

Desalination of Sea & Brackish Water Project

Guideline for Environmental Impact Assessments for Sea and Brackish Water Desalination Plants



Photo on cover page: Photos for Desalination Plants in Jordan

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Contents

1.	Introduction	5
1.1	Background.....	5
1.2	Objective & Justification	6
1.3	International Practices For “ESIA” Process	7
1.3.1	UNEP and WHO Guidance	10
2.	Legal Framework for “ESIA” Practices in Jordan	11
3.	Aspects to be covered in ESIAs for Desalination Projects	15
3.1	Legislative & Institutional Framework.....	15
3.2	Responsibilities	15
3.3	Description of the Project.....	18
3.4	Environmental Settings in the Project Area	26
3.5	Identification of Potential Impacts	27
3.5.1	Potential Impacts by Geohazards	28
3.5.2	Potential Impacts on Water Resources.....	31
3.5.3	Impacts of Site Clearance and Preparation for Construction	32
3.5.4	Impacts on Air Quality & Noise Levels	32
3.5.5	Potential Environmental Impacts of the Resulted Fluid Wastes.....	33
3.5.6	Potential Environmental Impacts of Resulted Solid Wastes	33
3.5.7	Potential Impacts Related To The Socio-economic Context	33
3.5.8	Impacts on Marine Biodiversity (in case of seawater desalination)	34
3.5.9	Occupation Health & Safety.....	34
3.5.10	Public health & Safety.....	34
3.6	The Project’s Environment & Social Management Plan (ESMP).....	35
3.6.2	Project Description	35
3.6.3	Project’s Potential Environmental Impacts.....	35
3.6.4	Proposed Mitigation Measures.....	35
3.6.5	Proposed Monitoring Plan	36
3.6.6	Capacity-Building & Staff Training Plan.....	38
3.6.7	Documentation & Environmental Communication	38
3.6.8	Environmental & Safety Audit	38
4.	Annexes	39
4.1	Annex-1: Jordan Major Structural Features.....	40
4.2	Annex-2: Jordan Seismic Zoning Map.....	41
4.3	Annex-3: Major Solid Wastes Dumping Sites in Jordan	42
4.4	Annex-4: Major Wastewater Treatment Plants in Jordan	43
4.5	Annex-5: Hazard Waste Dumping Site in Jordan	44

4.6	Annex-6: Standard Outline for Environmental Impact Assessment for Desalination Facilities in Jordan	45
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List of Tables

Table 1: Major monitored environmental issues during Construction & Operation phases of a Seawater desalination plant	16
Table 2: Major monitored environmental issues during the operation phase of a Brackish water desalination plant.....	17
<i>Table 3: Potential Environmental Risks That Result from The Different Parts of The Brackish water Desalination System</i>	<i>19</i>
<i>Table 4: Potential Environmental Risks That Results from The Different Parts of The Sea Water Desalination System</i>	<i>22</i>

List of Figures

Figure 1 Typical Brackish Water “RO” System [BWRO]	8
Figure 2: Typical Seawater “RO” System [SWRO]	9
Figure 3: “ESIA” Processes & Steps in Jordan	12
Figure 4: Examples Pictures and Sketches for Landslide	28
Figure 5: Rockfalls (Jordan Valley)	29
Figure 6: Example for Land Subsidence Incident	29
Figure 7: Examples for Sinkholes	30
Figure 8: Soil Liquefaction	30
Figure 9: Flash Floods in Built-up Areas in Jordan	31

1. Introduction

1.1 Background

Desalination projects require an Environmental and Social Impact Assessment (ESIA) study to determine the potential impacts a project can have on the environment. The “ESIA” considers all environmental pathways. It evaluates the potential impacts on air, land, and marine environments and proposes mitigation measures to reduce environmental impacts.

The potential impacts of desalination plants are different from the environmental impacts of other facilities. In particular, the brine discharge from desalination plants can have huge impacts. Therefore, it is proposed by this document to follow a dedicated routine in the ESIA process for brackish and seawater desalination plants.

An “ESIA” needs to cover the following stages of a project which are: the construction; the operation, and the decommissioning stages.

During the construction stage, the construction process can be time-consuming, inconvenient, loud, destructive, and disruptive to the environment. It is ideal to have as little impact from the construction as necessary. If used water resources, connections to services, and water infrastructure are near the proposed plant site, then there will be fewer constructional interventions required and thus less potential environmental damages would occur. When construction begins, the party responsible for follow-up on the ESIA needs to monitor according to the Environmental Management Plan issues identified in the ESIA so that the agreed plan is implemented and followed.

For the operation stage, the “ESIA” report discusses the chosen desalination process, the emissions the process will generate, the implications the facility will have on the environment, the considerations to be made about the energy supply, the benefits the facility will have on the local community from a socio-economic perspective, and the proposed mitigation measures to reduce problems associated with the facility. It is even more important to monitor all aspects addressed in the ESIA’s Environmental Management Plans (EMP) during the operational stage to ensure consistent compliance with agreed permissible environmental impacts.

The major environmental issue of concern to be discussed during the operational stage is the safe disposal, discharge, or reuse of the resulting brine. Environmental-friendly brine management can make desalination rather expensive. Proper brine management methods incorporated in the plant’s design can mitigate the impact on the receiving environment, in particular, on groundwater resources or the sea.

The brine contains a high TDS concentration and other elements that are detrimental to human health or plant growth. For agriculture, in particular, when using seawater desalination, the main concern is the boron content. In brackish water desalination, heavy metals or radioactive elements may be contained in the brine and backwash. Brine and backwash will also contain the chemicals used during pretreatment and post-treatment processes. Characteristics of the generated concentrate depend on the type of desalination technology used. The brine quality (if not well managed) will have a serious impact on the natural water sources, local soil, and the local biodiversity system.

A general layout for a brackish water desalination system and a seawater desalination system are presented in Figures 1 and 2 respectively.

In the ESIA for sea or brackish water desalination plants all components of the facility requested to be constructed have to be considered:

- Seawater intake or groundwater abstraction scheme;
- Pumping station,
- Reservoirs;
- Hydropower or photovoltaic components;
- Pretreatment;
- Backwashes;
- Desalination unit.
- Chemicals management;
- Posttreatment;
- Cleaning of all above units;
- Management of wastewater and wastes, in particular exchange of membranes;
- Brine discharge/disposal/reuse.

1.2 Objective & Justification

This report is an attempt to present a standard outline and a description of all elements that must be addressed in an “ESIA” for planned desalination projects in Jordan. The construction and operation of a desalination plant for brackish or seawater can result in the following potential impacts:

❖ **Brackish water desalination plants:**

Pollution of downstream surface and groundwater resources and soils due to

- Leakages/overflows from brackish water abstraction scheme
- Backwash and disposal/storage/drying of pretreatment rejects
- Leakages/overflows from brackish water storages at desalination scheme and conveyances between abstraction/desalination/discharge schemes
- operation of RO and chemicals/waste management (storage, transfer, handling, disposal) at desalination scheme
- discharge or unsafe disposal/reuse of brine and backwash.

❖ **Seawater desalination plants:**

Pollution of marine and land environments due to:

- In the sea: seawater intake and cleaning of it (pegging/chlorination) may impact sea life
- On land and in the sea: leakages/overflows from seawater storages and conveyances between abstraction/desalination/discharge schemes may lead to pollution of downstream surface and groundwater resources and soils and sea life

- On land and in the sea: backwash and disposal/storage/drying of pretreatment rejects
- On land and in the sea: operation of RO and chemicals/waste management (storage, transfer, handling, disposal) at desalination scheme
- On land and in the sea: Discharge or unsafe disposal/reuse of brine and backwash.

Chemicals and wastes occurring in the raw water, in particular in brackish water, and used in pretreatment, desalination, and posttreatment vary largely. For each of these, a dedicated flow process and management/monitoring plan have to be designed.

In addition to the above, the construction operations for such projects will produce a series of fluid and solid wastes that will be produced by the different construction operations.

The “ESIA” and the related “ESMP” will work on eliminating (where possible) or reducing the project’s negative impacts.

1.3 International Practices For “ESIA” Process

Starting from the 1970s, the concepts of environmental impacts assessment and environmental management planning started to be formulated worldwide. Since that time and up to date, such concepts expanded and become more and more comprehensive to cover all elements of the environment including health and safety.

Moreover, the UN agencies working in the field of environment protection and conservations have prepared a set of handbooks and guidelines for “ESIA” and “ESMP” that can be used or implemented worldwide by the different countries to establish their national guidelines for environmental protection and conservation. One of the major agencies working in this field is the United Nations Environment Programme (UNEP), where the following recent guidelines were produced in the said field:

- The Guidelines for Conducting Integrated Environmental Assessments (2019)
- Assessing Environmental Impacts- A Global Review of Legislation (2018)
- Desalination - Resource and Guidance Manual for Environmental Impact Assessments (2008)

Besides, major funding agencies such as the World Bank, OPEC, EU, USAID, GIZ, JICA, etc., have developed their environmental conservation and protection regulations including guidelines and procedures for “ESIA” (or sometimes EIA) implementation. Conducting an ESIA (or EIA) has become a major requirement for project funding.

Reflecting the interest in environmental protection and conservation, most countries have established their national environmental protection agencies and related regulations. Among such regulations are the guidelines and procedures for “ESIA” implementation for different types and scales of projects.

Regarding the desalination projects, worldwide, such projects are usually considered major projects with high potential environmental impacts and thus require an “ESIA” to minimize the negative environmental impacts.

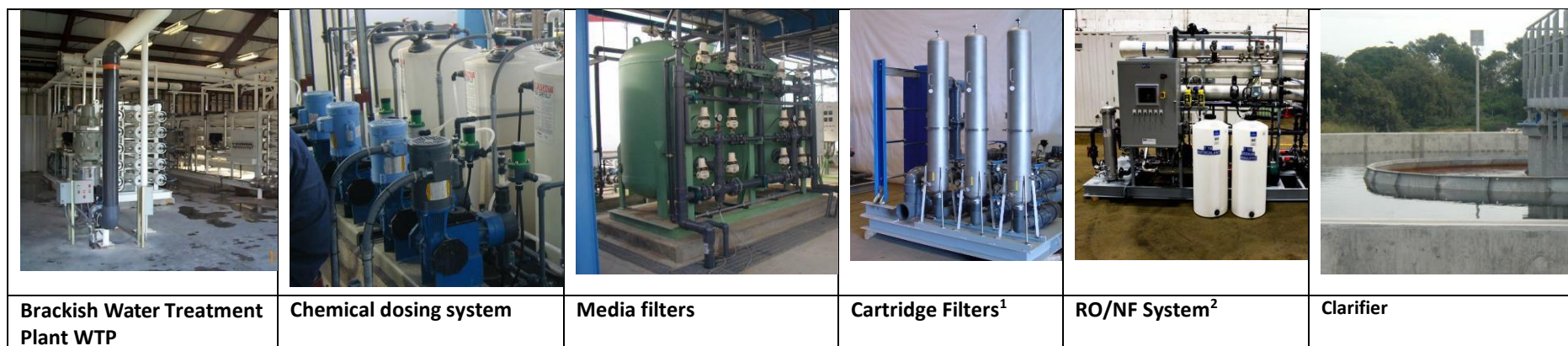
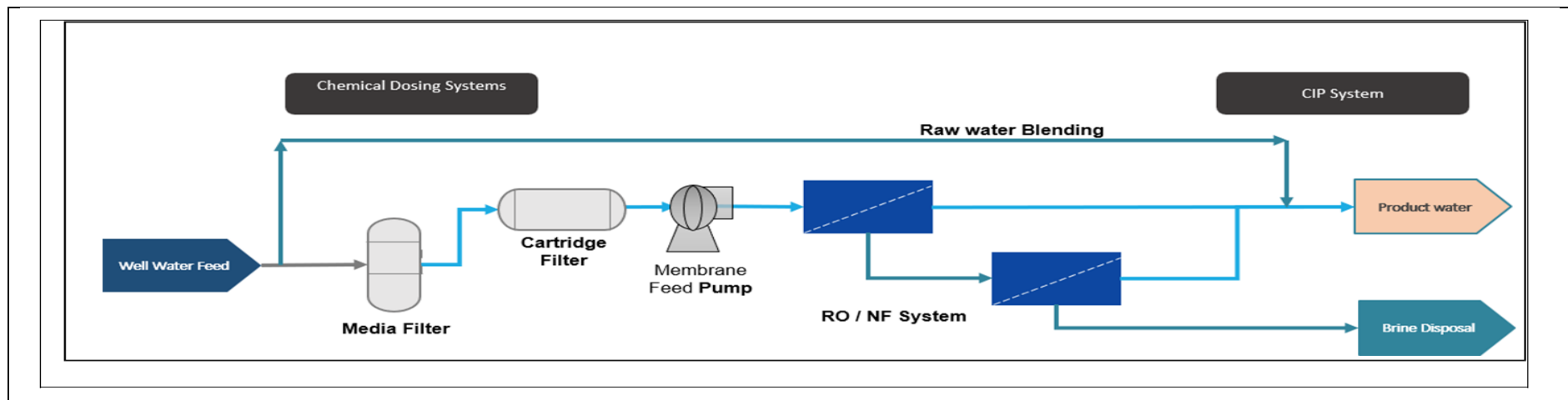


