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7 July 2011

Mr. Jay Wright
AIRA Program Manager
National Fish and Wildlife Foundation
1133 15th Street, NW Suite 1100
Washington, D.C. 20005

Subject: Phase A – Aleutian Islands Risk Assessment Consequence Analysis Report and Task 5 Accident Scenario and Causality Study Report Deliverables

Dear Mr. Wright,

ERM-West, Inc. (ERM) and Det Norske Veritas (U.S.A.), Inc. (DNV) appreciate the opportunity to provide our consulting services for the Phase A – Aleutian Islands Risk Assessment (AIRA). This cover letter transmits the Consequence Analysis Report, which covers Task 3 - Characterizing Spills and Task 4 – Consequence Analysis; as well as the Task 5 – Accident Scenario and Causality Study Report of the Phase A Preliminary Risk Assessment (PRA).

The Phase A PRA consists of eight main tasks. However, it is imperative to recognize that each task is defined by the scope of work and is not a discrete unit of analysis. Rather, the work described in these reports and related tasks are inter-related with studies completed under other tasks and deliverables. Thus, the information provided in the Consequence Analysis Report and Accident Scenario and Causality Report are based on the volume of work completed to date and best understood in reference to previous reports.

Overview

The results of the Task 1 and 2 studies were used to develop the inputs for the Consequence Analysis Report. Additionally, two webinars were conducted (April 2010 and June 2010) to characterize the spills and develop the Risk Matrix during Task 3. Based on the risk matrix results from Task 3, 16 scenarios were developed with consensus from the Management Team and Advisory Panel members for evaluation of the Consequence Analysis (Task 4) and development of the Accident Scenario and Causality Study (Task 5). The enclosed reports incorporate revisions to address cumulative comments received from the Peer Review Panel and Management Team on the draft reports submitted on March 7, 2011.

Scope and Objectives

The studies completed by the risk analysis team were defined by the scope and objectives of the Phase A PRA Program as described in the Transportation Research Board Special Report 293 and more directly, the Phase A Request for Proposal. Thus, the analyses and information should be reviewed in context with the scope of the Phase A AIRA Program.

The objectives of these deliverables are to summarize the findings of the Conseqence Analysis and Accident Scenario and Causality Study and provide documentation of the studies completed for Tasks 3, 4, and 5 of the Phase A PRA.

In accordance with the scope of work, the studies focused on characterizing spills based on identify the hazardous substances, representative spill sizes, and locations of spills from the highest-risk accidents. This process led to the selection of 16 hypothetical high-risk spill scenarios associated with the Aleutian Islands study area, based on the unique combinations of vessel type, spill volumes, accident types, and spill material (Task 3). Once the scenarios were selected, a high-level spill trajectory and fate analysis for the selected spill scenarios was performed. The spill model outputs (surface oiling, shoreline impacts, subsurface concentrations, and sediment concentrations) were used to then perform a qualitative assessment of the potential resource damage and socioeconomic impact of these representative spills (Task 4). The intent was to gain an understanding of the relative environmental consequences associated with the scenarios and use the information as input into the accident scenario and causality analysis (Task 5) and to assess potential risk reduction measures (Tasks 6 and 7).

Consequence Analysis Report

The purpose of the consequence analysis is to gain an understanding of the relative impact of spill size, types of hazardous substance spilled, and spill location on environmental consequences. The analysis is a qualitative assessment of the potential resource damage and socioeconomic impact of selected high-risk spill scenarios and provides a high-level assessment of vulnerability of identified natural resource(s).

Since the goal of the spill scenario selection process was to identify the hazardous substances, representative spill sizes, and locations of spills associated with the highest-risk accidents, this resulted in selection of "reasonable worst case" spill scenarios. Thus, caution should be exercised if trying to make a leap to other spill events.

For each location, the analysis included evaluating a) the probability of the various environmental and socioeconomic resources/receptors coming into contact with a spill and b) the extent of impact (e.g., area or concentration level). The oil spill modeling output results and ecological and socioeconomic impacts for each of the 16 scenarios are summarized in Table 5.4 of the Consequence Analysis Report.

Based on the findings of the consequence analysis, the ecological receptors potentially at greatest risk include seabirds and marine mammals, while the socioeconomic resources at greatest risk are subsistence use areas and fisheries. Clearly, an oil spill of a notable amount has the potential to result in ecological and/or socioeconomic impacts depending on the relation to important receptors of the study area.

Even Scenario 4, characterized as a 25,000-barrel diesel fuel spill north of Unimak Pass (Location1), has the potential to result in impacts to marine mammal habitat if receptors are present during the winter season. Of additional note, scenarios associated with large spills (400,000 barrels) of persistent oil at high-release rates (e.g., Scenarios 3, 8, and 12) indicate the greatest potential of ecological and socioeconomic impacts.

This study represents a qualitative assessment of potential environmental and socioeconomic impacts associated with selected high-risk scenarios to receptor categories present within the Aleutian Islands. The scenarios, spill locations, and consequence analysis reflect best professional assessments based on experience, existing data, and modeling outputs. The spill scenarios, of course, are not exhaustive of all possible spills; however, they do provide a wide spectrum of high-risk scenarios with which to evaluate the relative impacts and potential consequences to the study area's resources should a spill occur. Notably, a potential spill event would likely have greater socioeconomic consequences than could be evaluated in this study because region-wide impacts were not evaluated due to the scope constraints.

Accident Scenario and Causality Study Report

The work performed under Task 5 is more directly linked to the work performed under Tasks 1, 2, and 3, and is not readily linked to Task 4. Task 4 seeks to more fully understand the consequence of spills, whereas Task 5 presents information on the causality of spills. The objective of Task 5 is to evaluate the major causes of the higher-risk scenarios and assign probabilities of occurrence.

The main purpose of the Accident Scenario and Causality Study Report is to provide a stronger narrative of how marine risks arise, to complement the mainly numerical results presented in the Task 2A Report. As documented in the enclosed report, the Task 5 risk results show that, for the hypothetical (referred to as representative) accident scenarios:

- The spill volumes are generally over estimated compared to what the event trees predict is most likely to happen.
- The collision and powered grounding accidents are predominantly attributed to human error.
- The drift grounding accidents are predominantly attributed to technical failures.

The comparison of the Representative Accident Scenarios with historical accidents shows that the Phase A Accident Scenarios are mostly pessimistic (larger spill volumes, more toxic spilled materials) compared to that observed historically, but in other ways are similar to historical accidents. It is concluded that the Representative Accident Scenarios are indeed, reasonable worst case scenarios, consistent with Phase A AIRA Program requirements. This conclusion should be considered when the results from Task 4 are interpreted.

The Risk Analysis Team appreciates the opportunity to work with the Management Team and other stakeholders as part of the AIRA Phase A Program. If you have questions or inquires concerning this submittal, please contact Laura Tesch at 425-214-0453 or laura.tesch@erm.com.

Sincerely,

Laura Tesch
AIRAProgram Director

Dr. Jack Colonell
Partner-in-Charge

Enclosure via email:
Consequence Analysis Report
Task 5 Accident Scenario and Causality Study Report

cc: David Pertuz, DNV
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Prepared for:
National Fish and Wildlife Foundation,
United States Coast Guard, and
Alaska Department of Environmental Conservation

Consequence Analysis Report

Aleutian Islands Risk Assessment
Phase A – Preliminary Risk Assessment
Aleutian Islands, Alaska

Tasks 3 and 4

July 2011

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National Fish and Wildlife Foundation
United States Coast Guard
Alaska Department of Environmental Conservation

Consequence Analysis Report

Aleutian Islands Risk Assessment
Phase A – Preliminary Risk Assessment
Aleutian Islands, Alaska

Tasks 3 and 4

July 2011
Project No. 0105563

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°	Degrees
°F	Degrees Fahrenheit
ACC	Alaska Coastal Current
ACFEC	Alaska Commercial Fisheries Entry Commission
ADCCED	Alaska Department of Commerce, Community, and Economic Development
ADEC	Alaska Department of Environmental Conservation
ADF&G	Alaska Department of Fish and Game
AEB	Aleutians East Borough
AEBCMP	Aleutians East Borough Coastal Management Plan
AFSC	Alaska Fisheries Science Center
AIRA	Aleutian Islands Risk Assessment
AMNWR	Alaska Maritime National Wildlife Refuge
ANSC	Aleutian North Slope Current
APICDA	Aleutian Pribilof Islands Community Development Association
AWCRSA	Aleutian West Coastal Resource Service Area
bbl	barrels
BSAI	Bering Sea-Aleutian Islands
CDQ	Community Development Quota
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cm	centimeter
cm/s	centimeters per second
COSIM	Chemical and Oil Spill Impact Module
DCRA	Department of Community and Regional Affairs
DNV	Det Norske Veritas (U.S.A.), Inc.
DWT	Deadweight tons
EC50	effect concentrations where 50 percent of the population experiences adverse effect
EEZ	Exclusive Economic Zone

ERM	ERM-West, Inc.
ESA	Endangered Species Act
ESI	Environmental Sensitivity Index
EVOS	Exxon Valdez Oil Spill Trustee Council
GESAMP	Group of Experts on the Scientific Aspects of Marine Pollution
IBA	Important Bird Area
IPIECA	International Petroleum Industry Environmental Conservation Association
IPQ	Individual Processor Quota
IUCN	International Union for Conservation of Nature
k	thousand
km	kilometer
LC50	lethal concentrations where 50% of population dies
LD50	lethal dose
MARCS	Marine Accident Risk Calculation System
m	meter
MMPA	Marine Mammal Protection Act
mph	miles per hour
NFWF	National Fish and Wildlife Foundation
NMFS	National Marine Fisheries Service
NMML	National Marine Mammal Laboratory
NOAA	National Oceanic and Atmospheric Administration
NRHP	National Register of Historic Places
ppb	part per billion
PQS	Processor Quota Shares
PRA	Preliminary Risk Assessment
RRO	Risk Reduction Option
SF	Sensitivity Factor
TAC	Total allowable catch
UK	United Kingdom

UNESCO	United Nations Educational, Scientific and Cultural Organization
US	United States
USFWS	United States Fish and Wildlife Service

1.0 *INTRODUCTION*

The Aleutian Islands Risk Assessment (AIRA) program was created to produce a comprehensive evaluation of the risk of vessel accidents and spills in the Aleutian Islands. The risk assessment is being conducted in two Phases, Phase A – Preliminary Risk Assessment (PRA; semiquantitative assessment, current phase) and Phase B – Focused Risk Assessment (National Fish and Wildlife Foundation [NFWF] 2010)[i]. The Phase A scope of work consists of the following eight tasks:

- Task 1 - Marine Traffic Study
- Task 2 – Baseline Spill Study
- Task 3 – Characterizing Spills from the Highest-Risk Accidents
- Task 4 – Consequence Analysis
- Task 5 – Accident Scenario and Causality Study
- Task 6 – Qualitative Assessment of Risk Reduction Options (RROs)
- Task 7 – Evaluation of RROs
- Task 8 – Prioritization of RROs

Tasks covered in this report

This document is the Phase A – Consequence Analysis Report and was prepared by the Risk Analysis Team on behalf of the AIRA Management Team, which consists of the NFWF, United States Coast Guard, and the Alaska Department of Environmental Conservation (ADEC). It characterizes the following two tasks of the Phase A – Preliminary Risk Assessment:

- Task 3 – Characterizing Spills from the Highest-Risk Accidents: Using findings from the marine traffic and baseline spill studies, a risk matrix approach is used to identify and characterize the higher risk accidents.
- Task 4 – Consequence Analysis: Based on the spills and locations identified in Task 3, the consequence analysis involves modeling numerous hypothetical spill scenarios to evaluate the relative impact

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[i] www.aleutiansriskassessment.com.

on the environment of spill size, types of hazardous substance spilled, and spill location. This is a qualitative assessment of the potential resource damages and socioeconomic impacts of an illustrative mix of spill events.

1.1 SCOPE AND OBJECTIVES

As described in the scope of work for the AIRA Request for Proposal, the Phase A study is semiquantitative. The scope of the Phase A PRA consists of the following main limits and bounds:

- Vessel Size – vessels more than 300 gross tons carrying hazardous substances and smaller vessels with a fuel capacity of at least 10,000 gallons;
- Types of Vessels – Containerships, bulk carriers, general cargo vessels, gas carriers, roll-on/roll-off vessels and pure car carriers, cruise ships, crude oil carriers, product tankers, tank barges, cargo barges, chemical carriers, fish processors, fishing vessels, tugs, and Government vessels; and
- Geographic Region – vessel traffic and spill accidents within the vicinity of the Aleutian Islands, including innocent passage transiting immediately to the south of the Aleutian Chain.

The purpose of this consequence analysis is to gain an understanding of the relative environmental impacts to identified receptor categories given spill size, types of hazardous substances spilled, and spill location. As such, this analysis is a qualitative assessment of the potential environmental resource damage and socioeconomic impact of select high-risk spill scenarios and provides a high-level assessment of vulnerability of identified natural resource(s). At this phase, the consequence analysis is not a comprehensive assessment of biological or socioeconomic impacts, or costs of natural resource damage.

The objectives of this report are to summarize the preliminary findings of the Consequence Analysis and provide documentation of the data sources and methodology used to complete the studies for Tasks 3 and 4 of the Phase A PRA.

1.2 RELATIONSHIP OF THIS REPORT TO PHASE A PRA

The results of the first two tasks were presented in the following reports:

- Task 1 – Marine Traffic Study Report (ERM/DNV 2010a);
- Task 2A – Marine Spill Frequency and Size Report (ERM/DNV 2010b); and
- Task 2B – Baseline Spill Study Report (ERM/DNV 2010c).

As described in the Task 2A Report, the results from the Marine Accident Risk Calculation System (MARCS) model indicate where accidents are likely to occur as well as type and quantity of material that would be released into the water. These results were used to develop the high-risk scenarios based on spill location and vessel type as part of Task 3.

In Task 4, the baseline spill model established during Task 2B becomes the platform for analysis of spill events, each of which is characterized by specifying the oil type, specific locations, and spill volumes and duration. These characteristics are used along with the forcing function data to set up the complete the 3-D stochastic modeling for predicting the transport and fate of the spilled substance. The model provides the necessary outputs discussed in Task 4 for the subsequent consequence analysis.

