Vulnerability Analysis of Key Locations near the Southern Arava Region of the Trans-Israel Oil Pipeline

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Report Submitted to:
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Abstract

The Trans-Israel pipeline spans from the Red Sea to the Mediterranean, and is used to transport crude oil. Since its creation in 1968, there have been several significant spills in the Southern Arava Region of the pipelines. This project used GIS mapping as a tool to help identify vulnerability in social ecological systems to crude oil spills. The team gathered data from sources including GIS databases and people with different backgrounds. This data was layered onto GIS maps to visually highlight potential areas that could be vulnerable to a future spill. We also created and outlined scenarios to show how different conditions of an oil spill could create varying impacts. These scenarios and maps were given to the Eilot Regional Council to help them create possible action plans.

Authorship

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Results and Discussion	Jakob Sperry & Michela Benazzi
Recommendations	Noah Kantor & Michela Benazzi
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We would also like to thank Professor Isa Bar-On and Professor Seth Tuler for advising us. Their adaptability to our work conditions, challenged by the current international health crisis, was critical for the successful completion of our project. Their prompt feedback steered us in the right direction and prevented us from taking anything for granted. We are also grateful for their support, which extended to a personal level; thank you for making this IQP a caring experience.

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Lastly, a sincere thank you to other external collaborators. Dr. Nitzan Segev and Dr. Armoza-Zvuloni from the Dead Sea and Arava Science Center gave us detailed background information that helped us understand oil spill pathways, which we employed during mapping. Nadav Solowey from Kibbutz Ketura broadened our understanding of possible spill causes and shared precious information about legal precedents of the community with the EAPC. Ilan Yarmolovski's contribution of GIS data was critical for the success of the project. Ofri Haziz from the Eilot Regional Council was another precious contact who introduced us to current pipeline monitoring protocols employed by the EAPC.

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1. Introduction

Crude oil currently accounts for 35.3% of the world's energy (KWES, 2020). Pipelines, tanker ships, trains, and trucks are used to ensure distribution of crude oil and other liquid fuels. While these transportation methods come with risks, they are all needed to transport oil across oceans and continents to get oil and fuel from oil drills to refineries and then to its final destination. Transportation of oil through underground pipelines is considered one of the safest methods due to being buried and static (Furchtgott-Roth & Green, 2013). However, there are still risks to the nearby ecology and communities (Bonvicini et al., 2015). In the event of a release, oil can decimate local ecology, cause human health impacts, interrupt infrastructure and ruin recreational areas (Haddad, 2018; Nothers et al., 2017). Oil spills are particularly concerning because of the tendency for petroleum to persist in ecosystems for prolonged periods of time, and the possibility of short and long term impacts to the surrounding area (Ignat et al., 2021). Recent data from an Israeli spill that occurred in 1975 shows that the contaminated soil is still not conducive of seed germination or promoting healthy plant growth and it is not known when the soil will recover (Nothers et al., 2017).

There are two pipelines in Israel which transport crude oil and kerosene that run from the Red Sea coast to the Mediterranean coast of the country. These pipelines, locally known as KATZA (from the Hebrew acronym of Eilat-Ashkelon Pipeline), traverse a fragile desert ecosystem within the Negev desert, directly adjacent to small communities called kibbutzim, and are very close and uphill from the Jordanian border. Additionally, the company that controls KATZA, the Europe Asia Pipeline Company (EAPC), does not publish operational data, maintenance records, or financial records which makes it hard to create comprehensive response plans and policies.

The goal of this project was to analyze the Southern Arava region of KATZA to identify highly vulnerable ecology, communities or infrastructure to crude oil spills. We studied past oil spills in the area and investigated the effects of oil on ecosystems and human populations. We interviewed experts about the possible effects of future spills in the area and how the ecosystem and populations would respond to certain spill events. With this information, we built a Geographic Information System (GIS) map of layers to show where these impacts could occur. These GIS layers helped us create a map that displays highly vulnerable areas and infrastructure near the pipeline and what sorts of effects a spill from that section could cause. This map includes information such as who/what would be affected by a spill and an area which could be contaminated. The potential contamination map was coupled with scenario flow charts and was

presented to Itai Shanni, ecologist at the Eilot Regional Council, so that he can help build a plan on how to improve preventive planning in the region.

2. Background

The Trans-Israel pipeline is an important pipeline in the Middle East that has operated while publishing limited information since it was built. It is an old pipeline that has spilled many times in its lifespan. These spills have caused multiple ecological disasters and affected humans in many ways. Oil spills in deserts have many impacts that can last for a long time. With a fragile desert ecosystem in southern Israel, small impacts make a big difference to the ecological balance. Studies show that the ecosystem has yet to recover from old spills and the data does not yet show when it will. Humans are impacted in many ways including health risks, infrastructure disruption and economic impacts.

2.1 Overview of the Trans-Israel Oil Pipeline and Past Spills

The Europe Asia Pipeline Company (EAPC) owns many pipelines in Israel including two major lines that go from Eilat on the Red Sea to Ashkelon on the Mediterranean sea *(shown in Figure 1)*. One line has a 42 inch diameter and is used to move crude oil and the other line has a smaller diameter of 16 inches and transports kerosene. Before these pipelines were built in 1968, oil had to be shipped around Africa or through the Suez canal (EAPC, 2013). Both of these alternatives are more time consuming and expensive than using a pipeline through Israel (Gorvett, 2021). In addition to transporting oil to European and Asian markets, the EAPC also provides Israel with oil and fuel through ports and long term storage.

These two main pipelines are buried underground and the exact location of the pipes is not publicized by the EAPC. The EAPC also does not publicize information about management and maintenance procedures, preventive planning, technical risk assessment, or past spills. *Figure 1* can be found on the EAPC website and shows how the EAPC displays the location of the pipelines, pumping stations, refineries and ports. In person on-site visits give evidence that this map is inaccurate and simply a graphical representation of their infrastructure.

Figure 1. Graphical representation of the locations of pipelines and associated infrastructure (EAPC, 2013).

Although pipelines are a relatively safe method to transport oil and fuel, they do not come without risk (Furchtgott-Roth & Green, 2013). KATZA, in particular, has demonstrated an extensive spill history over its 54 years, summarized in *Table 1* and *Figure 2*, including two major crude oil spills in 1975 and 2014 and two large kerosene spills from 2011.

Year	Location	Type of fuel	Approximate quantity of oil spilled
1975	Near Be'er Ora	Crude Oil	9,000 m^3 (Haddad, 2018)
2011	Nahal Tzin	Kerosene	720 m^3 (Joffre, 2022)
2014	Near Be'er Ora	Crude Oil	5,000 m^3 (Staff, 2018)
2021	Near Ashkelon	Kerosene	100 m^3 (Joffre, 2022)
2022	Near Ashkelon (from a tank)	Crude Oil	700 m^3 (Joffre, 2022)

Table 1. Documented spills from KATZA.

Figure 2. Map of previous pipeline spills and approximate location of the pipeline.

2.2 Environmental Impacts of Oil Spills in Desert Climates

Oil spills in hyper-arid desert areas present a danger to the ecosystem both in the short and long term. One of these hyper-arid regions, the Negev Desert, is crossed by the Southern portion of KATZA (Segev et al., 2015) and is home to a wide variety of wildlife including birds, reptiles, and hooved animals such as gazelles (Exponent, n.d.). The plant and animal life live in a fragile equilibrium within this ecosystem. When it does rain in the Negev, the water is spread by a system of dry riverbeds called wadi (Munzbergova & Ward, 2002) and then permeates through the soil which allows plants to absorb it (Haddad, 2018). The majority of vegetation is located within the path of water flow during rains.

When an oil spill occurs, the oil follows the same path of flow as water which can be seen in *Figure 3* from the 2014 spill. Oil flows through the wadi and penetrates into the soil, which decreases water permeability, drastically limiting the amount of water received by the

plants (Haddad, 2018). That includes keystone species like the acacia tree, which is native to the Negev Desert (Ferrante et al., 2020) and provides shade, food, shelter and stabilizes soil nutrient content to other plant and animal species in the ecosystem (Munzbergova & Ward, 2002). In areas of past oil spills, acacia trees show a decreased capacity to photosynthesize and a reduction of seed germination (Nothers et al., 2017). Multiple studies on the germination and growth of the plants in soil contaminated by the oil show that, while established trees with deep roots were able to overcome the presence of oil, germination drastically decreased and the plants that were able to germinate showed mutations and growth defects (Segev et al., 2015); (FiriAppah et al., 2014). Data recently collected from soil contaminated in 1975 by crude oil does not yet show how the ecosystem will recover or if the soil will ever be conducive of germination (Haddad, 2018). Although the effects on the ecosystem of decreased germination and mutated young trees may not be seen immediately, the unaffected acacia trees will eventually die and there will be few trees left.

Figure 3. Oil flowing through wadi from 2014 Israel oil spill (Exponent, n.d.).