Figure 1 Typical Brackish Water "RO" System [BWRO]

¹ <https://www.samcotech.com/technologies/filtration/cartridge-filtration/>

² <https://www.samcotech.com/technologies/ro-nf/>

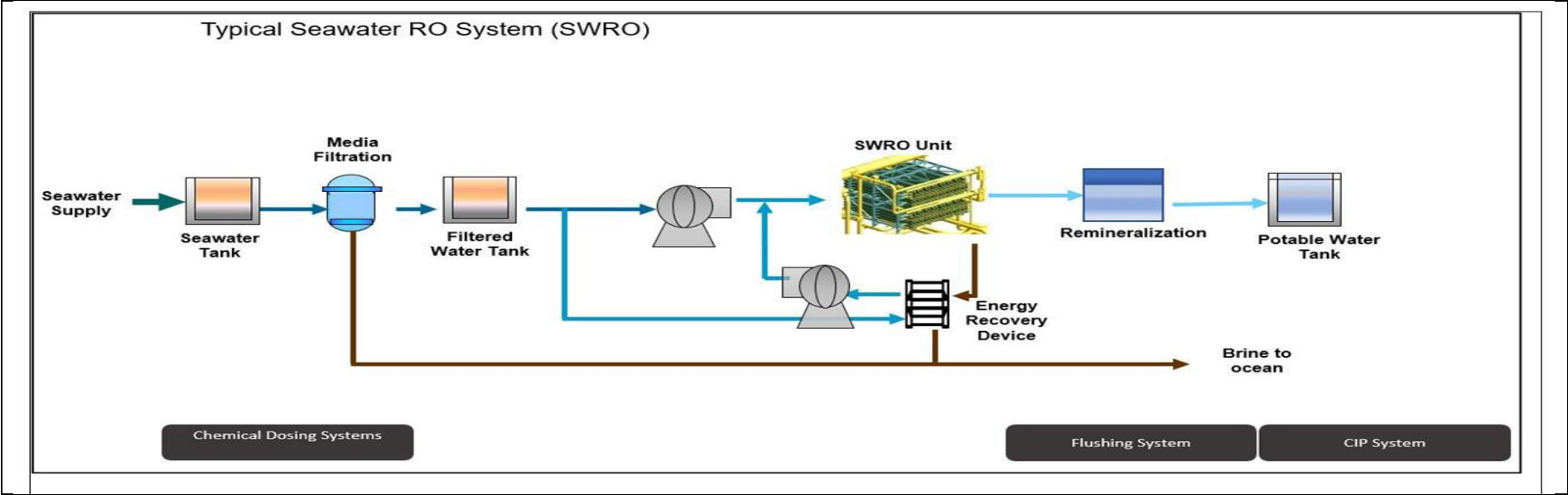


Figure 2: Typical Seawater “RO” System [SWRO]

1.3.1 UNEP and WHO Guidance

A dedicated ESIA guidance for desalination projects was developed by UNEP & WHO (2008) under the title [Desalination: Resource and Guidance Manual for Environmental Impact Assessments (unep.org)]. This guideline, however, does not consider brackish water desalination schemes, which are quite different in terms of their potential negative impact. The said guideline raised a wide range of potentially relevant issues attendant to the use of desalination as a community water supply, including environmental, cultural, socio-economic, and human health implications. It provides a review on a case-by-case basis which issues may be relevant to a particular desalination project, and presents the following major topics:

- An introduction to the concept, methodology, and practice of EIAs
- The EIA process was proposed for desalination projects. It is not limited to desalination plants but can be applied to other water infrastructure projects in a similar manner.
- A modular outline of an EIA report for desalination projects
- An overview of a range of thematic issues that may be relevant to desalination projects. It may also serve as a reference source and blueprint for preparing EIA reports.
- Detailed information on project screening and scoping, which constitute the first two steps of an EIA,
- Overview of the effects of desalination intakes and discharges on marine ecosystems based on a survey of recent literature.

Georisks are currently not sufficiently considered in all stages of a project. They may, however, have a severe impact, not only on the operability of a site but also on the environment. Risks that have to be considered here include: [tectonic movements, earthquakes, landslides, rockfalls, sinkholes, land subsidence, soil liquefaction (unstable soil), flooding, etc.]. the said risks are presented in detail in section 3-4-1 of this report.

2. Legal Framework for “ESIA” Practices in Jordan

In Jordan, Law No. 6 for the year 2017 is the active environmental protection law, reinforced by a set of bylaws, regulations, and instructions for protecting and conserving the different elements of the environment. Moreover, the Ministry of Environment (MoEnv) is the responsible governmental agency responsible for requesting the “ESIA” studies, defining its type, supervising its review, approving or rejecting such studies according to instruction No.69 for the year 2020 for “Project’s Environmental Classification & Licensing System”.

Article Nos. 4 and 5 tackle the subject of “ESIA” and the project’s licensing. Furthermore, instruction No.69 for the year 2020 for “Project’s Environmental Classification & Licensing System”, describes in detail the project’s classification according to the project’s impacts on the environment and the “ESIA” preparation as a tool needed for projects’ licensing. Figure-1 presents a summary of the “ESIA” process in Jordan.

The “ESIA” applies to all public, private, national, and international projects that will be implemented in Jordan which may affect the environment. Based on instruction No. 69 for the year 2020, desalination (Brackish or seawater) projects are considered of “High potential environmental impacts” and require a comprehensive “ESIA”. This can be related to the following facts:

- (i) The limited available water resources for different usages.
- (ii) The medium to high vulnerability (against pollution) of the available water resources
- (iii) The importance of the gulf of Aqaba shore (being the only shore in Jordan) for tourism purposes

A. Overview ESIA procedure

- Based on instruction No. 69 for the year 2020, (MoEnv) decides if a project needs a comprehensive ESIA, an initial ESIA, or no ESIA.
- If an initial “ESIA” reveals that the project has a potentially significant impact on the environment, a comprehensive ESIA needs to be conducted.
- A comprehensive ESIA starts with a scoping phase. The party proposing the project (proponent) prepares a draft ToR for the EIA study and submits this to the Ministry.
- “MoEnv” organizes stakeholder engagement based on this draft. Then, the proponent submits an updated ToR to the Ministry for approval, where the assigned Technical Committee reviews this ToR.
- Following the scoping phase, the assessment is carried out. It must be undertaken by a recognized Advisory Body (consultancy).
- The ESIA document is submitted to the “MoEnv”, to be reviewed by the Technical Committee. The said committee submits its findings to the “MoEnv” to take a decision.
- The follow-up takes place on basis of the Environmental Mitigation and Monitoring Plans, and the approval conditions.

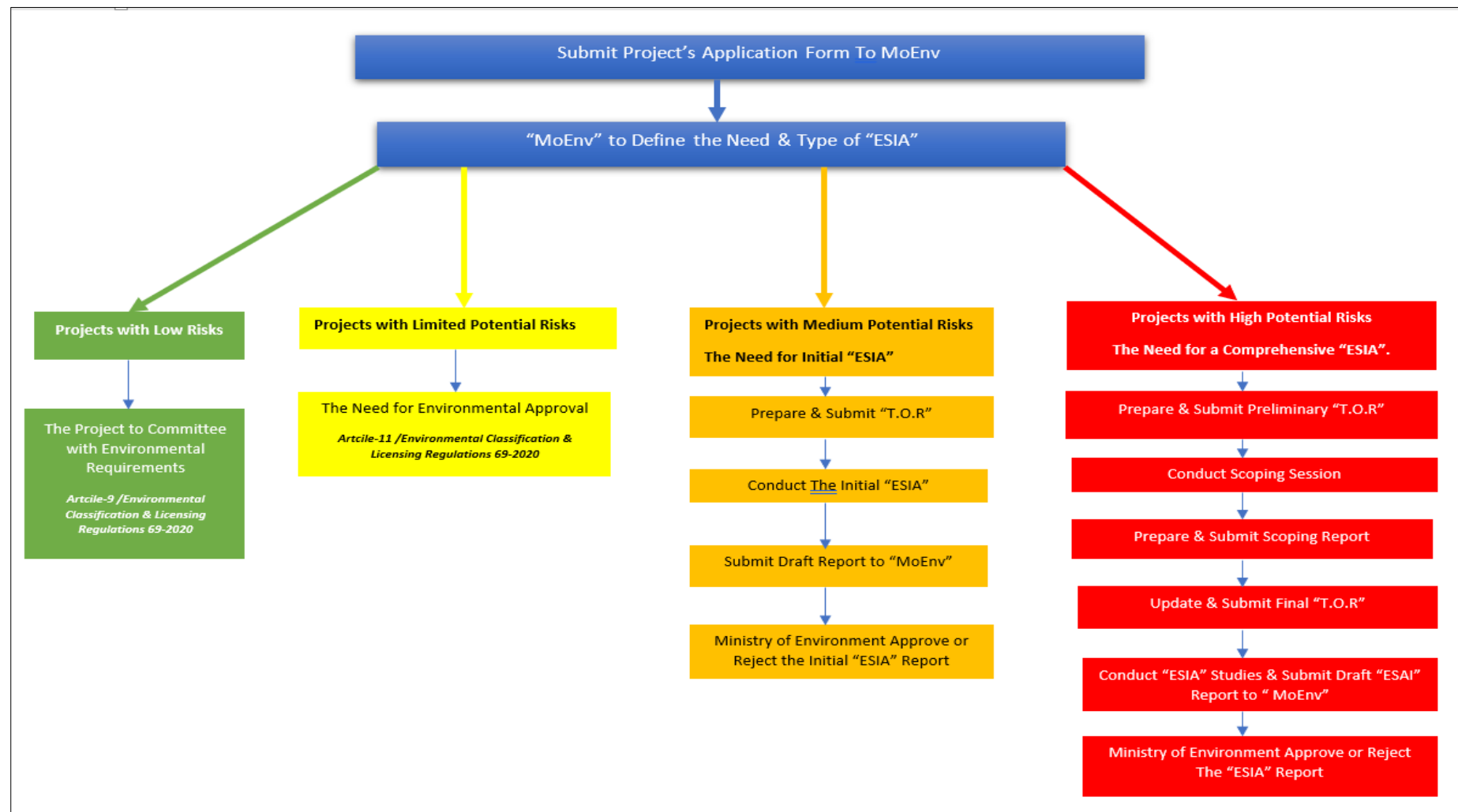


Figure 3: "ESIA" Processes & Steps in Jordan

B. Screening Process

- The project proponent submits the required information on the project to the “MoEnv.”.
- The Licensing Committee of the “MoEnv” screens the project against the categories set out in instruction No. 69 for the year 2020.
- This Committee determines if the project is classified as:
 - Category 1 project [with high potential risks], for which a comprehensive EIA needs to be carried out.
 - Category 2 project [with moderate potential risks], for which an initial EIA is required. If the preliminary environmental impact assessment reveals that the project has a potentially significant impact on the environment, “MoEnv” shall request the proponent to conduct a comprehensive EIA.
 - Category- 3 projects [with limited potential risks], for which no environmental analysis is required. If this is the case, the Ministry shall inform the proponent that the project does not require an EIA and that the project is considered approved based on fulfilling the required environmental requirements.
 - Category-4 project [with low potential risks], where the project does not require an EIA, and that the project is considered approved if the proponent shall be committed to the defined environmental conditions.

C. Scoping Process

- The Proponent submits a preliminary (ToR), after consultations with “MoEnv”.
- A scoping meeting will be held under the supervision of the “MoEnv” by the Proponent and any concerned individual or representative of a public or private party that may be potentially affected by the project to identify the significant impacts on the environment.
- The final ToR for the “ESIA” will be prepared including a summary of the discussion of the meeting with the affected parties’ discussions, the parties which attended, and the significant Impacts identified.
- The Ministry's Technical Committee then reviews and approves the ToR.

D. Assessment Process

If the “ToR” is approved, the proponent shall undertake the assessment and prepare the draft of the EIA document.

E. Review Process & Review Expertise

- The review of the “ESIA” document is carried out by the Technical Committee, which is also involved in the review of the “TOR”. It will submit its recommendations to the “MoEnv” to make the required decision.
- The committee may ask the proponent for additional information if it finds that the “ESIA” document does not fulfill the requirements.
- The technical committee is headed by the Secretary-General of the Ministry of Environment
- The Technical Committee includes representatives of various ministries:
 - Ministry of Local Administration
 - Ministry of Water and Irrigation

- Ministry of Health
- Ministry of Agriculture
- Ministry of Industry and Trade
- Ministry of Energy and Mineral Resources
- Ministry of Tourism and Antiquities
- Royal Society for the Conservation of Nature (RSCN)
- Any other concerned entity specified by the Minister

F. Integration of ESIA into Decision-Making

If the draft “ESIA” document fulfills all of the requirements, the Technical Committee submits its recommendations to the Secretary, where the final decision may be:

- Approving the draft and considering it the final ESIA Document. This constitutes the environmental approval of the project, and it is valid for one year from the date it is issued.
- Denial of environmental approval of the project if it is shown that its implementation would cause a significant impact on the environment and that the plan for reducing adverse impacts is inadequate.