Under Task 5, the representative accident scenarios are determined from the dominant accident types identified under Task 3 in terms of:

- Type of vessel(s) (oil tanker, container ship, etc.) involved in the accident;
- Type of accident (collision, powered grounding, etc.) that occurred;
- Type of material released to the environment (cargo oil, bunker oil, hazardous packaged goods, etc.);
- Quantity of material released into the environment; and
- Location of the accident.

The results of this report and the Task 5 Accident Scenario and Causality Study will be used in performance of Tasks 6 and 7 to evaluate and rank RROs. The deliverable for Tasks 6 and 7 will be the Risk Reduction Evaluation Report. As part of the RRO Evaluation Report, the consequence categories, impact area and probability of impact identified in this analysis will be used to score and rank the spill scenarios. Risk, in terms of expected spill sizes, types of hazardous substances spilled, and impacts will also be determined based on estimated frequencies of occurrence and consequence categories for each scenario identified and assessed in this report.

As described above, the Phase A PRA consists of eight main tasks. However , it is imperative to recognize that each task is defined by the scope of work and is not a discrete unit of analysis. Rather, the work described in this report and related tasks are inter-related with studies completed under other tasks and deliverables. Thus, the information provided in the Consequence Analysis Report is based on the volume of work completed to date and best understood in reference to previous reports.

1.3 OVERVIEW OF CONSEQUENCE ANALYSIS

Task 4 of the Phase A PRA includes two main components: 1) using the GEMSS® - Chemical and Oil Spill Impact Module (COSIM) models to provide mass balance of the key spill constituents and prepare useable model outputs to assess the consequence of a spill; and 2) to qualitatively identify the consequences of the hypothetical spill scenarios to five main receptor groups: physical (habitat), mammals, seabirds, fish and socioeconomic.

For this preliminary consequence analysis, the extent of surface oiling and concentrations of oil is used to assess impact on natural and socio-economic resources. More specifically, exposure expressed in terms of surface water oiling and shoreline oiling was used to provide an indicator of impact on seabirds and mammals. To provide an indicator of impact on fish and invertebrates, the subsurface concentration in the water column and the area of bottom sediment contamination affected above thresholds of concern (as determined by review of available toxicity values) was used from the stochastic model.

Figures 1.1 and 1.2 provide schematic representations of the assessing impacts to natural and socioeconomic resources.

Figure 1.1 Diagram of Potential Impacts for Environmental Resources

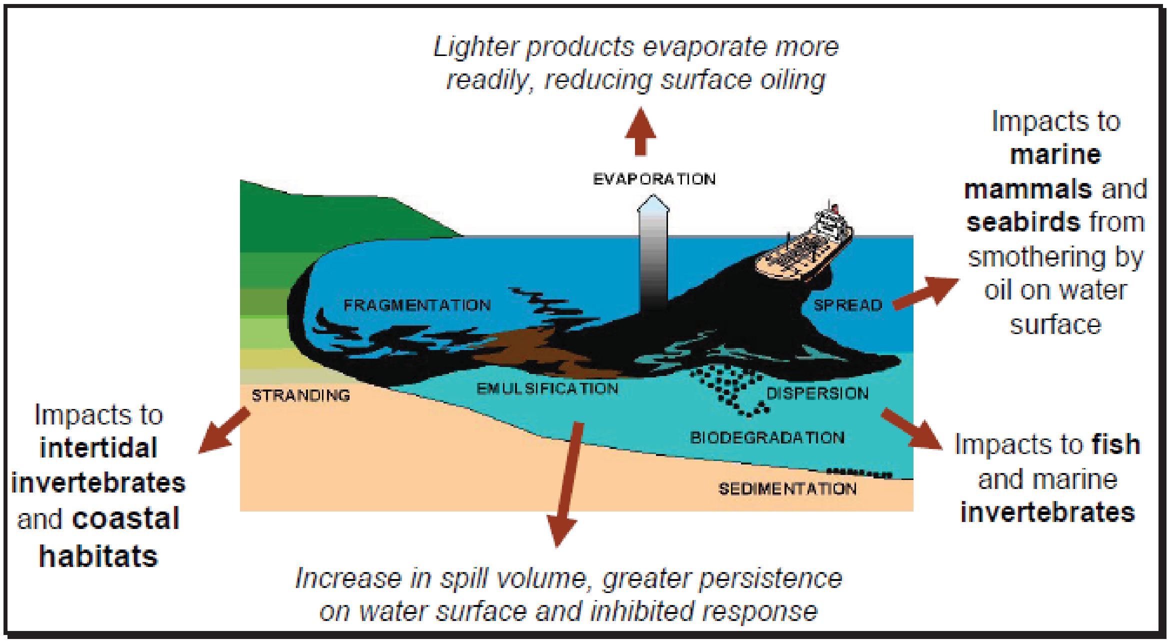
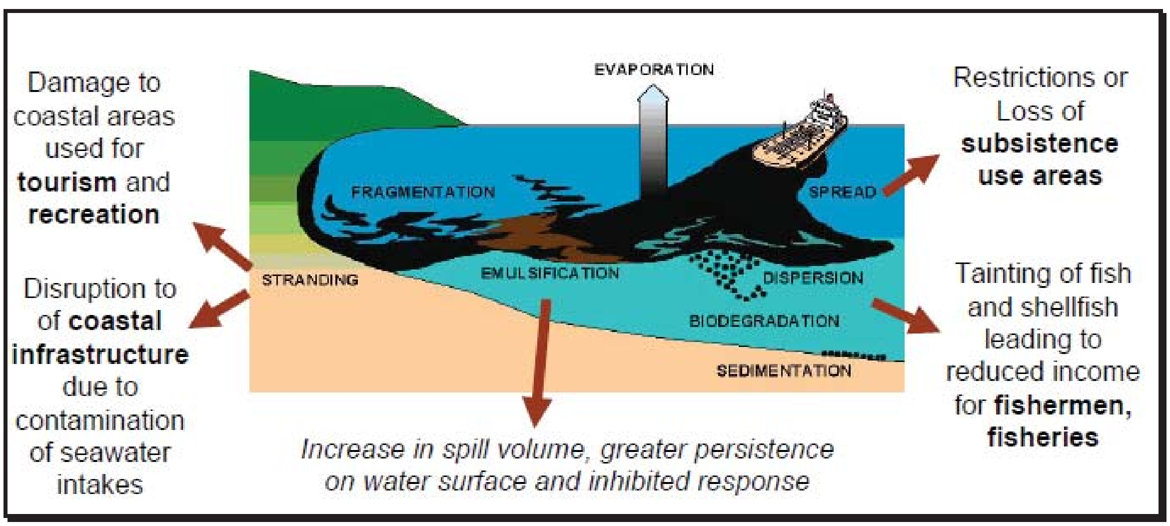


Figure 1.2 Diagram of Potential Impacts for Socioeconomic Resources



Additional details on the approach used to conduct the consequence analysis are provided in subsequent sections.

1.4 DOCUMENT ORGANIZATION

The Consequence Analysis Report is organized as follows:

- Section 1 – *Introduction* provides a brief introduction of the study followed by its objectives;
- Section 2 – *Characterizing Spills* presents the approach and results for characterizing spills from the Highest-Risk Accidents and the 16 high-risk scenarios identified from the Task 3 webinars;
- Section 3 – *Baseline Characteristics* describes the environment of the Study Area, including the important ecological and socioeconomic resources associated with the Aleutian Islands;
- Section 4 – *Consequence Analysis* discusses the environmental modeling results and evaluation of impacts to five major receptor groups (habitat, mammals, fish, birds, and socioeconomic) from the 16 scenarios;
- Section 5 – *Summary* presents a discussion of methods and results of the Phase A consequence analysis; and
- Section 6 – *References* lists the data sources used in preparation of this report.

The Task 5: Accident Scenario and Causality Study Report is presented as a separate report.

2.0 *CHARACTERIZING SPILLS – TASK 3*

Using findings from the marine traffic and baseline spill studies, a risk matrix approach is used to identify and characterize the higher risk accidents.

2.1 *OBJECTIVE OF TASK 3*

The main objectives of this task are to identify high-risk accidents in the study area and develop specific scenarios for modeling in Task 4. The scope of Task 3 consists of risk ranking the output of the baseline spill study and identifying high risk spill locations within the study area. The Task 3 output is a list of scenarios with the following identified for each:

- Hazardous material spilled;
- Representative spill size; and
- Location.

Task 3 Goal: Identify the hazardous substances, representative spill sizes, and locations of spills associated with the highest-risk accidents.

2.2 *APPROACH FOR RISK MATRIX AND SCENARIO SELECTION*

Scenarios are selected based on output from the MARCS model concerning the spills posing the greatest risk of release. Results from the MARCS model are provided in Task 2 of this study. Available output data include potential spill frequency, type of vessel, potential release volume, and geographical diagrams identifying high-risk locations.

Risk to the environment can be evaluated in three distinct ways:

A. Spill risk is the expected mass or volume of material released per year (from MARCS).

B. Impact risk is evaluated by combination of spill risk with a spill trajectory model and some sort of effect criterion (e.g., toxicity data). It describes the magnitude of the environment affected by the spill using data on spill size, spill rate, critical concentrations and weather data (see Section 4.1).

C. Receptor risk is the combination of impact risk overlaid with the environmental receptors (and their sensitivity) in the impact zone at the time of year (see Section 4.4).

A risk matrix approach is used (Figure 2.1) to identify the scenarios with the greatest combination of likelihood and spill volume. Risk is defined as the product of likelihood and consequences (also called severity). In this portion of the study (Task 3), the product of likelihood and spill volume is used as a surrogate for receptor risk; that is, Approach A (above) is implemented. Spill volume (barrels) is temporarily substituted for severity to assist the study team to identify scenarios that would receive more detailed consequence modeling as part of Task 4.

The risk matrix below quantifies the severity of an incident in barrels of oil spilled. Using barrels provides a good sense of scale, but may not correlate well with the amount of ecological damage done by the spilled oil. The fragile Aleutian ecosystems are geographically dispersed and are more vulnerable at specific times of the year. As a result, receptor risk is strongly preferred as the metric for later evaluation of RROs. The usefulness of the barrel-based ranking in this exercise is as a quantitative screening exercise with the purpose of identifying scenarios for detailed consequence modeling.

Figure 2.1 Task 3 Risk Matrix

Frequency of Occurrence	**Severity of Incident (1000 bbl)**				
	>0 to 130	>130 to 1,300	>1,300 to 13,000	>13,000 to 130,000	>130,000 to 1,300,000
Frequent (A)				**High**	**Risk**
Occasional (B)					
Seldom (C)					
Remote (D)	**Low**	**Risk**			
Unlikely (E)					

Note: bbl = barrels

Tasks 4 and 5 evaluated severity to a greater level of detail. A qualitative risk matrix was deemed useful to meet the objective of Task 3: to identify potential high risk spills for modeling.

During the initial Task 3 Advisory Member Webinar (April 27, 2011), a 5x5 matrix was selected to allow the best balance between the need to differentiate risk from the many scenarios and the need to have a tool simple enough to implement. The frequency ranges were selected to cover the maximum extent of the MARCS output frequencies. Therefore, ranges of two orders of magnitude were necessary. The severity ranges were sized in orders of magnitude so the largest possible spill could be mapped into the matrix.

MARCS output 720 scenarios (unique sets of frequency-volume-vessel-type). Of the 720 accident scenarios, 485 do not result in a spill and have not been not evaluated further, as this study is focused on spill risk. The remaining 235 scenarios are plotted in the risk matrix. Of these, 128 fall in the "High Risk" (red) zone. Figure 2.2 provides a graphic representation of the 235 scenarios populated within the matrix.

Figure 2.2 Number of MARCS Scenarios Plotted in the Risk Matrix

Frequency of Occurrence (/yr)	Severity of Incident (1000 bbl)				
	0 to 130	130 to 1,300	1,300 to 13,000	13,000 to 130,000	130,000 to 1,300,000
$1x10^{-1}$ to 10		4	**0**	**2**	**0**
$1x10^{-3}$ to $1x10^{-1}$			13	**24**	**37**
$1x10^{-5}$ to $1x10^{-3}$			10	49	**65**
$1x10^{-7}$ to $1x10^{-5}$			2	13	11
$<1x10^{-7}$				3	2

The cells in the matrix each represent a qualitative risk level based on spill volumes and frequency of occurrence[ii]. The cell representing the greatest spill risk is labeled Cell A; Cell F represents the least risk among the "High Risk" scenarios as presented in Figure 2.3.

Figure 2.3 Risk Level Represented by each Matrix Cell

Frequency of Occurrence (/yr)	Severity of Incident (bbl)				
	0 to 130	130 to 1,300	1,300 to 13,000	13,000 to 130,000	130,000 to 1,300,000
$1x10^{-1}$ to 10			D	B	A
$1x10^{-3}$ to $1x10^{-1}$				E	C
$1x10^{-5}$ to $1x10^{-3}$					F
$1x10^{-7}$ to $1x10^{-5}$					
$<1x10^{-7}$					

The "risk value" of any cell can be calculated and compared with the risk represented by any other cell by multiplying the median value of the frequency with the median value of the severity. The difference in risk between Cell B and Cells C and D (which have identical risk value) is approximately one order of magnitude. Therefore, it would take 10 (average) scenarios in Cell C or Cell D to pose equal risk as one (average) scenario in Cell B.

Cell A contains no scenarios from MARCS. This is as expected, because the most extreme volume spills (spill severities) are usually not the most frequent (i.e., not necessarily highest spill risk).

The greatest spill risk identified in Task 3 is in Cell B. This cell represents a wide range of potential spills, from 13,000 to 130,000 bbl with frequencies ranging from 10 per year to 1 in 10 years. For the task at hand (identifying scenarios to model), it is not necessary to pin down exactly

[ii] Refer to Task 2A Report (ERM/DNV 2010b) for more detail on MARCS outputs and methodology.

where in the range the identified risks lie, but it must be possible to develop a useful description representing this cell posing the greatest apparent risk. The Cell B scenarios include a powered and a drift grounding of a Tank Barge in the size range 6 to 14 thousand deadweight tons (kDWT). The spilled material in these scenarios is non-persistent oils (i.e., diesel, heating oil, or fuel).