Oil spill cleanup measures are another possible environmental stressor. After the 2014 spill, thirteen grown acacia trees died due to both direct oil damage and cleanup (Haddad, 2018). Generally, oil spill cleanup in the desert can involve extinguishing open flames and clearing the contaminated areas by pumping out pooled oil and manually removing contaminated soil (Kostreba, 1999). The mechanical removal of soil typically results in the removal of a large amount of vegetation because the wadi promotes vegetation by providing a source of water. The manual removal process also requires the creation of roadways and the introduction of heavy machinery which disrupts the fragile balance of the ecosystem and water flow. While research of efficient and sustainable strategies for environmental remediation of oil spills is still underway, the current methods of oil removal can sometimes result in further damage to the ecosystem after a spill, while leaving a substantial amount of oil behind (Kostreba, 1999).

The relationship between impacts of an oil spill is often complicated. A flow chart can be used to display such causal pathways of different impacts. For example, *Figure 4* shows how a stressor such as an oil spill can cascade to primary and then to higher order effects. An oil spill in the desert causes three primary outcomes, these outcomes then cascade into impacts. This diagram shows a small subset of impacts and focuses on surface oil. It shows how surface oil has primary effects such as requiring clean up measures or decreasing the germination of the soil. These then cascade into higher order effects. These higher order effects can be harder to trace back to being caused by an oil spill, but can be very impactful.

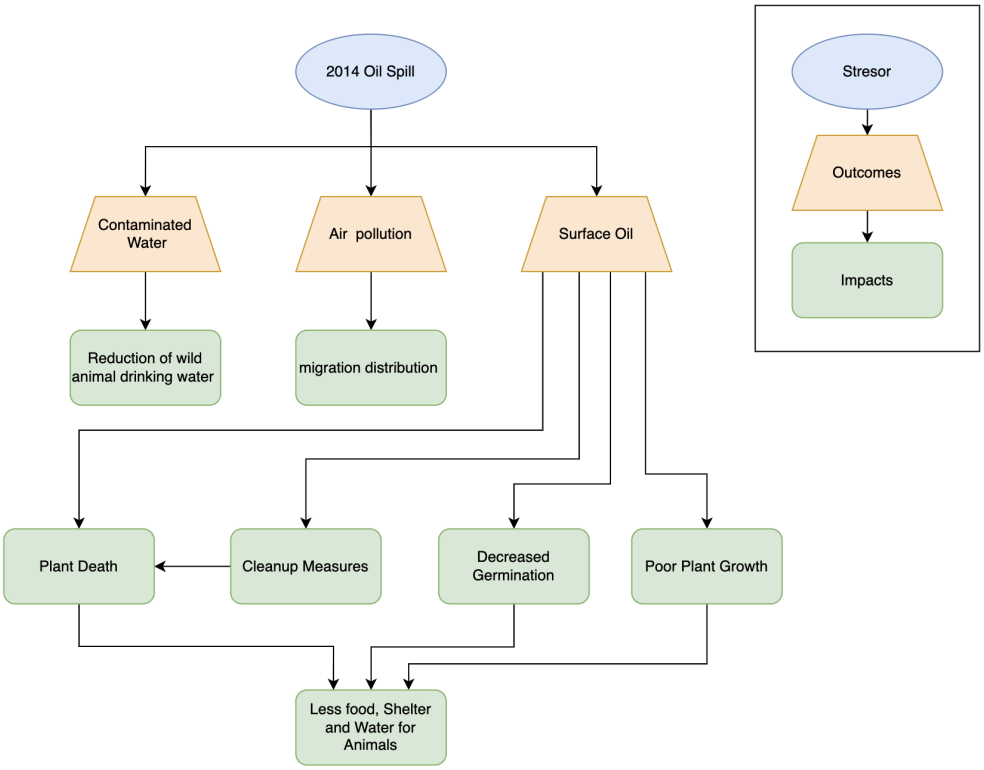

Figure 4. Pathways to ecological effects from an oil spill.

2.3 Human and Social Impacts of Oil Spills In Desert Climates

There are a variety of impacts from oil spills on people and communities. After the 2014 oil spill, there were 80 hospitalizations due to breathing difficulties and headaches from the fumes (Frenkel, 2014). Other similar physical health effects were seen in people who were directly or indirectly in contact with oil after the Deepwater Horizon disaster. After other spills, people reported eye irritation, nausea, joint pain and other health effects (D'Andrea & Reddy,

2014). These physical health effects tend to not be life threatening but they are shown to be able to persist even 5 years after exposure. Mental health is also a major concern with public health and it is shown that people who live in areas affected by oil spills have negative mental health effects. These effects include anxiety, depression, and mental illness and can persist even after the oil exposure is gone. After the Exxon Valdez 1989 oil spill, there were increased rates of drug and alcohol use, domestic violence and social conflicts (D'Andrea & Reddy, 2014).

People are also impacted by economic effects after oil spills including property damage, tourism loss, and closed recreation. There can be economic impacts related to cleanup measures as well, including compensation from the oil company and disaster relief efforts (Chang et al., 2014). Marine spills show loss in income for nearby fish industries as well as decreased beach tourism on affected coasts. After the 2014 spill in Israel, highway 90, the main road to Eilat, was closed due to the oil on the road. Road closures may have a wide range of economic effects including interrupting the transportation of goods, preventing people from getting to work, and disturbing essential emergency vehicles.

Figure 5 displays various human impacts of oil spills and how they can be caused by different sources of oil contamination, leading to physical and mental health problems. The oil spill causes three primary outcomes like above, but then cascades into impacts that cause human disturbances. Oil spill cleanup measures are in both diagrams as a step to different impacts. New jobs from cleanup measures is also listed as a human impact, this is a positive impact for the community and shows that impacts are not always detrimental.

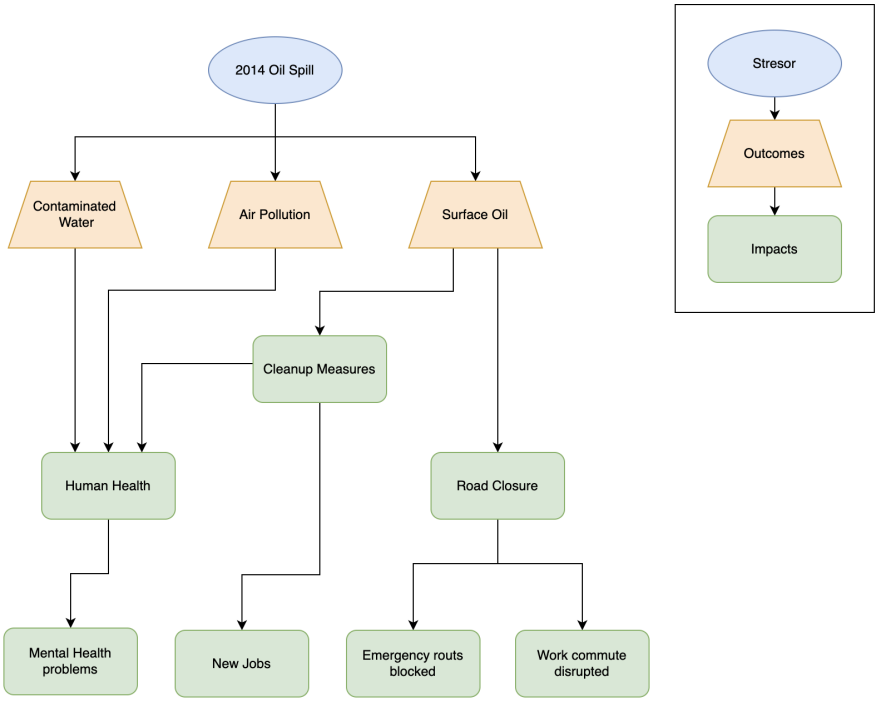

Figure 5. Pathways to human effects of an oil spill.

3. Methodology

The goal of this project was to analyze the Southern Arava Valley region of KATZA to identify highly vulnerable ecology, communities or infrastructure. To determine vulnerable locations, we first collected GIS spatial data to identify the vulnerability of social and ecological systems to a spill from the pipeline. These layers were then compiled into an ArcGIS map which was used to locate potentially highly vulnerable areas surrounding the pipeline. Second, we created potential contamination maps and scenario diagrams to explain hypothetical oil spill disasters. Together, the maps and diagrams help display information to assist us to find which areas are vulnerable, why they are vulnerable, and how to potentially reduce the impacts of future oil spills with suggestions for preventive planning informed by past experiences.

3.1 Obtain Spatial Data Through Semi-Structured Interviews

The first objective was to identify factors that affect vulnerability to oil spills and acquire GIS data to represent these vulnerabilities. We did this through semi-structured interviews with

experts and local people. All subjects were residents of Israel, who lived reasonably close to the pipeline at the time of the interviews. The interviewees consisted of: ecologist Dr. Nitzan Segev, hydrologist Dr. Rachel Armoza-Zvuloni, Ketura resident Nadav Solowey and Ofri Haziz from the ministry of environmental protection.

