Czech University of Life Sciences Prague

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Ecological Impact Assessment of the Red Sea-Dead Sea Water Conduit Project

Bachelor Thesis

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BACHELOR THESIS ASSIGNMENT

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Ecological Impact Assessment of the Red Sea-Dead Sea Water Conduit Project

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Objectives of thesis

The main aim of this thesis is to review certain aspects of the Red Sea-Dead Sea water conduit project proposed by Israel, Jordan, and the Palestinian Authority. My research describes the project's main motivations and provides an assessment of the potential ecological impacts that such a large-scale water project may cause on the surrounding environment.

Methodology

Review and present concepts from a variety of literary sources.

The proposed extent of the thesis

30 p.

Keywords

The Red Sea-Dead Sea Conduit, Desalination, Hydropower, Water Scarcity, Ecological Impacts

Recommended information sources

Beyth, M. (2007). The Red Sea and the Mediterranean–Dead Sea canal project. Desalination, 214(1-3), 365-371.

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Qdais, H. A. (2008). Environmental impacts of the mega desalination project: the Red–Dead Sea conveyor. Desalination, 220(1-3), 16 – 23.

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Declaration

I declare that I have written this bachelor thesis by myself under the supervision of Ing. Vojtěch Havlíček, Ph.D. I have listed all the literary sources and publications I drew from. I declare that the printed version coincides with the version submitted via the University Information System.

As the author of this bachelor thesis, I declare that the thesis does not break the copyrights of any person.

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Abstract

Ecological Impact Assessment of the Red Sea-Dead Sea Water Conduit Project

The region of Israel, Jordan, and the Palestinian Authority lays in a semi-arid and arid area of the world with low precipitation and a high evaporation rate. In the last decades, these governments have been overexploiting the Dead Sea and its only tributary the Jordan River, which has led to the rapid drying of these vital water resources. As a result of the Jordan River's low inflow and the extreme climate conditions in the area, the Dead Sea's water level started rapidly decreasing throughout a short period. To fight water scarcity and to save the Dead Sea, Israel, Jordan, and the Palestinian Authority have agreed to construct the Red Sea-Dead Sea Conduit. The project aims is to connect the Red Sea to the Dead Sea via a conduit and pump water from the Red Sea to fill up and stabilize the Dead Sea's water basin. Part of the project is a construction of desalination and hydropower plant. This thesis evaluates the potential environmental impacts associated with the development of the conduit. To compare and contrast the presented advantages and disadvantages to assess the project's feasibility, all previous information and proposals regarding the Red Sea-Dead Sea Conduit project were reviewed. The project brings benefits such as stabilizing the Dead Sea, providing hydropower, and supplying water for the entire region. But the negative impacts, which could be long-term and potentially irreversible to the environment, outweigh the benefits. The evolution of the project also brings to question: is protecting the Dead Sea merely a promotional instrument, while the true underlying goal is to provide water and energy to water-scarce countries? In the conclusion of that, solving an environmental issue through another huge human intervention into nature is, in this case, inefficient and unsustainable. Another simpler and less-intrusive solution could be established, one that would not include stabilizing the Dead Sea's water level.

Keywords:
The Red Sea-Dead Sea Conduit, Desalination, Hydropower, Water Scarcity, Ecological Impacts

Abstrakt

Posouzení ekologických dopadů projektu “The Red Sea-Dead Sea Conduit”

Izrael, Jordánsko a Palestinská autonomie se nachází na Blízkém východě v oblasti s vysokými teplotami a nízkými srážkami. V posledních desetiletích vlády těchto státních útvarů v nadměrné míře využívaly jejich hlavní společný zdroj vody – jezero Mrtvé moře a jeho přítok řeku Jordán. Odčerpávání těchto důležitých vodních zásob v kombinaci s náročným podnebím má za následek klesající hladinu Mrtvého moře v krátkém časovém úseku. V zájmu boje proti nedostatku vody v této oblasti a záchrany Mrtvého moře se Izrael, Jordánsko a Palestinská autonomie rozhodli uskutečnit projekt „The Red Sea-Dead Sea Conduit”, díky kterému by se čerpala voda z Rudého moře do Mrtvého moře přes 200 km dlouhé potrubí vedené přes poušť Arava. Cílem tohoto projektu je stabilizace hladiny Mrtvého moře. Součástí projektu je i stavba vodní elektrárny a odsolovacích zařízení.

Tato bakalářská práce je zaměřena na zhodnocení uvažovaného projektu z hlediska proveditelnost a dopadů na životní prostředí, a to na základě rešerše odborné literatury. Propojení obou moří přináší mnoho pozitivních dopadů, jako je stabilizace hladiny Mrtvého moře, poskytování vodní energie a vody do celého regionu. Avšak negativní dopady, které by mohly být dlouhodobé a potenciálně nevratné v rámci životního prostředí, převyšují možné přínosy. Diskutabilní je také dlouhodobá udržitelnost takto radikálního zásahu do krajiny v uvažovaném rozsahu. V rámci práce jsou proto zmíněny i alternativy k posuzovanému projektu.

Klíčová slova:
The Red Sea-Dead Sea Conduit, Odsolování, Vodní Energie, Nedostatek Vodních Zdrojů, Ekologické Dopady

Table of Contents

List of Used Abbreviations

AV	Arava Valley
DS	Dead Sea
GA	Gulf of Aqaba
JR	Jordan River
LJR	Lower Jordan River
MCBM	million cubic meters
MEDRC	Middle East Desalination Research Centre
MS	Mediterranean Sea
NB	northern basin
PA	Palestinian Authority
RS	Red Sea
RSDSC	Red Sea-Dead Sea Conduit
SB	southern basin

1. Introduction

The Dead Sea (DS) is a hypersaline lake with a salt concentration 10 times higher (34 %) than standard ocean saltwater (The World Bank, 2014). This unique water body is the lowest place on Earth and is also situated in a desert shared by Israel, the Palestinian Authority (PA), and Jordan (Ben-Avraham, 2001). The DS area is a popular tourist destination with an extensive history, but it also provides a vital water resource to the region.

Besides the DS's remarkable existence, its water surface continuously decreases, currently dropping at a rate of 1 m/year (Qdais, 2007). This phenomenon is a manifestation of severe desertification caused by an anthropogenic intervention such as mining and rapid water withdrawal from the DS and the Jordan River (JR); the DS's only tributary. Another factor that contributes to this annual drop is climate change, where low precipitation, high temperatures, and decreasing humidity, have caused high evaporation of the area (Gavrieli & kol. 2005).

The water loss of the DS leaves behind massive salt deposits (Gavrieli & kol. 2005), which degrade the land quality (Qdais, 2007) and have already destroyed some of the road and housing infrastructure along the northern shore of the DS. Due to drying, the DS has divided into two basins.

The region of Israel, Jordan, and the PA lays in a semi-arid and arid area with a low average of precipitation and a high rate of evaporation (Brooks & kol. 2020). As a result of large water consumption and intake of natural water sources by the three countries, to find an alternative water supply solution became a necessity (Brooks & kol. 2020). In order to fight water scarcity, Israel keeps developing desalination plants on the Mediterranean Sea (MS), accompanied by the implementation of innovative water-saving strategies, such as wastewater reuse (Brooks & kol. 2020). Jordan and the PA rely on natural water sources, such as rivers, springs, and wells, and water recycling, and water support from Israel (Brooks & kol. 2020).

Nevertheless, the Mediterranean countries understand the challenges posed on the DS concerning changing water quantity and climate in the region. Therefore, to address these issues of restoring the DS water level, solving water scarcity problems in this region, and strengthening Middle East political relations, Israel and Jordan began publicly cooperating to establish a massive public works project, the Red Sea-Dead Sea Conduit (RSDSC) in 2002 (Hussein, 2017). With additional coordination and support from the World Bank, the PA joined the RSDSC project in 2005 (Hussein, 2017). The goal of the project is to pump water from the Red Sea

(RS) via 200 km long construction of pipelines and channels into the DS (The World Bank, 2014). The project also includes the construction of two hydropower plants and one desalination plant along with the system (The World Bank, 2014). Due to different elevations between the RS and the DS, the hydropower plants will harness hydroelectric energy (The World Bank, 2014). Potable water from the desalination process will be distributed to Israel, Jordan, and the PA for affordable prices (Aggestam & Sundell, 2016). The RS saltwater and rejected brine from the desalination will be mixed and then introduced into the DS to stabilize and gradually raise the water level back to ideal conditions (Gavrieli & kol. 2002).