Subsequent paragraphs describe the matrix cell contents in order of decreasing risk. The high-risk scenarios are indicative of the materials and spill sizes that are included in the scope of the Task 4 modeling.

Cell C contains 37 scenarios with the ship types and accident types indicated in the Table 2.1. The spilled material is primarily persistent oils.

Table 2.1 Scenario Details Associated with Cell C

	Vessel collision	Structural Failure	Fire/explosion	Powered Grounding	Drift Grounding
Container Ships <4500 TEU 14-30 kDWT				X	X
Container Ships <4500 TEU 30-50 kDWT	X	X	X	X	X
Container Ships <4500 TEU 50-90 kDWT	X	X	X	X	X
Container Ships >4500 TEU 50-90 kDWT	X	X	X	X	X
Container Ships >4500 TEU 90-130 kDWT	X	X	X	X	X
Bulk Carriers 50-60kDWT					X
Bulk Carriers 60-90kDWT	X	X	X		X
General Cargo Ships 30-50kDWT	X	X	X		X
General Cargo Ships 50-90kDWT					X
LNG Ships 30-50kDWT					X
RoRo Ships 14-30kDWT					X
Product Tankers 14-30kDWT					X
Chemical Tankers 14-30kDWT					X
Refrigerated Cargo Ships 6-14kDWT				X	

Cell D contains no scenarios from MARCS.

Cell E contains 24 scenarios with the ship and accident types indicated in the Table 2.2. The spilled material is primarily persistent oils.

Table 2.2 Scenario Details Associated with Cell E

	Vessel collision	Structural Failure	Fire/explosion	Powered Grounding	Drift Grounding
Bulk Carriers 14-30kDWT	X		X		X
Bulk Carriers 30-50kDWT	X		X		X
General Cargo Ships 6-14kDWT	X	X	X		X
General Cargo Ships 14-30kDWT					X
Tank Barges 6-14kDWT	X	X	X		
Tank Barges 14-30kDWT				X	X
Tugs 0-2kDWT	X			X	X
Government Vessels 0-2kDWT				X	X
Government Vessels 2-6kDWT				X	
Refr Cargo 2-6kDWT				X	X

Cell F contains 65 scenarios with the ship and accident types indicated in Table 2.3. The spilled material in these scenarios is primarily persistent oils (i.e., bunker fuel).

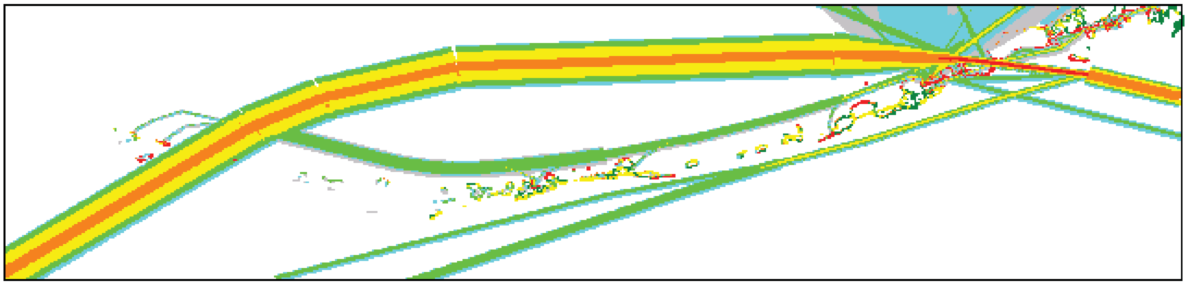
Table 2.3 Scenario Details Associated with Cell F

	Vessel collision	Structural Failure	Fire/explosion	Powered Grounding	Drift Grounding
Container Ships <4500 TEU 14-30Kdwt	X	X	X		
Container Ships >4500 TEU 30-50Kdwt	X	X	X	X	X
Bulk Carriers <60kDWT	X	X	X	X	
Bulk Carriers 60-90kDWT				X	
Bulk Carriers 90-130kDWT	X	X	X	X	X
Bulk Carriers >130kDWT	X	X	X	X	X
General Cargo Ships 30-50kDWT				X	
General Cargo Ships 50-90kDWT	X	X	X	X	
RoRo Ships 14-30kDWT	X	X	X	X	
Crude Oil Carriers 30-50kDWT					X
Crude Oil Carriers 90-130kDWT	X		X	X	X
Product Tankers 14-30kDWT	X	X	X	X	
Product Tankers 30-50kDWT	X	X	X	X	X
Chemical Tankers 14-30kDWT	X	X	X	X	
Refr Cargo Vessels 6-14kDWT	X	X	X		X
Other Vessels 14-30kDWT	X			X	X
Other Vessels 30-50kDWT	X			X	X
LNG Ships 30-50kDWT	X	X	X	X	
LNG Ships 50-90kDWT					X

The above discussion addresses types of material and spill volume associated with the high spill risk scenarios (both available from MARCS output). An additional MARCS output is a traffic plot and geographical distribution of cargo and bunker spill and accident risk. Each colored area represents a reasonably uniform frequency-volume of spill per year (Figure 2.4). The highest risk locations considered in development of the list of hypothetical spill scenarios to be modeled are:

- Locations in red near shore (groundings are a major contributor to accident risk); and
- Locations in red in the traffic lane (collisions are a secondary contributor to accident risk).

Figure 2.4 MARCS Output Risk by Location



Color	Spill Risk (Tons of bunker or cargo oil spilled per year within each calculation location)
(grey)	1.0 E-08 – 1.0 E-06
(light blue)	1.0 E-06 – 1.0 E-05
(green)	1.0 E-05 – 1.0 E-04
(yellow)	1.0 E-04 – 1.0 E-03
(orange)	1.0 E-03 – 1.0 E-02
(red)	> 1.0 E-02

2.3 SCENARIOS SELECTED

A Task 3 webinar was held on June 14, 2010, with the AIRA Management Team and Advisory Panel members to review the preliminary results of the risk matrix findings. The following three parameters were agreed upon that defined the 16 scenarios to be modeled in Task 4:

1. Types of material – The materials of concern to high-risk spills include both persistent and non-persistent oils.
2. Spill volume – The effect of spill volume is the subject of further analysis in Task 4 modeling, so the Management Team decided to select a broad range of spill sizes to be modeled.
3. Location – Spill Locations 1, 2, and 3 were recommended by the Risk Analysis Team as high risk locations as determined from MARCS output results. The Management Team requested three additional locations for inclusion due to their remoteness or proximity to resources of concern (locations 4, 5, and 6). The locations are described below.

The high risk spill volumes are characterized by the following conditions:

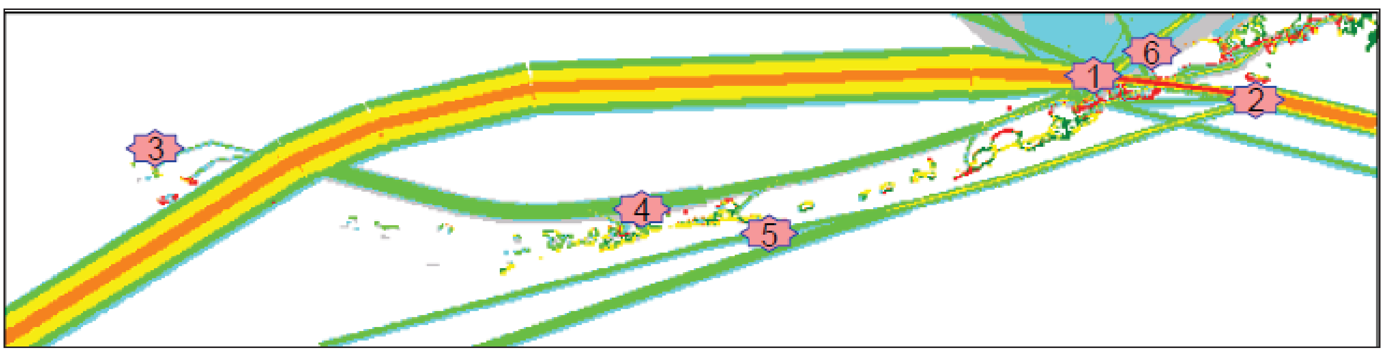
- Tank Barges fall in the risk matrix cell representing the greatest risk. Container ships also pose similar significant spill risk.

- A representative catastrophic spill volume is estimated to be 400,000 bbl of persistent oil.
- A more frequent spill volume would be 40,000 bbl of non-persistent oil.
- A 50th percentile spill volume would be 15,000 bbl of persistent oil.
- A lesser, but more likely spill volume is a 3,000 bbl spill of persistent oil.

Spill locations suggested for modeling in Task 4 are located in Red Areas (high frequency-volume risk) in the MARCS-generated map.

The six spill locations selected to represent the greatest risk areas are discussed below.

Figure 2.5 General Spill Locations Selected for Modeling



Congested traffic areas along the Great Circle Route near the islands are high risk due to groundings, collisions, and other accident types. Spills at this location will be modeled five times (two different materials and three different spill volumes).

- **Location 1** – Northern side of Unimak Pass (Figure 2.6).

The Great Circle Route intersection with the eastern Aleutians is at high risk. Spills at these locations are modeled four times (two different materials and two different spill volumes).

- **Location 2** – Off Sanak Island on the south side of Unimak Pass (Figure 2.6).
- **Location 3** – Holtz Bay on Attu Island (Figure 2.7). The spill volumes for this location are based on upper limits for the associated

vessel/material type combination because of the response time required to assist vessels in this area.

Many nearshore locations are high-risk due to groundings. The locations listed below pose potential environmental *and* economic risks (locations suggested during June 14, 2010, Webinar).

- **Location 4** – A scenario releasing 40,000 bbl of non-persistent oil just north of Adak (Figure 2.8);
- **Location 5** – A scenario releasing 40,000 bbl of non-persistent oil south of Amlia Island (Figure 2.9); and
- **Location 6** – A scenario releasing 15,000 bbl of persistent oil 2 miles north of the shores of Urilia Bay (Figure 2.6).

In summary, the main elements considered in the high-risk scenario selection process were material type, spill volume and location. These criteria were determined as part of the scope of work and recommendations from SR 293 (TRB Special Report 293 (2009). Type of accident, vessel type, material type, spill volume and geographical location are outputs from MARCS that were utilized in the scenario selection process. Additional factors such as seasonality and biological abundance was also taking into consideration as represented by scenarios associated with Locations 4, 5 and 6. Thus, the development of the high-risk scenarios represents a robust selection process that ensures key drivers to overall risk were considered.