G. Compliance Monitoring

Both the “ESIA” regulation and the Environmental Protection Law state that “MoEnv” shall monitor the compliance with the conditions and requirements stipulated in the Environmental Approval. The Ministry has inspection powers to this effect.

H. Institutional Setting

- Central ESIA authority: Ministry of the Environment
- Other key (governmental) parties

“MoEnv” forms a Technical Committee with specific tasks in the EIA procedure, chaired by the Secretary-General. Membership of the committee is presented in section “E”.

- (De)centralization of mandates

In general, the ESIA mandate is centralized. However, the Aqaba Special Economic Zone (ASEZ) Authority has been mandated to implement ESIA in this zone and has established specific ESIA requirements as part of its environmental regulation [Regulation No. (21) for the Year 2001: Regulation for the Protection of the Environment in the Aqaba Special Economic Zone]³. The said regulation is computable with the national legislations for environment protection and conservation such as “Environment protection Law No.6 – Year 2017” and “Regulation No. 69 of 2020 Environmental Classification & Licensing”

³ Issued in Accordance with Articles (52) and (56) of the Aqaba Special Economic Zone Law No. (32) for the Year 2000

3. Aspects to be covered in ESIA for Desalination Projects

3.1 Legislative & Institutional Framework

This section outlines the policies, laws, and regulations relevant to environmental and socio-economic issues in the Hashemite Kingdom of Jordan and describes relevant international conventions and treaties signed and ratified by Jordan and incorporated into the national law. ESIA need to present the currently applied laws and regulations relevant to the desalination operations and process, and include, but are not limited to, the following:

- Environmental Protection Law;
- Environmental Protection Law for “ASEZA”;
- Water Authority of Jordan Law;
- Jordan Valley Authority Law;
- Public Health Law;
- Groundwater Protection By-law;
- The instructions for conducting “ESIA” studies;
- The instructions for protecting the water resources.
- The following binding standards:
 - Drinking water standard (JSM 286/2015)
 - Wastewater reuse standard (JSM 893/2006)
 - Air quality standard (JSM 1140/2006).
 - The standard for the Maximum Allowable Limits of Air Pollutants Emitted from Stationary Sources (JS 1189/1998).
 - Treated Sludge and Sludge Disposal Standard, JS 1145 (2006)
 - The standard for the prevention and elimination of noise (2003).

3.2 Responsibilities

The ESIA should point out who is responsible for doing what in the process. Of particular interest is the follow-up on the required monitoring through the Environmental and Social Management Plan (ESMP).

❖ Sea Water Desalination Projects

Following are the major environmental elements that need to be covered and the responsible entity to do that.

During the construction stage, implementing the components of the “ESMP” will be the joint responsibility of the Contractor’s Environmental unit and the environmental unit of the project’s owner. While monitoring the said implementation will be the responsibility of ASEZA environmental directorate. Moreover, the major environmental issues that need to be monitored during the construction and operation phase of the seawater desalination plant are presented in Table 1.

Table 1: Major monitored environmental issues during Construction & Operation phases of a Seawater desalination plant

Activity	Environmental Elements	Managed By	Monitored By
Inappropriate management for the construction activities especially those related to the intake area and the brine dumping area: <ul style="list-style-type: none"> uncontrolled construction operations will cause severe damage to the different elements of the marine environment. uncontrolled construction operations will cause severe damage to the different elements of the terrestrial environment. 	<ul style="list-style-type: none"> Conserving terrestrial Biodiversity. Conserving Marine Biodiversity. 	The “EHS” unit of the plant’s operating entity	<ul style="list-style-type: none"> ASEZA – Environmental Directorate
Inappropriate management for resulted brine and backwash water during the operation stage of the project	Sea, surface water, groundwater, soil: Brine and backwash composition (pretreatment, desalination, posttreatment)	The “EHS” unit of the plant’s operating entity	<ul style="list-style-type: none"> ASEZA – Environmental Directorate. Water monitoring samples to be collected and analyzed by ASEZA central labs.
Inappropriate management for the resulting solid wastes during the construction and operation phases of the project	Sea, surface water, groundwater, soil: Solid wastes management	The “EHS” unit of the plant’s operating entity	<ul style="list-style-type: none"> ASEZA – Environmental Directorate
Inappropriate management for the resulting fluid wastes during the construction and operation phases of the project	Sea, surface water, groundwater, soil: Fluid wastes management	The “EHS” unit of the plant’s operating entity	ASEZA – Environmental Directorate
Inappropriate management for resulting hazardous wastes [Solid and/or fluid] during the construction and operation phases of the project	Sea, surface water, groundwater, soil: Hazardous wastes	The “EHS” unit of the plant’s operating entity under the supervision of the ministry of environment	ASEZA – Environmental Directorate
Inappropriate selection for the facility site	Human beings and animals: Occupational Health & Safety	“OHS” unit at the operating company	The “OHS” Unit” at ASEZA or the Aqaba water company.
The absence of a Disaster risk management/Mitigation Plan:	Sea, surface water, groundwater, soil: Georisks causing damage to any part of the site	<ul style="list-style-type: none"> ASEZA Board Jordan Armed Forces Ministry of Interior Aqaba water company MWI&WAJ 	National Center For Security and Crisis Management - Jordan

❖ Brackish Water Desalination Projects

Concerning already existing brackish water desalination schemes, it becomes clear that many of the required functions are currently not properly covered. It is recommended that “MoEnv.”

together with the other involved parties such as MWI and WAJ reaches an agreement that will bridge these gaps. Major environmental issues that need to be monitored during the operation phase of the brackish water desalination plant are presented in Table-2.

Table 2: Major monitored environmental issues during the operation phase of a Brackish water desalination plant

Risk	Environmental Elements	Managed By	Monitored By
Inappropriate management for resulted brine and backwash water during the operation stage of the project	Surface and groundwater; public health and safety: Brine and backwash composition (pretreatment, desalination, posttreatment)	The “Environment Unit” at WAJ. Collected water samples to be analyzed at WAJ central labs	<ul style="list-style-type: none"> Ministry of Environment in cooperation with the Royal Scientific Society (RSS)
Inappropriate management for the resulting solid wastes during the construction and operation phases of the project	Surface and groundwater; public health and safety: Solid wastes management	The “Environment Unit” at WAJ in coordination with the Environment unit at the operating company*	<ul style="list-style-type: none"> Ministry of Environment Environmental Rangers
Inappropriate management for resulting fluid wastes during the construction and operation phases of the project	Surface and groundwater; public health and safety: Fluid wastes management	The “Environment Unit” at WAJ	<ul style="list-style-type: none"> Ministry of Environment Environmental Rangers
Inappropriate management for resulting hazardous wastes [Solid and/or fluid] during the construction and operation phases of the project	Surface and groundwater; public health and safety: Hazardous wastes	The “Environment Unit” at WAJ under the supervision of the ministry of environment	<ul style="list-style-type: none"> Ministry of Environment Environmental Rangers
Inappropriate selection for the facility site. Thus, Geo-risks cause damage to any part of the site	Occupational Health & Safety	“OHS” unit at the operating company	The “OHS” Unit” at WAJ
The absence of a disaster risk management/mitigation Plan	surface water, groundwater, soil: Geo-risks causing major damage to any part of the site	<ul style="list-style-type: none"> Jordan Armed Forces Ministry of Interior MWI&WAJ 	National Center For Security and Crisis Management - Jordan
* -Operating Company: Yarmouk Company on the North – Miyahuna in the Central Parts – Aqaba Water Company in Aqaba Governorate.			

Also, responsibilities for the process of “ESIA” preparation and acceptance should be clarified.

Implementation of large-scale projects in the past has shown that active stakeholder participation is a key element for local acceptance.

3.3 Description of the Project

The description of the project is to be prepared based on information and data provided by the client and the Project Implementing Company. Project details are to be analyzed and described by the study team from an environmental point of view through discussions with the implementation team. Accordingly, the project's ESIA will present and elaborate on the following project details:

- Project purpose, rationale, and justification.
- The project area (including the direct location of the facility). The potentially impacted area by the project should be defined and described within this section of the report. Also, the reasons for site selection.
- Summary description of the project including type, size, and capacity.
- Project components and their description (including Operations & Facilities, troubleshooting).
- All components of the desalination facility to be documented and described in detail in this part, addressing all aspects relevant for the "ESIA" [Examples for Brackish water Desalination System & Sea Water Desalination system are presented in Figure Nos. 4 and 5 respectively] such as :
 - Functions of each component and which technology is applied.
 - Materials used for each component;
 - Location and size of temporary storage basins (in case of emergency) for brine water;
 - what installations/constructions are planned to provide the optimal protection of the environment (e.g. water resources).
- Activities associated with the project implementation period (detailed information of processes or activities of the project, energy & infrastructure requirement, and other details associated with the project construction and operation so the project can be operated smoothly.
- A Risk management plan that covers (among others) what needs to be done if some parts of the system do not work as planned, as part of troubleshooting measures.
- Human and material resources related to the project.
- Project implementation schedule.
- The breakdown for the manpower that will work during the construction and operation phases of the project.
- Identification of the project's alternatives.
- Identification of stakeholders.
- Where the brine water from the facility will be deposited or be reused?

The potential environmental risks that result from the different parts of the brackish and seawater desalination systems are presented in Table Nos. 3 and 4 respectively.

Table 3: Potential Environmental Risks That Result from The Different Parts of The Brackish water Desalination System

System's Component	Potential Risk during the Operation Stage
Well pumps and piping	<p>Well pumps are used to draw water from the source aquifer, at depths from 50m to 1500m below ground level, delivering non-potable water to the desalination plant for treatment.</p> <p>Environmental Impact:</p> <ul style="list-style-type: none"> Leaks or failure in the piping system could contaminate agricultural land and crops If the well water contains radionuclides a potential health and safety risk exists Improper materials of construction of the well casing and piping may lead to corrosion and contamination of the raw water source to the desalination plant Incorrect design of the well casing and packing may lead to failure of the well and the inability to provide raw water to the desalination plant
Chemical dosing systems	<p>Chemical dosing systems are used in a desalination plant for pre and post-treatment and uses could generally be for membrane protection, conditioning of raw water to enhance filtration, correction of alkalinity and corrosivity of the product water, and for providing a disinfection potential in the potable water.</p> <p>Environmental Impact and Occupational Health & Safety:</p> <ul style="list-style-type: none"> Incorrect chemical storage may lead to chemical spills, which if not contained, could result in soil contamination, and affect the health and safety of the operating staff Incorrect isolation of chemicals, in storage and operation, may result in toxic fumes and severe corrosion Incorrect design of gaseous chemicals, such as chlorine gas, could lead to toxic emissions Incorrect PPE used for combating chemical leaks or hazardous emissions could lead to death or harm to operators Leaks in the chemical storage vessels, if not contained, may result in soil contamination and health and safety concerns Incorrect piping or tubing on the pump discharge may lead to rupture and localized chemical spray affecting operators or other personnel in the vicinity Incorrect use of chemicals, due to lack of training and/or proper labeling could result in damage to membranes Insufficient or incorrect chemical dosage in the treatment process may result in delivery of water to the public which is not considered potable
Cartridge and Bag filters	<p>Cartridge or Bag filters are used as safety filtration of particulate matter which has the potential to block the downstream membranes.</p> <p>Environmental Impact:</p> <p>The consumable cartridge or bag filters can be a source of solid waste when replaced during the implemented maintenance program</p>
Media filters	<p>Media filters are used as the primary pre-treatment of the raw water, removing particulate contaminants in the raw water source before being delivered to the membrane treatment plant.</p> <p>Environmental Impact:</p> <p>The media used in the filters can be a source for solid wastes when replaced during the implemented maintenance program</p>

System's Component	Potential Risk during the Operation Stage
RO/NF system	<p>The reverse osmosis (RO) or Nano-filtration (NF) membranes are the technology by which water is separated into a pure water stream and a disposable brine. The membranes are manufactured from polymeric materials which are limited in their percentage recovery, temperature tolerance, and tolerance of oxidants and other foulants in the raw water stream.</p> <p>Occupational Health & Safety:</p> <ul style="list-style-type: none"> • Incorrect protection of the high-pressure pumping system or incorrect selection of piping materials may lead to catastrophic failure and subsequent risk of damage to equipment and personnel • Incorrect selection or installation of flexible couplings in the piping system may lead to leakage or rupture resulting in the risk of damage to equipment and personnel • Incorrect use of chlorine in the raw water, or failure to neutralize this chlorine, could result in membrane failure and the inability to produce water. • The RO membranes, when replaced, might be considered a hazardous waste if the raw water includes radionuclides. • A source for occupation health and safety hazard if the appropriate "OHS" measures were not implemented during managing or maintaining the system.
Clarifier	<p>Clarifiers are settling tanks built with mechanical means for the removal of solids deposited by sedimentation. Clarifiers generally employ chemicals to augment the removal of certain contaminants and suspended matter through chemical reaction and/or coagulation. Settleable matter, discharged from the bottom of the tank, is known as sludge while the particles that float to the surface of the liquid are called scum. The supernatant, or clarified water, is used as a source of feed to the desalination plant.</p> <p>Occupational H&S and Environmental Impact:</p> <ul style="list-style-type: none"> • The chemistry of the clarification process is critical and may lead to upsets in the process and subsequent failure • Chemical handling and pumping are inherent to all clarification processes and could be an occupational health and safety concern • The waste sludge produced in the clarification process may contain minerals and suspended material which result in liquid waste, which if not treated and disposed of correctly, could result in environmental contamination
Membrane feed pump	<p>Also called the high-pressure pump, it has to provide the required pressure to the desalination membranes, overcoming the natural osmotic pressure of the raw water and providing the requisite additional pressure to cause freshwater to pass through the membranes at the desired flow rate.</p> <p>Occupational Health & Safety:</p> <ul style="list-style-type: none"> • When replaced, such pumps can be considered solid waste. • Without the appropriate protection devices, the pump and its motor could fail or create a very high pressure in the discharge piping and pump casing which may result in harm to the device and personnel. • A source for occupation health and safety hazard if the appropriate "OHS" measures were not implemented during operating or maintaining such pump.
Remineralization System	<p>Reverse Osmosis or Nano-filtration membrane separation results in a permeate (product water) low in alkalinity, devoid of hardness, and mostly in an acidic state.</p> <p>Occupational H&S and Environmental Impact:</p>