Despite the projects best intentions, the massive public works project has been associated with irreversible damage to surrounding environment such as (i) the destabilization of the soil infrastructure and contamination of the marine environment of the RS shore; (ii) habitat fragmentation, land disruption, and air pollution along the constructed conduit; (iii) increased carbon dioxide emissions produced by the desalination plants; (iv) the creation of two different saline waters of chemical composition and with diverse densities; among the development of other potential environmental problems (Qdais, 2007).

2. Aims of the Thesis

1. To combine all previous information and proposals regarding the RSDSC project to provide an impartial review of the situation

2. To characterize the DS and RS basins as separate entities, from an ecological and historical perspective.

3. To compare and contrast the presented advantages and disadvantages to assess the project’s feasibility.

4. Most important to our field of study, to evaluate the potential environmental impacts associated with the development of the conduit and the desalination plants. Will the project achieve the proposed objectives, or will it present other, unsolvable ecological challenges?

3. Literary Research

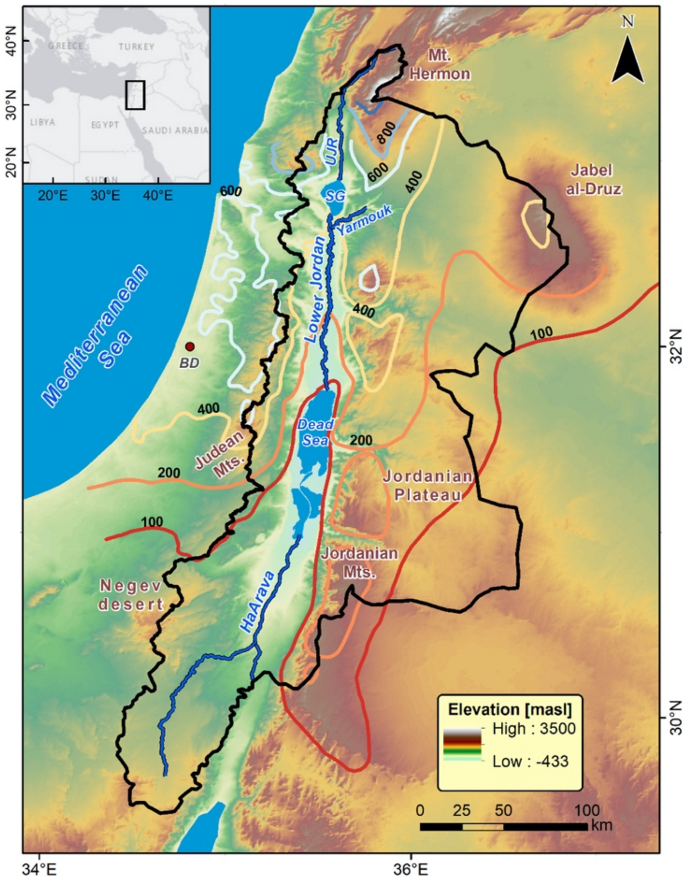
3.1 The Dead Sea

The DS, also known as the Sea of Salt, was formed over one million years ago by the movement of tectonic plates and gradual desertification (Mart, 1991). The DS is bordered by Israel from the southwest coast, the PA from the northwest coast, and Jordan from the east coast (Sharieh & kol. 2018). Along the entire length of the DS, there are roads, beaches, and neighborhoods on both the Israeli and Jordanian sides. The DS fills a depression in the Near East between the Jordan Valley in the north and the Arava Valley (AV) in the south (Mart, 1991). The western portion of the DS is bordered by the Judean mountains range filled with sharp cliffs and long canyons (Segal & kol. 1983), and from the eastern site spreads Jordanian plateau (Enzel & kol. 2006) (see *Picture 1*).

Topographically, it is the lowest terrestrial point on Earth, located 429 meters below sea level (measured in 2014) (Sharieh & kol. 2018). It is around 150 km long and up to 17 km wide (Ben-Avraham, 2014). As the name suggests, the DS is a hypersaline lake of 35 % salt concentration, a 348 g/L of total dissolved solids (TDS) (see *Table 1*) (Golan & kol. 2016), and with a density of 1.24 kg/L (Golan & kol. 2016).

The DS's only water inflow is precipitation, groundwater, and the JR, while the DS is currently without a runoff. An average precipitation rate of the DS area is annually 100 mm (Belachsen & kol. 2017). However, the DS's water level is decreasing. That is caused by a mineral harvesting and potash production and during the DS's water surface evapotranspiration (around 994±88 mm, measured between 2014-15) (Metzger & kol. 2018). This phenomenon is a result of a constant water level drop since 1950, as the surface area declined to 620 km² from 950 km² (The World Bank, 2014).

Due to this drastic water decline, the DS has separated into a southern and northern basin; each basin has its unique characteristics (Garfunkel & Ben-Avraham, 1996).



Picture 1: Map of the Dead Sea area. The Dead Sea watershed (black line). Colored contours are mean annual rainfall isohyets [mm/year] based on 1961–1990 data. Major streams (blue lines). SG = Sea of Galilee; UJR = Upper Jordan River. BD = Bet Dagan (Armon & kol. 2019).

Parameter	Units	DSB average
Na^{+}	mmol kg^{-1} solution	1081
K^{+}	mmol kg^{-1} solution	169
Ca^{2+}	mmol kg^{-1} solution	391
Mg^{2+}	mmol kg^{-1} solution	1663
Sr^{2+}	mmol kg^{-1} solution	3.5
Cl^{-}	mmol kg^{-1} solution	5294
Br^{-}	mmol kg^{-1} solution	62
B	mmol kg^{-1} solution	4.6
Alkalinity (TA)	mmol kg^{-1} solution	3.826
DIC	mmol kg^{-1} solution	0.86
pH		6.27
TDS	g L^{-1}	348
Density @25 °C	kg L^{-1}	1.242

Table 1: Average Dead Sea (2013) chemical composition. DSB = Dead Sea brine (Golan & kol. 2016).

3.1.1 The Northern Basin

The northern basin (NB) extends in the Jordan Rift Valley as the larger part of the DS. It is around 50 km long and 15 km wide with a depth of about 307 m (Hall, 1996).

Annual precipitation in this region is minor, about 150 mm/year (Belachsen & kol. 2017). It is also accompanied by high temperatures in the summer and cooler rainy weather in the winter (Belachsen & kol. 2017). During the hot summer months, a high evapotranspiration rate in the NB's area is noticeable.

The main and only tributary of the DS is the 220 km long JR (Hillel & kol. 2015). The Lower Jordan River (LJR) flows from the Sea of Galilee (Lake Kinneret, or Lake Tiberias) to the DS. Its water acts as a resource for agriculture, industry, and potable water for Israel, Jordan, and the PA (Hillel & kol. 2015). The JR is, from a historical and religious point of view, characterized as one of the most sacred rivers in the world, but it has been overexploited in the last several decades and the water level has dropped by 90 % (Hillel & kol. 2015). Now, the water of the LJR has high salinity and is largely contaminated (Hillel & kol. 2015).

3.1.2 The Southern Basin

The southern basin (SB) is a smaller and more shallow part of the DS occupying the AV (Hall, 1996). Annual precipitation in the southern part is less than 50 mm (Belachsen & kol. 2017). This area has semi-arid to hyper-arid climate, and in comparison with the NB, the SB has a higher potential to drain (Kishcha & kol. 2018).

Considering the small size of the basin, the SB plays a crucial role in Israeli and Jordanian mining companies, the Dead Sea Works (Israel), and the Arab Potash Company (Jordan) (Wedyan & kol. 2013). To save the SB from drying up, they constructed artificial lagoons with evaporation ponds and pump water from the NB into the SB (Wedyan & kol. 2013). In 2014, the SB was stabilized on an elevation of - 406 m (The World Bank, 2014). Despite the SB's water level rising, the mining industry in the area is one of the major factors of the DS critical water situation, where the factories annually pump water from the SB to harvest minerals (Oren, 2010).

3.1.3 Causes of Water Decline

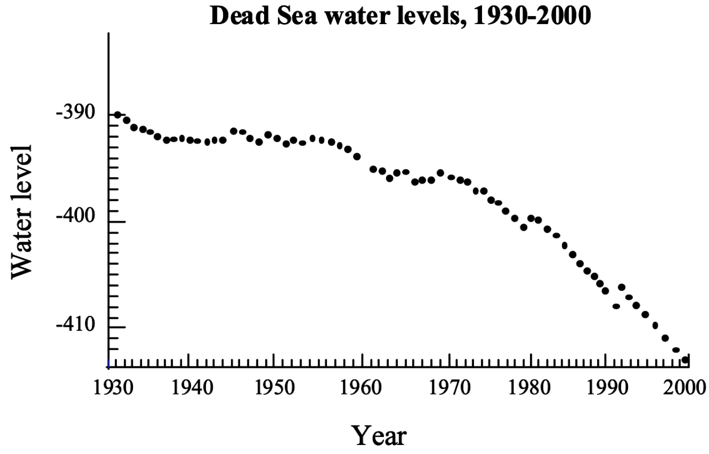
As mentioned before, the JR, groundwater, and precipitation are the only forms of water supply to the DS (Wedyan & kol. 2013). Mainly because of two influential human interventions during the last decades, the DS water level rapidly declined, currently at a rate of 1 m/year (see *Picture 2* and *Table 2*), that is about 300 MCBM of freshwater per year (Qdais, 2007). Such a decline indicates that the water resources of the DS are no longer sustained.

