report and suggests that Israel should contribute 54 percent of the recommended 400 MCM/year, or

220 MCM/year. The 54 percent figure is determined by "adjustments for socio-economic considerations." The remaining 46 percent should be allocated by Syria (24 percent) and Jordan (22 percent). The objective of the Environmental Flows Report is to demonstrate how Israel's contribution of 220 MCM/year, and the annual flood event, could be achieved.

The Roadmap Report calculates the required 220 MCM/year from Israel could be achieved via three steps:

1. Maintaining the current estimated flow of the lower Jordan River (76 MCM/year); plus
2. Measures and policies already agreed or under implementation (64 MCM/year); plus
3. Additional new measures (81 MCM/year).

See table below for details.

Summary of Proposals from FoEME of Israeli Measures to Restore Lower Jordan Environmental Flow (Based on Reports from FoEME)

Measure	*MCM/year*
Current Flow in Lower Jordan River	76
Measures Already Agreed or Under Implementation	
Reduced transfer to the National Water Carrier	98
Population growth	-5
Future trends in agriculture (as a result of climate change - increased irrigation)	-20
Pending reform for fish farms	10
Transfer of brine to fish ponds in Emeq Hamaayanot	-4
Depletion and salinization of existing springs and wells	-15
Sub-total including Current Flow	140
Additional Required Measures	
Brine from the Saline Water Carrier transferred to Dead Sea	-8
Further & earlier reduced transfer to National Water Carrier	30
Exchanging 50% of fish ponds for field crops and Alfalfa	10
Diminish saline agriculture by 30% by 2020	10
Diminish fresh agriculture by 30% by 2020	10
Maintain present (2009-2011) consumption level in the Upper Jordan River	27
Discharge some Kishon treatment plant effluents to Harod River	2
Sub-total	81
Total possible increase in flows to Lower Jordan River	221

The report concludes that Israel could meet the goal of an additional 225 MCM/year flow within 10-15 years at a cost of NIS 3.4 billion (US$0.9 billion) spread out over 30 years. However, the report also cautions that the goal could probably not be met if there were to be consecutive drought years, and the salinity goal would be unlikely to be met in any year.

An important assumption in the analysis is that transfers to the Israeli National Water Carrier will be reduced by 128 MCM/year, as the net result of increased reliance on desalination and the lower rainfall levels that are expected to be brought about by climate change. However, the cost of desalination water is likely to be greater than that for treated water from Lake Tiberias and it is unclear in the report if this cost is included in the NIS3.4 billion cited above. Another important assumption is that current agricultural quotas will remain in place for the foreseeable future, equal to about 27 MCM/year. Finally, climate change models are not yet reliable, especially for smaller geographical areas. Considering the above, the report correctly cautions that results presented should be "regarded with due care."

Table 5.2: Lower Jordan River Restoration - Full Restoration of the Lower Jordan River – Pros and Cons (FL1)

	PROS	CONS
Overview	• Priority restoration of the Lower Jordan River Basin's environmental services	• The policy challenges of this option are considerable and may not allow it to be endorsed and implemented
Technical	• Possible with recycled water in	• Would require major changes

	the long run	in the operation of current infrastructure
Economic and Financial	• Potentially avoids significant investment and operational costs of major water transfer options from the Red Sea or Mediterranean Sea to the Dead Sea • Additional diking and conveyance infrastructure would need to be evaluated • Reduced incidence of new sink-holes and decreased costs for stabilization and repairs • Reduced expenditures for repairs to roads, bridges, irrigation and other infrastructure caused by fall in level of Dead Sea • Generation of construction employment during necessary works	• Strong negative impact on industries and communities– especially irrigated farming and related employment, provided by diversion and supply infrastructure installed in Lower Jordan River, especially those built in last half-century • Opposition from the governments of all three Beneficiary Parties to this alternative due to these potential economic and social impacts
Environmental and Social	• Contribution to restoring part of natural flows to Dead Sea and stabilization of Dead Sea level • Help to remedy sink-hole problems, damage to infrastructure and visual impacts • Enhancement of tourist amenities at Dead Sea and in Lower Jordan River region • Partial restoration of ecological diversity and natural habitat of Lower Jordan River	• Reductions in farm productivity and in general vigor and productivity of rural communities • Serious social disruption of communities established during past half century, including employment loss
Other	• Regional cooperation required would contribute to advancing regional peace process	• Unprecedented levels of multi-lateral cooperative effort required to address challenge of providing alternative livelihoods for those displaced by re-allocation of water–both natural and re-used–to provision of environmental services

Table 5.3: Lower Jordan River Restoration - Partial Restoration of the Lower Jordan River– Pros and Cons (FL2)

	PROS	CONS
Overview	• Would provide for new approaches to water policy and management in the Jordan River Basin • Would significantly improve quantity, quality and timing of flows in the Lower Jordan River and make a partial contribution of the restoration of the Dead Sea • Consistent with respect to sustainable utilization of natural	• Governments of Beneficiary Parties and many user groups averse to idea that high quality, potentially potable water should flow into Dead Sea • Risk of improper future implementation of any management plan • Widespread assumption that high quality water released to

	resources and restoration of environmental services of water	Lower Jordan River would be used downstream for domestic, industrial and irrigation uses. Concern therefore, the water would not reach Dead Sea • Volumes of water envisaged – 400 to 600 MCM/year – not sufficient to remedy decline in level of Dead Sea or sink-hole and infrastructure impacts of decline of Dead Sea level
Technical	• Not technically demanding to restore flows	• Would require significant restructuring of infrastructure and operational practices
Economic and Financial	• Relatively low costs to fund restoration • Employment generated during necessary works	• Potable water would be "lost" to Dead Sea instead of being used for drinking, agriculture and industry • Economic impacts associated with restructuring of water use with potential employment issues
Environ-mental and Social	• Improvement in environmental health of Lower Jordan River • Lowered rate of decline in level of Dead Sea	• Not enough water available to arrest significantly fall in Dead Sea level • Potentially potable water flowing to Dead Sea • Employment disruption/loss for farmers and fish farmers
Other	• Difficult but feasible approach that advances introduction of ecological priorities	• Requires very broad commitment to cooperation to make significant changes in water policy and management among a number of parties

CONCLUDING COMMENTS

- The Study of Alternative Team concurs with the view expressed by the NGOs that a restoration of the Lower Jordan River is highly desirable and entails large economic values, some of which could be internalized by the development of a tourism industry along the River.

- However, data used by the NGOs' studies, discussed in Boxes 5.2 and 5.4, are at odds with related data taken from official sources (Box 5.1). As the Study of Alternatives Team bases all analyses and assessments on data obtained from official sources, it draws different conclusions regarding the feasibility of using natural and desalinated water for Lower Jordan River restoration purposes.

- The main conclusion of the Study of Alternative Team is that full restoration of the Lower Jordan River is feasible but in the long run and based on recycled water. The Study of Alternatives Team proposes an additional alternative that addresses this issue in Section 12, *Combination CA1. Desalination at Aqaba and Mediterranean Sea, Water Importation from Turkey, and Water Recycling and Conservation*.

Box 5.3: Resolution of the European Parliament on the Jordan River Basin - 2011

The European Union has highlighted its concern about water resources and water scarcity in the Jordan Basin. It recorded its concern in a *Resolution of the European Parliament* (European Parliament Resolution, 2011/C 308 E/14) on September 9, 2010 entitled the "*Situation of the Jordan River with* *special regard to the Lower Jordan River area."* The main relevance of this debate and related documentation is the evidence it provides of a high level overarching concern about the condition of the natural water resources of the Jordan River Basin countries, and the Lower Jordan River in particular, and the urgency of reversing the water ecosystem trends in the Lower Jordan (EN C 308 E/82 *Official Journal of the European Union* 20.10.2011).

In the resolution of the European Parliament, its members welcomed the initiative by the Israeli Ministry of the Environment to draw up a master plan for landscape development in the Lower Jordan River area and urged the Jordanian Government and the Palestinian Authority to take similar initiatives with the aim of adopting master plans for the rehabilitation of the sections of the river that flow through their respective territories. It stressed the importance of access to the river for all parties concerned and noted that such master plans could form the basis for a comprehensive regional plan to rehabilitate and protect the Lower Jordan River area.

It called on the authorities of all the riparian countries to cooperate and rehabilitate the Jordan River by drawing up and implementing policies which focus on achieving tangible results in the areas of domestic and agricultural water-demand management, water conservation and the management of sewage and agricultural and industrial effluents, and on ensuring that an adequate quantity of fresh water flows into the Lower Jordan River. It welcomed the cooperation among Israeli, Jordanian and Palestinian local communities facing similar water challenges in the Lower Jordan River area; and called on Israel and Jordan fully to honor commitments made in their Treaty of Peace concerning the rehabilitation of the Jordan River.

It also called on the European Council, European Commission and European Union Member States to encourage and support a comprehensive plan to rectify the degradation of the Jordan River and to continue to provide financial and technical support for the rehabilitation of the Jordan River, and the Lower Jordan River in particular, in the framework of the Union for the Mediterranean. It stressed the issue of effective water management, and particularly the fair distribution of water in keeping with the needs of all the people living in the region and the importance of such measures for lasting peace and stability in the Middle East.

European Parliament, 2011, Resolution of 9 September 2010 on the Situation of the Jordan River with special regard to the Lower Jordan River area, EN C 308 E/82 *Official Journal of the European Union* 20.10.2011.

Box 5.4: Recent Externally Funded Studies of the Jordan River Basin

The Jordan River Basin has been the focus of a number of externally funded water related research studies. The problems addressed range widely but mainly examine the water resource itself and the problems of water scarcity that would be exacerbated by the anticipated negative climate change scenarios. These scenarios assume lower annual precipitation as well as higher temperatures. A number of the research projects also address the social and economic aspects of improving water use efficiency in irrigated agriculture and protecting water and other ecosystems. These studies include the following:

GLOWA – Global Change and the Hydrological Cycle Program – Jordan River Project

The GLOWA Jordan River Project is a German supported study of the future of the water scarce Jordan River basin under the impact of climate and global change. Teams of researchers from Germany, Israel, Jordan and the Palestinian Authority are working on how best the hazards posed by climate and global change to the future of the Jordan River basin can be faced and overcome. The study is intended to provide applied scientific support for water managers in the Jordan River basin based on state-of-the art science, and explicitly addressing the problems associated with climate and global change in a transboundary context. It is expected that the results will: (i) provide guidance as to the potential change and variability in temperatures and precipitation, and to the anticipation of extreme climatic events in the basin over the coming decades, analyzing their impacts on the water resources; (ii) indicate how new sources of surface ("blue") water can be utilized to the best advantage in the basin; (iii) suggest how land use planning and crop patterns can be managed so as to make full use of water retained in the soil ("green water"); and (iv) predict actual and potential changes in ecosystem services and biodiversity in the basin.

SMART – Sustainable Management of Available Water Resources with Innovative Technologies

This research activity focuses on Integrated Water Resources Management (IWRM) in the Lower

Jordan Rift Valley. The SMART research project has the goal of developing a transferable approach for IWRM in the water shortage region of the Lower Jordan Valley. It is funded by the German Federal Ministry of Education and Research (BMBF). The research partners are from Germany, Israel, Jordan and the Palestinian Authority. The project started with phase I from 2006-2010 and is now in phase II, 2010-2013. In this context the following questions play a central role: How to increase the water availability and water quality in the catchment area of the Lower Jordan River without endangering vital ecosystems and social and economic welfare? Which innovative technologies, decision support systems and management strategies can be applied in a reasonable and effective way for a sustainable use of water resources? The Helmholtz Center for Environmental Research (UFZ) is part of the SMART-consortium and coordinates the project together with the Universities of Karlsruhe and Göttingen.

Phases 1 and 2 have produced, among other contributions: a large research base including 20 professional journal articles, several book chapters and a number of presentations at professional meetings; a database management system for the Lower Jordan; the development of decentralized wastewater treatment technologies; new brackish water irrigation techniques; artificial aquifer recharge methodologies; guidelines for establishing spring and well protection zones; formal education opportunities; stakeholder forums and workshops; and region specific climate change modeling.

SWIM – Sustainable Water Integrated Management – Jordan River Demo Project

The Water and Environmental Development Organization (WEDO)/Friends of the Earth Middle East (FoEME), together with consortium partners, the Stockholm International Water Institute (SIWI) and Global Nature Fund (GNF) came together in 2012 to launch the SWIM-JR Project to produce the "FoEME Master Plan: A Vision for the Lower Jordan River", the first ever trans-boundary integrated master plan for the Jordan River.

This study aims to be a comprehensive master planning program to rehabilitate the Lower Jordan River and its tributaries. The master plan would determine coordinated regional flow regimes, set water quality standards, identify solutions to treat all pollution sources, launch restoration and preservation programs, establish ecological corridors, and identify opportunities to expand ecotourism infrastructures in the Jordan Valley, including the preparation of regional heritage routes. The FoEME Master Plan will develop complementary plans for the Palestinian and Jordanian sections of the Lower Jordan to produce the first ever comprehensive regional master plan for the Lower Jordan. At the same time, the Israeli government has launched a process to prepare a master plan for the Israeli section of the Lower Jordan River.

The studies can be accessed at the following sources:

GLOWA – Global Change and the Hydrological Cycle.
www.glowa-jordan-river.de/
www.iisd.org/pdf/2012/nascap_marx_jordan.pdf
www.usf.uni-kassel.de/cesr/index.php?option=com_project&task=view_detail&agid=65&lang=en
SMART – Sustainable Management of Available Water Resources with Innovative Technologies
www2.ufz.de/index.php?de=15689
SWIM – Sustainable Water Integrated Management – Jordan River Demo Project
foeme.org/www/?module=projects&record_id=205 ;
www.swim-sm.eu/index.php?option=com_content&view=article&id=49&Itemid=39&lang=en
www.globalnature.org/33226/PROJECTS/Nature-Conservation-Biodiversity/Master-Plan-Jordan/02_vorlage.asp
MED EUWI – Mediterranean European Water Initiative
http://www.euwi.net/wg/mediterranean

Box 5.5: United States Congress Support for the Jordan River and Dead Sea – Senate Resolution – November 2007

In November 2007, the Senate of the United States endorsed Resolution 387 concerning the Jordan River and Dead Sea. The resolution encourages Israel, Jordan and the Palestinian Authority to continue to work in a spirit of cooperation as they address the degradation of the Jordan River and Dead Sea. It notes that "The governments of Israel and Jordan, as well as the Palestinian Authority, [have worked] together in an unusual and welcome spirit of cooperation" to address many of the water challenges confronting the region. The Resolution also supports the Beneficiary Parties' efforts "to assess the environmental, social, health and economic impacts, costs and feasibility of the Red Sea-

Dead Sea Water Conveyance Concept in comparison to alternative proposals, such as those that focus on the restoration of the Jordan River."

Senate Resolution 387 can be found at: http://thomas.loc.gov/cgi-bin/query/D?c110:1:./temp/~mdbsaUKbmo::

6. WATER TRANSFER OPTIONS – MEDITERRANEAN SEA – DEAD SEA (TR1.1 – TR1.4)

A DIVERSITY OF WATER TRANSFER OPTIONS

Overview. Over the last 40 years a series of options have been considered at various levels of detail concerning the transfer of water from the Mediterranean Sea to the Dead Sea (see Map 5). Initially these proposals focused on the generation of hydropower; however, over time they have been expanded to include the transfer of potable water from coastal desalination plants and the transfer of marine water to facilities for desalination in the Jordan Valley.

Transfer of Mediterranean Sea Water to the Dead Sea

Description. A number of parties have examined the transfer of Mediterranean Sea water to the Dead Sea using a diversity of alignments for the generation of hydropower and to provide water to the Dead Sea (see Boxes 6.2 and 6.3). Many of these options were studied in detail in the 1980s and 1990s so the numbers used are now out of date and of limited use for comparison with the 2010 estimates prepared by Coyne et Bellier for the Red Sea–Dead Sea Water Conveyance Study Program. In the present study of alternatives, Mediterranean Sea–Dead Sea options are evaluated based on the Red Sea–Dead Sea cost data of Coyne et Bellier (2010), adapted to the Mediterranean Sea–Dead Sea situation. The Mediterranean Sea–Dead Sea option includes consideration of three alternative routes: a northern route and two southern routes, which are reviewed below.

Water Transfers Also Linked to Desalination. Desalination has also been recognized as a potential benefit of water conveyance between the two seas. The Study of Alternatives Team has therefore examined options based on numbers from Coyne et Bellier (2010) and the costs for pumping from Lake Tiberias to the Israeli National Water Carrier. These alternatives are considered in Section 8 rather than in this section. As the population of the region has increased and agricultural development has intensified, the supply of potable water has become a leading priority. Versions of some of the alignments discussed below have been considered in feasibility studies that also address desalination options. These are also discussed in Section 8 as desalination options.

Samuel Neaman Institute Report. A comparative cost analysis of a number of Mediterranean Sea–Dead Sea alternative options is presented in the Neaman (2007) report. The Neaman Report, however, is based on studies made in the 1980s and 1990s. Since then, technologies and economic conditions (prices) have changed considerably, rendering some technical and cost elements of the analysis outdated (see Box 6.1).

Box 6.1: The Samuel Neaman Institute Report

The Samuel Neaman Institute was established in 1978 as an independent multi-disciplinary Israeli national policy research institute. The institute works on issues in science and technology, education, economy and industry, physical infrastructure and social development. Its 2010 Annual Report lists a professional staff of 28 Fellows, Project Managers and Project Coordinators.

The report titled "Reclaiming the Dead Sea: Alternatives for Action"* (Y. Avnimelech, Y. Baron, N.Y. Rosenthal, and G. Shaham, August 2007) summarizes work performed by the Neaman Institute upon the joint initiative of the Dead Sea Research Center, the Tamar and Megilot Regional Councils, the "Negev Bar Kayma" (a nongovernmental organization) and the Dead Sea Works, Ltd.

The Neaman Report was published almost a year before the start of the first studies commissioned by the World Bank-managed Red Sea–Dead Sea Water Conveyance Study Program. It therefore represents an initial effort by experts to identify alternatives to the conveyance option that had been described by the three Beneficiary Parties in the Study Program Terms of Reference.

Variations of eight alternatives were discussed in the Report. Alternatives viewed by the authors as less feasible were not evaluated on economic terms. These included halting all abstractions from the Jordan River and replacing that water with desalination, an option to rehabilitate the lower Jordan River only, and options that did not include desalination.

The following four alternatives were given a more in-depth and economic analysis:

- The No Action alternative;
- A Red Sea–Dead Sea Canal alternative; and
- Two Mediterranean–Dead Sea alternatives.

Many of the technical assumptions made in the Neaman Report are now, five years later, dated by findings of the draft final reports under the Study Program. Nevertheless, the conclusions reached in many areas broadly correspond to those of the Study Program. For example, the Neaman Report recommended:

- That the No Action alternative is the most expensive alternative because of expected damage to the environment, infrastructure and tourism;
- That a Mediterranean–Dead Sea option, with desalination at Beit She'an, is likely the lowest cost option to both provide potable water to Amman and stabilize the Dead Sea level. However, this study concludes that the risk of carrying brine across tracts underlain by groundwater that provides municipal water services and supplementary irrigation water makes this alignment non feasible; and
- The large scale mixing of sea water and/or brine in the Dead Sea has the potential for serious environmental effects and needs to be carefully studied before any conveyance scheme is implemented.

*http://www.neaman.org.il/neaman/publications/publication_item.asp?fid=831&parent_fid=490&iid=4958

Box 6.2: Historical Proposals for Mediterranean Sea–Dead Sea Navigation and Hydropower Generation

Changing Objectives. The objectives for transferring water from the Mediterranean Sea to the Dead Sea have changed over the years. The first proposal for a conduit between the two seas was made over 150 years ago before there was an understanding of the relative elevations between sea level and the Dead Sea. This had navigational objectives, aiming to establish a shorter shipping route between Europe and India. Later proposals prioritized hydropower generation, exploiting a better understanding of the difference in elevation between the two seas. A rapid decline in the level of the Dead Sea and associated environmental degradation has made the stabilization of the Dead Sea a priority in recent years. A historical review of Mediterranean Sea–Dead Sea water transfer proposals with navigational, hydropower and Dead Sea level stabilization objectives can be found in Vardi (1990).

Navigation Links. The first proposal to link the Dead Sea to the Mediterranean was put forward in 1855 by British Royal Navy officer William Allen (Vardi 1990). The objective was navigational, to enable European shipping to move from the Mediterranean Sea to the Jordan Valley and on to the Red Sea via another canal. The route was put forward as an alternative to the proposed Suez Canal, which had not been constructed at the time. Haifa Bay on the Mediterranean coast was the proposed starting point for this canal. The plan involved flooding the Jordan Valley between Lake Tiberias and the southern Wadi Araba/Arava Valley with seawater, forming a giant elongated lake with a surface level many tens of meters above the Dead Sea level at the time. This would have submerged significant towns including Tiberias and Jericho. Limited topographical and geological information was available when this proposal was made so an accurate assessment of the potential technical feasibility was not possible. The plan was proposed again by a British general in 1883 following the completion of the Suez Canal as the British foresaw a possible loss of access to the Suez route.

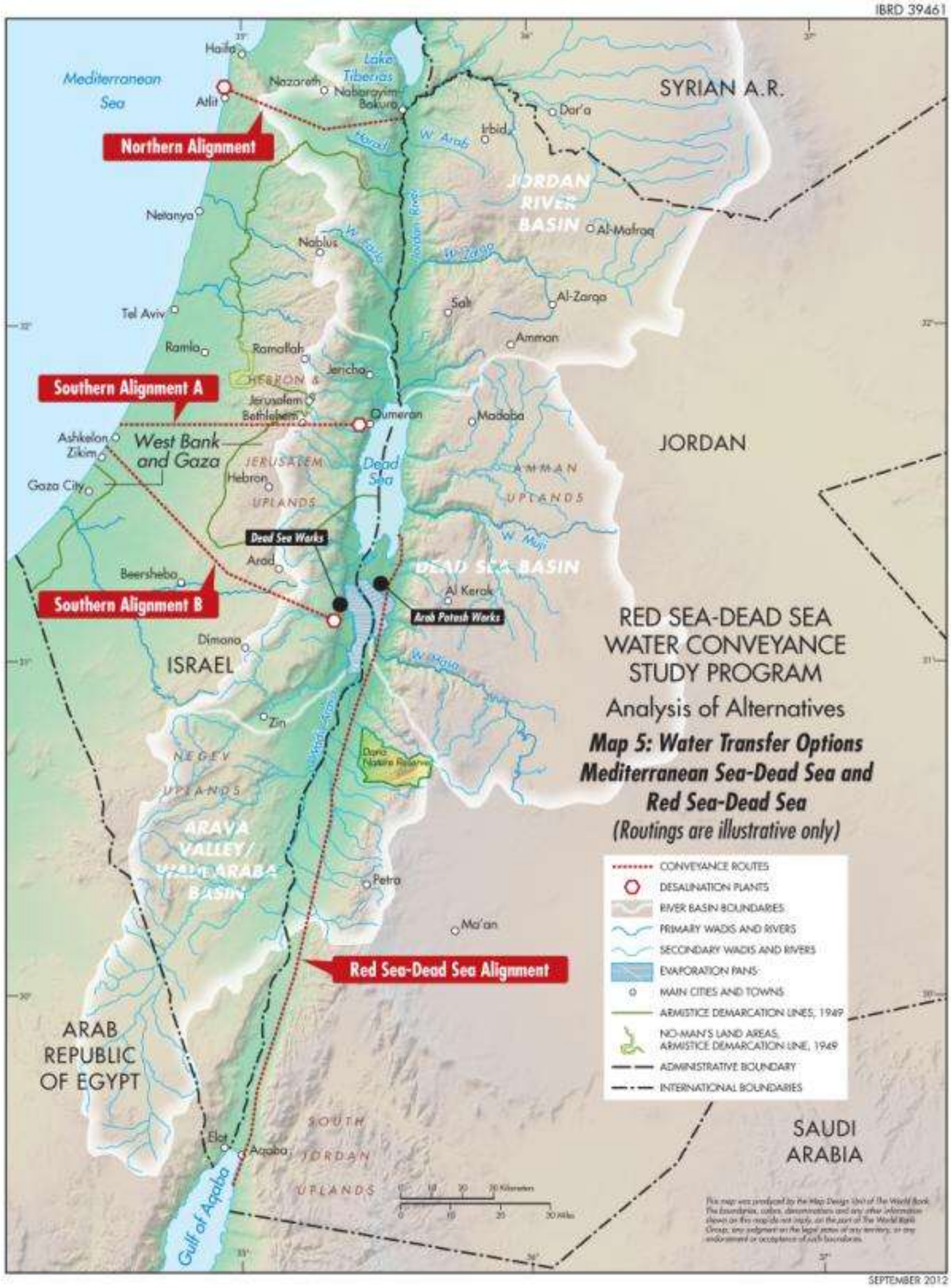
Hydropower Generation. As planners considered ways to develop industry and economic growth in the region, generation of electricity became a priority alongside navigation. The topographical difference in elevation between the Mediterranean and the Dead Sea was known by 1897 and a canal linking Haifa to Lake Tiberias, with the objective of generating hydropower, was proposed to Theodore Herzl by the Austrian manufacturer, Kremenezsky. The Kremenezsky plan was elaborated upon by the Swiss engineer Bourcart, who in 1899 proposed a tunnel that would convey water from the Mediterranean Sea to the Dead Sea with the generation of hydropower. A side effect would have been a 100 m increase in the level of the Dead Sea (Vardi 1990).

Proposals During the Mid 20th Century. During the British Mandate period, a number of proposals were made by entrepreneurs, including one by Gandillon (1925), a French engineer who proposed the diversion of the Jordan River so that its riverbed could be used for conveyance of Mediterranean water to the Dead Sea. The old river channel would be fed with Mediterranean water pumped through a series of dammed canals to an elevation of 80 m near Afula (Vardi 1990) and allowed to flow into the Jordan Valley just below Lake Tiberias. A later proposal by Lowdermilk also involved diversion of the Jordan River and the replacement of its flow with Mediterranean water. By this time, interest in a navigational canal had dwindled and hydropower generation was the main priority. A similar proposal to that of Lowdermilk was proposed by

Blass (1941). The Jordan River diversion element of these plans was partially implemented with the construction of the Israeli National Water Carrier following the establishment of the State of Israel.

Studies in the Late 20th Century. Numerous proposals have been made for a Mediterranean Sea–Dead Sea Water Conveyance but it was not until the late 1970s onwards that detailed, high quality engineering and costed pre-feasibility and feasibility studies were undertaken. The first of these was carried out by Tahal and a public steering committee investigating six Mediterranean Sea–Dead Sea and Red Sea–Dead Sea alignment transfer routes with associated hydropower generation. This study was published in 1981. A subsequent report was published by The Dead Sea Company in 1984.

More Recent Studies. The idea of a Mediterranean Sea–Dead Sea Water Conveyance was revisited in 1994 by Tahal, which examined the hydropower potential in detail. It produced a summary report in Hebrew for the Israeli Ministry of Energy. In 2007, Beyth carried out a review of these sources with the addition of desalination objectives. This study is considered in Section 8 under desalination alternatives. The Samuel Neaman Institute also examined two Mediterranean Sea–Dead Sea transfer options in its 2007 report "Reclaiming the Dead Sea - Alternatives for Action" (Box 6.1). These are also examined in Section 8 as they feature desalination options.



Southern Mediterranean Sea–Dead Sea Alignments (TR 1.1/TR 1.2)

Of the two southern routes for the Mediterranean Sea–Dead Sea Alignment (see Map 5), the Southern B route from Ashkelon to the southern Dead Sea is lower cost for both the Low Level Gravity Tunnel (LLGT) and the Phased Pipeline (PPL) options. The Mediterranean Sea–Dead Sea PPL option entails higher costs (both for the Dead Sea stabilization subproject and the desalination subproject) compared to those of the Red Sea–Dead Sea PPL, because its maximum surface elevation would be 560 m (compared with 220 m for the Red Sea–Dead Sea PPL) and it requires low level desalination resulting in higher costs of conveyance to Amman.

In reviewing the Southern A and Southern B alignments and their associated investments, the Study of Alternatives Team concluded that since the Southern A alignment delivers water to the northern edge of the Dead Sea it would be able to convey water at a lower cost to Amman and other areas with significant water demand than either of the Southern B options. Consequently, the most southern Mediterranean Sea–Dead Sea alignment termed Southern B has been screened out and this study considers only the Southern A alternative going from Ashkelon to the northern Dead Sea.

The Ashkelon to North Dead Sea (PPL) alignment from Ashkelon on the Mediterranean coast to the northern Dead Sea (see Map 5) has a length of 90 km and would rise to a maximum surface elevation of 840 m. Like the Southern B alignment, the high elevation renders the Mediterranean Sea–Dead Sea PPL option cost-ineffective, leaving only the Mediterranean Sea–Dead Sea LLGT option as a viable alternative for this route. The course of a tunnel from Ashkelon to the northern Dead Sea intersects the southern part of the mountain groundwater aquifer. The exact route would need to be determined in order not to potentially harm this sensitive and important water source; thus the actual route could be longer and/or deeper, with potentially substantial cost impacts. Further cost analysis will be needed after the exact route has been determined.

The approach to the cost analysis of the Southern A - Mediterranean Sea–Dead Sea LLGT alternative is the same as that of the Red Sea–Dead Sea LLGT and PPL, based on the cost data of Coyne et Bellier (2010) and adapted to the different circumstances. The project is divided into two subprojects – the Dead Sea stabilization subproject and the desalination subproject, for each of which annual costs (US$ million) and break-even costs (US$/$m^3$) are calculated. The annual costs of the Dead Sea stabilization subproject are presented in the figures below (see Figure 6.1). The costs in the lower chart were calculated under the assumption that water conveyance would be initiated at full capacity (2,000 MCM/year); the costs in the upper chart were calculated under the assumption that water conveyance would increase gradually, commensurate with the phases of the Red Sea–Dead Sea PPL option. It should be noted that the Tahal modelling study of the Dead Sea (2011) suggests that a gradual increase of seawater-brine discharge in the Dead Sea decreases the risk of damage.

Mediterranean Sea–Dead Sea Southern A - Ashkelon to North Dead Sea LLGT (TR1.1). This is an infrastructure based alternative. The cost estimate is based on calculations using numbers obtained from Coyne et Bellier. It involves the transfer of Mediterranean Sea water to the Dead Sea by LLGT. The intake for the scheme would be located at Ashkelon on the Mediterranean coast in Israel and the outlet would be at the northern Dead Sea near Qumeran. The conveyance route between the two points is 90 km. The scheme would generate hydropower and potable water by desalination at the Dead Sea. This could then be further transferred to Amman and other areas for use.

Mediterranean Sea–Dead Sea Southern A - Ashkelon to North Dead Sea PPL and Gravity Tunnel (TR1.2). This is an infrastructure based alternative. The cost estimate is based on calculations using numbers obtained from Coyne et Bellier. It involves the transfer of Mediterranean Sea water to the Dead Sea by Phased Pipeline (PPL) and Gravity Tunnel (GT). The intake for the scheme would be located at Ashkelon on the Mediterranean Sea coast in Israel and the outlet would be at the northern Dead Sea. The scheme would generate hydropower and potable water by desalination.

The main anticipated effects of both options TR1.1 and TR1.2 are summarized in Table 6.1.

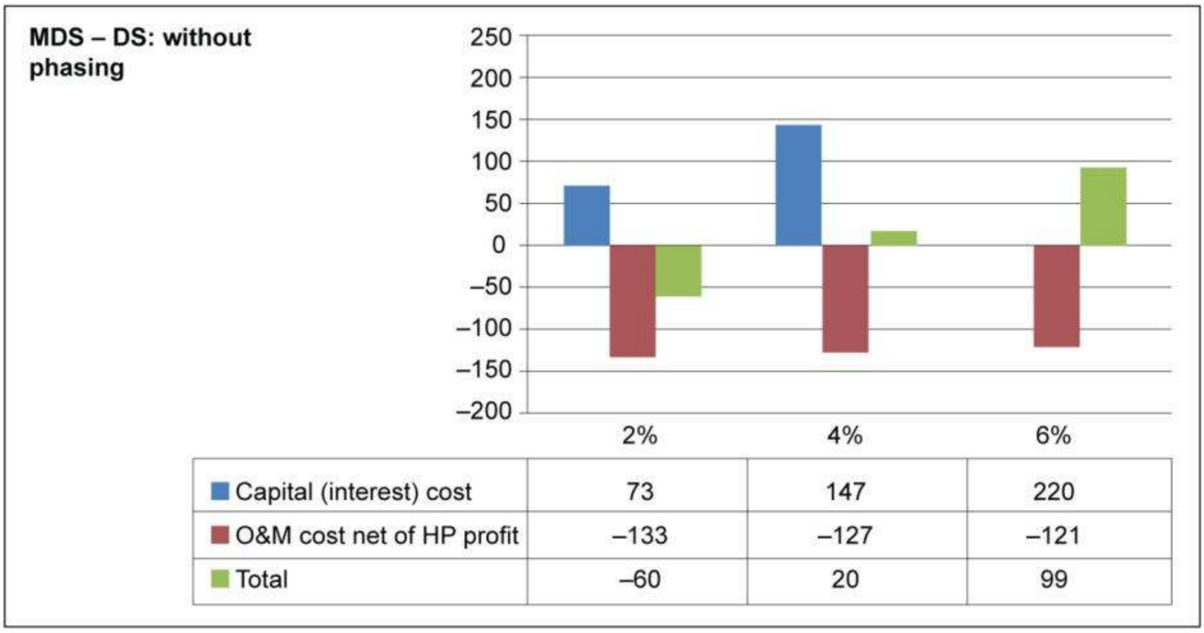
Table 6.1: Water Transfer Options–Southern A – Mediterranean Sea–Dead Sea Alignment–Pros and Cons (TR1.1/TR1.2)

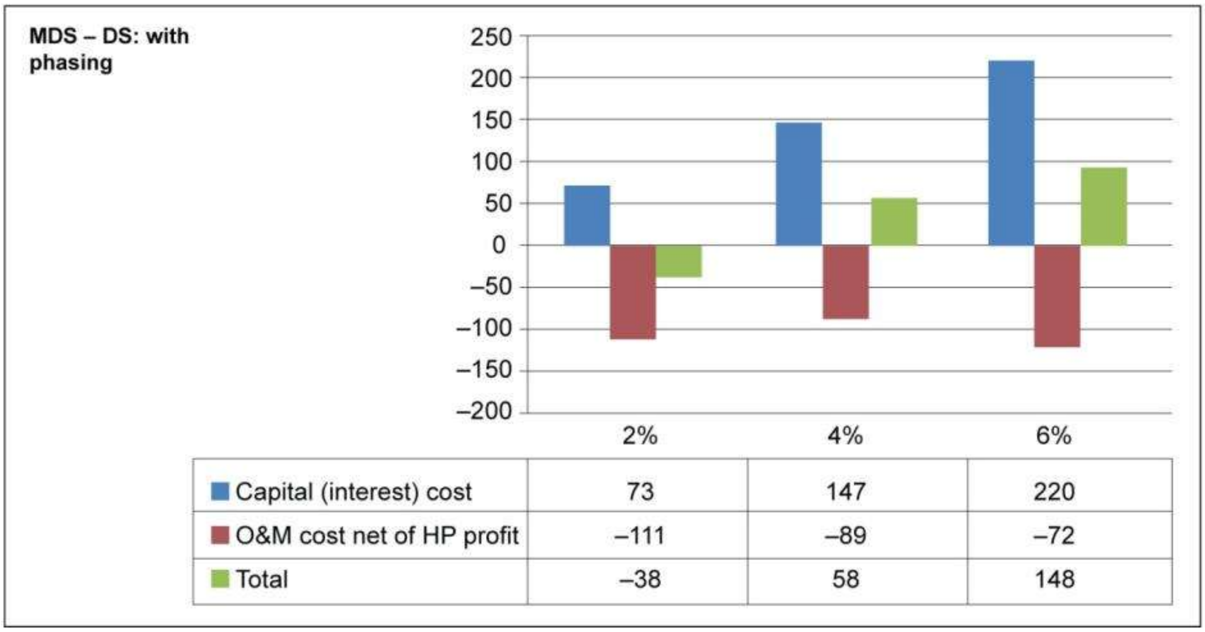
	PROS	CONS
Overview	• Pipelines or tunnels half the length of Red Sea project • Restoration of Dead Sea level and delivery of substantial volumes of high quality water • Potentially positive economic outcomes	• Major infrastructure with potentially environmentally negative consequences although most could be significantly mitigated • Risk of unknown consequences from mixing Mediterranean Sea and Dead Sea waters unless adequately studied and tested
Technical	• Use of proven technology–except with respect to mixing of Mediterranean Sea and Dead Sea waters	• Risk of impacts if proceeding with transfer of water from Mediterranean Sea to Dead Sea without adequate studies and testing • Risks associated with building project components across areas susceptible to seismic events • Risk of a seismic event, accident or intentional damage to infrastructure with environmental impacts • Operational framework would be complex and high risk
Economic and Financial	• Lower capital costs and operational costs than Red Sea–Dead Sea option • Lower cost of water delivered to Amman and other destinations compared to Red Sea–Dead Sea option • Hydropower generation and electrical power potentially positive • End to rising costs of repairs to road and other infrastructure caused by fall in level of Dead Sea • Employment generation during construction and limited employment during operation	• Costly sites for surface facilities, especially at Mediterranean coast and along pipeline/tunnel alignment • High capital costs • High operational and maintenance costs • High desalinated water cost
Environ-mental and Social	• Hydropower to offset partially energy requirements for desalination • Secure water supplies of potable water for Amman and the Dead Sea areas • Positive social impacts such as improved access to reliable sources of high quality potable water	• No studies completed on coastal impacts at the Mediterranean Sea • Possibilities of damage to ground water reserves as a result of potential sea water leaks along conveyance system • Anticipated to require limited involuntary resettlement and some land acquisition • Large negative environmental and social effects during construction, which can be mitigated • Possible significant effects on Dead Sea from mixing with Mediterranean Sea water and

	desalination brine
Other	• Could be difficult for all Beneficiary Parties to accept

Figure 6.1 below provides the annual costs of the Dead Sea Stabilization subproject for the Southern A - Mediterranean Sea–Dead Sea Route, adopting the LLGT option.

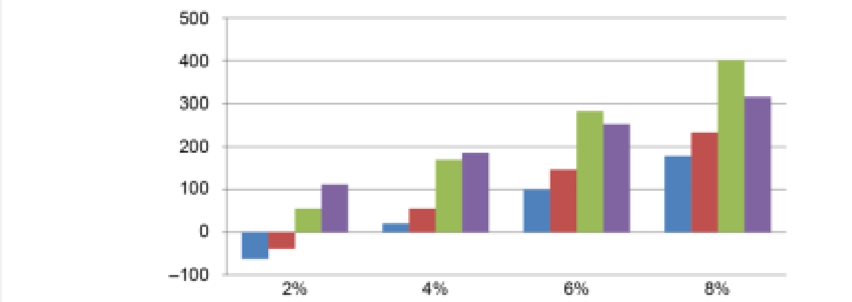
Figure 6.1: Annual Costs (US$Million) of the Dead Sea Stabilization Subproject for the Southern A – Mediterranean Sea–Dead Sea Route adopting the LLGT Option with a Break-Down into Capital (Interest) Cost and O&M Cost Minus Hydropower Profits





The figure reveals that under a 2 percent rate of interest, restoring the Dead Sea via a Mediterranean Sea–Dead Sea LLGT (from Ashkelon to north Dead Sea) is a profitable operation with and without phasing, in that the profits of the hydropower plant exceed the annual cost. Overall, the Dead Sea stabilization costs of the Mediterranean Sea–Dead Sea LLGT alternative are lower than those of the Red Sea–Dead Sea LLGT and PPL. A comparison of the two alternatives is given in Figure 6.2.

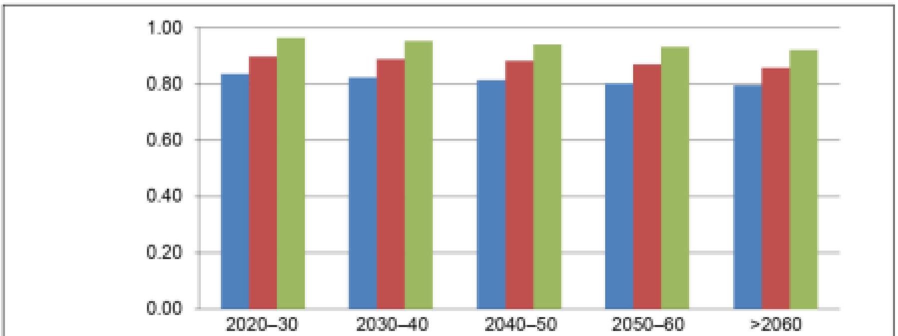
Figure 6.2: Annual Cost (US$million) of Seawater-Brine in the Dead Sea: Comparison of the Southern A - Mediterranean Sea–Dead Sea Alignment with and without Phasing (MDS-LLGT and MDS-PLLGT, Respectively) with the Two Red Sea–Dead Sea Options (LLGT and PPL) under the Electricity Tariffs Regime B



	2%	4%	6%	8%
MDS-LLGT	–60	20	99	178
MDS-PLLGT	–38	58	148	234
RSDS-LLGT	58	169	284	401
RSDS-PPL	114	184	252	318

Desalination under the Southern A – Mediterranean Sea – Dead Sea alignment would be located along the northern shore of the Dead Sea at a low level (near Sweimeh). The conveyance cost from Sweimeh to Amman is currently about US$0.40/$m^3$ - US$0.44/$m^3$ (which is lower than the corresponding cost of the Red Sea–Dead Sea alternative–with high level desalination–due to the shorter distance). The break-even costs (US$/$m^3$) of water in Amman are depicted in Figure 6.3.

Figure 6.3: Break-Even Costs (US$/$m^3$) of Water in Amman under the Southern A - Mediterranean Sea – Dead Sea - LLGT Alternative

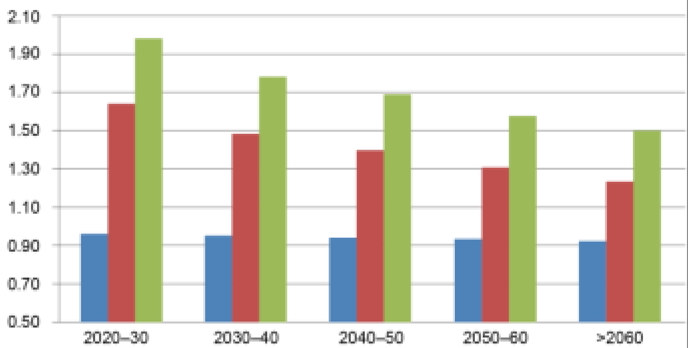


	2020–30	2030–40	2040–50	2050–60	>2060
2%	0.84	0.83	0.82	0.81	0.80
4%	0.90	0.89	0.88	0.87	0.86
6%	0.97	0.96	0.95	0.94	0.93

A comparison of the break-even costs ($/$m^3$) of desalinated water in Amman under the MDS-LLGT and RDS-LLGT at 6% interest rate is presented in the following figure.

A comparison of the break-even costs (US$/$m^3$) of desalinated water in Amman under the Mediterranean–Dead Sea LLGT and Red Sea–Dead Sea LLGT at 6 percent interest rate is presented in Figure 6.4.

Figure 6.4: Break-Even Cost (US$/m³) of Desalinated Water in Amman: Comparison of the Southern A - Mediterranean Sea – Dead Sea(LLGT) Alignment and the Two Red Sea – Dead Sea Options (LLGT and PPL) under a 6% Interest Rate



	2020–30	2030–40	2040–50	2050–60	>2060
MDS-LLGT	0.97	0.96	0.95	0.94	0.93
RSDS-LLGT	1.64	1.49	1.40	1.31	1.24
RSDS-PPL	1.98	1.79	1.69	1.58	1.50

The cost advantage of the shorter Southern A - Mediterranean Sea–Dead Sea alignment over the two Red Sea–Dead Sea options (LLGT and PPL) is evident for both stabilizing the Dead Sea and increasing the supply of potable water in Amman. Moreover, the Southern A - Mediterranean Sea–Dead Sea alternative avoids potential environmental risks associated with the Red Sea–Dead Sea alternative, namely, potential environmental damage to the northern Gulf of Aqaba/Eilat. However, the report of the Red Sea Modelling Study (Thetis, 2011) has concluded that an intake properly designed and at the appropriate depth presents minimal risk to the marine environment.

On the down side, the Southern A - Mediterranean Sea–Dead Sea alignment extends over the three Beneficiary Parties, which would complicate the planning, construction, management and operation of this alternative. Both the Red Sea–Dead Sea Water Conveyance and Mediterranean Sea–Dead Sea Conveyance would face intense contention in negotiating the site for a pumping station. The impacts of the low level gravity tunnel option of both alignments would also be similar and low. Comparing the low level gravity tunnel of both conveyance alignments the disturbance at the surface would also be similar and in both cases low.

There is a complicating factor in the case of both alignments, however, as it is probable that the mode of conveyance would not be determined on the basis of costs of construction and of environmental and social alignment impacts alone. If a precautionary phased approach would prove to be the preferred option, because of the uncertain impacts of mixing different brines in the Dead Sea, then the Mediterranean Sea–Dead Sea Conveyance alignment would be a much more controversial option. The high surface elevation of a Mediterranean Sea-Dead Sea alignment would exclude the economic feasibility of using a phased pipeline option. As a result, a pilot project to test the mixing of Mediterranean and Dead Sea waters, if needed, must be constructed separately and this would increase the costs.