Figure 2.6 Spill Locations 1, 2, and 6

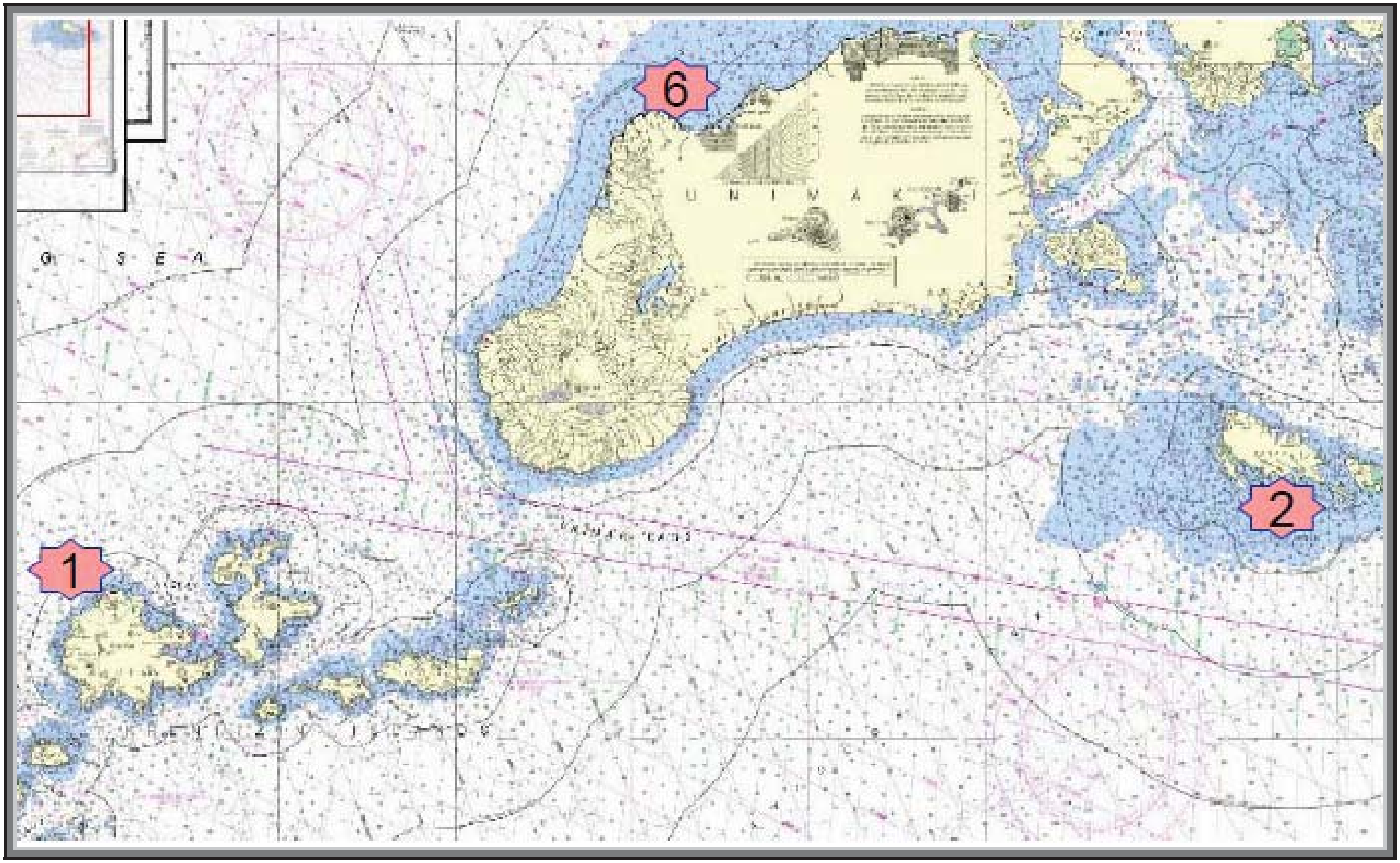


Figure 2.7 Spill Location 3

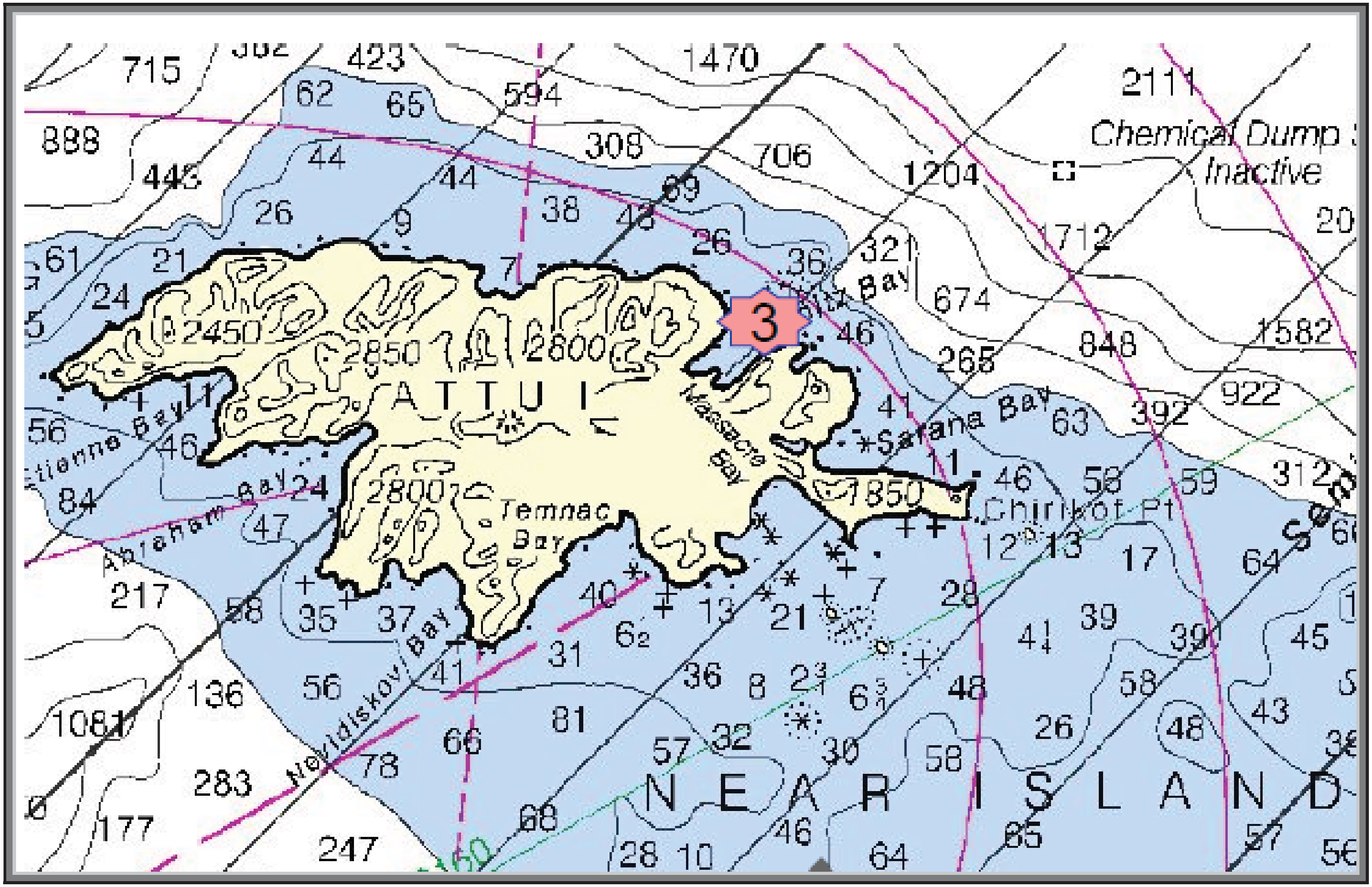


Figure 2.8 Spill Location 4

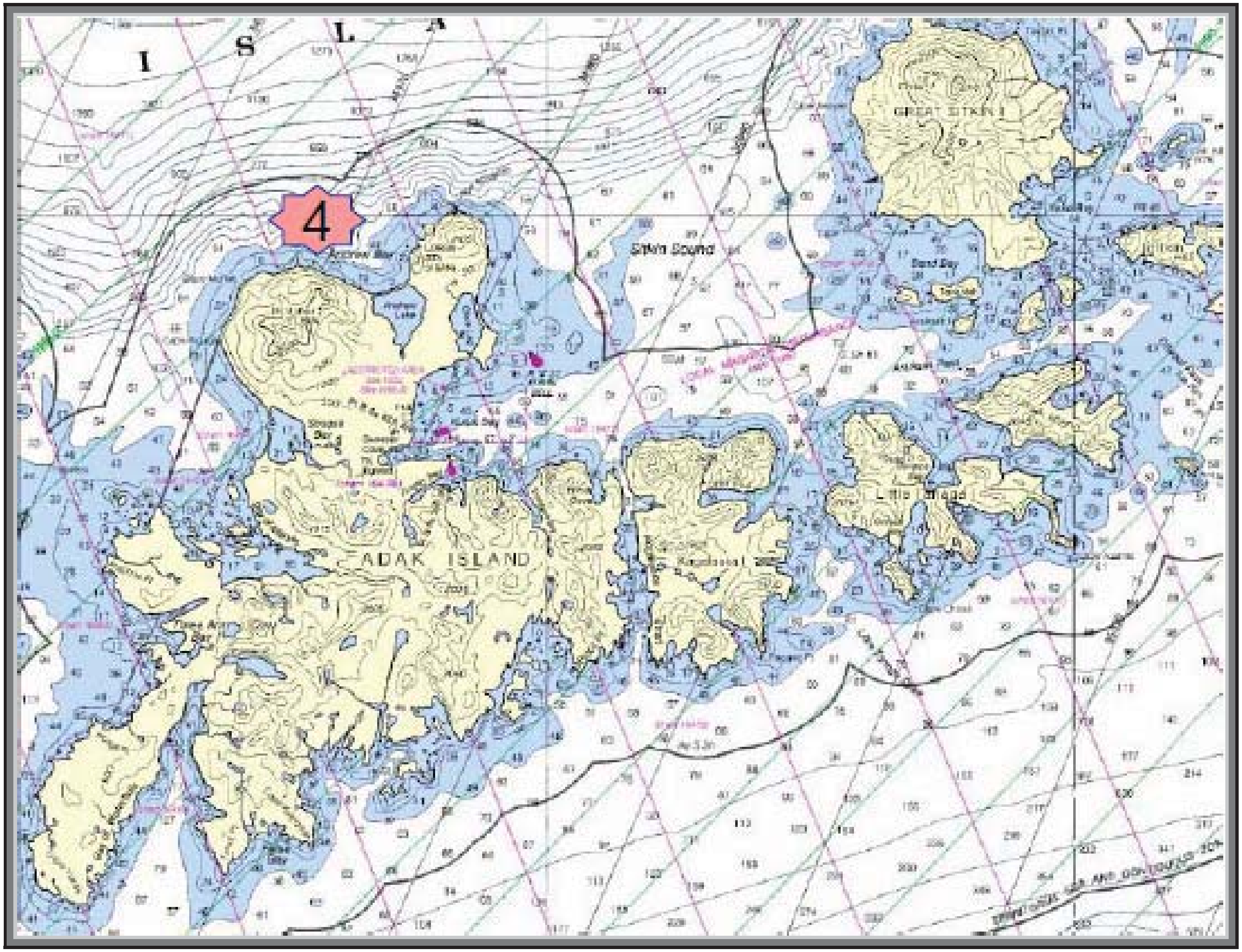
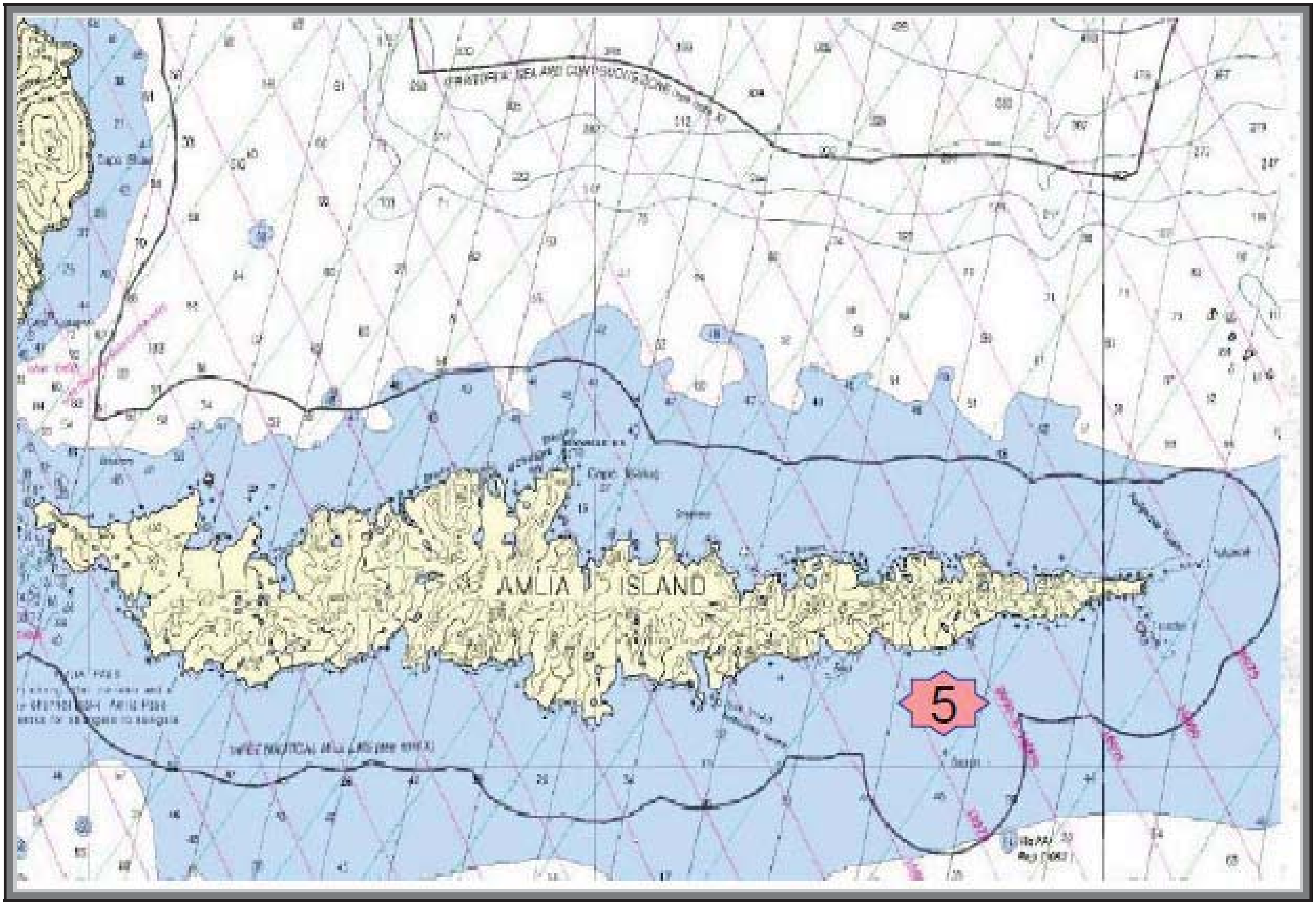


Figure 2.9 Spill Location 5



The six agreed locations for modeling of marine spill risk were analyzed to identify the most likely ship types. Based on the ship type, material / spill volume pairs were assigned to each. Several scenarios were developed for each of the first three locations (1 through 3). A single scenario was developed for each of the last three locations (3 through 6). Locations 1 to 3 were selected to model scenarios that represent high risk of a spill occurring. Locations 3 to 6 were selected to model scenarios that would potentially affect areas of known environmental sensitivity. Table 2.4 provides a summary of the final scenarios selected for evaluation during Task 4.

Table 2.4 Summary of Scenarios Developed for Modeling in Task 4

Scenario	Material and Ship Type	Spill Volume	Location of Spill
Scenario 1	Persistent oil Container Ship 50kDWT	3,000 bbl	Location 1
Scenario 2	Persistent oil Bulk Carrier >60kDWT	15,000 bbl	Location 1
Scenario 3	Persistent oil Crude Oil Tanker	400,000 bbl	Location 1
Scenario 4	Non-persistent oil Product tanker 10kDWT	25,000 bbl	Location 1
Scenario 5	Non-persistent oil Tank Barge	40,000 bbl	Location 1
Scenario 6	Persistent oil Container Ship 50kDWT	3,000 bbl	Location 2
Scenario 7	Persistent oil Bulk Carrier >60kDWT	15,000 bbl	Location 2
Scenario 8	Persistent oil Crude Oil Tanker	400,000 bbl	Location 2
Scenario 9	Non-persistent oil Tank Barge	40,000 bbl	Location 2
Scenario 10	Persistent oil Container Ship 50kDWT	25,000 bbl	Location 3
Scenario 11	Persistent oil Bulk Carrier >60kDWT	40,000 bbl	Location 3
Scenario 12	Persistent oil Crude Oil Tanker	400,000 bbl	Location 3

Scenario	Material and Ship Type	Spill Volume	Location of Spill
Scenario 13	Non-persistent oil Product tanker 10kDWT	50,000 bbl	Location 3
Scenario 14	Non-persistent oil Tank Barge	40,000 bbl	Location 4
Scenario 15	Persistent oil Container Ship	40,000 bbl	Location 5
Scenario 16	Persistent oil Bulk Carrier	15,000 bbl	Location 6

3.0 BASELINE CHARACTERISTICS OF ALEUTIAN ISLANDS

The AIRA study area spans a wide range of environmental conditions, receptors, and resources. The North Pacific's Great Circle Route between western North America and eastern Asia is a shipping lane that passes through the Aleutian Chain near large aggregations of animals and sensitive natural resources. For example, Unimak Pass in the eastern Aleutians is in close proximity to important haul-outs, rookeries, and nesting sites of marine mammals and seabirds, while also being close to active commercial fishing grounds and one of the largest, protected, essential fish habitats in the world.