1. In the 1950s, a high-water demand resulted in a massive reduction of the JR's flow (The World Bank, 2014). Around 1 300 MCBM/year has been withdrawn, mainly by Israel, Jordan, and the Syrian Arab Republic (The World Bank, 2014). The main drivers were potable water for irrigation, industry, and water supply for a growing population.

2. The second significant intervention that caused the water decline and severe damage to a unique habitat is high water consumption at the southern point of the DS for evaporation ponds of chemical industries owned by Israeli (the Dead Sea Works) and Jordanian (the Arab Potash Company) governments (Malkawi & Tsur, 2016). The Dead Sea Works was founded in 1929, back then known as the Palestine Potash Company; and the Arab Potash Company in 1956. These mining companies pump around 400 - 450 MCBM of DS's water per year into evaporation ponds built on the SB shore (Khlaifat & kol. 2010). These evaporation ponds serve to evaporate carnallite (a hydrated potassium magnesium chloride) as well as halite (sodium chloride, "rock salt") (Khlaifat & kol. 2010). After the evaporation process, the rest of the brine (around 200 MCBM/year) is then released back into the DS (Gavrieli & kol. 2005). The harvested minerals are produced as potash, magnesium, manganese, and bromide (Khlaifat & kol. 2010). Potash is probably the most valuable substance used mainly in potassium-containing fertilizers (IIED, 2002) and many more applications.

   Both of the interventions had a negative effect on the climate. The result was regional warming and heat flow from the land during the day causing greater evapotranspiration rates (Kishcha & kol. 2018).

   The highest measured water level of the DS reached -390 m in 1930 (see *Graph 1*) (Gavrieli & kol. 2002). As mentioned before, the dramatic water decline started in late 1950 and it was continuously increasing until current -426 m, which means 36 m decline since then until now (see *Table 2*).



Picture 2: The Dead Sea water levels measured from 1930 until 2000 (Gavrieli & kol. 2002).

Period	Level change (b.s.l.)	Water volume loss (km^3)	Surface area loss km^2	Drop rate m/a
1932–1955	389–399	3 (0.13 km^3/a)	78.1 (4 km^2/a)	0.1
1955–1978	399–400	6.7 (0.29 km^3/a)	286.8 (11.7 km^2/a)	0.35
1978–1995	400–409	6 (0.36 km^3/a)	56,3 (3.3 km^2/a)	0.5
1995–2009	409–422	6.9 (0.49 km^3/a)	72.5 (5.2 km^2/a)	1
2010–2020 (expected)	423–433	3.4 (0.34 km^3/a) (Eq. 1)	55.8 (5.6 km^2/a) (Eq. 3)	1

Table 2: Water level and water volume, surface area loss and drop rate of the DS since 1932 until 2020 (Ghazleh & kol. 2011).

3.1.4 Future Prospects

Even though the DS's water level is annually rapidly decreasing, this phenomenon is expected to continue for another 200 years (IME, 2006). After that, the DS's extremely saline water should be stabilized by itself at level of about -500 to 550 m, which represents a surface area of 450 km^2 (Ghazleh & kol. 2011; Levy & kol. 2020). The evapotranspiration rate is estimated to decrease in relation to the highly saline brine (Ghazleh & kol. 2011). The water level should stabilize naturally because of an equal rate of inflow and outflow (evapotranspiration) of the DS (Gavrieli & Bein, 2007).

Even though the DS's water quality should become worse, due to many scientific predictions, the DS is not expected to dry up.

3.1.5 Minerals Composition

High temperatures and high evaporation rates surrounding the DS area lead to salinization; the process of increasing water density due to increased sodium chloride (NaCl) concentrations over time (Jaime, 2002). As a result of the high water salinity, the salt (halite, NaCl) in the water started precipitating since the 1980s until now; this is referred to as the halite point (Gavrieli & kol. 2005). Precipitation of minerals is a chemical reaction during which sedimentary rocks are created from a liquid like water (Gavrieli & kol. 2005). The higher concentrations of halite suppress the concentration of sodium (Na) in water, which leads to a high increase of magnesium (Mg). Based on its unique conditions, the DS makes an ideal environment for NaCl and Mg deposits (Wedyan & kol. 2013). Besides, the DS basins are oversaturated in minerals such as aragonite ($CaCO_3$), anhydrite ($CaSO_4$), potassium (K) (Gavrieli & kol. 1989), manganese (Mn), bromide (Br) (Golan & kol. 2016), and a unique composition of calcium chloride ($CaCl_2$) (Wedyan & kol. 2013).

3.1.6 Microorganisms Composition

From an ecological standpoint, the high concentration of the salts and magnesium in the water creates a hostile environment for many species, but some halophyte microorganisms manage to thrive in these conditions (Wedyan & kol. 2013). Their rapid proliferation occurs when freshwater enriched with phosphate is introduced, therefore a spike is regularly observed during rainy winter months and at the point of inflow from the JR (Wedyan & kol. 2013). To a large extent, on the surface and the bottom of the DS live diversities of algae, bacteria, protozoa, and ciliates (Nissenbaum, 1975). The main producer during proliferation is green algae (*Dunaliella* sp.) and red halophilic Archaea (Nissenbaum, 1975). *Dunaliella* is of considerably high interest to scientists for its ability to survive in extreme conditions, especially in the hypersaline water bodies (Nader & kol. 2011).

Surrounding the DS, researchers have found complex systems of microbial communities in the groundwater (Nader & kol. 2011). These communities cover rocks and are part of depositing sediments.

3.1.7 Creation of Sinkholes along the Dead Sea Shore

Another environmental impact threatening the DS area is the formation of sinkholes. A sinkhole is a certain collapse in the soil caused by salty groundwater turning into salt deposits (Frumkin & Raz, 2001). This salt layer is then washed and submerged by groundwater or rainwater (Yechieli & kol. 2016). During high evaporation events, this salt dissolution in the ground results in harmful salt karst forming chamber caves of different sizes (Frumkin & Raz, 2001). Since the 1980s, more than 4 000 holes have formed around and under the western side, along the Israeli coast of the DS (Yechieli & kol. 2016). It has dramatically altered the environment, destroying infrastructures like roads and housing developments built on the shoreline (Frumkin & Raz, 2001). This water erosion phenomenon is a natural and irreversible disaster directly linked with the DS shirking (Yechieli & kol. 2016).

3.2 The Red Sea

The RS is a large water body situated between the African and Asian continents (Manasrah & kol. 2019). It is surrounded by Israel and Jordan in the north, in the east by Saudi Arabia and Yemen, and in the west by Egypt, Sudan, Djibouti, and Eritrea. The RS extends into the Red Sea Rift, which is part of the Great Rift Valley (Manasrah & kol. 2019). It is a 1 930 km long and around 280 km wide elongated inlet to the Indian Sea (Abdel-Halim & kol. 2016). Massive amounts of water are exchanged between the Arabian Sea and the Indian Ocean through the Gulf of Aden (Abdel-Halim & kol. 2016).

The salinity of the RS ranges between 36 g/kg (in the south) and 41 g/kg (in the north) (Ngugi & kol. 2011), which is significantly lower than the salinity of the DS. The Red Sea is poor in nutrients, except some small areas (Manasrah & kol. 2019). Precipitation in this area is low (maximum of 120 mm/year on average) (Al-Mutairi & kol. 2019). Low precipitation and high temperatures of this area resulting in high evapotranspiration, and relatively hot surface water (during the winter 2°C, during the summer around 30°C) in the south (Manasrah & kol. 2019).

The RS's water tributaries are the Barka, Haddas, and the Anseba Rivers flow into the RS through the southern end of the sea called the Bab-el-Mandeb, meaning the Gate of Tears (Manasrah & kol. 2019). The RS has two further inlets in the northern portion extending into the Gulf of Aqaba (GA) and the Gulf of Suez, which is both connected to RS through sea passages (Eyal & kol. 2019).

3.3 The Gulf of Aqaba

The zone of proposed construction lies in the northern portion in the semi-enclosed basin of the RS, the GA, which is connected to the RS by the Strait of Tiran (Manasrah & kol. 2019). The gulf is bordered by Arabian plate from the eastern site and by the Sinai plate from the western site (Ribot & kol. 2018). The GA is 180 km long, 5 - 25 km wide and the average depth of the GA is 800 m, with a maximum depth at 1 825 m (Manasrah & kol. 2019).