Dr. Nitzan Segev was interviewed because of her work as a desert ecologist studying the aftermath of the 2014 and 1975 oil spills. Dr. Segev discussed how the soil contamination has affected the growth and germination of acacia trees. We also talked about the human health effects from the 2014 spill and how aerosolized crude oil fumes will flow with the South winds and cause strong smells and headaches. We then interviewed Dr. Rachel Armoza-Zvuloni to learn more about aquifer contamination risks with any large-scale oil spill as well as the potential paths which oil could take. She told us about how crude oil is not likely to penetrate the aquifers, but kerosene could. Additionally, Dr. Armoza-Zvuloni talked about how acacia trees and other vegetation grow in the path of water, which is the path oil follows in a spill. Both Dr. Segev and Dr. Armoza-Zvuloni, are researchers currently working for the Dead Sea and Arava Science Center. They were able to give several recommendations on spatial considerations to qualitatively assess the vulnerability of these areas to a spill. To gain a more well rounded perspective of KATZA, we interviewed local Ketura Kibbutz resident Nadav Solowey because of his involvement with the class action lawsuit following the 2014 oil spill. Nadav informed us of the risks associated with earthquakes and fault lines. He explained how the pipeline crosses multiple fault lines and in the event of a major earthquake the pipe would almost certainly burst. The pipeline can also experience mechanical failure after long-term subtle shifts along fault lines. Additionally, we had the chance to interview Ofri Haziz. He is the Infrastructure Superintendent for the Ministry of Environmental Protection, who oversees the legislation and regulations set for the EAPC's operations. He was very insightful when it came to sharing the important factors of environmental vulnerabilities around the pipeline that are looked at by the ministry. Mr. Haziz said the most relevant factors for environmental vulnerabilities are: wadis, creeks and nature reserves. He also noted that mapping human populations would be important to look at as an overall vulnerability of the pipeline for our project.

We integrated interview findings with background research to understand what factors can affect vulnerability. The factors we concluded to affect vulnerability are contour lines, slope data, location of farms, locations of communities, fault lines, wadi and surface water locations.

We obtained spatial data for use with ArcGIS by researching online GIS databases and contacting Ilan Yarmolovski, a GIS expert at the Eilot Regional Council, who was able to provide spatial data including the location of both pipelines. *Table 2* shows all the GIS layers that

we have found to represent factors that affect vulnerability and how we found the layer. The following *Table 2* shows information we used for mapping or simply for background knowledge.

GIS Layer	**Source**	**Relevance**
42” Pipeline	Eilot Regional Council	This pipeline transports crude oil, the main focus of the project.
16” Pipeline	Eilot Regional Council	This is the kerosene pipeline, relevant for future analysis.
Contour Lines	Eilot Regional Council	The contour lines identify the path of spill flow from the pipeline.
Existing Farm Land	Eilot Regional Council	Farming provides income to the kibbutz.
Surface Water	Eilot Regional Council	Contaminated surface water could affect humans, animals and plants.
Roads	Eilot Regional Council	There are few major roads in Israel (e.g. Route 90). A road closure could obstruct transportation of resources and communication.
Active Fault Lines	Feature Layer by: “GISPublisher”	Fault lines movement could rupture pipelines and cause spills near water sheds.
Kibbutzim and schools	Feature Layer by: “dsk_gisucla	Kibbutzim show residential areas to identify human health impacts. Floods would affect the education of the students due to the presence of only one regional school.
Terrain: Slope Map	ArcGIS	This map shows us how steep the terrain is in order to predict oil direction and speed.
World Topographic Map	ArcGIS	Used to show relation of borders and roads to pipeline
World Hillshade	ArcGIS	Used for further understanding of terrain for oil flow patterns

Table 2. GIS layers and sources.

Adding on the content displayed in *Table 2*, one of the major roads that connects the Southern kibbutzim and also Northern and Southern Israel is Route 90, which has been previously flooded with 2014 spill oil. Route 90 also connects the port city of Eilat to the rest of

the country. Eilat is an important connection to the rest of the country because it is one of only three commercial ports in Israel.

3.2 Identifying and Assessing Vulnerable Areas

The process started by locating critical infrastructure and locations such as kibbutzim, schools, farms and protected land that could appear vulnerable based on their proximity and relative height to the pipeline. The chosen locations were then analyzed and possible highly impactful contamination zones were identified by assessing the slope and terrain data in the area. An analysis was performed to determine sections of pipeline that would result in a devastating spill to humans and ecology. While any spill would affect both human and ecology, certain areas could have more notable effects on one of these. Sections that we determined to cause primarily human or ecological effects and color coded accordingly. The contamination zones were identified by analyzing the terrain and wadi of an area to find flow patterns. The primary impact group was identified by analyzing the contamination zone. If the contamination zone came very close to or north of human populations, schools, farms, the area was identified to be a human impact zone and colored in purple. If the contamination zone entered wadi that would spread the oil to a large vegetation area the zone was identified as an ecological zone and colored as yellow. For each location, a scenario flowchart was made to explain the different impacts of an oil spill under different conditions. These flow charts also discuss various assumptions and explain the impacts if these assumptions proved false. For example, if a flood dike around a kibbutz fails or can not withstand crude oil, how would the oil flow path and in turn the impacts change. The scenarios also discuss impacts in the event of small or large spills. This is defined by greater or less than the volume of the 2014 oil spill of 5000 m^3 and a travel distance of about 3 km.

4. Results and Discussion

We selected to analyze five key areas in the Southern region of the pipeline. These areas include both human and ecological impacts. Specific large wadi and downhill/downwind from the pipeline kibbutzim were chosen including areas around Yotvata, Grofit/Ketura, Samar/Elifaz, the Ramon International Airport, and the salt pools. These areas can be seen in *Figure 6* and span a large area in the Southern Arava Valley. Another important mapping consideration is that the oil pathways follow the wadi and would flow through ecologically important vegetation.

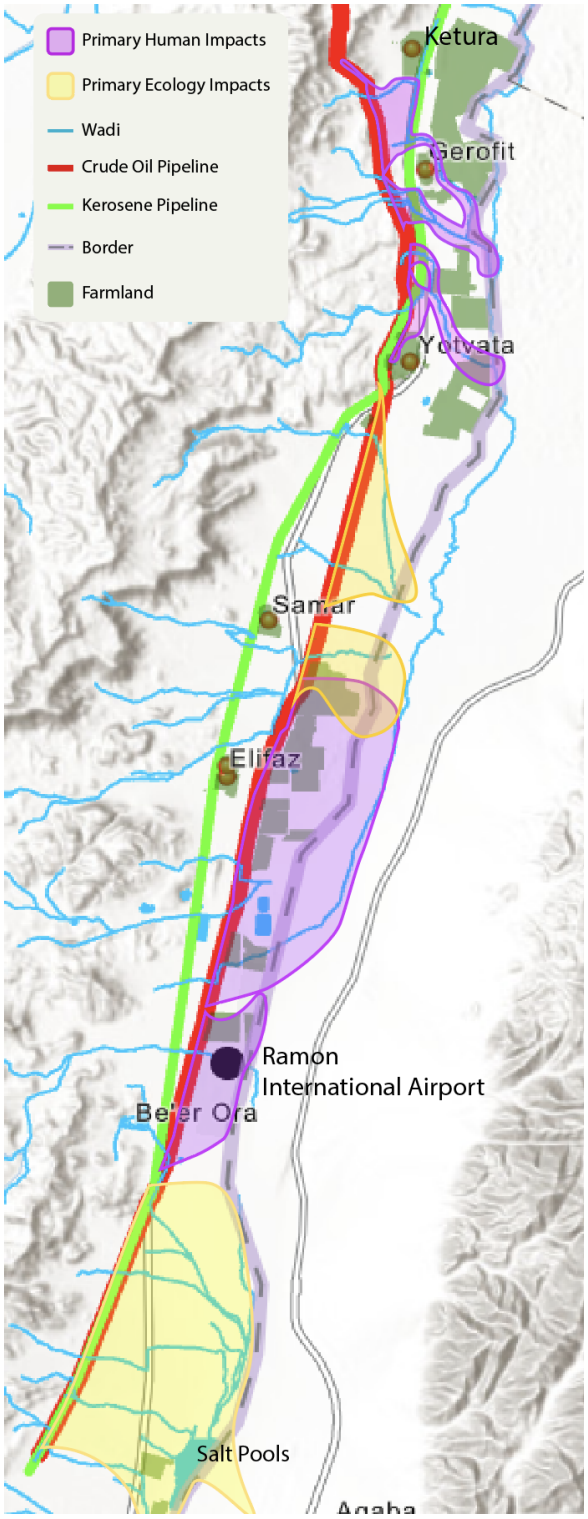

Figure 6. Crude oil spill potential contamination map of the Southern Arava desert.