System's Component	Potential Risk during the Operation Stage
	<ul style="list-style-type: none"> • The improper re-mineralization process to add alkalinity and a small amount of hardness into the product water may result in severe corrosion of metal components downstream of the membranes, causing a safety hazard. • Resulting corrosion in piping systems may create a health hazard • Failure to chlorinate the RO product water would leave a potable water source with no residual disinfection potential, leading to bacterial contamination and possible health effects to the consumer
Electrical System	<p>The electrical system could include sub-stations, distribution panels, motor controls, wiring and cabling, and grounding. This would be the entire power supply system from the grid to the desalination plant.</p> <p>Environmental, Health & Safety:</p> <ul style="list-style-type: none"> • Incorrect design of the protection devices and cabling could cause a fire hazard and damage to drives. This, in addition to damaging equipment, may cause an environmental impact (such as oil leaks from transformers) and the health and safety threat • Incorrect or insufficient grounding protection could lead to a safety hazard to operators and other personnel at the desalination plant

Table 4: Potential Environmental Risks That Results from The Different Parts of The Sea Water Desalination System

System's Component	Potential Risk during the Operation Stage
Seawater Intake	<p>The seawater intake is generally an open structure or screen located at the end of a pipeline. The location of the inlet, and depth, are decided based on bathymetric studies, affect on the natural fauna and coral, quality of water, temperature, the effect of sunlight, and other factors affecting the environmental conditions.</p> <p>Environmental Impact:</p> <ul style="list-style-type: none"> • Incorrect location of the intake may affect fauna and coral, destroying the natural habitat • Incorrect location of the intake may result in highly turbid water or high levels of chlorophyll entering the desalination plant • A high velocity in the intake pipeline will result in fish and other ocean life forms being brought into the pipeline and eventually through the seawater pumps. • Improper disinfection or inability to clean the intake pipeline may result in the growth of barnacles inside the pipe and eventually restrict flow to the desalination plant • An improperly anchored intake may result in pipeline breakage due to tidal action and resulting damage to the ecosystem and the availability of seawater to the desalination plant
Seawater pump station	<p>The seawater pump station transfers water from the intake structure to the desalination plant. The pump station is generally located at the coastline.</p> <p>OH&S Impact:</p> <ul style="list-style-type: none"> • Without the appropriate electrical protection devices and proper grounding, the pump and its motor could fail which may result in harm to the device and personnel. • The incorrect piping design may result in damage to equipment and personnel during operation and/or maintenance • Improper facilities like the absence of lifts or overhead cranes, makes removal of intake pumps, for maintenance, difficult and results in the potential for an OH&S risk
Media filters	<p>Media filters are used as the primary pre-treatment of the raw water, removing particulate contaminants in the raw water source before being delivered to the membrane treatment plant.</p> <p>Environmental Impact:</p> <ul style="list-style-type: none"> • The media used in the filters can be a source for solid wastes when replaced during the implemented maintenance program • Improperly designed filter vessels, in the case of pressure filters, may result in rupture of the vessels, resulting in both an environmental as well as health & safety risk • Failure to treat the backwash from the media filters could lead to contamination of the brine outfall and resultant risk to the natural habitat in the ocean
Ultrafiltration and Microfiltration	<p>Ultrafiltration (UF) or microfiltration (MF) is an advanced, membrane-based, technology used to further improve the quality of the seawater entering the desalination reverse osmosis membranes.</p> <p>OH&S Risk:</p> <ul style="list-style-type: none"> • Over-pressurization of the UF/MF modules can lead to rupture and an OH&S risk

System's Component	Potential Risk during the Operation Stage
	<ul style="list-style-type: none"> • Incorrect operation of the UF/MF membrane system may lead to system failure and disrupt or terminate the production of desalinated water • Improper wiring, cabling, and chemical injection may lead to risks to operating personnel and plant operation • Failure to treat the backwash from the filters could lead to contamination of the brine outfall and resultant risk to the natural habitat in the ocean
High-pressure pump	<p>The high-pressure pump provides the required pressure to the desalination membranes, overcoming the natural osmotic pressure of the seawater and providing the requisite additional pressure to cause fresh water to pass through the membranes at the desired flow rate.</p> <p>Occupational Health & Safety:</p> <ul style="list-style-type: none"> • When replaced, such pumps can be considered solid waste. • Without the appropriate protection devices, the pump and its motor could fail or create a very high pressure in the discharge piping and pump casing which may result in harm to the device and personnel. • A source for occupation health and safety hazard if the appropriate "OHS" measures were not implemented during operating or maintenance
Seawater RO Unit	<p>These units consist of pressure vessels housing the reverse osmosis membranes, supported on a structural frame with the piping and all the instrumentation and analytical devices required to monitor performance.</p> <p>OH&S Risks:</p> <ul style="list-style-type: none"> • Inadequate support of the pressure vessels and piping could lead to failure of the structural frame and result in damage to equipment and personnel • Incorrectly selected pressure vessel housings could lead to vessel rupture and damage to equipment and personnel • Incorrectly selected flexible couplings, installed in the piping system, may lead to catastrophic failure and resultant damage to equipment and personnel • Incorrectly selected piping, pressure rating, and corrosion resistance could lead to catastrophic failure and damage to equipment and personnel • Incorrect use of chlorine in the raw water, or failure to neutralize this chlorine, could result in membrane failure and the inability to produce water. • The RO membranes, when replaced, might be considered a hazardous waste if the raw water includes radionuclides. • A source for occupation health and safety hazard if the appropriate "OHS" measures were not implemented during managing or maintaining the system. • the consumable RO membranes might be considered as solid waste if the treated raw water included isotopes.
Energy recovery device (ERD)	<p>The energy recovery device may take the form of a work exchanger or a turbo charger and its purpose is to mechanically exchange the potential energy in the RO brine stream and transfer this energy to the membrane feed thereby reducing the energy consumed by the high-pressure pump.</p> <p>OH&S Risks:</p> <ul style="list-style-type: none"> • Energy recovery systems produce a significant level of noise. Occupation safety hazards to the workers if inappropriate "OHS" procedures are not implemented.

System's Component	Potential Risk during the Operation Stage
	<ul style="list-style-type: none"> • Incorrect selection of the ERD may fail the device and resultant damage to equipment and personnel • Incorrectly selected flexible couplings, installed in the piping system, may lead to catastrophic failure and resultant damage to equipment and personnel • Incorrect protection of the low-pressure piping on a pressure exchanger type of ERD could lead to catastrophic failure and resultant damage to equipment and personnel
Remineralization unit	<p>Reverse Osmosis membrane separation results in a permeate (product water) low in alkalinity, devoid of hardness, and mostly in an acidic state.</p> <p>Occupational H&S and Environmental Impact:</p> <ul style="list-style-type: none"> • Improper re-mineralization process, to add alkalinity and a small amount of hardness into the product water, may result in severe corrosion of metal components downstream of the membranes, causing a safety hazard. • Resulting corrosion in piping systems may create a health hazard • Failure to chlorinate the RO product water would leave a potable water source with no residual disinfection potential, leading to bacterial contamination and possible health effects to the consumer • Due to the process of reverse osmosis, desalinated water tends to be very corrosive, and is characterized by: Low pH, Soft or with primarily non-carbonate hardness and Low alkalinity
Brine Outfall	<p>The brine outfall transfers the concentrated seawater, after the membrane process, along with other process wastes back into the ocean. Environmental Impact:</p> <ul style="list-style-type: none"> • Incorrectly designed brine dispersion methods, to reduce the impact of high salinity on the ambient seawater, may result in damage to the ocean habitat • Incorrect location of the brine outfall may affect fauna and coral, destroying the natural habitat • Incorrect location of the brine outfall may cause short-circuiting of brine into the seawater intake causing failure in the desalination process • An improperly anchored outfall pipeline may result in breakage due to tidal action and resulting damage to the eco system • Toxic chemicals, such as chlorine, if uncontrolled may result in damage to the ocean habitat • Low oxygen levels in the brine, remaining uncontrolled, may result in damage to the ocean habitat
Chemical dosing systems	<p>Chemical dosing systems are used in a desalination plant for pre and post-treatment and uses could generally be for membrane protection, conditioning of raw water to enhance filtration, correction of alkalinity and corrosivity of the product water, and for providing a disinfection potential in the potable water.</p> <p>Environmental Impact and Occupational Health & Safety:</p> <ul style="list-style-type: none"> • Incorrect chemical storage may lead to chemical spills, which if not contained, could result in soil contamination, and affect the health and safety of the operating staff • Incorrect isolation of chemicals, in storage and operation, may result in toxic fumes and severe corrosion • Incorrect design of gaseous chemicals, such as chlorine gas, could lead to toxic emissions • Incorrect PPE used for combating chemical leaks or hazardous emissions could lead to death or harm to operators

System's Component	Potential Risk during the Operation Stage
	<ul style="list-style-type: none"> Leaks in the chemical storage vessels, if not contained, may result in soil contamination and health and safety concerns Incorrect piping or tubing on the pump discharge may lead to rupture and localized chemical spray affecting operators or other personnel in the vicinity Incorrect use of chemicals, due to lack of training and/or proper labeling could result in damage to membranes. Insufficient or incorrect chemical dosage in the treatment process may result in delivery of water to the public which is not considered potable
Cleaning System	<p>Chemical dosing systems are used in a desalination plant for pre and post-treatment and uses could generally be for membrane protection, conditioning of raw water to enhance filtration, correction of alkalinity and corrosivity of the product water, and for providing a disinfection potential in the potable water.</p> <p>Environmental Impact and Occupational Health & Safety:</p> <ul style="list-style-type: none"> Incorrect chemical storage may lead to chemical spills, which if not contained, could result in soil contamination, and affect the health and safety of the operating staff Incorrect handling of chemicals, in storage and operation, may result in toxic fumes and severe corrosion Incorrect use of chemicals may damage the membranes Failure to neutralize CIP waste could result in contaminants being transferred to the brine outfall Incorrect PPE used for combating chemical leaks or hazardous emissions could lead to death or harm to operators Leaks in the chemical storage vessels, if not contained, may result in contamination and health and safety concerns
Electrical System	<p>The electrical system could include sub-stations, distribution panels, motor controls, wiring and cabling, and grounding. This would be the entire power supply system from the grid to the desalination plant.</p> <p>Environmental, Health & Safety:</p> <ul style="list-style-type: none"> Incorrect design of the protection devices and cabling could cause a fire hazard and damage to drives. This, in addition to damaging equipment, may cause an environmental impact (such as oil leaks from transformers) and health and safety threats. Incorrect or insufficient grounding protection could lead to a safety hazard to operators and other personnel at the desalination plant

3.4 Environmental Settings in the Project Area

The purpose of this part of the “ESIA” is to document the current status of the environmental baseline conditions in the entire project area, to be used to verify later the environmental impacts (positive or negative) that were caused by the project. Generally, an ESIA for a desalination project should address the following areas of impact:

i. The Physical Environment (Abiotic)

Under this category, the following elements will be described:

- Climate including temperature and rainfall
- Topography & Morphology
- Geological & structural setting
- Noise levels
- Air quality data
- Water Resources, and include
 - The status of groundwater resources includes different types of wells and springs, with a special focus on wells and springs used for drinking purposes.
 - The status of the surface water resources.
 - It is important to mention which water resources are used, the purpose of usage, and the used amount.
 - Available water quality data from springs, wells, dams, major water conveyors, and surface water streams that could be affected, should be collected and documented. The documentation of the status should be accompanied by results of certified laboratories, photos, etc. which must be part of the report.
- In the case of seawater desalination projects, the quality characteristics of the seawater need to be presented.
- Land use within the whole project area is expected to be influenced by the construction and operation of the project.

ii. The Biodiversity (Biotic Environment):

This part encompasses the terrestrial biological resources, including flora and fauna, in particular sensitive species that inhabit the area impacted by the proposed project. For the seawater desalination projects, a detailed assessment of marine life needs to be presented.

iii. Socio-Economic Context

This part of the report shall present the Socio-economic considerations within the project area, with a focus on the following major elements:

- Demographic characteristics of the project area
- Demographic characteristics for the beneficiary areas
- Major practiced human activities.
- The project’s effects on the day-to-day lifestyle of the beneficiaries from the project
- The project’s impact on local and regional development.

iv. Cultural Heritage

This section of the “ESIA” needs to address and highlight the cultural heritage sites (if present) within the project area, and needs to be preserved.

v. Public Health

Under this section, public health addresses the quality of life (well-being), improvement in community health, and potential risks associated directly or indirectly with the desalination project.