The climate at this portion of the RS is arid, with a low annual precipitation rate of 22 mm of rain per year in combination with a high evaporation rate in the GA of 179 mm water lost each year (Abdel-Halim & kol. 2016). In winter months, the temperature ranges between 18˚C to 20˚C and is accompanied by relatively high humidity ranging from 54.6 % to 63.5 % (Abdel-Halim & kol. 2016). In the summer months, there are extremely arid conditions marked by strong winds, temperatures ranging between 31.5˚C to 32.7˚C, and relatively lower humidity of 47.5 % to 55.6 % (Abdel-Halim & kol. 2016).

The GA is well known for its abundant biodiversity and protected coral reef ecosystems along the shoreline. The basin is mainly surrounded by mountains and a few villages and settlements (The World Bank, 2014). On the northern coast of the gulf exist two well-populated touristic cities, Eilat in Israel and Aqaba in Jordan, which are still growing and developing (The World Bank, 2014). They offer recreation facilities, hotels, restaurants, shopping areas, and beaches. Since the GA is a popular touristic location, the environment has been largely degraded through land development, a growing population and tourism industry, and construction of the infrastructure needed to meet the growing demand in the region (Abdel-Halim & kol. 2016).

3.3.1 Water Characteristics

The GA is composed of saline marine water with an average density of 1.03 kg/L containing 4 % of salt (Biton & Gildor, 2011). The water's surface temperature is around 20˚C in the winter and 28˚C in the summer, but, same as the water density, it fluctuates with seasons (Paldor & Anati, 1979). Warm surface water flows from the RS into the GA through the Strait of Tiran sea passage and exchanges with cooler, saltier water from the sea bottom, creating a mixing effect (Abdel-Halim & kol. 2016).

The water of the GA is supersaturated with minerals like aragonite and calcite (Steiner & kol. 2019). The high salinity of the GA, and the RS as well, always increasing landward, causes extensive corrosive actions. This disturbs the soil structure and groundwater quality. Low salinity infiltration of the water raises the groundwater causing floods to occur in the low urbanized areas (Katz & kol. 2015).

3.3.2 Microorganisms Composition

The GA is known for its diverse ecosystem with over 198 unique fish species and benthic ecosystems of seagrass (Khalaf & Kochzius, 2002). There are a high number of soft coral species (120) and reef-building corals (192) in the GA (Qdais, 2007). The gulf is rich in inorganic nutrients such as ammonia, nitrate, phosphate, and silicate, which support marine phytoplankton to thrive in these waters (Manasrah & kol. 2020). These nutrients are more abundant during the winter and as a result, plankton is extremely productive during these months (Manasrah & kol. 2020).

The high evapotranspiration rate (around 5 - 10 mm/day) of the GA creates a relatively high saline concentration of its water, which is close to the physiological limit for many aquatic organisms (Manasrah & Al-Majali, 2019).

Unfortunately, the water and marine ecology of the gulf has degraded in recent decades, through processed solid wastes being released into the environment (The World Bank, 2014). Heavy metals introduction to the coastal environment comes from a variety of different sources, such as domestic and industrial waste, shipping and fishing, oil pollution, brine discharges from desalination plants in Saudi Arabia, coastal constructions and human-made waste accumulation (43.7 % of total waste) (Naser, 2013). For instance, oil pollution is a very severe phenomenon that is affecting the functions of the entire ecosystem, drastically impacting metabolic processes, reproduction, and the presence of organic matter used for consumption (Manasrah & Al-Majali, 2019). These factors directly result in the loss of species diversity. For instance, plankton, food for many marine species, is highly sensitive to oil (Manasrah & Al-Majali, 2019). If something is not done to combat the accumulation of oil over time, it could result in the removal of the species in the GA altogether (Manasrah & Al-Majali, 2019).

The RS contains several physicals, chemical, and biological contaminants that threaten the stability of this marine ecosystem, due to their toxicity and persistence (Abdel-Halim & kol. 2016). These pollutants are not only harmful to the ecosystem, but they are also deleterious to humans (Abdel-Halim & kol. 2016). Without proper protection, these waters will become unusable for a tourism industry that has come to depend on this thriving biodiversity.

3.4 The Red Sea-Dead Sea Conduit Project

The RSDSC is a mega-public works project sponsored by combined international powers to raise and stabilize surface water of the DS by connecting the RS and the DS via a pipeline (Hussein, 2017). The goal of this project is to save the DS from drying, to prevent a major water crisis from escalating, and to strengthen peace in the region between Israel, Jordan, and the PA (Aggestam & Sundell, 2016). This plan will be attained by creating a peace treaty to facilitate cooperation in water production, producing hydropower and building desalination plants along the shore of the DS (Hussein, 2017).

3.4.1 Historical and Political Background

The idea to connect water basins in the Mediterranean region was already conceptualized in the year 1665, when a Jesuit, Athanasius Kircher, suggested creating a canal for transportation between the RS and DS (Hussein, 2017). A similar, more developed, plan had been proposed in 1855 when an English naval captain named William Allen suggested creating a pipeline from the MS in the northern part of Israel to Lake Tiberias, connecting through the JR, flowing downstream to the DS, and out to the RS (Gavrieli & kol. 2002). Any investment was forgotten by the opening of the Suez Canal in 1869 (Hussein, 2017). The vision of the MS and the DS pipe appeared again in a Zionist Theodor Herzl's novel in 1902 containing his idea to gain hydropower from the different elevations between the two water basins. This idea was gravelly considered in 1973 after the Arab-Israeli War and an oil crisis which raised prices of the energy in the whole world (Alpanda & Peralta-Alva, 2010), but in 1985 repealed because of financial and political reasons (Hussein, 2017).

Previous aims of connecting the two water basins had mainly political and economic motivations. But in more recent decades, the focus has turned to prevent water scarcity in the region. As mentioned before, water scarcity in the Middle East is directly linked to human exploitation with natural water sources in combination with high aridity in the region, which raises surface temperature

(Hamidi, 2020). As a result, the evaporation rate has risen, which rids the soil of moisture and reduces its quality (Brooks & kol. 2020). This relationship presents a positive feedback loop that continues to compound on itself, making the situation very dire (Hamidi, 2020).

In 1993, the Palestine Liberation Organization at the time and Israel signed an Oslo agreement with a declaration of an inter-regional economic plan (Hussein, 2017). To strengthen relations between the Israeli and Jordanian governments, the two nations signed The Treaty of Peace in 1994 which contained, among other things, an agreement for cooperative water use from the Jordanian river (Hussein, 2017). To share water sources within the Palestinian territory as well, Israel and the PA signed the Oslo II Agreement in 1995 (Hussein, 2017). In 1996 the World Bank attempted to work with the three territories to prevent water scarcity by stabilizing and desalinating the DS (Hussein, 2017). As such, all three signed the Trilateral Declaration on Principles for Cooperation on Water-Related Matters and New and Additional Water Resources (Hussein, 2017). This act led to the foundation of an international organization called the Middle East Desalination Research Centre (MEDRC) in 1996 (Hussein, 2017). MEDRC's mission is to support the development of solutions to address water scarcity and regional environmental issues in general (MEDRC, 2020).

In 2002, Israeli and Jordanian governments publicly identified the construction of the RSDSC project as a less questionable and necessary project for strengthening the peace in the region affected by water scarcity (Hussein, 2017). In 2005, Israel, the PA, and Jordan agreed to initiate a feasibility study looking into the RSDS Conduit (Water Authority, 2015).

The population of the three entities has increased rapidly since the end of the 20th century. Currently, the populations average roughly 22 million people with a mere water supply of 3 000 MCBM/year in total between the three territories (Brooks & kol. 2020). This amount of water does not meet the high-water demand from industrial, agricultural, and domestic usage. Despite this call for alternative approaches, Israeli apprehensions about the water issue are less dramatic, because of their access to the MS and the RS. Since it's a declaration as a country, Israel has kept developing new water technologies, including strides in the fields of water sanitation and education, water treatment and monitoring, cyber-security and measurement as well (Zecher, 2019). Also, Israel invests a lot of research and money in water conservation, recycling, management, and desalination plants (Zecher, 2019). Since 2001, Israel has built 5 desalination plants along the MS shore (Ashdod, Ashkelon, Palmachim, Hadera, and Sorek), which are among the biggest plants in the world, producing almost 600 MCBM of freshwater per year (Kress & kol. 2020). Another 4 potential plants are planned for the coming decades (Zecher, 2019). This technological advancement in water has paid off for Israel, meeting the country's demands while having enough surplus to export water to Jordan and the PA (in 2016 $2.5 billion) (Zecher, 2019).