Further, the alignment from the Mediterranean would cross tracts that have been very intensely developed compared with the desert landscapes traversed by a Red Sea–Dead Sea pipeline alignment. It is probable that the transaction costs of planning, contracting and managing a project that crosses land in different sovereignties would be difficult. In this case the Red Sea–Dead Sea alignment would have an advantage.

These considerations are summarized in Table 6.2 below.

Table 6.2: Comparison of the Southern B - Mediterranean Sea–Dead Sea (LLGT and PPL) Alternative and the Red Sea–Dead Sea Options (LLGT and PPL)

	MDS		RSDS	
	LLGT	**PPL**	**LLGT**	**PPL**
Annual cost of brine-seawater discharge in the Dead Sea (6%>2060) (electricity tariffs regime B)	US$99 million	US$148 million	US$284 million	US$252 million
Break-even cost of desalinated water in Amman (6%, >2060)	US$0.93/$m^3$	US$0.93/$m^3$	US$1.24/$m^3$	US$1.5/$m^3$
Effect of pilot project on costs	Increases	Increases	Increases	Increases
Potential environmental impacts (risk to coral reef; alignment over area of high seismic activity)	Lower		Higher	
Potential environmental impacts (risk to groundwater aquifers)	Similar		Similar	
Planning, Coordination, Management and Operation	More Complex – Requires Full Cooperation Between the Three Beneficiary Parties		Less Complex Physical Works Only in One Beneficiary Party	

The Northern Mediterranean–Dead Sea Alignment (TR 1.3/TR 1.4)

Northern - Atlit to Naharayim-Bakura. This alternative proposes desalination of Mediterranean seawater on the coast near Atlit and buried pipeline conveyance to the Jordan Valley near Naharayim-Bakura, where the Yarmouk flows into the Jordan River. This is an infrastructure based alternative. The cost estimates for this alignment are based on calculations using numbers obtained from Coyne et Bellier. This alternative includes implementation of a project with hydropower (TR1.3) and a phased project without hydropower (TR1.4).

The main anticipated effects of TR1.3 and TR1.4 are summarized in Table 6.3.

Table 6.3: Water Transfer Options - Northern Mediterranean - Dead Sea Alignment – Pros and Cons (TR1.3/TR1.4)

	PROS	CONS
Overview	• Low risk, low impact option but only addresses need for high quality water and not restoration of Dead Sea	• Level of Dead Sea not stabilized
Technical	• Use of proven technologies	• Operational framework would be complex and high risk • Risks associated with building project components across areas susceptible to seismic events

Economic and Financial	• Compared to the Red Sea-Dead Sea Water Conveyance, this has:
	  • Lower capital costs
	  • Lower operational costs
	  • Lower cost of water delivered to Amman and other destinations
	• End to rising costs of repairs to road and other infrastructure caused by fall in level of Dead Sea
	• Employment generation during
		• Costly sites for surface facilities, especially at Mediterranean coast and along pipeline/tunnel alignment
		• High capital costs
		• High operational and maintenance costs
		• High desalinated water cost especially if used to stabilize the Dead Sea

	construction and limited employment during operation	
Environ-mental and Social	• No environmental impacts on Red Sea • Low environmental risks from spills as pipeline conveying high quality water • Positive social impacts such as improved access to reliable sources of high quality potable water • Possible partial restoration of Lower Jordan River (but expensive and socially complicated)	• No studies completed on coastal impacts at the Mediterranean Sea • Adverse impacts on Mediterranean Sea coast due to need for desalination and pumping facilities • Anticipated to require limited involuntary resettlement and some land acquisition • Significant short term negative environmental and social effects during construction, which can be mitigated • Wastes from construction of conveyance structure • Difficult to locate site for pumping water to Amman and other destinations in area designated as of outstanding natural or cultural importance
Other		• Could be difficult for all Beneficiary Parties to accept to cooperate

Proposed Location. The Mediterranean end of the northern Mediterranean Sea–Dead Sea route is around Atlit (see Map 5) and its outlet is north of Beit She'an, near Naharayim-Bakura, where the Yarmouk flows into the Jordan River. Its length would be 65-70 km with surface elevation of at least 170 m (depending on the specific course). The location of the eastern outlet opens up opportunities to combine this option with partial restoration of the Lower Jordan River.

Conveyance of Seawater or Freshwater? The possibility of conveying seawater (while desalinating at the eastern outlet) is ruled out for two reasons. First, the course of the Mediterranean Sea–Dead Sea northern alignment extends over the fertile valleys of Zvulun, Yizrael, Harod and Beit She'an, hence the potential for damage from leakage is high. Second, if desalination is done near Naharayim-Bakura, the brine will have to be delivered to the Dead Sea along the Lower Jordan River. This approach would require expensive construction of a conveyance canal built specifically for brine conveyance, making the price of brine delivered to the Dead Sea prohibitively high. As a consequence, for the northern Mediterranean Sea–Dead Sea alignment the study confines analysis to the case in which only fresh water is conveyed from the Mediterranean coast to the eastern outlet near Naharayim-Bakura. The source of the fresh water could be desalination plants on the Mediterranean coast or water imported from Turkey (or other places), depending on costs.

Configuration Options. The cost of conveyance (see Appendix 2) to Naharayim-Bakura has been calculated based on the Coyne et Bellier data with the appropriate parameters, e.g., capacities (volumes), distances and elevations, changed to fit the current circumstances. The elevation difference of more than 370 m can be exploited to generate hydropower in the Naharayim-Bakura case. Two options are considered in this analysis: (i) no hydropower generation; and (ii) hydropower generation with a pumped storage near Koukab-el-Houah (Kochav Hayarden).

Options for Conveyance to Amman. Regarding the conveyance of potable water from Naharayim-Bakura to Amman, two options have been considered (additional analysis would be required to evaluate conveyance options to other locations):

- Direct conveyance to Amman, by expanding existing infrastructure (such as the King Abdullah Canal) and pumping to Amman; and

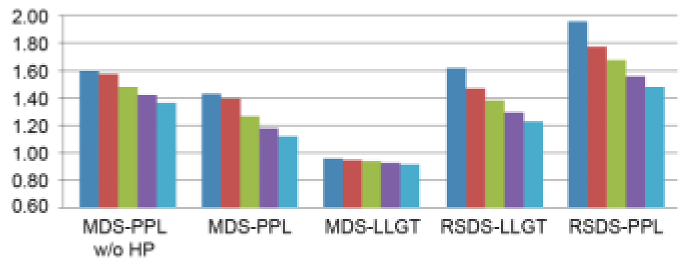
- Letting the water flow along the Lower Jordan River, capturing it around Beit She'an, treating it and conveying it to Amman.

Currently the Lower Jordan River serves as an outlet for sewage and brackish water (see Section 5 above). The second option would require an overall change in this situation, for otherwise the cost of treating the water downstream, before conveying to Amman, would be too high.

The possibility of letting the desalinated water flow into the Dead Sea is not recommended for two reasons. First, the price of the water (after desalination and conveyance from the Mediterranean coast to Naharayim-Bakura) will exceed US\$0.5/m^3, which is prohibitively high for Dead Sea stabilization purposes and is much higher than the break-even costs of the Dead Sea stabilization under other alternatives. Second, delivering the water to Amman enables reuse of about half of the water as recycled water, possibly for Dead Sea stabilization purposes in the future.

Cost of Water in Amman. The break-even cost (US\$/m^3) of water in Amman is obtained by adding the cost of conveyance from Naharayim-Bakura to Amman. The current cost of conveyance from Lake Tiberias to Amman is US\$0.75/m^3 (personal communication to Study of Alternatives Team, 2010), including treatment costs. Since the desalinated water would need no further treatment, the conveyance cost would be cheaper – about US\$0.60/m^3. Figure 6.5 presents the break-even costs (US\$/m^3) of water in Amman for the Mediterranean Sea–Dead Sea and Red Sea–Dead Sea options.

Figure 6.5: Break-Even Costs (US\$/m^3) of Water in Amman for Southern A - MDS-LLGT, Northern Mediterranean Dea – Dead Sea -PPL (With and Without Hydropower Generation): Comparison with Red Sea – Dead Sea LLGT and PPL Options



	MDS-PPL w/o HP	MDS-PPL	MDS-LLGT	RSDS-LLGT	RSDS-PPL
2020–30	1.62	1.45	0.97	1.64	1.98
2030–40	1.60	1.41	0.96	1.49	1.79
2040–50	1.50	1.28	0.95	1.40	1.69
2050–60	1.44	1.20	0.94	1.31	1.58
>2060	1.38	1.14	0.93	1.24	1.50

Conclusions

Two Proposed Alignments. Two Mediterranean Sea–Dead Sea transfer alignments have been considered in greater detail following the decision to drop the Southern B alignment: a Southern A alignment from Ashkelon on the Mediterranean coast to Qumeran at the northern edge of the Dead Sea, and a Northern alignment from near Atlit on the Mediterranean coast to the Jordan Valley near Naharayim-Bakura, where the Yarmouk flows into the Jordan River.

Southern A Alignment. The length of the Southern A alignment is about 90 km with surface elevation above 800 m. The high elevation of the surface alignment rules out the surface pipeline option, thus the LLGT is the only viable option for this southern Mediterranean Sea–Dead Sea route. Since desalinated water is too expensive for the purpose of Dead Sea stabilization, only desalination near the Dead Sea is considered for the southern route.

Northern Alignment. For the northern route, desalination would be performed on the Mediterranean coast to avoid possible damage to the fertile valleys along the way due to leakage of seawater. For the northern route, therefore, only conveyance of potable water to Amman is considered. It is noted that this water could be reused, such that about half of the quantity could be discharged after treatment into the Dead Sea as recycled water. The Northern Mediterranean Sea–Dead Sea alignment addresses only the goal of increasing the supply of potable water in Amman and, as a result, requires no pilot project. It delivers potable water to Amman at costs below the Red Sea–Dead Sea options but above the southern Mediterranean Sea–Dead Sea alignment.

Comparison of Mediterranean Sea-Dead Sea Alignments. A comparison of the Southern A and Northern Mediterranean Sea–Dead Sea alignments with the two Red Sea–Dead Sea options is presented in Table 6.4 below. The cost of desalinated water in Amman associated with the Mediterranean Sea–Dead Sea alternatives varies over the project's stages, depends on the options – southern or northern alignments – and is sensitive to the cost of capital (depreciation and interest rate). In the long run (after the project reaches a steady state) the cost of water in Amman ranges between US$0.93/m^3 for the southern alignment (6 percent interest rate) and US$1.14/m^3 for the northern alignment. It should also be noted the Northern Mediterranean Sea–Dead Sea alignment could allow for partial restoration of the Lower Jordan River.

Table 6.4: Comparison of the Mediterranean Sea – Dead Sea and Red Sea – Dead Sea Alignments

	MDS			RSDS	
	Southern A LLGT	**Southern A PPL**	**Northern PPL with Hydropower**	**LLGT**	**PPL**
Annual cost of brine-seawater discharge in the Dead Sea (6%, >2060)(electricity tariffs regime B for RSDS)	US$99 million	US$148 million	NA	US$284 million	US$252 million
Break-even cost of desalinated water in Amman (6%, >2060)	US$0.93/m^3		US$1.14/m^3	US$1.24/m^3	US$1.5/m^3
Effect of pilot project on costs	Noticeable		None	Noticeable	
Potential environmental impacts to coastal zone	Moderate		Moderate	Moderate	
Risks from seismic activity	Moderate		Moderate	Moderate	
Management and operation complexity	High		Moderate	Low	
Possibility to incorporate Lower Jordan River restoration	No		Partial	No	

Box 6.3: An Earlier Proposal for Mediterranean Sea–Dead Sea Water Transfer - Southern Qatif–Ma'ale Ya'ir Alignment (Dead Sea Co. 1984)

This is an earlier proposal that involves pumping seawater from the Mediterranean Sea to the Dead Sea with the generation of hydropower. This option was examined in detail by the Dead Sea Company of Israel in 1984. In June 1981, Tahal and the Ne'eman Committee published the findings of a detailed feasibility study of six Mediterranean Sea–Dead Sea and Red Sea–Dead Sea options for conveyance of sea water for hydropower generation. An alignment between Qatif in the Gaza Strip to Ma'ale Yair was viewed as technically and economically better than all other options.

The options were investigated in greater detail between 1981 and 1984 by the Dead Sea Company. Its report described the proposed approach as follows: seawater would be drawn at an intake point at Qatif on the Mediterranean coast and conducted by buried pipeline for 8 km under the Gaza Strip. It would then flow for 20 km by open channel to Kibbutz Urim where it would enter a 5.8 m diameter steel and concrete tunnel and flow east (south of Be'er Sheva) to a 9.5 MCM capacity storage reservoir at Ma'ale Ya'ir, overlooking the Dead Sea. From there flow would be regulated in accordance with power demands to an underground power station of 800 MW installed capacity. Construction costs were estimated at US$1,793 million using 1984 prices (Vardi 1990).

The plan presented a number of significant benefits which included a 17-20 year filling period to restore the Dead Sea Level to -393. Once the level had stabilized a steady state flow of 1,200 MCM/year would be assumed. There was also great potential for pumped storage, enabling hydropower to be generated during periods of peak demand. Mediterranean water would be pumped to storage at a time of day when electricity tariffs were at their lowest. It would be released for hydropower generation at a time of peak demand when tariffs were at their highest.

The potential for pumped storage was never fully investigated but it is believed to present significant economic benefits. The issue of pumped storage is revisited by the Study of Alternatives Team in Section 10. The most significant advantage associated with this Mediterranean Sea–Dead Sea alignment is that only 30 percent of the energy it produces in hydropower is required for pumping. The surplus would be available for sale into the national grid (Vardi 1990).

7. WATER TRANSFER OPTIONS – TURKEY VIA PIPELINE AND EUPHRATES RIVER VIA PIPELINE (TR2/TR3)

TURKEY TRANSFER VIA PIPELINE (TR2)

Description. This is an infrastructure based alternative. The idea of transferring significant quantities of high quality water from the Seyhan and Ceyhan Rivers in Turkey to the water scarce Middle Eastern economies to the south has been the subject of discussions for two decades. The Peace Pipeline (see Box 7.1) is the popular name of the conveyance. It would take water from Turkey though Syria in a pipeline to Jordan and the Palestinian Authority. The conveyance is attractive because it addresses both the goal of restoring the level of the Dead Sea and that of providing significant volumes of high quality water to Amman and other destinations. In addition, the Lower Jordan River would be much more comprehensively restored. The conveyance would be low risk with respect to leaks as the water being conveyed would be high quality.

Box 7.1: The Peace Pipeline – A Brief History

Brown and Root (1987) published a pre-feasibility study proposing a two phase project to construct international pipelines to convey high quality water from the Seyhan and Ceyhan Rivers in southeastern Turkey to the water scarce economies to the south. It was estimated that a total of 3.25 MCM/per day (1.18 BCM/year) of water could be diverted. Phase One would convey 2 MCM/per day (0.73 BCM/year) to cities in Syria, Jordan and Israel. Phase Two would convey 1.25 MCM/per day (0.45 BCM/year) to Janbu and Jeddah in eastern Saudi Arabia. Saudi Arabia showed no enthusiasm for the proposal and it faded from the range of options to remedy the water supply problems of the region.

President Ozal of Turkey had proposed a similar 2 BCM/year project in 1986 when he was Prime Minister, also sourced from the Seyhan and Ceyhan Rivers. This project was called the Peace Pipeline and was different in that it proposed to deliver an additional volume of water to the states of the Gulf (Gruen 2007). The Gulf States and Saudi Arabia evidenced no interest for the proposal. President Ozal died suddenly in 1993 and the proposal lost its place in regional water scarcity mitigation scenarios. Phase One of these 1980s initiatives was revisited in the early 1990s by Wachtel (1993). He republished the proposal during the period of Red Sea–Dead Sea Water Conveyance studies (Wachtel, 2010).

The Seyhan and Ceyhan Rivers have high winter and spring flows and join close to the city of Adana. They flow in to the Mediterranean and together have total average flows of about 16 BCM/year. However, the estimated 2 BCM/year of surplus water of two decades ago is no longer judged to be available. Turkish irrigators and industries are using more water. In addition, estimates of low summer flows have been revised downwards. It is judged that flows in either of these rivers would not be enough, now or in the near future, to meet water demands of Turkey in summer when secure water would be a priority. Turkish engineers responsible for the allocation and use of water in the Seyhan and Ceyhan River Basins confirmed to the Study of Alternatives Team during technical level discussions that the Peace Pipeline would not be a viable project given contemporary water demands in Turkey.

The main anticipated effects of the transfer of water from Turkey by pipeline are summarized in Table 7.1 and from the Euphrates in Table 7.2.

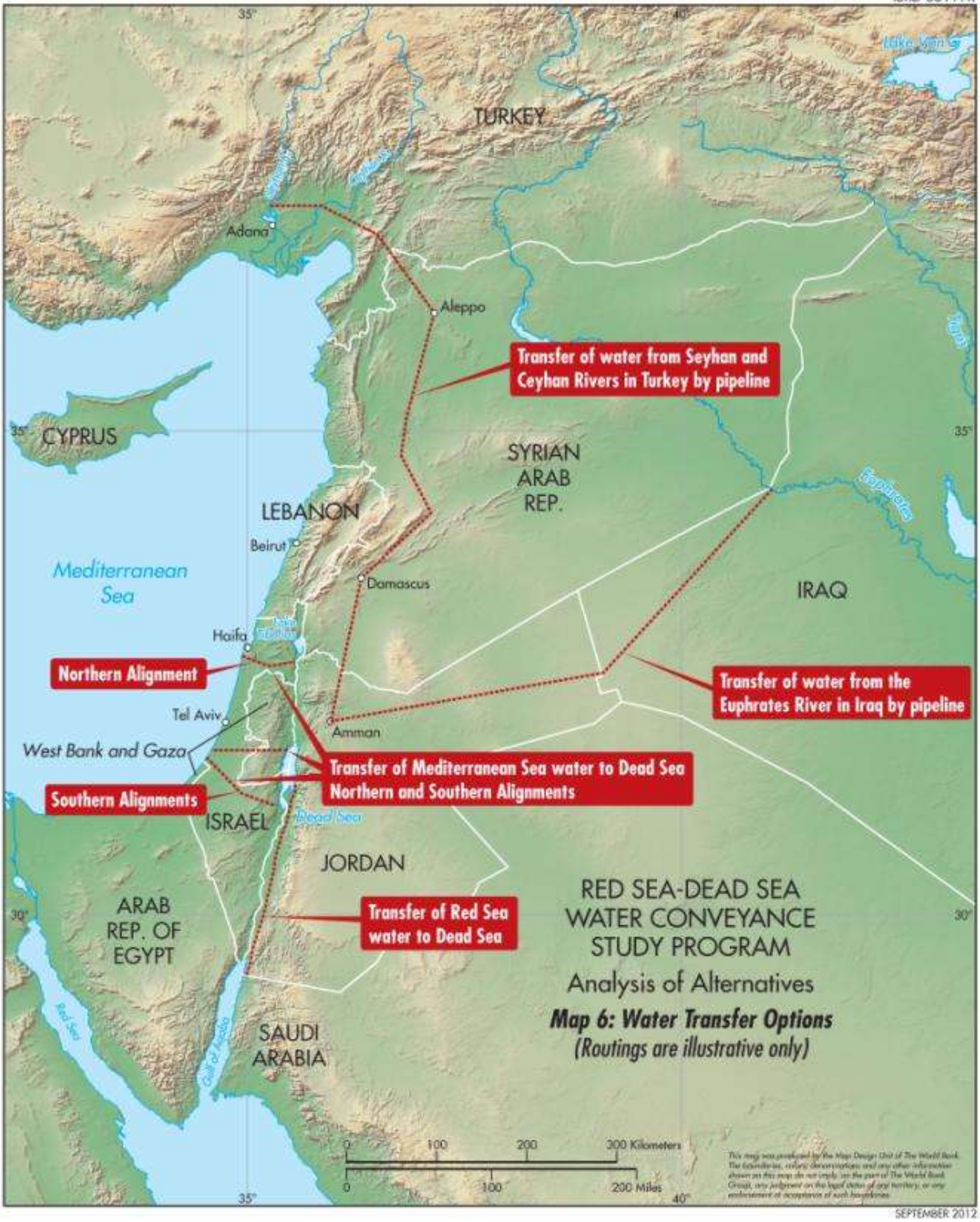

IBRD 38119R
TURKEY
Adana
Aleppo
Transfer of water from Seyhan and Ceyhan Rivers in Turkey by pipeline
CYPRUS
SYRIAN ARAB REP.
LEBANON
Beirut
Mediterranean Sea
Damascus
IRAQ
Haifa
Northern Alignment
Transfer of water from the Euphrates River in Iraq by pipeline
Tel Aviv
Amman
West Bank and Gaza
Transfer of Mediterranean Sea water to Dead Sea Northern and Southern Alignments
Southern Alignments
ISRAEL
Dead Sea
JORDAN
ARAB REP. OF EGYPT
Transfer of Red Sea water to Dead Sea
RED SEA-DEAD SEA WATER CONVEYANCE STUDY PROGRAM
Analysis of Alternatives
Map 6: Water Transfer Options
(Routings are illustrative only)
SAUDI ARABIA
Red Sea
Gulf of Aqaba
0 100 200 300 Kilometers
0 100 200 Miles
SEPTEMBER 2012

Table 7.1: Water Transfer Options–Transfer of Water from Turkey by Pipeline–Pros and Cons (TR2)

	PROS	CONS
Overview	• If adequate water available, would provide high quality water for use in Amman and other areas • Would support broader regional cooperation and provide for economic links between a larger number of parties	• Insufficient water available in Seyhan and Ceyhan to meet Dead Sea restoration goal or potable water needs of Beneficiary Parties • Unable to eliminate water shortages of the three Beneficiary Parties
Technical	• Use of proven technologies	
Economic and Financial	• Costs of delivered water possibly competitive with some proposed alternatives, but not the Mediterranean Sea–Dead Sea southern option • Employment generation during construction and limited employment during operation	• Infrastructure to convey and pump water in pipelines and canals more than three times the length of Red Sea–Dead Sea Water Conveyance, with high capital and operational costs • Cost of delivered water difficult to estimate as cost of water at source not known
Environ-mental and Social	• Provides large amounts of high quality water • Low environmental risks from spills as pipeline conveying high quality water • Positive social impacts such as improved access to reliable sources of high quality potable water • Amelioration of water shortages in communities and cities located along pipeline	• Impacts on the Seyhan and Ceyhan Rivers and coastal impacts at the Mediterranean Sea from reduced freshwater flows and sediment transport to the coastal zone • Anticipated to require some involuntary resettlement and significant land acquisition • Large negative environmental and social impacts during construction, which can be mitigated • Potentially locally significant impacts on cultural heritage with pipeline passing through Turkey, Syria and Jordan in areas with high cultural value, which would require careful consideration to avoid or mitigate
Other		• Significant risk in terms of cooperation, with pipeline passing through Turkey, Syria and Jordan

Peace Pipeline Proposal. The idea of conveying river water from the Seyhan and Ceyhan Rivers to the Jordan Basin in what has become known as the Peace Pipeline stemmed from the ambitious 1986 proposal by the Turkish Government (Kaya, 2008) to deliver over 4 BCM of water per year in two pipelines to regions in the Middle East. An eastern alignment would have delivered water to the Gulf economies. A western alignment would have delivered water to the cities of Syria and Jordan and to the western Saudi cities. The Gulf and the Saudi Governments are reported to have shown limited interest–mainly on grounds of high risk operational reliability–and interest in this regional project was short lived.

Conveyance from Seyhan and Ceyhan Rivers. From the early 1990s and during the early 2000s the section of the project which addressed the conveyance of Seyhan and Ceyhan waters to Jordan was promoted by Turkish groups (Bilen, 2000), regional analysts (Gruen, 2004) and Israeli groups (Wachtel, 1992). The volume of water to be conveyed in the proposed Peace Pipeline has always been about 2 BCM per year. The proposal is still being advocated by a consultant in Israel (Wachtel, 2009).

Peace Pipeline Projects. Literature from the 1980s and 1990s is rich in studies of these proposed projects, but the only study that could be regarded as a substantial pre-feasibility study was one from 1997 by Brown and Root which evaluated the proposed grand regional projects. A copy of this report has not been located. The other studies of the Mini-Peace Pipeline are at the reconnaissance or pre-feasibility levels (Wachtel, 1992; Darley, 2002 and 2008). They do not provide an in depth analysis of feasibility, impacts or risks.

Conclusions. The study of this alternative is seriously devalued by the non-availability of important sources of information. Based on the limited available information it is concluded that first, the long-term availability of 2 BCM of water from the Seyhan and Ceyhan Rivers is unreliable; second, a version of the Peace Pipeline would be technically feasible. Third, the cost of water would be in the range of US$0.50 to 1.00 per m^3. This cost would be acceptable for domestic and industrial water uses. It would not be acceptable at this cost to restore the environmental services of the water environment of the Dead Sea and the Lower Jordan River.

It is further concluded – albeit on the basis of very inadequate limited reconnaissance studies – that the environmental and social impacts and the impacts on cultural heritage resources, with appropriate mitigation and monitoring during construction, would be low to moderate in all the countries through which the pipeline would be constructed.

There would be a reduced availability of water for residents of the supply area in Turkey, which may be partially offset if benefit sharing were adopted. On the other hand, the social impacts could be positive for the people living in the substantial cities of Syria and Jordan that would lie along the alignment of the pipeline.

The Peace Pipeline is unique in the suite of options and alternative options in that it addresses both the challenges of restoring the Dead Sea and the scarcity of potable water in the Jordan Basin with high quality water. However, the construction of such a pipeline would have locally negative impacts on the terrestrial environment, on economic and heritage assets. It would not have significant negative impacts on the groundwater resources along its alignment. Even spillage–caused either by sabotage or a natural event–would only have short term impacts on the aquifers beneath the alignment.

EUPHRATES RIVER BASIN TRANSFER VIA PIPELINE (TR3)

Description. This pipeline alternative would convey water from the west bank of the Euphrates River in Iraq to Jordan. The length of the pipeline would be almost 600 km (see Map 6). Pumps to lift water 1,400 m would be needed for this 600 km infrastructure (Murakami, 1995). The pipeline would be technically feasible but pumping costs could make the water relatively expensive. The alternative is not viable as the Iraqi authorities no longer believe they have water to export. In addition the proposed volume of about 160 MCM/year is no longer a significant volume compared with the amounts being mobilized by desalination and recycling.

This option was reviewed in the 1980s by USAID and in the mid-1990s by GTZ (1996, Appendix A). Since then there have been events in the region that have made this option non-viable both economically and environmentally. First, the demands on Euphrates water by its riparians have increased. Secondly, it would be necessary to augment the flow of the Euphrates if there were to be withdrawals in Iraq to pump river water into a 600 kilometer pipeline to supply Jordan with about 160 MCM/year. There are no signs that the hydraulic infrastructure to convey additional water to the upper Euphrates to augment its flow in Turkey will be built. The estimated cost of the project in the mid-1990s was US$2.0 billion.

There has been no recent reference to the proposal mainly because conditions in Iraq have been unstable, and periodically seriously disrupted militarily, for over three decades.

Table 7.2: Water Transfer Options - Transfer of Water from Euphrates River Basin by Pipeline– Pros and Cons (TR3)

	PROS	CONS
Overview	• This is a transfer option that has not been seriously reviewed for over 20 years during which time major changes have taken place in Iraq and the greater Euphrates River Basin. In the view of the Study of Alternatives Team this is not a viable option at this time • If an adequate supply of water was available for transfer from the Euphrates, this could be an attractive option for the provision of a limited amount of high quality potable water	• Insufficient water is available from the Euphrates River to address even small volumes of high quality water needed for municipal and industrial use in Jordan. Volume considered in earlier studies only 160 MCM/year; alternatives in other reports consider volumes of 800 MCM/year • No solution to water shortage in the three Beneficiary Parties • Continued decline in level of Dead Sea
Technical	• Use of proven technologies	• No recent estimates of capital and operational costs nor of cost of delivered water
Economic and Financial	• Low capital costs of small diameter pipeline • Employment generation during construction and limited employment during operation	• Higher costs of operations and delivered water as pipeline four times length of Red Sea–Dead Sea alternative; 830 m of static lift and 1,300 m of total pumping head required • Water volumes too small to address current water needs
Environ-mental and Social	• Limited potential environmental and social impacts due to the alignment • Low environmental risks from spills as pipeline conveying high quality water • Positive social impacts such as improved access to reliable sources of high quality potable water. • Amelioration of water shortages in communities and cities located along pipeline	• Anticipated to require some involuntary resettlement and land acquisition • Large negative environmental and social effects during construction, which can be mitigated • Potential for locally significant negative impacts on cultural assets along pipeline route without proper avoidance and mitigation measures
Other		• Security of water resource a function of unstable regional relations at time of writing

Reduction in Flow. Iraq no longer considers itself to be water rich especially on the Euphrates. The lower reaches of this river have been heavily impacted by the reduction to just over half its natural flow. The reduction in flow is partly a consequence of the construction of the hydraulic infrastructure in Turkey since the 1970s, in particular the withdrawal of water for Greater Anatolian Project (GAP) supported irrigation projects since the early 1990s. Syrian and Iraqi withdrawals have also contributed to the decline in flow. Iraq would find it hard to justify the transfer of a volume of 160 MCM per year. This volume could be relevant in a Combination of Alternatives. But alone it is not a significant medium- or long-term source of water.

Technically Feasible. A Euphrates pipeline from Iraq is technically feasible. Its water would be cheaper than water conveyed from Turkey and competitive with Red Sea–Dead Sea Water Conveyance desalinated water delivered to Amman. Its direct environmental impacts and cultural heritage impacts would be moderate given the limited area needed for construction and operation of the conveyance structure. Its social impacts along the alignment of the pipeline in Iraq would be negligible due to low population density in the area. In Jordan they would be positive because of increased access to good quality freshwater. Given the need to transfer water from the Euphrates basin there would be downstream impacts on water quality, aquatic ecosystems including wetlands, and on water users in Iraq.

Volumes of Water Increasingly Problematic. In summary, a structure to convey reasonably high quality water from the Euphrates in Iraq would be technically and economically feasible. But the volumes of water available would be increasingly problematic as Turkey, Syria and Iraq increase their use of water.

Concluding Remarks (TR2 and TR3)

Water Is Not Available for the Transfers. The transfer of river water of very low salinity from outside the region has for three decades appeared to be a viable option. By 2010, however, the transfer of water from the Seyhan and Ceyhan Rivers in Turkey was no longer possible because of the development of local in-basin uses and the predicted impacts of climate changes. The Euphrates has also become a non-viable source because of increased demands in Turkey, Syria and Iraq.

Seyhan and Ceyhan Rivers. The Seyhan and Ceyhan Peace Pipeline would be operationally risk-prone because it is not certain that 2 BCM of water per year will be reliably available. A project delivering 2 BCM per year would address both problems – the restoration of the Dead Sea and the provision of potable water. The Peace Pipeline is a technically feasible project and the quality of the water delivered would be high. The costs of the water could be easily borne by municipal and industrial users. But there would be no obvious source of funds to pay for US$0.6/$m^3$ Turkish water to restore the Lower Jordan and the Dead Sea. (Cost estimates range from US$0.5 to US$1.5 per m^3.) In addition the construction related negative environmental and heritage impacts would be moderate or high in Turkey, Syria and Jordan. Special attention would need to be given in the routing to minimize resettlement, land acquisition and impacts to heritage. The social impacts would also be significantly negative in Turkey unless benefit sharing for local populations is well planned and implemented. The social impacts would, however, be significantly positive for the major cities lying on the alignment of the pipeline in Syria and Jordan. The operational and financial risks would be very high.

Euphrates River. Transferring water from the Euphrates is not a viable option. The Euphrates is no longer a river with exportable water at any season. A water conveyance from the Euphrates would only address the provision of municipal water. It would not provide water to restore the Dead Sea. The cost estimates are very vague but appear to be about US$0.6 per m^3. The environmental and heritage impacts in Iraq and Jordan would be high. The inadequacy of the source would make the option a high operational and financial risk.

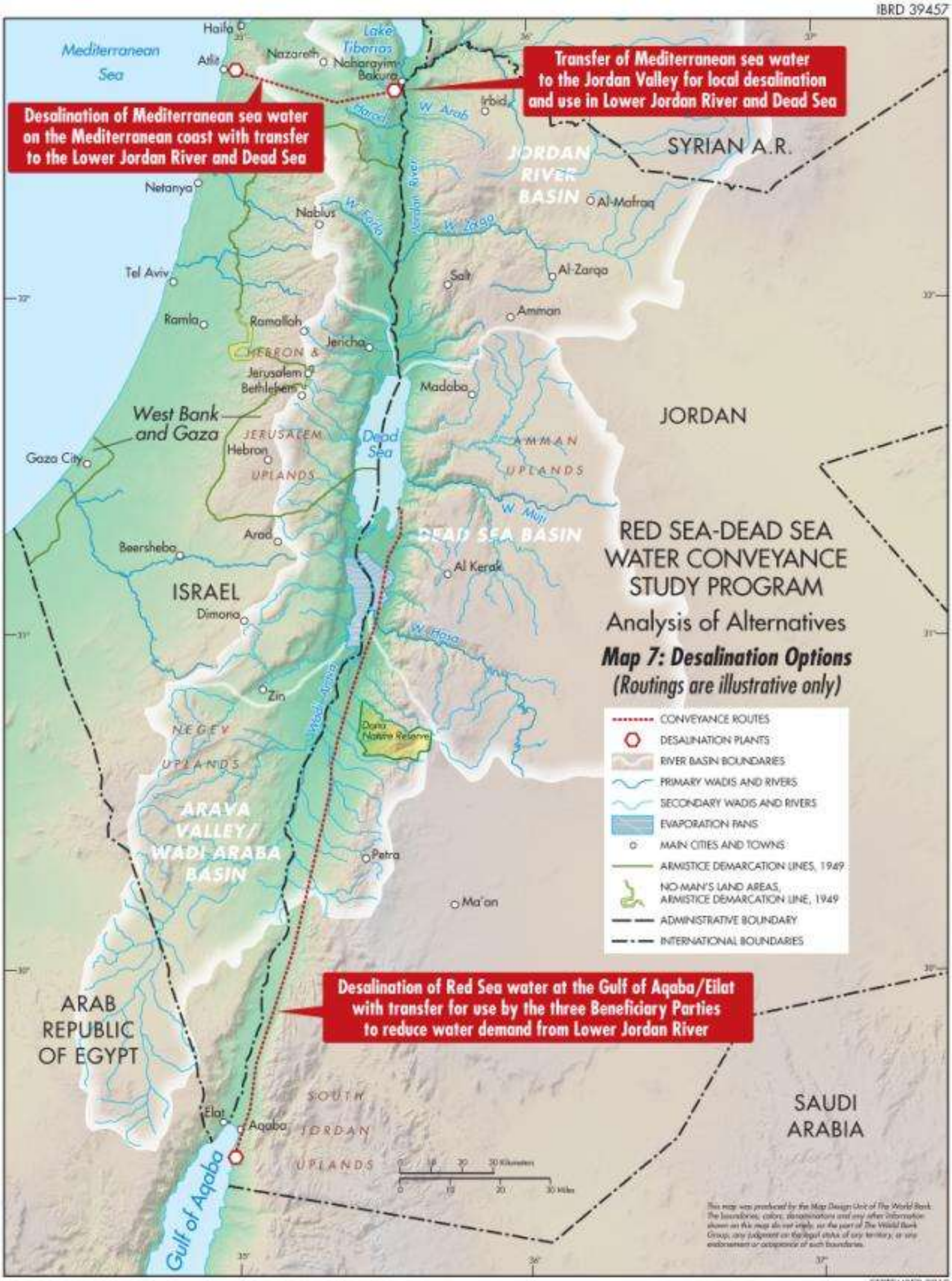
8. DESALINATION OPTIONS (DS1-DS4)

Description. In the context of the alternatives considered here, the purpose of desalination is to increase the supply of potable water for Jordan, mainly for Amman, and to a lesser extent in regions of Israel and the Palestinian Authority. Using desalinated water for Dead Sea stabilization purposes is not viable economically and will not be discussed. The following alternatives are included in this section:

- DS1 – Desalination of Mediterranean Sea Water on the Mediterranean Coast with Transfer to the Lower Jordan River and Dead Sea Region (See also TR1.3/TR 1.4 in Section 6);
- DS 2 – Transfer of Mediterranean Sea Water to the Jordan Valley for Local Desalination and Use in Lower Jordan River and Dead Sea Region;
- DS 3 – Increased Desalination of Mediterranean Sea Water on the Mediterranean Coast with Transfer for Use by the Three Beneficiary Parties to Reduce Water Demand from Lower Jordan River; and
- DS 4 – Desalination of Red Sea Water at the Gulf of Aqaba/Eilat with Transfer for Use by the Three Beneficiary Parties to Reduce Water Demand from the Lower Jordan River.

Note that an additional alternative, the Jordan Red Sea Project, is being actively evaluated by the Government of Jordan, as a national project (see Box 4.1) and text at the end of this section.

Background information on the cost of desalination in Israel is provided in Box 8.1 below.


IBRD 39457
RED SEA-DEAD SEA WATER CONVEYANCE STUDY PROGRAM
Analysis of Alternatives
Map 7: Desalination Options
(Routings are illustrative only)
Transfer of Mediterranean sea water to the Jordan Valley for local desalination and use in Lower Jordan River and Dead Sea
Desalination of Mediterranean sea water on the Mediterranean coast with transfer to the Lower Jordan River and Dead Sea
Desalination of Red Sea water at the Gulf of Aqaba/Eilat with transfer for use by the three Beneficiary Parties to reduce water demand from Lower Jordan River
CONVEYANCE ROUTES
DESALINATION PLANTS
RIVER BASIN BOUNDARIES
PRIMARY WADIS AND RIVERS
SECONDARY WADIS AND RIVERS
EVAPORATION PANS
MAIN CITIES AND TOWNS
ARMISTICE DEMARCATION LINES, 1949
NO-MAN'S LAND AREAS, ARMISTICE DEMARCATION LINE, 1949
ADMINISTRATIVE BOUNDARY
INTERNATIONAL BOUNDARIES
Mediterranean Sea
SYRIAN A.R.
JORDAN
ISRAEL
West Bank and Gaza
ARAB REPUBLIC OF EGYPT
SAUDI ARABIA
JORDAN RIVER BASIN
DEAD SEA BASIN
ARAVA VALLEY/ WADI ARABA BASIN
Lake Tiberias
Dead Sea
Gulf of Aqaba
Haifa
Atlit
Nazareth
Naharayim-Bakura
Irbid
Al-Mafraq
Netanya
Nablus
Tel Aviv
Salt
Al-Zarqa
Amman
Ramla
Ramallah
Jericho
Jerusalem
Bethlehem
Madaba
Gaza City
Hebron
Arad
Beersheba
Al Kerak
Dimona
Zin
Petra
Ma'an
Elat
Aqaba
Dana Nature Reserve
HEBRON &
JERUSALEM
UPLANDS
AMMAN
UPLANDS
NEGEV
UPLANDS
SOUTH
JORDAN
UPLANDS
W. Arab
W. Zarqa
W. Mujib
W. Hasa
Jordan River
Wadi Araba
SEPTEMBER 2012

Box 8.1: The Cost of Desalination in Israel

The cost of desalinated water in Israel is between US$0.52/m^3 and $0.70/ m^3. This compares to $1.18/ m^3 in Cyprus, $0.75/ m^3 in Australia and $0.67/ m^3 in Tampa Bay, Florida, USA.

Israel's cost of desalinated water is the result of a variety of factors, some of which are unique to this country:

- Use of reverse osmosis technology. Reverse osmosis involves lower energy consumption and operating costs than thermal desalination systems such as flash distillation.
- Use of natural gas fired power installations to produce electricity to run the desalination process. Natural gas power generation is 7% to 8% cheaper than coal fired methods and produces on average only 20% of CO_2 emissions.
- Desalination plants are often accompanied by dedicated natural gas power generating plants. Any surplus energy produced by the power installations that is not used for desalination can be sold into the national grid, thus reducing overall costs.
- Desalination plants are often equipped with energy recovery systems, thereby reducing overall energy use.
- Common use of long-term "take or pay" contracts reduces private sector risk and encourages competitive pricing.
- Israel has a stable and well developed financial sector, which often permits attractive financing packages for construction.
- Consensus at the government level and within the general public that desalination is an attractive water supply option.

Source: Tenne, A., 2010, *Sea Water Desalination in Israel: Planning, coping with difficulties, and economic aspects of long-term risks,* State of Israel Desalination Division.

DESALINATION OF MEDITERRANEAN SEA WATER ON THE MEDITERRANEAN COAST WITH TRANSFER TO THE LOWER JORDAN RIVER AND DEAD SEA REGION (DS1)

Description. This is an infrastructure based alternative that involves increasing desalination capacity on the Mediterranean coast in northern Israel. Brine produced during the desalination process would be returned to the Mediterranean Sea and desalinated water would be distributed by pipeline and/or channel to the Beneficiary Parties and the Jordan River. This is a stand alone option that is solely based on desalination and conveyance of desalinated water to Beneficiary Parties and the Lower Jordan River Valley. The aims are to:

- Increase the amount of potable water available to the Beneficiary Parties;
- Stabilize the level of the Dead Sea; and
- Generate hydropower.

Review by Samuel Neaman Institute. The Samuel Neaman Institute (2007), as one of four options (see Box 6.1), examined the following: desalination of seawater on the Mediterranean coast, south of Haifa, to produce 1,800 MCM/year of freshwater. Of this, 270 MCM/year would be designated to the Palestinian Authority and communities in the Negev and 400 MCM/year would be designated to users of the Israeli National Water Carrier, which would cease pumping from Lake Tiberias. A total of 1,130 MCM/year would be transferred through a tunnel in Mount Carmel and through a series of valleys up to Ramat Zva'im where it would fall to the Naharayim area in the Jordan Valley and be used to generate hydropower. Then 530 MCM/year would be transferred to Jordan (to the Amman region) and the remaining 600 MCM/year would be conveyed to the Dead Sea or Lake Tiberias. When combined with the 400 MCM/year saved from the cessation in pumping by the National Water Carrier, this provides 1,000 MCM/year high quality water for restoration of the Dead Sea. A total of

1,200 MCM high quality water is made available to the Beneficiary Parties. This approach would require significant expansion of desalination facilities on the Mediterranean coast, with demands for energy which would result in air emissions and discharges of brine into the marine environment. Environmental impacts from the water conveyance beyond those associated with the construction of necessary pipelines, desalination and hydropower plants would be low as there would be no conveyance of brine or seawater over aquifers. Total net running cost (2007) was estimated in the Samuel Neaman Institute report at US$1,210 million per year and total investment cost at US$7,620 million.

The main anticipated effects of the desalination options DS1–DS4 are summarized in Tables 8.1–8.4.

Table 8.1: Desalination Options – Desalination of Mediterranean Sea Water on the Mediterranean Coast with Transfer to the Lower Jordan River and Dead Sea Region – Pros and Cons (DS1)

	PROS	CONS
Overview	• Desalination of sea water is a well understood technology and its costs are falling	• The desalination options only incrementally address the restoration of the level of the Dead Sea
Technical	• Uses proven technologies	• Energy costs of pumping desalinated water to highland destinations • Desalination process generates wastes that need to be properly disposed
Economic and Financial	• Low capital costs compared with other options. Operational costs and delivered costs of water moderate and potentially falling	• Energy costs of pumping desalinated water to highland destinations • High cost of land on the Mediterranean coast and pipeline tunnel alignment
Environmental and Social	• Increased potable water, the volume of which could be increased as needed • Low risk in conveying high quality water • Positive social impacts such as improved access to reliable sources of high quality potable water • Employment generation during construction and limited employment during operation	• Negative impact of the desalination plant in a very congested coastal area on the Mediterranean Sea • No studies completed on coastal impacts at the Mediterranean Sea • Anticipated to require limited involuntary resettlement and some land acquisition • Potentially large negative environmental and social effects during construction, which can be mitigated • Carbon impact of power generated to desalinate water and operate the conveyance • Negative impact of salt/brine disposal in the Mediterranean Sea
Other		• Potential cooperation and reliability of supply issues for Jordan (and possibly also the Palestinian Authority) concerning water sourced outside Jordan

TRANSFER OF MEDITERRANEAN SEA WATER TO THE JORDAN VALLEY FOR LOCAL DESALINATION AND USE IN LOWER JORDAN RIVER AND DEAD SEA REGION (DS2)

Description. This is an infrastructure based alternative that involves abstracting seawater from the Mediterranean coast in northern Israel and transferring it inland by pipeline/tunnel/channel for desalination in the Jordan Valley. The brine from this process would then be transferred by pipeline (or channel) to the Dead Sea. It would be a stand alone alternative which aims to:

- Stabilize the level of the Dead Sea; and
- Increase the amount of potable water available to the Beneficiary Parties.

Review by Samuel Neaman Institute. The Samuel Neaman Institute examined the following option: transferring 2,000 MCM/year of sea water from the Mediterranean south of Haifa for inland desalination in the Naharayim – Beit She'an area. This would produce 800 MCM/year of high quality desalinated water that could be supplied to Jordan, mainly to the Amman area. The brine from the process (1,200 MCM/year) would be transferred to the Dead Sea by canal or pipeline. This process would involve transferring seawater and brine across aquifers that are used for potable water so the alternative does present considerable environmental risk. Total net running cost (2007) was estimated at US$875 million per year and total investment cost (2007) at US$5,710 million.