3.5 Identification of Potential Impacts

Impacts identifications need to cover the following stages of the project: Preparation, construction; and operation. In general, the key aspects that should be investigated in EIAs for desalination projects are:

- Impacts related to the siting of the desalination facility and supporting infrastructure.
- Impacts related to the different construction operations and the potential resulted in fluid and solid wastes.
- Impacts related to the construction of the temporary labor camps (in case of major or mega projects).
- Impacts related to the transportation of construction equipment and materials.
- Impacts related to the intake of source water,
- Impacts related to the discharge of concentrates, cooling water, and other waste streams resulting from the process, include:
 - an investigation of the hydrological mixing process in the discharge area.
 - an investigation of impacts related to salinity, temperature, pH or dissolved oxygen levels deviating from ambient conditions in the mixing zone.
 - an investigation of environmental fate and potential toxic effects of chemical residuals and by-products from the process, particularly of pretreatment and cleaning chemicals.

Grounded on the description of the project and the provided environmental baseline conditions for the project area, all potential impacts must be defined, described, and evaluated. For any potential impact:

- To define where and under which circumstances the said impact may take place,
- what the scale of the impact and which resources may be impacted. Also, (where possible) based on the available collected data, the risk must be quantified.

Usually, the impacts of the activities can be considered as significant if they are:

- extensive over space and time and/or intensive concerning its impacts on natural resources.
- likely to impact public health and/or safety.
- likely to limit the use of resources on which people rely for existence.
- likely to reduce the quality or quantity of natural resources (water, soil).
- potentiality to disrupt or threaten the lifestyle of a large number of people.
- likely to affect declared protection areas, nature or water conservation areas, ecologically sensitive areas, rare or endangered species, or cultural heritage sites.

3.5.1 Potential Impacts by Geohazards

All potential geohazards (or Geo-risks) within the project area need to be presented, discussed, and evaluated. Such risks include (but not limited to) :

✱ Fault zones with active tectonic movements.

A map for the major structural features in Jordan is illustrated in Annex-1.

✱ Earthquakes

Generally, the construction of desalination facilities on or near major fault zones should be avoided because earth movements in a tectonically active region like Jordan will most certainly have immense negative environmental impacts, not only on humans but especially on water resources. Not all identified fault zones must, however, necessarily be still active but could indicate tectonic movements which happened millions of years ago. It is therefore important to identify the current regional tectonic stress field.

Site selection for the construction of seawater and brackish water desalination plants in tectonically active areas, such as all areas extending from Aqaba to the northern Jordan Valley (Dead Sea Transform fault) need to take into consideration the risk of earthquakes, tectonic movements, and landslides. Jordan's seismic risk map is illustrated in Annex -2.

✱ Landslides:

A landslide (Figure-4) is defined as the movement of a mass of rock, debris, or earth down a slope. Landslides are denoting any down-slope movement of soil and rock under the direct influence of gravity.

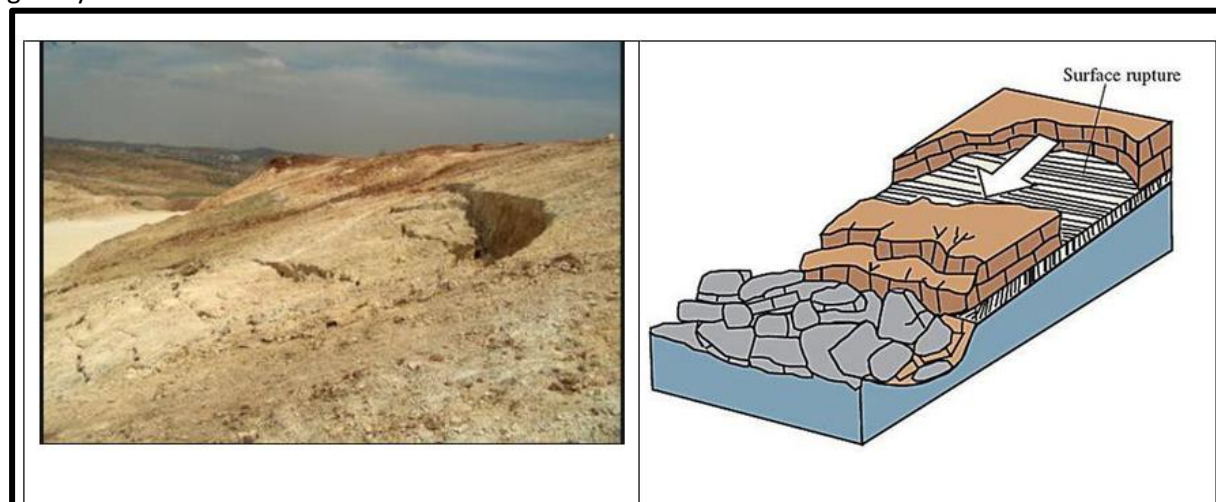


Figure 4: Examples Pictures and Sketches for Landslide⁴

✱ Rockfalls :

A rockfall (Figure-5) refers to quantities of rock falling freely from a cliff face. The term is also used for the collapse of rock from roof or walls of mine or quarry workings. "A rockfall is a fragment of rock (a block) detached by sliding, toppling, or falling, that falls along a vertical or sub-vertical cliff, proceeds down the slope by bouncing and flying along ballistic trajectories or by rolling on talus or debris slopes.

⁴ Fathi M. Shaqour, Ghaleb Jarrar, Steve Hencher; Mostafa Kuisi: Geotechnical and mineralogical characteristics of marl deposits in Jordan–Environmental Geology /V.55-Year 2007

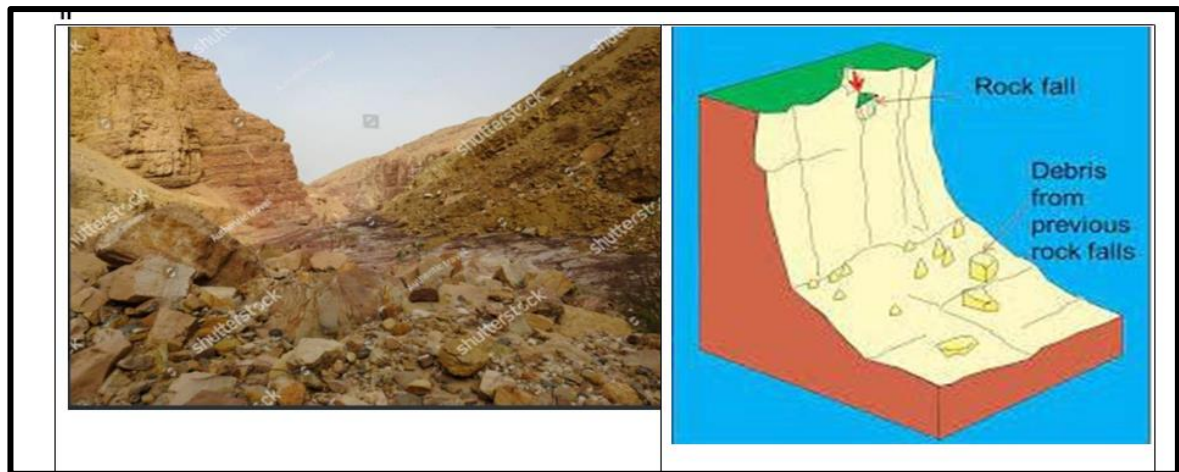


Figure 5: Rockfalls (Jordan Valley)⁵

✿ Land Subsidence

Land subsidence (Figure-6) is a gradual settling or sudden sinking of the Earth's surface due to the removal or displacement of subsurface earth materials. The principal causes include aquifer-system compaction associated with groundwater withdrawals; drainage of organic soils; underground mining, and natural compaction or collapse, such as with sinkholes or thawing permafrost⁶



Figure 6: Example for Land Subsidence Incident

✿ Sinkholes

Sinkholes (Figure-7) are common where the rock below the land surface is limestone, carbonate rock, salt beds, or rocks that can naturally be dissolved by groundwater circulating through them. As the rock dissolves, spaces and caverns develop underground. Sinkholes are dramatic because the land usually stays intact for a while until the underground spaces just get

⁵ <https://www.shutterstock.com/image-photo/jordan-rift-valley-wadi-ad-dardour-1037157115>

⁶ https://www.usgs.gov/mission-areas/water-resources/science/land-subsidence?qt-science_center_objects=0#qt-science_center_objects

too big. If there is not enough support for the land above the spaces, then a sudden collapse of the land surface can occur. These collapses can be small (as this picture shows), or they can be huge where a house or road is on top⁷.

Dissolution and widening of the underground karst system might continue and lead to further collapses. Land subsidence might occur in areas where insufficiently consolidated recent sediments have accumulated, especially in landslide areas.

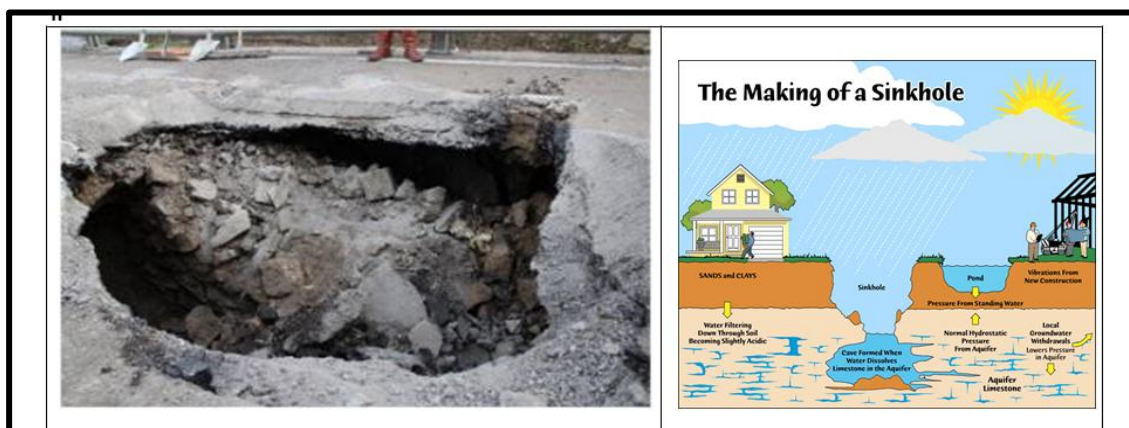


Figure 7: Examples for Sinkholes

Moreover, the construction of desalination plants should avoid landslides and rockfalls areas. If not avoidable, mitigation measures have to be specified and their implementation monitored. Also, landslides and rockfalls' preexisting features will give a good indication of which geological units in which topographic setting are prone to such risks. However, human activities, like mining, construction of roads and buildings, etc. will lead to an increased risk, especially where topographic gradients are high. Generally, desalination facilities should not be built on existing landslide masses because the underground might not be well consolidated and not be stable enough.

✱ Liquefaction

Liquefaction (Figure-8) is a process by which water-saturated sediment temporarily loses strength and acts as a fluid. This effect can be caused by earthquake shaking. Liquefaction takes place when loosely packed, water-logged sediments at or near the ground surface lose their strength in response to strong ground shaking. Liquefaction occurring beneath buildings and other

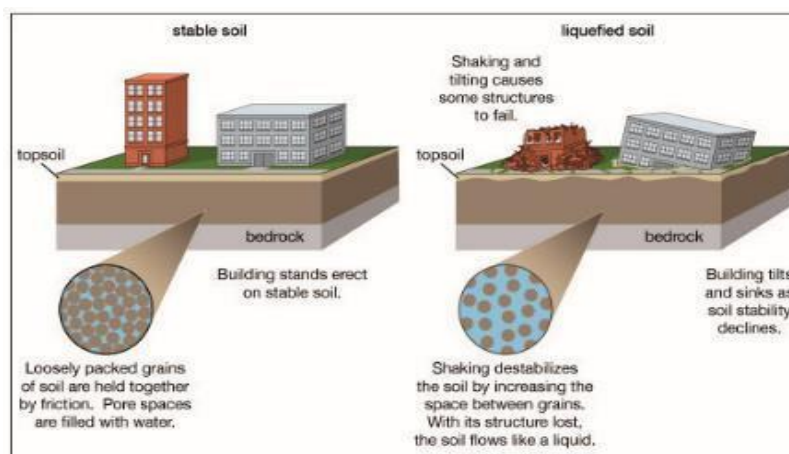


Figure 8: Soil Liquefaction⁸

⁷ EmanueleIntrieri ;GiovanniGigli: Sinkhole monitoring and early warning: An experimental and successful GB-InSAR application-Geomorphology/Volume 241, 15 July 2015, Pages 304-314

⁸ <https://constructionor.com/soil-liquefaction/>

structures can cause major damage during earthquakes. Also, Soil liquefaction is a process that occurs where loosely packed water-saturated sediments are suddenly transferred from a solid to a liquid mass by an increase in water pressure. Commonly soil liquefaction is triggered by earthquakes or explosions (e.g. in quarries or mines).