Water recovery in the West Bank, by the PA, is mainly collected by water basins and reservoirs (Brooks & kol. 2020). Thanks to foreign donations, the PA also has created wastewater treatment plants in Gaza and major cities like Ramallah, Jenin, Tulkarem, and Jericho (Brooks & kol. 2020). To reduce conflict and to address water demands, Israel and the PA began successfully cooperating. As mandated in the Water Agreement from 1994, Israel continues to provide water to the PA, with many worldwide donors helping to achieve 90 % of the 1 000 proposed water projects in the West Bank (Brooks & kol. 2020).

The Jordanian government's attitude on finding innovative solutions in the RSDS desalination mega project results from an unstable economy (Hussein, 2017) which depends on 12 surface and 15 groundwater basins within the country. With such little water available in the country, these basins are largely overexploited (Walschot & kol. 2020). Several of Jordan’s main water sources are shared with neighboring countries and unlike their water independent neighbors, Jordan is not able to create an alternative water source (Walschot & kol. 2020). High prices of oil to run desalination plants are not affordable to the Jordanian government, as a result Jordan heavily depends on natural sources of water, leading to exploitation (Walschot & kol. 2020). This current situation is not sustainable to meet the growing water demands of an increasing population in Jordan, which continues to actively take in refugees from Syria (Talozi & kol. 2019). The current number of Syrian immigrants has reached over half a million in Jordan (Walschot & kol. 2020). Desperate for a sustainable solution, a government source declared that Jordan would continue in the Project with or without Israel as a partner (Namrouqa, 2018).

In December 2013 Israel, Jordan, and the PA signed a memorandum of understanding in Washington D.C. to implement the first phase of the RSDS project (Hussein, 2017). The first phase is to install Jordan’s very first desalination plant in Aqaba, which could potentially desalinate around 65 - 80 MCBM of water annually

(The World Bank, 2014). The excluded brine from the plant will be discharged via pipeline into the DS (Hussein, 2017). The agreement also included the exchange of potable water from Israel to the PA. In February 2015, Israel and Jordan signed a bilateral agreement regarding phase one. This agreement is a continuation of the 2013 agreement, with an additional treaty between Israel and Jordan, where*:" the Arava and Eilat region will receive 30 - 50 million cubic meters of the water. Jordan will receive 30 million cubic meters of water for use in the south. Israel will also sell Jordan another 50 million cubic meters of water from the Kinneret for use in the north "* (Zecher, 2019).

Since then, the RSDSC project has been delayed due to financial obstacles, bureaucratic red tape, and environmental impact assessment. Israel and Jordan are making strides to budget for the RSDSC project, but hesitating has created diplomatic tension between Jordan and Israel.

3.4.2 Construction

The design of the RSDSC operation is divided into two stages, (i) a filling stage, where the aim is to raise the DS level, and (ii) a steady stage when the brine and seawater are mixed, the bottom and surface water are balanced and the precipitation rate is equal to the total inflow (The World Bank, 2014). A pipe pumping the seawater 230 m uphill through the AV will be constructed in Jordan and using that gravity to transport the seawater to a network of pipelines leading to the DS and each of the stakeholders (The World Bank, 2014). The difference in land elevation in the AV is considered as an advantage for generating energy.

Many studies discuss the most feasible prototypes for the project design of each stage while taking into account economic, social, and environmental impact considerations.

The GA was chosen as the water intake location for the RSDS project. Despite this decision, this location is vulnerable to flooding flowing from the AV and Wadi Yum watersheds due to elevation and arid land infrastructure (Farhan & Anaba, 2016). This event can damage roads and the surrounding habitats, as well as create complications during the intake implementation and maintenance during its operating.

Within the GA the specific site where water is drawn from has to be determined to prevent any associated negative impacts to the marine ecosystem. This concept will be discussed in more detail in the *"Impacts on the Marine Environment"* section below (*3.5.1*). Two possible intake locations in the GA were proposed, along the northern and in the eastern shoreline (see *Picture 3*) (The World Bank, 2014).

Picture 3: The Gulf of Aqaba - two proposed water intake locations for the RSDSC project. Orange dot: proposed location in the middle of cities Eilat (Israel) and Aqaba (Jordan). Red dot: chosen intake location (Jordanian side) (https://zoom.earth/ edited by author, 2020).

The northern intake lies between the Israeli and Jordanian borders, with the Aqaba Airport located towards the north. This location is a typical runoff point during floods from the Wadi Yutum (Katz & kol. 2015). Due to seismic and bathymetric data, the location is more sensitive to seismic activity, than the eastern intake (The World Bank, 2014).

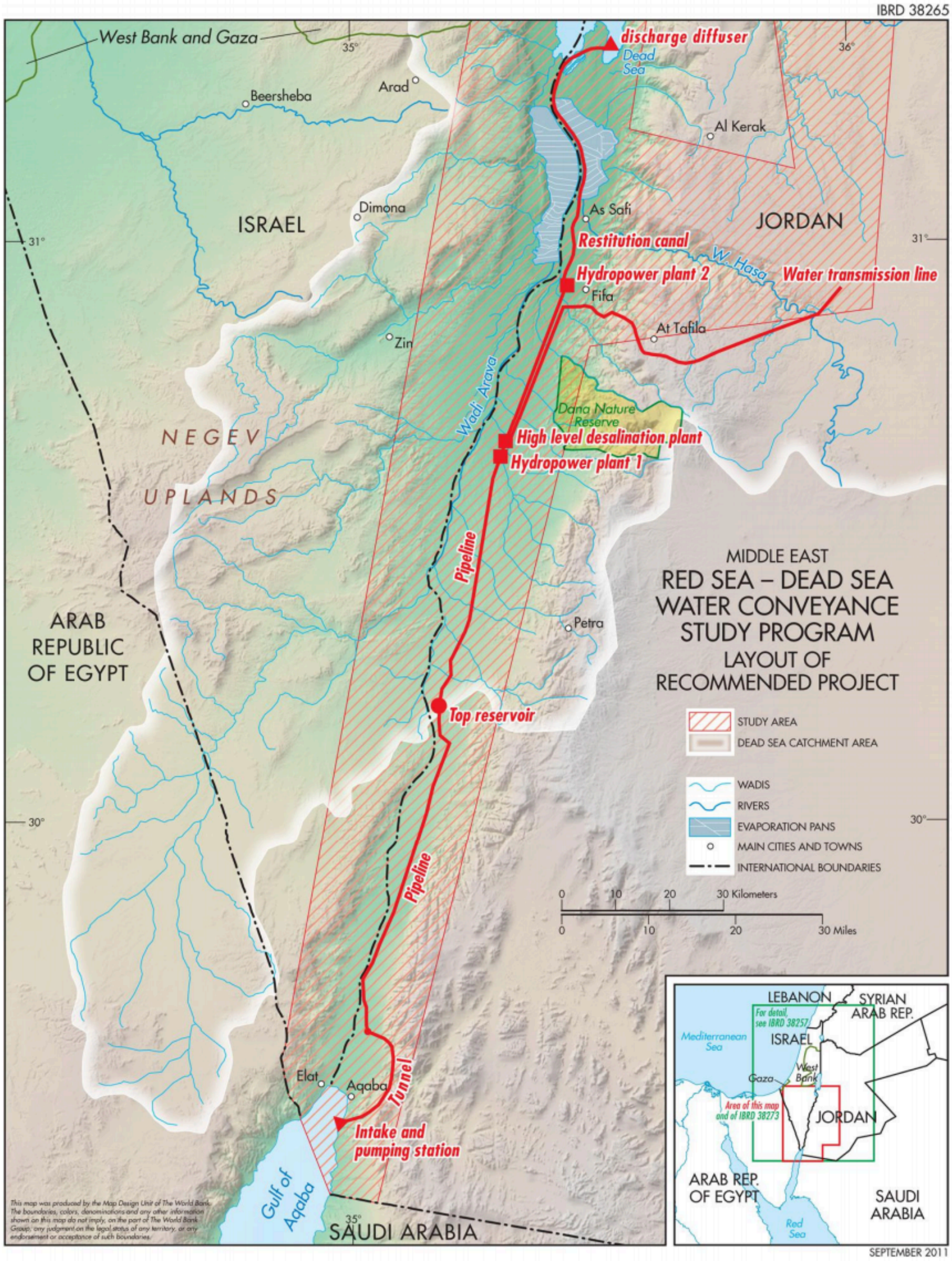
The eastern intake would be built in the gulf on the Jordanian shoreline. This area is less subject to flooding and sedimentation inflow. It is not a seismic-sensitive area. The chance of water contamination is lower than in the northern part, because of the distance from the major cities in this area, Eilat (Israel) and Aqaba (Jordan). For better feasibility, the eastern intake is more likely recommended than the northern one.