4.1 Kibbutz Ketura and Grofit

Ketura is a kibbutz that primarily relies on date palm and algae farming. Kibbutz Grofit also has business in date palm farming but they also grow vegetables and have a small solar array. These kibbutzim are very close to each other and spills in the area could affect both of them depending on the location along the pipeline. Ketura and Grofit are the two Northernmost kibbutzim that were selected in the Southern Arava region. *Figure 7* shows the analysis of the area surrounding kibbutz Ketura and kibbutz Grofit. A spill along this section could have primarily human impacts on agriculture, blocked roadways and bike paths. Grofit is elevated about 35 meters above the road so it is not very vulnerable to direct exposure to oil, but the fumes could be problematic to the human population. We expect oil to pool on and under the road northwest of Grofit, causing strong fumes. Ketura is less susceptible to direct impacts due to being out of the predicted path of flow and being North of possible contamination zones. The Ketura/Grofit farming land is also home to vegetation and multiple wadi. These ecological systems could be heavily impacted, but we find that contamination could primarily cause human impacts because of the vicinity to the two residential kibbutzim, farming land and Route 90.

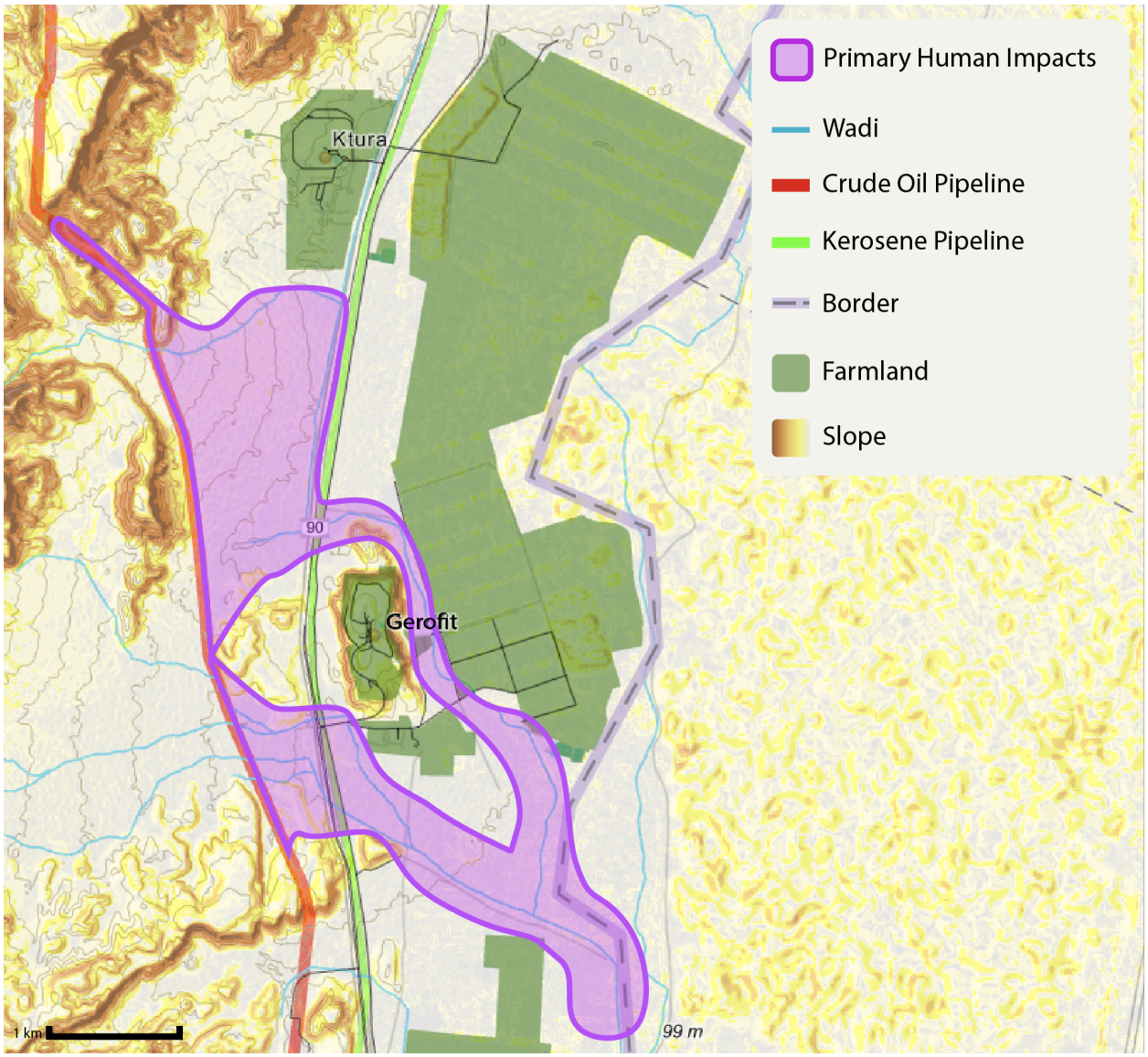

Figure 7. Map showing areas of potential contamination near Ketura and Grofit.

Figure 8 shows a scenario chart about possible oil spills in the area. The main flow path shows what could happen if all assumptions are true including a dike functioning as expected. The oil spill described by that path is a large oil spill that could flow approximately 3 kilometers, crossing the road and contaminating the land between Grofit and the date palms. If a dike were to fail in this case, the oil could flow into the agricultural fields. This could cause direct damage to the trees and soil and require intervention for oil removal. Secondly, even if the dikes were to operate as expected, the kibbutz could still experience health risks due to the vapors. That could

be more of a concern in summer because oil vapors will be expected in increasing volumes in a direct relationship with temperature (Petrucci et al., 2007).

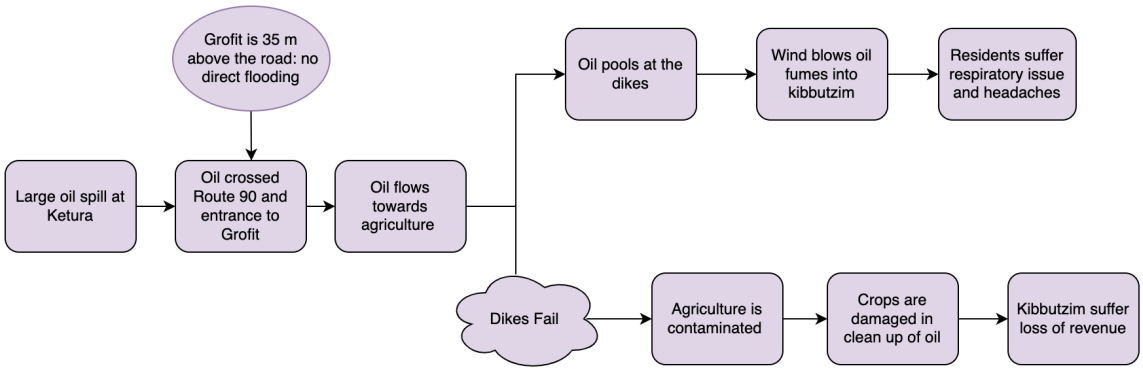

Figure 8. Scenario flowchart of area around Kibbutz Ketura and Grofit.

1	Factors of the Area	2 Kibbutzim near spill (Grofit and Ketura) Both Kibbutzim have agricultural land that borders Jordan Population of 450+ at Ketura and 250+ at Grofit Grofit's population is generally protected from direct exposure due to it being substantially elevated from any spill path
2	Approximate Distance to Pipelines	Crude oil pipeline is about 1 km from Grofit and 2.3 km from Ketura uphill from both kibbutzim
3	Estimated Number of Pathways for Spill/ Sections with Hazardous Spill Potential	2 estimated spill sections of the line which would likely cover long distances through the wadi
4	Nearby Terrain	Reasonably steep near the oil line but gradually decreasing slope along spill paths towards East
5	Distance from Jordanian Border to Oil Line	2.4 km

Table 3. Data of area around Ketura and Grofit.

4.2 Kibbutz Yotvata

Yotvata is a large kibbutz that has business in dairy farming. Over 700 people live in Yotvata, making it the largest kibbutz in this analysis. This kibbutz also has a strong presence in the tourism of the area. In fact, it provides tour buses, a large gift shop and ice cream store. *Figure 9* shows an analysis of Kibbutz Yotvata and indicates a human impact zone and an ecological impact zone. The purple contamination area, which denotes primarily human impacts, runs directly North of the kibbutz, through multiple farm areas and flows very close to two schools. Although kibbutzim do have dikes built to protect from floods which should help prevent oil floods, these will not prevent the movement of fumes. The stars indicate schools in the area that could be heavily affected by these oil spills. The school in the North services the entire region as a high school and has a low parking lot directly next to the pipeline that is at risk of flooding. The yellow section on the map and the smaller satellite figure show a large wadi that is home to native plants and animals. This wadi also connects to a larger wadi system that flows into Jordan: if an oil spill was followed by rains, which happen periodically in winter, the wadi would be flooded with oil or remnants of it in case cleanup operations are still underway. *Figure 9* shows a causal diagram with various scenarios of oil spills and how the effects could change under different scenarios.