✱ Flooding.

With the impacts of the climate change phenomena on the rainfall mechanism over Jordan during the last two decades (similar to other parts of the world), the process of designing the components of any proposed desalination plants needs to take into consideration the protection of the project components from flooding. Figure-9 shows examples of the flash floods impacts on built-in areas in Jordan.



Figure 9: Flash Floods in Built-up Areas in Jordan

Thus, hydrological evaluation for the project site needs to be a major component of the project “ESIA”. Therefore, all components of the proposed Water Desalination Plants must be designed in such a way that should be entirely safe from flooding, thus, would not causing any negative environmental impact. Currently, MWI is working on improving the surface water runoff monitoring system in Jordan to be able to have an accurate prediction (as much as possible) of the highest possible level of flooding. Predicting the highest possible level of flooding therefore often will have to follow proxy information, like historic records or witnesses. When using records from gauging stations, it must be taken into consideration that those apply only for this specific section.

It is important to consider that, such risks are not only risks for the environment but also water supply security. Seawater desalination plants require constant availability not only of water but also of energy. If energy is interrupted due to a major earthquake, sabotage, or war, water supply security is at risk. Therefore, such risks need to be considered as well in the overall planning and ESIA.

Geohazards need to be taken into consideration not only during the site selection for the planned seawater or brackish water desalination plant but also during construction and operation.

3.5.2 Potential Impacts on Water Resources

This section of the “ESIA” needs to address the impacts of each component of the proposed desalination project on groundwater and surface water resources in terms of quality and quantity.

Impacts on water resources might be caused by:

- inadequate site selection.
- The impacts of the karstification phenomena on the vulnerability level of the local aquifer system within the project area.
- inadequate design (methods, technology, capacities, diameters, etc.)
- inadequate materials
- Errors during installation/construction
- Errors during operation (e.g. inadequate maintenance, monitoring, etc.)
- Brine water leakages from gaskets and joints (e.g. due to inadequate material or wrong installation),
- Overflow of brine water due to pressure breaks.

3.5.3 Impacts of Site Clearance and Preparation for Construction

Environmentally sound practices need to be applied during the construction of such project, and include (but are not limited to):

- Only materials not hazardous to the environment, especially water should be used.
- During transportation, storage, handling, collection, and safe disposal of substances hazardous to the environment, especially to water resources, special precautions have to be taken (e.g. oil and fuel for machinery should be stored and handled safely)

Many factors affect site selection such as available energy sources, costs, and the risks associated with transporting the feedwater to the plant, as well as the location of concentrate discharge.

The proximity of a desalination plant to population centers and environmentally protected and sensitive areas are also critical factors. A major issue to consider, is land use in the proximity of a proposed desalination plant site. If planners place a desalination plant in densely populated areas, it may impact the residential environment.

3.5.4 Impacts on Air Quality & Noise Levels

Desalination of saline water is generally an energy-intensive process. Depending on the desalination technology and energy sources, large-scale water desalination plants have the potential to add significantly to the greenhouse gas emissions held largely responsible for climate change. In many instances, desalination plants emitted pollutants such as NO_x, SO_x, particulates, etc.

Also, some desalination plants generate noise and gas emissions. For example, reverse osmosis plants generate noise because of the use of high-pressure pumps. Moreover, if the desalination projects are located near population centers or other public facilities, plans should include steps to mitigate noise pollution such as using canopies or acoustical planning.

Desalination plants can have an indirect impact on the environment because many plants receive energy from the local grid instead of producing their own. The burning of fossil fuels and increased energy consumption allows more air pollution and gas emissions to occur. Gaseous emissions from desalination stacks include carbon monoxide (CO), nitric oxide (NO), nitrogen dioxide (NO₂), and

sulfur dioxide (SO₂). These air pollutants can harm public health [mainly for seawater desalination projects].

3.5.5 Potential Environmental Impacts of the Resulted Fluid Wastes

The major streams of the fluid wastes that might result during the construction and operation phases of a desalination project (include but not limited to):

- Different types (hazardous and non-hazardous) fluid wastes that will result from the different construction operations
- Chemical spill risks
- Environmental Aspects of RO Membranes Cleaning Chemicals
- Environmental Aspects of Acid Addition
- Environmental Aspects of Polyphosphate Scale Inhibitors
- Potential Environmental Impacts of The Brine Water

The desalination process separates saline water into two streams: (i) A low dissolved solid concentration stream (freshwater or desalinated water), and (ii) another stream containing the remaining dissolved solids (brine reject or blow-down). Thus, to extract, separate, and concentrate the salts in the rejected brine solution in desalination plants, intensive thermal or electrical energy is required.

Moreover, during the process of desalination, the physical and chemical properties of the brine reject change significantly. The characteristics of the reject brine were found to be a direct function of the quality of the feed water, the desalination technology used, the percent recovery, the chemical additives used within the process, the construction material, and proficiency of the operators. Thus, the "ESIA" needs to address the following issues of concern:

- Environmental aspects of brine thermal discharge (for seawater desalination plants)
- Environmental aspects of high salinity in brine reject
- Environmental aspects of trihalomethanes (THMs) in brine reject
- Environmental aspects of antifouling agents (chlorine) in brine
- Environmental aspects of trace metals in brine reject
- Environmental aspects of anti-scalants in brine reject

3.5.6 Potential Environmental Impacts of Resulted Solid Wastes

under this section, the environmental aspects for the following two types of solid wastes generated during the construction, operation, and decommissioning phases need to be presented and evaluated:

- Non-hazardous wastes
- hazardous wastes

3.5.7 Potential Impacts Related To The Socio-economic Context

Under this section, the potential impacts that will affect the socioeconomic context during the construction and operation phases of any desalination project to be addressed. Such impacts

include (but not limited to) the following:

❖ **During the construction phase**

- Temporary work opportunities for members of the local community in the project (where possible).
- Mismanaging the resulting solid and fluid wastes from the construction operations. Such an issue will negatively impact the life indices of the local communities.
- Temporary increase in the noise levels within the project site due to the different construction operations.
- Temporary deterioration in the air quality within the project area due to the site preparation works.
- Increase traffic density on the local roads network. Thus, the possibility for the occurrence of traffic accidents needs to be considered

❖ **During the Operation Phase**

- Improve the life indices for the beneficiary communities through providing fresh and clean water.
- Mismanaging resulting solid and fluid wastes during this phase. Such an issue will negatively impact the life indices of the local communities.
- Possible increase in the noise levels within the project site due to the different construction operations.
- Affect the value of the lands located in the vicinity of the plant or close to it.
- Inappropriate management for the brine water might reduce the overall value of the surrounding lands.

3.5.8 Impacts on Marine Biodiversity (in case of seawater desalination)

The different types of brine rejection have a negative impact on the marine biodiversity within the discharge area

3.5.9 Occupation Health & Safety

Issues related to occupational health and safety during the different stages of the project need to be addressed within the context of the “ESIA”.

3.5.10 Public health & Safety

The “ESIA” should address the potential impacts (positive & negative) related to public health and safety during the different stages of the project.

During the construction phase, the public health and safety of the surrounding local communities might be negatively impacted by the uncontrolled construction operations of the desalination plant. Such construction operations include (but not limited to):

- Site preparation and excavation
- The movement of the project heavy vehicles for transporting the construction materials
- In the absence of a relevant wastes’ management plan, the resulting fluid and solid wastes

from the construction operations

During the operation phase, the public health and safety of the nearby local communities will be potentially impacted as the following:

- Positively through improving the public health of the nearby local communities through making freshwater available.
- In the absence of appropriate wastes management plan, the resulting fluid and solid wastes from the desalination operation might harm the public health of the surrounding local communities.

3.5.11 Environmental Aspects of Desalination Plants Intakes (For Sea Water desalination)

All seawater desalination plants require large volumes of feedwater, to be processed to produce freshwater as a final product. In mega desalination plants, substantial masses of seawater are required; the pumping of the feedwater into the plant can result in significant environmental impacts due to impingement and entrainment.

3.6 The Project's Environment & Social Management Plan (ESMP)

The "ESMP" is an essential part of any "ESIA". It is advised to prepare it in a way that can be used (if needed) independently from the other parts of the "ESIA". Thus, it is recommended for the "ESMP" to include the following major parts:

3.6.2 Project Description

Under this section, a summary of the project needs to be presented

3.6.3 Project's Potential Environmental Impacts

Summary of the defined potential environmental impacts of the proposed project. Usually, tables are used to present the said summary.

3.6.4 Proposed Mitigation Measures

The proposed mitigation measures should cover the construction, operation phases of the project. It should include a detailed description of the proposed mitigation measures that need to be implemented to maximize the project's positive impacts and minimize the project's negative impacts.

➤ The mitigation strategy

It is recommended that the mitigation strategy is based on:

- Preventive measures and design inputs.
- Preventive measures during the phases of project implementation.
- Corrective measures to rectify unavoidable impacts (rehabilitation, reinstatement, and monetary and non-monetary compensation if necessary);
- Feedback loop to the design stage to ensure its incorporation into the project implementation; and
- Additional benefits to the environment and nature conservation.

➤ **The proposed mitigation measures should also comprise:**

- Alternative solutions concerning site selection (location);
- Alternative solutions concerning design (methods, technology, capacities, diameters, etc.);
- The suggestion of alternative solutions concerning the selected materials;
- The suggestion of alternative solutions concerning installation/construction procedures.
- The suggestion of alternative solutions concerning operational procedures.
- Suggestions on how to mitigate the impact of individual geohazards through alternative sites or constructional changes.
- Suggestions on how to manage the resulting solid wastes during the construction and operation phases of the project (including non-hazardous and hazardous fluid wastes). In this regard, Annex-3 of this report includes a location map for the major fluid waste dumping sites in Jordan.
- Suggestions on how to manage the resulting fluid wastes during the construction and operation phases of the project (including non-hazardous and hazardous solid wastes). In this regard, Annex-4 of this report includes a location map for the major solid waste dumping sites in Jordan. Moreover, Annex-5 presents a location map for the Swaqa hazard wastes dumping site.

➤ **The Residual Impacts:**

The likelihood, significance, and extent of residual impacts after mitigation should be analyzed to allow decision-makers to determine whether those could be accepted.

➤ **A Contingency and Emergency Plan**

Such a plan should be prepared in case of adverse impacts of large scale (e.g. uncontrolled discharge of Brine water or the accidental stoppage of the desalination plant). Contingency planning is especially important for adverse impacts on the natural water resources such as wells, surface water bodies, and springs. It has to mention what alternative water sources are to be used in case of disruption of water supply due to pollution. This should be complemented by a remedial action plan that describes what needs to be done and who is responsible for the individual actions in case a water source became polluted, for instance by an accidental brine spill or chemical spills from the fluids used in the desalination process. Remedial actions are usually long-term response actions that seek to permanently and significantly reduce the risks associated with releases or threats of releases of substances adverse to human health.

3.6.5 Proposed Monitoring Plan

Environmental monitoring is necessary to gauge the impact of operations on the site. By implementing appropriate plans with sufficient detail, it is possible to minimize and control waste generation, limit physical disturbances, and operate responsibly.

The proposed monitoring plan needs to cover the project's construction and operation phases. Detailed description for the recommended monitoring plan that needs to be implemented during the project; and, also, the responsible parties to implement the said monitoring plan needs to be defined (based on the project location, size, and type). In general, implemented mitigation measures for the following major environmental issues of concern needs to be monitored through a comprehensive monitoring plan.

<u>Issues of Concern</u>	<u>Responsibility for implementations</u>	<u>Follow up responsibility</u>
<ol style="list-style-type: none"> 1. Appropriate management for resulting solid wastes 2. Appropriate management for resulting fluid wastes 3. Noise levels due to construction operations 4. Possible air quality due to site preparation works 5. Appropriate life indices at the workers' camps (in case of major and Megaprojects) <p>Conserving local biodiversity system</p>	<ul style="list-style-type: none"> • The contractor's environment, health, and safety team. • The project consultant's environment, health, and safety team. 	<ul style="list-style-type: none"> • MoEnv. • Environment department at WAJ • ASEZA Environment Department (for projects located in ASEZA area)
<p>During the operational phase the project's monitoring plan needs to include (among others) the following major issues of concern:</p>		
<ol style="list-style-type: none"> 1. Monitoring the implemented management plan for the resulting fluid wastes with a special focus on the resulting brine. 2. Monitoring the implemented management plan for the resulting solid wastes 3. monitoring of the impact on water resources and cover: <ul style="list-style-type: none"> ○ monitoring of brine water quality according to environmental standards. ○ monitoring of the quality of downstream water resources according to environmental standards (drinking water standard). 	<ul style="list-style-type: none"> • The contractor's environment, health, and safety team. • The project consultant's environment, health, and safety team. 	<ul style="list-style-type: none"> • MoEnv. • Environment department at WAJ <p>ASEZA Environment Department (for projects located in ASEZA area)</p>

3.6.6 Capacity-Building & Staff Training Plan

This plan will explain how the workers in the different stages of the project will be trained on environment protection and health & safety aspects, and also be aware of the aspects of protection and preservation of natural resources. Training is divided into technical, theoretical, and practical, and supervised by the EHS manager.