For operational reasons and to lower potential environmental risks, the intake would be 25 m high and installed 140 m under the surface water. The planned annual water withdrawal is 2 000 MCBM/year (The World Bank, 2014). The intake will be connected to an initial pumping station, which would pump the seawater from the RS.

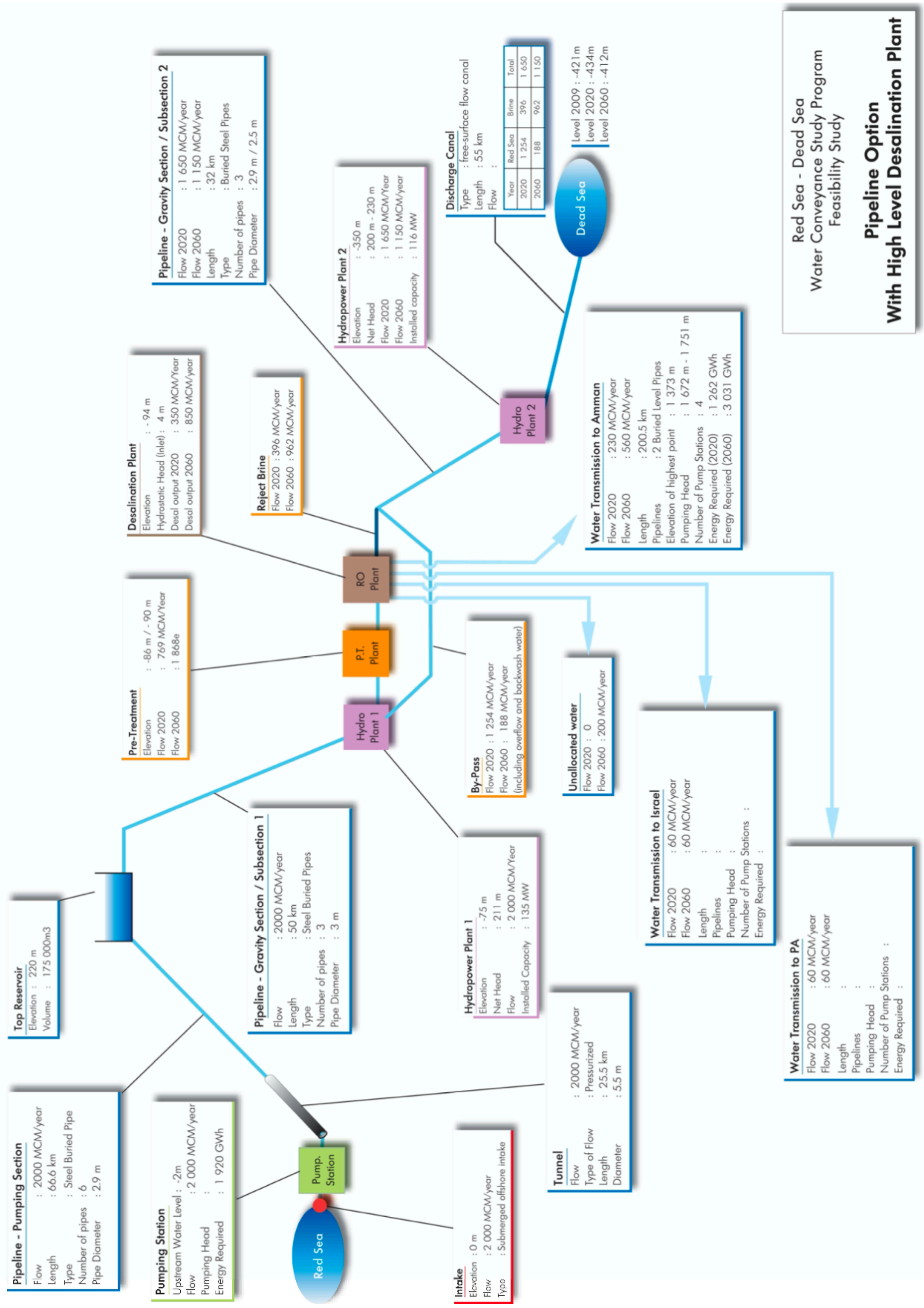
Due to the geological condition of the land infrastructure, the pumping station in the eastern intake would connect to a 25.5 km long tunnel, which would end in the AV (The World Bank, 2014). Then, the water would be pumped through Jordan through the AV via a 66 km long-buried pipeline which would continue to a high elevated reservoir at the highest point along the pipeline, which would serve as a balancing point between the different elevations (The World Bank, 2014).

A second 50 km long-buried pipeline would flow directly to a hydropower plant (The World Bank, 2014). This hydropower plant (at an elevation of 75 m below sea level) would then split into two directions, with one leading to a desalination plant that would process roughly 800 MCBM of water per year, resulting in a byproduct of 400 MCBM of salty brine (The World Bank, 2014). The other, supplementary pipeline which transports 1 200 MCBM then meets with the brine byproduct from the desalination plant, the two mix together, and continues to a final hydropower plant (at an elevation of 350 m below sea level) situated close to the southern basin of the DS (The World Bank, 2014). The hydropower plant would provide clean energy to Israel, Jordan, and the West Bank (Aggestam & Sundell, 2016). A 50 km long open canal would transport water into the northern basin of the DS. The total construction of the network would be over 200 km in length (Aggestam & Sundell, 2016). 60 MCBM of water per year from the desalination plant would remain a water supply for Israel (The World Bank, 2014). The rest of the water will be sold to the PA (60 MCBM/year) and the city of Amman in Jordan (230 MCBM/year) for pre-estimated prices; to Jordan for $1.90 to 2.70 per cubic meter of water, and the PA for $2.20 to 3.50 per cubic meter (The World Bank, 2014). These calculations include desalination operation and delivery costs.

A general layout of the project's construction demonstrates *Picture 4*, and the project scheme demonstrates *Picture 5.*



Picture 4: The Red Sea-Dead Sea Conduit – general layout of the project (The World Bank, 2014).



Picture 5: The Red Sea-Dead Sea Conduit – the project scheme (The World Bank, 2014).

3.4.3 Costs

The costs for the RSDSC project are provided by the World Bank from 2014 (see *Table 3*) The calculations and final cost summaries were discussed and estimated with cooperation from financial specialists. All numbers are represented in US Dollars ($). The annual operational and maintenance costs take into account paying staff and any unpredictable costs as well.

As we can see in the *Table 3,* the construction of the intake at the beginning of the project represents the lowest expenditure of the entire network ($23 million), where little to no maintenance is required. On the other hand, the highest costs are represented by the tunnel and pipelines that form the entire conduit system ($4 689.98 million). The operational and maintenance costs of these sections are relatively high ($132.91 million) because if any defect occurs, the whole system would have to shut down for repairs. The desalination plant is the second-highest cost ($2 436.85 million) with every year increasing maintenance.

The environmental and social management plan (ESMP) is a document, which describes all possible environmental or social risks and costs carried out during the project design and execution. It also includes project location, developments, and geographic exposure. The freshwater created from the desalination plant and the energy generated from the two hydropower plants will eventually compensate for the entire system, although it is unknown how long this will take (The World Bank, 2014).

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
Land Costs	220,00	/	/	/	/	/	/
Environmental and Social Management Plan	75,10	/	/	/	/	/	/
Total	**10 913,79**	**369,22**	**418,02**	**473,07**	**547,58**	**634,88**	**28,70**

Table 3: Estimated full cost of the Red Sea-Dead Sea Conduit construction. All costs are in millions of $US (MUSD). CAPEX – capital expenditure (The World Bank, 2014).

3.5 Environmental Impact Statement

3.5.1 Impacts on the Marine Environment

The RSDSC would negatively affect the GA and would drastically alter the fragile characteristics of this unique marine environment, which has already been affected by human interventions and climate change in the past (Abdel-Halim & kol. 2016). Therefore, the construction may lead to the vast loss of biodiversity in the region.

Accumulation of waste, discharge of pollutants, and construction of the intake pipeline may potentially damage and destroy the benthic environment. To avoid this situation, it is important to select an area minimizing the negative impact by its character of deep water, or an area with low marine habitats, etc.

Species were found in the GA that rely on the interconnectivity between other species within the coral reef ecosystem (Abdel-Halim & kol. 2016). The disturbance of the subsurface area would hurt coral larvae fluxes and the connection between the ecosystems. To address this potential risk, the suggestion is to install the seawater intake in deeper water, where the minimal contact with larvae fluxes would be in-depth of 140 m (The World Bank, 2014).