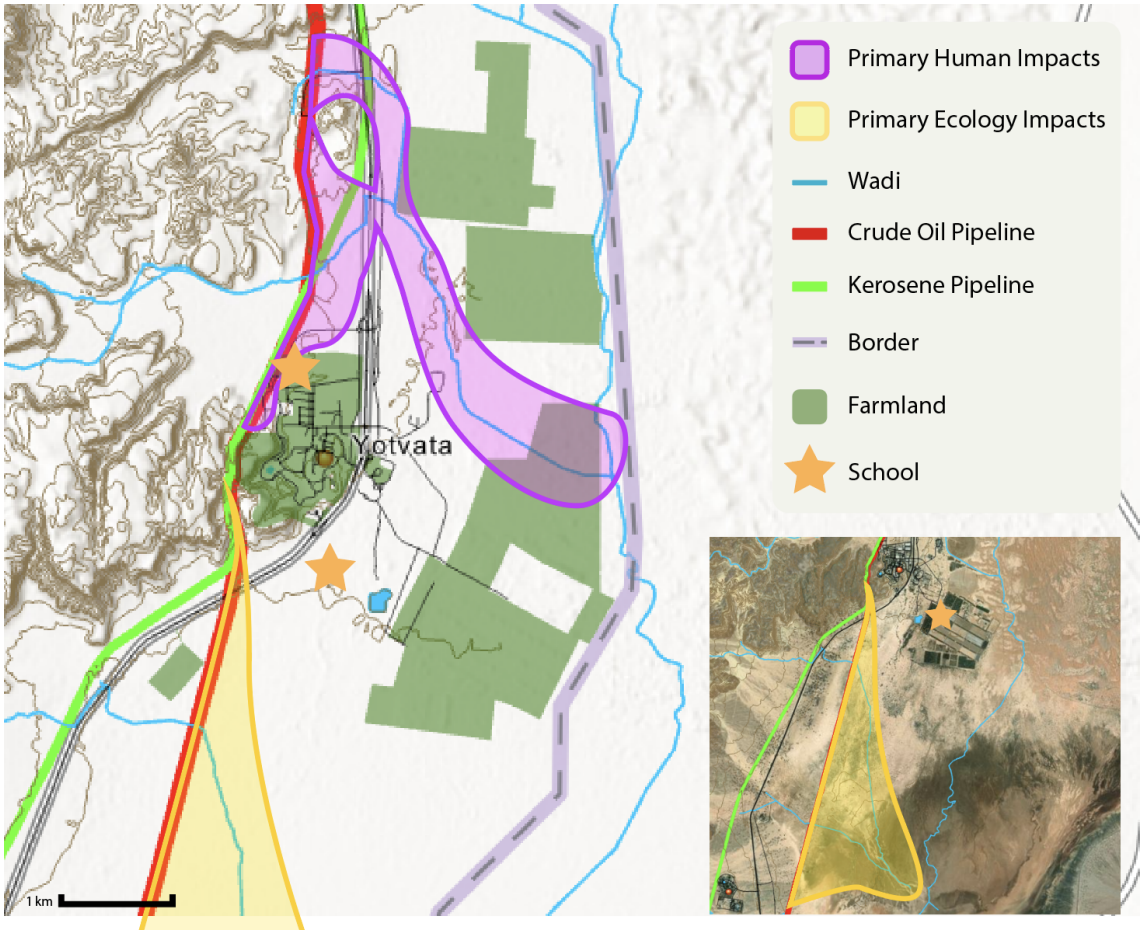

Figure 9. Map showing areas of potential contamination near Kibbutz Yotvata.

Figure 10 shows a scenario flow chart of possible outcomes and impacts in the event of an oil spill near the regional school. Here a small spill is shown which is defined as a spill of less than 5000 m^3, however, a spill of even less than 1000 m^3 could cause the same effects. This flowchart shows one case in which an oil spill floods the school parking lot and there is not a plan on how to relocate the students and resume school while cleanup measures take place. In this scenario, the school is forced to shut down to prevent exposing students to oil fumes. The second scenario shows if there is a plan to relocate the school. In this case, the students could be relocated to a different location and resume schooling while cleanup measures are performed at the orignal school.

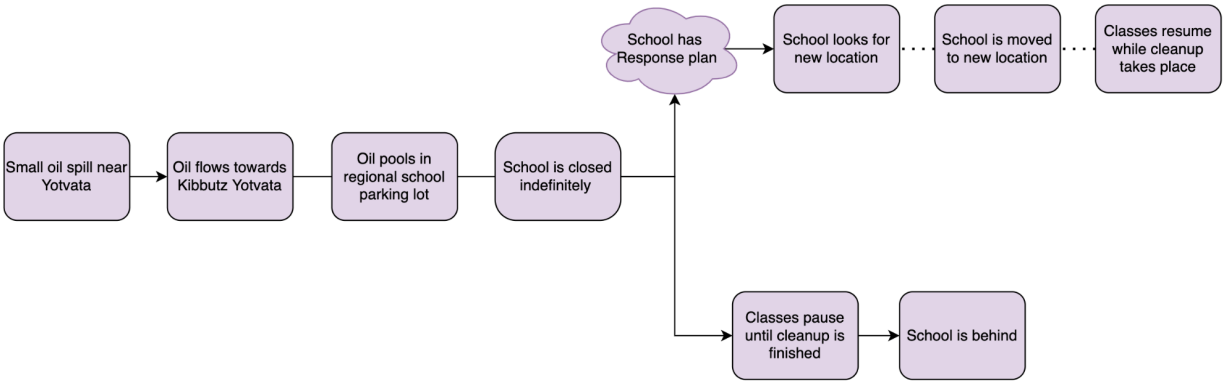

Figure 10. Scenario flow chart of area around Kibbutz Yotvata.

1	Factors of vulnerability	2 Schools directly next to pipeline 700+ residents with lots of tourists South winds could impact schools and the kibbutz if a spill were to pool in the flat due North
2	Approximate Distance to Pipelines	At the nearest point, the pipeline is just meters uphill from the kibbutz The pipeline sits about 0.5 km away from other infrastructures in the kibbutz area
3	Estimated Number of Pathways for Spill/ Areas with Hazardous Spill Potential	3 estimated main paths which an oil spill could potentially take
4	Nearby Terrain	Pipeline is roughly 250 m from an active fault that could cause major damage to the pipeline in the event of an earthquake Steep grade on mountains directly West of the kibbutz Wadi traveling from the mountains to Jordanian border (ca. 4 km)
5	Distance to Jordanian Border from Oil Line	2.9 km

Table 4. Data of area around Yotvata.

4.3 Kibbutz Samar and Elifaz

These are two small kibbutzim South of Yotvata. Kibbutz Samar mainly has business in cow and date farming as well as solar energy. Kibbutz Elifaz is very close to ancient Timna and has business in tourism and hospitality. As seen in *Figure 11* a spill along the section of the pipeline that runs near Kibbutz Samar and Kibbutz Elifaz could cause direct damage to agriculture, sensitive wadi, tourism, and could potentially increase international tensions. The pipeline is downhill from the kibbutzim but uphill from farmland. A spill in this area would put a serious test on the flood protection of agriculture. In the event of dike failure, the agriculture fields could flood and the kibbutz could experience major economic losses. Mechanical removal of spilled oil presents a disruption to living organisms. This applies to the agricultural areas by the kibbutzim, as the entire field might need to be plowed or have the soil removed and cleaned, compromising soil structural stability and availability of nutrients.