Table 8.2: Desalination Options - Transfer of Mediterranean Sea Water to the Jordan Valley for Local Desalination and Use in Lower Jordan River and Dead Sea Region – Pros and Cons (DS2)

	PROS	CONS
Overview	• The desalination of sea water is a well understood technology and its costs are falling	• The desalination options only incrementally address the restoration of the level of the Dead Sea
Technical	• Uses proven technologies	• Requires access to large areas of land for the facilities and pipeline • Energy costs of pumping desalinated water to highland destinations • Desalination process generates wastes that need to be properly disposed of
Economic and Financial	• Low capital costs compared with other options • Operational costs and delivered costs of water moderate and potentially falling	• Energy costs of pumping desalinated water to highland destinations • High cost of land on the Mediterranean Sea and along pipeline/tunnel alignment
Environmental and Social	• Increased potable water, the volume of which could be increased as needed • Low risk in conveying high quality water • Positive social impacts such as improved access to reliable sources of high quality potable water • Employment generation during construction and limited employment during operation	• Negative impact of the pumping station in a very congested coastal area on the Mediterranean Sea • No studies completed on coastal impacts at the Mediterranean Sea • Anticipated to require limited involuntary resettlement and some land acquisition • Potentially large negative environmental and social effects during construction, which can be mitigated • Possibilities of damage to ground

	water reserves as a result of potential sea water leaks along conveyance system • Need to collect and dispose of waste materials during operation • Carbon impact of power generated to desalinate water and operate the conveyance • Negative impact of salt/brine transfer on the Lower Jordan • Possible significant effects on Dead Sea from mixing with Mediterranean Sea water and desalination brine
Other	• Potential cooperation and reliability of supply issues for Jordan (and possibly also the Palestinian Authority) concerning water sourced outside Jordan

INCREASED DESALINATION OF MEDITERRANEAN SEA WATER ON THE MEDITERRANEAN COAST WITH TRANSFER FOR USE BY THE THREE BENEFICIARY PARTIES TO REDUCE WATER DEMAND FROM LOWER JORDAN RIVER (DS3)

Description. This is an infrastructure based alternative that would involve increasing desalination capacity on the Mediterranean coast of Israel and Gaza through the construction of new desalination plants and upgrade of existing plants. Desalinated water would be conveyed to demand centers in Israel and the Beneficiary Parties to reduce water demands in the Jordan Valley. Increased availability of new water could enable Israel to reduce pumping from Lake Tiberias into the National Water Carrier making more water available for the stabilization of Dead Sea levels. This is not a stand alone alternative and would need to be coupled with water savings in agriculture and industry to achieve the stabilization of the Dead Sea water level.

Background. In 2010, Israel had capacity to desalinate 284 MCM/year on the Mediterranean coast (Tenne, 2010). It aims to increase Mediterranean desalination capacity to 600 MCM/year by 2014. In addition to Mediterranean desalination plants there are also plans to desalinate an increased volume of brackish spring water at various locations around the country. By 2050 Israel plans to desalinate a total of 1,500 MCM/year which is designated to meet 70 percent of all national potable water demands and 100 percent of domestic water demands. Any surplus desalinated water generated in this process is available for the natural environment. The current plans are aimed at servicing Israeli domestic demand so additional capacity would need to be built in to serve demands of other Beneficiary Parties. For example, this quantity could be increased to meet some of the urban water needs of Jordan as well, both (i) by reducing the pumping from Lake Tiberias to the Israeli National Water Carrier and accordingly increasing the allocation of Lake Tiberias water to Jordan, and (ii) by transferring water desalinated near Haifa to Amman via Naharayim-Bakura (see the northern alignment of the Mediterranean Transfer Alternative TR.3, TR.4 above). The current cost of desalination in Israel stands at US$0.52/m^3.[4]

The Palestinian Authority is working with the European Union and other donors for the development of a 55 MCM/year desalination plant in Gaza (Secretariat of the Union for the Mediterranean, May 2011).

[4] http://news.bbc.co.uk/2/hi/middle_east/3631964.stm

Table 8.3: Desalination Options - Increased Desalination of Mediterranean Sea Water on the Mediterranean Coast with Transfer for Use by the Three Beneficiary Parties to Reduce Water Demand from Lower Jordan River – Pros and Cons (DS3)

	PROS	CONS
Overview	• The desalination of sea water is a well understood technology and its costs are falling	• The desalination options only incrementally address the restoration of the level of the Dead Sea
Technical	• Uses proven technologies	• Requires access to large areas of land for the facilities and pipeline and significant sources of energy • Desalination process generates wastes that need to be properly disposed of
Economic and Financial	• Low capital costs compared with other options • Operational costs and delivered costs of water moderate and potentially falling	• Energy costs of pumping desalinated water to highland destinations • High cost of land on the Mediterranean coast and pipeline/tunnel alignment
Environmental and Social	• Increased potable water, the volume of which could be increased as needed • Low risk in conveying high quality water • Positive social impacts such as improved access to reliable sources of high quality potable water • Employment generation during construction and limited employment during operation	• Negative impact of the desalination plant in a very congested coastal area on the Mediterranean Sea • No studies completed on coastal impacts at the Mediterranean Sea • Anticipated to require limited involuntary resettlement and some land acquisition • Potentially large negative environmental and social effects during construction, which can be mitigated • Carbon impact of power generated to desalinate water and operate the conveyance • Negative impact of brine disposal in the Mediterranean Sea
Other		• Potential cooperation and reliability of supply issues for Jordan (and possibly also the Palestinian Authority) concerning water sourced outside Jordan

DESALINATION OF RED SEA WATER AT THE GULF OF AQABA/EILAT WITH TRANSFER FOR USE BY THE THREE BENEFICIARY PARTIES TO REDUCE WATER DEMAND FROM LOWER JORDAN RIVER (DS4)

Description. This is an infrastructure based alternative that would involve either establishing desalination capacity on the shore of the Gulf of Aqaba/Eilat and transferring desalinated water from the Red Sea coast to the three Beneficiary Parties by pipeline/channel/tunnel, including transfer of brine from the desalination process at Aqaba to the Dead Sea, or transfer of sea water by pipeline/tunnel/channel to the Dead Sea for desalination and sharing among the Beneficiary Parties.

Background. The Samuel Neaman Institute, as another option, also examined the abstraction of 2,000 MCM/year seawater from the Gulf of Aqaba/Eilat, conveyed via a canal from the Red Sea to the Dead

Sea with desalination at the Dead Sea to produce 800 MCM/year potable water for Jordan (to be pumped to Amman) and a flow of 1,200 MCM/year seawater and brine to the Dead Sea (see Box 6.1). Investment costs are estimated at US$5,000 million and operational costs at US$1,085 million/year (2007). Possible environmental impacts identified include leakage of seawater into aquifer zones. This alternative is very similar to the Red Sea–Dead Sea Water Conveyance but differs in the sense that it is purely designed to meet the water needs of Jordan.

The cost of desalination in Aqaba and conveyance to Amman is about US$2 per m^3 under this approach. The cost of desalination in Aqaba and conveyance to the densely populated areas of Israel and the Palestinian Authority would be about the same. This cost of US$2 per m^3 would be considerably larger than the cost of desalination along the Mediterranean Sea and conveyance to the three Beneficiary Parties or the cost of the Red Sea–Dead Sea Water Conveyance. This alternative would provide an appropriate approach to increase the supply of potable water in the Aqaba/Eilat region.

Table 8.4: Desalination Options - Desalination of Red Sea Water at the Gulf of Aqaba/Eilat with Transfer for Use by the Three Beneficiary Parties to Reduce Water Demand from Lower Jordan River – Pros and Cons (DS4)

	PROS	CONS
Overview	• The desalination of sea water is a well understood technology and its costs are falling	• The desalination options only incrementally address the restoration of the level of the Dead Sea
Technical	• Uses proven technologies	• Requires access to large areas of land for the facilities and pipeline and significant sources of energy • Desalination process generates wastes that need to be properly disposed of
Economic and Financial	• Low capital costs compared with other options • Operational costs and delivered costs of water moderate and potentially falling	• Energy costs of pumping desalinated water to highland destinations • High cost of land on the Red Sea coast
Environmental and Social	• Increased potable water, the volume of which could be increased as needed • Low risk in conveying high quality water • Positive social impacts such as improved access to reliable sources of high quality potable water • Employment generation during construction and limited employment during operation	• Negative impact of the desalination plant in a very congested coastal area on the Red Sea • Anticipated to require limited involuntary resettlement and some land acquisition • Potentially large negative environmental and social effects during construction, which can be mitigated • Carbon impact of power generated to desalinate water and operate the conveyance • Negative impact of salt/brine disposal if disposed of in the Red Sea
Other		• Potential cooperation and reliability of supply issues for Jordan (and possibly also the Palestinian Authority) concerning water sourced outside Jordan

JORDAN RED SEA PROJECT (JRSP) (WWW.JORDAN-JRSP.COM, NOT INCLUDED IN THE STUDY OF ALTERNATIVES TERMS OF REFERENCE)

This alternative is a Jordan only initiative that does not involve Israel or the Palestinian Authority (see Box 4.1). This alternative was not identified in the Terms of Reference. It has become a prominent alternative promoted by the Government of Jordan and it is appropriate to consider it in this section. This could be a stand alone alternative if sufficient desalination capacity could be established at the Gulf of Aqaba or on the Dead Sea coast to meet potable water demands in the three Beneficiary Parties and sufficient brine or sea water could be conveyed to the Dead Sea to stabilize water levels.

It is a phased proposal (5 phases) which ultimately aims to abstract 2,150 MCM/year seawater from the Gulf of Aqaba, partially desalinate this water to produce 80 MCM/year potable water in the Aqaba area, and convey the remaining seawater and brine by pipeline through the Wadi Araba/Arava Valley for desalination at the Dead Sea (to produce a further 850 MCM/year potable water for use in Jordan). A total of up to 1,220 MCM/year would be discharged to the Dead Sea. Phase I of this project aims to produce 250 MCM/year desalinated water and 190 MCM/year Dead Sea discharge by 2018.

The project completion date is 2055. The objectives of this initiative are to:

- Establish a secure and affordable water supply for Jordan while saving the Dead Sea from extinction;
- Support widespread economic growth;
- Provide potential water for regional needs; and
- Facilitate private and public financing through the JRSP Company.

The proposed site for the intake of this scheme would be located at the top of the Gulf of Aqaba/Eilat immediately on the Jordanian side of the border. It should be noted that this site was studied as part of the Feasibility Study for the Red Sea–Dead Sea by Coyne et Bellier (2010) and was found to be unsuitable due to seismic and flooding risks.

RECENT STUDIES BY NONGOVERNMENTAL ORGANIZATIONS

The Jerusalem Institute for Israel Studies and FoEME have both recently prepared reviews involving desalination issues (see Boxes 8.2 and 8.3).

Box 8.2: Jerusalem Institute for Israel Studies

The Jerusalem Institute for Israel Studies, JIIS Series Report No. 417, December 2011 (full report in Hebrew, Synopsis and Executive Summary in English), "Altering the Water Balance as a Means to Addressing the Problems of the Dead Sea: An Independent Assessment of Alternatives for a 'Water Conduit' and the Achievement of Its Objectives," examined alternatives to the Red Sea–Dead Sea Water Conveyance under the following objectives/options:

- Two options for provision of 200 MCM/year of fresh water to Amman (from Aqaba or Lake Tiberias and no connection to the Red Sea);
- Six options for provision of 200 MCM/year of fresh water to Amman and 800 MCM/year of seawater/desalination brine to the Dead Sea (desalination plant at either Fifa or on the Mediterranean);
- Desalination at the Mediterranean Sea to provide 200 MCM/year to Amman, plus 800 MCM/year of fresh water to the Dead Sea via the Jordan River channel; and
- Desalination at the Mediterranean Sea to provide 200 MCM/year to Amman, plus 100 MCM/year of fresh water to the Dead Sea via the Jordan River channel, plus 700 MCM/year of seawater/brine to the Dead Sea outside the Jordan River channel.

The study's principal assumptions are: (i) continuous electricity generation; (ii) pump storage to take advantage of Israel's current electricity tariffs; (iii) limited inclusion of benefit streams; (iv) no environmental costs; (v) cost of supplying fresh water to Israel and the Palestinian Authority not included, and (vi) total amount of water to be conveyed capped at 1,000 MCM/year.

The estimated net present value (capital cost and operation costs over 30 years at a 7% discount rate) for the various options, on a cost effectiveness basis excluding public good benefits, ranged from US$2.7 billion to US$7.4 billion. The least expensive option was water for Amman directly from Lake Tiberias (no water to the Dead Sea) and the most expensive option was the third bullet above.
In comparison, the Coyne et Bellier Feasibility Study has none of the first 5 assumptions listed above and conveyance is capped at twice the amount (2,000 MCM/year). It also provides for a total of 850 MCM of desalinated water, including 560 MCM/year to Jordan. The estimated net present value (capital cost and operation costs over 50 years, at a 10% discount rate) of Red Sea–Dead Sea Water Conveyance options, on a cost benefit basis including estimated public good benefits, was about US$13 billion.
Similar to the Coyne et Bellier Study, the JIIS study recommends that because of the substantial uncertainties any chosen option should be implemented in a modular manner.
A major shortcoming of this study is that not more than 800 MCM/year is allocated to the Dead Sea under any option. Coyne et Bellier has, in contrast, determined that a minimum of 1,200 MCM/year is required to stabilize the level of the Dead Sea.

Box 8.3 FoEME, 2012, *Desalination: How much and what is the alternative*? Tel Aviv: Friends of the Earth Middle East.

The purpose of this analysis is to question the acceptance of the scale of investment in and proposed dependence on desalination technologies. It quotes the Israeli Water Authority 2012 [citation to be added] on existing and proposed desalination programs in Israel (see Table below):

Desalination Programs in Israel up to 2030:

Year	Facilities	Output per facility*	Accumulative output
2011	Ashkelon, Palmachim, Hadera	300	300
2012	Ashdod	100	400
2013	Soreq	150	550
2016	Western Galilee	50	600
2020			750
2030			940

Source: Israeli Water Authority

The analysis reminds the reader that Israel's water management has been severely criticized (Parliamentary Committee of Inquiry 2002). It urges caution, arguing that there is a down side to desalination. It solves one problem but creates others associated with greenhouse gas emissions and costly energy use – 2,900 megawatts of electricity. It recommends that the shift to desalination should wait for the arrival of the new 'direct osmosis' technologies (Elimelech et al, 2011). In addition, desalination plants occupy valuable coastal sites and have negative impacts on coastal ecosystems. The availability of so much new water leads to a tendency amongst consumers and governments to lessen their efforts for water conservation, which is a source of concern. The study also points out that control over this vital national resource – water – is shifting to the private sector, where a very small number of companies has become influential in a strategic industry that depends on the state to maintain conditions to ensure consumption and payment for agreed volumes of desalinated water (bar Eli, 2011).

The study finally urges a 'balanced approach to desalination,' emphasizing that desalination is often a relatively expensive approach to resolving water supply challenges, both for the economy as whole and for the consumer, with profits from the high costs going to the wealthy, the manufacturers of membranes abroad and the construction of facilities (using temporary contract workers, not necessarily Israelis). A water economy based on conservation and demand management would reinstate a greater portion of water resources to public ownership and nurture collective social responsibility regarding the use and ownership of water. Conservation and demand management remain very important elements of water policy.

References:
bar Eli, Avi, 2011, "The Concentration [of control] in the Desalination Industry is Drying up the Country," *The Marker*, September 2011
Elimelech, M., and Philpe, W., 2011. "The Future of Seawater Desalination: Energy, Technology and the Environment," *Science* 313, pp. 712–717.

9. TECHNICAL AND WATER CONSERVATION OPTIONS – CHANGES IN TECHNOLOGY BY THE DEAD SEA CHEMICAL INDUSTRIES (TC1)

Overview. This section examines the potential contribution of changes in the potash industries of Jordan and Israel to the objective of stabilizing the Dead Sea level. This is not a stand alone option and would need to be deployed together with other measures to stabilize the Dead Sea water level and make potable water available to the Beneficiary Parties.

Description. This alternative is based on the deployment of a technical solution to decrease evaporative water losses incurred by the chemical industries at the southern end of the Dead Sea (Arab Potash Company in Jordan and the Dead Sea Works in Israel). Based on results from a recent study (described immediately below), these industries currently extract roughly 727 MCM/year from the Dead Sea and pump it into solar evaporation pans as part of the process of mineral extraction (see Table 9.1). After chemical processes, roughly 465 MCM/year is returned to the Dead Sea (including seepage from the solar pans). Thus, the estimated net use of Dead Sea water by the chemical industries is 262 MCM/year (Zbranek, 2012; see also Table 9.3 below). This compares with an estimated 764 MCM/year that evaporates from the Dead Sea itself. Together, the two chemical plants produce about 5.8 million tons of potash annually (see Table 9.1).

Much of the technical material used in this Section comes from a background study carried out in 2012 (Zbranek, 2012). The objectives of this background study were to:

- Document the chemical processes used by the Dead Sea Works and the Arab Potash Company;
- Determine the amount of Dead Sea water used annually by the two chemical companies; and
- Describe other chemical processes, if any, which would result in a substantial reduction in demand for Dead Sea water.

The background study was completed by a qualified chemical engineer with long and extensive experience in the chemical extraction industry. For the study, a mass balance model was developed for both chemical companies covering total flows, water, individual ions, and estimates for leakage/seepage. It represents the most detailed study on water use by the chemical industry in many years. The background paper is available on the Study Program website.

Background. Israel and Jordan have important evaporation based chemical industries that are adjacently located at the southern end of the Dead Sea with associated evaporation pans (see Map 8).

The Dead Sea Works, Ltd. (DSW). The DSW had its roots in the Palestine Potash Company, which established the first potash plant at the northern end of the Dead Sea in 1930 in Kalia. Construction at the current plant site in the Sodom area, at the southern end of the Dead Sea, was completed in 1936 with a production capacity of 80,000 tons per year. DSW was established in 1952 as a wholly government owned state enterprise. By 1975 production reached 1 million tons/year. Cold crystallization processes were installed in 1980 and by 1986 production exceeded 2 million tons/year. Current production is about 3.5 million tons/year. In 1999 the company was privatized with the State of Israel maintaining a "golden share." DSW is currently 52 percent owned by the Ofer Holdings Group Ltd and the Potash Corporation of Saskatchewan owns 14 percent.

The Arab Potash Company (APC). The APC was set up in 1956 by the Government of Jordan. Production of potash from the Dead Sea began in 1983 when the Ghor El-Safi refinery and processing plant were completed. Capacity at the plant was initially 1.2 million tons/year. The facility underwent upgrades and expansions and in 1994, a second plant using cold crystallization was started, bringing capacity up to 1.8 million tons/year. Further expansions and optimization since that time have boosted capacity to 2.25 million tons/year. Currently, about 59 percent of total production is via the cold crystallization process. The largest owners of APC are the Government of Jordan, Potash Corporation of Saskatchewan and the Arab Mining Company, which together represent 74 percent of the company's ownership.

Table 9.1: Potash Company Basic Statistics

	Pan Area (km^2)	**Potash Production million tons/year**
Dead Sea Works	150	3.50
Arab Potash Company	112	2.26

Source: Zbranek, 2012.

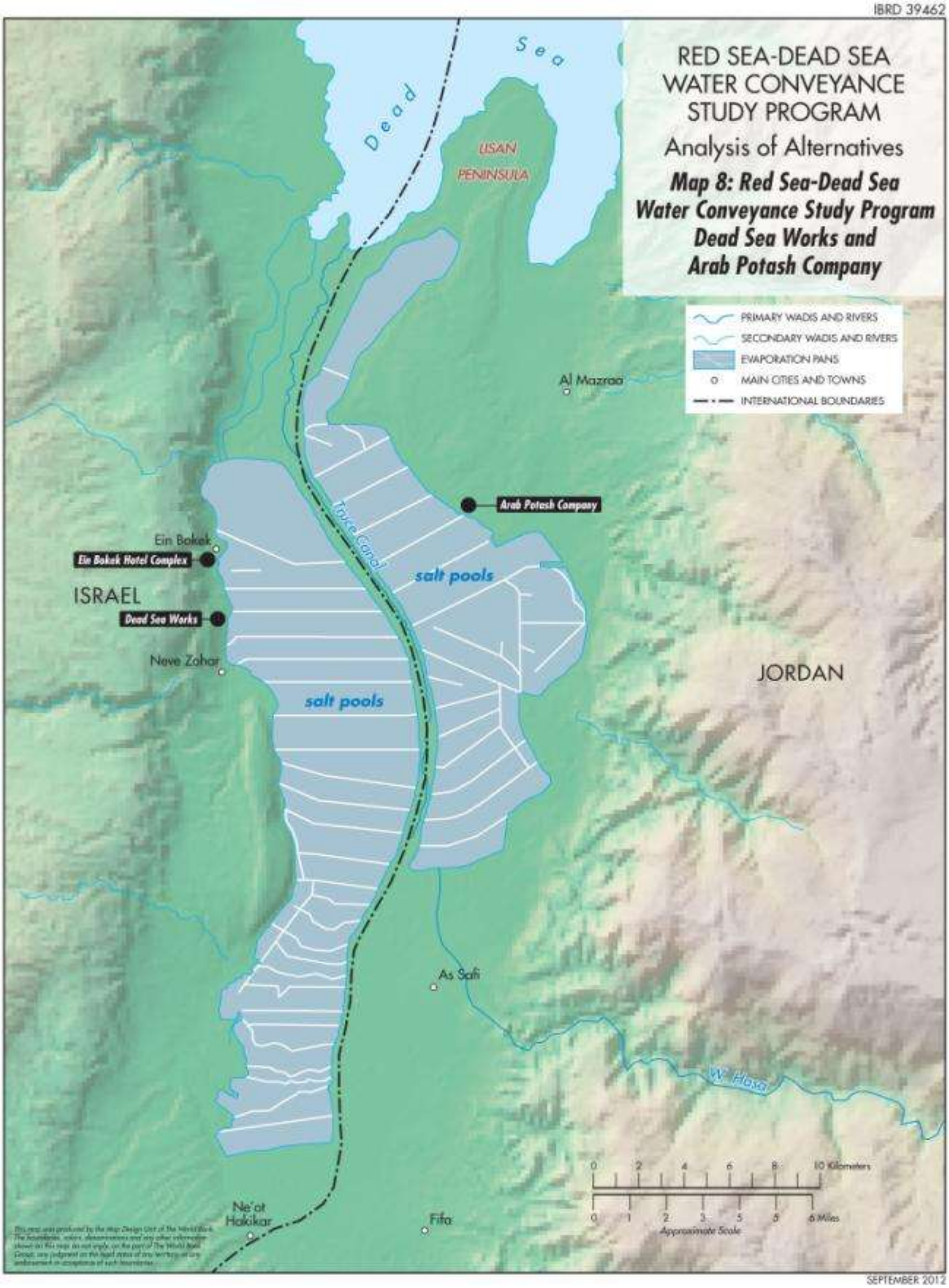
As mentioned above, both companies have deployed a process of cold crystallization to remove higher value salts from Dead Sea brine. This is a tertiary process deployed after brine has passed through primary and secondary evaporation ponds. The process involves using energy to cool the brine down to a temperature at which precipitation of desired salts occurs. Once crystallization of salts has taken place water can be pumped back to the Dead Sea without any water loss. Cold crystallization has improved the efficiency of mineral extraction resulting in energy (but not water) cost savings for the companies.

The main anticipated effects of technical conservation option TC1 are summarized in Table 9.2.

Table 9.2: Technical Conservation Options - Changes in Technology Used by the Dead Sea Chemical Industry–Pros and Cons (TC1)

	PROS	**CONS**
Overview	• Significant role in economy of Dead Sea region - important contributors to respective GDPs • New technologies in the future could possibly reduce water losses • Would contribute on an incremental basis to improvement of the Dead Sea • No cost estimates available	• Account for about 262 MCM/year of water losses in Dead Sea • Restoration of Dead Sea level not addressed • Potable water for Amman and other destinations not provided
Technical	• May provide an opportunity for technical cooperation between the DSW and APC	• More efficient technologies not yet available for large scale use
Economic and Financial	• No information • Enhanced economic performance and viability of the industries through improved technologies	• No information; however, it can be anticipated that water use fees would increase the cost of chemical recovery
Environmental and Social	• Significant positive environmental impacts through improved technologies • Important source of employment, both direct and indirect, at the local level in both countries • Development of new	• Significant carbon footprint from energy required for brine pumping and in the chemical recovery and manufacturing processes • Very large amounts of salt produced as a byproduct of potash production, which largely remains on site • Expansion of chemical industries would require land conversion with

	technologies would allow for increased production without expansion of evaporation pond footprint • Would reduce risk of future employment losses from reduction of chemical production levels	potential localized impacts to environment and cultural heritage
Other	• Possible importance as an element in a combination alternative	


IBRD 39462
RED SEA-DEAD SEA
WATER CONVEYANCE
STUDY PROGRAM
Analysis of Alternatives
Map 8: Red Sea-Dead Sea
Water Conveyance Study Program
Dead Sea Works and
Arab Potash Company
PRIMARY WADIS AND RIVERS
SECONDARY WADIS AND RIVERS
EVAPORATION PANS
MAIN CITIES AND TOWNS
INTERNATIONAL BOUNDARIES
Dead Sea
LISAN
PENINSULA
Al Mazraa
Arab Potash Company
Truce Canal
Ein Bokek
Ein Bokek Hotel Complex
ISRAEL
Dead Sea Works
Neve Zohar
salt pools
salt pools
JORDAN
As Safi
W. Hasa
Ne'ot
Hakikar
Fifa
10 Kilometers
6 Miles
Approximate Scale
SEPTEMBER 2012

Significant Consumption of Dead Sea Water. As was mentioned above, the most recent estimate of net Dead Sea water use by the two chemical companies was done in Zbranek 2012. This estimate of Dead Sea Water use was calculated in detail on a chemical mass water balance basis and was the result of close consultation with the two chemical companies, including field trips and in-depth interviews and exchange of correspondence. Results of this extensive study estimated net water consumption as 262 MCM/year (see Table 9.3 below).

Table 9.3: Net Dead Sea Water Usage by the Potash Industries (MCM/year – 2011)

	Dead Sea Works	Arab Potash Works	Total
Pumped from Dead Sea	448	279	727
Returned to Dead Sea	286	179	465
Net Usage	162	100	262

Source: Zbranek, 2012.

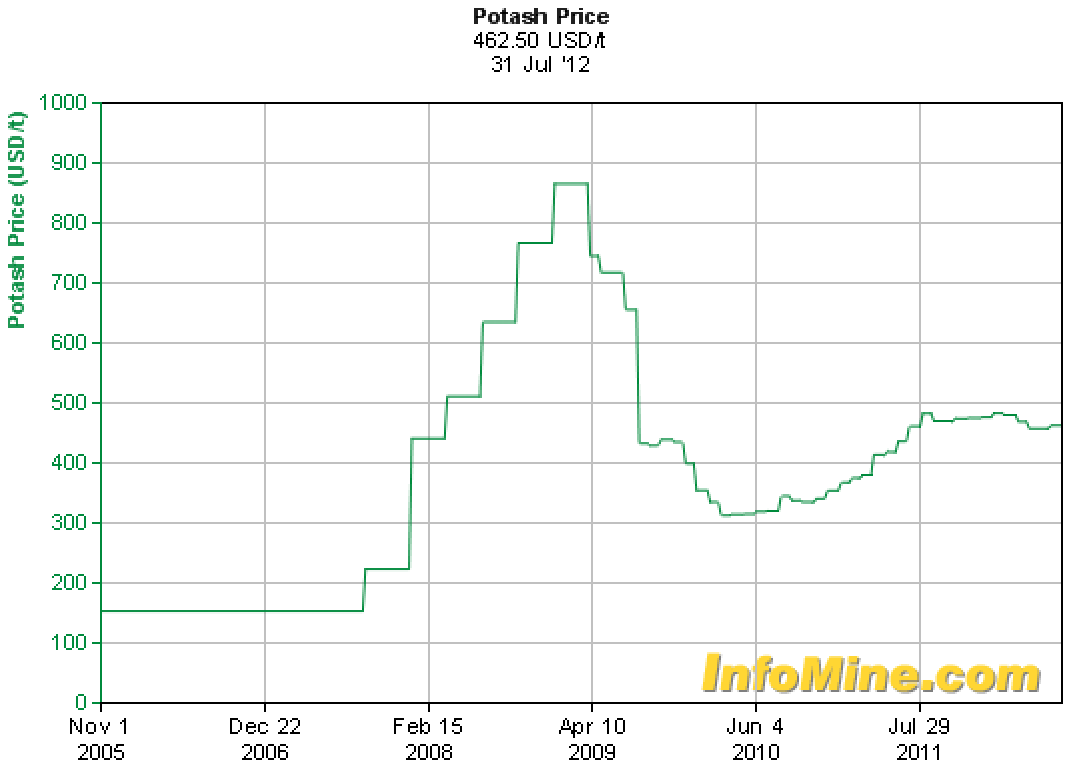
Another estimate of Dead Sea water usage was 250–300 MCM/year for both companies combined, by Israel's Ministry of the Environment and Geological Survey (2006, Table 4.2).

Coyne et Bellier (2010, Table 3.3.8) estimates the same range for total net Dead Sea water extractions for both companies. According to Coyne et Bellier, and similar to the findings from Zbranek, the Israeli Dead Sea Works consumes about two thirds (150–200 MCM/y) while the Jordanian Arab Potash Company consumes about one third (100 MCM/y).

In sum, the results of Zbranek appear to be consistent with previous studies and also appear to be a more precise estimate given the detailed methodology used. The net figure of 262 MCM/year is therefore used from this point forward.

Important Source of Revenues, Royalties and Taxes. In 2011, the Dead Sea Works gross profit from its potash operations were US$1,554 million (ICL 2011). The profit before tax of the Arab Potash Company in 2009 was US$220 million (156.3 million JD – Arab Potash Company, 2009). As Figure 9.1 below shows, 2011 and the first half of 2012 were regular years in the potash market (the potash price, like prices of other commodities, peaked in 2008 and then dropped quickly to the normal price trend).

Figure 9.1: Potash Prices during 2005–2012



Based on the information described above, the 162 MCM consumed by the Dead Sea Works during 2011 generated an operating profit (before royalties, finance costs and any taxes) equivalent to US$9.59/$m^3$ (in millions: US$1,554/162 m^3). It should be noted that very few, if any, agricultural activities provide such a high rate of return per m^3 of water use. In 2011, the Dead Sea Works paid 85 million NIS (about US$22 million) in royalties to the State of Israel (private communication to the World Bank from Dead Sea Works, dated 1 August 2012) – equivalent to about NIS 0.53 (US$0.14) per m^3 of Dead Sea water consumed.

Figures for the Arab Potash Company for comparison are not available.

Over the medium term, it appears that the total of royalties and corporate taxes from the Dead Sea Works and Arab Potash Company could exceed the cost of stabilizing the Dead Sea by either: (i) desalination and letting the same amount of water flow from Lake Tiberias to the Dead Sea; or (ii) by implementing a Dead Sea "stabilization only" conveyance from either the Red Sea–Dead Sea or Mediterranean Sea–Dead Sea alternatives.

Use of Economic Incentives. Neither the Study of Alternatives Team nor the author of the *Chemical Industries Study* has been able to identify existing technologies to reduce the water consumption per ton of produced potash. However, because the potash industries are not required to pay for their water consumption, there is no incentive in place to develop water saving technologies. Charging for (net) water consumption (say, about US$0.10/$m^3$-US$0.20/m^3) comparable to the rate of brine-seawater discharge into the Dead Sea of the cost-effective Red Sea–Dead Sea project options would create such an incentive and could accelerate the development of water-saving technologies. Such water charges would have a small effect on the profitability of the potash industries but could have substantial impact on their water consumption (see Box 9.1).

An Action Plan for Dead Sea Conservation. In parallel with the consideration of economic incentives, it may be advisable for the chemical industries to initiate an "Action Plan for Dead Sea

Water Conservation" that could include relevant studies followed by field tests and trial processes. Such an approach would also support regional cooperation.

Box 9.1: Contributing to the Stabilization of the Dead Sea Water Level: Promotion of Alternative Mineral Extraction Technologies and Financial Incentives Needed (FoEME)

The study highlights the fact that, unlike any other user of water in the region, the mineral extraction companies are allowed to pump water out of the Dead Sea and into evaporation ponds without the need for a water license. There is no public monitoring of water quantities withdrawn and no price is paid for the water itself. While both Dead Sea industries pay a royalty for the minerals they produce, by not being charged a price for the Dead Sea water that they consume, they have no incentive to conserve that water, with resulting very negative impacts on the natural ecosystem.

The study recommends first, the promotion of research and development of alternative technologies for mineral production that minimize loss of seawater by creating a public led research fund for the purpose. It points out some company sponsored studies that are underway in a university (not identified in the study) in the United States. Secondly, it recommends the metering of Dead Sea water usage under a governmental license. Thirdly, it recommends the levying of water fees, which would capture the environmental impacts of Dead Sea water use.

Reference: FoEME, forthcoming, Contributing to the Stabilization of the Dead Sea Water Level: Promotion of Alternative Mineral Extraction Technologies and Financial Incentives Needed, Tel Aviv: Friends of the Earth Middle East

10. TECHNICAL AND WATER CONSERVATION OPTIONS – WATER CONSERVATION–MUNICIPAL AND DOMESTIC (TC2-4)

Overview. This section examines the potential contribution of water conservation in the agricultural sectors of the three Beneficiary Parties with the objective of stabilizing the Dead Sea level.

Description. This is a technical and demand management based alternative aimed at increasing the amount of available water through improving water conservation and treating wastewater for reuse in irrigation. This is not a stand alone option and would need to be deployed together with other measures to stabilize the Dead Sea water level and make potable water available to the Beneficiary Parties.

Background. Israel currently recovers 460 MCM/year from the treatment of wastewater. Jordan currently recovers 84 MCM/year. As urban water consumption increases within all three Beneficiaries, the potential for increased wastewater treatment increases.

Over the period 2007-2009, the Israeli Water Authority increased the water tariffs for domestic and industrial users in Israel. It has been estimated that the consequent saving in water was 13-15 percent, or over 100 MCM of water annually. This volume is equivalent to a large scale desalination plant or two-thirds of the net amount required annually to operate the Dead Sea Works and roughly equivalent to the net amount used by the Arab Potash Company (see Table 9.3). It is equivalent to 60 percent of the domestic water use by households in the Palestinian Authority and approximately the volume to be delivered by the Disi-Amman pipeline now under construction in Jordan.

The main anticipated effects from increased water conservation in the Lower Jordan are summarized in Table 10.1 and from increased use of treated wastewater and greywater in Table 10.2.

INCREASED WATER CONSERVATION IN THE LOWER JORDAN BASIN (TC2)

Table 10.1: Technical Conservation Options - Increased Water Conservation in the Lower Jordan Basin – Pros and Cons (TC2)

	PROS	CONS
Overview	• Significant volumes of water saved only in Lower Jordan River by changing water using practices in irrigation sector • No major urban centers other than Jericho and no major industrial users of water • Achievement of allocative efficiencies by changing cropping patterns	• Restoration of Dead Sea level only incrementally addressed • Potable water for Amman and other destinations not provided • Investment in irrigation and regulation technologies required to achieve water savings • Negative livelihood impacts from reducing water use, causing resistance to such measures
Technical	• Water saving and regulating technologies available and well understood	
Economic and Financial	• Significant water savings shown to be possible on irrigated farms of Beneficiary Parties • Livelihoods further enhanced by using water more productively and raising higher value crops • Water saved devoted to other economic uses	• Poor farmers with low investing capacity unable to engage in water conserving practices
Environ-mental and Social	• Enhancement of environmental flows and ecological diversity through use of water savings for environmental priorities	

Other	• Possible element of combination alternative (see Section 11)	• High risk of conflict with irrigators with respect to water use and regulation

INCREASED USE OF TREATED WASTEWATER AND GREYWATER (TC3)

Table 10.2: Technical Conservation Options - Increased Use of Treated Wastewater and Greywater – Pros and Cons (TC3)

	PROS	CONS
Overview	• Consistent with mission to use and where possible intensify sustainable use of environmental resources and mitigate damage being done to them	• Restoration of Dead Sea level not addressed • Potable water for Amman and elsewhere not provided
Technical	• Proven possible through experience in generating re-usable water at various quality levels in Israel and Jordan	
Economic and Financial	• Relatively low capital and operational costs compared with other alternatives • Substantial volumes of water possible	• New investment needed
Environ-mental and Social	• Reduced pressure on natural water resources–especially groundwater • Improvement in rural livelihoods if re-used water used to increase productivity on farms • Provide incremental increases in water for the Lower Jordan River	• No significant positive impact on level of Dead Sea
Other	• Economically and socially feasible • Possible element of combination alternative (see Section 11)	

Water Conservation Through Increased Use of Treated Wastewater and Greywater. Water could be conserved in the municipal, industrial and domestic sectors through the increased use of treated wastewater. For example, in Israel the use of fresh/potable water in irrigation has been reduced from 896.8 MCM in 1995 to 490.7 MCM in 2008 (Israeli Water Authority) [citation to be added]– a reduction of almost 50 percent – and these allocations will continue to decline (see Table 10.3). This volume is significant in any policy aiming to secure water and the sustainability of the environmental services of water in the Jordan Basin.

The re-use of water in high value activity sectors, in the municipal (gardening), industrial and domestic (greywater) sectors, is also water conserving. The achievements in installing these technologies and related regulatory regimes in the Beneficiary Parties are impressive in global terms. These are the estimated amounts of treated wastewater currently being used by the Beneficiary Parties in 2008.

Table 10.3: Irrigation Supply by Treated Wastewater vs. Total Irrigation Demand

	MCM/y		Supply as % of Demand
Location	Recycled and Saline	Total	

Israel	544	1044	52%
Jordan	110	1000	11%
Palestinian Authority	0	200	0%

Source: Israel's Water Authority 2010, p. 19 (http://www.israelwater.org.il/December%202010.pdf), Gorskaya et al (2010).

It is increasingly recognized that one cubic meter of water utilized in high value activities should be counted as 1.5–1.7 cubic meters as a consequence of re-use (Cohen et al, 2008). This principle applies to any water produced by a Red Sea–Dead Sea desalination plant and all the desalination plants associated with other alternatives.

Changes in Crop Type and Cultivation Methods (TC4)

Description. This is a demand management based alternative that aims to reduce the amount of high value potable water designated to watering low value crops. It is achieved by modifying cropping patterns and changing trade policies on water-intensive crops (e.g., bananas). This is not a stand alone option and would need to be deployed together with other measures to stabilize the Dead Sea water level and make potable water available to the Beneficiary Parties.

The main anticipated effects of changes in crop type and cultivation methods are summarized in Table 10.4.

Table 10.4: Technical Conservation Options - Changes in Crop and Cultivation Methods–Pros and Cons (TC4)

	PROS	CONS
Overview	• Consistent with mission to use and where possible intensify sustainable use of environmental resources and mitigate damage being done to them	• Restoration of Dead Sea level not addressed • Potable water for Amman and other destinations not provided
Technical	• Proven possible through experience in water management in Israel	
Economic and Financial	• Possible higher value added crop production	• Investment required although less costly than most alternatives • Reduced revenues in irrigated agricultural enterprises
Environmental and Social	• Reduced diversion of natural water use to economy and greater availability for environmental services • Possible reduction in groundwater over-use • Beneficial for Lower Jordan River flows and biodiversity	• No significant positive impact on level of Dead Sea • Negative impacts on rural livelihoods in some cases with consequences for rural families
Other	• Possible element in combination alternative (see Section 11)	• Difficult to implement this activity in all Beneficiary Parties

Background. The potential for water conservation in the irrigation sectors of the three Beneficiary Parties is currently substantial (see Gafny et al, 2010 and Gorskaya et al, 2010), even if hard to calculate. For example, a summary of the research of Gorskaya et al is shown below:

Table 10.5: Potential for Water Conservation in Irrigation in the Beneficiary Parties

Location	MCM/y	Methodology
Israel	183	Price increases and elimination of trade barriers
Jordan	170	Various, including price increases and increase in treated wastewater
Palestinian Authority	11	Promotion of drip irrigation
Total	**364**	

Source: Gorskaya et al, 2010.

The conclusions of Gorskaya et al, even if based on subjective assumptions, do show meaningful levels of potential savings of fresh water. However, they also illustrate the lack of "low hanging fruit" as the methodologies outlined for achieving water savings would be very difficult for all of the Beneficiary Parties to employ. In addition, this potential will diminish over time, as it is recognized that the rising demand for high value potable water by households must be met by re-allocating water devoted to low value uses in irrigation.

The issue of allocation is relevant in this Study of Alternatives. The stakes have been raised by discussion of the Red Sea–Dead Sea Water Conveyance, which will require new commitments in terms of funding as well as potential risks associated with a myriad of uncertainties. Water conservation and re-allocation are relevant at all levels for the Beneficiary Parties.

Highlands of Jordan. Significant reduction in water demand could be achieved if there was a shift away from irrigating low-profitability crops (e.g., olive trees) in the highlands of Jordan, which currently consume one quarter of all good quality groundwater abstracted for irrigation in the Jordan (Courcier et al, 2005). Groundwater is very scarce in this region; only 5.2 percent of the 8,500 MCM/year precipitated annually reach storage. Most water either runs off into salt sinks or evaporates. Hagan (2008) records enduring resistance to regulating the use of water to improve water productivity as well as to stopping the drilling of new wells that perpetuate inefficient practices. He also states that most irrigated cropping on the plateau should cease. Where economically and hydrologically irrigated cropping is viable, it should be devoted to high value herbs, aromatic oils, medicinals and improved non-irrigated forage rather than olives.

Courcier et al estimate that the groundwater available in the Yarmouk Basin is 30-40 MCM/year and in the Zarqa-Amman Basin 65-70 MCM/year. This suggests savings of up to 20 MCM/year could be possible.

Northern Lower Jordan River Basin in Jordan

Citrus tree cultivation dominates the northern area of the Lower Jordan River basin. Water savings could be achieved if regulated deficit irrigation were to be introduced, ensuring that trees were only watered at critical times during the fruit production life cycle (Rawabdeh 2010). Barley crops could be left to rain-fed watering only during drought years, despite lower yields.

Southern Lower Jordan River Basin

Water savings could be achieved in the southern Lower Jordan River basin by modifying cropping patterns, eliminating bananas, reducing eggplant cultivation and scaling up date palm and tomato production (Rawabdeh 2010). There could be a greater emphasis on producing off-season crops when market prices are highest to maximize profits at times of peak demand but this will require new investment and farmers will have to acquire new skills.

These shifts in cropping assume that market demand exists for the replacement crops, which may not be the case without an adjustment to current trade policies, such as those which banana production enjoys. A shift away from bananas to other crops would have socio-economic implications and a transitional phase compensating farmers would be necessary (Al-Assaf, 2007). In addition, farmers in the southern Lower Jordan River basin have complained of poor access to global markets (Jordan Times, 2008), implying initiatives in this area could increase alternative crop options. Some farmers on the Jordanian side of the southern Lower Jordan River basin desalinate small amounts of water for irrigation so water quality may not be a limiting factor in crop selection. High-value crops could be cultivated in the right soil conditions.

The irrigation of grain crops in the southern Lower Jordan River basin and in Jordan more generally is very water intensive. It has been noted that regulated deficit irrigation could be introduced for barley crops in the south to maximize crop water productivity (Rawabdeh, 2010). But the practice of irrigating grain crops in this region is very unlikely to be economic or effective in water productivity terms.

Israel

The Israeli experience shows that the gradual implementation of water re-allocation policies can be highly effective and can increase the efficient use of scarce water. These measures have been based on quotas and pricing coupled with accessible extension services. They have helped farmers make the necessary transition to changing their crop mix and their cultivation and irrigation methods.

A transition to water conservation can be achieved by developed and diverse economies. As shown above, Israel’s irrigation sector already consumes more recycled water than fresh (natural) water and in ten to twenty years, it is planned that irrigated agriculture will be based solely on recycled and marginal (low quality) water. It is anticipated that the Jordanian and Palestinian irrigation sectors will follow this trend. FoEME (2010) suggest that changes in agricultural water management and changes in cropping could contribute significantly to water conservation in Israel. They estimate low, medium and high conservation savings in agriculture of 70, 138 and 200 MCM annually by 2020.

Data from the Israeli Water Authority (Israeli Water Authority, 2012) [citation to be added] estimate that the recent reduction in domestic consumption in Israel following the increases in tariffs resulted in a reduction in use of over 10 percent, about 100 MCM annually. This demonstrates: (i) the importance of water conservation in the overall water budget of the region; and (ii) that there may be additional scope for further conservation gains. However, these measures have been difficult to agree to and equally challenging to implement (see Box 10.1).

Eventually, environmental water will be supplied by secondary sources (recycled and brackish) and allocation to the various environmental purpose and sites will be based on environmental cost-benefit criteria (Becker and Katz, 2009). As was mentioned above, any alternative that increases the supply of potable water indirectly contributes to environmental water allocation by increasing the supply of reused (recycled) water.

It is anticipated that these trends will continue and it is possible that there will be a volume of water in the order of 100 MCM annually that will be available for environmental services compared with the situation in 2012. Improvements in crop productivity and the use of recycled water will increase. The volumes of water available for environmental services resulting from changes in cropping and in water allocation and management could increase to beyond 200 MCM over the next two decades in Israel alone. See Figures 10.1 and 10.2 on Israel’s water sources. Boxes 10.1 and 10.2 provide information on water demand management.