The scope of this assessment is qualitative so, as such, this section provides a high-level characterization of the sensitive features of the biological environment that could be impacted by an oil spill in the Aleutian Islands. The baseline description has been based on a range of publicly available information sources, including the United States Fish and Wildlife Service (USFWS), National Oceanic and Atmospheric Administration (NOAA), and information contained within Environmental Sensitivity Index (ESI) maps prepared by the ADEC. Data sources are described in more detail in Section 3.9.

3.1 PHYSICAL CONDITIONS

3.1.1 Climate

The Aleutian Islands have a maritime climate characterized by persistently overcast skies, frequent and often violent cyclonic storms, and high winds. Weather conditions are often localized with fog, low ceilings, precipitation, and clear weather all encountered over relatively short distances. Year-round temperatures are generally cool, but not normally severe, with a mean annual temperature of 40 degrees Fahrenheit (°F). Annual mean temperatures for some Aleutian Islands are shown in Table 3.1. Strong winds, occasionally exceeding 100 knots, can induce very cold chill factors (USFWS 1988).

Table 3.1 Aleutians West Coastal Resource Service Area Annual Mean Temperatures

Recording Station	Avg. Maximum Temperature (°F)	Avg. Minimum Temperature (°F)	Average Precipitation (in)	Average Snowfall (in)
Dutch Harbor	45.8	35.9	61.24	91.6
Adak	44.7	36.2	61.50	99.4
Amchitka	42.0	35.4	35.68	48.1
Shemya	41.5	36.0	31.75	74.0
Attu	43.0	34.6	52.64	76.3

Source: State of Alaska, Western Regional Climate Center 2010.

During summer months, the Pacific high-pressure system located south of the Aleutian Chain has a cooling effect on ocean surfaces and results in the formation of widespread fog and low stratus clouds. More than 50 inches of precipitation occurs during this period, but the frequency of storms is higher during the winter season. Colder air from the northern Siberian high-pressure system reaches the Aleutian Chain during the winter months. When it encounters slightly warmer, open water areas in the vicinity of the chain, frequent and severe storms often result. Winter storms are characterized by gusty winds, rain, and snow, or rain mixed with snow. During the 6- to 9-month winter period, 50 inches of precipitation or more is not uncommon. Within the region, frost can be expected every month, except possibly July and August (USFWS 1988).

3.1.2 Winds

A normal storm track along the Aleutian Island Chain, the Alaska Peninsula, and all of the coastal area of the Gulf of Alaska exposes these parts of the state to a large majority of the storms crossing the North Pacific, resulting in a variety of wind conditions. Direct exposure results in the frequent occurrence of winds in excess of 50 miles per hour (mph) during all but the summer months. Shemya, on the western end of the Aleutian Islands, has experienced winds on an estimated 139 mph (estimated because the wind recorder pen could only record up to 128 mph). Wind speeds approaching 100 mph are not common, but do occur, and are usually associated with mountainous terrain and narrow passes.

Aleutian winds are legendary and they have taken their toll on both merchant and fishing vessels.

An occasional storm will either develop in or move into the Bering Sea and then move north or northeast, creating strong winds along the western coastal area. Because of the low, flat ground in many places along the coast, these winds will cause flooding during the time the winds are blowing onshore. Winter storms moving eastward across the southern Arctic Ocean cause winds of 50 mph or higher along the Arctic coast. Except for local strong wind conditions, winds are generally light in the interior sections.

Strong winds, or in fact, any wind occurring in the areas of extreme winter cold, create a hazard to personnel exposed for even brief periods of time. For example, (using a wind chill chart developed by the United States [US] Army) a temperature of 35°F and an accompanying wind of 15 mph equals conditions that would be experienced with a temperature of 13°F and no wind (State of Alaska Western Regional Climate Center 2010).

3.1.3 Currents

The Aleutian Archipelago is influenced by three major ocean currents: the Aleutian North Slope Current (ANSC) in the Bering Sea, and the Alaska Coastal Current (ACC) and Alaskan Stream in the North Pacific (Favorite et al. 1976; Stabeno et al. 1999). East of Samalga Pass (170°W), the ACC flows southwestward along the southern side of the Aleutian Islands. This relatively fresh and shallow current hugs the shoreline and turns northward entering the Bering Sea through the eastern passes: Unimak, Akutan, Umnak, and Samalga (Ladd et al. 2005). West of Samalga Pass, the shelf south of the islands is much narrower. This narrow shelf allows the Alaskan Stream, the deep current that flows along the continental slope in the western Gulf of Alaska, to approach the islands. The Alaskan Stream flows southwestward along the southern side of the islands, connecting the Gulf of Alaska to the Aleutian Islands region (Favorite et al. 1976). Waters from the Alaskan Stream flow northward through the central and western Aleutian Passes to feed the ANSC, which flows northeastward along the northern side of the islands and the Alaska Peninsula (Reed and Stabeno 1999; Figure 3.1).

While oscillating tidal currents are responsible for the extreme current speeds and mixing within the passes, the net northward transport of water from the Pacific to the Bering Sea plays a major role in transport of nutrients and biota. There is evidence that transport in the Alaskan Stream influences transport in some passes. In particular, in the winter of

2001/2002, transport variations in the Alaskan Stream were shown to be related to transport variations through Amukta Pass (Stabeno et al. 2005). Large variations in transport in the Alaskan Stream may be related to the passage of mesoscale eddies (Okkonen 1996; Crawford et al. 2000) that move westward along the shelf-break from the Gulf of Alaska. The frequent occurrence and persistence of these eddies are believed to be responsible for productivity "hotspots" observed throughout the region (Batten et al. 2006).

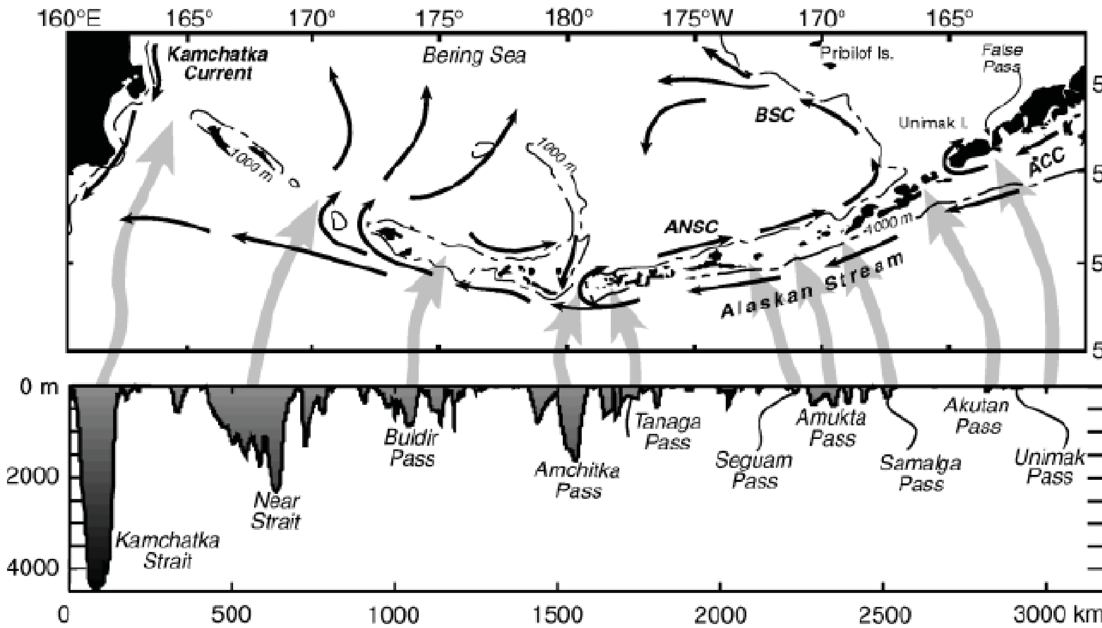
Due to the influence of the ACC, the shallow narrow passes east of Samalga Pass (longitude 170° W) can be classified as a coastal environment with a strong influence of coastal freshwater discharge. These waters are warmer, fresher, more strongly stratified, and nitrate-poor compared with the Aleutian waters west of Samalga Pass. West of Samalga Pass, the passes are deeper and wider. The marine environment can be classified as oceanic with primary influence from the Alaskan Stream (Ladd et al. 2005). The wider passes allow bidirectional currents with mean flow to the north (from the Pacific to the Bering) on the eastern side of the passes and to the south on the western side (Stabeno et al. 1999). However, the northward flow is generally stronger, more consistent, and occurs over most of the cross section of the passes so, except in Kamchatka Strait far to the west, the net transport through the Aleutian Passes is northward from the Pacific Ocean to the Bering Sea.

Within the passes, strong tidal currents, often exceeding 1,000 centimeters per second (cm/s) (Stabeno et al. 2005), present hazards to navigation and equipment. The tides result in substantial mixing within the passes. As the tidal current pushes water over the shallow sills of the passes, salt, nutrients, and plankton from deeper water are mixed into the surface waters. The influence of tidal mixing on surface nutrient concentrations depends on the depth of the pass. Passes with depths between 120 and 200 meters (m), such as Seguam and Tanaga passes, are shallow enough to mix top to bottom, but deep enough that the mixing can access the deep nutrient reservoir. Thus, these passes are most efficient at mixing nutrients into the euphotic zone. In contrast, nutrient concentrations are lower at the bottom of shallower passes, such as the Unimak and Akutan passes, so mixing does not result in substantially increased surface concentrations. In even deeper passes (>200 m), such as the Amukta and Amchitka passes, the interaction of tidal currents and the bottom topography cannot result in mixing that reaches the surface.

Although tidal mixing can result in high surface nutrients in the passes, it can hinder the development of phytoplankton blooms by mixing the phytoplankton out of the euphotic zone and reducing their access to light

(Sverdrup 1953). Thus, blooms often occur north of the passes, away from the intense mixing in the passes, but utilizing the nutrients supplied by the mixing (Mordey et al. 2005). The vertical circulations created by interactions of tidal currents with steep and variable bathymetry can also result in surface convergences (i.e., fronts, eddies), creating regions of increased concentrations of prey for seabirds (Hunt et al. 1998) and other predators.

Figure 3.1 Mean Aleutian North Slope Current (ANSC)

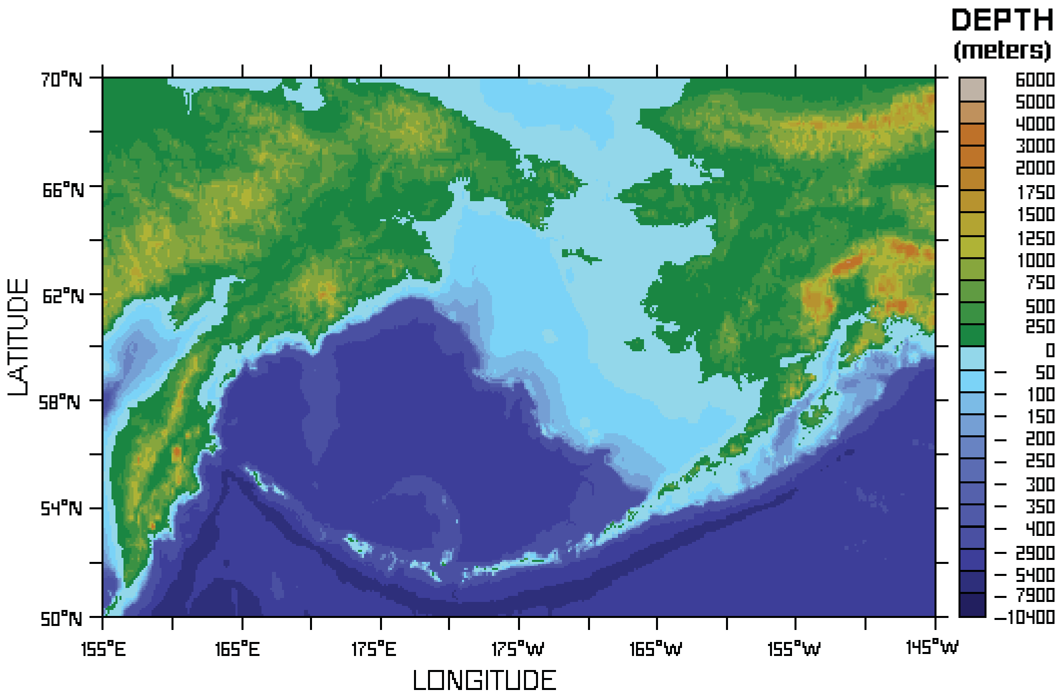


Notes:
ACC and Bering Sea Current directions along the Aleutian Islands (upper panel).
Depth of passes between islands (lower panel).
Source: Reproduced from Stabeno et al. 2005.

3.1.4 *Bathymetry*

The Aleutian Archipelago consists of 14 large, 55 small, and over 200 islets separated by oceanic passes that connect the waters of the North Pacific with the Bering Sea. The Aleutian Island chain marks the tectonic subduction zone between the North American and Pacific Plates. Bathymetry changes dramatically in a very short distance. The Bering Sea, to the north of the Islands, is shallow (<150 m) at the eastern end of the chain and more than 3,500 m deep at the western end. To the south of the Aleutian Islands, the Aleutian Trench is greater than 7,000 m deep (Figure 3.2). The passes between the islands vary from narrow, shallow passes in the east, to wider, deeper passes in the west (Figure 3.1).

Figure 3.2 Bathymetry Surrounding the Aleutian Islands



Source: Goddard Earth Sciences Data and Information Services Center.

3.2 HABITAT COMMUNITIES

3.2.1 Coastal Community

3.2.1.1 Littoral/Intertidal

The littoral zone, also known as the intertidal zone, is the area of the foreshore and seabed that is exposed to the air at low tide and submerged at high tide. There are four main intertidal habitats found on the Aleutian Islands: rocky intertidal, mudflats and beaches, eelgrass beds, and tidal marshes.