3.6.7 Documentation & Environmental Communication

The environmental management process must be accompanied by monitoring tools designed to document and communicate the results of the implemented plans between the staff and the various responsibility levels involved in the project. Among these tools, reports, minutes, and periodic official communications produced by the various involved parties allow documenting the undertaken actions, the non-compliance cases, and measures taken to adjust them.

In this regard, (for medium and large size desalination plants) a monthly Environment, Health, and safety report need to be prepared during the operation stage of the project, the content of the said report should highlight the following major issues :

- The implementation of the proposed mitigation measures with relation to the different project operations.
- Waste management plan;
- Risk management plan.
- Environmental monitoring.
- Work at the natural reserves;
- Site restoration (when & where needed);
- HSE monthly statistics include major HSE incidents; HSE training program, and any updates to the project's HSE procedures.

3.6.8 Environmental & Safety Audit

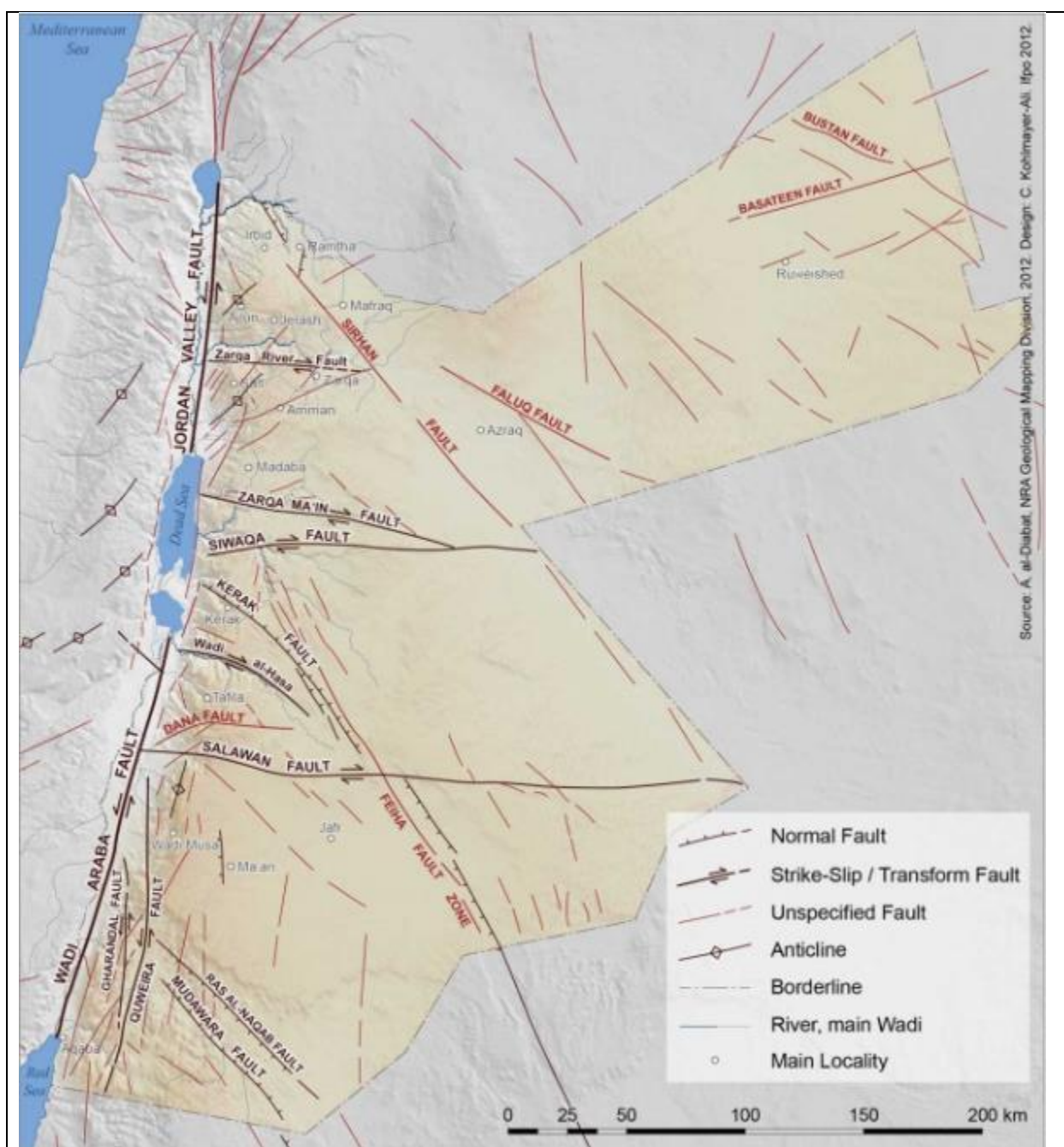
A schedule of environmental audits will be developed and will ensure that the following elements of the Environmental/HSE procedures and plans are audited:

- Making use of mitigation measures.
- Waste management plan;
- Risk management plan.
- Disaster risk management/mitigation plan.
- Environmental monitoring.
- Capacity building & staff training plan.
- Documentation & environmental communication.
- Site restoration.
- HSE implementation; and HSE training.

Standard Outline for Environmental Impact Assessment for Desalination Facilities in Jordan is presented in Annex-6 of this report.

4. Annexes

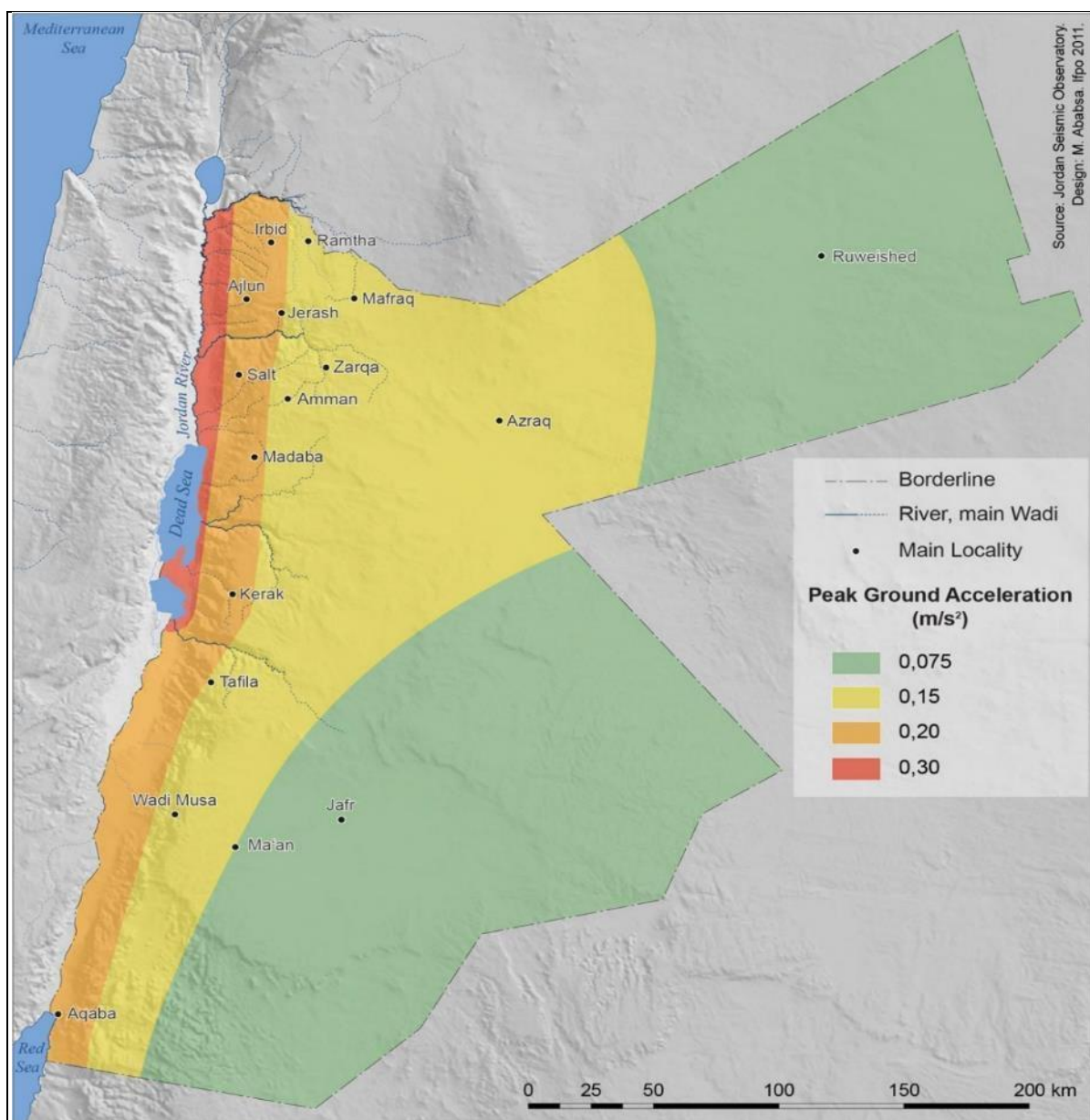
4.1 Annex-1: Jordan Major Structural Features



Jordan Major Structural Features⁹

⁹ Atlas of Jordan – 2013 – Myriam Ababsa

4.2 Annex-2: Jordan Seismic Zoning Map

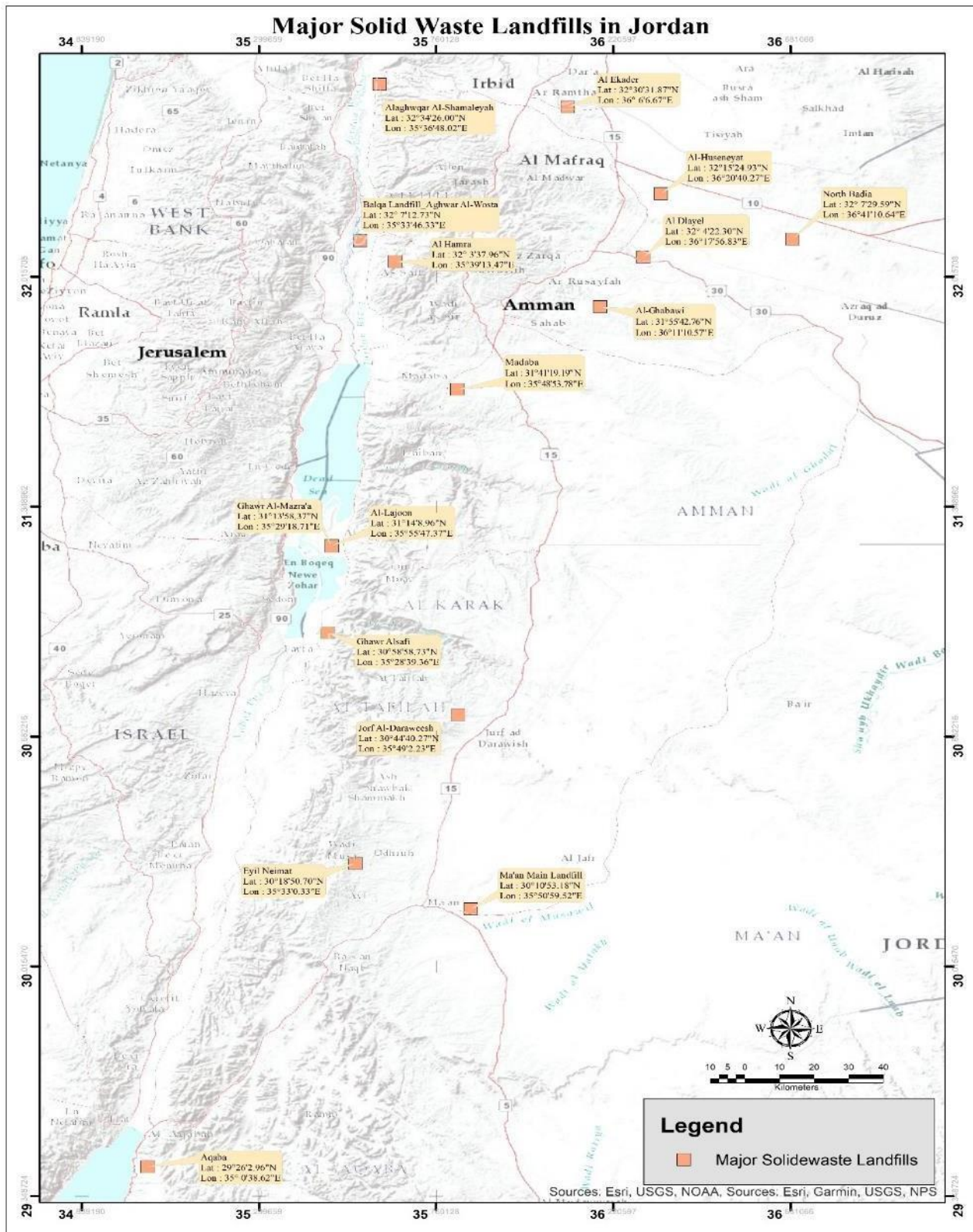


Peak Ground Acceleration (PGA) is equal to the maximum ground acceleration that occurred during earthquake shaking at a location. PGA is equal to the amplitude of the largest absolute acceleration recorded on an accelerogram at a site during a particular earthquake. Earthquake shaking generally occurs in all three directions. Therefore, PGA is often split into horizontal and vertical components. Horizontal PGAs are generally larger than those in the vertical direction, but this is not always true, especially close to large earthquakes. PGA is an important parameter (also known as an intensity measure) for earthquake engineering,