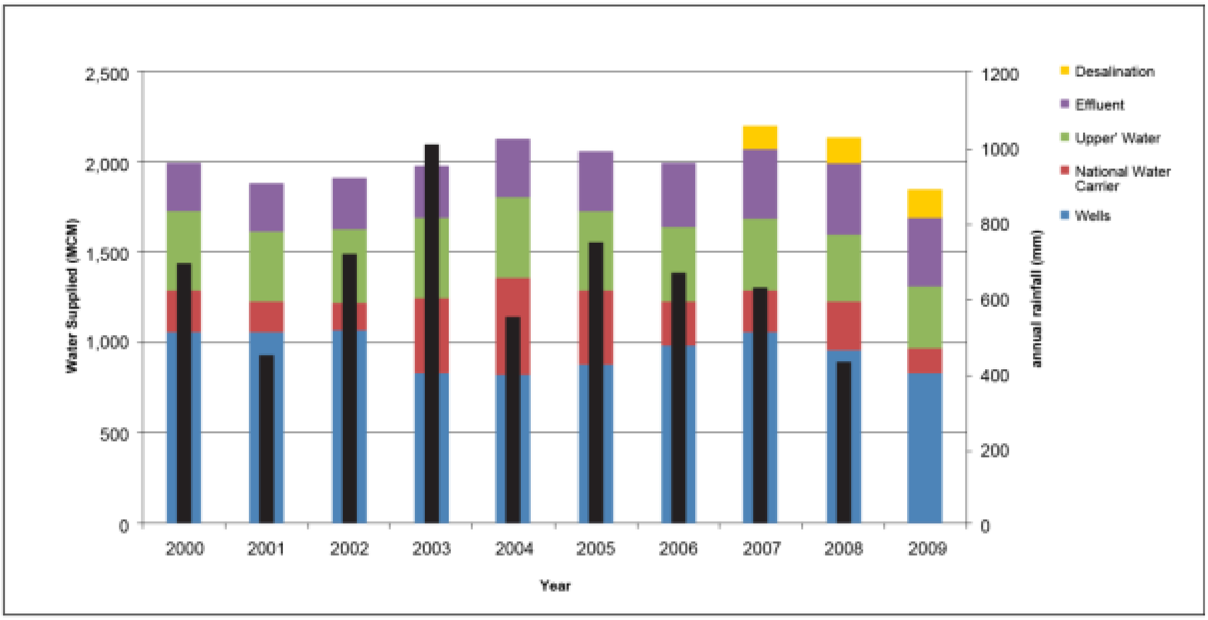
Box 10.1: A Remarkable Decade: Water Demand Management and Stewardship Achievements

Water security in the Middle East and North Africa is achieved mainly through embedded water in imported food. This is particularly the case for the three Beneficiary Parties. Together, they have 3,000 MCM/year of renewable surface and ground water and about 2,000 MCM/year of green (root-zone) water. They “import” three times as much - about 14,000 MCM/year of virtual water. The net figure–imports minus exports–is about 11,500 MCM/year. Thus the water security of the Beneficiary Parties is overwhelmingly externally sourced. Managing this high level of water insecurity has proved to be economically feasible, as food has been inexpensive and economic diversification progressive (data from Mekonnen, M.M. and Hoekstra, A.Y., 2011, "National water footprint accounts: the green, blue and grey water footprint of production and consumption," *Value of Water Research Report Series No.50*, Delft: UNESCO-IHE).

The availability since the 1960s of this global trade remedy made it possible to defer dealing with the two mounting water crises. First, the need to deliver sufficient fresh water and second, remedying the consequences of its over-use. During the past two decades, however, the Beneficiary Parties have had to pay increasing attention to these twin crises. Water policies have shifted. Outcomes are evident in the water use data for Israel since 2000. Through recycling, desalination and demand management, Israel was by 2009 recording remarkable reductions in its use of natural water, to 1961 levels (Gilmont, 2012, in press).

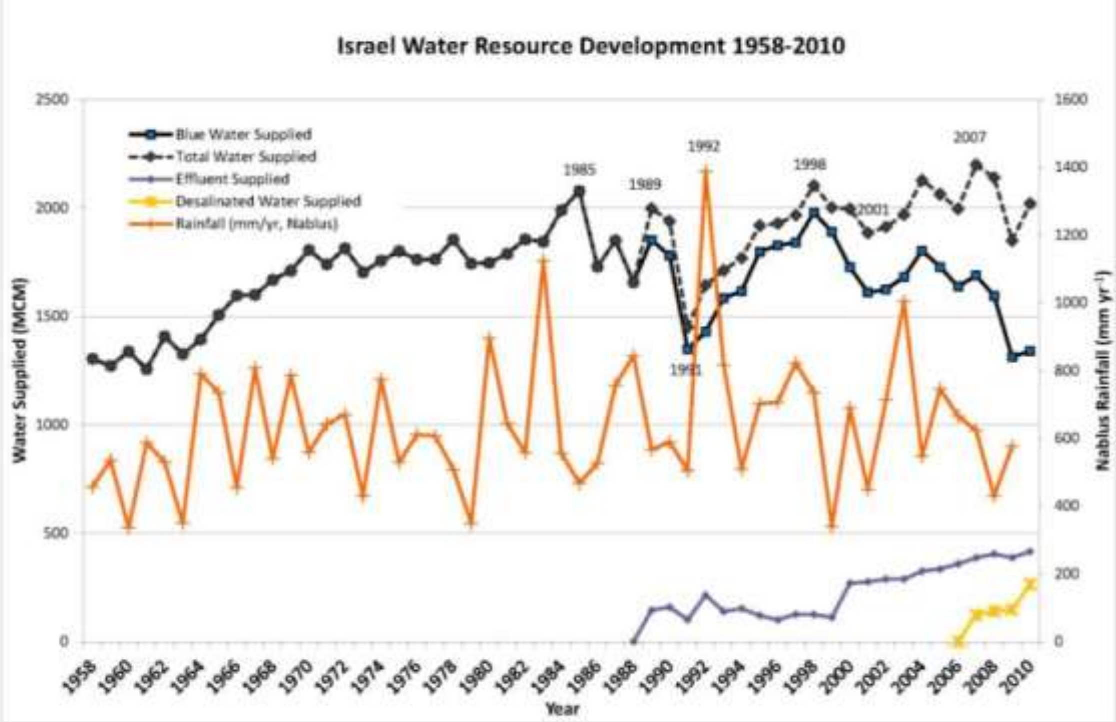
These reductions in the use of renewable, natural, surface and ground waters required three mechanisms. First, by 2009 Israel was recycling around 400 MCM of municipal water. Second, it was desalinating about 150 MCM of sea water with an equivalent additional volume envisaged. Both recycling and desalination numbers are on rising trajectories. Third, it was progressively reducing demand in all sectors–most recently introducing domestic tariffs which brought down domestic use by 75 MCM/year between 2008 and 2009 with further reductions of 30 MCM/year expected to be shown in the statistics for 2010 when they are issued. By substituting sources of new water and by using demand management measures, Israel has been able to reduce its use of natural water by 778 MCM/year from a peak of 2,078 MCM/year in 1985 to the 1961 level of about 1,300 MCM/year (Gilmont, 2012).

Figure 10.1: Water Sources of Israel



Source: Gilmont 2012, based on Israeli Central Bureau of Statistics data.
1 The role of the different storages is evident in the relationship between rainfall and the withdrawals from Lake Tiberias/Kinneret. These range from 100 to 500 MCM/year. In an era of falling costs of desalinated water perhaps Israel will not need to pump water from Lake Tiberias/Kinneret at the same levels in the future.

Figure 10.2: Total Water Supply of Israel 1958-2010



Gilmont, 2012, based on Israeli Central Bureau of Statistics data; House of Water and Environment (HWE); Lumes and Rinburg, 1992, Reconstruction of Seasonal Rain in Nablus, 1870-1990, *Water and Irrigation* 313:26-29 (in Hebrew); information received in private communication from Meteorological Service, Israel and Marwan Haddad, Nablus.

Box 10.2: Lower Jordan River Management–Challenges of Achieving Environmental Priorities

Rivers and lakes are vital natural resources: they provide drinking water and crucial habitats for many different types of wildlife, and are an important resource for industry and recreation.

The environmental flows of the Lower Jordan River have been seriously affected by the withdrawals of surface flows since the 1960s. The concept of minimum environmental flows is a recently developed set of principles and indicators that identifies standards and metrics on remediation of damaged ecosystems. This approach gained acceptance in the 1980s and 1990s in North America and Europe and was given substance in the *Water Framework Directive* of the European Union (2000). Environmental flows have been much discussed internationally since then and the water authorities in all three Beneficiary Parties recognize the need to address environmental priorities.

The aim of such remediation is to attain good ecological status of surface and groundwater by achieving high standards of water quality and ecosystem diversity, as well as minimum river flow levels through the year. These measures are advocated on the assumption that a strong economy and human welfare depend on enduring and sustainable ecologies–including the environmental services of water. Few river basins have been so affected by water withdrawals for economic and social services as the Lower Jordan. Reversing such impacts in the current demographic, socio-economic and transboundary circumstances of the Beneficiary Parties is extremely challenging.

The environmental and social priorities advocated by numerous government agencies and applied research institutes are increasingly recognized as issues that need to be addressed in water management. However, the capacities of the three Beneficiary Parties are not well aligned for basin-wide adoption of consistent standards. Israel's efforts over the past three decades show how early attempts to reduce the use of and re-allocate natural water on the basis of sustainability principles may fail. The major achievements to reduce natural water use have only come about in the past decade after two decades of contentious allocation policies (see **Figure 10.1 and Box 10.1**). None of the reductions in natural water abstraction in Israel to date has been devoted to restoring Lower Jordan flows.

11. ADDITIONAL ALTERNATIVES (AA1- AA3)

Overview. A number of alternatives have been considered by the Study of Alternatives Team in which the Beneficiary Parties have been either formally involved through studies or in which they have taken a less formal interest. The alternatives reviewed were: (i) sale of electricity from Jordan to Israel possibly with pump storage schemes; (ii) water tankering and bag conveyance from Manavgat in Turkey; and (iii) sub-marine water pipelines from Turkey.

SELLING ELECTRICITY TO ISRAEL AND PUMPED STORAGE (AA1)

Description. This is an addition to the Red Sea–Dead Sea Water Conveyance (BC1, BC2), presenting a different economic model to increase project viability. The economic viability of energy intensive industries can be significantly impacted by the cost of energy. The Red Sea–Dead Sea Water Conveyance and the alternatives that would involve lifting and conveying water over long distances, such as the Mediterranean Sea–Dead Sea alternatives, would be subject to the cost of energy. As the Red Sea–Dead Sea Water Conveyance and the other conveyance alternatives would require more energy for operation than they would generate from associated hydropower installations, there is a big incentive to examine the economic impact of selling project electricity during periods when the tariffs would be high in Israel and using electricity from the grid when the tariffs are low. Electricity tariffs vary in Israel by season, by day of the week and by time of day. The low tariffs are about one third of the high tariffs.

The main anticipated effects of the sale of electricity and pumped storage are summarized in Table 11.1.

Table 11.1: Additional Alternatives Identified by Consultant - Selling Electricity to Israel and Pumped Storage–Pros and Cons (AA1)

	PROS	CONS
Overview	• Cost of energy increasingly significant in determining economic viability of delivering water and is a constraint to cost effective provision of non-conventional potable water • May serve as a complementary action to other options under consideration	• Radical and untested approach both technically and with respect to international relations • Restoration of Dead Sea level not addressed • Potable water for Amman and elsewhere not provided
Technical	• Proven technology with respect to pump storage	• Problem of storing sea water in proposed reservoir storage sites untested and outcomes unpredictable
Economic and Financial	• Operational costs significantly lowered by selling energy when electricity tariff is high and using energy in project when it is low	• High capital costs and unpredictable operational costs • Possible changes in Israel's electricity tariff regime, either price and/or source of supply • Very difficult to sustain international arrangements in volatile economic circumstances which characterize global energy market
Environmental and Social	• Lower operational costs resulting in lower costs for consumers of metered water	• Storage of sea water at high elevations untested in the region • High risk storage with respect to potential leakage, especially in

		karst (very pervious and leak prone geological conditions) environments. Possible Jordan sites at moderate risk; Israel sites in high risk karst regions
Other	• Strengthened cooperation between Beneficiary Parties through adoption of cross border electricity transfers based on optimized tariffs	

The electricity rates in Jordan differ from those in Israel and each varies substantially during a day and between seasons (see details in Appendix 2). It may be possible to take advantage of the different rates and sell the hydropower at a higher rate (during high demand hours) to Israel. Thus, this option depends on: (i) the ability of Jordan to sell electricity to Israel at a price significantly higher than the former's cost; and (ii) no decrease in the electricity tariff schedule in Israel, and in particular its diurnal nature.

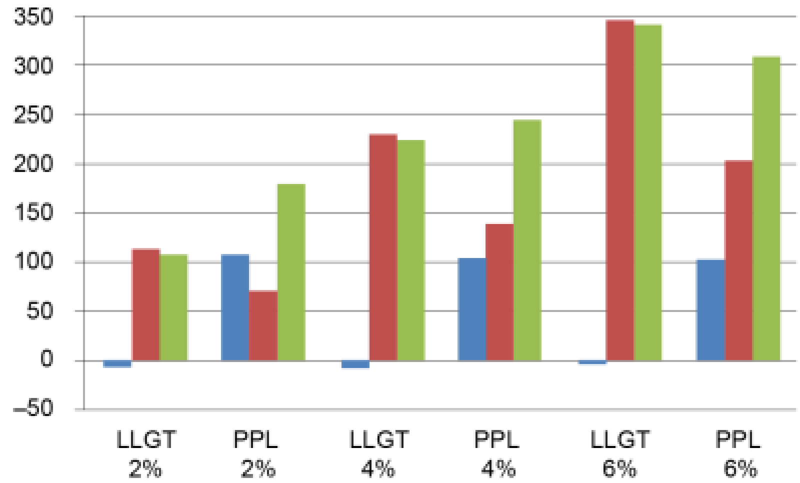
If a storage reservoir is feasible, it will allow scheduling the electricity production so as to take advantage of the peak load prices (in Israel, the ratio of high to low prices equals six in some seasons and suppliers of renewable, clean electricity receive an additional premium). These aspects are incorporated by considering three electricity tariff regimes:

- Case (i) The baseline case: consumption and production of energy under the Jordanian electricity tariff of US$60/MWh (Figure 11.1);
- Case (ii) Energy consumption according to the Jordanian tariff of US$60/MWh; selling the hydropower to Israel at the average Israeli tariff of US$110/MWh, which includes the clean energy premium embedded in the Israeli tariff schedule (Figure 11.2); and
- Case (iii) The same as (ii) but with a storage reservoir that allows hydropower production during 12 hours a day, increasing the average selling price to US$142/MWh (Figure 11.3).

As an example, only the imputed annual costs of stabilizing the Dead Sea are isolated, as depicted in Figure A2.1 in Appendix 2 for a range of interest rates. These costs are sensitive to the electricity tariffs because the latter affect the profit of the hydropower plant (subtracted from the operating expenses to provide the imputed cost figures), as well as the energy cost of pumping and conveying. The values in Figure A2.1 have been calculated based on the electricity tariffs of US$60/MWh, assumed by Coyne et Bellier (2010), based on Jordanian electricity tariffs relevant for water pumping.

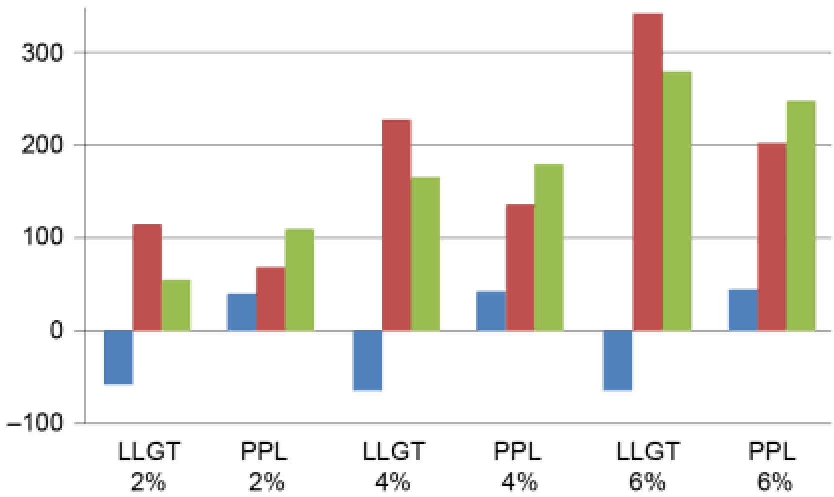
The annual imputed cost of a subproject changes over time as the subproject is phased in (for the PPL option) and with the schedule of availability of desalinated water (see Coyne et Bellier, 2010). This schedule affects the profits of the hydropower plant, as it changes the volume of water available for hydropower generation. Figures 11.1-11.3 present average annual costs, obtained by calculating present values and multiplying by the discount rate. The total annual costs are broken down into capital and operation and maintenance (O&M) components. The first is the interest payments on outstanding loans needed to build the Dead Sea Stabilization subproject. The second component accounts for O&M cost (including capital depreciation) minus the hydropower profit. The latter is negative when the hydropower profits exceed the O&M costs of pumping, conveying and discharging the seawater and brine.

Figure 11.1: Imputed Annual Costs (US$ million) of the Dead Sea Stabilization Subproject for a Range of Interest Rates under the Baseline Electricity Tariffs of Case (i), with a Breakdown Into Capital (Interest) Cost and O&M Cost Minus Hydropower Profit



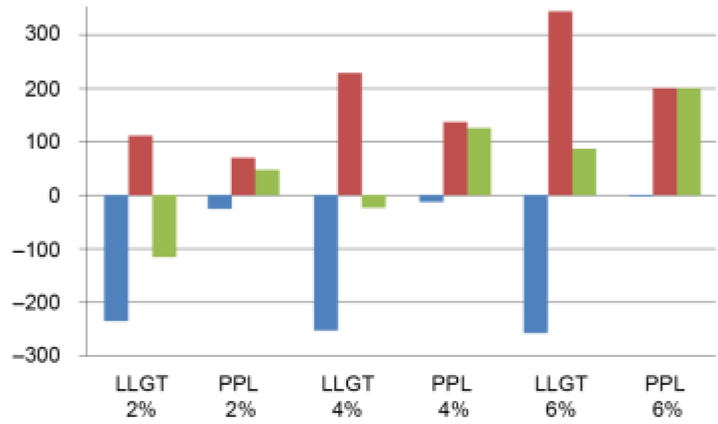
	LLGT 2%	PPL 2%	LLGT 4%	PPL 4%	LLGT 6%	PPL 6%
O&M cost net of HP profit	–6	110	–6	106	–4	104
Capital (interest) cost	116	72	232	141	348	206
Total	110	182	226	247	344	310

Figure 11.2: Imputed Annual Costs (US$ million) of the Dead Sea Stabilization Subproject for a Range of Interest Rates under the Electricity Tariffs of Case (ii), with a Breakdown into Capital (Interest) Cost and O&M Cost Minus Hydropower Profit



	LLGT 2%	PPL 2%	LLGT 4%	PPL 4%	LLGT 6%	PPL 6%
O&M cost net of HP profit	–58	42	–63	43	–64	46
Capital (interest) cost	116	72	232	141	348	206
Total	58	114	169	184	284	252

Figure 11.3: Imputed Annual Costs (US$ million) of the Dead Sea Stabilization Subproject for a Range of Interest Rates under the Electricity Tariffs of Case (iii), with a Breakdown into Capital (Interest) Cost and O&M Cost Minus Hydropower Profit



	LLGT 2%	PPL 2%	LLGT 4%	PPL 4%	LLGT 6%	PPL 6%
O&M cost net of HP profit	–233	–22	–251	–11	–258	–1
Capital (interest) cost	116	72	232	141	348	206
Total	–117	50	–19	130	90	206

The hydropower profits include the cost of added hydropower capacity. The cost of the storage reservoir is not included and would have to be factored into the economic evaluation of this option.

The electricity tariffs of case (iii) have been obtained by operating the hydropower plant at certain hours of the day when tariffs are high (based on the current Israeli tariff schedule). This requires a storage reservoir and a larger capacity hydropower plant. Both (the reservoir and the higher hydropower generation capacity) entail costs. Figure 11.3 gives the imputed annual costs of the Dead Sea Stabilization subproject, accounting for the higher cost of hydropower generation, but without the cost of the storage reservoir.

In this alternative, the costs are sensitive to the interest rate and to the electricity tariffs for the consumption and sale of hydropower. The interest rate represents the price of capital. The electricity tariffs depend on the ability to take advantage of the peak-load electricity tariffs in Jordan and Israel and on the feasibility of a storage reservoir.

Under the electricity tariffs of case (iii) (taking full advantage of Israel's peak load pricing schedule with a storage reservoir), conveying water from the Red Sea to the Dead Sea, while exploiting the elevation difference to generate hydropower, becomes a profitable operation for the LLGT project option under 2 percent or 4 percent interest rates when the annual cost of a storage reservoir does not exceed US$17 million or US$19 million, respectively.

Comparing the annual costs with and without a storage reservoir (Figures 11.2 and 11.3) reveals that under a 6 percent interest rate, a storage reservoir whose annual cost falls short of US$194 million (284 – 90) pays off for the LLGT option, in that it reduces the cost of Dead Sea restoration. The corresponding figure for the PPL option is US$183 million (252 – 69). Under a 4 percent interest rate, a storage reservoir pays off for the LLGT or PPL if its annual cost falls short of US$188 (169+19) or US$201 million (184 +17), respectively.

A storage reservoir whose annual cost does not exceed US$54 million (which allows taking full advantage of Israel's peak load pricing schedule) turns the Dead Sea restoration with the LLGT subproject into a profitable operation for any interest rate at or below 4 percent.

WATER TRANSFERS BY TANKER, BAG AND SUB-MARINE PIPELINE FROM TURKEY (AA2)

The main anticipated effects of the transfer of water from Turkey by tanker, bag and submarine are summarized in Table 11.2.

Table 11.2: Additional Alternatives Identified by Consultant – Transfers by Tanker, Bag and Submarine Pipeline from Turkey – Pros and Cons (AA2)

	PROS	CONS
Overview	• Technologies for transferring water by tanker are in operation in the Mediterranean and world-wide. Turkey built loading infrastructures in Manavgat with a 400 MCM/year capability	• This method of conveyance would not address the challenge of restoring the level of the Dead Sea. • The experience in the region in developing reliable market and regulatory infrastructures has been unsatisfactory
Technical	*Tankering* • Availability of affordable high volume tankers uncertain but if Turkey and Beneficiary Parties committed to long-term contracts, tankers would be available • Well understood technology *Bag technologies* • Small bag technologies proven to be reliable *Loading* • Loading facilities in place at Manavgat for 400 MCM/year *Volume* • 400 MCM/year of high quality water	*Bags* • Technology of large bags at necessary scale (250,000 tons/m^3) not yet available *Unloading* • Unprecedented and untested unloading infrastructure on Mediterranean coast of the scale required
Economic and Financial	• Cost of water competitive if purchase contracts well drafted to assure commercial viability	• Reliable markets difficult to maintain if cheaper sources become available
Environ-mental and Social	• Environmental impacts of establishing loading infrastructure already assumed in Turkey • Low risk of conveying high quality water in all types of conveyance	• Localized environmental impacts of unloading infrastructure on Mediterranean coast in areas already under pressure, which can be mitigated by careful design and operation • Volumes of water available in Turkey substantial but summer availability problems possible in years of extremely low flow
Other	• Turkey in favor of transfer by tanker • Possible element of combination alternative	• Transfer of water from Turkey complicated in terms of cooperation

Scope, Assumptions, Impacts and Risks

This section will analyze the feasibility of transferring water by sea conveyance and sub-marine pipeline from Turkey to the Beneficiary Parties. It is assumed that transfer options that have secure long-term water sources will be analyzed.

The evaluation in this section is different from other sections of the study in that two of the options involve unproven technologies. The use of floating bags to convey high quality water at the scale required is unproven and the sub-marine pipeline proposal is untried in the conditions between Turkey and north Cyprus.

Relevant Environmental and Economic Contexts

The conveyance infrastructures proposed in this suite of options would mainly be built, and their impacts would almost entirely occur outside the territories of the Beneficiary Parties. Surface water flows would be reduced in Turkey, where the disruptions of constructing pipeline infrastructures and water loading facilities have already been incurred. The investment costs and impacts of unloading water would occur in Israel and/or in the Palestinian Authority in Gaza.

There are very few examples of the conveyance of international transboundary waters by pipeline or tanker. There is some experience in the Mediterranean of tankering water, but this activity has been limited to serving island communities within the national territorial jurisdictions of individual nations. Even these transactions have proven to be difficult to regulate and water providers have not generally been able to maintain sustainable commercial operations. The installation of markets in tankered water has proven to be difficult as levels of demand fluctuate and customers are unwilling to purchase tankered water when alternative – lower cost – supplies resume. If a potential water importer can claim that it produces water by desalination at below US$0.60.m^3, the risks of conveying water from outside national borders can be avoided.

There is also limited experience in establishing contracts for the supply of fresh water internationally. The 1994 Agreement between Jordan and Israel did establish an arrangement for storage of Yarmouk winter flows in Lake Tiberias for use in the summer in Jordan. Further afield, a 100 year contract for piping water across a multi-purpose causeway from Johor in Malaysia to Singapore has been in place since 1961 and has another 49 years to run. But that arrangement came under severe strain in the late 1990s. The politics associated with an attempt to renegotiate the terms of the contract were only mitigated for Singapore by the timely development in 2000 of the much lower cost reverse osmosis desalination technologies. Singapore has insured itself against vulnerability to interruptions in the supply of potable water by building desalination capacity. This option is available to a high income economy [citation to be added].

Tankering and Floating Bags Conveyance from Manavgat

This is an infrastructure based alternative that involves the transfer by tanker or floating bag of up to 180 MCM/year of water from a terminal on the Manavgat River in southern Turkey to a coastal terminal in northern Israel. Turkey and Israel have discussed the option of tankering water from Manavgat for about two decades. A contract was almost in place by 2001 but the arrangement was overtaken by the revelation that reverse osmosis technologies could produce desalinated water at less than US$0.6/m^3 at Ashkelon. The water storage reservoir and loading facilities at Manavgat have been constructed and could deliver volumes of water big enough to make a difference to the Beneficiary Parties, especially to those with a Mediterranean coastline. The Manavgat facility could deliver 400 MCM/year, or more, of high quality water. Tankering of water would have the advantage of being less demanding of energy and much less polluting than water produced by reverse osmosis. Markets for the conveyance of water by tanker have a poor record, but contracts between Turkey and any of the Beneficiary Parties could be enforceable and durable. Previous pilots of the floating bag option have experienced challenges in rough weather. Turkey has invested US$147 million in this scheme so far but further investment in pumps, pipes, and tankers and tugs in Israel would be required to make the scheme operational. The scheme is currently on hold in part because its viability is influenced by the cost of desalination on the Mediterranean coast.

Tanker Conveyance in the Mediterranean

The tanker conveyance of water is a technology that has been widely used, especially in the Mediterranean. The experience in the Mediterranean has, however, revealed regulatory and institutional problems associated with installing commercially sustainable tankered water supply systems.

Other international experience has not been encouraging. The proposed export of water from Newfoundland's Gisbourne Lake involved ships capable of holding about 275,000 m^3 of water. Tankers would have to make the return trip empty, have removable containers, or else return with a liquid cargo that would not contaminate the water on the next trip out, which constituted a problem with significant cost impacts. The availability and cost of tankers varies according to economic cycles and they are expensive to operate. The cost per m^3 of water payload per day of transport has a broad range of US$0.12–US$0.60 per m^3 per day, depending on current oil tanker market conditions, fuel prices, and the size of tanker involved. With a tanker typically able to cover about 400 km in a day of sailing, the cost is therefore highly dependent on distance. The Turkish water sources are favourably located in terms of distance; however, all other proposed sources would be seriously impacted by the distance of conveyance.

Tankering as Alternative to the Red Sea–Dead Sea Water Conveyance

There are four major problems associated with this alternative. First, there are no up-to-date estimates of the costs of loading tankers at Manavgat or at the Seyhan and Ceyhan Rivers or the costs of transporting and unloading the water in the volumes needed by the Beneficiary Parties. Secondly, the volumes of about 400 MCM/year envisaged by this alternative are significant in relation to the potable water requirements of the Beneficiary Parties but they would not address the task of restoring the Dead Sea.

It has been shown elsewhere in this report that the Red Sea–Dead Sea Water Conveyance and other tunnel/pipeline conveyance alternatives do address the big volumes of potable water and brine estimated to be needed by the water resource planners of the Beneficiary Parties.

Thirdly, desalination technologies have been tested during the past decade and have been shown to be a competitive option if they are installed in an effective and very highly regulated context. Israel's desalination plants achieve impressive costs of production per cubic meter of water with a mix of attractive financing, a very strictly controlled Build-Operate-Transfer process, and a nuanced policy of energy production and use which maximizes the benefits of the national electricity tariff regime. The high level of commitment of both the state and society to the national desalination project is also very important. This commitment is evident in the undertaking to purchase all the desalinated water that is produced. This condition, which applies to no other water source, gives water produced in desalination plants, protected by these unique measures, an exceptional financial advantage.

Fourthly, there is no equivalent movement at either the national or the international level that supports the water tanker option. In scenarios where a mix of alternatives is evaluated, the tanker option would be relevant to Gaza in association with desalination.

Risks and Impacts

The technical operational risks are well understood as the technology is being widely used. The economic operational risks are substantial. The investment risks have to some extent already been taken in that the exporting infrastructure is already installed in Turkey at Manavgat.

The tankering option is attractive with respect to environmental and social impacts. The water being conveyed would be of high quality with no associated pollution risks in the event of spillage. The main negative environmental impact would be the atmospheric pollution caused by the use of oil to power the tankers. As the conveyance is offshore the social impact would be zero.

Water Transfer by Tanker to Jordan via Israel

In 1999 an international private sector joint venture was proposed by PSG International, a United States pipeline development company, owned by Bechtel Enterprises and GE Capital, and the Bergesen Group, a Norwegian independent shipping company with long experience of operating Very

Large Crude Carrier (VLCC) tankers. It was proposed that four VLCCs of approximately 300,000 deadweight tons each, be converted to transport water, operating a loop shuttle from Manavgat to off-shore of the port of Hadera in Israel. The proposed project would be able to deliver 95 MCM per year. The vessels would lift water from Manavgat and use their discharge pumps to feed the water into a project-developed receiving system including two single point mooring buoys, a booster pump station and a storage reservoir. A pump station would lift the water from the reservoir through a buried steel pipeline to a booster pump station 1 kilometer away and from there to a reservoir approximately 3 kilometers further away, located at an elevation of 45 meters. The water would then be pumped across Israel to points in Jordan determined by the Jordanian Ministry of Water and Irrigation. The project economics varied depending on the alternative delivery points in Jordan (PSG International and Bergesen Group, 1999).

The commercial structure was designed to enable the project to obtain non-recourse or limited recourse project financing via a Build-Own-Operate concept. The project sponsors would set up a Project Company, which would hold 100 percent of the shares in three local companies – the Marine Company, the Israel Pipeline Company and the Jordan Pipeline Company. The financing plan was developed in financial institutions in Washington DC and commercial banks in London, Tel Aviv and Amman. The United States Ex-Im Bank and the Overseas Private Investment Corporation (OPIC) showed interest in the proposed investment. The total project cost of the favored alternative was estimated at $338 million with an assumed debt to equity ratio of 70/30 (PSG International and Bergesen Group, 1999, pp 9-11).

Technical and Economic Feasibility

Tankering from Manavgat to the coast of Israel was and remains technically feasible. Unfortunately operating costs of the proposed option are not available. The alternative was evaluated at a point when a number of conveyance options from Turkey were being examined and cooperation was much in evidence among the parties. After Israel opted for its local desalination policy in 2001 this alternative was no longer discussed.

Risks and Impacts

As the water conveyed would be of high quality, the conveyance risk would be negligible. The loading facilities are already in place so adopting the proposed mode of conveyance would have no negative environmental or social impacts in Turkey. There would be significant impacts in Israel as land would be needed for unloading, pump-station and reservoir facilities in the congested Hadera area.

Concluding Comment on Tankering from Turkey

Turkey has made a significant commitment to the export of water by investing US$147 million in facilities at Manavgat in the late 1990s (Ariyoruk, 2003). The Turkish authorities remain hopeful that the investment in Manavgat will eventually become an economically viable operation. Currently, no water is being exported from Manavgat although the resource is substantial. It is claimed that 400-500 MCM/year are exportable (Fakioglu, 2011; Ozmedir, 2011). This volume is of a scale very relevant to the current need for high quality water in the Beneficiary Parties. It is equivalent to the additional volumes of water that Israel expects to desalinate in the next two decades at the Mediterranean shore. It is also a volume of desalinated water similar to that which Jordan is planning to mobilize via the proposed Jordan Red Sea Project.

Water Bag Conveyance by Sea

The volume of water considered for conveyance via water bags to Israel in discussions between Turkish and Israeli officials in the late 1990s was 50 MCM per year (Ariyoruk, 2003; Rende 2004).

The water bag technology for conveying potable water operated for four years between 1998 and 2002. Bicak and Jenkins (2000) estimated that 10,000 m^3 bags could convey 3 MCM annually with three bags delivered per week from the Soguksu River in Anamur, Turkey (Theodoulou 1998;

Nachmani, 2000). Bags 30,000 m^3 in size would have delivered 7 MCM of water to pipelines to convey to the cities of Nicosia and Famagusta.

The first contract in history to convey water in plastic bags was signed in 1997 between the Turkish government and the Nordic Water Supply Company. The 10 year contract was to deliver water priced at US$0.55/$m^3$ (Rende, 2007). During the four years of operation, Rende (2007) and Elkiran and Turkman (2007) estimated that the water bags conveyed about 41 MCM from the Aydikcik region in Turkey to a reservoir at Kumkoy on the north coast of Cyprus. The last water bag broke before reaching Kumkoy in 2000 and the project was abandoned (General Directorate of State Hydraulic Works, 2010 http://www.dsi.gov.tr/english/service/icmekulsue.htm) on the grounds that the bags could not cope with rough seas (Ariyoruk, 2003; Elkiran and Turkman, 2007). Until 2008 the abandoned last plastic bag was still visible outside the port of Famagusta (Brouma, 2012).

Rende (2007) describes another water bag proposal put forward in 2003 involving an agreement with the Israeli Inbar Water Distribution Company to deliver water at a cost of US$0.60 per m^3. Meanwhile this water conveyance option is being reviewed currently in the Israeli Water Authority, likely focused on water from the Göksu River, which reaches the Mediterranean immediately north of Cyprus. The Study of Alternatives Team could not obtain any information on this study in either Israel or Turkey.

The costs of conveying water to the northern area of Cyprus from Manavgat have been quoted as US$0.60/$m^3$ (Rende, 2004). Loading and transporting costs have been estimated to be US$0.13-US$0.18 up to US$0.7-US$0.8, making a significant difference to the final cost (IPCRI, 2010). The US$0.60 cost caused the proposed deal with Israel to fail in 2001-2002 because desalination costs for Israel's first major Mediterranean desalination plant at Ashkelon were estimated at US$0.56/$m^3$. It has also been suggested that a much lower price of US$0.18/$m^3$ could be negotiated for Manavgat water (Cohen, 2002).

A number of designers have proposed other bag technologies, including the Spragg Bag, the Medusa Bag and the Aquarius Bag. Bags as big as 250,000 m^3 have been designed to be towed in multiples, but they are not yet operational at the scale needed to address the volumes of water required by the Beneficiary Parties.

Another operational problem commented on in reports on the water bag conveyance proposals is unloading on the coast of Israel. The shallow coastline of Israel and Gaza is not ideal for the construction of offshore terminal facilities needed to receive the water (IPCRI, 2010).

Comments

The floating bag technology has the advantage of low environmental risk but it also has significant operational risks on the basis of experience to date. Investment risks are high as the technologies are unproven and the feasibility of this alternative is uncertain, especially in the short term. The history of water conveyance by sea in the Mediterranean has been characterized by inadequate contractual and regulatory institutions. Both the rules and the organizations for conveying water by sea have proved to be inadequate.

The tanker alternative is attractive from the point of view of environmental and social impacts and risks. It would have no terrestrial impacts and zero terrestrial risks. The technology is operationally vulnerable commercially as well as with respect to its carbon footprint and the variation in the cost of energy for transportation. But there would be no spillage impacts as the water conveyed would be high quality. The investment risks would be high as there is no coordinated international commitment to tankering technology and the associated market, and these risks are aggravated in the present case as there is a strong commitment by two of the Beneficiary Parties to alternatives that include desalination.

Sub-marine Pipelines associated with Oil and Energy Conveyance–Medstream (AA3)

This is an infrastructure based alternative that involves the construction of five 460 km long undersea pipelines that would carry water, natural gas, crude oil, electricity and fiber optic lines from Ceyhan on Turkey's southeastern Mediterranean coast to Haifa in northern Israel. The oil pipeline would link two existing pipelines – between Ceyhan in Turkey and Baku in Azerbaijan and between Ashkelon and Eilat. It would make Caspian Sea oil/gas reserves available to the Asian market from the Red Sea at a lower shipping cost. The water component of the pipeline would aim to supply between 400 and 1,000 MCM/year from the Ceyhan River in Turkey to Haifa. The economic viability of the water component of this project is dependent on the cost of desalination on the Mediterranean. If the cost of a cubic meter of water from the pipeline exceeds the cost of desalination, the water component becomes unviable. The total investment cost of the scheme is estimated at between US$2.4 and $4 billion (2010). Israel would be the primary beneficiary to receive water but Jordan and the Palestinian Authority could also be secondary beneficiaries. This is not a stand alone alternative as it would not deliver sufficient quantities of water to restore the Dead Sea directly. It could however offset a proportion of water demands in the Beneficiary Parties, meaning more water could be allowed to flow down the Jordan River.

The main anticipated effects of the Medstream option are summarized in Table 11.3.

Table 11.3: Additional Alternatives Identified by Study Team–Submarine Pipelines associated with Oil and Energy Conveyance–Medstream–Pros and Cons (AA3)

	PROS	CONS
Overview	• Volume of water available but source on southern Mediterranean shore of Turkey unclear	• Water from the Seyhan and Ceyhan Rivers not sufficient to provide water reliably in low flow years • Restoration of Dead Sea level not addressed
Technical	• Potentially technically feasible and economic means of conveying volumes of water of up to 500 MCM/year from Turkey in an innovative multi-functional suite of pipelines–oil/energy/water	• Conveyance technologies unproven
Economic and Financial	• Part of need for high quality water of Amman and elsewhere addressed	• No estimates available • No high quality water available for Dead Sea region
Environmental and Social	• Low environmental risks and impacts • Low social impacts	• Some negative environmental impacts at loading site in Turkey • Conveyance means from coast of Israel to Amman unclear
Other	• Significant regional cooperation possible through combined conveyance	• Significant information deficit

In 2007 Israel and Turkey agreed to a full-scale feasibility study for a proposed infrastructure corridor between the two countries (Global Water Intelligence, 2007). The plan called for a series of five co-located undersea pipelines conveying water, natural gas, crude oil, electricity and fiber optics from the Ceyhan region on Turkey's southeastern Mediterranean coast to Israel. Ceyhan is the discharge point for Azerbaijan oil conveyed by a trans-Turkey pipeline (IPCRI, 2010). The Study of Alternatives Team has not located the feasibility study.

Water is not the dominant element of this proposed multi-service infrastructure. The oil and gas link would be part of a much wider inter-continental network linking oil and gas from the Caspian via the Middle East to India (Mohapatra, 2010; IPCRI, 2010). The conveyance of water between Turkey and the Beneficiary Parties would be a very minor, though potentially significant, element for such an intercontinental project.

There are other uncertainties, pending the outcome of a feasibility study. For example, it is not clear whether the water conveyance pipes could withstand the pressures at depths of 800-900 m (Wachtel, 2009).

Comment

The operational risks of the Medstream proposal are difficult to evaluate. The proposal is very complicated in terms of funding and operation as there would be many partners. As a result the investment risks would be high. The environmental risks associated with the Medstream project are under-researched but they are likely to be acceptable. Reaching an agreement would be challenging but there are major interests beyond those of Turkey and the Beneficiary Parties that could drive the project and make it viable.

Experience with Undersea Pipelines

Pipeline options have always been associated with the proposed conveyance of larger volumes of water than bag or tankered systems in the Cyprus context. The proposed alignments have been from the Anamur or Manavgat regions in Turkey to Kumkoy or Kormacit in the northern area of Cyprus. A proposal was approved by the Turkish Government - Decree No. 98/11202 of 27 May 1998 (Rende, 2007). A consortium of domestic and foreign companies led by ALARCO designed facilities for the diversion, conveyance and storage of water (Rende, 2007; Nachmani, 2000). Since 2002, the pipeline project has figured consistently in Turkey's DSI investment program (DSI website http://www.dsi.gov.tr/english/service/icmekulsue.htm).

In the mid-1990s Bicak et al (1996) evaluated a Build-Operate-Transfer via an undersea pipeline proposal to convey 82 MCM of water annually, of which 7.5 MCM were for domestic consumption, 29 MCM for aquifer replenishment, and a substantial volume for sale to Cyprus. The guaranteed period of the Build-Operate-Transfer project was 30 years with ownership after 15 years. Because such a project would be financially viable only with a significant proportion of the water was sold to Cyprus (Bicak and Jenkins, 2000), the arrangement was not considered feasible to undertake in the 1990s (Nachmani, 2000, page 85). By 2005, however, a Memorandum of Understanding was signed between DSI and ALARKO (http://www.hri.org/news/cyprus/tcpr/2005/05-10-10.tcpr.html).

The sea pipeline option has been re-visited frequently during the years since the 2006 drought (Cartwright, 2008). Current proposals envisage a pipeline with a 75 MCM per year capacity needing ten years to build (Rende, 2007). Additionally, financing of the project has been identified as the most important obstacle. Elkiran and Turkman (2007) estimated project costs at US$400-600 million, a level of investment that concerned Gökçekuş (2001). The feasibility study is not publicly available.

This sea pipeline is a constant focus of concern and controversy. On April 4, 2010, the Turkish Minister for Environment and Forestry made public the problems associated with putting the pipeline on the sea-bed. It was suggested that a floating pipeline could be used, located at a depth of 250 m. The approach would be the first of its kind, using patented Turkish know-how. On July 16, 2010, the agreement on the construction of the pipeline was signed during the visit of the Deputy Prime Minister to the northern area of Cyprus for the celebrations to commemorate the 1974 events (Hürriyet Daily News, 16 July 2010) and the countries agreed to proceed with construction (see Box 11.1).

Box 11.1: Turkey-Northern Cyprus Water Supply Project

The Project, which is mainly based on a pipeline system, will be installed at approximately 250 m below the sea surface and tethered to the seabed (max. depth 1,400 m), It will include about 80 kms of sea crossing, originating at Anamur (Turkey) and terminating at Güzelyali (in the northern area of Cyprus). The pipeline will

be formed as a single line high density polyethylene-100 pipe, 1,600 mm in diameter, and will provide 75 million m3/year water. It will be the first project of such a length to be constructed. Works to be conducted include: geophysical, geotechnical, bathymetric, oceanographic land and sea explorations; biofouling studies; environmental impact assessment; physical modeling and hydrodynamic studies; preparation of execution drawings and technical specifications for the off-shore and on-shore land structures, which include the Alaköprü Dam on the Dragon River (Turkey) and the Geçitköy Dam (in the northern area of Cyprus), approx. 25 kms of on-shore steel transmission pipelines, a balancing tank (10.000 m3) and pumping stations. (see http://www.alsimalarko.com.tr/newdetail1.asp?item_id=73&)
Regional news sources reported that ground was broken at the Alaköprü Dam in Turkey in 2011 and at the location of the Geçitköy Dam in the northern area of Cyprus earlier in 2012 (see also http://setimes.com/cocoon/setimes/xhtml/en_GB/features/setimes/features/2012/04/03/feature-04).

A Greek Ministry of Foreign Affairs source (February 2007, April-August 2008) noted that a number of foreign companies – Norwegian, Danish and American – have shares in the proposed enterprise. The document also mentions the possibility of selling water to Cyprus, as well as to Greek islands. Technical back-up to the pipeline project was provided by a Turkish company – ARTI PROJE Ltd, by the Danish Hydraulic Institute for Water and Environment, and by the British companies NEPTUNE Oceanographics Ltd, AQUATEC Group Ltd and Trevor Jee Associates of UK (www.phileleftheros.com/main/showarticle_prt.asp?id=488077).

Concluding Comments

It is technically possible for water to be conveyed from Turkey to the Beneficiary Parties, and such water could play a useful role in meeting the need for high quality water, although it would be insufficient to remedy the decline of the Dead Sea. But there is sufficient water in the Manavgat River, the Soguksu River in Anamur and the Göksu River to supply strategic volumes of water to the Beneficiary Parties.

The information available is distorted by policies that reflect past decisions and commitments. Israel is committed to desalination and claims low production costs based on prices of potable water produced in an economy where every cubic meter manufactured is guaranteed to be purchased. Turkey has water in volumes that would be useful to the economies of the Beneficiary Parties, has installed the infrastructure to enable exports and wants to export from Manavgat. A number of questions remain. Why investigate the potential of the Göksu River when the Manavgat potential is not being exported?

The potential of the Turkish rivers to supply high quality water to the Beneficiary Parties is evident. Some infrastructure has been installed and additional infrastructure could be installed. Turkish water should certainly be considered in the section on the combination of alternatives.

12. COMBINATION OF ALTERNATIVES (CA1 – CA4)

INTRODUCTION

The Terms of Reference require that "a range of combinations of alternatives be examined to assess the benefits of such an approach" by the Study of Alternatives Team.