Rocky intertidal habitats of the Aleutians are categorized as exposed rocky steep shores that endure high to moderate wave energy, exposed wave cut platforms that endure high to moderate wave energy, and sheltered rocky shores found inside sheltered bays and coves that experience low energy waves.

Mudflats and beaches are also found in the intertidal zone with substrate ranging from soft silty clays (mud) to cobble and ranging from gentle sloping to steep beaches. Mudflats are found within sheltered areas where tidal currents expose the substrate at low tide. The substrate can consist of mud, sand, or a combination of the two. Because these areas are subject to low wave energy, they have gently sloping beaches that generally consist of fine-grained sands. Shores that are exposed to higher wave energy have beaches that are composed of cobble and gravels.

Eelgrass (*Zostera spp*.) represents the dominant seagrass community in Alaska, and is also the most studied seagrass in the state (McRoy 1968). *Zostera* grows in soft sediments of protected bays, inlets, and lagoons in Alaska (McRoy 1968) and plays an important role in their ecosystems. Eelgrass beds are ecologically important as primary producers in the food web, and as a source of cover from predators for fish and invertebrates (Wood et al. 1969). Izembek Lagoon, located east of Unimak Island on the Alaska Peninsula, contains the largest known bed of eelgrass in the world (15,000 to 16,000 hectares) (Ward et al. 1998).

Tidal marshes are typically located at river mouths; behind barrier islands, coves, and spits; and on tide flats where low energy wave action and fine sediment deposits provide elevated land for marsh vegetation to establish. They are located at mid- to upper intertidal elevations and characterized by salt-tolerant plant communities such as various types of sedges and grasses. Some of Alaska’s most extensive tidal marshes occur in the Bering Sea (Society of Wetland Scientists 1998).

3.2.1.2 Offshore

The offshore Aleutian Island habitats have a complicated mixture of substrates, including a significant proportion of hard substrates (pebbles, cobbles, boulders, and rock) (Heifetz et al. 2005). There are two distinct zones: east and west of Samalga Pass. East of the pass, the Aleutian Islands rise from shallow continental shelf covered by several sediment types deposited mainly during periods of glaciation. West of Samalga, steep rocky slopes to the north and south surround a mostly submerged mountain range resting on the Aleutian ridge (Hampton 1983). Cold-water corals and sponge communities are a dominant feature of benthic communities on the steep rocky slopes of the Aleutian Islands and likely provide important habitat for a variety of fish and invertebrate species. The geographical split in substrate type at Samalga Pass is coincident with a shift in coral species diversity with higher diversity to the west as well as shifts in surface water properties and populations of fish, invertebrates, seabirds, and marine mammals (Heifetz et al. 2005).

3.2.2 *Benthic Community*

3.2.2.1 Subtidal

Corals and sponges

Within the Aleutian Islands, there is an increase in diversity of corals west of about longitude 169°W. This distinct ecological boundary, in the vicinity of Samalga Pass between Chuginadak and Umnak islands, is likely the result of the interaction of physical processes and is not restricted to benthic communities (Coyle 2005). The Aleutian Islands may harbor highest diversity and abundance of cold-water corals in the world (Heifetz et al. 2005). To date, 97 species or subspecies of corals have been reported from the Aleutian Islands, and 25 of these species are believed to be endemic to the region (TRB Special Report 293 2009).

In the Aleutians, corals and sponges form large "groves," which are sensitive to human-induced or natural change; some species are believed to live hundreds if not thousands of years (Andrews et al. 2002). Corals and sponges provide important habitat and refuge for a variety of fish and invertebrates (Kreiger and Wing 2002). Epifauna associated with these groves include sea stars, basket stars, polychaetes, snails, sponges, anemones, rockfish, shrimp and crabs. In the Aleutian Islands, corals and sponges may be "keystone species" (Tews et al. 2004) that by their presence determine benthic fish and invertebrate diversity and abundance.

3.2.2.2 Pelagic Zone

High primary productivity over the Bering Sea shelf results from the northward movement of nutrient-rich water entering the Bering Sea through the passes from the Gulf of Alaska onto the outer eastern continental shelf (Stabeno et al. 1999). As this water moves westward across the outer shelf as a slope current, it splits into northward and southward components. Most of the northward flow passes to the west of St. Lawrence Island. The productivity of the southeast Bering Sea middle shelf, between 50 and 100 m in depth, depends on nutrients transported into the area or regenerated in situ, and over this part of the shelf the northward flow is insufficient to compensate for utilization by the primary producers in spring and summer (Schumacher and Stabeno 1998). Mesoscale processes such as upwelling and transport by eddies are important in nutrient supply. One result of this hydrographic regime is a belt of high productivity in summer along the outer edge of the shelf, the so-called "Green Belt," which lies seaward of the 160 m isobath (Springer et al. 1996).

3.2.2.3 *Intertidal*

The key representative receptor of the intertidal area evaluated in this report is eelgrass. The distribution of eelgrass is limited by light penetration and is typically found in low intertidal and shallow subtidal sandy mudflats along sheltered coastlines. Izembek lagoon in the eastern Aleutians is the site of one of the largest eelgrass beds in the world. The physical structure of eelgrass beds provides increased living substrate and cover for invertebrates and fish. Eelgrass is particularly sensitive to turbidity and changes in water quality.

3.3 SEABIRDS

Seabirds observed in the Aleutians include albatrosses, shearwaters, petrels (*Procellariiformes*), cormorants (*Pelecaniformes*), and two families of Charadriiformes, gulls (*Laridae*), and auks (*Alcidae*), which include puffins, murres, auklets, and murrelets. Several species of sea ducks (*Merganini*) also spend much of their lives in marine waters in the project area. The Aleutians provide a substantial portion of the worldwide range for many of these species. Most of these species rely primarily on forage fish, although several auklets are more planktivorous and eiders take more crustacea.

The short-tailed shearwaters (*Puffinus tenuirostris*) and northern fulmars (*Fulmarus glacialis*) are the most abundant seabirds in the coastal waters of the eastern Aleutian Islands and in the oceanic waters of the central Aleutian Islands, respectively.

3.3.1 Breeding Birds

The 1,800-kilometer (km) long Aleutian Archipelago provides suitable breeding habitat for more than 10 million seabirds (Byrd et al. 2005), comprising 26 species. Distribution is largely dictated by suitable nesting sites and prey availability (fish and zooplankton) for seabirds. Passes between islands are considered to be particularly important foraging habitats for breeding seabirds due to strong tidal currents, often overflowing sills, which bring nutrient-rich water to the surface and concentrate plankton, creating favorable feeding conditions for many species.

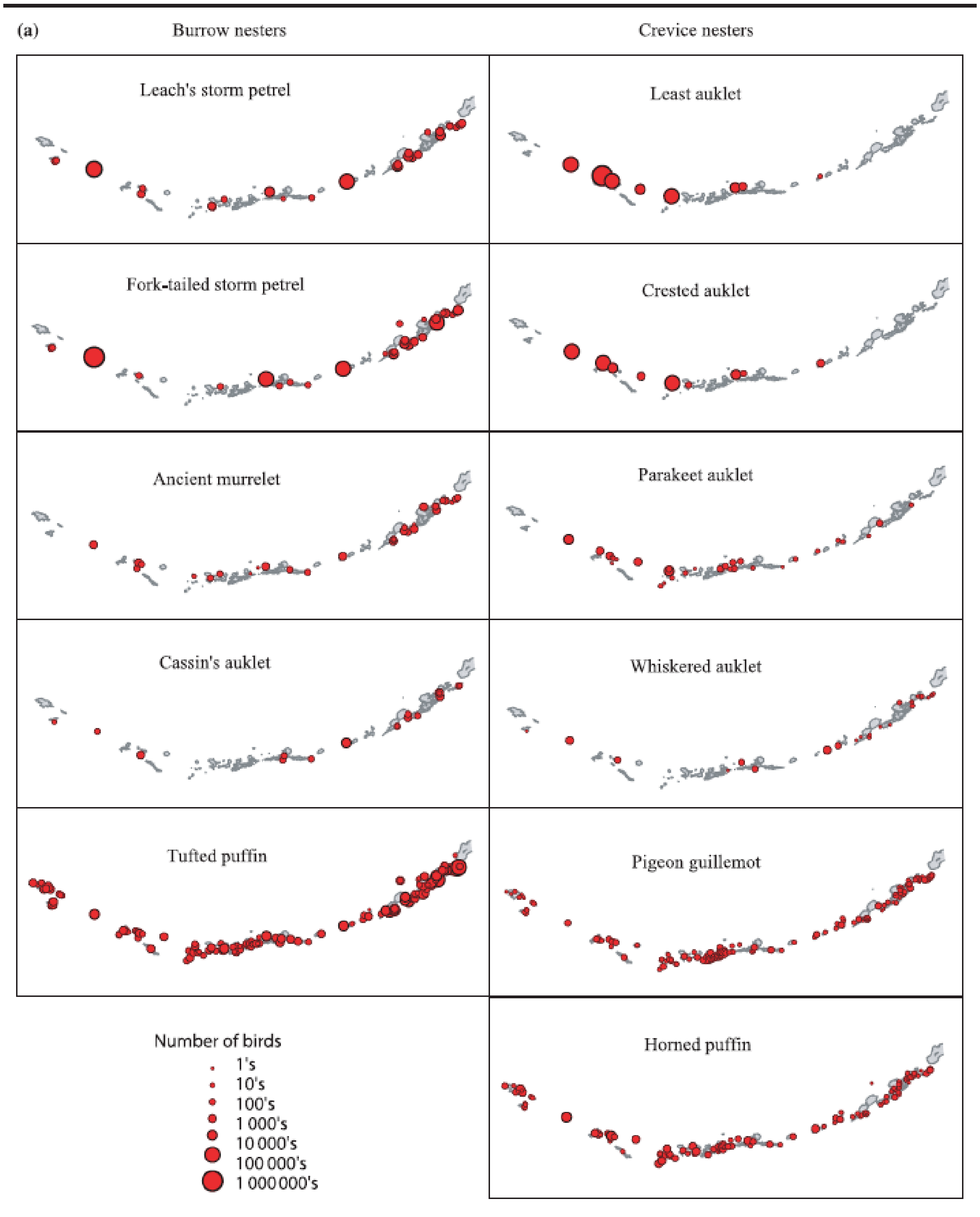
Seabirds breeding in the Aleutian Islands are known to occupy various habitats along the shoreline. There are four types considered:

- Crevice nesters (eggs are laid inside crevices within talus fields, boulder-strewn beaches and cracks in cliffs);
- Burrow nesters (these species excavate tunnels to nest sites in soil);
- Ledge nesters (eggs are laid on ledges on cliff faces); and
- Surface nesters (eggs are laid on the ground).

Figure 3.3 and Figure 3.4 show the distribution of nesting seabird colonies in the Aleutian Islands and the relative number of birds found at these colonies. Breeding colonies of least and crested auklets (*Aethia pusilla* and *Aethia cristatella*) occur in the western and central Aleutians, typically between Buldir and Gareloi islands. Whiskered auklets (*Aethia pygmaea*) have been recorded on nearly 40 percent of all the islands with seabird colonies of any type.

All species of burrow nesters in the Aleutians show apparently similar distributions (see Figure 3.3). Four planktivorous species (Leach's and fork-tailed storm-petrel, *Oceanodroma leucorhoa* and *furcata*, ancient murrelet, *Synthliboramphus antiquus*, Cassin's auklet, *Ptychoramphus aleutica*) occur in a patchy distribution throughout the Aleutians, with the largest colonies on Buldir, Koniuji, and Chagulak. Smaller colonies occur in relatively dense concentrations in the eastern Aleutians. The whiskered auklet (*Aethea pygmaea*) is one of the rarest seabirds in the US. An estimated 116,000 whiskered auklets live in the Aleutians. The whiskered auklet is secretive and nocturnal and is particularly susceptible to disturbance and mortality from lighted vessels.

Figure 3.3 Maps Showing Distribution of Nesting Colonies of Burrow and Crevice Nesting

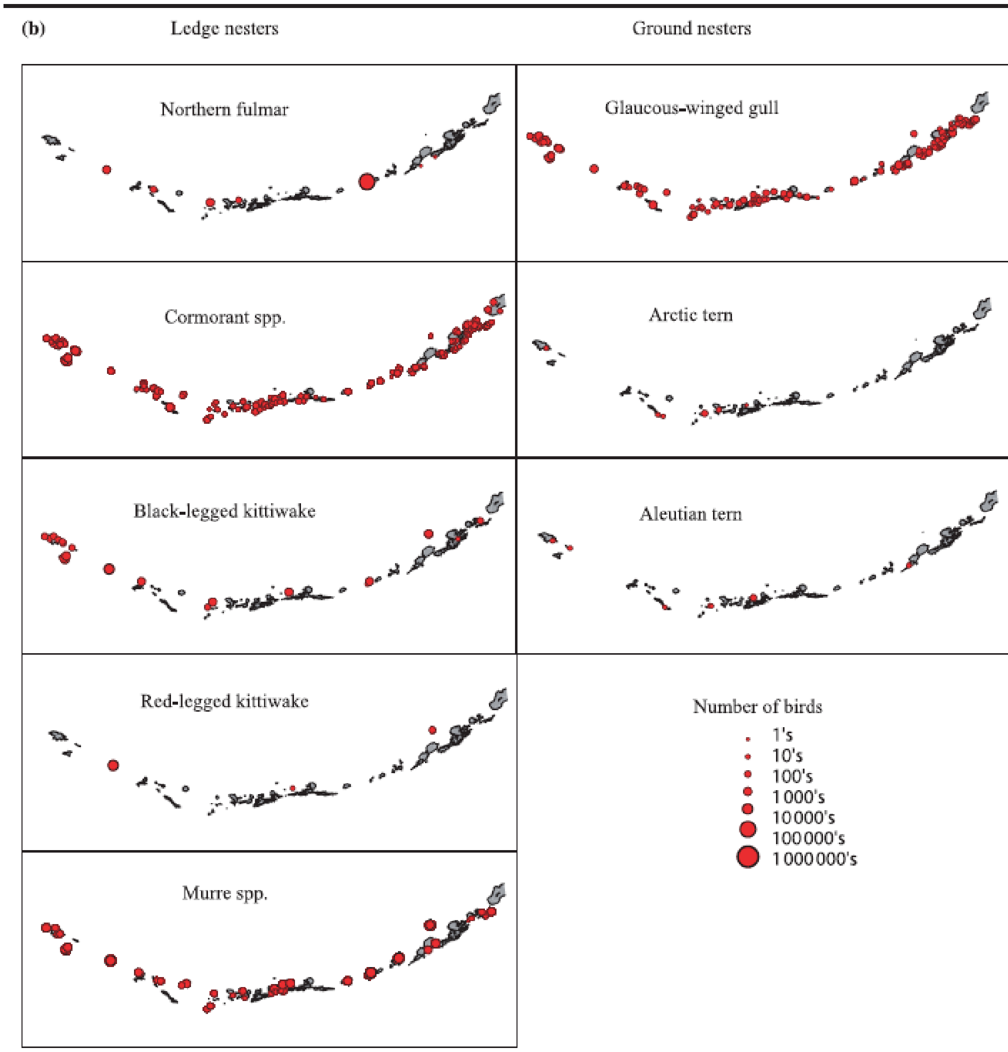


Source: Byrd and Renner 2005.