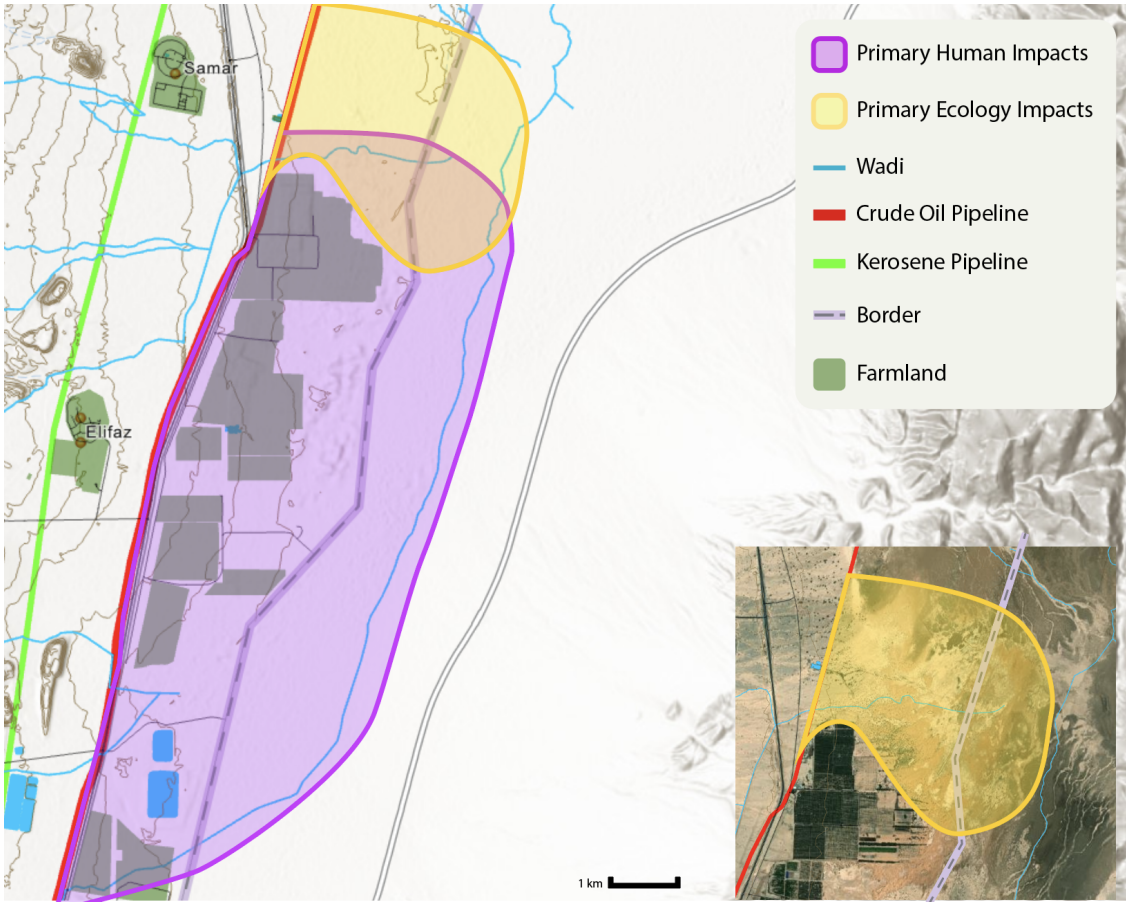

Figure 11. Map showing areas of potential contamination near Kibbutz Samar and Elifaz.

Figure 12 shows a scenario diagram of what could happen if an agricultural dike failed in the event of an oil spill. If the dike does not fail here, the oil could be diverted around the fields. This scenario shows a large spill of greater than 5000 m^3. From the 2014 spill we can see that this volume is able to travel up to 3 km. In locations, the Jordanian border is less than 1 km from the pipeline and if oil reaches Jordan, the spill could require more than just the EAPC to clean up. Additionally, the kibbutzim are very close to this location and they could also suffer health effects from the proximity of oil. In the event that an agricultural dike were to fail, oil could flood the field and contaminate the crops. This could result in massive revenue losses and major economic impacts for the kibbutz.

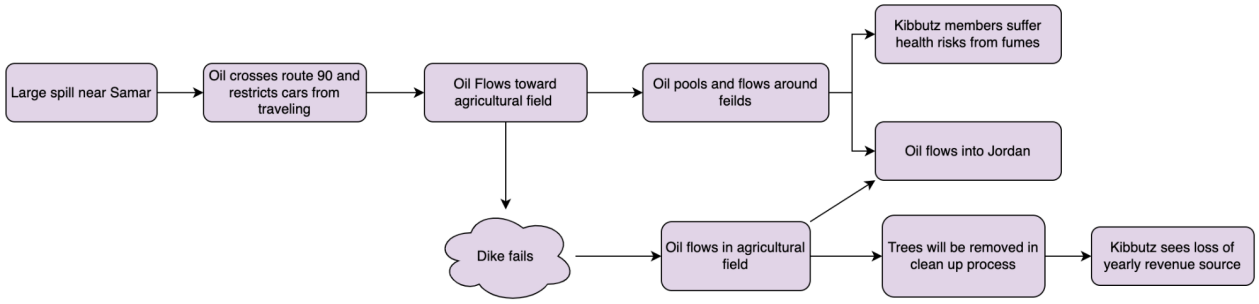

Figure 12. Scenario flowchart of area around Kibbutz Samar and Elifaz.

1	Factors of vulnerability	Oil line is directly due East from the Kibbutzim Population of 270+ at Samar and 150+ at Elifaz
2	Approximate Distance to Pipelines	The pipeline is just meters from the agricultural land of Elifaz Oil line is 1.3 km, downhill from kibbutz Elifaz, 1.2 km from Samar
3	Estimated Number of Pathways for Spill/ Sections with Hazardous Spill Potential	Any spill along the highlighted section of the pipeline presents hazardous scenarios for the agriculture of Elifaz Pooling would be likely to occur around the flat areas of Samar and Elifaz before oil hits key areas such as the wadi
4	Nearby Terrain	Very flat with several small wadi and few larger wadi Gradual and downward slope towards East
5	Distance from Jordanian Border to Oil Line	1.5 km

Table 5. Data of area around Samar and Elifaz.

4.4 Ramon International Airport and Evrona Reserve

The Ramon International airport sees about 1.8 million passengers per year and is located downhill from the pipeline. The airport does have fortification measures to prevent flooding, but if the roadways and surrounding areas were contaminated, the airport may still need to pause

activities. This sort of closure could have short term economic effects that reach much farther than the analyzed area; for example, the city of Eilat could have reduced tourism and supply chain disturbances. As shown in *Figure 13* The airport is also very close to the Jordan border and oil could reach the border quickly in the event of a large spill. This area is also close to the area of the 2014 and 1975 spill and both spills are within the yellow section. If another release were to occur into this area, much of the wadi could be contaminated with crude oil. This could have major ecological effects, including loss in germination or abnormal plant growth. Lastly, the flood protection infrastructures have proved to be a leading pathway of spilled oil in the past: the system, originally built to divert water flow towards the Evrona Reserve, has also diverted crude oil from the 2014 spill, causing it to pool in the Reserve. It is likely that future spills in the surroundings will also converge in the same location.

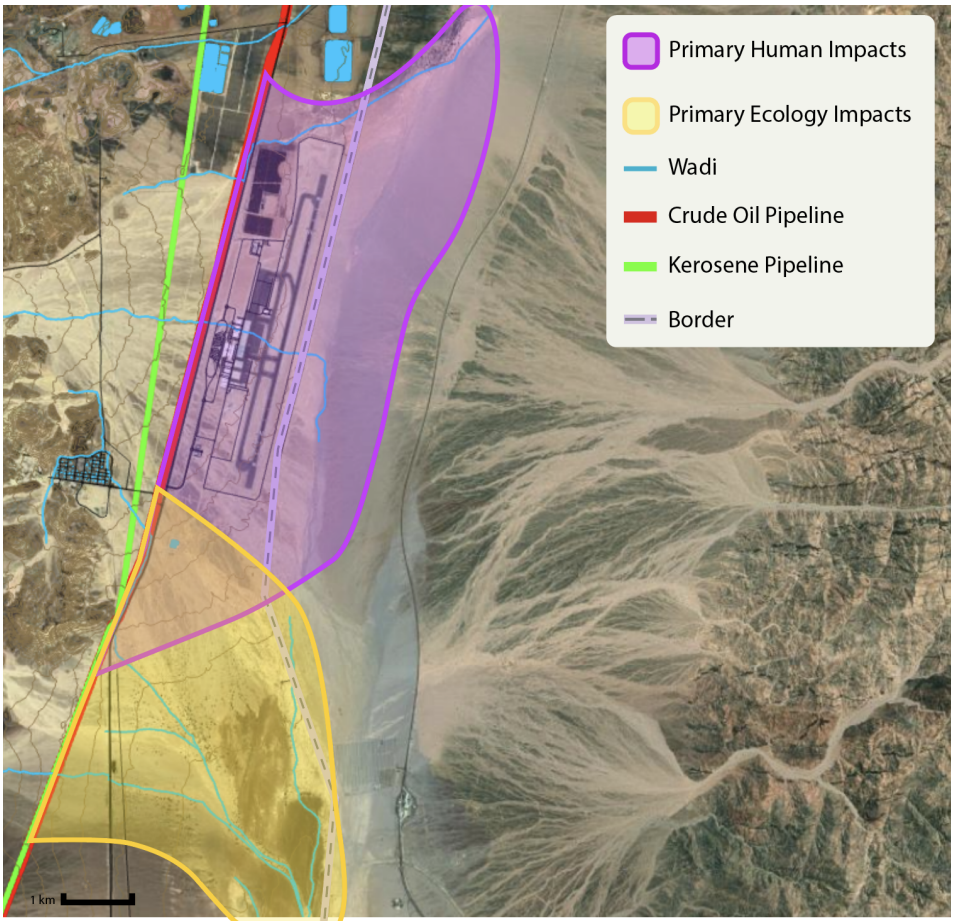

Figure 13. Map showing areas of potential contamination near the Ramon International Airport.