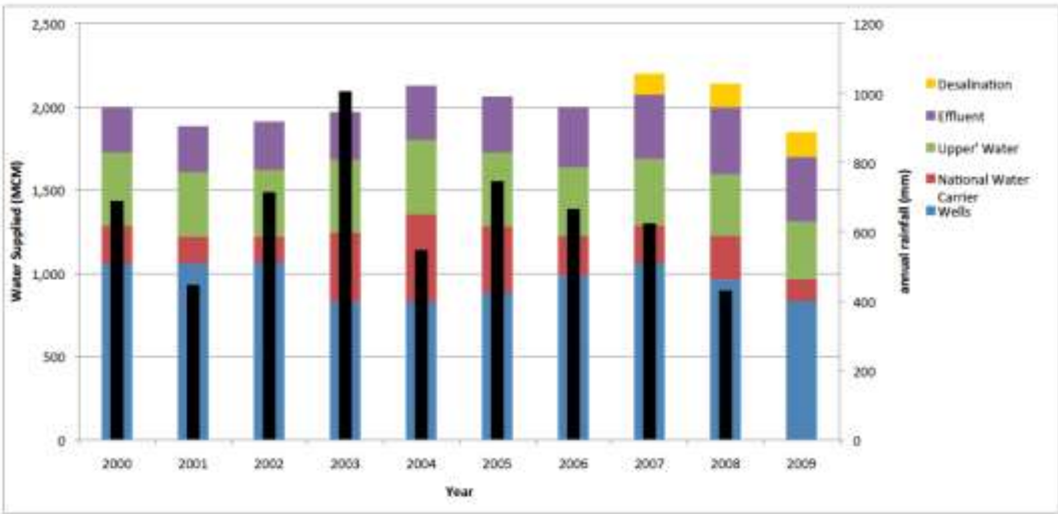
The Beneficiary Parties each have in place separate water management policies but they also cooperate in a number of monitoring, infrastructure, regulatory and other institutional arrangements. The Red Sea–Dead Sea Study Program is a major example of the cooperative approach. All future basin level water management regimes will involve a range of combinations of alternatives whether or not the conveyance is financed and built. Desalination, the re-use of effluent and increasing the productivity of water in all sectors are integral to the water futures of all the Beneficiary Parties.

The purpose of this section is to examine a limited number of combined alternatives for discussion in the consultation process to determine the extent to which two of the three goals of the Red Sea–Dead Sea Water Conveyance, i.e., (i) stabilizing the level of the Dead Sea, and (ii) the provision of potable water mainly to Amman – and also to Israel and the Palestinian Authority – could be achieved with combinations of alternatives.

ASSUMPTIONS

- While demand management approaches are always difficult to implement they should nevertheless be considered as alternatives especially as Israel has demonstrated an exceptional success in achieving reductions in the use of natural water in the past decade. Figure 11.4 below records a reduction of use in water from wells since 2000 of about 300 MCM/year and an overall reduction in the use of natural water of over 400 MCM/year. These numbers do not take into account the savings consequent on the increase in municipal water tariffs in 2009 which have resulted in a further reduction in demand of about 100 MCM/year. These numbers are in the range of the volumes of potable water being mobilized by the Red Sea–Dead Sea Water Conveyance. They are also similar to the volumes of water being produced in Israel from effluent and desalination.

Figure 11.4. Water Sources of Israel–2000 to 2009



Source: Central Bureau of Statistics of Israel 2011 and previous years [2009 rainfall to be added when available]

- It will be assumed that some water can be saved from irrigation, municipal and industrial uses in Jordan and the Palestinian Authority. But these volumes will be limited. First, because the volumes of water used in the Palestinian Authority are small and also mainly included in the Israeli statistics. Secondly, the natural water used in Jordan is half that of Israel and the capacity of Jordanian institutions to install demand management measures is less advanced.

- Ideally, for a combination of alternatives to be relevant it should mobilize about 500 MCM/year of potable water and address to some extent the stabilization of the Dead Sea.

- Turkey cannot be a source of volumes of water that would address the stabilization of the Dead Sea. At the same time high quality water could be economically sourced from Turkey by tanker. About 500 MCM per year could be tankered to the coast of Israel and/or Gaza.

- It is assumed that the conveyance of saline water from the Mediterranean coast to the Jordan valley is not feasible in terms of the cooperation required. For the same reason, it is assumed that it would also not yet be feasible to take into account volumes of tankered water delivered to the Mediterranean coasts of Israel or Gaza and reallocate equivalent volumes of natural water – in for example the Jordan Valley – so that Jordan River water could be diverted to different users and different uses.

COMBINATION NO. 1. DESALINATION AT AQABA AND MEDITERRANEAN SEA, WATER IMPORTATION FROM TURKEY, AND WATER RECYCLING AND CONSERVATION (CA1)

This combination of alternatives takes a long perspective of at least three or more decades and would be implemented incrementally by the Beneficiary Parties. An incremental approach has a number of advantages. First, it can be flexible and responsive especially to technological advances. Secondly, the approach will usually be more fundable than one that requires a very big up-front investment.

Thirdly, it addresses both the objective of restoring the Dead Sea and the objective of providing potable desalinated water for use mainly in Amman. Fourthly, it has the potential to do so without the need for a major sea to sea conveyance. Fifthly, and very importantly, it would also avoid the risks of mixing Red Sea or Mediterranean Sea waters with Dead Sea water. Last, it would avoid the expensive pilot studies that would be necessary to undertake in advance of proceeding to a full scale sea to sea conveyance of water.

At the same time this alternative would certainly require, and could promote, close and sustained cooperation between the Beneficiary Parties via a suite of complementary planning, investment and management actions.

Recent experience in Israel has demonstrated that municipal and industrial water can be effectively recycled to provide strategic volumes of water suitable for irrigation and environmental restoration purposes. It is anticipated here that over a period of three or more decades the same policies could be implemented in Jordan. Jordan currently recovers about 84 MCM/year from the treatment of wastewater and uses this water to supplement its water supply principally for the irrigation of suitable crops. It is estimated by the Study of Alternatives Team that three to four decades from now, the total allocation of water for urban water consumption in Jordan will be about 1.2 BCM/year. This would consist of the following:

- ***Natural water –*** use of existing water allocation. 350 MCM of the existing river water allocation (Jordan Water Strategy JWS, 2008-2022);

- ***Reallocated water –*** reallocation of water from irrigation to urban use. 300 MCM/year that will be re-allocated from irrigation to urban use;

- ***Water from improved management*** – technical measures and water user behavior changes – including reduced leakage and unaccounted water (loss) by the implementation of technical measures and the introduction of appropriate water tariffs and other conservation incentives; 100 – 200 MCM/year.

- New water:
  - *Additional water* from Lake Tiberias (100 - 200 MCM/year), desalination in Aqaba 100 MCM/year), desalination along the northern Mediterranean coast, and/or water importation from Turkey -Manavgat (400 MCM/year); and
  - *Recycling urban water.* 60 percent of the total annual urban allocation of 1.2 BCM could be recycled to generate 720 MCM/year of treated water.

Under this combined alternative it would be possible to meet the potable water needs of Jordan and stabilize the Dead Sea by partially restoring the flow of the Lower Jordan River. The following measures would have to be implemented in order to gain the acceptance of irrigators in Jordan: 300 MCM/year of the 720 MCM/year of recycled water would be allocated to irrigation in Jordan to replace the natural water that would be taken away from the irrigation sector for urban uses. The remaining water – about 400 MCM/year – would be available for the restoration of both the Lower Jordan River and the Dead Sea.

A similar approach in Israel and the Palestinian Authority would provide an additional supply of recycled water of about 600 MCM/year over and above recycled water allocated for irrigation. This water could be used for the restoration of the Lower Jordan River and the Dead Sea after future demands for irrigation water have been satisfied.

In about 30–40 years, the residual supply of recycled water – net of the recycled water allocated for irrigation – would potentially provide about 800-1,000 MCM/year of recycled water for environmental restoration. These changes in water use could be incrementally achieved and would provide sufficient water to restore the lower Jordan River and stabilize the level of the Dead Sea above its current level.

The main anticipated effects of Combination No. 1 are summarized in Table 12.1.

Table 12.1: Combination No 1. Desalination at Aqaba and Mediterranean Sea, Water Importation from Turkey, and Water Recycling and Conservation–Pros and Cons

	PROS	CONS
Overview	• Would reinforce cooperative approaches to water policy and management in the Jordan River Basin • Would eventually restore the "quantity", quality and timing of flows in the Lower Jordan River and would eventually restore the Dead Sea to an acceptable level • Consistent with sustainable utilization of natural resources and the restoration of water-based environmental services • The incremental mode of implementation would be in harmony with the need to cooperate and adapt to unpredictable economic circumstances	• Governments of Beneficiary Parties and many user groups are averse to the idea that relatively high quality, potentially potable water should flow into Dead Sea • There is a widespread assumption that high-quality water released to the Lower Jordan River would be used downstream for domestic, industrial and irrigation purposes. Concern about water potentially not reaching Dead Sea Basin
Technical	• Desalination technologies and water treatment of recycled water are already well proven region-wide. • Water tankering is not yet	• The transfer of desalinated and/or tankered water between the Beneficiary Parties is not yet a tested and accepted mode

	operational at scale but is technically feasible.	technically or commercially • Landing tankered water on the congested coastline of Israel and/or Gaza would be challenging
Economic and Financial	• Desalination and use of treated recycled water are proven to be economic throughout the region. Tankering from Manavgat would deliver competitively priced water. Feasibility studies would still be needed for the tankering element • The scale and phasing of project funding would be incremental and less challenging than in a major civil project • Many elements of the combined alternative would be installed as conservation and water use efficiency measures in all three Beneficiary Parties as they become economically and socially feasible	• Covering the cost of high quality water to restore water ecosystems would be an economic challenge and one that will take time to be socially acceptable • There would be a long transitional period when irrigating communities would have to adjust to livelihood impacts • The proposed measures have not been properly costed. Studies would still be needed including studies to identify the transaction costs of installing new reforms and regulatory measures
Environ-mental and Social	• Improvements to the environmental health of the Lower Jordan River • The Dead Sea level would be restored • The negative impacts of the Dead Sea decline – extension of the area affected by sink-holes and damage to the road and other infrastructures would be reversed • The risks of conveying sea-water – especially over vulnerable aquifers – would be avoided • The negative social impacts of constructing a major seawater conveyance would be avoided	• Not enough water available to arrest significantly fall in Dead Sea level • Potentially potable water flowing to Dead Sea Basin • Employment disruption/loss for land and fish farmers
Other	• The adoption of (i) appropriate conservation measures, (ii) technologies that increase water usage efficiency, and (iii) governance reforms that incentivize water users to change their water using habits are consistent with successful provisioning of water services for human and ecosystem health and the added remediation of damaged water ecosystems as experienced in other economies located in similar water-scarce semi-arid environments • All elements of the combined alternative would ultimately require and promote regional cooperation	• Would require: (i) very broad commitment to cooperation to make significant changes in water policy and management among a number of parties, and (ii) sustained commitment on the part of all the Beneficiary Parties commensurate with necessary advances by challenging reforms

Combination No. 2. Decreased Chemical Industry Water Extraction and Decreased Irrigation through Cropping and Other Agronomic Changes (CA2)

This combination of alternatives was chosen for analysis because: (i) the chemical companies would be likely to lower the Dead Sea extractions if a per cubic meter fee for Dead Sea water was assessed; and (ii) cropping pattern reform has been under discussion in the region for some time and the arguments and alternatives are familiar, even if difficult.

The main anticipated effects of Combination No. 2 are summarized in Table 12.2.

Table 12.2: Combination No 2. Decreased Chemical Industry Water Extraction and Decreased Irrigation through Cropping and Other Agronomic Changes–Pros and Cons (CA2)

	PROS	CONS
Overview		• Restoration of Dead Sea level not addressed
Technical	*Chemical technologies* • Under investigation *Agronomic and cropping changes* • Available technology and knowledge to make changes	*Chemical technologies* • Technologies unproven *Agronomic and cropping changes* • Requires changes in operation of existing investments
Economic and Financial	*Chemical technologies* • Some costs associated with pumping and dikes reduced *Agronomic and cropping changes* • Available and low cost	*Chemical technologies* • High capital and operational costs for Dead Sea chemical industries *Agronomic and cropping changes* • Complicated to implement given established water use patterns
Environmental and Social	• Reduced use of Dead Sea water • Increased flow in Lower Jordan River would support improved environmental conditions	• Negligible impacts on Dead Sea level • Minor positive impact on Lower Jordan River flows • Potential negative impacts from changes in cropping and agronomy on livelihoods and household incomes
Other		• Difficult challenge to reduce use of water in agriculture

Chemical Works Decreased Water Use

This combined alternative would result from reductions of water used in the Dead Sea chemical industries. Experimentation is taking place in at least one university setting examining technologies that reduce water use. Complete closure would reduce annual Jordan Basin water use by at least 250 MCM per year (Oren et al, 2004; Lensky et al, 2005; Zbranek, 2012).

In recent years both companies installed to varying degrees the process of cold crystallization to remove higher value salts from Dead Sea water. This is a tertiary process deployed after brine has passed through the primary and secondary evaporation ponds. The process involves using energy to cool the brine down to a temperature at which precipitation of desired salts occurs. Once crystallization of salts has taken place water can be pumped back to the Dead Sea without any water loss. This eliminates the need for further solar evaporation to isolate salts from the brine. There are a number of cold crystallization methods. These include passing the brine solution over cooled surfaces, direct mixing of the brine solution with a liquid coolant, direct mixing of the brine solution with a gas coolant, and direct mixing of the brine solution with a boiling cooling agent. It can also be achieved by adiabatic vacuum crystallization. These methods could be explored further (Al-Harhsheh et al, 2005).

For this scenario, it is assumed that a saving of 20 percent could be achieved through further advances in cold crystallization technologies enabling reductions in water losses amounting to about **50 MCM/year.**

Reduced Natural Water Use in Irrigation through Agronomic Changes

The Israeli experience shows that significant volumes of natural water can be saved in both irrigation and municipal and industrial uses. Israel has saved 500 MCM of natural water since 2000 and further savings are underway. Jordan consumes half the volume of natural water used by Israel. As Jordan increases the use of treated effluent it will be able to reduce its use of natural water in irrigation. There are no studies that would provide an accurate estimate of potential water saving in the irrigation and municipal and industrial sectors in Jordan. Trends in Jordanian municipal and industrial use show that any immediate savings in municipal and industrial water use will be devoted in the short term to meeting rising demands for high quality water.

On the basis of Israeli experience it is reasonable to expect a saving of at least 33 MCM/year in the irrigation sector of Jordan. Israel could nominate 100 MCM/year of its ongoing savings in the use of natural water to this combined alternative.

Conclusion

This combined alternative would provide savings of 183 MCM annually – Dead Sea Industry 50 MCM, Jordan irrigation savings 33 MCM and Israel 100 MCM. Such gross savings could be achieved but it is not a significant alternative to the Red Sea–Dead Sea Water Conveyance. It neither provides a significant volume of high quality water nor would it address the remediation of the Dead Sea level.

Combination No. 3. Aqaba Desalination Plus Decreased Use from the Chemical Industries, Plus Increases in Recycled Water for Irrigation (CA3)

This combination of alternatives was chosen for analysis because: (i) a desalination plant has been discussed under both the Red Sea–Dead Sea Study Program and the Jordan Red Sea Project; (ii) the cold crystallization process (or another process) now being implemented by the potash companies may prove possible to make more efficient over the short term; and (iii) there is already substantial use of recycled water for irrigation in both Israel and Jordan and it appears at least possible that an even larger increase in the use of this resource is feasible.

The main anticipated effects of Combination No. 3 are summarized in Table 12.3.

Table 12.3: Combination No. 3. Aqaba Desalination Plus Decreased Use from the Chemical Industries, Plus Increases in Recycled Water for Irrigation–Pros and Cons (CA3)

	PROS	CONS
Overview	• Provides high quality water at Aqaba, improves water use efficiency of chemical industries and irrigated agriculture	• Restoration of Dead Sea level not addressed • Need to dispose of brine
Technical	• Proven desalination technologies • Proven recycling technologies	• New Dead Sea chemical technologies not proven
Economic and Financial	• Some future needs for potable water of Amman metropolitan region addressed • Shorter length through use of	• Requires significant capital investments and potentially increased operational costs • Costly capital and operational

	Disi Pipeline for part of conveyance • Lower capital costs compared to Red Sea–Dead Sea option • Lower operational costs compared to Red Sea–Dead Sea option	costs for disposal of brine
Environmental and Social	• Low risk from leakage of potable water • Positive social impacts such as improved access to reliable sources of high quality potable water • Employment generation during construction and limited employment during operation	• Challenge of locating site for desalination plant at Aqaba • Localized environmental impacts of desalination plant on Red Sea coast in areas already under pressure, which can be mitigated by careful design and operation • Major disruption during construction • Negative carbon impact of desalination from significant use of energy in processes • Need to properly dispose of brine – risk of adverse impact with disposal in Dead Sea
Other	• Construction of a desalination plant at Aqaba would benefit from coordination with the other countries bordering the Gulf of Aqaba	• Economically and socially difficult to reduce irrigation water use • Sensitivity by many parties concerning potential for discharge of brine into Red Sea at Aqaba

Aqaba Desalination

Studies are at a conceptual stage evaluating the technical and economic feasibility, and also the impacts of, a regional project to construct a desalination facility at Aqaba. For example, the initial desalination plant under the Jordan Red Sea Project would be located close to Aqaba, and would be wholly in Jordanian territory and wholly Jordanian owned and financed as a Build-Operate-Transfer project. The plant would produce about 100 MCM/year of potable water. Brine could be piped to the Dead Sea – in Jordanian territory via the Wadi Araba/Arava Valley – with a possible outlet in the small bay on the eastern side of the Lisan Peninsula in the southern Dead Sea.

Chemical Works Reduced Water Use

A saving of 20 percent as outlined in the previous section is assumed to be potentially possible, yielding 50 MCM/year.

Increased Use of Recycled Water in Irrigation

Israel was by 2009 using 300 MCM of effluent–see Figure 11.1 above. The trend indicates that this figure will increase during the next decade. If a proportion of this treated re-used water were counted as an element in a combined alternative it could amount to 100 MCM.

Jordan is increasing its treated effluent production. It could choose to devote 50 MCM/year to this combination.

The Palestinian Authority will be able in the future to re-use treated effluent from wastewater treatment plants. This could amount to 10 MCM/year and higher volumes in the longer term.

Conclusion

The total volume of water contributed by this combination would be 310 MCM/year of water, 100 MCM/year would be potable and the remainder suitable for irrigation.

The approximate amount of 100 MCM/year of brine would not have a positive impact on the Dead Sea level but it would have potential experimental value.

Both these volumes are inadequate to address the goals of Dead Sea restoration and significant long-term supplies of potable water.

COMBINATION NO. 4. REDUCED EXTRACTIONS FROM THE JORDAN RIVER, PLUS AQABA DESALINATION AND DECREASED IRRIGATION USE THOUGH AGRONOMIC CHANGES (CA4)

This combination of alternatives was chosen for analysis because: (i) reduced extractions from the Lower Jordan River could be accomplished through a variety of measures including cropping/agronomic changes, increased use of recycled water or irrigation technology changes; and (ii) a desalination plant in the Aqaba area is under discussion as part of the proposed Jordan Red Sea Project.

The main anticipated effects of Combination No. 4 are summarized in Table 12.4.

Table 12.4: Combination No. 4. - Reduced Extractions from the Jordan River, Plus Aqaba Desalination and Decreased Irrigation Use though Agronomic Changes–Pros and Cons (CA4)

	PROS	CONS
Overview	• Could partly be used for the restoration of environmental services of water in the Lower Jordan River.	• Restoration of Dead Sea level not addressed
Technical	• Shorter length of conveyance through use of Disi Pipeline for part of distance	
Economic and Financial	• Future needs for potable water of Amman metropolitan region addressed • Shorter conveyance length • Capital costs easier to meet • Lower operational costs • Positive social impacts such as improved access to reliable sources of high quality potable water • Employment generation during construction and limited employment during operation	• Need for potable water in Amman and elsewhere only partially met • No contribution of high quality water to Dead Sea region • Requires significant capital investments and potentially increased operational costs • Costly capital and operational costs for disposal of brine
Environmental and Social	• Low risk from leakage of potable water • Contribution to partial restoration of Lower Jordan River flows • Socially positive	• Major disruption during construction that can be predicted and mitigated • Challenge of locating site for desalination plant at Aqaba • Negative carbon impact of desalination from significant use of energy in processes • Need to properly dispose of brine – risk of adverse impact with disposal in Dead Sea • Negative impacts of changes in

		cropping and agronomy on livelihoods and household incomes
Other	• Construction of a desalination plant at Aqaba may benefit from coordination with the other countries bordering the Gulf of Aqaba	• Difficult to reduce irrigation water use

Reduced Jordan River Extractions

The storage in Lake Kinneret/Tiberias has been pivotal in Israel's water security but this role is declining because of the expanded use of desalinated water from the Mediterranean Sea. The average withdrawal from Lake Kinneret/Tiberias has been dropping steadily. Over the period 1996-2010 the average was 226 MCM/year[5] but since then it is believed to be sometimes less than 200 MCM/year. Withdrawals from Lake Kinneret/Tiberias are associated with significant pumping costs and atmospheric impacts from energy used in pumping. For this Combination, is assumed that pumping 100 MCM/year from Lake Kinneret/Tiberias could be avoided.

Aqaba Desalination

The contributions of this regional project are discussed in the previous sub-section.

Reduced Natural Water Use in Irrigation through Agronomic Changes

Again in a sub-section above it is shown that on the basis of Israeli experience it is reasonable to expect a saving of at least 100 MCM/year in the irrigation sector of Israel. Israel could nominate 100 MCM/year of its ongoing savings in the use of natural water to this combined alternative. Jordan is likely to be able to save 33 MCM/year.

Conclusion

The three elements of this combination would contribute 333 MCM year of water–100 MCM/year of high quality water from Lake Tiberias, and 100 MCM/year from desalination at Aqaba, plus 133 MCM/year from agronomic changes that could partly be used for the restoration to the environmental services of water.

These volumes do not match those of the Red Sea–Dead Sea Water Conveyance.

General Conclusions

The combination options could make significant but not strategic contributions to the provision of potable water and environmental water (see Table 12.5). If all the elements of the combination alternatives were implemented 200 MCM/year of high quality water could be produced, 210 MCM/year of re-used effluent that could be devoted to irrigation and 183 MCM/year of water could be devoted to the environmental services of water – such as restoring the flows of the Lower Jordan and the level of the Dead Sea. These are all significant alternatives in a two decade perspective. However, they would not provide for longer term water security.

Table 12.5: Total Possible Savings If All Four Combined Options Implemented

Water Saving Measure		Combination 1 MCM	Combination 2 MCM	Combination 3 MCM	Combination 4 MCD
Dead Sea Chemical Industry		0	50	50	
Increased Re-use for Irrigation	Israel			100	
	Jordan	(300 of recycled)		50	
	PA			10	

[5] FOEME 2011, p. 33-35, Figure 7.

Savings in Irrigation/Municipal	Israel	Irrig		100		100
		Mun'l				
	Jordan	Irrig	??	33		33
		Mun'l	100			
	PA	Irrig	??	10		10
		Mun'l				
Aqaba Desal			100		100	100
Med Desal			100			
Turkish Tankered Water			400			
Reduced Jordan Transaction			350-300=50			100
Additional Water	Lake Tiberias Releases		100			
	Re-cycled Municipal Israel & Jordan		600+400 of 1500+720			
TOTALS			1850-300 = 1550	193	310	343

13. COMPARATIVE REVIEW OF ALTERNATIVES

This section provides a comparative review of the wide range of alternatives that have been considered in the report. It aims to provide broad comparisons between individual and combined options in a form helpful to decision makers and the public.

PRINCIPAL FINDINGS AND CONCLUSIONS

No Action Alternative (NA1)

There will be economic, environmental and social costs associated with not remedying the decline of the Dead Sea and the imminent deficit of potable water in Jordan. Current cost estimates, based on limited data, are in the range of US$73–227 million a year. These estimates are based on impacts to the local population. However, the unique characteristics of the Dead Sea imply that the benefit of its preservation extends beyond the region and includes the international community as a whole. The total benefit of preventing the decline of the Dead Sea is therefore likely to be larger than the above range.

The No Action alternative will force Jordan to seek other ways to increase the supply of potable water. The most likely course of action is to desalinate in Aqaba and exploit the Disi–Amman pipeline (currently under construction) for water conveyance. The cost of conveyance from Disi to Amman is estimated at US$1.1/$m^3$ because Disi is about 325 kilometres from Amman and there is a significant elevation change between Disi and Amman. The distance from Aqaba to Disi is about 70 km and the elevation in the Disi area is 800 m, implying an additional conveyance cost from Aqaba to Disi of at least US$0.4/$m^3$. Adding the cost of desalination (US$0.5/$m^3$) gives a figure above US$2/$m^3$ as the cost of desalinated Aqaba water in Amman. This cost is substantially larger than comparable costs of other alternatives.

Red Sea–Dead Sea Water Conveyance (BC1/BC2)

The cost of seawater-brine discharged in the Dead Sea depends on the chosen project option, varies along the project stages and is sensitive to economic parameters such as the rate of interest and electricity tariffs. Average annual costs after project completion (at full capacity) ranges between US$58 million and US$344 million. The cost of water in Amman after project completion (full capacity) ranges between US$1.1/$m^3$ and US$1.5/ m^3.

Lower Jordan Options (FL1/FL2)

Restoring the Lower Jordan River is a desirable goal with high environmental, historical and cultural values. Full restoration to historical flows is not economically or socially feasible at this time. Full restoration, according to Gafny et al (2010), would require a flow of between 1,200 and 1,400 MCM, which they conclude are quantities beyond the ability of the region and, therefore, there is little likelihood that this can be realized as an alternative.

In the short and medium term, partial restoration of the Lower Jordan River should be seriously considered as a priority for water resources and environmental management in combination with partial restoration of the Dead Sea or increased supply of potable water to Amman and other areas. Partial restoration of the ecological services of the Lower Jordan River would aim to ensure a minimum environmental flow to rehabilitate some of the aquatic ecological diversity of the river. The partial restoration of Lower Jordan River flows, over a two decade term, could possibly contribute 40 percent of the quantity of water needed to stabilize the Dead Sea level. Engagement and cooperation on the part of the Beneficiary Parties would also be enhanced. The main sources of water to achieve partial restoration would be: use of recycled wastewater, limited releases of water from Lake Tiberias (see Box ES.4); and transfer of desalinated water from the Mediterranean Sea associated with the conveyance of potable water to Amman

Partial restoration of the ecological services of the Lower Jordan River would aim to ensure a minimum environmental flow to rehabilitate some of the aquatic ecological diversity of the river. There would be no contribution to the high quality water needs of the Beneficiary Parties; rather the contribution of this alternative would reside in restoration of environmental services. Engagement and cooperation on the part of the Beneficiary Parties would also be enhanced.

The main sources of water to achieve partial restoration would be: use of recycled wastewater, limited releases of water from Lake Tiberias; and transfer of desalinated water from the Mediterranean Sea associated with the conveyance of potable water to Amman. The 600 MCM/year Lower Jordan River flows cited by Gafny et al would not, however, be a sufficient quantity to stabilize the Dead Sea. According to Coyne et Bellier, a minimum of 1,200 MCM/year is required to stabilize the Dead Sea.

A feasible source for augmenting Lower Jordan River flow to support restoration is secondary water, such as recycled water. The growing population will gradually increase the potential supply of recycled water. Implementing any alternative that brings in additional potable water will indirectly contribute to the feasibility of Lower Jordan River restoration by increasing the potential supply of recycled water. Every m^3 of added potable water will enable additional uses that when combined account for more than 1.5 m^3 of water.

The Study of Alternatives team identified a combination of alternatives over the long term – 30 to 40 years – that would enable full restoration of the the Lower Jordan and the Dead Sea. Such an amount of time is a span not dissimilar to that for the full implementation of a major conveyance alternative. This would require the mobilization of water with many measures including desalination at Aqaba and the Mediterranean, water importation from Turkey, mainly by recycling municipal water and conservation. See the Combined Alternative, CA1, in Section 12 above.

Water Transfer Options

Transfer of Mediterranean Sea Water to Dead Sea (TR1.1 - TR1.4)

Two Mediterranean Sea–Dead Sea project alignments–southern and northern–are considered. These include Mediterranean Sea-Dead Sea Southern A – Ashkelon to North Dead Sea (Low Level Tunnel) (TR1.1) and a Phased Pipeline and Gravity Tunnel option (TR1.2) which both use the Southern A alignment. The northern alignment includes two options: Mediterranean Sea–Dead Sea Northern – Atlit to Naharayim-Bakura – with hydropower (TR1.3) and without hydropower (TR1.4). In reviewing the Southern A and Southern B alignments and their associated investments, the Study of Alternatives Team concluded that since the Southern A alignment delivers water to the northern edge of the Dead Sea it would be able to provide water at a lower cost to Amman and other areas with significant water demand. Consequently, the most southern Mediterranean Sea–Dead Sea alignment termed Southern B has been screened out and this study considered only the Southern A –TR1.1 and TR1.2 as southern options.

The course of the southern Mediterranean Sea–Dead Sea alignment intersects the southern structures of the mountain aquifer and the exact route should be determined in order not to harm this sensitive and important water source. The high surface elevation of the southern Mediterranean Sea–Dead Sea alignment renders a phased pipeline option (as an integrated component) not feasible economically. A pilot project to test the mixing of Mediterranean Sea and Dead Sea waters must be constructed separately and this will increase the cost. The actual route may be longer and/or deeper, with potentially substantial cost impacts. Further cost analysis would be needed after an exact route has been determined.

The Low Level Gravity Tunnel of the Red Sea–Dead Sea Base Case Plus would deliver potable water at \$1.11-1.24/m^3. The Base Case Plus Red Sea–Dead Sea Phased Pipeline is estimated at \$1.33-1.50/m^3. Potable water delivered by the Mediterranean Sea–Dead Sea Southern A – Low Level Gravity Tunnel would deliver equivalent water at \$0.85-\$ 0.93/m^3 (see Section 6 and Table 6.2). The Mediterranean Sea–Dead Sea alternative would deliver water at 86 percent of the best Red Sea–Dead

Sea Tunnel alternative and at 65 percent of the cost of water via the Red Sea–Dead Sea Phased Pipeline.

The cost advantage of the southern Mediterranean Sea–Dead Sea alignment over the Red Sea–Dead Sea options is evident for both stabilizing the Dead Sea and increasing the supply of potable water in Amman due to shorter distances involved.

A northern alignment that could be used for the transfer of Mediterranean Sea water to the Dead Sea is not considered feasible because its course would pass through fertile valleys that overlay sensitive aquifers. This would entail serious environmental risks associated with conveying salt water across tracts where groundwater is used to provide domestic and industrial water and some vital complementary irrigation services. Given this concern, the northern alternatives (TR1.3 and TR 1.4) involve an approach that includes desalination undertaken on the Mediterranean coast with freshwater being transferred to Amman and other areas by a pipeline.

The eastern outlet of the northern Mediterranean Sea–Dead Sea route would be near Naharayim–Bakura, at the confluence of the Yarmouk and Jordan Rivers. From Naharayim–Bakura the water could be conveyed straight to Amman, by expanding existing conveyance infrastructure, or it could flow along part of the Lower Jordan River, and then be captured, treated and conveyed to Amman. The northern Mediterranean Sea–Dead Sea alignment delivers potable water to Amman at costs between US\$1.14/m^3 and US\$1.38/m^3, which compares favorably with the Red Sea–Dead Sea costs of US\$1.11/m^3–US\$1.5/m^3."

Transfer of Water from Turkey by Land Pipeline (TR2)

The reliability of supplies of potable water in Turkey is the key issue. Nearly twenty years ago, when a version of the Seyhan-Ceyhan sourced Peace Pipeline was being proposed, it was assumed that there would be 2 BCM of reliably available water in the Seyhan-Ceyhan Rivers – near the city of Adana in southeastern Turkey – in all seasons. Transfer of 2 BCM of water annually would have been sufficient to address two of the Study Program objectives described above. However, 2 BCM/year are no longer available in the opinion of Turkish officials and scientists who met with the Study of Alternatives Team.

The cost estimates of previously proposed land pipelines are not robust nor are they up-to-date. At this point the costs of delivering potable water by land from Turkey would not seem to be competitive with well installed and managed desalination systems located in the Beneficiary Parties.

The environmental risks and impacts of water piped from Turkey would be low as the water being conveyed would be high quality water rather than sea water or brine. Social impacts would be carefully evaluated given the diversity of settlement patterns and land use along the alignment. Measures would also need to be taken to avoid or minimize potential impacts to cultural heritage along the alignment. Cumulative impacts would exist from the transfer of water from the Seyhan and Ceyhan Rivers ecosystems downstream of the point from which water is withdrawn and extend to the Mediterranean coastal zone. Management of potential environmental and social impacts would require actions to be taken by Turkey, Syria and Jordan within their respective territories.

Transfer of Water from the Euphrates (TR3)

A Euphrates pipeline from Iraq would be technically feasible. Its water would be lower cost than water conveyed from Turkey and competitive with Red Sea–Dead Sea Water Conveyance desalinated water delivered to Amman. Its direct social impacts in Iraq would be limited as the alignment has very few settlements while in Jordan there is extremely limited settlement along the alignment until it reaches the Amman urban area. Measures would need to be taken in both Iraq and Jordan to avoid or minimize potential impacts to cultural heritage along the alignment. Cumulative impacts would exist from the transfer of water from the Euphrates ecosystem downstream of the point from which water is withdrawn. In Jordan there could be positive impacts as there would be more potable water available to users and a potential for introduced water to partially reflow into the Dead Sea basin.

A structure to convey reasonably high quality water from the Euphrates in Iraq would be technically and economically feasible. But the volume of water – 160 MCM/year proposed in studies undertaken in the 1990s – would be too small even to address the potable water needed in the Jordan Basin. Water from the Euphrates would not address Dead Sea restoration and could only provide supplemental potable water supply for Jordan. Today, Iraq cannot spare any water from the Euphrates as the flow has been significantly reduced as a consequence of water abstraction from the river in Turkey, Syria and Iraq.

Desalination Options (DS1-DS4)

Background for Desalination Alternatives (DS1-DS4). By 2014 Israel plans to have desalination capacity of about 600 MCM/year. By 2050, Israel plans to desalinate a total of 1,500 MCM/year which is designated to meet 70 percent of all national potable water demands and 100 percent of domestic water demands. Any surplus desalinated water generated in this process is available for the natural environment. The current plans are aimed at servicing Israeli domestic demand only, so additional capacity would need to be added in order to meet demands from other Beneficiary Parties. With support from the Union for the Mediterranean, the Palestinian Authority is examining the technical and financial feasibility of a desalination facility in Gaza capable of supplying up to 55 MCM/year. The current cost of desalination in Israel stands at $0.52/m^3$, which can be used as a benchmark for any of the desalination options described below.

Desalination of Mediterranean Sea Water on the Mediterranean Coast with Transfer to the Lower Jordan River and Dead Sea Region (DS1)

This alternative involves increasing desalination capacity on the Mediterranean coast in northern Israel. Brine produced during the desalination process would be returned to the Mediterranean Sea and desalinated water would be distributed to the Beneficiary Parties and the Jordan River. The Samuel Neaman Institute (2007) examined this alternative some five years ago. Its analysis consisted of desalination on the Mediterranean coast, south of Haifa, to produce 1,800 MCM/year of freshwater. Two hundred seventy MCM/year would be designated to the Palestinian Authority and communities in the Negev, and 400 MCM/year would go to the Israeli National Water Carrier. A total of 1,130 MCM/year would be transferred to the Jordan Valley and used to generate hydropower. Of this amount, 530 MCM/year would be transferred to Jordan and the remaining 600 MCM/year could be conveyed to the Dead Sea. When combined with the 400 MCM/year saved from the cessation in pumping to the National Water Carrier, this alternative provides 1,000 MCM/year high quality water for restoration of the Dead Sea. It would require significant expansion of desalination facilities on the Mediterranean coast, with significant energy, carbon footprint and brine impacts. However, environmental impacts from the water conveyance, beyond those associated with construction of necessary pipelines, desalination and hydropower plants, would be low as there is no conveyance of brine or seawater over aquifers. The Samuel Neaman Institute estimated total net running cost (2007) at US$1,210 million per year and total investment cost at US$7,620 million.

Partial restoration of the Lower Jordan River using desalinated water is possible to a limited extent if implemented in conjunction with the goal of increasing the supply of potable water in Amman (see the northern alignment of Transfer from the Mediterranean Sea to the Dead Sea, TR1.3 and TR 1.4, above). It is the view of the Study of Alternatives Team that the use of potable water – from Lake Tiberias, from desalination plants or from other sources of natural potable water – for Dead Sea stabilization purpose would not be a viable or desirable strategy as long as the Beneficiary Parties experience acute shortages of potable water.

Transfer of Mediterranean Sea Water to the Jordan Valley for Local Desalination and Use in Lower Jordan River and Dead Sea Region (DS2).

This alternative is similar to DS1 except that the seawater extracted from the Mediterranean coast is transferred inland by pipeline/tunnel/channel for desalination in the Jordan Valley. The brine from this process would then be transferred by pipeline (or channel) to the Dead Sea. The Samuel Neaman Institute examined an option consistent with this alternative. It involved transferring 2,000 MCM/year of sea water from the Mediterranean south of Haifa to the Naharayim–Beit She'an area. This would produce 800 MCM/year of high quality desalinated water that could be supplied to Jordan. The brine from the process (1,200 MCM/year) would be transferred to the Dead Sea by canal or pipeline. This process involves transferring seawater and brine across aquifers that are used for potable water so the alternative would present considerable environmental risk. Total net running cost (2007) was estimated by the Samuel Neaman Institute at US$875 million per year and total investment cost (2007) at US$5,710 million.

Increased Desalination of Mediterranean Sea Water on the Mediterranean Coast with Transfer for Use by the Three Beneficiary Parties to Reduce Water Demand from Lower Jordan River (DS3).
This alternative involves increasing desalination capacity on the Mediterranean coast of Israel and Gaza through construction of new desalination plants and the upgrade of existing plants. Increased availability of new water could enable Israel to reduce pumping from the Sea of Tiberias into the National Water Carrier making more water available for stabilization of Dead Sea levels. This alternative overlaps with other desalination alternatives discussed above. Israeli authorities are considering plans to increase desalination capacity along the Mediterranean coast to 1.5 BCM /year by the year 2050 to meet the domestic water needs in Israel and the Palestinian Authority. This quantity could be increased to meet some of the urban water needs of Jordan as well, both (i) by reducing the pumping from Lake Tiberias to the Israeli National Water Carrier and accordingly increasing the allocation of Lake Tiberias water to Jordan, and (ii) by transferring water desalinated near Haifa to Amman via Naharayim-Bakura (see the northern alignment of the Mediterranean Transfer Alternative TR.3, TR.4 above). In addition, the Palestinian Authority is working with the European Union and other donors for the development of a 55 MCM/year desalination plant in Gaza (Secretariat of the Union for the Mediterranean, 14 May 2011)

Desalination of Red Sea Water at the Gulf of Aqaba/Eilat with Transfer for Use by the Three Beneficiary Parties to Reduce Water Demand from Lower Jordan River (DS4).
This alternative would involve either: (i) establishing desalination capacity on the shore of the Gulf of Aqaba/Eilat and transferring desalinated water from the Red Sea coast to the three Beneficiary Parties; it includes brine transfer to the Dead Sea; or (ii) transferring sea water to the Dead Sea for desalination and sharing among the Beneficiary Parties.

Jordan Red Sea Project (Not Included in the Terms of Reference)
The Jordan Red Sea Project is an alternative that was not included in the Terms of Reference for the Study of Alternatives, but it has become a well known alternative in the last two years. This alternative is a "Jordan only" initiative and does not involve Israel or the Palestinian Authority (see Box 4.1). It consists of 5 phases and ultimately would aim to abstract 2,150 MCM/year seawater from the Gulf of Aqaba, partially desalinate this to produce 80 MCM/year potable water in the Aqaba area, and convey the remaining seawater and brine by pipeline for desalination at the Dead Sea in order to produce a further 850 MCM/year potable water. A total of up to 1,220 MCM/year would be discharged to the Dead Sea. Phase I, possibly for completion in 2018, would produce 250 MCM/year desalinated water and 190 MCM/year of Dead Sea discharge.

Technical and Water Conservation Options (TC1-TC4)

Change of Technology Used by the Dead Sea Chemical Industry (TC1)
The Study of Alternatives Team is unaware of any new technologies being used to significantly reduce the water consumption per ton of produced potash by the Dead Sea chemical industries. The cold crystallization process is being used both by the Dead Sea Works and by the Arab Potash Company. Because neither of the Dead Sea chemical industries in Israel or Jordan is required to pay for their consumption of water from the Dead Sea, there are no incentives in place to develop or adopt more efficient water use technologies. A mechanism of resource use fees, proportionate with their water consumption, should be considered to create such an incentive.

Increased Water Conservation in the Lower Jordan River Basin (TC2)

Israel currently recovers 460 MCM/year from the treatment of wastewater and Jordan currently recovers 84 MCM/year. As urban water consumption increases within all three Beneficiaries, the potential for expanded wastewater treatment increases.

Over the period 2007-2009, the Israeli Water Authority increased the water tariffs for domestic and industrial users in Israel. Data from the Authority [citation to be added] estimate that the recent reduction in domestic consumption in Israel following the increases in tariffs brought an annual reduction in use of over 10 percent, about 100 MCM annually. This volume is equivalent to a large scale desalination plant or two-thirds of the net volume required annually to operate the Dead Sea Works and is approximately the net amount of Dead Sea water used annually by the Arab Potash Company. It is equivalent to 60 percent of the domestic water used by households in the Palestinian Authority and 50 percent more than the volume to be delivered by the Disi-Amman pipeline now under construction in Jordan.

This alternative demonstrates: (i) the importance of water pricing. When set properly, and introduced carefully, water prices generate the right incentives to use water efficiently and minimize the unaccounted water losses that result from badly maintained infrastructure; (ii) the importance of water conservation in the overall water budget of the region; and (iii) that there is likely considerable additional scope for further conservation gains. However, these measures have been difficult to agree to and equally challenging to implement (see Box 9.1).

Increased Use of Treated Wastewater and Greywater (TC3)

Water could be conserved in the municipal, industrial and domestic sectors through the increased use of treated wastewater. For example, in Israel the use of fresh/potable water in irrigation has been reduced from 896.8 MCM in 1995 to 490.7 MCM in 2008 (see data on website of Israel's Water Authority) – a reduction of almost 50 percent – and these allocations will continue to decline. This volume is significant in any policy aiming to secure water and the sustainability of the environmental services of water in the Jordan Basin.

The re-use of water in high value activity sectors, in the municipal (gardening), industrial and domestic (greywater) sectors is also water conserving. The achievements in installing these technologies and related regulatory regimes in the Beneficiary Parties are impressive in global terms. It is increasingly recognized that one cubic meter of water utilized in high value activities should be counted as 1.5–1.7 cubic meters as a consequence of re-use (Cohen et al, 2008). This principle applies to any water produced by a Red Sea–Dead Sea desalination plant and all the desalination plants associated with other alternatives.

Changes in Crop Type and Cultivation Methods (TC4)

This alternative aims to reduce the amount of high value potable water allocated to watering low value crops. Water savings would be achieved by modifying cropping patterns and changing trade policies. The potential for water conservation in the irrigation sectors of the three Beneficiary Parties is currently substantial (see Gafny et al, 2010 and Gorskaya et al, 2010). Other research finds gains from a shift away from irrigating low-profitability olive trees in the highlands of Jordan, which currently consume one quarter of all good quality groundwater abstracted for irrigation in the Jordan (Courcier et al, 2005). Groundwater is very scarce in this region; only 5.2 percent of the 8,500 MCM/year precipitated annually reach storage. Where irrigated cropping is viable, it should be devoted to high value herbs, aromatic oils, medicinal plants and improved non-irrigated forage rather than olives.

Citrus tree cultivation dominates the northern area of the Lower Jordan River basin. Water savings could be achieved if regulated deficit irrigation is introduced, ensuring that trees are only watered at critical times during the fruit production life cycle (Rawabdeh 2010). Barley crops could be left to rain-fed watering only during drought years, despite lower yields.

Additional Alternatives Identified by the Consultants (AA1-AA3)

The following additional alternatives are discussed that provide partial contributions to meeting the objectives of the Study Program:

Selling Electricity to Israel and Pumped Storage (AA1)
This alternative would aim to put in place infrastructure and international management contracts that would enable the use of pumped storage in Jordan associated with the Red Sea–Dead Sea Water Conveyance. Electricity could then be generated to take advantage of Israel's peak-load electricity tariffs to decrease project energy costs and increase proceeds from selling hydropower.

Transfers by Tanker, Bag, Submarine Pipeline from Turkey (AA2)
This alternative involves water conveyance from the Seyhan and Ceyhan Rivers and/or from the Manavgat area in Turkey by means of tankering, floating bags or sub-marine pipeline. Turkey is very interested to sell potable water from its major investment in the facilities at Manavgat. The volumes of water available at Manavgat – up to 400 MCM/year – would be significant to meet potable water demands but would not contribute to the restoration of the Dead Sea. Overall the sea-borne conveyance by tanker, bag or submarine pipeline from Turkey would not address the stabilization of the Dead Sea; however, it could provide an incremental supply of high quality potable water. However, major uncertainties have emerged concerning the availability of sufficient quantities of water from the Seyhan and Ceyhan Rivers, which had been a prominent potential source in the past.