The distribution of offshore feeders such as the black-legged kittiwake (*Rissa tridactyla*) and tufted puffins (*Fratercula cirrhata*) extend across the Aleutians. Huge colonies of kittiwakes take up residence on the steep cliffs of the Aleutian Islands. Horned puffins (*Fratercula corniculata*) and cormorant species are found across the Aleutians feeding in the nearshore and nesting in crevices and ledges, respectively.

Piscivorous surface nesters breeding with the Aleutian Archipelago include northern fulmars (*Fulmarus glacialis*), glaucous-winged gulls (*Larus glaucescens*), marbled (*Brachyramphus marmoratus*), Kittlitz's murrelets (*Brachyramphus brevirostris*), and Aleutian and Arctic terns (*Sterna aleutica* and *S. paradisaea*). These species are particularly vulnerable to predation on islands where mammals, e.g., rats and foxes, are present.

Figure 3.4 Maps Showing Distribution of Nesting Colonies of Ledge and Ground Nesting Seabirds in the Aleutian Islands



Source: Byrd and Renner 2005.

Pelagic and red-faced cormorants (*Phalacrocorax pelagicus* and *Phalacrocorax urile*) typically nest in fairly small colonies (<200 birds). Red-faced cormorants are listed on the Audubon's Alaska Bird Watch List as a species at risk (Audubon 2007a). Other breeding seabird species of most concern in the Aleutians include (Audubon 2007b):

- Red-throated loon (*Gavia stellata*), a species particularly vulnerable to marine oil spills and bycatch by fisheries; and
- Green-winged teal (Aleutian) (*Anas crecca nimia*), a subspecies restricted to the Aleutian Islands year-round (vulnerable to introduced predators, such as rats).

Breeding populations of black scoter (*Melanitta nigra*) and the long-tailed duck (*Clangula hyemalis*), both diving ducks that feed on benthic invertebrates, are vulnerable to marine oil spills and contaminants.

3.3.1.1 Gulls and Terns

The distribution of offshore feeders such as the black-legged kittiwake (*Rissa tridactyla*) extend across the Aleutians. Huge colonies of kittiwakes take up residence on the steep cliffs of the Aleutian Islands (USFWS 2006).

Example piscivorous surface nesters with breeding areas within the Aleutians include northern fulmars (*Fulmarus glacialis*), glaucous-winged gulls (*Larus glaucescens*), and Aleutian and Arctic terns (*Sterna aleutica* and *S. paradisaea*). These species are particularly vulnerable to predation on islands where mammals, e.g., rats and foxes, are present (USFWS 2006).

Northern fulmars (*Fulmarus glacialis*) are a very abundant pelagic seabird in the coastal waters of the eastern Aleutian Islands. Over 70 percent of the world's population is estimated to live in Alaska in 38 different breeding colonies. Unlike the short-tailed shearwaters, the northern fulmars are found year-round as their breeding grounds are found in the eastern and central Aleutian Islands (USFWS 2006).

3.3.1.2 Waterfowl

Cormorant species are found across the Aleutians feeding in the nearshore and nesting on ledges. Pelagic and red-faced cormorants (*Phalacrocorax pelagicus* and *Phalacrocorax urile*, respectively) typically nest in fairly small colonies (<200 birds) (USFWS 2006). Red-faced cormorants are listed on the Audubon's Alaska Bird Watch List as a species at risk (Audubon 2007a). Other breeding seabird species of most concern in the Aleutians include (Audubon 2007b):

- Red-throated loon (*Gavia stellata*) which is a species particularly vulnerable to marine oil spills and bycatch by fisheries; and

- Green-winged teal (Aleutian) (*Anas crecca nimia*), a subspecies restricted to the Aleutian Islands year-round. This species is vulnerable to introduced predators such as rats.

Breeding populations of black scoter (*Melanitta nigra*) and the long-tailed duck (*Clangula hyemalis*), both diving ducks that feed on benthic invertebrates, are vulnerable to marine oil spills and contaminants.

3.3.1.3 Auks

Breeding colonies of least and crested auklets (*Aethia pusilla* and *Aethia cristatella*, respectively) occur in the western and central Aleutians, typically between Buldir and Gareloi islands. Whiskered auklets (*Aethia pygmaea*) have been recorded on nearly 40 percent of all the islands with seabird colonies of any type. The whiskered auklet (*Aethea pygmaea*) is one of the rarest seabirds in the US. An estimated 116,000 whiskered auklets live in the Aleutians. The whiskered auklet is secretive and nocturnal and is particularly susceptible to disturbance and mortality from lighted vessels.

The burrow nesters, Cassin's auklet (*Ptychoramphus aleutica*) and ancient murrelet, (*Synthliboramphus antiquus*) occur in a patchy distribution throughout the Aleutians, with the largest colonies on Buldir, Koniuji, and Chagulak islands.

All species of burrow nesters in the Aleutians show apparently similar distributions (see Figure 3.3). Two planktivorous species (i.e., Leach's and fork-tailed storm-petrel, *Oceanodroma leucorhoa* and *furcata*;) occur in a patchy distribution throughout the Aleutians, with the largest colonies on Buldir, Koniuji, and Chagulak.

Piscivorous surface nesters breeding within the Aleutian Archipelago include marbled murrelets (*Brachyramphus marmoratus*) and Kittlitz's murrelets (*Brachyramphus brevirostris*). These species are particularly vulnerable to predation on islands where mammals, e.g., rats and foxes, are present.

Horned puffins (*Fratercula corniculata*) are found across the Aleutians feeding in the nearshore and nesting in crevices. Tufted puffins (*Fratercula cirrhata*) are offshore feeders and are distributed across the Aleutians.

3.3.2 *Wintering or Migratory Birds*

The Aleutian Islands provide important feeding and foraging areas for many migrating seabirds. Migratory birds include shearwaters, pintails and mallards, Canada geese, cackling Canada geese, Pacific white-fronted geese, black scoters, and black brants.

3.3.2.1 *Waterfowl*

Mudflats are an important stopover for migrating birds such as western sandpiper (*Calidris mauri*) and dunlin (*Calidris alpina*), which depend in ice-free foraging grounds during their spring migration. Sandpipers as well as many of the migrating species feed primarily on Baltic macoma clams (*Macoma balthica*). Species known to feed on mudflats during the winter include long-tailed ducks (*Clangula hyemalis*), surf scoters (*Melanitta perspicillata*) and black scoters (*M. nigra*).

Coastal waters are an important staging area for migratory waterfowl, particularly seaducks. Migratory waterfowl species on the Audubon Watchlist include (Audubon 2007b):

- Emperor goose (*Chen canagica*) – there is a small global population and they are particularly vulnerable to marine oil spills and winter habitat loss (eelgrass beds);
- King eider (*Somateria spectabilis*) – there are declining numbers of spring migrants;
- Black scoter (*Melanitta nigra*) – vulnerable to marine oil spills; and
- Long-tailed duck (*Clangula hyemalis*) – this population is undergoing long-term decline, although some recovery has been observed in recent years.

The short-tailed shearwaters (*Puffinus tenuirostris*) are one of the most abundant seabirds found in pelagic Alaskan waters. However, as they migrate to Australia to breed, they are not found in Alaskan waters during the summer (USFWS 2006a).

3.3.3 *Endangered Species Act-Listed Species*

Three species of seabirds found within the Aleutian Islands are listed as either endangered or threatened under the Endangered Species Act (ESA). These include:

- Short-tailed albatross (*Phoebastria albatrus*) (endangered);

- Spectacled eider (*Somateria fischeri*) (threatened); and
- Steller's eider (*Polysticta stelleri*) (threatened).

The population of short-tailed albatross is estimated to be 1,200 worldwide and they are only known to breed in Japan; however, they forage on the outer shelf across the Aleutian Islands outside of their breeding season (Alaska Fish and Wildlife Service). Numerous spectacled eiders and Steller's eiders moult and over-winter primarily in the eastern Aleutian Islands.

3.3.4 Important Bird Areas

There are 39 Important Bird Areas (IBAs) designated across the Aleutian Islands. An IBA is an area designated as being globally important habitat for the conservation of bird populations developed by BirdLife International. To qualify as an IBA, a site must regularly support significant numbers of species of conservation concern; attract large numbers of breeding, wintering, or migrating birds; or support species characteristic of a unique habitat.

3.4 MAMMALS

There are at least 26 species of marine mammal residents or migrants of the seas around the Aleutian Islands, including pinnipeds, cetaceans, otters, and walrus. The islands provide important breeding habitat for many species of marine mammals including Steller sea lions and northern sea otters, listed as endangered and threatened under the ESA, respectively. Harbor seals are abundant in the Aleutian Islands and are also an important subsistence species. Table 3.2 provides details of the relevant distribution and timings of these mammals and their conservation status under the ESA of 1973 and Marine Mammal Protection Act (MMPA), as well as the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (IUCN 2009).

Table 3.2 Relevant Distribution and Timing of Marine Mammals

Marine Mammal	Latin Name	Relevant Distribution and Timing	Status under the ESA	Status under the MMPA	IUCN Conservation Status
Pinnipeds					
Steller Sea Lion (Western Distinct Population Segment)	*Eumetopias jubatus*	The species is known to haul out throughout the Aleutian Islands in high abundances (IUCN 2009). Haulout sites are used for periods of rest, molting, and as rookeries for mating and pupping during the breeding season. The breeding season extends from late May-early July when dispersal occurring by mid-September. Breeding takes place on a large number of islands. Primarily found from the coast to the outer continental shelf and slope. Areas important to the success of the species have been designated as 'critical habitat' by the National Marine Fisheries Service (NMFS). Feeds on many varieties of fish and invertebrates including walleye Pollock, Pacific cod, atka mackerel, herring, sand lance, several varieties of flatfish, salmon and rockfish, and invertebrates such as squid, octopus, bivalves and gastropods. Evidence of a major decline in Steller sea lion abundance throughout most of its range (NOAA 2010).	Endangered (Western DPS)	Depleted	Endangered
Northern fur seal	*Callorhinus ursinus*	The species is known to haul out throughout the Aleutian Islands in high abundances (IUCN 2009). They are one of the most pelagic pinnipeds, spending most of the year at sea, returning to land only during the breeding season. Males spend an average of only 45 days ashore a year and females only 35 days a year. During breeding season (mid-June - August), most of the worldwide population is found on the Pribilof Islands in the northern Bering Sea where they remain for up to 6 months of the year. Only breeding site in Aleutians is Bogoslof Island, where population has increased (IUCN 2009). These islands host the world's largest rookeries	Threatened	Depleted	Vulnerable

Marine Mammal	Latin Name	Relevant Distribution and Timing	Status under the ESA	Status under the MMPA	IUCN Conservation Status
		for this species. Following breeding, migration through the Aleutian Islands into the North Pacific Ocean (Ream et al. 2005).			
Pacific harbor seal (Bering Sea Stock)	*Phoca vitulina richardsi*	Coastal species - mainly found in waters of the continental shelf. They haul out on rocks, reefs, and beaches. Two periods of relatively high activity on Aleutians- pupping during May - June and molting August - September. Harbor seals are gregarious at haul-out sites, but generally found alone in coastal waters. Generally non-migratory and undergo only local movements associated with such factors as tides, weather, season, food availability, and reproduction (Ream et al. 2005). Populations in the GOA and Prince William Sound have recently declined, thought partly to be related to the effects of the Exxon Valdez disaster, although the overall decline in GOA is unexplained (IUCN 2009).	Protected	Protected	Least Concern
Spotted seal (southern distinct population segment)	*Phoca largha*	Distribution largely associated with ice - this species is concentrated in the north of the Bering Sea. Known to occasionally occur around the Pribilof Islands, Bristol Bay, and the eastern Aleutian Islands.	Threatened	Protected	Data Deficient
Ribbon seal	*Histriophoca fasciata*	Distribution is largely associated with ice - over winters in the north of the Bering's Sea. Ribbon seals are solitary for much of their lives. Range extends as far south as the Aleutian Islands.	Protected	Protected	Data Deficient
Cetaceans					

Marine Mammal	Latin Name	Relevant Distribution and Timing	Status under the ESA	Status under the MMPA	IUCN Conservation Status
Killer whale	*Orcinus orca*	Killer whales are found both seasonal visitors and resident throughout Alaska, with population resident to the Aleutian Islands (Braham and Dahlheim 1982). In the northeastern Pacific, from California to the western Aleutian Islands and Bering Sea, at least 2,250-2,700 resident, transient, and offshore whales are currently thought to exist (NOAA Fisheries 2010a). Most abundant in coastal waters and are rarely seen offshore. In the eastern North Pacific, the resident killer whale populations mainly feed on salmonids such as Chinook and chum salmon, while the transient population feeds on other marine mammals, such as Dall's porpoises, Pacific white-sided dolphins, Steller sea lions, harbor seals, sea otters, and even large baleen whales (NOAA Fisheries 2010a).	Protected	Protected	Data Deficient
Pacific white-sided dolphin	*Lagenorhynchus obliquidens*	The species is common both in coastal waters and offshore. They prey on squid and small schooling fish such as capelin, sardines, and herring.	Protected	Protected	Least Concern
Harbor porpoise	*Phocoena phocoena*	Primarily frequents coastal waters and is found throughout the Aleutian Islands mostly in waters less than 100 m in depth. They feed on demersal and benthic species, mainly consisting of schooling fish (e.g., herring and capelin) and cephalopods.	Protected	Protected	Least Concern
Sperm whale	*Physeter macrocephalus*	Sightings surveys conducted by National Marine Mammal Laboratory (NMML) in the summer months between 2001 and 2006 have found sperm whales to be the most frequently sighted large cetacean in the coastal waters around the central and western Aleutian Islands (NMML unpublished data) (Angliss and Allen 2009). Sperm whales tend to inhabit areas with a water depth of 600 m or more, and are uncommon in waters less than 300 m deep (NOAA Fisheries 2010c).	Endangered	Depleted	Vulnerable