In *Figure 14*, it is shown how there are drastically different effects based on the path that the oil could take from a spill on this section. The main path shows the oil flowing past the

airport due to flood protection or raised roads and into the Evrona nature reserve where the 2014 and 1975 spill occured. A spill here could be devastating to the local ecology and affect more of the area in this nature reserve. Additionally, a spill of similar magnitude of the 2014 oil spill could reach the jordanian border and flow into Jordan if not managed properly.

If a spill were to pool in the airport roads and parking lot, the impacts would be more human related. This could cause airport closure and canceled flights. If flights were to be canceled, the area would experience less tourism and in turn economic losses.

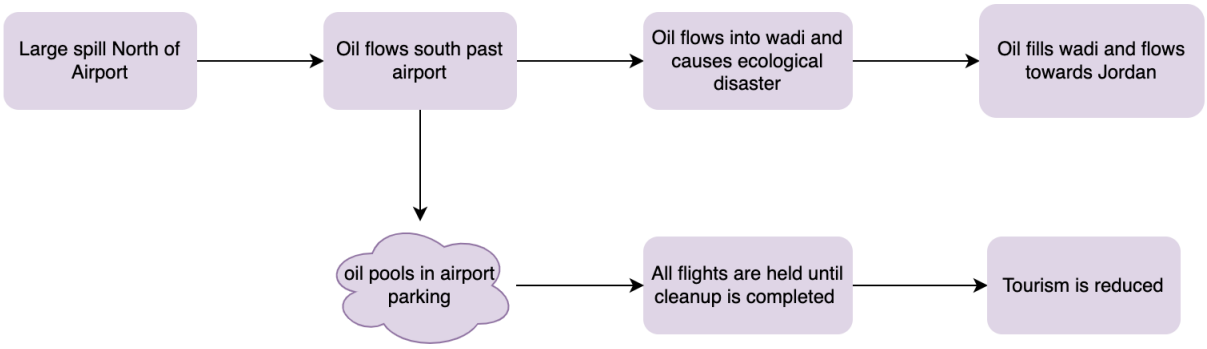

Figure 14. Scenario flowchart of area around Ramon International Airport.

1	Factors of vulnerability	1.8 million passengers travel through this airport every year (IAA n.d.) Route 90 follows the entire length of the airport runways Evrona Nature Reserve sits due South of the airport
2	Approximate Distance to Pipelines	The oil line sits just less than 600 m West of the runway
3	Estimated Number of Pathways for Spill/ Sections with Hazardous Spill Potential	Evrona has many interconnected wadi which travel Southeast through the reserve Oil or water will flow from airport flood protection to Evrona
4	Nearby Terrain	Gradual and downward slope towards East
5	Distance from Jordanian Border to Oil Line	1.6 km

Table 6. Data of area around Ramon International Airport.

4.5 Salt Pool Area

The salt pools in *Figure 15* are employed to harvest salt from the waste product of the Eilat Sea Water Desalination Plant. The pools have a very high salt content and are home to flamingos in the area. The salt pools are elevated above ground level and have very good flood

protection. This means that we can be reasonably certain that oil would not contaminate the salt pools directly and instead oil could flow around the pools. The salt pools are very close to the Jordanian border and if oil were to reach the pools, it could be diverted directly into jordan. It can also be seen in *Figure 14* that there are many wadi that lead directly to these pools. This means that any spill in the area could contaminate fragile wadi systems. Additionally, If that was the case, the introduction of crude oil and fumes could disrupt the flamingos' small habitat.

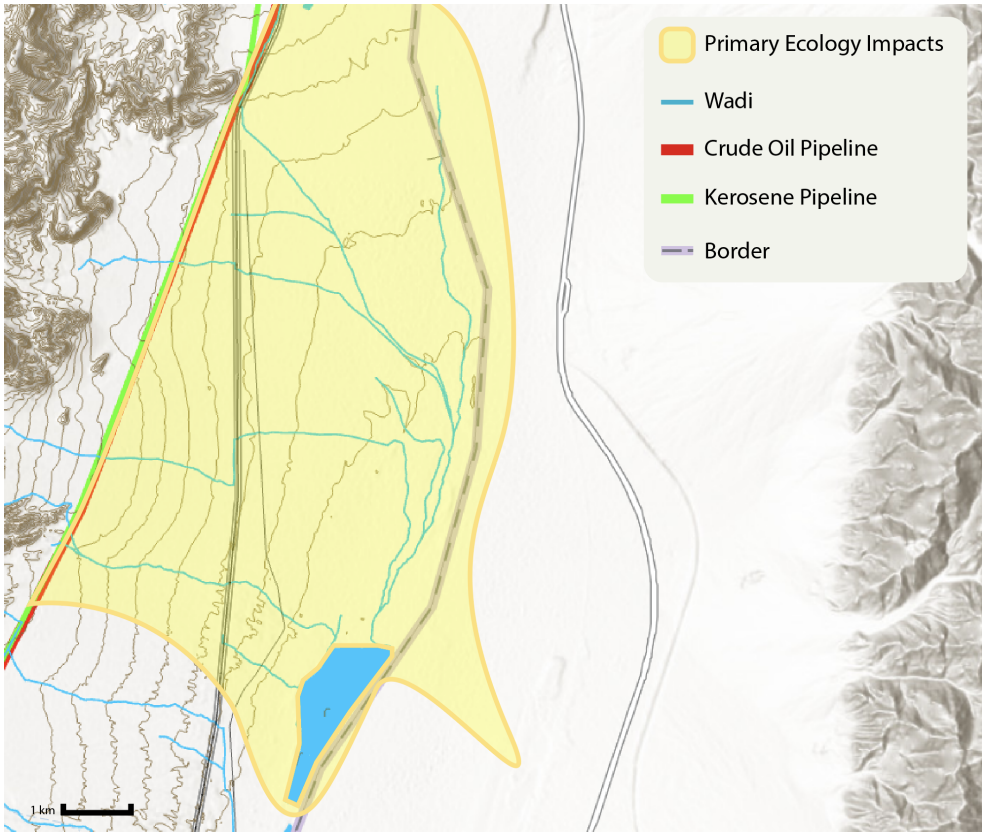

Figure 15. Map showing areas of potential contamination by the salt pools.

Figure 16 shows what could happen if the oil penetrates the salt pools in the event of a spill. In this event, the oil has already crossed the road and damaged the wadi. If the flood protection of the salt pools functions as expected, the flamingo population could still be forced to relocate due to the fumes of the nearby oil. This is problematic because the flamingos have a very limited habitat in the area and rely on these artificial salt pools. In the event that oil does penetrate the salt pools, there are both ecological and economic impacts. This could cause the flamingo habitat to be disrupted and possibly expose the birds to direct oil contact. Contaminated

salt pools could also cause economic losses for the salt company because they would no longer be able to use the salt produced.

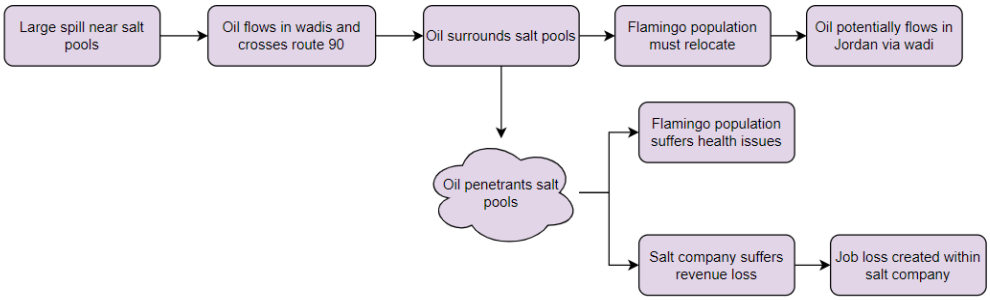

Figure 16. Scenario flow chart of area around the salt pools.

1	Factors of vulnerability	4.5 miles from Jordanian Border Flamingos inhabit the salt pool area Company uses salt pools for revenue
2	Approximate Distance to Pipelines	The Salt Pool is located located 3.7 km East of the pipeline
3	Estimated Number of Pathways for Spill/ Sections with Hazardous Spill Potential	Approximately 5 different pathways of spillage towards the salt mines through wadi One large portion of the line could potentially feed several of these wadi
4	Nearby Terrain	Gradual and downward slope towards East
5	Distance from Jordanian Border to Oil Line	4.5 km

Table 7. Data about the area around salt pools.

5. Recommendations

This analysis shows that the Trans-Israel pipeline presents hazards to the communities and ecology in the Southern Arava region. We prepared a short list of suggestions, mainly for the Eilot Regional Council, that could help prepare the region for a potentially disastrous spill from the pipelines.