Submarine Pipelines Associated with Oil and Energy Conveyance-Medstream (AA3)
Water would be one of the resources conveyed by the Medstream submarine pipeline from Turkey. The volumes of water to be conveyed have not been firmly established. The volumes would not be sufficient to restore the Dead Sea. They would contribute to the regional demand for potable water.

Combination of Alternatives (CA1-CA4)

The Terms of Reference require that "a range of combinations of alternatives be examined to assess the benefits of such an approach." The study examines four of a potentially very large number of combined alternatives.

Combination CA1. Desalination at Aqaba and Mediterranean Sea, Water Importation from Turkey, and Water Recycling and Conservation
This combination of alternatives takes a longer perspective of at least three or more decades and could be implemented incrementally by the Beneficiary Parties. It addresses both the objective of restoring the Dead Sea and the objective of providing potable desalinated water for use mainly in Amman, and has the potential to do so without the need for a major sea to sea conveyance. It also would avoid the risks of mixing Red Sea or Mediterranean Sea waters with Dead Sea water. At the same time this alternative would certainly require, and could promote, close and sustained cooperation between the Beneficiary Parties via a suite of complementary planning, management and investment actions.

Box 13.1: A Proposal for Raising the Dead Sea without a Red Sea-Dead Sea Project

An article published by Rosenberg in April 2011 highlights some new technical and economic options. These options have emerged during the first decade of the 21st century, as evidence of the potential of evolving desalination and recycling technologies and the significance of different economic conditions became clear. The author identifies two restoration alternatives, arguing that they are more economically viable than the proposed Red Sea–Dead Sea Water Conveyance Project.

- The first is the expanded installation of decentralized wastewater facilities across all three Beneficiary Parties to produce new water for irrigation and for the restoration of environmental services. The recycling technologies would not only provide recycled water. They would also reduce losses from leaks and promote water conservation. It is estimated that 900 MCM/year could reliably be delivered to the Dead Sea mainly via the Lower Jordan River.
- Secondly, it is concluded that a smaller Red Sea–Dead Sea Water Conveyance – that would only generate hydropower – could deliver large and significant flows to restore the Dead Sea when the sale price of generated electricity is sufficiently high.

For all restoration options, water scarcity rises and net benefits fall as increased flows to the Dead Sea are generated. The rising costs reflect increasing water scarcity as water from diverse sources would be progressively devoted to restore environmental flows. Benefits would decrease as water would be reallocated from existing economic users in agriculture and industry to restoring the lower Jordan River and the Dead Sea. Model results suggest the existing system cannot economically meet the 900 MCM year flow threshold.
This finding has relevance for both the Beneficiary Parties and potential outside funders. The Beneficiary Parties would have no incentive to return water to the Dead Sea. Potential funders wanting to raise the level of the Dead Sea would have to provide long-term direct operational incentives to ensure delivery of water to the Dead Sea in addition to funding the capital expenditure of the conveyance infrastructure.
The analysis in the study aligns with a number of conclusions of the Study of Alternatives Team. First, that the price of electricity is a key factor in determining the economic viability of any conveyance option. Secondly, the predictable availability of as much new water from desalination technologies and via recycling as is currently available from natural water sources would potentially make a significant contribution to the restoration of the Lower Jordan River and the Dead Sea.
Rosenberg, D. E.*, 2011, "Raising the Dead without a Red Sea-Dead Sea project? Hydro-economics and governance," *Hydrology and Earth System Sciences [HESS]*, Vol 15, pp 1243-1255. http://www.hydrol-earth-syst-sci.net/15/1243/2011/hess-15-1243-2011.pdf
* Department of Civil and Environmental Engineering and Utah Water Research Laboratory, Utah State University, Logan, Utah, USA

Combination CA2. Decreased Chemical Industry Water Extraction and Decreased Irrigation through Cropping and Other Agronomic Changes

This combined alternative could potentially provide savings of 183 MCM annually. Dead Sea Industry saving would 50 MCM, Jordan irrigation saving would be 33 MCM and Israel irrigation saving about 100 MCM. Such gross savings could be achieved but it is not a significant alternative to the Red Sea–Dead Sea Water Conveyance. It neither provides a significant volume of high quality water nor would it address the remediation of the Dead Sea level.

Combination CA3. Aqaba Desalination Plus Decreased Use from the Chemical Industries, Plus Increases in Recycled Water for Irrigation

The total estimated volume of water that could be contributed by this combination would be 310 MCM/year – saving 100 MCM/year of new water, 50 MCM saving from Dead Sea industries, 100 MCM in brine from the desalination plant and 60 MCM from increased recycled water. The 100 MCM/year of brine plus 50 MCM from potash industry reduction would not have a positive impact on the Dead Sea level.

Combination CA4. Reduced Extractions from the Jordan River, plus Aqaba Regional Desalination and Decreased Irrigation Use though Agronomic Changes

The three elements of this combination would contribute 333 MCM year of water – 100 MCM from reduced Jordan River extractions (via increased flow from Lake Tiberias), 100 MCM of new water from desalination, plus 133 MCM from decreased irrigation use (Jordan 33 MCM and Israel 100 MCM). The total would not be enough to stabilize the Dead Sea and would only partially address the region's demand for potable water.

Combination Alternatives – General Conclusions

Adoption and implementation of the CA1 alternative could potentially have a strategic impact on the Lower Jordan River and a positive incremental impact on the Dead Sea; however, it would require unprecedented cooperative planning and sustained engagement at the operational level among the Beneficiary Parties. This is the most complex of the combination alternatives and would require further detailed review at the government level in addition to more consideration of the potential technical, economic, environmental and social aspects of this proposition.

The combination alternatives CA2-4 could make significant but not strategic contributions to the provision of potable water and/or water for environmental purposes. If all the elements of the combination alternatives were implemented 100-200 MCM/year of high quality water could be added, more than 200 MCM/year of re-used effluent could be devoted to irrigation and about the same quantity of water could be devoted to the environmental services of water – such as restoring the flows of the Lower Jordan and the level of the Dead Sea (see Table 13.1). These are all significant alternatives in a two decade perspective; however, they would not provide longer-term water reliability of water.

COMPARATIVE REVIEW OF ALTERNATIVES

A Framework for Review of Alternatives. A comparative review of the wide range of alternatives that have been considered in the Study of Alternatives is provided below, and allows for broad comparisons between individual and combined options in a form helpful to decision makers and the public. The Study of Alternatives is designed to evaluate and compare the various alternatives according to the following criteria:

- Dead Sea stabilization or restoration;
- Production of new potable water to be shared in the Region;
- Demonstrated cooperation among the Beneficiary Parties;
- Cost of construction and operation; and
- Potential environmental and social impacts.

The capacity of the alternatives to produce hydropower is also noted but is not given significant weight as the Red Sea – Dead Sea Water Conveyance and nearly all the potential alternatives are require more energy than they produce.

Up to this point the analysis has been carried out according to the structure set out in the Terms of Reference. The comparative review of alternatives in this section has adopted a simplified classification of the alternatives. The classification is twofold, based on the extent to which an alternative or a combined alternative either comprehensively addresses the three objectives of the Red Sea–Dead Sea Water Conveyance, or only partially addresses them. As the analysis progressed it became clear that the partial alternatives all had the characteristic of providing incremental solutions. This second class of alternatives is referred to as both partial and incremental alternatives.

The Alternatives

No Action Alternative. The No Action alternative is described in detail in both the Feasibility Study (Coyne et Bellier, 2012) and the Environmental and Social Assessment Study (ERM, 2012). Both conclude that this scenario involves substantial and adverse changes to the Dead Sea and its surrounding environment. By the year 2070 the area of the Dead Sea would decrease by an additional 16 percent, or a cumulative decrease of 40 percent from the level in the early 1900s. Under this alternative, the chemical industries would also eventually go out of business incurring another substantial reduction in regional GDP. If the chemical industries halt production within the next few decades, then the Dead Sea would eventually stabilize under the No Action alternative at about 515 meters below sea level, or almost 100 meters lower than today's level.

Comprehensive Alternatives. Two alternatives and one combination of alternatives have been identified that would comprehensively address all the five criteria described above. These are: (i) the Red Sea–Dead Sea Water Conveyance Base Case Plus (BC1); (ii) the Mediterranean Sea–Dead Sea Water Conveyance – Southern A (TR1); and (iii) Combination No.1 Desalination at Aqaba and Mediterranean Sea, Water Importation from Turkey and Water Recycling and Conservation (CA1). The Mediterranean Sea–Dead Sea Conveyance addresses all the key technical features and is anticipated to have a lower cost; however, it may prove to be significantly more challenging to set in place the necessary multiple cooperative agreements necessary to gain support for and implement this alternative. It should be noted that alternatives (i) and (ii) are anticipated to need a pilot program to physically test the mixing of either Red Sea or Mediterranean Sea waters with Dead Sea waters, which would require significant expenditures and adequate time to conduct and evaluate. An advantage of the Red Sea–Dead Sea Phased Pipeline (PPL) Alternative over the Mediterranean Sea–Dead Sea southern alignment (Gravity Tunnel) is that the former could accommodate a pilot as an integrated phase whereas for the latter a pilot must be constructed independently of this alternative. The added pilot cost could therefore be much larger for the Mediterranean Sea–Dead Sea Southern alignment than for the Red Sea–Dead Sea PPL project. Even with the added pilot cost, the cost of seawater/brine discharge into the Dead Sea and of desalinated water in Amman is likely to be considerably smaller for the Mediterranean Sea–Dead Sea southern alignment than for the Red Sea–Dead Sea Phased Pipeline.

Non-Comprehensive Alternatives. Nineteen alternatives were also examined that do not comprehensively meet the five criteria described above. They include those identified in previous studies, raised by other parties or proposed by the Study of Alternatives Team, along with combinations of the above. Information available for these alternatives is sometimes limited and often dated. However, it is worth noting that many of these "non-comprehensive" alternatives may be more technically and economically attractive for investors and easier for the parties to implement.

Comprehensive Alternatives – Red Sea–Dead Sea Water Conveyance (BC1) and Mediterranean–Dead Sea Conveyance (TR1) and Combination Alternative No. 1 (CA1)

Both the Red Sea–Dead Sea Water Conveyance Base Case Plus and the Mediterranean–Dead Sea Conveyance Southern A alternatives would be iconic hydraulic infrastructure projects of regional and global significance. Both would address the first three criteria above. They would restore the level of the Dead Sea without imposing unacceptable ecosystem costs except for the uncertainty of impacts on the Dead Sea consequent on the importation and mixing of alien brine from Red Sea or Mediterranean Sea water. The precautionary option of progressive development via pilot phases would add significantly to the capital costs for both alignments. Both conveyances would enable the delivery of potable water to the Beneficiary Parties. Both conveyances would also require and enhance cooperation.

Potable water from the Red Sea–Dead Sea Low Level Gravity Tunnel would be \$1.11-1.24/m^3 or \$1.33-1.50/m^3 by the Red Sea–Dead Sea Phased Pipeline. Potable water delivered by the Mediterranean Sea – Dead Sea conveyance would be \$0.85-0.93/m^3. The Mediterranean Sea–Dead Sea alternative would deliver water at 86 percent of the best Red Sea–Dead Sea LLGT alternative and at 65 percent of the cost of water via the Red Sea–Dead Sea Phased Pipeline. The comprehensive alternatives all require land for water-handling plants, desalination and hydropower plants and, in the case of the pipeline options, land for the conveyance structures. The construction phase would be locally disruptive in all cases, yet long-term negative environmental impacts would be modest. Social impacts would not be significantly negative after mitigation.

From a cost standpoint, the Mediterranean Sea–Dead Sea Conveyance would be the preferred alternative. The region's immediate need to augment potable water supplies could encourage the required tri-lateral cooperation to put this into place. The significant environmental and social impacts of the two comprehensive alternatives can be mitigated. However, and even with appropriate mitigation measures, during construction there would be short term major environmental and social impacts. With proper mitigation and competent management, there would be minimal but permanent post construction environmental and social impacts. See Tables 13.3 and 13.4 below.

One of the Combination Alternatives (CA1) addresses all three objectives – it would save the Dead Sea, meet potable water needs and promote co-operation. Combination CA1 proposes desalination at Aqaba and at the Mediterranean Sea, water importation from Turkey, and substantial water recycling and conservation. The time scale of this alternative would be three or more decades. But this period is not out of line with that which it would take to prepare, complete pilot studies, plan and construct the Red Sea–Dead Sea Water Conveyance.

Non-Comprehensive Alternatives

While none of the non-comprehensive alternatives in this report would totally restore the level of the Dead Sea to the target level of about 416 meters below sea level, they could nevertheless play an incremental role in stabilizing it above its current level. They represent measures that taken individually or alone could have a positive incremental impact on the condition of the Dead Sea.

Two of the technical and water conservation options – TC1, changes in technology of the Dead Sea industries and TC2, increased water conservation in the Lower Jordan – if effectively managed, would deliver additional volumes of water to the Dead Sea but the volumes would have insignificant restoration impacts. The same is the case for the Combined Alternatives, CA2, CA3 and CA4, which would include: in the case of CA2 reduced water to chemical industries and decreased irrigation; in CA3 reduced water to chemical industries and increased recycled water; and in CA4 reduced Jordan water and reduced irrigation water. Again the volumes of water that would potentially flow to the Dead Sea would have negligible impact on Dead Sea levels.

The non-comprehensive alternatives would, by contrast, play a very significant role in providing additional potable water to be shared in the region by making incremental improvements in the availability of potable water. All of the desalination options would provide additional potable water via projects where the construction costs and the costs per cubic meter of potable water would be in line with the current state-of-the-art desalination plants. Since the inception of the Red Sea–Dead Sea Study Program, Israel has installed or has under construction desalination capacity of 600 MCM/year. A capacity of 750 MCM/year is planned to be installed by 2020. But other sources of desalinated water would have to be mobilized over the longer term.

Estimates of the costs of the non-comprehensive alternatives are inadequate to enable precise comparison. However, as they mainly comprise proposed projects that would deliver desalinated water from state-of-the-art plants where the costs of desalinated water are well known, it can be assumed that the capital costs of the proposed desalination plants and the prices of the potable water produced would be acceptable to funders.

The "after mitigation" environmental and social impacts of the non-comprehensive alternatives would be at worst moderate. In many cases, an alternative would improve the current situation. However, and similar to the case under the comprehensive alternatives, during construction of many of the non-comprehensive alternatives there would be major short-term environmental and social impacts. Even with proper mitigation and competent management, for most there would be minimal but permanent post construction environmental and social impacts.

Cooperation: Important for the Beneficiary Parties, Lenders, Donors and Investors

Political Acceptability Is Beyond the Scope of the Study of Alternatives. It is beyond the scope of the Study of Alternatives to assess political acceptability of various alternatives on an individual or comparative basis. In the end it is the Beneficiary Parties that will need to make their own assessments and decisions concerning the complex political issues that would need to be addressed to proceed with the Red Sea–Dead Sea Water Conveyance, other individual alternatives or a combination of alternatives. The outcome of such processes will determine in part how much the Study Program is able to "build a symbol of peace and cooperation in the Middle East."

The Study Program – A Reflection of Cooperation. The Study Program reflects the sustained existence of a cooperative platform established by the Beneficiary Parties to examine potential options to address the challenges of managing the Dead Sea, generating hydropower and producing additional potable water through desalination. The Study of Alternatives expands this process by looking at a range of alternatives beyond the Red Sea–Dead Sea Water Conveyance. Going forward the Beneficiary Parties will need to redefine and renew their platform for cooperation, demonstrating to potential donors and investors, as well as other stakeholders, that there is a long-term commitment to the cooperative management and investment actions that would need to be undertaken.

Importance of Cooperative Frameworks. The Beneficiary Parties will need a variety of cooperative frameworks between governments and/or inter-governmental agreements in order to move from planning to action on the ground to address the diverse challenges of managing the Dead Sea. Such agreements would be required for the development, construction and operation of the infrastructure interventions proposed in many of the alternatives considered in the Study of Alternatives. Mobilization of resources from both public and private sources will require clear and formal arrangements and in many cases, such arrangements will need to be transparent in nature and accessible by investors, donors and the public.

Need for Significant and Sustained Cooperation. All the alternatives examined in this Study of Alternatives would require significant and sustained cooperation among the Beneficiary Parties. The three comprehensive alternatives would promote the deepest cooperation. The international funding bodies that may be called upon to fund the alternatives would require agreement of all the Beneficiary Parties, especially for any alternative that would bring about discharges of brine into the Dead Sea or any projects that would involve moving brine or potable water across the territory of one Beneficiary Party to another.

Elements of Successful Cooperation. Large complex programs of action such as those under consideration require the development of a shared vision among the cooperating parties and key stakeholders that allows for a sustained approach to meeting long-term objectives. The success of cooperation rests on a variety of elements, including: a public commitment to cooperate on a sustained basis; development of a framework for cooperation; and the ability of cooperating parties to adapt to changes that may occur. Beyond these features, in the context of the Dead Sea it would be necessary for the cooperating parties to make use of new management approaches as they evolve, effectively adopt and successful use policy and economic instruments including economic incentives; and have a willingness to apply new technologies and methods at a variety of levels and for diverse purposes.

Approach Used in the Study of Alternatives. The methodology adopted in the Study of Alternatives has been to examine the options on the assumption that the concerned parties will be willing to cooperate to implement them. At the same time, it is necessary to recognize that there are significant risks that some or all parties may not be willing to be cooperative on a sustained basis or at all. These risks to cooperation increase with the number of parties involved, the complexity of actions requiring cooperation and the funding needs for investment and operating costs. The Study of Alternatives Team, in the analysis of alternatives and their comparative review has provided comments concerning these factors in the text and the tables of pros and cons. This has allowed the Team to highlight both the challenges and the opportunities for cooperation associated with a range of alternatives.

Environmental, Social and Cultural Heritage Impacts and Risks

Environmental, Social and Cultural Heritage Impacts and Risks. All alternatives, including the “No Action” alternative, present potential positive and negative environmental, social and/or cultural heritage impacts of varying types and significance. Table 2.1 provides a summary of the studies prepared for potential alternatives over the years. The level of information on environmental, social and cultural heritage aspects of these alternatives is highly variable in nature, ranging from detailed impact assessment studies that have been subject to public consultation and disclosure through studies that only give consideration to engineering and economic aspects.

The potential impacts and risks from the alternatives are summarized in Table 13.3, which provides a broad comparison of all alternatives from a variety of perspectives. This table is complemented by Tables 13.4 and 13.5, which provide an overview of the spatial distribution and magnitude of environmental and social issues whose zones of influence are shown in Map 9. These tables use the same qualitative rating approach as was adopted by ERM (2012) for the Environmental and Social Assessment of the Red Sea – Dead Sea Water Conveyance Box 13.2.

A Variety of Locations and Types of Impacts. As illustrated in Map 9, some alternatives under consideration have potential impacts that may occur over large areas with significant differences in environmental or social conditions. The potential impacts of other alternatives may be more localized. The types of impacts and risks include direct impacts associated with the action, as well as indirect impacts that may be caused or induced by the action. In addition, consideration needs to be given in selection of an alternative or a combination of alternatives to the potential cumulative impacts of the proposed action with other planned or anticipated actions that may occur in the area of influence, including the need for associated infrastructure and other types of facilities. It should be noted that most alternatives involving construction of infrastructure can provide significant flexibility at the local level in terms of siting of facilities, such as desalination plants, or alignment, such as for pipelines. This flexibility allows for development of designs that avoid or reduce impacts on the environment, people and cultural heritage.

An Opportunity for Positive Impacts. Implementation of comprehensive, partial or combination alternatives have the potential to provide positive impacts including: (i) protection and restoration of a global public good by enhancing the status of the Dead Sea; (ii) increasing the availability and reliability of available water to Israel, Jordan and the Palestinian Authority; and (iii) providing opportunities for sustained cooperation between the Beneficiary Parties for resource management and social development. Measures to address the decline of the level of the Dead Sea are also anticipated to reduce the ongoing physical degradation of the areas adjacent to the shoreline, which suffer from land subsidence and the development of sinkholes. Not taking action to address the issue of improving the management and status of the Dead Sea in a timely manner presents a range of risks that need to be recognized when considering alternatives individually or in combination. It is also worth noting that many management related actions with limited impacts and risks can be taken that would partially contribute to both improving the Dead Sea and increasing water supply in the medium and long term.

Potential Modification of Ecosystems. Many of the alternatives reviewed in this study, including the Red Sea–Dead Sea Water Conveyance, Mediterranean Sea–Dead Sea water conveyance options and proposals for transfer of water from Turkey and Iraq would result in direct and indirect modification of ecosystems. The most complex potential impact would be the outcome of mixing variable amounts of Red Sea or Mediterranean Sea water and brine from desalination operations with the water in the Dead Sea. While this has been subject to a number of studies, including a major modeling study by Tahal (2011), given the major impacts and risks associated with these interventions, additional studies, including a physical pilot, are needed before any of these alternatives should move forward. In this regard, special consideration needs to be given to the impact on the chemical and tourism industries from changes in the composition of the water in the Dead Sea. The transfer of fresh water from external sources, such as Turkey or Iraq, using pipelines, tankers or other methods would also have impacts on the ecology of the river channel from which the water is abstracted and further downstream in coastal zones, by reducing the flow of water. In contrast, measures that facilitate the improvement of the quantity and quality of the water flows into the Lower Jordan River would support restoration of both the river and the Dead Sea.

Use of Desalination. With proper site selection and careful design of intakes, the physical and ecological impacts from large scale abstraction of sea water from either the Red Sea or the Mediterranean Sea should be able to be successfully managed. At the same time, desalination facilities require significant land whether they are located on the limited coastal zone of the Beneficiary Parties or at an inland site. Further, desalination requires significant amounts of energy, with associated impacts from generation, and involves the use of membranes and other materials that then need to be disposed of properly. The management of brine generated from the proposed desalination plants varies widely among alternatives, with some using the brine as a resource to recharge the Dead Sea and others disposing of it in the Mediterranean Sea. In the case of the Mediterranean Sea, impacts would vary depending on the sensitivity of the coastal and offshore environment at the proposed location and the design used for brine discharge. The impacts associated with alternatives involving desalination will vary depending on the sites for the intake, plant and discharge. The impacts from operation of the facilities should be generally viewed as directly proportional to the size and technology adopted for the plant(s).

Fresh Water, Sea Water and Brine Conveyance. The transfer of sea water, brine or freshwater through tunnels or pipelines presents potential impacts during construction and operation. The most important issue has been the need to properly assess seismic and other types of geological risks associated with construction and operation of pipelines and tunnels given the concern about their rupture and release of sea water or brine into heavily used aquifers. A concern raised by some parties has been the disruption of biological corridors during the construction period of pipelines and during operation if they are not buried. An additional concern has been impacts on local habitats from the disposal of tunnel excavation waste material. In addition, these investments will require involuntary resettlement and land acquisition that will vary in proportion to the length and alignment of the pipeline, as well as land for disposal of excavated material in the case of tunnels. Risks to cultural heritage also need to be addressed using field based surveys and chance find procedures. These issues under normal circumstances can be addressed by careful selection of the alignment to minimize or avoid impacts, the adoption of designs that provide for significant protection from leakage, and careful construction supervision, including environmental and social monitoring.

Water Management Measures and Use of Economic Incentives. Alternatives under review individually or in combination with others include measures for water conservation, increased use of treated wastewater and greywater, changes in crop types and use of economic incentives. These alternatives present actions that, if taken, could have positive impacts on the use of water resources, regardless of whether measures to manage the Dead Sea are included. The conservation of water and the expanded use of treated wastewater provide opportunities for enhanced surface and groundwater availability and quality. Changes in crop types and irrigation methods can also support a better water balance. The most significant potential benefits over the medium and long term, if successfully adopted and implemented, may result from the use of economic incentives to promote the conservation and more efficient use of water and Dead Sea brine. This would contribute to reduced use of water and brine allowing for a more stable Dead Sea and improvements in the Lower Jordan River.

Increasing the Availability and Reliability of Water. Numerous alternatives focus on supporting actions to increase the water available to the Beneficiary Parties. These alternatives include the creation of natural water though water transfers from outside sources such as Turkey and Iraq, while others focus on manufacturing water from desalination. There are major social benefits from increased availability of additional freshwater in the future including access to high quality water for domestic consumption as well as in the rapidly expanding tourism sector. Creating this new water, hence changing the water balance, creates important opportunities for economic activities and frees up lower quality water for other types of uses. Many remain concerned that there is a risk that additional water reduces incentives to increase water use efficiency; to avoid such an outcome would require a well planned outreach program and careful monitoring.

Diverse Social Impacts and Risks. The alternatives reviewed in the Study present diverse direct and indirect social impacts and risks. Consideration of social issues is an important element in determining the potential benefits and viability of an alternative and special consideration should be given to the differential impact on women, the needs of disadvantaged groups and social equity. While broad views of the potential social impacts of alternatives have been provided in Table 13.5, these issues can only be effectively assessed in detail at the project level using qualified social scientists working at the field level and engaging with communities.

Involuntary Resettlement and Land Acquisition. A major issue with a number of the alternatives under consideration, especially the water transfer and desalination alternatives, is the anticipated need for involuntary resettlement and land acquisition. While the government in many instances is the formal owner of the land, recognition needs to be given to often long established informal use of these lands by local communities and in some cases nomadic populations. Some alternatives, particularly those concerning conveyance from the Mediterranean Sea to the Dead Sea, pass through areas on the coast and inland that are heavily populated, in contrast to the sparse population living between the Red Sea and the Dead Sea, with the exception of the Aqaba/Eilat region. Implementing alternatives in more densely settled areas should be anticipated to be more complex in their planning and permitting, and more expensive with regard to compensation for land, structures and other losses. In all cases, it would be important to have site specific resettlement and land acquisition plans developed on the basis of a social assessment and consultation process and including a grievance mechanism to address disputes.

Regional Development and Employment. Alternatives that have been reviewed have a potential to support regional development, including tourism development, and generate employment during construction and operation. Potential benefits for tourism, especially at the Dead Sea, include improved conditions that lead to an incremental reversal of the decline of this unique resource. In contrast, significant adverse impacts could result from the discharge of brine into the Dead Sea without adequate knowledge regarding the potential for an aesthetically adverse reaction, which would lessen the amenity value of the region and reduce tourist interest. While local employment opportunities will be created by alternatives that involve construction activities, it will be important to manage public expectations in this regard. . Construction activities as proposed would require a large number of workers during the construction and commissioning phases but would have limited needs for longer term employment during operations. All alternatives that involve construction will need to carefully manage the potential influx of foreign workers and associated risk of social conflict. In addition, induced environmental and social impacts, such as informal settlement adjacent to construction sites, presents a challenge that will need to be analyzed and controlled on a case by case basis.

Management of Health and Safety. All alternatives that involve building will require measures for management of construction phase impacts and provisions to address the health and safety of local communities and workers (World Bank Group, Environment, Health and Safety Guidelines, 2007). Common problems include construction related impacts from nuisances and disturbances such as noise, vibration and dust that need to be carefully monitored and controlled by the government, contractors and others. Measures would also need to be taken to address health and safety of workers as a key element of planning and oversight during the construction period to protect them and others from a range of risks. All construction related activities should include provisions for the management of risk associated with HIV/AIDs. Potential impacts to health and safety should be anticipated to be proportional to the size of the construction program and the complexity of operating facilities that may be built to implement an alternative.

Cultural Heritage – A Special Issue. The protection and conservation of cultural heritage is a special issue that needs to be given significant consideration in the development and implementation of nearly every alternative reviewed in this study. This is a concern that is highly site specific and requires the conduct of field based surveys by qualified parties to determine the potential impacts and risks to cultural resources (World Bank 2009). While the importance of cultural heritage in the region is widely recognized it has not been a significant factor when parties have proposed and developed alternatives. The Red Sea–Dead Sea Water Conveyance included the conduct of this type of survey as part of the Environmental and Social Assessment (ERM 2011). Other alternatives, to the knowledge of the Study of Alternatives Team, have not undertaken the field based surveys which would be needed to fully assess their potential impacts. Use of properly supervised “chance find procedures” would be needed, given the high concentration of cultural resources, both known and unknown, in areas where alternatives that involve construction or other activities would result in changes to the surface and immediate subsurface of land.

A Need for Management, Mitigation and Monitoring. A decision to proceed with one or more of the alternatives by the Beneficiary Parties would require development and implementation on a project specific basis of a robust and properly funded environmental and social management plan. The plan would be used to integrate these concerns into design, implementation and operation of the project or projects. This would include specific provisions for addressing these issues in the project budget and integrating key measures into the implementation schedule. Provisions should be included for implementation and monitoring of various types of measures for management and mitigation of potential adverse impacts by government agencies with specialized capacities. Where appropriate, use should be made of third party monitoring, which is an emerging good practice for complex projects.

Continued Use of an Independent Panel of Experts. Consistent with established international good practice, the use of an independent Panel of Experts should be continued if a decision is made by the Beneficiary Parties to proceed with further development and/or implementation of the alternatives reviewed in this study. The use of a Panel of Experts would be beneficial to all stakeholders given the complexity of the actions proposed under nearly all of the alternatives and the sensitive environmental and social setting and extensive cultural heritage in the region.

Comparative Tables

Table 13.1 – Summary Comparison by Selected Cost Criteria. The table compares each alternative against selected criteria in the Terms of Reference for the Study of Alternatives. It also calculates the cost of potable water in Amman for alternatives where such a calculation was possible. In addition, it shows a judgment in the form of a "Viability Assessment" for each element of the table which represents the subjective view of the Study of Alternatives Team on the difficulty of realization of this alternative.

Table 13.2 – Water Conveyance for Dead Sea Stabilization Only. The table proves a physical and cost description of the nine Dead Sea "stabilization only" alternatives. It includes the estimated construction costs and electricity potential for each option and an indication of the elevation profile.

Table 13.3– Comparison of Alternatives. The table provides the reader with a visual presentation to compare each alternative as follows: (i) whether or not it can address the three Study Program objectives; (ii) an indication of its capital cost and energy requirements; and (iii) its potential environmental and social impacts both before and after mitigation measures.

Table 13.4 – Spatial Distribution and Magnitude of Potential Environmental Impacts. The table is organized by geographical location and is designed to provide the reader with a visual representation of the potential environmental impacts and risks of the various alternatives. For example looking at the Dead Sea Coast, nearly all the alternatives, with the exception of the No Action alternative, would have a positive impact on this highly sensitive area. The assessment methodology is outlined in Box 13.2 below.

Table 13.5 – Spatial Distribution and Magnitude of Potential Social Impacts. The table is organized by geographical location (see Map 9) and is designed to provide the reader with a visual representation of the potential social impacts and risks of the various alternatives. For example the "No Action" alternative has a major social impact on the Dead Sea Coast and Dead Sea. In contrast for many alternatives the social impact would be moderate or slight/none. The assessment methodology is outlined in Box 13.2 below.

Box 13.2: Impact Assessment Methodology

Key: ● = positive; O= slight/none; ● = moderate; ● = major

The Study of Alternatives Team has reviewed the potential environmental and social impacts from the alternatives. using the approach adopted by ERM for the Environmental and Social Assessment prepared for the Red Sea – Dead Sea Water Conveyance Study Program and providing ratings for both before and after adoption of mitigation measures.

The assessment has addressed impacts with different temporal characteristics (permanent impacts, temporary impacts, long-term impacts) and both routine impacts and non-routine impacts (i.e., those arising from unplanned or accidental events or external events).

Induced impacts, for example those caused by stimulating other developments to take place are also considered in the assessment, as are cumulative impacts with other developments taking place in the area at the same time.

The definition of these degrees of significance has been expressed in terms of design response as follows:

- Critical: the effect on a sensitive receptor is so severe as to be unacceptable (either because it breaches standards or norms relating to human health and livelihood, or causes irreversible damage to a valuable asset or resource) and mitigation is unlikely to change this;
- Major: the effect on a sensitive receptor must be mitigated, either because it breaches relevant standards, norms, guidelines or policy, or causes long-lasting damage to a valuable or scarce resource;
- Moderate: the effect on a sensitive receptor is either transient or mainly within currently accepted standards, etc., but should be mitigated to ensure that the effect does not become significant by virtue of cumulation or poor management;
- Slight/none: the effect is temporary, of low magnitude, within accepted standards etc, and of little concern to stakeholders; and
- Positive: The effect on the sensitive receptors is to improve their current state.

The Study of Alternatives Team, for the sake of consistency, has used the same approach to significance adopted for the Environmental and Social Assessment. As stated in the ESA, since there no statutory or agreed definition of significance, for the purposes of this assessment, the following practical definition is used:

"An impact is significant if, in isolation or in combination with other impacts, it should, in the judgment of the Environmental and Social Assessment team, be reported in the Environmental and Social Assessment Report so that it can be taken into account in the decision on whether or not the Scheme should proceed and if so under what conditions."

Table 13.1: Alternatives Compared by Selected Cost Criteria (% is assumed annual cost of capital)

Alternative	Case	Comments	Potable Water in Amman: Quantity satisfies demand schedule?	Potable Water in Amman: Cost (>2060) (US$/m^3)	Water Discharge in the Dead Sea: Quantity sufficient to stabilize Dead Sea water level?	Water Discharge in the Dead Sea: Annual cost (US$million)	Viability Assess-ment*
No Action NA1			NA	> 2	No	NA	High
Red Sea - Dead Sea Water Conveyance	Low Level Gravity Tunnel BC1	High Level Desalination and Hydropower Generation for a range interest rates	Yes	1.11 (4%) - 1.24 (6%)	Yes	58 -- 226	Medium/ High
	Phased Pipe Line BC2		Yes	1.33 (4%) - 1.50 (6%)	Yes	114 -- 247	High
Lower Jordan River Restoration	Full and Partial FL1/FL2	Releases from Lake Tiberias	No	Added cost: 0.38	No	NA	High
		North Mediterranean Sea – Dead Sea	No	Added cost: 0.5 - 0.75	No	NA	Medium
		Recycled Wastewater	No	NA	No	NA	High
Water Transfer Options	From Mediterranean to Dead Sea TR1.1 – TR1.4	Southern A - Ashkelon–North Dead Sea, low level desalination and hydropower	Yes	0.85 (4%) - 0.93 (6%)	Yes	-60 (2%) to 99 (6%)	Medium/ High
		Southern A - Ashkelon–North Dead Sea, low level desalination and hydropower (Phased)	Yes	0.85 (4%) - 0.93 (6%)	Yes	-38 (2%) to 148 (6%)	Medium
		Northern - Atlit to Naharayim-Bakura with hydropower		1.14 (6%)	No	NA	Medium
		Northern -Atlit to Naharayim-Bakura without hydropower	Yes	1.38 (6%)	No	NA	Medium
	Major Pipelines TR2 – TR3	From Turkey Seyhan-Ceyhan Rivers	Not certain	NA	No	NA	Low
		From Iraq–Euphrates River	No	NA	No	NA	Low
Desalination Options	Mediterranean Sea Water on Mediterranean Coast with Transfer to Lower Jordan River and Dead Sea DS1		Yes	?	No	NA	Medium
	Transfer of Mediterranean Sea Water to Jordan Valley for Local Desalination and Use in Lower Jordan River and Dead Sea Region DS2		Yes	?	No	NA	Medium

Alternative	Case	Comments	Potable Water in Amman: Quantity satisfies demand schedule?	Potable Water in Amman: Cost (>2060) (US$/m³)	Water Discharge in the Dead Sea: Quantity sufficient to stabilize Dead Sea water level?	Water Discharge in the Dead Sea: Annual cost (US$million)	Viability Assess-ment*
	Increased Desalination Med Sea Water on Mediterranean Coast with Transfer for Use by Three Beneficiary Parties to Reduce Water Demand from Lower Jordan River DS3		Yes	?	No	NA	Medium
	Red Sea Water at Gulf of Aqaba/Eilat with Transfer for Use by the Three Beneficiary Parties to Reduce Water Demand from Lower Jordan River DS4		Yes	?	No	NA	Medium
Technical Conservation options	Chemical Industries TC1	Arab Potash Company Dead Sea Works	No	?	No	NA	Medium
	Increased conservation and use of treated wastewater and greywater in agriculture TC2		No	?	No	NA	High
	Changes in crop types and cultivation methods TC3		No	?	No	NA	Medium
Additional Alternatives Identified by Study Team	Selling electricity to Israel based on Israeli peak-load pricing with and without storage AA1	See Main Report, Section 11 – Costs Vary According to Assumptions Used	Yes	$1.11-$1.50	Yes	58-247	Medium
	Tankering and Bags AA2	From Manavgat or Seyhan-Ceyhan Rivers in Turkey	No	1.5 - 4.5	No	NA	Low
	Transfer by Underwater Marine Pipeline (Medstream)AA3		Not Certain	?	No	NA	Low
Combination Options	No. 1. Desalination at Aqaba and Mediterranean Sea, Water Importation from Turkey, and Water Recycling and Conservation	Would require close and sustained cooperation between the Beneficiary Parties concerning planning, investment and management actions	Potentially	?	Partially	NA	Low/ Medium

Alternative	Case	Comments	Potable Water in Amman: Quantity satisfies demand schedule?	Potable Water in Amman: Cost (>2060) (US$/m^3)	Water Discharge in the Dead Sea: Quantity sufficient to stabilize Dead Sea water level?	Water Discharge in the Dead Sea: Annual cost (US$million)	Viability Assess-ment*
	No. 2. Decreased chemical industry water extraction and decreased irrigation through cropping and other agronomic changes CA2		No	?	No	NA	Low
	No. 3. Aqaba desalination plus decreased use from the chemical industries, plus increases in recycled water for irrigation CA3		No	?	No	NA	Low
	No. 4. Reduced extractions from the Jordan River, plus Aqaba regional desalination and decreased irrigation use though agronomic changes CA4		No	?	No	NA	Low

**** Viability Assessment Ranking***

High The alternative can be realized/constructed through determined cooperation efforts and the application of moderate mitigation measures.

Medium The alternative can be realized/constructed through very determined and sustained cooperation efforts plus the application of significant environmental and social mitigation measures.

Low The level of cooperation effort, and/or the environmental and social costs, required to realize/construct the alternative are so significant that it makes the alternative very unlikely to be undertaken.

Table 13.2: Water conveyance for Dead Sea stabilization only (quantity, length, effective elevation, power generation, capital cost) does not include added costs associated with desalination

			Quantity of Water (MCM)[1] (Q)	Total Length of the Water Conveyance (km)	Effective Elevation (m) (h)	Power Generation (GWh/year)[2]	Power Generation (MW)	Construction (Capital) Cost (Billion US$)
Red Sea-Dead Sea Water Conveyance	Low Level Gravity Tunnel (LLGT)		Unlimited	180	390	1911	218	5.80
	Phased Pipeline (PPL)		Unlimited	180	324	1588	181	3.43
Mediterranean Sea –Dead Sea Water Conveyance	Southern Alignment (A)	Low Level Gravity Tunnel	Unlimited	90	--	--	--	3.67
		Phased Pipeline	Unlimited	90	145	711	81	3.05
	Southern Alignment (B)	Phased Pipeline	Unlimited	90	238	1166	133	3.3
	Northern Alignment Phased Pipeline	With Hydropower	Unlimited	65-70	220	1078	123	1.69 [3]
		Without Hydropower	Unlimited	65-70	220	--	--	1.69 [3]
Transfer of Water from Seyhan and Ceyhan Rivers in Turkey by Pipeline			400	800	>1500 Cumulative[4]	nil	nil	5.00 [5]
Transfer of Water from the Euphrates River in Iraq by Pipeline			160	600	500	nil	nil	not available

[1]Quantity of Water Assumed 2000 MCM/year i.e., flow rate of ≈ 63.0 m^3/s.
[2]Power (W) = ρ*Q*h*g (ρ is the density of water, Q is the flow rate of water in m3/sec, h is the height difference in m, and g is 9.8 m/s2. The actual hydropower is about 90% of the theoretical value).
[3]Construction cost for conveyance from Atlit to Naharayim-Bakura.
[4] This alignment would require many pumping lifts.
[5] 1992 costs from: Gruen, G. E., 1994, Contribution to water imports to Israeli-Palestinian-Jordanian Peace, Shuval, H. and Isaac, J., *Water & peace in the Middle East,* Proceedings of the first Israeli-Palestinian conference on water resources, held in Zurich in 1992, Amsterdam: Elsevier, pp 273-288.