Another negative impact on the GA marine environment has the desalination plant, which is part of phase one of the RSDSC project. Even though desalination is an important technology that contributes to a higher living standard, its brine is usually discharged into a sea or another water basin where contaminates the water and unfavorably increases water salinity (Sadhwani & kol. 2005). The desalination facility harms the land and creates noise pollution in the surrounding area (Sadhwani & kol. 2005).

3.5.2 Impact of the Conduit Construction

As mentioned before, the construction should start with the intake and the tunnel occurring in the southern region of Jordan. This area is not surrounded by any developed habitat. Even though the tunnel ends 2 km north of the Airport of Aqaba, it does not affect any social or economic aspects of the community. From an ecological point of view, using the heavy techniques during the construction activities on the coastline would compress the soil on the beaches, which would affect the microbial environment living in the sand (Qdais, 2007). A high number of sediments are created during the constructing. This deposit would be washed up into the sea and aggravate the respiration of marine organisms. The sediment would also create a layer limiting the planktonic organisms to absorb sunlight (Qdais, 2007). The intake by itself would suck in many species living at the shore and kill them. Into the sea would be released a big amount of oil according to the operation and maintenance of the tunnel.

The first pipeline, between the tunnel and water reservoir, goes uphill and does not cross or interact with any city or road infrastructure. From the reservoir, the second pipeline continues through wadis and in the north and ends up in the DS basin. Because both of the pipelines are buried underneath the ground, it disturbs the underground soil ecosystems and may create dust sedimentation from drilling. The dust can be washed up by rainfall or during flooding and create flood mud.

The complete construction activities appear to happen in a hard-rock area with steep or shallow gradients. The system in wadis may be disturbed by water and sediment flooding. Any development would be associated with a loud noise and result in a complete change of land structure and its usage, where remains from the construction and dust would pollute the air and surroundings vegetation (Ergenzinger & Asmar, 2002). The pipeline would also divide the land into two parts. That can split members of communities, or keystone species of this area, like acacia trees (*Acacia raddiana* and *Acacia tortilis*) (Al-Ashhab & kol. 2020), or rare and endangered species, like acacia gazelle (*Gazella acaciae*) (Breslau & kol. 2020), who would be threatened on their existence. Impacts of the development intervention in the AV would cause that the mountains and wadis would become hard to live in for example for (i) birds, like black scrub robin (*Cercotrichas podobe)*, pallid scops owl (*Otus brucei*), or striated heron (*Butorides striatus*) (Perlman & kol. 2017), which have been using this Valley for breeding, or nesting spot, or migration route; (ii) tree species, like tree species of family *Moringaceae* (Makin & Solowey, 2017); (iii) herbivores, like the Arabian oryx (*Oryx leucoryx*), or addax (*Addax nasomaculatus*) (Stavi & kol. 2015); or (iv) reptiles, diurnal lizards (*Acanthodactylus* spp.), or geckos (*Stenodactylus doriae*) (Zaady & Bouskila, 2002).

3.5.3 Risk of the Groundwater Contamination

The risk of groundwater contamination may occur during the leaking of the seawater from the conduit. The leakage can occur because of earthquakes or according to the engineering of the water system (Ergenzinger & Asmar, 2002). Earthquakes represent potential risks occurring in the area once per 120 years (Ergenzinger & Asmar, 2002). The land infrastructure of the AV is not stable

(Ergenzinger & Asmar, 2002). Any tectonic event of higher intensity of 7.5 - 8 in the Mercalli Scale could create significant damage to the construction (Ergenzinger & Asmar, 2002).

The leakage from the water system accords to the engineering design of the conduit and may occur with a higher probability. The water system would carry 2 000 MCBM/year, which represents a large power to deal with. That can be prevented by proper isolation of the pipeline and a maintenance with regular monitoring (Markel & kol. 2013). The system should be shut down, during a severe leaking situation to reduce any possible risk of groundwater contamination and wash-off of organisms and nutrients from the ground environment.

3.5.4 Mixing Seawater and the Dead Sea water

As described before, the RSDSC project includes two objects, where at the first one, water will be pumped from the RS into the DS to fill up the lake to raise the water level - filling stage. The second phase is to keep the water level at the desired rise, while the evapotranspiration from the lake would be compensated by the input of seawater from the RS or the brine from the desalination plant (Gavrieli & kol. 2005). The released brine is about 15 % saltier than the original saltwater and includes chemicals from the pre- and post-treatment, which may include remaining chlorine, acid, antiscalant, antifoaming product, polyphosphate (Mohamed & kol. 2005). Discharged brine also contains heavy metals, organic and inorganic compounds dissolved during the desalination process (Mohamed & kol. 2005).

The slower the filling phase will take, the longer the target water will remain. The final elevation should be the same or lower than the elevation of the two DS basins, the northern and the southern basin. Otherwise, it will cause floods in the shallower southern part and swamp the evaporation ponds of the Israeli and Jordanian industries (Gavrieli & kol. 2005). A rainy winter season also poses a threat to raise the water level rapidly, therefore the targeting water level should include a buffer, at least 2 meters high, to avoid the overflow (Gavrieli & kol. 2005). The evaporation dams should be protected from this scenario as well.

Large volumes of the saltwater with a density of 1.03 kg/L mixing with the DS water with a density of 1.24 kg/L can result in dilution of an upper water layer in the DS and create water stratification in the DS water body (Gavrieli & kol. 2002). During the water inflow, the surface layer salination decreases by mixing the saltwater with already mixed water in the DS (Steinhorn, 1985). Higher inflow creates more diluted brine (Steinhorn, 1985). When the filling stage is done, the water level is maintained to remain constant. During this phase, the water inflow evaporates, and the density and salinity of the upper layer will slowly increase. By the time, the stratified waters mixed and united the water body (Steinhorn, 1985).

As already mentioned, the DS is unique for its diverse mineral composition. The DS is saturated by halite (K), magnesium (Mg), aragonite ($CaCO_3$), anhydrite ($CaSO_4$), and potassium (K) (Beyth, 2007). While the DS's lower water body includes various minerals, the upper body is undersaturated with halite and oversaturated with respect to aragonite and anhydrite (Gavrieli & kol. 2005).

In the DS water, mineral precipitation (creation of crystalline sediments) occurs mainly in halite, aragonite, or gypsum presence (Gavrieli & kol. 2005). Aragonite crystallizes and sinks on a bottom where it creates white sediment (Gavrieli & kol. 2005). A hydrated form of anhydrite - gypsum ($CaSO_4 * 2H_2O$) creates crystals on the DS shore (Gavrieli & kol. 2002). Both of these minerals can produce white particles remaining in the upper water layer, called surface “whitening”, which can have ecological consequences affecting the climate (Steinhorn, 1985). Gypsum could create a crystal layer on the surface, which will reflect the sunlight and decrease the evapotranspiration rate. Or, the gypsum could create a layer near the upper surface, therefore the sunlight would be absorbed, the water would start warming up resulting in high evapotranspiration. *“The mixing of seawater with the Dead Sea will introduce relatively high concentrations of sulfate (3000 mg/L) that will mix with the high concentration of calcium (>18,000 mg/L) found in the Dead Sea, resulting in spontaneous gypsum precipitation”* (Gavrieli & kol. 2005). While halite is predicted to precipitate during the steady stage, during the seawater filling stage should be suppressed (Gavrieli & kol. 2005).

3.5.5 Evaporation

Evaporation depends on the salinity of the top water layer and humidity of the area. High salinity results in lower evaporation. However, during the precipitation of gypsum and halite, the salinity of the water is suppressed (Gavrieli & kol. 2005). Therefore, to sustain the steady stage of the DS water level, the salt concentration of the DS should be raised and maintained. Previous studies showed the calculated required amount of salt in the DS based on water level and the meteorological records (see *Table 4*) (Gavrieli & kol. 2005).

When we talk about evaporation, we should not forget that filling the lake with water means expanding its surface. High evapotranspiration rates require higher water inflow, but with the consideration of groundwater cessation. A study of Salameh (2009) described the water balance model, where the inflow should be greater with the recess of the groundwater input, around 400 MCBM/year.

Therefore, the RSDSC project requires a massive amount of water, which can evolve with a changing climate. It is crucial to forecast evaporation trends in addition to hydrology and meteorology of the surrounding area.

Salinity (g/kg)	Water level (m)	Period	Data source for calculations	Evaporation rates (m/yr)
225	–393	1942/46	Neumann 1958	1.70–1.75
240	–395	1959/60	Neev and Emery 1967	1.47–1.65
256–279	–401	1979/80	Anati et al. 1987*	1.30–1.54

Table 4: Range of estimated evaporation rates as a function of surface salinity in the Dead Sea (Gavrieli & kol. 2005).