5.1 Detailed Spill Analysis

We recommend that more spill analyses be completed for the impacts and vulnerable locations for both kerosene and crude oil.

Both the EAPC and the Eilot Regional Council should consider carrying out a detailed hazard, impact, and vulnerability assessment on the areas surrounding the pipelines. We believe our project provides a reason and method to carry out further investigation. A future analysis could include modeling of potential spills, showing the most probable spill paths as well as areas that could be flooded or contaminated on a smaller scale. Our analysis mainly considered crude oil spills, but the different chemical and fluid properties of kerosene should be considered further by the EAPC and the Regional Council.

5.2 Dike Fortification and Planned Fluid Redirection

We recommend that dikes be routinely monitored and fortified where needed.

Through our analysis of potential oil spills, we have confirmed the importance of functioning and adequate dikes to protect sensitive land from oil spills. We suggest that inspection and maintenance protocols be enacted to ensure the stability and functionality of dikes in relevant areas. This should be coupled with detailed oil spill analysis (as seen in *Section 5.1*) and dikes that are shown to be in the path of potential oil spills should be fortified. It might also be worthwhile to look into more modern dike designs and compare them with the design used in the kibbutz. The Council should consider fluid simulations to understand the upper limits of flow containment capacity of the dike. It is necessary that existing flood protection structures consider the regions that will be pooled with oil in case of a spill, and that measures be taken to either contain oil while allowing wadi water flow or selectively let water through the barriers; one possibility is oil-repelling netting.

5.3 Collaborative Cleanup and Disaster Relief Plan

We recommend that the Eilot Regional Council develop an agreement with the EAPC for a joint cleanup and disaster relief plan for future spills.

The Regional Council of Eilot should consider forming a concrete action plan to ensure that any considerable spill within their jurisdiction is taken care of by the EAPC or by joint efforts. Kibbutzim, the Ramon Airport, major roadways like Route 90, and large areas of nature reserves are all vulnerable in the event of a spill with the volume of the 1975 or 2014 releases. Many locations like kibbutzim already have flood protection around their property to protect their citizens as well as their farms from water flooding. What is still lacking is a comprehensive cleanup plan where the Regional Council oversees and collaborates with the EAPC for the entire duration of cleanup operations. This plan should include information such as who would be directly responsible to respond to the scene of the spill and what measures they could use to clean up rapidly. More research should be done on which specific measures need to be used to clean up different spills in various locations. The government being prepared is essential to mobilize quickly in the event of any large scale spill.

Several of the kibbutzim are located in areas where they could be negatively impacted in several ways were a large spill to happen again. Yotvata, in particular, is vulnerable to human health impacts due to its close proximity to the oil and kerosene lines. This kibbutz is also downhill relative to the pipelines, which means there is potential for a larger spill to directly affect those in the community. There are two schools on the premises which could be impacted if oil were to pool in the flat area surrounding them. This means there will be a need for evacuation or relocation of students to avoid toxic fumes from the crude oil. These students or residents who may leave their homes would need to seek refuge somewhere in the general vicinity. We believe The Council should prepare for the event that large groups are displaced from their homes, even if a massive spill is not the most probable scenario. In that sense, a collaboration between neighboring kibbutzim might be most useful in ensuring sufficient coverage of relocation measures. Moreover, it would provide more options for relocations and ensure that the entire network of resources available in the region be open for disaster relief planning.

6. Conclusion

This project aimed to identify ecological and socioeconomic systems that are vulnerable to a spill near the Trans-Israel pipeline as an informative guide for the Eilot Regional Council to consider during spill preventive planning. Mapping these key areas and locations allows the reader to visualize the potential contamination pathways from the nearby oil pipeline segments. This pipeline presents serious danger to local populations and ecology and has a long history of spills in the area, including two major crude oil spills that affected a large amount of land and soil. Being a 54 year old pipeline implies that the materials and design of the pipeline are outdated and relatively more prone to rupture. Thus, the next spill could happen anytime, leaving areas in the Southern Arava vulnerable to serious damage and in dire need of efficiently situated preventive planning measures. With the maps created in this project, as well as the system used to develop them, the Eilot Regional Council will have the ability to review vulnerable land and assess how to protect it. Furthermore, the maps and the considerations outlined throughout this report will inform the Eilot Regional Council on how to divert more resources to planning and protecting the local social and ecological systems from the hazards of the aging pipeline.

References

Bonvicini, S., Antonioni, G., Morra, P., & Cozzani, V. (2015). Quantitative assessment of environmental risk due to accidental spills from onshore pipelines. *Process Safety and Environmental Protection*, *93*, 31–49. https://doi.org/10.1016/j.psep.2014.04.007

Chang, S. E., Stone, J., Demes, K., & Piscitelli, M. (2014). Consequences of oil spills: A review and framework for informing planning. *Ecology and Society*, *19*(2). https://www.jstor.org/stable/26269587

D'Andrea, M. A., & Reddy, G. K. (2014). Crude Oil Spill Exposure and Human Health Risks. *Journal of Occupational and Environmental Medicine*, *56*(10), 1029–1041.

EAPC. (2013). *Eilat Ashkelon Pipeline Company Ltd. Booklet*. https://www.eapc.com/wp-content/uploads/2013/07/EAPC-booklet.pdf

Exponent. (n.d.). *2014 Israeli Oil Spill | Experience | Exponent*. Retrieved November 23, 2021, from https://www.exponent.com/experience/2014-israeli-oil-spill

Ferrante, M., Möller, D. M., Möller, G. M., Lubin, Y., & Segoli, M. (2020). Seed Predation on Oil-Polluted and Unpolluted Vachellia (Acacia) Trees in a Hyper-Arid Desert Ecosystem. *Insects*, *11*(10), 665. https://doi.org/10.3390/insects11100665

FiriAppah, C., Okujagu, D. C., & Bassey, S. E. (2014). Effects Of Crude Oil Spill In Germination And Growth Of Hibiscus Esculentus (Okra) Inbayelsa State Niger Delta Region Of Nigeria. *The International Journal of Engineering and Science (IJES)*, *3*(6), 30–40.

Frenkel, B. (2014, December 8). Southern Israel oil spill four times worse than initially reported. *Ynetnews*. https://www.ynetnews.com/articles/0,7340,L-4600972,00.html

Furchtgott-Roth, D. E., & Green, K. (2013). *Intermodal Safety in the Transport of Oil* (SSRN Scholarly Paper ID 2345409). Social Science Research Network. https://papers.ssrn.com/abstract=2345409

Gorvett, J. (2021, June 18). *The pipeline that brings Israel and UAE together*. Asia Times. https://asiatimes.com/2021/06/the-pipeline-that-brings-israel-and-uae-together/

Haddad, R. (2018). December 2014 Evrona Oil Spill: Report of the Professional Consultant to the Mediator. *Exponent*, 101.

Ignat, T., De Falco, N., Berger-Tal, R., Rachmilevitch, S., & Karnieli, A. (2021). A novel approach for long-term spectral monitoring of desert shrubs affected by an oil spill. *Environmental Pollution*, *289*, 117788. https://doi.org/10.1016/j.envpol.2021.117788

Joffre, T. (2022). *Ashkelon Municipality says company tried to hide oil leak—The Jerusalem*

Post. https://www.jpost.com/breaking-news/article-696570

Kostreba, L. (1999). Oil Spill Remediation Efforts in the Middle East. *Restoration and Reclamation Review*, *4*(3), 1–5.

KWES. (2020). *Key World Energy Statistics 2020 – Analysis—IEA*. https://www.iea.org/reports/key-world-energy-statistics-2020

Munzbergova, Z., & Ward, D. (2002). Acacia trees as keystone species in Negev desert ecosystems. *Journal of Vegetation Science*, *13*(2), 227–236. https://doi.org/10.1111/j.1654-1103.2002.tb02043.x

Nothers, M., Segev, N., Kreyling, J., Hjazin, A., & Groner, E. (2017). Desert Vegetation Forty Years after an Oil Spill. *Journal of Environmental Quality*, *46*(3), 568–575. https://doi.org/10.2134/jeq2016.03.0078

Petrucci, R. H., Harwood, W. S., Herring, G. F., & Madura, J. D. (2007). *General Chemistry: Principles & Modern Applications* (Ninth). Pearson/Prentice Hall.

Segev, N., Pipman, I., Shemtov, R., Reinheimer, H., & Shlomi, Y. (2015). Oil Spill Reclamation. *Arava Institute for Environmental Studies*. https://arava.org/arava-research-centers/center-for-arid-socio-ecology/oil-spill-reclamation/

Staff, T. (2018). *Damages from massive 2014 oil spill amount to NIS 281 million*. Times of Israel. https://www.timesofisrael.com/damages-from-massive-2014-oil-spill-amount-to-nis-281-million/