Table 13.3: Comparison of Alternatives

Key: ✗ No; ✓ Yes; $ Billion USD; ⚡ Gigawatt hour; 🟢 = positive; ○ = slight/none; 🟠 = moderate; 🔴 = major

Alterna-tive Code	Alternative name	Stabilizes level of Dead Sea	Provides water for three benefi-ciaries	Gener-ates hydro-power	Promotes regional cooperation	Capital cost billions USD $	Net energy requirement GWH/yr	Environmental impact		Social impact	
								Before mitigation	After mitigation	Before mitigation	After mitigation
A – No Action											
NA1	No Action	✗	✗	✗	✗	cost of damage to infrastructure and tourism		🔴		🔴	
B – Red Sea–Dead Sea Water Conveyance											
BC1	Base case plus – Low Level Gravity Tunnel (LLGT)	✓	✓	✓	✓	$$$$$ $$$$$	⚡⚡⚡⚡ ⚡⚡	🔴	🟠/🔴	🟠	🟠
BC2	Base case plus – Phased Pipeline (PPL)	✓	✓	✓	✓	$$$$$ $$$$$	⚡⚡⚡⚡ ⚡⚡	🔴	🟠/🔴	🟠	🟠
C – Lower Jordan River Restoration – Partial Restoration of Jordan River Flows											
FL1	Full restoration of historic Jordan River flow levels	✗	✗	✗	✓	not known; but costly	⚡⚡	🔴	🟢	🔴	🟠
FL2	Partial restoration of historic Jordan River flow levels	✗	✗	✗	✓	$$	⚡⚡	🔴	🟢	🔴	🟠
D – Water Transfer Options											
TR1.1	Transfer of Mediterranean Sea water to the Dead Sea – Southern A (Low Level Tunnel)	✓	✓	✓	✓	$$$$$	⚡⚡⚡⚡ ⚡	🔴	🟠	🟠	🟢
TR1.2	Transfer of Mediterranean Sea water to the Dead Sea – Southern B (Phased Pipeline and Gravity Tunnel)	✓	✓	✓	✓	$$$$$	⚡⚡⚡⚡	🔴	🟠	🟠	🟢
TR1.3	Transfer of Mediterranean Sea water to the Dead Sea – Northern with hydropower	✗	✗	✓	✓	$$$$$	⚡⚡⚡	🔴	🟠	🟠	🟠

Alternative Code	Alternative name	Stabilizes level of Dead Sea	Provides water for three beneficiaries	Generates hydropower	Promotes regional cooperation	Capital cost billions USD $	Net energy requirement GWH/yr	Environmental impact		Social impact	
								Before mitigation	After mitigation	Before mitigation	After mitigation
TR1.4	Transfer of Mediterranean Sea water to the Dead Sea – Northern without hydropower	✗	✗	✗	✓	$$$$	⚡⚡⚡⚡	Red	Orange	Orange	Orange
TR2	Transfer of water from Turkey by pipeline (Peace Pipeline)	✗	✓	✗	✓	$$$$$ $	⚡⚡⚡⚡ ⚡	Red	Orange	Red	Orange
TR3	Transfer of water from the Euphrates River Basin by pipeline	✗	✓	✗	✗	$$$$	⚡⚡⚡	Red	Orange	Red	Orange
E - Desalination Options											
DS1	Samuel Neaman Institute MD-1 alignment - Desalination of Mediterranean Sea Water on the Mediterranean Coast with Transfer to the Lower Jordan River and Dead Sea Region	✓	✓	✓	✓	$$$$$ $	⚡⚡⚡⚡ ⚡⚡⚡	Red	Orange / Red	Red	?
DS2	Samuel Neaman Institute MD-2 alignment - Transfer of Mediterranean Sea Water to the Jordan Valley for Local Desalination and Use in Lower Jordan River and Dead Sea Region	✓	✓	✗	✓	$$$$$ $	⚡⚡⚡⚡ ⚡	Red	Orange	Orange	Green
DS3	Increased Desalination of Mediterranean Sea Water on the Mediterranean Coast with Transfer for Use by the Three Beneficiary Parties to Reduce Water Demand from Lower Jordan River	✗	✓	✗	✓	$$$	⚡⚡⚡⚡	Red	Orange	Red	Orange
DS4	Desalination of Red Sea Water at the Gulf of Aqaba/Eilat with Transfer for Use by the Three Beneficiary Parties to Reduce Water Demand from Lower Jordan River	Partial but not sufficient	✓	✗	✓	$	⚡⚡⚡	Red	Orange	Orange	Green
F - Technical and Water Conservation Options											
TC1	Changes of technology used by the Dead Sea Chemical Industry	Partial but not	✗	✗	✓	Unknown	Unknown	Red	Orange	Red	Green

Alterna-tive Code	Alternative name	Stabilizes level of Dead Sea	Provides water for three benefi-ciaries	Gener-ates hydro-power	Promotes regional cooperation	Capital cost billions USD $	Net energy requirement GWH/yr	Environmental impact		Social impact	
								Before mitigation	After mitigation	Before mitigation	After mitigation
		sufficient									
TC2	Increased water conservation in the Lower Jordan River Basin	✗	✓	✗	✓	Unknown	Unknown	🔴	🟠/🟢	🟠	🟠
TC3	Increased use of wastewater and greywater	✗	✓	✗	✗	Unknown but substantial	Unknown	🔴	🟠/🟢	🔴	🟢
TC4	Changes in crop types and cultivation methods	✗	✓	✗	✗	Unknown but substantial	Unknown	🟠	🟠/🟢	🟠	🟠
G - Additional Alternatives Identified by the Study of Alternatives Team											
AA1	Selling electricity to Israel and pumped storage	✓	✓	✓	✓	$$$$$$ $$$$$	⚡⚡⚡⚡⚡ ⚡	🔴	🟠/🔴	🟠	🟠
AA2	Transfers by Tanker and Bags	✗	✓	✗	✓	$	⚡	🟠	🟢	🟢	🟢
AA3	Transfers by Sub-marine Pipeline from Turkey	✗	✓	✗	✓	$$$$$$	⚡⚡⚡⚡⚡	🟠	🟠	🟢	🟢
H - Combination of Alternatives											
CA1	Desalination at Aqaba and Mediterranean Sea, water importation from Turkey, and water recycling and conservation	✓	✓	✗	✓	Unknown but substantial	⚡⚡⚡⚡⚡	🔴	🟢	🟠	🟢
CA2	Decreased chemical industry water extraction and decreased irrigation through cropping and other agronomic changes	Partial but not sufficient	✓	✗	✓	Unknown but substantial	Unknown but substantial	🟠	🟠/🟢	🟠	🟠
CA3	Aqaba desalination plus decreased use from the chemical Industries, plus increases in recycled water for irrigation	Partial but not sufficient	✓	✗	✓	$$	⚡⚡	🔴	🟠	🔴	🟠
CA4	Reduced extractions from the Jordan River, plus Aqaba desalination and decreased irrigation use though agronomic changes	Partial but not sufficient	✓	✗	✓	$$	⚡⚡	🔴	🟠	🔴	🟠

Table 13.4: Spatial Distribution and Magnitude of Potential Environmental Impacts

Key: ● (green) = positive; O = slight/none; ● (orange) = moderate; ● (red) = major

Alternative Code	Alternative	Red Sea – Dead Sea Area: Red Sea	Red Sea Coast	Wadi Araba/Arava Valley	Desalination Plant and Hydro-power Plant	Chemical Industries	Dead Sea Coast	Dead Sea	Desalinated Water Conveyance	Other Areas: Lower Jordan River	Eastern Mediterranean Sea	Eastern Mediterranean Coast	Transfer Eastern Med to Dead Sea	Comments
Relative Sensitivity of Area (Low, Medium, High)		**M**	**M**	**H**	**M**	**H**	**M**	**H**	**M**	**H**	**M**	**M**	**H**	
A – No Action														
NA 1	No Action	O	O	O	O	● (moderate)	● (major)	● (major)	O	● (moderate)	O	O	O	
B – Red Sea -- Dead Sea														
BC1	• Low Level Gravity Tunnel (LLGT)	● (moderate)	● (moderate)	● (major)	● (moderate)	● (moderate)	● (positive)	● (major)	● (moderate)	O	O	O	O	High Level Elevation Desalination and Hydropower Facilities
BC2	• Phased Pipeline (PPL)	● (moderate)	● (moderate)	● (moderate)	● (moderate)	● (moderate)	● (positive)	● (major)	● (moderate)	O	O	O	O	
C – Lower Jordan River Restoration – Partial Restoration of Jordan River Flows														
FL1	• Releases from Lake Tiberias	O	O	O	O	O	● (positive)	● (positive)	O	● (positive)	O	O	O	
FL2	• Production and Transfer of Desalinated Water from Mediterranean Sea	O	O	O	O	O	● (positive)	● (positive)	● (positive)	● (positive)	● (moderate)	● (moderate)	● (moderate)	
FL3	• Recycled Treated Wastewater	O	O	O	O	O	O	● (positive)	O	● (positive)	O	O	O	
D – Water Transfer Options														
TR1.1	*From Mediterranean to Dead Sea* • Southern A - Ashkelon to Northern Dead Sea (Low Level Tunnel)	O	O	● (moderate)	● (moderate)	● (moderate)	● (positive)	● (major)	● (positive)	O	● (moderate)	● (moderate)	● (major)	Low Elevation Desalination and Hydropower Facilities
TR1.2	• Southern A - Ashkelon to Southern Dead Sea (Phased Pipeline and Gravity Tunnel)	O	O	● (moderate)	● (moderate)	● (moderate)	● (positive)	● (major)	● (positive)	O	● (moderate)	● (moderate)	● (major)	Phased Low Elevation Desalination and

Alternative Code	Alternative	Red Sea – Dead Sea Area								Other Areas				Comments
		Red Sea	Red Sea Coast	Wadi Araba/Arava Valley	Desalination Plant and Hydro-power Plant	Chemical Industries	Dead Sea Coast	Dead Sea	Desalinated Water Conveyance	Lower Jordan River	Eastern Mediterranean Sea	Eastern Mediterranean Coast	Transfer Eastern Med to Dead Sea	
Relative Sensitivity of Area (Low, Medium, High)		**M**	**M**	**H**	**M**	**H**	**M**	**H**	**M**	**H**	**M**	**M**	**H**	
														Hydropower Facilities
TR1.3	• Northern A - Atlit to Naharayim-Bakura – with hydropower	**O**	**O**	**O**	🟠	🟠	🟢	🔴	🟢	🟢	🟢	🟠	🔴	With Hydropower
TR1.4	• Northern B - Atlit to Naharayim-Bakura – without hydropower	**O**	**O**	**O**	🟠	🟠	🟢	🔴	🟢	🟢	🟢	🟠	🔴	Without hydropower
TR2	*Pipelines* • From Turkey Seyhan-Ceyhan Rivers	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**	🟢	🟠	🔴	🟠	Turkish authorities indicate that proposed withdrawal was not feasible due to inadequate quantities of water Proposed to provide fresh water for drinking water purposes only
TR3	• From Iraq – Euphrates River	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**	This is an old proposal; water from the Euphrates does not appear to be available at this time. Proposed to provide fresh water for drinking water purposes only
E – Desalination Options														
DS1	• Desalination of Mediterranean Sea Water on the Mediterranean Coast with	**O**	**O**	**O**	**O**	**O**	**O**	**O**	🟠	**O**	🟠	🟠	🟠	Desalination to occur on Med.

Alternative Code	Alternative	Red Sea – Dead Sea Area								Other Areas				Comments
		Red Sea	Red Sea Coast	Wadi Araba/Arava Valley	Desalination Plant and Hydro-power Plant	Chemical Industries	Dead Sea Coast	Dead Sea	Desalinated Water Conveyance	Lower Jordan River	Eastern Mediterranean Sea	Eastern Mediterranean Coast	Transfer Eastern Med to Dead Sea	
Relative Sensitivity of Area (Low, Medium, High)		**M**	**M**	**H**	**M**	**H**	**M**	**H**	**M**	**H**	**M**	**M**	**H**	
	Transfer to the Lower Jordan River and Dead Sea													Coast
DS2	• Transfer of Mediterranean Sea Water to the Jordan Valley for Local Desalination and Use in Lower Jordan River and Dead Sea Region	**O**	**O**	**O**	**O**	**O**	**O**	🔴	🟠	🟢	🟠	🟠	🔴	Desalination plant located north of Dead Sea
DS3	• Increased Desalination of Mediterranean Sea Water on the Mediterranean Coast with Transfer for Use by the Three Beneficiary Parties to Reduce Water Demand from Lower Jordan River	**O**	**O**	**O**	**O**	**O**	**O**	**O**	🟢	**O**	**O**	🟠	🟢	
DS4	• Desalination of Red Sea Water at the Gulf of Aqaba/Eilat with Transfer for Use by the Three Beneficiary Parties to Reduce Water Demand from Lower Jordan River	🟠	🟠	🟠	🟠	🟠	🟢	🟢	🟠	🟢	**O**	**O**	**O**	
F – Technical and Water Conservation Options														
TC1	• Potash Industries New Technologies	**O**	**O**	**O**	**O**	🟢	🟢	🟢	**O**	**O**	**O**	**O**	**O**	
TC2	• Increased Water Conservation in the Lower Jordan River Basin	**O**	**O**	**O**	**O**	🟢	🟢	🟢	**O**	🟢	**O**	**O**	**O**	
TC3	• Increased Use of Treated Wastewater and Grey Water	**O**	**O**	**O**	**O**	**O**	🟢	🟢	**O**	🟢	**O**	**O**	**O**	
TC4	• Changes in Crop Types and Cultivation Methods	**O**	**O**	🟢	**O**	**O**	🟢	🟢	**O**	🟢	**O**	**O**	**O**	

Alternative Code	Alternative	Red Sea – Dead Sea Area								Other Areas				Comments
		Red Sea	Red Sea Coast	Wadi Araba/Arava Valley	Desalination Plant and Hydro-power Plant	Chemical Industries	Dead Sea Coast	Dead Sea	Desalinated Water Conveyance	Lower Jordan River	Eastern Mediterranean Sea	Eastern Mediterranean Coast	Transfer Eastern Med to Dead Sea	
Relative Sensitivity of Area (Low, Medium, High)		**M**	**M**	**H**	**M**	**H**	**M**	**H**	**M**	**H**	**M**	**M**	**H**	
G – Additional Alternatives Identified by Study Team														
AA1	• Selling electricity to Israel based on Israeli peak-load pricing with and without storage	O	O	O	O	O	O	O	O	O	O	O	O	See section 11
AA2	• Transfers by tanker, bag and sub-marine pipeline from Manavgat in Turkey	O	O	O	O	O	O	O	O	O	🟠	🟠	🟠	For drinking water purposes
AA3	• Sub-marine pipelines associated with oil and energy conveyance-Medstream	O	O	O	O	O	O	O	O	🟠	🟠	🟠	🟠	For drinking water purposes; Impacts shared with energy and oil services; small water volume
H – Combination of Alternatives														
CA1	• No. 1. Desalination at Aqaba and Mediterranean Sea, water importation from Turkey and water recycling and conservation	🟠	🟠	🟠	🟠	🟠	🟢	🟠 / 🟢	🟠	🟢	🟢	🟠	🟠	
CA2	• No. 2. Decreased chemical industry water extraction and decreased irrigation through cropping and other agronomic changes	O	O	O	O	🟠	🟢	🟢	O	🟢	O	O	O	
CA3	• No. 3. Aqaba desalination plus decreased use from the chemical industries, plus increases in recycled water for irrigation	🟠	🟠	🟠	🟠	O	🟢	O	🟠	O	O	O	O	Desalination facility located at Aqaba on Red Sea
CA4	• No. 4. Reduced extractions from the Jordan River, plus Aqaba regional desalination and decreased irrigation use though agronomic changes	🟠	🟠	🟠	🟠	🟠	🟠	O	🟠	🟢	O	O	O	

Table 13.5: Spatial Distribution and Magnitude of Potential Social Impacts

Key: ● (green) = positive; O = slight/none; ● (orange) = moderate; ● (red) = major

Alternative Code	Alternative	Red Sea – Dead Sea Area								Other Areas				Comments
		Red Sea	Red Sea Coast	Arava Valley/ Wadi Araba	Desalina-tion Plant and Hydro-power Plant	Chemical Industries	Dead Sea Coast	Dead Sea	Desali-nated Water Conve-yance	Lower Jordan River	Eastern Medi-terranean Sea	Eastern Medi-terranean Coast	Transfer Eastern Med to Dead Sea	
Relative Sensitivity of Area (Low, Medium, High)		M	M	H	M	H	M	H	L	H	L	M	H	
A – No Action														
NA1	No Action	O	O	O	O	● (orange)	● (red)	● (red)	O	O	O	O	O	
B – Red Sea -- Dead Sea														
BC1	• Low Level Gravity Tunnel (LLGT)	● (orange)	● (orange)	● (red)	● (green)	● (orange)	● (green)	O	● (green)	O	O	O	O	High Level Elevation Desalination and Hydropower Facilities
BC2	• Phased Pipeline (PPL)	● (orange)	● (orange)	● (orange)	● (green)	● (orange)	● (green)	O	● (green)	O	O	O	O	
C – Lower Jordan River Restoration – Partial Restoration of Jordan River Flows														
FL1	• Releases from Lake Tiberias	O	O	O	O	O	O	● (green)	O	● (green)	O	O	O	
FL2	• Production and Transfer of Desalinated Water from the Mediterranean Sea	O	O	O	O	O	● (green)	● (green)	O	● (orange)	● (orange)	● (orange)	● (orange)	
FL3	• Recycled Treated Wastewater	O	O	O	O	O	O	● (green)	O	● (green)	O	O	O	
D – Water Transfer Options														
TR1.1	*From Mediterranean to Dead Sea* • Southern A - Ashkelon to North Dead Sea (Low Level Gravity Tunnel)	O	O	O	O	O	● (orange)	● (red)	O	O	O	● (orange)	● (red)	Low Elevation Desalination and Hydropower Facilities
TR1.2	• Southern B - Ashkelon to North Dead Sea (Phased Pipeline and Gravity Tunnel)	O	O	O	O	O	● (orange)	● (red)	O	O	O	● (orange)	● (red)	**Phased** Low Elevation Desalination and Hydropower

Alternative Code	Alternative	Red Sea – Dead Sea Area								Other Areas				Comments
		Red Sea	Red Sea Coast	Arava Valley/ Wadi Araba	Desalination Plant and Hydro-power Plant	Chemical Industries	Dead Sea Coast	Dead Sea	Desalinated Water Conveyance	Lower Jordan River	Eastern Mediterranean Sea	Eastern Mediterranean Coast	Transfer Eastern Med to Dead Sea	
Relative Sensitivity of Area (Low, Medium, High)		M	M	H	M	H	M	H	L	H	L	M	H	
														Facilities
TR1.3	• Northern A - Atlit to Naharayim-Bakura – with hydropower	O	O	O	🟠	🟠	🟢	🟢	🟢	🟢	🟠	🟠	🔴	With Hydropower
TR1.4	• Northern B - Atlit to Naharayim-Bakura – without hydropower	O	O	O	🟠	🟠	🟢	🟢	🟢	🟢	🟠	🟠	🔴	Without hydropower
TR2	*Pipelines* • From Turkey Seyhan-Ceyhan Rivers	O	O	O	O	O	O	O	O	🟢	🟢	🟢	O	Proposed to provide fresh water for drinking water purposes only
TR3	• From Iraq – Euphrates River	O	O	O	O	O	O	O	O	O	O	O	O	
E – Desalination Options														
DS1	• Desalination of Mediterranean Sea Water on the Mediterranean Coast with Transfer to the Lower Jordan River and Dead Sea	O	O	O	🟠	🟢	🟢	🟢	🟠	🟢	🟠	🟠	🟠	Desalination to occur on Med. Coast
DS2	• Transfer of Mediterranean Sea Water to the Jordan Valley for Local Desalination and Use in Lower Jordan River and Dead Sea Region	O	O	O	🟠	🟢	🟢	🟢	🟠	🟢	🟠	🟠	🔴	Desalination plant located north of Dead Sea
DS3	• Increased Desalination of Mediterranean Sea Water on the Mediterranean Coast with Transfer for Use by the Three Beneficiary Parties to Reduce Water Demand from Lower Jordan River	O	O	O	🟠	🟢	🟢	🟢	🟠	🟢	🟠	🟠	🟠	
DS4	• Desalination of Red Sea Water at the Gulf of Aqaba/Eilat with Transfer for Use by the Three Beneficiary Parties to Reduce Water Demand from Lower Jordan River	🟠	🟠	🟠	🟠	🟠	🟢	🟠	🟠	O	O	O	O	
F – Technical and Water Conservation Options														

Alternative Code	Alternative	Red Sea – Dead Sea Area								Other Areas				Comments
		Red Sea	Red Sea Coast	Arava Valley/ Wadi Araba	Desalina-tion Plant and Hydro-power Plant	Chemical Industries	Dead Sea Coast	Dead Sea	Desali-nated Water Conve-yance	Lower Jordan River	Eastern Medi-terranean Sea	Eastern Medi-terranean Coast	Transfer Eastern Med to Dead Sea	
Relative Sensitivity of Area (Low, Medium, High)		**M**	**M**	**H**	**M**	**H**	**M**	**H**	**L**	**H**	**L**	**M**	**H**	
TC1	• Potash Industries new technologies	**O**	**O**	**O**	**O**	🟠	🟢	🟢	**O**	**O**	**O**	**O**	**O**	
TC2	• Increased Water Conservation in the Lower Jordan River Basin	**O**	**O**	🟢	**O**	**O**	🟢	🟢	**O**	**O**	**O**	**O**	**O**	
TC3	• Increased Use of Treated Wastewater and Grey Water	**O**	**O**	**O**	**O**	**O**	🟢	🟢	**O**	🟠	**O**	**O**	**O**	
TC4	• Changes in Crop Types and Cultivation Methods	**O**	**O**	**O**	**O**	**O**	🟢	🟢	**O**	🟠	**O**	**O**	**O**	
G – Additional Alternatives Identified by Study Team														
AA1	• Selling electricity to Israel based on Israeli peak-load pricing with and without storage	**O**	**O**	🟠	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**	**O**	See report
AA2	• Transfers by tanker, bag and sub-marine pipeline from Manavgat in Turkey	**O**	**O**	**O**	**O**	**O**	🟢	🟢	**O**	**O**	🟠	🟠	🟠	For drinking water purposes
AA3	• Sub-marine pipelines associated with oil and energy conveyance-Medstream	**O**	**O**	**O**	**O**	**O**	**O**	**O**	🟠	**O**	🟠	🟠	🟠	For drinking water purposes; Impacts shared with energy and oil services
H – Combination of Alternatives														
CA1	• No. 1. Desalination and Aqaba and Mediterranean Sea, water importation from Turkey and water recycling and conservation	🟠	🟠	🟠	🟠	🟠	🟢	🟢	🟠	🟢	🟠	🟠	🟠	
CA2	• No. 2. Decreased chemical industry water extraction and decreased irrigation through cropping and other agronomic changes	**O**	**O**	**O**	**O**	🔴	🟢	🟠	**O**	🟠	**O**	**O**	**O**	

Alternative Code	Alternative	Red Sea – Dead Sea Area								Other Areas				Comments
		Red Sea	Red Sea Coast	Arava Valley/ Wadi Araba	Desalination Plant and Hydro-power Plant	Chemical Industries	Dead Sea Coast	Dead Sea	Desalinated Water Conveyance	Lower Jordan River	Eastern Mediterranean Sea	Eastern Mediterranean Coast	Transfer Eastern Med to Dead Sea	
Relative Sensitivity of Area (Low, Medium, High)		**M**	**M**	**H**	**M**	**H**	**M**	**H**	**L**	**H**	**L**	**M**	**H**	
CA3	• No. 3. Aqaba desalination plus decreased use from the chemical industries, plus increases in recycled water for irrigation	🟠	🟠	🟠	🟠	🟢	🟢	🟢	🟢	🟢	**O**	**O**	**O**	Desalination facility located at Aqaba on Red Sea
CA4	• No. 4. Reduced extractions from the Jordan River, plus Aqaba regional desalination and decreased irrigation use though agronomic changes	🟠	🟠	🟠	🟠	🟠	🟠	🟠	🟠	🟠	**O**	**O**	**O**	

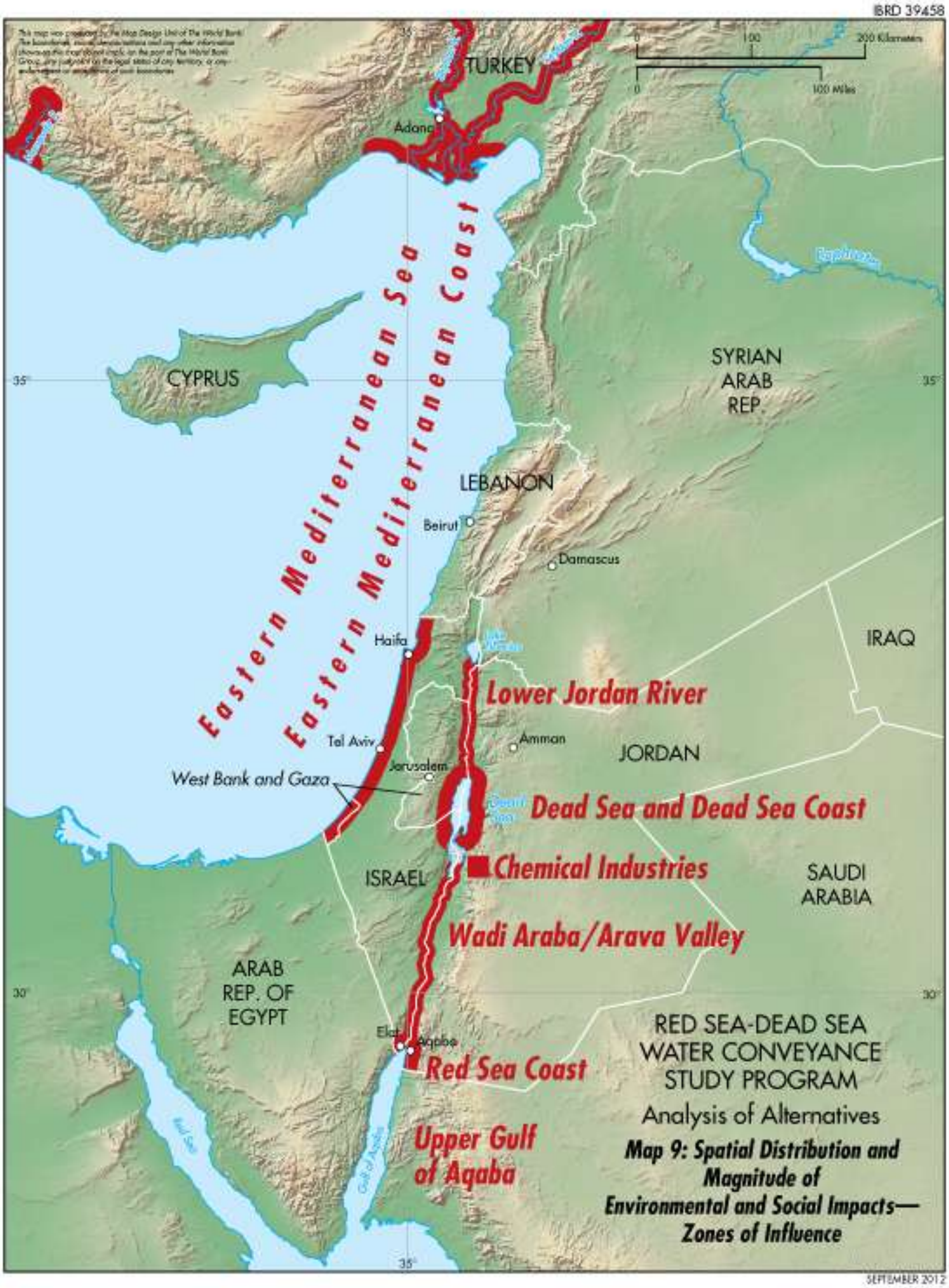

IBRD 39458
TURKEY
Adana
CYPRUS
SYRIAN
ARAB
REP.
LEBANON
Beirut
Damascus
Eastern Mediterranean Sea
Eastern Mediterranean Coast
Haifa
Tel Aviv
Jerusalem
Amman
West Bank and Gaza
IRAQ
JORDAN
Lower Jordan River
Dead Sea and Dead Sea Coast
Chemical Industries
ISRAEL
SAUDI
ARABIA
Wadi Araba/Arava Valley
ARAB
REP. OF
EGYPT
Elat
Aqaba
Red Sea Coast
Upper Gulf
of Aqaba
RED SEA-DEAD SEA
WATER CONVEYANCE
STUDY PROGRAM
Analysis of Alternatives
Map 9: Spatial Distribution and
Magnitude of
Environmental and Social Impacts—
Zones of Influence
SEPTEMBER 2012

Table 13.6: Study of Alternatives – Summary Table of Pros and Cons

TO BE RECONSTITUTED WHEN SEPARATE TABLES ARE FINALIZED

Table 13.7: Summary Description of Alternatives

ALTERNATIVE	DESCRIPTION
No Action – NA	
NA1 - No Action	The 'No Project Scenario' is a projection of future conditions that would be likely to develop if no action were taken to address declining Dead Sea levels. The main anticipated effects are • No direct capital costs or operation and maintenance expenditures • No large infrastructure investment needed • Short term increase in production of potash • Does not address ongoing decline of sea level and associated degradation Does not provide additional water and energy to the region
Red Sea -- Dead Sea Base Case – BC	
BC 1 - Low Level Gravity Tunnel (LLGT)	The Feasibility Study examined three main options for conveying Red Sea water about 180 km to the Dead Sea. The study labels the conveyance scheme options as the "Alternative Base Case Plus Conveyance Configurations" (see Maps 3a and 3b) and defines these as: • A buried pipeline; • A tunnel starting at 0 m elevation (the 'low-level tunnel'); and • A tunnel and canal system at 220 m elevation (the 'high-level tunnel'). ***Low Level Tunnel Option*.** The Low Level Tunnel alignment is located within the eastern escarpment of the Dead Sea rift valley. The tunnel will have an internal diameter of 8.3 m and will fall gently from the eastern intake at Aqaba to an outlet portal some 160 km north of the city of Aqaba. The alignment is below the groundwater table over most of its length. From the tunnel outlet the conveyance will fall more steeply in buried steel penstocks 11 km long to a hydropower plant at the southern end of the Dead Sea. The desalination plant for the high level desalination variant of this configuration will be located at the tunnel outlet portal. The desalination plant for the low level desalination plant variant will be located at the downstream end of the penstocks adjacent to the hydropower plant. ***The High Level Tunnel Option*.** The High Level Tunnel incorporates a pumping station immediately adjacent to the eastern intake site just south of Aqaba on the Gulf of Aqaba. The conveyance alignment rises sharply from the eastern intake pump station to a high point at an elevation of +220 m some 4.4 km from the eastern intake from where it falls gently in a sequence of tunnel and open canal sections to a tunnel outlet portal some 160 km north of the city of Aqaba. The tunnel sections are located in the eastern escarpment of the Dead Sea rift valley and will generally be located above the groundwater table. The open canal sections of this configuration lie within the Wadi Araba/Arava Valley at the toe of the eastern escarpment. From the tunnel outlet the conveyance will fall more steeply in buried steel penstocks 14 km long to a hydropower plant at the southern end of the Dead Sea. The desalination plant for the high level desalination variant of this configuration will be located at the tunnel outlet portal. The desalination plant for the low level desalination variant will be located adjacent to the hydropower plant.
BC 2 - Phased Pipeline (PPL) Buried Pipeline Option	The Buried Pipeline incorporates a pumping station immediately adjacent to the eastern intake site just south of Aqaba on the Gulf of Aqaba. The pumped riser main comprises a short section of pressurized tunnel around the eastern and northern fringes of the city of Aqaba and a series of parallel pipelines from the downstream end of the tunnel to a regulating tank at a high point on the Gharandal Saddle, which marks the watershed between the Red Sea and Dead Sea water catchments. From the regulating tank, flow is by gravity, again in a series of parallel pipelines, to the hydropower plant at the southern end of the Dead Sea. The pipelines' alignment is approximately parallel to the Israeli/Jordanian border, typically 5 km to 10 km east of the border, and crosses the Dead Sea road a number of times. The desalination plant for the high level desalination variant of this configuration will be located on the pipeline alignment about 50 km north of the Gharandal Saddle, and this variant includes a second hydropower plant just north of the regulating tank located at the Gharandal Saddle. The desalination plant for the low level desalination variant will be located adjacent to the hydropower plant.
Lower Jordan River Restoration – FL	

ALTERNATIVE	DESCRIPTION
FL 1- Full Restoration of historic Lower Jordan River flow levels	Full Restoration of the Lower Jordan River would mean: • The river's flow would be more than 1,100 MCM/year; and • That entire amount reaches the Dead Sea. According to Gafny, "It is important to acknowledge that full restoration is seldom possible. Firstly, because of the on-going water shortage in the Lower Jordan River (Orthofer et al, 2007) the quantities and quality of the water required for full restoration are beyond the ability of the countries in the region. Secondly, our knowledge of what exactly the original pre-perturbation condition is limited. Thirdly, such restoration would mean modifying the physical and biological character of the reach (channel form, biological communities) so that they replicate the original state. This would involve changing all of the inputs and outputs (water quality and quantity, sediment, and organisms) from upstream, downstream and the riparian zone, to the pre-perturbation state. Because of the connections between the Lower Jordan River and its catchment, in most situations this would only be possible if the entire river network, and most of the catchment surface, would also be restored. Clearly, this will probably not be possible. Even if the attempt was made, the changes that have occurred over the last 100 years may have been great enough to alter the river irreversibly." (Gafny et al., 2010, pg. 55). The Study of Alternatives Team concurs with this observation and, therefore, is of the view that full restoration of the Lower Jordan River is not possible in a period of 20 years. The Study of Alternatives Team does, however, argue that in a period of 30 to 40 years, through measures outlined in the Combined Alternative (CA1), full restoration of the Lower Jordan flow and of the Dead Sea could be achieved.
FL2 - Partial restoration of historic Jordan River flow levels	The natural annual flow of the Lower Jordan River of about 1,300 MCM/year (FoEME) has been reduced by major diversion infrastructures in Israel and Jordan and by a large number of minor structures in Syria. Partial restoration would aim to restore a minimum environmental flow in the Lower Jordan to restore much of the aquatic ecological diversity of the Lower Jordan River. The volume of water that the NGO – Friends of the Earth Middle East (FoEME) identifies to be necessary to achieve a satisfactory environmental status would be 400 MCM/year with an annual small flood event of 4 MCM over 24 hours. This volume would restore about one third the former natural flow. The consensus amongst the environmental proponents is that the restoration of flows would be incremental. They suggest that an initial target of 400 MCM/year could be increased to 600 MCM/year. These partial levels of restoration would be achieved through technical, economic, institutional and regulatory interventions described in some of the alternatives considered in this study.
• **Releases from Lake Tiberias**	The annual inflow of the Upper Jordan into Lake Tiberias has averaged 581 MCM/year in the period 1973-2009. Evaporation from the lake in the same study was shown to have averaged 249 MCM/year. Leaving an average net water balance of 332 MCM/year. About 90 MCM/year are used for local consumption and allocated to Jordan as agreed by Jordan and Israel in 1994. Outflow at the Degania Dam of high quality water varies greatly. High rainfall in 1991 caused a flow as high as the old flow of the river. The level of Lake Tiberias was also restored. But every decade there has been a multi-year drought when predominantly only sewage has flowed in the Lower Jordan River. It is suggested that 200 MCM/year could be released from Lake Tiberias mainly through a reduction of the volumes transferred by the Israeli National Water Carrier.
• **Production and Transfer of Desalinated Water from Mediterranean Sea**	The alignment of the Northern Mediterranean Sea - Dead Sea Transfer would make it possible to produce and deliver volumes of desalinated water large enough to restore Lower Jordan River flows. But the cost per cubic meter of desalinated water makes it a very unattractive option for river restoration. There would also be significant risks associated with transferring sea water from the Mediterranean across tracts with high agricultural, ecological and rural amenity values if desalination were to occur in the Jordan Valley as proposed as an alternative in the Samuel Neaman study.
• **Recycled Treated Wastewater and Greywater**	Treating and recycling domestic and industrial water from urban centers is now a proven method of augmenting national water supplies in Israel. The siting of major urban centers limits the potential of such water being available for restoring the Lower Jordan River. There are no major urban centers in Israeli or

ALTERNATIVE	DESCRIPTION
	Palestinian areas in or near the Jordan Valley – Tiberias (c40000), Jericho (c20000) and Beit She'an (c17000) would not provide significant volumes. The populations of the Greater Amman and other highland cities in Jordan are well sited to deliver treated wastewater in significant volumes. Jerusalem could also contribute. If Lower Jordan River restoration were to be given top priority over irrigation and other ecological and amenity uses the delivery of over 400 MCM per year of recycled water to the Lower Jordan River would be feasible.
Water Transfer Options – TR	
TR1 Transfer of Mediterranean Sea water to the Dead Sea **TR.1.1. Mediterranean Sea-Dead Sea Southern A – Ashkelon to North Dead Sea (Low Level Tunnel)**	This is an infrastructure based alternative formulated by the Study of Alternatives Team. 2000 MCM/year seawater would be abstracted from the Mediterranean at an inlet located in the Ashkelon area. This would be conveyed 90 km by low level gravity tunnel to the southern Dead Sea for desalination. Potable water from the process would then be conveyed to Amman and other areas. The brine would be ejected to the Dead Sea.
TR.1.2. Mediterranean Sea-Dead Sea Southern A - Ashkelon to North Dead Sea (Phased Pipeline and Gravity Tunnel)	This is an infrastructure based alternative formulated by the Study of Alternatives Team. This is the same as alternative TR1.1; however, it includes use of a phased pipeline and gravity tunnel.
Mediterranean Sea – Dead Sea – Southern B – Ashkelon to South Dead Sea **(subject to preliminary review only)**	This is an infrastructure based alternative formulated by the Study of Alternatives Team. 2,000 MCM/year seawater would be abstracted from the Mediterranean at an inlet located in the Ashkelon area. This would be conveyed 83 km by low level gravity tunnel to the southern Dead Sea for desalination. Potable water from the process would then be conveyed to Amman and brine would be ejected to the Dead Sea. In reviewing the Southern A and Southern B alignments and their associated investments, the Study of Alternatives Team concluded that since the Southern A alignment delivers water to the northern edge of the Dead Sea it would be able to provide water at a lower cost to Amman and other areas with significant water demand. Consequently, the most southern Mediterranean Sea–Dead Sea alignment termed Southern B has been screened out and this study considers only the Southern A –TR1.1 and TR1.2 as southern options.
TR1.3. Mediterranean Sea – Dead Sea Northern - Atlit to Naharayim-Bakura – with hydropower	This is an infrastructure based alternative formulated by the Study Team. 2,000 MCM/year of seawater would be abstracted from the Mediterranean Sea and desalinated on the Mediterranean Coast near Atlit. The brine from the process would be returned to the Mediterranean. 800 MCM/year potable water would be produced and conveyed 64-70 km across the northern valleys of Zvulun, Yizrael, Harod and Beit She'an to an outlet near Naharayim-Bakura, where the Yarmouk flows into the Jordan River. Potable water would be used to generate hydropower and would be ejected into the Lower Jordan River for further conveyance to Amman.
TR1.4. Mediterranean Sea – Dead Sea Northern - Atlit to Naharayim-Bakura – without hydropower	This is an infrastructure based alternative formulated by the Study of Alternatives Team. This is the same as alternative TR1.3; however, it does not include an investment for the generation of hydropower and therefore has a lower cost.
TR2 Transfer of water from Turkey by pipeline (Peace Pipeline)	This is an infrastructure based alternative. The idea of transferring strategic quantities of high quality water from the Seyhan and Ceyhan Rivers in Turkey to the water scarce Middle Eastern economies to the south have been under discussion for over two decades. The Peace Pipeline, is the popular name of the proposed conveyance. It would take water through Syria in a pipeline to Jordan, the Palestinian Authority and Israel. The proposed conveyance is attractive because it would address the goal of restoring the level of the Dead Sea and could provide strategic volumes of high quality water to Amman and other destinations. In addition the Lower Jordan River would be much more comprehensively restored. The conveyance would be low risk with respect to pollution following leaks as the water being conveyed would be high quality. The two rivers have high winter and spring flows and join close to Adana. They flow in to the Mediterranean and together have total average flows of about 16 BCM/year. The estimated 2 BCM/year of surplus water of two decades ago is no longer judged to be available. Turkish irrigators and industries are using more water. In addition estimates of low summer flows have been revised downwards. It is judged that they would not be enough flow to meet water demands in summer when secure water would be a priority. Turkish engineers responsible for the allocation and use of water in the Seyhan-Ceyhan Basin have announced

ALTERNATIVE	DESCRIPTION
	that the Peace Pipeline would not be a sound project.
TR3 Transfer of water from the Euphrates River Basin by pipeline	The proposed pipeline alternative would convey water from the west bank of the Euphrates River in Iraq to Jordan. The destination would be Amman. The length of the pipeline would be almost 700 km. The pipeline would be technically feasible but pumping costs could make the water relatively expensive. The alternative is not viable as the Iraq authorities no longer believe they have water to export. In addition the proposed volume of about 160 MCM/year is no longer a significant volume compared with the amounts being mobilized by desalination and re-cycling.
Desalination Options DS	
DS1. Desalination of Mediterranean Sea Water on the Mediterranean Coast with Transfer to the Lower Jordan River and Dead Sea Region – Haifa to Naharayim MD-1 alignment reviewed by Samuel Neaman Institute.	This is an infrastructure based alternative which involves increasing desalination capacity on the Mediterranean coast in Northern Israel. Brine produced during the desalination process would be returned to the Mediterranean Sea and desalinated water would be distributed by pipeline and/or channel to the beneficiary parties and the Lower Jordan River. This is a stand-alone option that is solely based on desalination and conveyance of desalinated water to beneficiary parties and the Lower Jordan River Valley. The aims are to: (i) increase the amount of potable water available to the beneficiary parties; (ii) stabilize the level of the Dead Sea; and (iii) generate hydropower **Samuel Neaman Institute option** The Samuel Neaman Institute examined the following option (MD-1). Desalination of seawater on the Mediterranean coast, south of Haifa to produce 1,800 MCM/year of freshwater. 270 MCM/year would be designated to the Palestinian Authority and communities in the Negev, 400 MCM/year would be designated to users of the Israeli National Water Carrier, which would cease pumping from the Sea of Galilee. 1130 MCM/year would be transferred through a tunnel in the Carmel mountain and through a series of valleys up to Ramat Zva'im where it would fall to the Naharayim area into the Jordan Valley. It would be used to generate hydropower. 530 MCM/year would then be transferred to Jordan (to the Amman area) and the remaining 600 MCM/year would be conveyed to the Dead Sea or Sea of Galilee. When combined with 400 MCM/year saved by ceasing pumping for the National Water Carrier this provides 1000 MCM/year high quality water for restoration of the Dead Sea. A total of 1,200 MCM high quality water is made available to the beneficiary parties. Environmental impacts beyond those associated with construction of necessary pipelines, desalination and hydropower plants are low as there is no conveyance of brine or seawater over aquifers. Total net running cost (2007) = US$1,210 million USD/year. Total investment cost (2007) = US$7,620 million.
DS2. Transfer of Mediterranean Sea Water to the Jordan Valley for Local Desalination and Use in Lower Jordan River and Dead Sea Region – Haifa to Naharayim MD-2 alignment reviewed by Samuel Neaman Institute	This is an infrastructure based alternative that involves abstracting seawater from the Mediterranean coast in northern Israel and transferring it inland by pipeline/tunnel/channel for desalination in the Jordan valley. The brine from this process would then be transferred by pipeline (or channel) to the Dead Sea. It is a stand alone alternative which aims to:(i) increase the amount of potable water available to the beneficiary parties; and (ii) stabilize the level of the Dead Sea **Samuel Neaman Institute Option** The Samuel Neaman Institute also examined the following option: Transferring 2000 MCM/year of sea water from the Mediterranean south of Haifa for inland desalination in the Naharayim area – Beit She'an. This would produce 800 MCM/year high quality desalinated water that could be supplied to Jordan, mainly to the Amman area. The brine from the process (1,200 MCM/year) would be transferred to the Dead Sea by canal or pipeline. This process involves transferring seawater and brine across aquifers so does present considerable environmental risk. Total net running cost (2007) = $875 million USD/year. Total investment cost (2007) – $5,710 million USD.
DS3. Increased Desalination of Mediterranean Sea Water on the Mediterranean Coast with Transfer for Use by the Three Beneficiary Parties to Reduce Water Demand from Lower Jordan River	This is an infrastructure based alternative that involves increasing desalination capacity on the Mediterranean coast of Israel and Gaza through construction of new desalination plants and upgrade of existing plants. Desalinated water would be conveyed to demand centers in order to reduce water demands in the Jordan Valley. Increased availability of new water could enable Israel to reduce pumping from Lake Tiberias into the Israeli National Water Carrier making more water available for stabilization of Dead Sea levels. This is not a stand alone alternative and would need to be coupled with water savings in agriculture and industry to achieve stabilization of the Dead Sea water level.
DS4.- Desalination of Red Sea Water at the Gulf of	This is an infrastructure based alternative that involves establishing desalination capacity on the shore of the Gulf of Aqaba and transferring desalinated water to

ALTERNATIVE	DESCRIPTION
Aqaba/Eilat with Transfer for Use by the Three Beneficiary Parties to Reduce Water Demand from Lower Jordan River	the three beneficiary parties by pipeline/channel/tunnel, including transfer of brine from the desalination process at Aqaba to the Dead Sea. This could be a stand alone alternative if sufficient desalination capacity could be established at the Gulf of Aqaba to meet potable water demands in the three beneficiary parties and sufficient brine or sea water could be conveyed to the Dead Sea to stabilize water levels. **Samuel Neaman Institute option** This is not strictly a DS4 alternative because it does not involve desalination on the Red Sea Coast. The Samuel Neaman Institute examine the abstraction of 2,000 MCM/year seawater from the Gulf of Aqaba, conveyed via a canal from the Red Sea to the Dead Sea with desalination at the Dead Sea to produce 800 MCM/year potable water for Jordan (to be pumped to Amman) and a flow of 1,200 MCM/year seawater and brine to the Dead Sea. Investment costs are estimated at $5,000 million USD and operational costs are estimated at $1,085 million USD/year (2007). Possible environmental impacts identified include leakage of seawater into aquifer zones. This alternative is very similar to the proposed action but differs in the sense that it is purely designed to meet the water needs of Jordan.
Jordan Red Sea Project (JRSP) (not an alternative identified in the Terms of Reference)	This is a Jordan only initiative that does not involve Israel or the Palestinian Authority. This alternative was not identified in the Terms of Reference. It has become a prominent alternative promoted by the Government of Jordan and it is appropriate to consider it in this table. It is a phased alternative (5 phases) which ultimately aims to abstract 2,150 MCM/year seawater from the Gulf of Aqaba, partially desalinate this to produce 80 MCM/year potable water in the Aqaba area, convey the remaining seawater and brine by pipeline, through the Wadi Araba/Arava Valley for desalination at the Dead Sea (to produce a further 850 MCM/year potable water for use in Jordan). A total of 1,220 MCM/year brine would be discharged to the Dead Sea. Phase I of this project aims to produce 250 MCM/year desalinated water and 190 MCM/year Dead Sea discharge by 2018. The project completion date is 2055. The objectives of this initiative are to: (i) establish a secure and affordable water supply for Jordan while saving the Dead Sea from extinction; (ii) support widespread economic growth; (iii) provide for potential regional water; and (iv) facilitate private and public financing through the Jordan Red Sea Project Company.
Technical and Water Conservation Options	
TC1 Changes of technology used by the Dead Sea Chemical Industry	This alternative is based on deployment of a yet unspecified technical solution to decrease evaporative water losses incurred by the chemical industries at the southern end of the Dead Sea (Arab Potash Company in Jordan and the Dead Sea Works in Israel). The Dead Sea Works and the Arab Potash company currently extract roughly 727 MCM/year from the Dead Sea and pump it into solar evaporation pans as part of the process of mineral extraction. An average of 287 MCM/year is lost as evaporation and roughly 465 MCM/year is returned to the Dead Sea. Any technology that can be deployed to reduce evaporative losses during the mineral extraction process could have a positive impact on the water balance of the lake. This is not a stand alone option and would need to be deployed together with other measures to stabilize the Dead Sea water level and make potable water available to beneficiary parties.
TC2 Increased water conservation in the Lower Jordan River Basin	This is a technical and demand management based alternative aimed at increasing the amount of available water through improving water conservation. This is not a stand alone option and would need to be deployed together with other measures to stabilize the Dead Sea water level and make potable water available to beneficiary parties.
TC3 Increased use of wastewater and greywater	This is a technical and demand management based alternative aimed at increasing the amount of available water through increasing use of treated wastewater and greywater for reuse in irrigation. This is not a stand alone option and would need to be deployed together with other measures to stabilize the Dead Sea water level and make potable water available to beneficiary parties.
TC4 Changes in crop types and cultivation methods	This is a demand management based alternative that aims to reduce the amount of high value potable water designated to watering low value crops. It is achieved by modifying cropping patterns and changing trade policies on bananas. This is not a stand alone option and would need to be deployed together with other measures to stabilize the Dead Sea water level and make potable water available to beneficiary parties.