3.6 Benefits of the Project

The main aim of the RSDSC project is to save the drying DS. With the right construction progress and project completion, the project will bring positive changes to the whole environment of the DS.

1. Saving the DS from drying and stopping the groundwater table from declining, which would stabilize the water table.

2. The region is in a high-water demand situation. Potable water supply from the desalination plant constructed on the DS for Israel, Jordan and the PA would help to solve the water crisis.

3. One of the biggest benefits of the RSDSC is generating electricity from hydro plants due to different elevations (400 m) between the RS and the DS. If there would be transported 1 600 MCBM of water per year through the hydropower plants, the produced energy would range around 1.3 billion kilowatt-hour (kWh) per year (Hrayshat, 2009). Electricity consumption in Jordan in 2015 reached 16 173 Gigawatt-hour (GWh) (over 1900 kWh per capita), where most

of the energy was consumed by the residential (42.9 %) and the industrial sector (24.8 %) (Al-Bajjali & Shamayleh, 2018). Electricity consumption in 2014 in Israel reached 54 232 GWh (6 600 kWh per capita) (IEA Statistics, 2014). In the PA, electricity consumption is very low in comparison to its neighbors. In 2012, the electricity consumption in the PA was 5 370 GWh (MAS, 2014).

4. Peaceful cooperation in the region between stakeholders. By reviving a significant water body, stabilizing the tourism economy, and providing a vital water resource the project will ease political tension between these neighboring countries.

5. The destructive character of sinkholes has affected habitat infrastructure and the natural environment along the DS coast. After stabilizing the DS, the creation of sinkholes would continue, but after time would gradually decrease until it would stop. The estimated time is 10 years after the DS stabilization (The World Bank, 2014).

6. After the damage to the DS environment caused by the Sea level drop, the tourism of the area rapidly declined. Successful completion of the project may attract tourism back, which would be beneficial to the economy of the region.

4. Resulting Appreciation

All possible impacts of the projects were examined, discussed, and evaluated. Benefits such as large amounts of clean energy and water supply for the three neighboring governments would mean solving many social and political problems. The RSDSC project is ambitious and unique, therefore requires greater reflection on the future social and environmental impacts. Also, a lot of time and a large investment, wherein such a megaproject may occur extra expenses associated with the construction, operating, and maintenance.

From my point of view, this project is an unnatural intervention, therefore it brings too risky and too many negative consequences to the environment. Such a drastic human intervention connected with the water pumping in the GA affects the marine environment and the water quality as well, while the construction in the AV affects the soil and the area occupied by many key and endangered species.

An alternative variant of the RSDSC project could be an extension of phase one of the project, construction of a desalination plant on the shore of GA. An extension, because the money planned for the conduit would be invested into a large-scale desalination facility belonging to Jordan. Such a project would give Jordan an independency and equal opportunities in the region in terms of water supply and development. The seawater from the GA would be desalinated by natural osmosis, which would require a minimum of energy. The targeting amount of desalinated potable water should range around 500 MCBM/year, which would be an even higher amount of water supply for Israel, Jordan, the PA, than from the RSDSC desalination plant. Even though the plant would be owned by Jordan, the water should be sold to Israel and the PA for an affordable and pre-arranged price. Further large investment under this project would be related to support the research of the desalination and the marine environment of the GA, to figure out how to avoid the harmful effect of the discharged brine from the desalination facility which adulterates the water quality.

Although this variant does not include the saving of the DS and it still may be harmful to the GA marine environment, it is more sustainable and still meets the governments' water demands.

5. Discussion

Water scarcity is a global issue that affects many communities, especially those that reside in arid environments. These three governments have been put into this dire situation due to human interventions with the environment by overexploiting their limited supplies of surface and groundwater, drawing water and harvesting minerals from the DS to the point of vulnerability, and failing to address the situations when they became evident.

The DS's water level fluctuation is a well-known event and this phenomenon is happening during a short period. Such an extreme event may ask for an extreme solution. For territories like Israel, Jordan, and the PA who have a drawn-out history of conflict with one another, it becomes a necessity to work together to develop solutions to water-related issues. Through many drafts and amendments, and a long process of deliberation these three entities have created what has come to be known as the RSDSC project.

This megaproject could stabilize the DS's water level, while, as mentioned before, there are another project's remarkable benefits in a matter of water and hydropower supply. Despite that, the RSDSC megaproject could bring further future undesirable changes in the environment. To stabilize the DS's water via water pumping, it is necessary to withdraw every day a massive amount of water from the GA. Any interference with channel function can slow down and disrupt the process of water filling the DS basin. Further interventions like the RSDSC project will not be a sustainable solution for the region, but rather just a temporary easement of their water stress.

In case, that the project is successful, and the DS is stabilized, there is no more water required in the DS basin, therefore the project could be closed, and the pumping could stop. But, if the conduit would keep operating, there would not be a place where to discharge the saline brine from the desalination plants. Resealing the brine into the DS in such a scenario is impossible, it would create a hypersaline and contaminated water basin, which would start drying up again. It is also undesirable to discharging the saline brine into the soil because that would cause high groundwater contamination. The last option is to release the brine into the MS or the RS. Such water transport would entail extra costs for water transport and increase water contamination in the discharging area.

Another issue to consider is if the RSDSC project will be big enough for future generations. As the population grows, so does the demand for food, water, and other essentials to live. Such a project could, in the future, support an increase of water pumping from the RS and though to increase the amount of desalinated potable water for agriculture, industry, and livelihood. That would require rebuilding or increasing the maintenance of the conduit.

The history of the project, the political background, and the future development of the DS have been well explained in many scientific articles. But the question remains why to embark on such a large project, which will take decades to complete. Looking at the project objectively, there are reasons to go forward with the project, but they do not outweigh the potential environmental dangers associated with constructing the project. At the end of the 20th century, agreements to stabilize the waters of the DS and to solve water scarcity in the region represented a certain peace agreement between Israel, Jordan, and the PA. The conclusion of these agreements was in the interest of all three territories. Currently, this project is primarily a solution for Jordan and the PA in view of the water shortage during increasing water demand for agriculture, industry, and the growing population, while Israel became water independently. It is evident, that the governments understand the ecological impacts, but the necessity of the water supply exceeds environmental consequences. Also, it is crucial to maintain a peaceful friendship between the territories, now and in the future.

From this point of view, we can discuss whether this is really not just a scarcity of water in the region, and saving the DS is merely a promotional instrument with a lower essence. As many scientific papers confirmed, the drying up of the DS will continue for about 200 years and maybe more, without any human intervention, to become naturally stabilized. In such a case, the construction of such a large scale makes no sense from an ecological and economic perspective.

Therefore, considering only the necessary water supply to Jordan and the PA, greater investment into a phase one of the RSDSC project, construction of a desalination plant in the GA, and support of future development of the desalination plants in Jordan could partly cover the project's benefits. Such a solution would still result in negative impacts on the RS shoreline and its marine environment, but the effects would be negligible compared to the drastic intervention into nature during digging, construction, and maintenance of the conduit facility.

The RSDSC project has a huge potential, although, construction of such a large project cannot avoid long-term environmental, social, and economic impacts. They need to be discovered to prevent all negative scenarios, otherwise, the project would start a never-ending circle harmful to the environment.

6. Conclusion

The DS and the JR were and are the main water providers to the region, mainly to Jordan and the PA. Over several decades, these water sources are slowly drying up. The lack of water associated with the hot desert climate and population increase resulted in water scarcity in this region. The severity of water scarcity affects these governments, where the RSDSC project may seems like a solution. The RSDSC project has been considering and discussing for many years. The information provided in this thesis shows that the negative and unpredictable impacts exceed the project's positives, where the RSDSC project's main goal is more likely to make high amounts of water and pure energy available to Israel, Jordan, and the PA.

Assessing how long this project has been considered, we can assume that the three governments are aware of the size and uniqueness of the project, which can create economic, environmental, and social uncertainness in the future. But despite all the impact statements, Israel, Jordan, and the PA decided to continue with the RSDSC project. Many sponsors from around the world support this decision. But taking into account how Israel hesitates with the implementation of the project, we can conclude that its government is under lower pressure due to lack of water while having access to the MS and the RS.

In this case, much simpler and environmentally milder solutions to the water crisis are offered, which would save money and time for the three governments. Even though it would not include preserving the DS's basin, a less nature harmful project is also more welcome because many scientists predicted that the severity of the DS drying is not that high. In fact, it will more likely stabilize its water level at some point and though stop decreasing.

In the conclusion of that, solving an environmental issue through another big human intervention into nature is sometimes necessary, but in this case, I think it is inefficient and unsustainable.

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7.3 List of Pictures

7.4 List of Tables