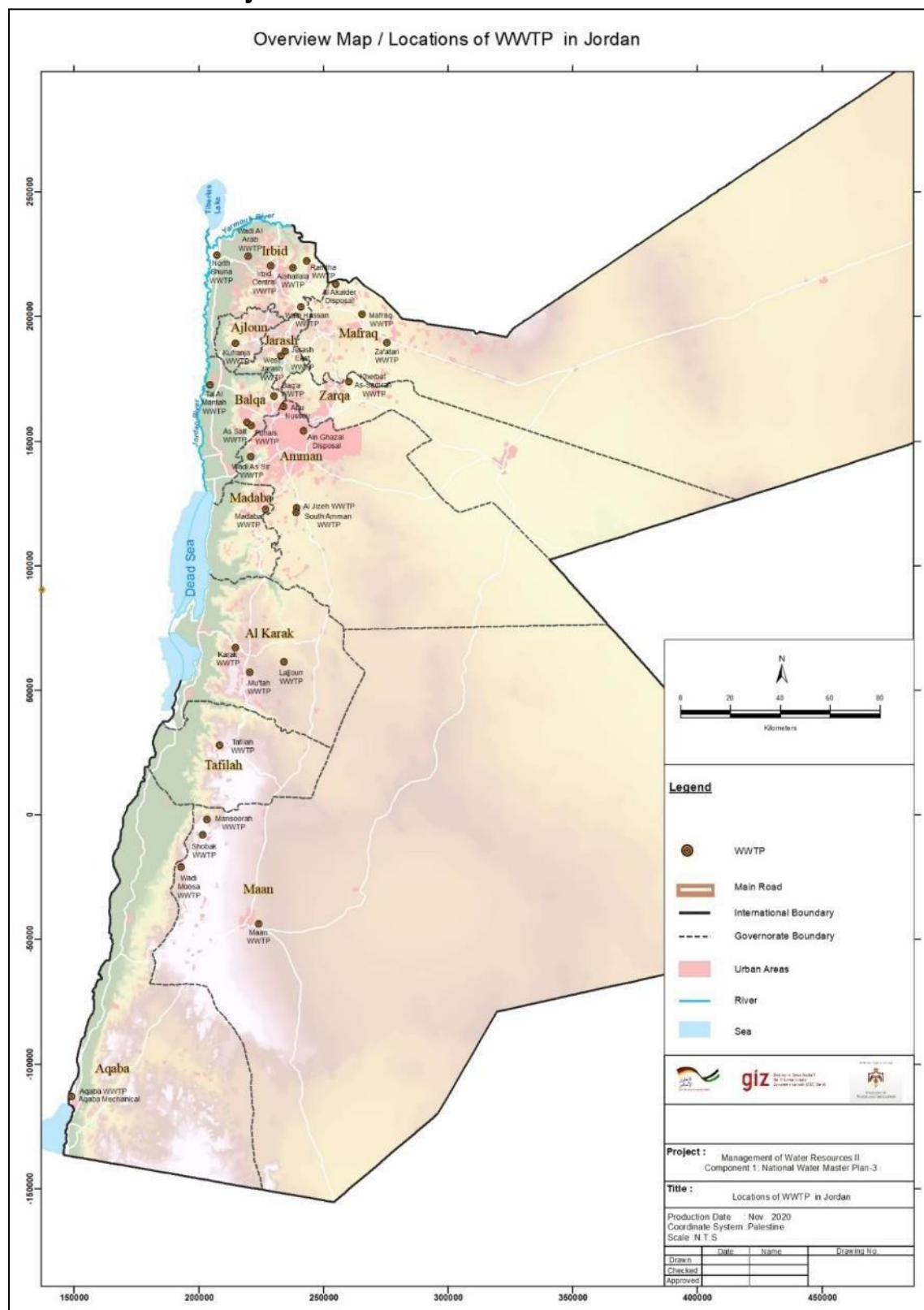
Jordan Seismic Zoning Map¹⁰

¹⁰ Atlas of Jordan – 2013 – Myriam Ababsa

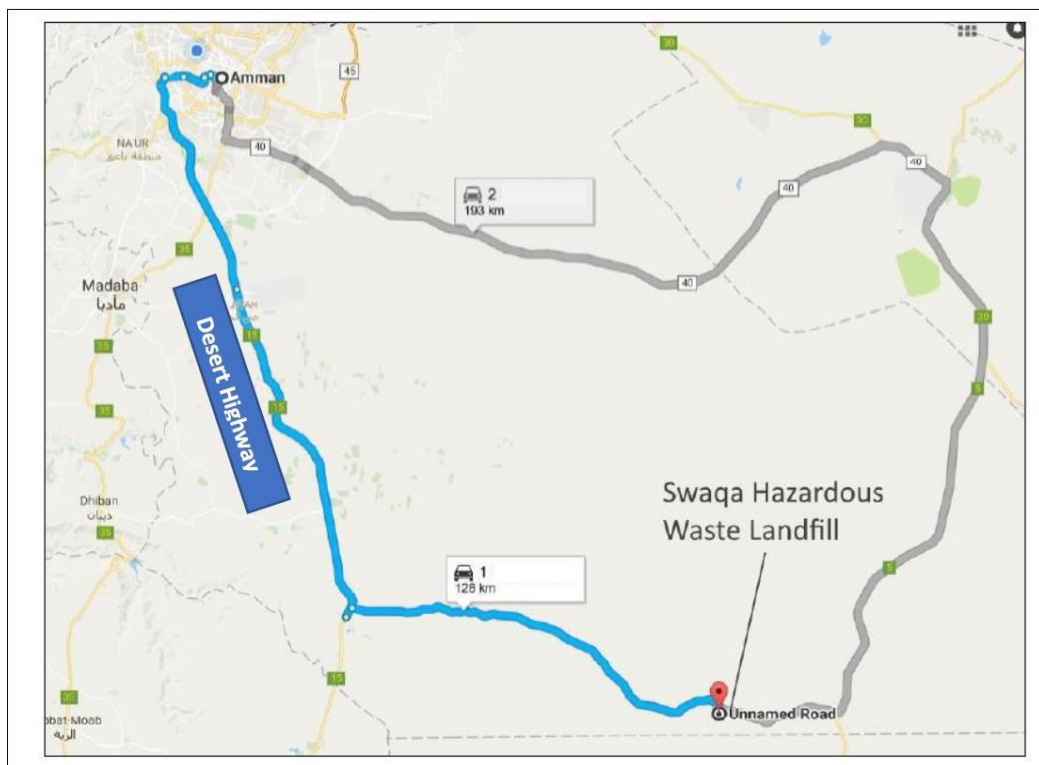
4.3 Annex-3: Major Solid Wastes Dumping Sites in Jordan



4.4 Annex-4: Major Wastewater Treatment Plants in Jordan



4.5 Annex-5: Hazard Waste Dumping Site in Jordan



4.6 Annex-6: Standard Outline for Environmental Impact Assessment for Desalination Facilities in Jordan

1 Introduction

- 1.1 Background
- 1.2 Objectives
- 1.3 Methodology
- 1.4 Report Components

2 Project Description

- 2.1 The Project
 - 2.1.1 Objective, schedule
 - 2.1.2 Project components
 - 2.1.3 Detailed description of the process of construction
 - 2.1.4 Detailed description of the process of operation and maintenance
- 2.2 The Project area
 - 2.2.1 Selection of sites with justification

3 Project Alternatives

- 3.1 Alternative sites
- 3.2 Alternative processes

4 Legislative and Institutional Framework

(Administrative frameworks, laws, policies and any international conventions that affect the project)

- 4.1 Legislative Framework
- 4.2 Institutional Framework

5 Environmental Baseline Data

- 5.1 Introduction
- 5.2 Physical Environment
 - 5.2.1 Current land use
 - 5.2.2 Meteorology & Climate
 - 5.2.3 Geological Setting and Tectonic Features
[including the risk of tectonic movements, earthquakes, landslides, rockfalls, sinkholes, land subsidence, liquefaction (instable soil)]
 - 5.2.4 Surface Water Resources
 - 5.2.5 Groundwater Resources
 - 5.2.6 Water Supply and Demand
 - 5.2.7 Infrastructure
 - 5.2.8 Fluid waste Management System
 - 5.2.9 Solid Waste Management System
 - 5.2.10 Noise Levels

5.2.11 Air Quality

5.3 Socio-Economic Context

5.3.1 Population

5.3.2 Major Economic Activities

5.3.3 Land Use

5.4 Biodiversity (including marine Biodiversity in case of seawater desalination)

5.4.1 Flora

5.4.2 Fauna

5.5 Archaeology

6 Assessment Approach, Methodology, and Tasks

6.1 Implemented Milestone Tasks

6.2 Detailed Implementation Methods

6.3 Conducting the Scoping Session

6.3.1 Scoping Findings

6.3.2 Valued Environmental Components

7 Potential Environmental Impacts

[including time, reason, and likelihood of impact occurrence including operational risks, accidents, and failures of desalination facilities]

7.1 Introduction

7.2 Impacts on all Components of the Proposed desalination Facility resulting from Geohazards

[including risks of tectonic movements, earthquakes, landslides, rockfalls, rock collapse structures, land subsidence, soil liquefaction (instable soil), flooding, etc.].

7.2.1 Impacts during Construction [including site clearance and preparation impacts]

7.2.2 Impacts during Operation

7.3 Impacts of the resulting solid wastes

[including predictive quantity and changes of solid wastes characteristics with time and solid wastes management]

7.3.1 Impacts during Construction

7.3.2 Impacts during Operation

7.4 Impacts of resulted fluid wastes

[including predictive quantity and quality, changes of effluent characteristics with time and liquid effluent management]

7.4.1 Impacts during Construction

7.4.2 Impacts during Operation

7.5 Impacts on Water Resources

[including impacts of all components of the proposed “WDS” facilities on groundwater and surface water resources, impacts resulting from the modification of surface drainage, etc.]

7.5.1 Impacts during Construction

7.5.2 Impacts during Operation

7.6 Impacts on Socio-Economic Context

[including residential areas, commercial areas, industrial areas, recreational areas, and public institutions]

7.6.1 Impacts during Construction

7.6.2 Impacts during Operation

7.7 Impacts on Public & Occupational Health and Safety

7.7.1 Impacts during Construction

7.7.2 Impacts during Operation

7.8 Impacts on Biodiversity

[In case of Seawater desalination, a separated section will be prepared and presented for the Marine Biodiversity]

7.8.1 Impacts during Construction

7.8.2 Impacts during Operation

7.9 Impacts on Archaeological, Touristic, and Cultural Sites

7.9.1 impacts during Construction Phase

7.9.2 impacts during Operation Phase

8 Environment & Social Management Plan

8.1 Introduction

8.2 Summary of Potential Project's Impacts

8.3 Proposed Mitigation Measures

[Covering Construction and Operation Phases]

8.3.1 Mitigating Impacts of Geohazards on Components of the Proposed Desalination Facility.

[including impacts of tectonic movements, earthquakes, landslides, rockfalls, sinkholes, land subsidence, soil liquefaction (instable soil), flooding, etc.]

8.3.2 Mitigating Impacts of Resulted Solid wastes including hazardous solid wastes

8.3.3 Mitigating Impacts of Resulted Fluid wastes including hazard fluid wastes.

8.3.4 Mitigating Impacts on Water Resources

[especially degradation of the water quality; groundwater and surface water]

8.3.5 Mitigating Dust Emissions

8.3.6 Mitigating Noise Pollution

8.3.7 Mitigating Impact on Biodiversity

8.3.8 Mitigating Public and Occupational Health Hazards

8.3.9 Mitigating Impact on Archaeological, Touristic, and Cultural Sites

8.4 Proposed Monitoring Plan

[This part of the "ESIA" need to highlight the major activities that needs to be monitored and which entity is responsible for conducting such monitoring; the elements that need to be monitored and the monitoring frequency]

8.4.1 Construction Phase

- Monitored Elements:

- Noise levels
- Dust levels
- The preparation and implementation of the occupational health and safety plan and procedures

8.4.2 Operation Phase

- Monitored Elements
 - Noise levels
 - The quality of the discharged brine.
 - The quality of the nearby surface water sources. [in case of brackish water desalination projects]
 - The quality of the nearby groundwater sources.
 - The seawater quality around the brine water discharge [in case of seawater desalination]
- The preparation and implementation of the occupational health and safety plan and procedures.

8.5 Documentation & Environmental Communication

8.6 Environmental & Safety Audit

9 Public Involvement and Participation

10 References

11. Annexes

- Annex 11-1: Topographic Map of the Study Area
- Annex 11-2: layout of the nearby water supply facilities
- Annex 11-3: Geological Map of the Study Area
- Annex 11-4: Hydrogeological Map of the Study Area, showing the distribution of the groundwater wells, springs, and major surface water bodies
- Annex 11-5: Map showing all Components of the Proposed Desalination Plant or Facility (overview and detailed views)