ALTERNATIVE	DESCRIPTION
Additional Alternatives Identified by Study Team	
AA1 Selling electricity to Israel based on Israeli peak-load pricing with and without storage	This is an addition to the proposed action that presents a different economic model to increase viability. The economic viability of energy intensive industries can be significantly impacted by the cost of energy. The proposed project and the alternatives that would involve lifting and conveying water over long distances such as the Mediterranean Sea -Dead Sea alternatives would be very subject to the cost of energy. As the proposed Red Sea – Dead Sea Water Conveyance and the other conveyance alternatives use more energy than they generate, there is a big incentive to examine the economic impact of selling project electricity during periods when the tariffs would be high in Israel and using electricity from the grid on projects when the tariffs are low. Electricity tariffs vary in Israel by season and by day of the week. The low tariffs are about one third of the high tariffs.
AA2 Sub-marine pipelines associated with oil and energy conveyance-Medstream	This is an infrastructure based alternative that involves the construction of five 460km long undersea pipelines that would carry water, natural gas, crude oil, electricity and fiber optic lines from Ceyhan on Turkey's south-eastern Mediterranean coast to Haifa in northern Israel. The oil pipeline would link two existing pipelines - between Ceyhan in Turkey and Azerbaijan (Baku) and between Ashkelon and Eilat. The water component of the pipeline would aim to supply between 400 MCM/year and 1000 MCM/year from the Ceyhan River in Turkey to Haifa. The economic viability of the water component of this project is dependent on the cost of desalination on the Mediterranean. If the cost of 1 m3 of water from the pipeline exceeds the cost of desalination, the water component becomes unviable. The total investment cost of the scheme is estimated at between US$2.4 and US$4 Billion (2010). Israel would be the primary beneficiary to receive water but Jordan and the Palestinian Authority could also be secondary beneficiaries. This is not a stand alone alternative as it would not deliver sufficient quantities of water to restore the Dead Sea directly. It could however offset a proportion of water demands in the beneficiary parties meaning more water could be allowed to flow down the Lower Jordan River.
AA3 Transfers by tanker, bag and sub-marine pipeline from Manavgat in Turkey	This is an infrastructure based alternative that involves the transfer by tanker or sea-bag of up to 400 MCM/year of water from a terminal on the Manavgat River in southern Turkey to a coastal terminal in northern Israel. Turkey and Israel have discussed the option of tankering water from Manavgat for about two decades. A contract was almost in place by 2001but the arrangement was overtaken by the revelation that reverse osmosis technologies could produce desalinated water at less than $0.6/m3 at Ashkelon. The water storage reservoir and loading facilities at Manavgat have been constructed and could deliver volumes of water big enough to make difference to the Beneficiary Parties, especially to those with a Mediterranean coastline. The Manavgat facility could deliver 400 MCM/year, or more, of high quality water. Tankering of water would have the advantage of being less demanding of energy and much less polluting than water produced by reverse osmosis. Markets for the conveyance of water by tanker have a poor record, but contracts between Turkey and any of the beneficiary parties would be enforceable and durable. Previous pilots of the floating bag variant of this alternative have experienced challenges in rough weather. The scheme is currently on hold. Turkey has invested $147 million in this scheme so far but further investment in pumps, pipes, and tankers and tugs in Israel would be required to make the scheme operational. The viability of the scheme is influenced by the cost of desalination on the Mediterranean coast.
Combination of Alternatives	
• **CA1 Desalination at Aqaba and Mediterranean Sea, water importation from Turkey and water recycling and conservation**	This combination of alternatives takes a long perspective of at least three or more decades and would be implemented incrementally by the beneficiary parties. It would consist of the following: • Natural water – use of existing water allocation. 350 MCM of the existing river water allocation; • Reallocated water – reallocation of 300 MCM/year from irrigation to urban use. • Water from improved management – technical measures and water user behavior changes; 100 – 200 MCM/year. • Additional water – from: Lake Tiberias (100 - 200 MCM/year); desalination in Aqaba 100 MCM/year); desalination along the northern Mediterranean coast, and/or water importation from Turkey -Manavgat (400 MCM/year); and

ALTERNATIVE	DESCRIPTION
	• Recycling urban water – 60 percent of the total annual urban allocation of 1.2 BCM could be recycled to generate 720 MCM/year of treated water. This alternative has a number of advantages. First, it can be flexible and responsive especially to technological advances. Secondly, the approach will usually be more fundable than one that requires a very big up-front investment. Thirdly, it addresses both the objective of restoring the Dead Sea and the objective of providing potable desalinated water for use mainly in Amman. Fourthly, it has the potential to do so without the need for a major sea to sea conveyance. Fifthly, it would also avoid the risks of mixing Red Sea or Mediterranean Sea waters with Dead Sea water. Last, it would avoid the expensive pilot studies that would be necessary to undertake in advance of proceeding to a full scale sea to sea conveyance of water.
• **CA2 Decreased chemical industry water extraction and decreased irrigation through cropping and other agronomic changes**	This combination of alternatives was chosen for analysis because: (i) there may be the possibility for a technical option that would result in a substantial decrease in raw water requirements by the chemical industries; and (ii) cropping pattern reform has been under discussion in the Region for some time and the arguments and alternatives are familiar, even if difficult.
• **CA3 Aqaba desalination plus decreased use from the chemical industries, plus increases in recycled water for irrigation**	This combination of alternatives was chosen for analysis because: (i) a desalination plant in Aqaba has been discussed under the Jordan Red Sea Project; (ii) there may be the possibility for a technical option that would result in a substantial decrease in raw water requirements by the chemical industries; and (iii) there is already substantial use of recycled water for irrigation in both Israel and Jordan and it appears at least possible that an even larger increase in the use of this resource is feasible.
• **CA4 Reduced extractions from the Jordan River, plus Aqaba regional desalination and decreased irrigation use though agronomic changes**	This combination of alternatives was chosen for analysis because: (i) reduced extractions from the lower Jordan River could be accomplished through a variety of measures including cropping/agronomic changes, increased use of recycled water or irrigation technology changes; (ii) a desalination plant in Aqaba has been discussed under the Jordan Red Sea Project.

APPENDIX 1: STAKEHOLDER CONSULTATIONS SUMMARY

[TO BE COMPLETED AFTER STAKEHOLDER CONSULTATIONS ARE CONDUCTED]

APPENDIX 2: COST ANALYSIS, DATA AND CALCULATIONS FOR THE RED SEA–DEAD SEA ALTERNATIVE

1. COST DECOMPOSITION

The Red Sea–Dead Sea (RSDS) projects vary with respect to the method of water conveyance and the location of the desalination plant (near the Dead Sea at high or low elevation or near the Red Sea). The feasibility study of Coyne et Bellier (2010) considers desalination near the Dead Sea at high or low elevation and a number of conveyance methods, including Low Level Gravity Tunnel, High Level Tunnel/Canal, Pipeline and Phased Pipeline (the pipeline option implemented in 4 phases – see Table A2.2.4). After preliminary screening based on costs, the Study of Alternatives Team focused on two conveyance methods with high level desalination near the Dead Sea. The conveyance methods considered are:

- Low Level Gravity Tunnel (LLGT); and
- Phased Pipeline (PPL).

The Study of Alternatives Team evaluated and compared the costs of each project based on the data in Coyne et Bellier (2010). To allow division of the costs between the two primary goals, each project is divided into two subprojects:

- Conveyance of seawater and brine from the Red Sea to the Dead Sea with hydropower generation; and
- Desalination and conveyance to the consumption areas (mainly Amman).

The first subproject corresponds to the goal of stabilizing the Dead Sea water level and is referred to as the *Dead Sea Stabilization* subproject; the second corresponds to the goal of increasing the quantity of potable water and is referred to as the *Desalination* subproject.

The Dead Sea Stabilization subproject can be carried out independently of the Desalination subproject. The latter depends on the Dead Sea Stabilization subproject for brine discharge. The two subprojects share the seawater intake and conveyance (up to the desalination plant) infrastructure.

The cost of the Dead Sea Stabilization and Desalination subprojects are evaluated and summarized in the form of annual cost (US$ millions) of water discharge in the Dead Sea and cost per m^3 (US$/$m^3$) of potable water in Amman, respectively. The former is the cost of stabilizing the Dead Sea water level; the latter is the cost of potable water to Amman. The cost of each subproject is broken into capital (fixed) and operating (variable) costs.

The engineering and cost data underlying all calculations were provided by Coyne et Bellier (see Section 2 below for description of data and calculations). The economic conditions are characterized by the interest rate (the cost of financing the project's components) and the electricity tariffs for consumption (pumping, desalination) and production (hydropower). These parameters can vary significantly and the Study of Alternatives Team reviewed their effects via a sensitivity analysis.

Capital cost and imputed annual cost

The capital cost represents the expenditures of building the infrastructure components (pumps, canals, tunnels, pipelines, discharge canal, hydropower plant, desalination plant). When some components are built at different time periods, the sum of the present values of all components are calculated and is called the present-value capital cost. The annual cost of capital consists of the interest payments on all capital cost components (i.e., the interest payments on the outstanding loans corresponding to the capital costs) plus the cost of capital depreciation (i.e., replacement and refurbishment of worn out capital components).

The imputed annual cost represents the total annual payments associated with a subproject. It consists of the imputed annual cost of capital plus the operational expense (energy, labor, material, contingencies) minus the net hydropower profit (for the Dead Sea Stabilization subproject) and represents the annual capital payments and all net operation and maintenance expenses (including hydropower profits when appropriate). The imputed annual costs of a subproject vary over time due, inter alia, to the increasing desalination schedule affecting the hydropower profit (more desalination implies less hydropower generation for a given quantity of seawater input).

The imputed annual costs of the Dead Sea Stabilization subproject are depicted in Figure A2.1.1 for a range of interest rates. These costs are sensitive to the electricity tariffs because the latter affect the profit of the hydropower plant (subtracted from the operating expenses to provide the imputed cost figures), as well as the energy cost of pumping and conveying. The values in Figure A2.1.1 have been calculated based on the electricity tariffs of US$60/MWh, assumed by Coyne et Bellier (2010), based on Jordanian electricity tariffs relevant for water pumping. The desalination purpose of the project allows using this special tariff. For other large industries (including the Dead Sea stabilization), the relevant electricity tariff is US$80/MWh. The cost saving associated with this difference in electricity tariffs is awarded to the desalinated water to reduce its cost.

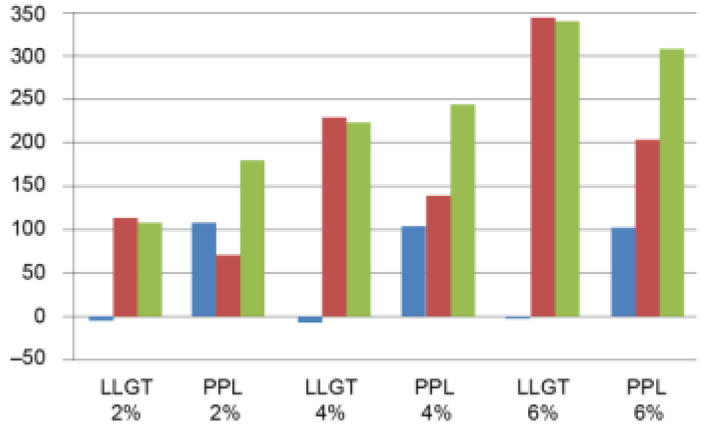
The electricity rates in Jordan differ from those in Israel and each varies substantially during a day and between seasons (see details in Section 2 below). It may be possible to take advantage of the different rates and sell the hydropower at a higher rate (by selling the electricity to Israel).

If a storage reservoir is feasible, it will allow scheduling the electricity production so as to take advantage of the peak load prices (in Israel, the ratio of high to low prices equals six in some seasons and suppliers of renewable, clean electricity receive an additional premium). The Study of Alternatives Team incorporated these aspects by considering three electricity tariff regimes (see Section 2 for details):

(i) The baseline case: consumption and production of energy under the Jordanian electricity tariff of US$60/MWh (Figure A2.1.1);
(ii) Energy consumption according to the Jordanian tariff of US$60/MWh; selling the hydropower to Israel at the average Israeli tariff of US$110/MWh, which includes the clean energy premium embedded in the Israeli tariff schedule (Figure A2.1.2); and
(iii) The same as (ii) but with a storage reservoir that allows hydropower production during 12 hours a day, increasing the average selling price to US$142/MWh (Figure A2.1.3).

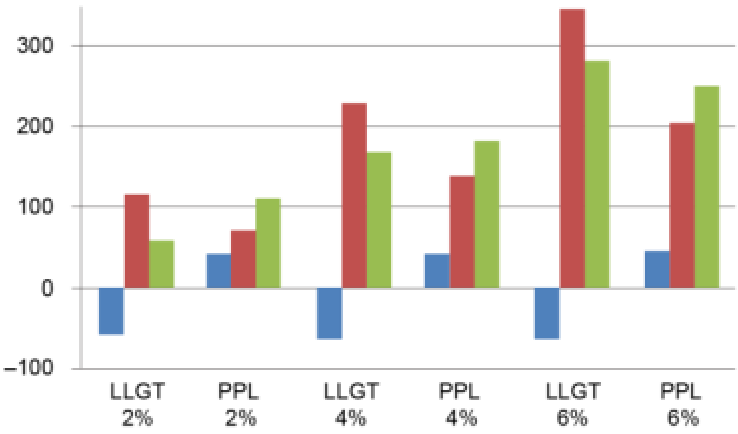
The annual imputed cost of a subproject changes over time as the subproject is phased in (for the PPL option) and with the schedule of desalinated water (see Coyne et Bellier, 2010). The latter affects the profits of the hydropower plant, as it changes the water available for hydropower generation. Figures A2.1.1 – 1.3 present average annual costs, obtained by calculating present values and multiplying by the discount rate. The total annual costs are broken down into capital and operation & maintenance (O&M) components. The first is the interest payments on outstanding loans needed to build the Dead Sea Stabilization subproject. The second component accounts for O&M cost (including capital depreciation) minus the hydropower profit. The latter is negative when the hydropower profits exceed the O&M costs of pumping, conveying and discharging the seawater and brine.

Figure A2.1.1: Imputed Annual Costs (US$million) of the Dead Sea Stabilization Subproject for a Range of Interest Rates under the Baseline Electricity Tariff Regime (i), with a Breakdown into Capital (Interest) Cost and O&M Cost Minus Hydropower Profit



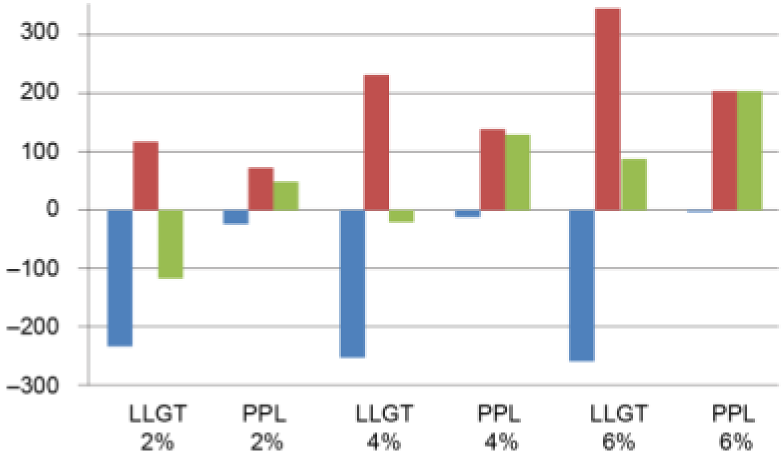
	LLGT 2%	PPL 2%	LLGT 4%	PPL 4%	LLGT 6%	PPL 6%
O&M cost net of HP profit	–6	110	–6	106	–4	104
Capital (interest) cost	116	72	232	141	348	206
Total	110	182	226	247	344	310

Figure A2.1.2: Imputed Annual Costs (US$million) of the Dead Sea Stabilization Subproject for a Range of Interest Rates under the Electricity Tariffs Regime (ii), with a Breakdown into Capital (Interest) Cost and O&M Cost Minus Hydropower Profit



	LLGT 2%	PPL 2%	LLGT 4%	PPL 4%	LLGT 6%	PPL 6%
O&M cost net of HP profit	–58	42	–63	43	–64	46
Capital (interest) cost	116	72	232	141	348	206
Total	58	114	169	184	284	252

Figure A2.1.3: Imputed Annual Costs (US$million) of the Dead Sea Stabilization Subproject for a Range of Interest Rates under the Electricity Tariff Regime (iii), with a Breakdown into Capital (Interest) Cost and O&M Cost Minus Hydropower Profit. The hydropower profits include the cost of added hydropower capacity. The cost of the storage reservoir is not included.



	LLGT 2%	PPL 2%	LLGT 4%	PPL 4%	LLGT 6%	PPL 6%
O&M cost net of HP profit	–233	–22	–251	–11	–258	–1
Capital (interest) cost	116	72	232	141	348	206
Total	–117	50	–19	130	90	206

The electricity tariffs of Regime (iii) have been obtained by operating the hydropower plant at certain hours of the day when tariffs are high (based on the current Israeli tariff schedule). This requires a storage reservoir and a larger capacity for the hydropower plant. Both (the reservoir and the higher hydropower generation capacity) entail costs. Figure A2.1.3 gives the imputed annual costs of the Dead Sea Stabilization subproject, accounting for the higher cost of hydropower generation, but without the cost of the storage reservoir.

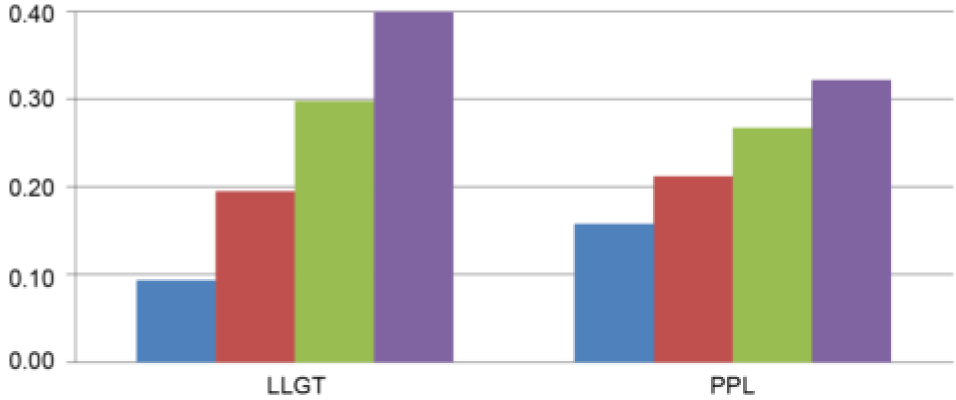
Under the electricity tariffs of Regime (iii) (taking full advantage of Israel's peak load pricing schedule with a storage reservoir), conveying water from the Red Sea to the Dead Sea, while exploiting the elevation difference to generate hydropower, becomes a profitable operation for the LLGT project option under 2% or 4% interest rates when the annual cost of a storage reservoir does not exceed US$117 million or US$19 million, respectively (Figure A2.1.3).

Comparing the annual costs with and without a storage reservoir (Figures A2.1.2 and A2.1.3) reveals that under a 6% interest rate, a storage reservoir whose annual cost does not exceed US$194 million (284–90) pays off for the LLGT option, in that it reduces the cost of Dead Sea restoration. The corresponding figure for the PPL option is US$183 million (252–69). Under a 4% interest rate, a storage reservoir pays off for the LLGT or PPL if its annual cost falls short of US$188 (169+19) or US$201 million (184 +17), respectively.

Break-even cost (US$/m^3) of discharge into the Dead Sea

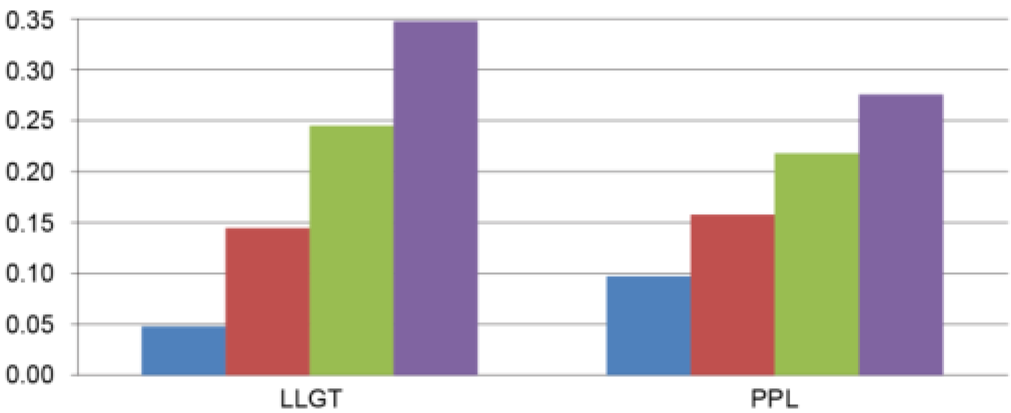
The break-even cost of seawater-brine delivered to the Dead Sea is obtained by dividing the imputed annual cost of the Dead Sea Stabilization subproject by the annual quantity of brine and seawater discharged into the Dead Sea. Figures A2.1.4 – 1.6 present the break-even costs of seawater-brine discharge in the Dead Sea under the three electricity tariff scenarios described above.

Figure A2.1.4: Break-even Cost of Seawater-Brine Discharge in the Dead Sea (US$/m^3) for a Range of Interest Rates under the Electricity Tariff Regime (i)



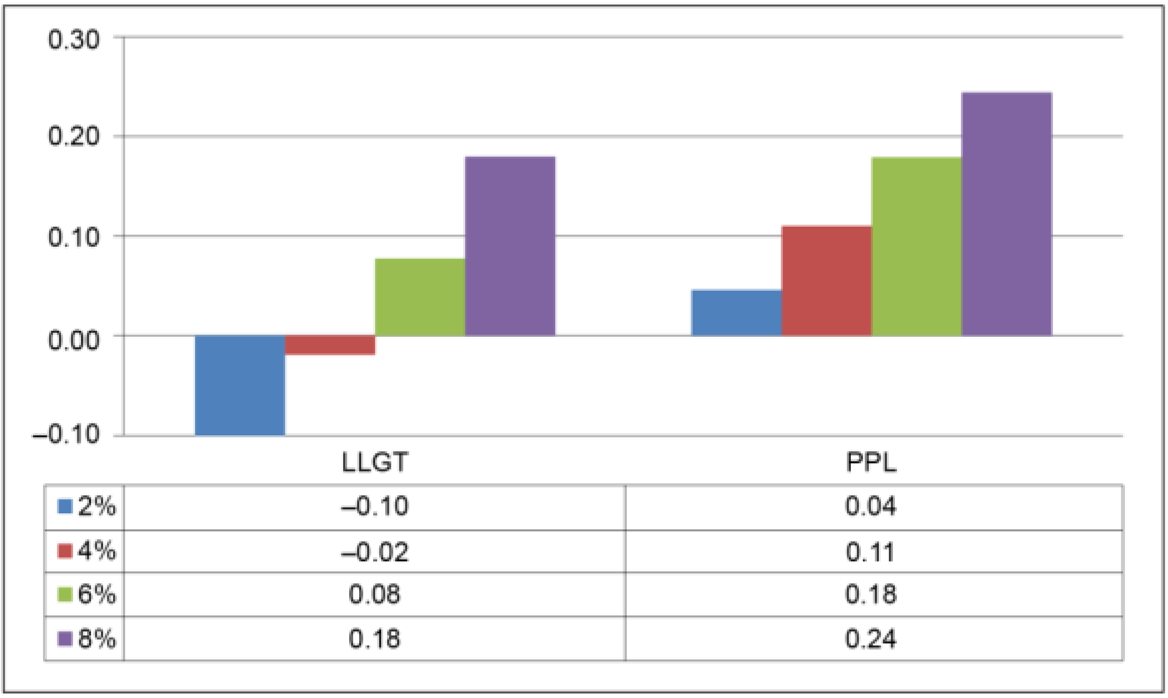
	LLGT	PPL
2%	0.10	0.16
4%	0.20	0.21
6%	0.30	0.27
8%	0.40	0.32

Figure A2.1.5: Break-even Cost of Seawater-Brine Discharge (US$/m^3) for a Range of Interest Rates under the Electricity Tariff Regime (ii)



	LLGT	PPL
2%	0.05	0.10
4%	0.15	0.16
6%	0.25	0.22
8%	0.35	0.28

Figure A2.1.6: Break-even Cost of Seawater-Brine Discharge (US$/m^3) for a Range of Interest Rates under the Electricity Tariff Regime (iii). Prices include the cost of added hydropower capacity but not the cost of a storage reservoir.



For the LLGT option, the quantity of water discharged into the Dead Sea will decrease over time until it reaches a steady state (of 1,150 MCM/year) when all the project components are completed and desalination has reached maximum capacity. Under the PPL option, the quantity of seawater-brine discharged into the Dead Sea and the quantity of desalinated water both increase over time as the project is phased in. The break-even costs in Tables A2.1.4 – 1.6 are calculated for the complete project, after desalination has reached the maximum capacity and the discharge quantity is 1,150 MCM/year.

The time evolution of the break-even costs along the stages of the project is presented in the following table.

Table A2.1.1: Break-Even Costs (US$/m^3) of seawater-brine discharge into the Dead Sea at different periods defined by the schedule of desalinated water

Electricity tariffs of Regime 1.					
	2020 – 30	2030 - 40	2040 – 50	2050–60	> 2060
LLGT 2%	0.06	0.06	0.07	0.08	0.10
PPL 2%	0.20	0.17	0.17	0.15	0.16
LLGT 4%	0.13	0.14	0.15	0.17	0.21
PPL 4%	0.29	0.25	0.24	0.22	0.23
LLGT 6%	0.20	0.21	0.24	0.26	0.31
PPL 6%	0.38	0.32	0.31	0.28	0.29
Electricity tariffs of Regime 2.					
	2020 – 30	2030 - 40	2040 – 50	2050–60	> 2060
LLGT 2%	0.02	0.02	0.03	0.04	0.06

PPL 2%	0.14	0.11	0.10	0.09	0.10
LLGT 4%	0.09	0.10	0.12	0.14	0.17
PPL 4%	0.23	0.18	0.18	0.15	0.16
LLGT 6%	0.16	0.18	0.20	0.23	0.27
PPL 6%	0.32	0.26	0.25	0.22	0.22
Electricity tariffs of Regime 3.					
	2020 – 30	2030 - 40	2040 – 50	2050–60	> 2060
LLGT 2%	-0.11	-0.11	-0.10	-0.08	-0.06
PPL 2%	0.08	0.04	0.04	0.03	0.04
LLGT 4%	-0.04	-0.03	-0.01	0.01	0.04
PPL 4%	0.18	0.12	0.12	0.09	0.10
LLGT 6%	0.04	0.05	0.07	0.10	0.15
PPL 6%	0.27	0.20	0.19	0.16	0.17

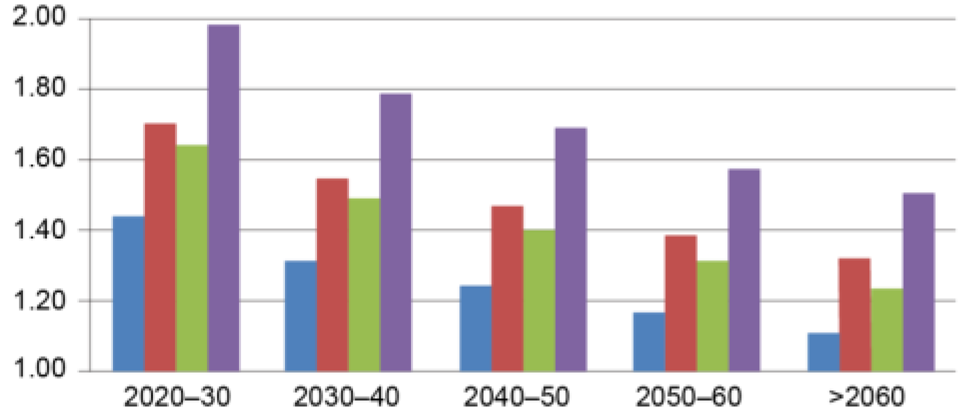
For the LLGT option and electricity tariffs of Regime (ii) (taking advantage of the Israeli electricity prices schedule, but without a storage reservoir), the break-even cost of water discharge into the Dead Sea is US$0.05/$m^3$ and US$0.15/$m^3$ under 2% and 4% interest rate, respectively. The corresponding discharge prices for the PPL option are US$0.1/$m^3$ and US$0.16/$m^3$. As expected, the advantage of the PPL option becomes more pronounced as the interest rate increases.

Break-even cost of desalinated water in Amman (US$/$m^3$)

The break-even cost of desalinated water in Amman is obtained by dividing the imputed annual cost of the Desalination subproject (which includes conveyance from the Red Sea, desalination, and conveyance to Amman) by the quantity of desalinated water. The break-even cost of desalinated water at the gate of the desalination plant varies little between the different project options and is currently estimated at around US$0.5/$m^3$. Technological progress is expected to reduce this cost in the future.

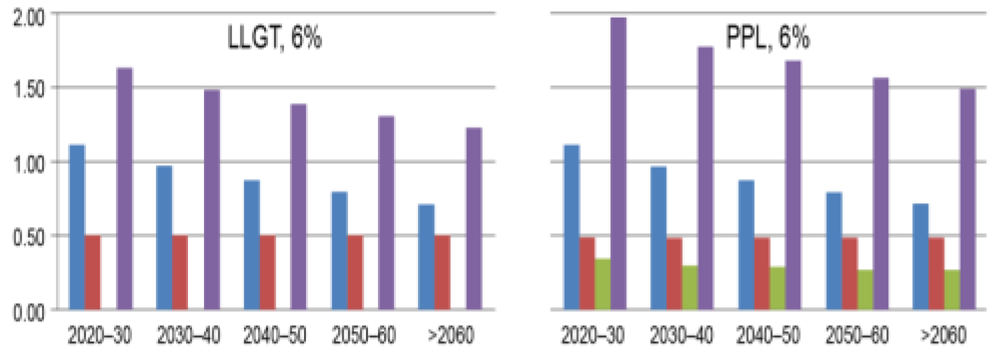
To obtain the break-even cost of desalinated water in Amman, one adds the cost per m^3 of conveyance from the Red Sea to the desalination plant and from the desalination plant to Amman. This cost varies over time with the (gradual) increase in the desalination capacity and may vary slightly between the LLGT and PPL project options due to different energy requirements associated with the location of desalination plants (see Chapter 21 of Coyne et Bellier, 2010). The total break-even costs of desalinated water in Amman along the project phases are presented in Figure A2.1.7. Figure A2.1.8 presents a breakdown of the break-even costs into the three cost components: conveyance from the Red Sea to the desalination plant, desalination, and conveyance from the desalination plant to Amman.

Figure A2.1.7: Break-even Costs (US$/m^3) of Desalinated Water in Amman



	2020–30	2030–40	2040–50	2050–60	>2060
LLGT 4%	1.44	1.31	1.24	1.17	1.11
PPL 4%	1.71	1.55	1.48	1.39	1.33
LLGT 6%	1.64	1.49	1.40	1.31	1.24
PPL 6%	1.98	1.79	1.69	1.58	1.50

Figure A2.1.8: Break-even Cost (US$/m^3) of Desalinated Water in Amman under a 6% Interest Rate, divided into 3 Components: Conveyance from Red Sea to the Desalination Plant; Desalination; and Conveyance from Desalination Plant to Amman. The left and right panels present the cost components for the LLGT and PPL options, respectively



LLGT, 6%

	2020–30	2030–40	2040–50	2050–60	>2060
Conveyance to Amman	1.13	0.98	0.89	0.80	0.72
Desalination	0.51	0.51	0.51	0.51	0.51
Conveyance from Red Sea	0.00	0.00	0.00	0.00	0.00
Total	1.64	1.49	1.40	1.31	1.24

PPL, 6%

	2020–30	2030–40	2040–50	2050–60	>2060
Conveyance to Amman	1.13	0.98	0.89	0.80	0.72
Desalination	0.50	0.50	0.50	0.50	0.50
Conveyance from Red Sea	0.36	0.31	0.30	0.28	0.28
Total	1.98	1.79	1.69	1.58	1.50

The "Conveyance from Red Sea" component measures the part of the conveyance cost due to desalination (i.e., the difference in conveyance cost between the situation in which only the Dead Sea Stabilization subproject is carried out and the situation in which both subprojects are implemented). For the LLGT option, this cost component is negligible (it is assumed that a tunnel can accommodate conveyance of the desalination water as well). For the PPL option this cost component is substantial, which explains why desalinated water in Amman is more expensive under this option.

Summary

A Red Sea–Dead Sea project consists of two subprojects, the Dead Sea Stabilization subproject and the Desalination subproject. The Dead Sea Stabilization subproject includes all the components needed to deliver water from the Red Sea to the Dead Sea and exploit the elevation difference to generate electricity. It can be a stand-alone project. The Desalination subproject includes the added components needed to desalinate and convey potable water to consumers (mainly in Amman). The cost of a project is the sum of the costs of the two subprojects. The break-even cost of water associated with the Dead Sea Stabilization subproject gives the price of a cubic meter discharged into the Dead Sea, under which the water proceeds just equal the imputed cost of the Dead Sea Stabilization subproject. The break-even cost of water associated with the Desalination subproject is the price of the desalinated water in Amman, under which the annual water proceeds just equal the annual cost of the Desalination subproject.

With the current state-of-the-art technology, the price of desalinated water (at the plant's gate) is around US$0.50/$m^3$ and is expected to fall in the future. The break-even cost of desalinated water in Amman is obtained by adding the conveyance cost of the water needed for desalination (from the Red Sea to the desalination plant and to Amman). Pricing desalinated water in this way ensures that the proceeds from selling the desalinated water cover the full cost of desalination.

The break-even cost of the Dead Sea Stabilization subproject gives the price of water discharged in the Dead Sea. This price is useful when considering who should pay for the Dead Sea stabilization. Unlike the provision of desalinated water for consumers in Amman (or other cities), where the direct beneficiaries (i.e., the water consumers) can be identified and charged for the cost of the desalinated water, the beneficiaries of the Dead Sea restoration are numerous and diverse and some are very difficult to link into financial transactions. They include the Dead Sea potash industries (Jordanian and Israeli), the Dead Sea tourism industry, the local governorates, the populations of the three Beneficiary Parties, and the international community as a whole. The latter are relevant because restoring the Dead Sea has global public good dimensions due to the unique heritage, geology, ecology, climate, topography and environmental amenities of this unique site. The cost of restoring the Dead Sea should be paid for by all beneficiaries. Expressing this cost in the form of US$/$m^3$ of discharged water would facilitate the design of a pricing mechanism for this purpose.

The LLGT project delivers the lowest cost of Dead Sea restoration if a small scale or no pilot project is required. A large scale pilot project (e.g., about 300 MCM/year for 5 years) is naturally integrated into a PPL project but not into a LLGT project. Such a pilot project will have little effect on the cost of the PPL project but a larger effect on the cost of the LLGT project.

The costs are sensitive to the interest rate and to the electricity tariffs for consumption and sale of hydropower. The interest rate represents the price capital. The electricity tariffs depend on the ability to take advantage of the peak-load electricity tariffs in Jordan and Israel and on the feasibility of a storage reservoir.

Comparing the annual costs with and without a storage reservoir reveals that under a 6% interest rate, a storage reservoir whose annual cost falls short of US$194 million (284–90) pays off for the LLGT option, in that it reduces the cost of Dead Sea restoration. For the PPL project option under 6% interest rate, a storage reservoir whose annual cost does not exceed US$46 million (252–206) reduces the cost of Dead Sea restoration.

A storage reservoir whose annual cost does not exceed US$54 million (which allows taking full advantage of Israel's peak load pricing schedule) turns the Dead Sea restoration with the LLGT subproject into a profitable operation for any interest rate at or below 4%.

2. Data and Cost Calculations

Tables A2.2.1, 2.2, 2.3 and 2.4 present the cost data, obtained from Coyne et Bellier, based on which all calculations are made.

Table A2.2.1: Cost Data for the Low Level Gravity Flow Tunnel (LLGT) Conveyance with High Level Desalination

Project Element	Capacity	Capital Cost		Operating Cost / Year		Comments
		Unit Cost	Total Cost US$ million	Unit Cost	Total Cost US$ Million	
Red Sea Intake works	2,000 MCM/year	Lump Sum	100	0.5% capex	0.5	
Pumping Station			Nil		Nil	
Pumping energy costs			Nil		Nil	
Tunnels	163 km	US$32 million/km	5,194	0.5% capex	26.0	
Open canal section			Nil		Nil	
Pipelines			Nil		Nil	
Desalination plant	850 MCM/year	US$1,100/m³/day	2,563	3.33kWh/m³	64.0	Opex covers energy costs only. Cost is for year 1.
Penstocks	11.10 km x 2 pipes	US$10 million/km	107	0.5% capex	0.5	
Hydro plant	149.2MW	US$925,000 / MW	138	2% capex	2.76	Does not include revenue from sale of power generated
Value of hydropower generated	1,077 GWh/yr		Nil	US$60 / MWh	-65	Income from sale of hydropower - year 1
Discharge canal to Dead Sea	56 km	Lump Sum	500	0.5% capex	2.5	
Sub-Total			8,602		31.3	
Contingencies		Inc. Above		20%	6.3	
Estimated Costs			8,602		38	

Opex = operating expenditures; Capex = capital expenditures

Table A2.2.2: Cost Data for High Level Tunnel/Canal (HLTC) Conveyance with High Level Desalination

Project Element	Capacity	Capital Cost		Operating Cost		Comments
		Unit Cost	Total Cost US$ million	Unit Cost	Total Cost US$ million	
Red Sea Intake works	2,000 MCM/year	Lump Sum	100	0.5% capex	0.5	
Pumping Station	206 MW	US$1.31 million/MW	269	2% capex	5.38	
Pumping energy costs	1,628 GWh/year		Nil	US$60/MWh	97.0	
Tunnels	115 km	US$38 million/km	4,303	0.5% capex	21.5	
Open canal section	50 km	US$11 million/km	578	0.5% capex	2.9	
Pipeline			Nil		Nil	
Desalination plant	850 MCM	US$1,169 / m^3/day	2,722	3.05 kWh/ m^3	59.0	Opex covers energy costs only. Cost is for year 1.
Penstocks	13.20 km x 2 pipes	US$17 million/km	227	0.5% capex	1.1	
Hydro plant	240 MW	US$608,000/ MW	146	2% capex	2.9	Does not include revenue from sale of power generated
Value of hydropower generated	1,748 GWh		Nil	US$60/MWh	-105	Income from sale of hydropower - year 1
Discharge canal to Dead Sea	56 km	Lump Sum	500	0.5% capex	2.5	
Sub-Total			8,845		87.8	
Contingencies		Inc. Above		20%	17.6	
Estimated Costs			8,845		105	

Opex = operating expenditures; Capex = capital expenditures

Table A2.2.3: Cost Data for Pipeline (PL) Conveyance with High Level Desalination

Project Element	Capacity	Capital Cost		Operating Cost		Comments
		Unit Cost	Total Cost US$ million	Unit Cost	Total Cost US$ million	
Red Sea Intake works	2,000 MCM/year	Lump Sum	100	0.5% capex	0.5	
Pumping Station	229 MW	US$1.38 million/MW	317	2% capex	6.34	
Pumping energy costs	1,920 GWh/year		Nil	US$60 / MWh	115.2	
Tunnels	26 km	US$74 million/km	1,880	0.5% capex	9.4	High Pressure, steel lined tunnel
Open canal section			Nil			
Pipeline	149 km	US$19 million/km	2,803	0.5% capex	14.0	
Desalination plant	850 MCM	US$1,046 / m^3/day	2,437	3.33 kWh/ m^3	64.0	Opex covers energy costs only. Cost is for year 1.
Penstocks			Nil	0.5% capex		
Hydro plant	251 MW	US$968,000/MW	243	2% capex	4.9	Does not include revenue from sale of power generated
Value of hydropower generated	1,831 GWh		Nil	US$60 / MWh	-110	Income from sale of hydropower - year 1
Discharge canal to Dead Sea	56 km	Lump Sum	500	0.5% capex	2.5	
Sub-Total			8,280		106.8	
Contingencies		Inc. Above		20%	21.4	
Estimated Costs			8,280		128	

Opex = operating expenditures; Capex = capital expenditures

Table A2.2.4: Cost Data of Pilot (PP) and Phased Pipeline (PPL) with High Level Desalination. Phases are designed to match growth in potable water demands

Pilot Phase (Year 2012)	**Capacity**	**Capital Cost - US$ Million**		**Operating Cost - US$ Million**	
Temporary pilot infrastructure	35 MCM/year	Lump Sum	200	Lump Sum	2.3

Phase 1 (Year 2020):-	**Capacity**	**Capital Cost - US$ Million**		**Operating Cost - US$ Million**	
Red Sea Intake works	2,000 MCM/year		100		
Pumping Station	1,000 MCM/year		220		
Tunnels	25.5 km		1,880		
Pipelines	1,000 MCM/year		1,623		
Desalination plant	450 MCM/year		1,292		
Hydro plant			172		
Discharge canal to Dead Sea	2,000 MCM/year		500		
Estimated Costs			5,787		

Phase 2 (Year 2033):-	**Capacity**	**Capital Cost - US$ Million**		**Operating Cost - US$ Million**	
Pumping Station	1,333 MCM/year		39		
Pipelines	1,333 MCM/year		427		
Desalination plant	600 MCM/year		426		
Estimated Costs			892		

Phase 3 (Year 2045):-	**Capacity**	**Capital Cost - US$ Million**		**Operating Cost - US$ Million**	
Pumping Station	1,667 MCM/year		39		
Pipelines	1,667 MCM/year		731		
Desalination plant	750 MCM/year		426		
Hydro plant			78		
Estimated Costs			1,274		

Phase 4 (Year 2054):-	**Capacity**	**Capital Cost - US$ Million**		**Operating Cost - US$ Million**	
Pumping Station	2,000 MCM/year		39		
Pipelines	2,000 MCM/year		374		
Desalination plant	850 MCM/year		292		
Estimated Costs			705		

Imputed annual cost calculations

The imputed annual cost of a subproject consists of the finance cost (i.e., the interest payment on the outstanding debt) plus the cost of capital depreciation (replacement and refurbishment of worn out components) plus the operating expenses (energy, labor, material, contingencies, etc.) minus the hydropower profit (for the Dead Sea Stabilization subproject). This cost is sensitive to the interest rate and is the relevant cost for calculating the break-even prices below. The annual imputed cost represents the annual payments, including the interest on outstanding debt plus operational and maintenance (O&M) expenses minus hydropower profit (for the Dead Sea Stabilization subproject).

Table A2.2.5: Operating Cost Assumptions

	Operating cost as a percent of capital cost (taken from Coyne et Bellier)	Depreciation rate
Intake and Conveyance:		
Red Sea Intake works	0.5%	3%
Tunnels	0.5%	Nil
Pumping, including energy cost	2%	3%
Open canal section	0.5%	Nil

Pipelines	0.5%	3%
Hydropower:		
Penstocks	0.5%	3%
Hydropower plant	2%	3%
Discharge:		
Discharge canal to Dead Sea	0.5%	1%
Contingencies cost	20% of operating cost	
Interest rate (percent)	2%, 4%, 6%, 8%	
Electricity rates (US$/MWh)	60, 110, 142	

The imputed annual costs of the LLGT or PPL options, shown in Figures A2.1.1–1.3, were calculated as follows. First, the interest payments on the capital cost (which varies over time due to phasing of construction of desalination capacity and other components) are calculated. To this cost flow is added the cost of capital depreciation and net annual operating costs (including contingencies) and subtract hydropower profit (for the Dead Sea Stabilization subproject). The present-value of the annual cost flow is then calculated and this present-value is multiplied by the interest rate.

The present-value cost calculations in Coyne et Bellier (2010, Chapter 21) are based on capital and energy costs, including potable water conveyance to Amman but excluding operation costs, for the period 2014 to 2070 (with 2020 as the base period). Costs of depreciation in these calculations enter indirectly via the capital expenditures. Calculating the same present-value costs under our assumptions (e.g., capital depreciation, energy balances, and electricity tariffs at US$60/MWh) gave similar results.

Cost of conveyance of desalinated water to Amman

The conveyance costs of desalinated water to Amman are calculated based on the data in Table A2.2.6 below (provided by Coyne et Bellier).

Table A2.2.6: Potable Water Transmission Pipelines to Amman - US$million

Year	**2020**	**2030**	**2040**	**2050**	**2060**
Water Supply to Jordan	230 MCM/Year	310 MCM/Year	370 MCM/Year	460 MCM/Year	560 MCM/year
Pipeline - Pumped riser main	142	142			
Pipeline - Gravity flow	867				
Pumps	139	28	28	28	
Pump Station	127				
Air vessels, regulating tanks etc	21	4			
Mechanical works	151				
Earthworks	159	21			
Estimated Capital Costs	1605	195	28	28	0
Pumping energy	73	94	114	144	176
Operations and maintenance	23	23	23	23	23
Estimated Operating costs	96	117	137	167	199

The above conveyance cost data pertain to a particular project option. The cost of water conveyance to Amman may vary slightly across project options due to different energy requirements associated with the location of desalination plants (see Chapter 21 of Coyne et Bellier, 2010).

Electricity rate calculations

Table A2.2.7 summarizes the peak-load electricity rates schedule in Israel (taken from Israel's electrical corporation site: www.israel-electric.co.il/). The US$0.11/kWh electricity rate (Regime ii) is obtained as follows. First the average daily rates for each season and for each part of the week are calculated. For example, the Summer&Sun-Thu average rate is US$0.12/kWh = [(0.17+0.02)×6+(0.11+0.02) ×10+(0.03+0.03) ×8]/24. The Winter&Sun-Thu average rate is US$0.12/kWh and the Off-Season&Sun-Thu average rate is US$0.13/kWh. The average Sun-Thu rate is obtained as the weighted average according to the number of days for each season: (0.12×90+0.12×90+0.13×185)/365. The average rates for Friday and Saturday are similarly calculated. The overall average, US$0.11/kWh, is obtained as a weighted average of these averages, weighted by the percent time during a year.

Table A2.2.7: Israeli Peak-Load Electricity Rates Schedule (US$/kWh) under exchange rate of 3.8 NIS per US$1

		Duration (hours)					
Season	Pricing	Sun–Thu	Friday	Saturday	Production Price US$/kWh	Renewable Price Premium US$/kWh	Total Price
Summer 90 days	Peak	6	0	0	0.17	0.02	0.19
	Regular	10	14	3	0.11	0.02	0.13
	Low	8	10	21	0.03	0.03	0.06
Winter 90 days	Peak	5	0	0	0.17	0.02	0.19
	Regular	12	11	5	0.11	0.02	0.13
	Low	7	13	19	0.03	0.03	0.06
off-season 185 days	Peak	14	0	0	0.15	0.02	0.17
	Regular	3	16	6	0.09	0.02	0.11
	Low	7	8	18	0.03	0.03	0.06
Percent time during a year		67.1%	16.4%	16.4%			
Average					0.09	0.02	0.11

The US$0.14/kWh of Case (iii) was calculated in a similar fashion, assuming that the hydropower plant is operated 12 hours a day and the operation time is so chosen as to maximize the resulting average electricity rate.

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