Marine Mammal	Latin Name	Relevant Distribution and Timing	Status under the ESA	Status under the MMPA	IUCN Conservation Status
Baird's beaked whale	*Berardius bairdii*	Baird's beaked whales' primary habitats appear to be over or near the continental slope and near oceanic seamounts in temperate oceanic waters 1,000 to 3,000 m deep. Distribution extends throughout the Aleutian Islands. Feed on pelagic fish species (e.g., mackerel and sardines), crustaceans, sea cucumbers, and cephalopods. Migratory species - between April and October, Baird's beaked whales been observed in the nearshore waters of the Bering Sea.	Protected	Protected	Data Deficient
Cuvier's beaked whale	*Ziphius cavirostris*	Found south of the Aleutian Islands preferring deep waters. When at the surface, Cuvier's beaked whales rarely breach or display other active behavior. Feed on mostly cephalopods (e.g., squid and octopus) and sometimes fish and crustaceans.	Protected	Protected	Least Concern
Stejneger's beaked whale	*Mesoplodon stejnegeri*	Several sightings and strandings of this species have taken place around the Aleutian Islands and near the central Aleutian Islands (Rice 1986). Feed on small deep-water fish, tunicates, and cephalopods (e.g., squid) of the families Gonatidae and Cranchiidae in deep waters.	Protected	Protected	Data Deficient
Gray whale	*Eschrichtius robustus*	Gray whales are found mainly in shallow coastal waters. Often found along the eastern Aleutian Islands in summer during feeding period. In autumn, gray whales migrate from their summer feeding grounds, to spend the winter in their breeding and calving areas off the coast of Baja California, Mexico. From mid-February to May, the Eastern North Pacific stock of gray whales can be seen migrating northward with newborn calves along the West Coast of the U.S.	Protected	Protected	Least Concern

Marine Mammal	Latin Name	Relevant Distribution and Timing	Status under the ESA	Status under the MMPA	IUCN Conservation Status
Humpback whale	*Megaptera novaeangliae*	The Bering Sea is an important feeding ground for the humpback whale. Humpbacks filter feed on tiny crustaceans (mostly krill), plankton, and small fish. Numerous humpback whales are found north of the central Aleutian Islands (Angliss and Allen 2009) although they are only occasional migrants to Aleutian Islands. During migration, humpbacks stay near the water surface.	Endangered	Depleted	Least Concern
Fin whale	*Balaenoptera physalus*	Fin whales are migratory, moving seasonally into and out of high-latitude feeding areas. During the summer, fin whales feed on krill, small schooling fish (e.g., herring, capelin, and sand lance), and squid. It is estimated that a population of 5,700 whales inhabit the Bering Sea, coastal Aleutian Islands and GOA (IUCN 2009).	Endangered	Depleted	Endangered
Minke whale	*Balaenoptera acutorostrata*	Minke whales are common in the Bering Sea, Central and Western Aleutian Islands and are thought to be migratory. The common minke whale occurs in both coastal and offshore waters and exploits a variety of prey including crustaceans (e.g., krill), plankton (e.g., copepods), and small schooling fish (e.g., capelin, cod, eels, herring, mackerel and salmon) (NOAA Fisheries 2010b).	Protected	Protected	Least Concern

Marine Mammal	Latin Name	Relevant Distribution and Timing	Status under the ESA	Status under the MMPA	IUCN Conservation Status
North Pacific right whale	*Eubalaena japonica*	Critical habitat north of the eastern Aleutians. They primarily occur in coastal or shelf waters, although movements over deep waters are known. Calve in coastal waters during winter. In 2006, the NMFS designated two areas as northern right whale critical habitat, one in the GOA and one in the Bering Sea (northeast of the Aleutian Island chain) (Angliss and Allen 2009). Migratory patterns of the North Pacific right whale are unknown, although it is thought the whales spend the summer on high-latitude feeding grounds and migrate to more temperate waters during the winter.	Endangered	Depleted	Endangered
Pacific walrus	*Odobenus rosmarus divergens*	Walruses feed on clams and a wide variety of other invertebrates from the seafloor. Distribution varies markedly with the seasons. Through the winter they generally congregate in two areas, one immediately southwest of St. Lawrence Island and the other in outer Bristol Bay. As pack ice begins to loosen in April, walruses begin to move northward. By late April the distribution extends from Bristol Bay northward to the Bering Strait.	Petitioned to be listed	Protected	Data Deficient

Marine Mammal	Latin Name	Relevant Distribution and Timing	Status under the ESA	Status under the MMPA	IUCN Conservation Status
Northern sea otter (Southwest Alaska Distinct Population Segment)	*Enhydra lutris kenyoni*	Sea otters pup throughout the year although their peak period of production is spring and summer (Kenyon 1969). The northern sea otter requires frequent access to benthic foraging habitat in subtidal and intertidal zones and is therefore most commonly observed within the 40 m depth contour since animals (Riedman et al. 1990). They typically stay within a kilometer of the shore. Their classic association is with rocky substrates supporting kelp beds, but they also frequent soft-sediment areas where kelp is absent. Kelp canopy is an important habitat for foraging and resting of this species. Sea otters feed almost exclusively on marine invertebrates, including sea urchins, a variety of bivalves such as clams and mussels, abalone, other mollusks, crustaceans, and snails. Not migratory. Very sensitive to oil spills as once oiled this species fur loses its insulative property and hypothermia occurs as sea otters have no blubber layer.	Threatened	Depleted	Endangered

Note: "Protected" means the species affords the protection of the ESA or MMPA, but do not have any special status under these Acts.
Source: NMFS 2009; IUCN 2009.

The Aleutian Islands provide suitable habitat for a number of migratory and resident species of marine mammal. Of all the marine mammals detailed in Table 3.2, it is considered that species typically associated with nearshore are likely to be most sensitive to an oil spill, e.g., sea otters, seals and walrus. Many of these species haul out or breed along the coast of the Aleutian Islands.

Steller sea lion critical habitat includes a 20-nautical-mile buffer around all major haulouts and rookeries, as well as associated terrestrial, air, and aquatic zones, and three large offshore foraging areas. There are 33 recognized rookery sites for this species across the Aleutian Islands and, as seen in Figure 3.5, most of the islands are designated critical habitat for this species (NMFS 2010a).

Figure 3.5 Steller Sea Lion Critical Habitat Map

Source: NMFS 2010b.

Sea otters, currently listed as threatened under ESA, are particularly sensitive to oil spills. They rely on air trapped in their fur for warmth and buoyancy. Contamination with oil drastically reduces the insulative value of the pelage, and consequently, sea otters are among the marine mammals most likely to be detrimentally affected by contact with oil (Angliss and Allen 2009). It is believed that sea otters can survive low levels of oil contamination (<10% of body surface), but that greater levels (>25%) will lead to death (Costa and Kooyman 1981; Siniff et al. 1982). Vulnerability of sea otters to oiling was demonstrated by the 1989 Exxon Valdez oil spill in Prince William Sound. It was estimated that 3,905 sea otters (range 1,904 - 11,257) died in Alaska as a result of the spill (DeGange et al. 1994). Evidence suggests that sea otters and the nearshore ecosystem have not yet fully recovered from the spill, with populations remaining below pre-spill levels (Bodkin et al. 2002; Stephenson et al. 2001).

Mobile species that are generally found offshore are less likely to be affected by an oil spill as they are typically benthic or pelagic feeders.

3.5 FISH

The marine environment of the Aleutian Islands is known to have an abundant and biodiverse fish population. Numerous species are regarded as particularly important for commercial fisheries. The key commercially important and ecologically sensitive species are identified within this section.

3.5.1 Commercial Species

In recent decades, it has been recognized that many populations of commercial species in the Bering Sea are in decline. Numerous species of demersal, pelagic, and slope rockfish (*Sebestas* and *Sebastolobus spp*.) are fished on a commercial scale along the Aleutians Islands, many of which are vulnerable to over-fishing. Arrowtooth flounder (*Atheresthes siomas*), Alaska plaice, Pacific halibut, rock sole, and flathead sole are the most abundant and/or important commercial flatfish species.

Groundfish (species that live on or near the sea floor and at the edge of the continental shelf) are regarded as the most valuable species in the Aleutian Islands. Pacific cod, walleye pollock (*Theragra chalcogramma*), Atka mackerel, and sablefish dominate the catch. The ecology and behavior of these key species are described below.

Walleye pollock, a member of the cod family, are schooling, midwater to bottom-dwelling fish. They typically inhabit shallow waters from 100-300 m depth, and up to depths of 1,000 m. In summer, pollock move inshore and in winter they occupy greater depths offshore. Pollock may live up to

17 years and reach a length of 100 centimeters (cm). Spawning takes place between March and May in Alaskan waters at depths of 100 to 250 m over a few weeks. At night, juvenile pollock feed on plankton near the surface and, during the day, they migrate to deeper waters. Mature fish consume copepods, shrimp, euphausiids, and fish. Walleye pollock are an important prey species for a wide range of piscivorous fish and marine mammals, including Steller sea lions and harbor seals.

Pacific cod (*Gadus macrocephalus*) are a demersal species and concentrate on the shelf edge and upper slope (100 to 250 m) in the winter and move to shallower waters (<100 m) in the summer. Cod feed on bivalves (clams), crustaceans (crabs and shrimp), and juvenile fish. They themselves are preyed upon by halibut and marine mammals. In the late winter, Pacific cod converge in large spawning masses over relatively small areas. Spawning takes place from January to April, near the bottom along the continental shelf and slope at depths of 100 to 200 m. In the summer, these fish move into shallower waters (less than 100 m deep) following spawning. Major spawning aggregations occur between Unalaska and Unimak islands and southwest of the Pribilof Islands (Shimada and Kimura 1994).

Atka mackerel (*Pleurogrammus monopterygius*), a schooling, semi-demersal species are abundant in the Aleutian Islands, especially from Buldir Island (Aleutians West) to Sequam Pass. Atka mackerel migrate from the shelf edge to shallow coastal waters (5 to 30 m) of the Aleutian Islands where they spawn between July and September. Eggs are adhesive and deposited in rock crevices, where they are guarded by the males until hatching, which occurs about 40 to 45 days later.

Sablefish (*Anoplopoma fimbria*) are found only in the North Pacific Ocean, the Bering Sea, and in adjacent waters from Hokkaido, Japan to Baja, and California. The greatest abundance of sablefish are found in the Gulf of Alaska (Alaska Department of Fish and Game [ADF&G] 2010a). Adult sablefish typically occur along the continental slope, shelf gullies, and in deep fjords commonly at depths of 366 to 914 m. Sablefish spawn in pelagic waters near the edge of the continental slope (300 to 500 m depth) in the spring of the year (McFarlane et al. 1988).

The most common flatfish species found in the waters surrounding the Aleutian Islands are Alaska plaice (*Pleuronectes quadriterculatus*), rex sole (*Glyptocephalus zachirus*), Dover sole (*Microstomus pacificus*), starry flounder (*Platichthys stellatus*), English sole (*Parophrys vetulus*), butter sole (*Isopsetta isolepis*), sand sole (*Psettichthys melanostictus*), and deepsea sole (*Embassichthys bathybius*). The adult form of these species is benthic.

Typically adults over-winter in deeper water and move into nearshore waters for spawning in late winter and spring. Spawning takes place as early as November for Dover sole (Hagerman 1952), but occurs from February through April for most species (Hart 1973). Most flatfish eggs are pelagic and sink to the bottom shortly before hatching.

Arrowtooth flounder are very important as a large, aggressive, and abundant predator of other groundfish species. Spawning is variable and probably occurs from September through March (Zimmerman 1997). Larvae are planktonic for at least 2 to 3 months and juveniles usually inhabit shallow areas.

3.5.2 *Other Important Species*

Several salmonoid species occur in the waters including the following Pacific salmon: pink (*Oncorhynchus gorbuscha*), chum (*O. keta*), sockeye (*O. nerka*), and coho (*O. kisutch*). Salmon spawn upstream in freshwaters between where their eggs hatch and go through several developmental stages. Salmonoids then migrate downstream as fry or smolts. A high abundance of salmonoid species is found in the waters off the Aleutian Islands. This is a result of a number of factors including favorable ocean conditions that promote high survival rates of juveniles, and hatchery production. Many of the streams and freshwater river systems within the Aleutian Islands act as important spawning grounds. Pink salmon are the most abundant and widespread of the species. In some years, Unalaska, Umnak, Unimak, Atka, Amlia, Adak and Attu islands produce large pink salmon runs.

Salmonoids typically begin their migration upstream between late summer and late autumn, although timing varies depending on species and streams, and between years.

3.5.3 *Fish Species of Conservation Importance*

Under the federal ESA, species considered to be endangered or threatened in Alaskan waters are awarded protection. There are no marine fish species regarded as being of conservation concern within the Aleutian Islands marine environment, with the exception of the Chinook salmon (*Oncorhynchus tshawytscha*).

The Snake River fall-run Chinook salmon is regarded as a species of conservation concern in Alaska and is recognized as a "Federal threatened species" (ADF&G 2010b). Chinook salmon are diadromous and undergo extensive migrations between their freshwater spawning grounds and their feeding grounds in the marine environment. This species is found inshore and offshore throughout the North Pacific and Bering Sea and is known to congregate around the Aleutian Islands and in the western Gulf of Alaska.

Spawning habitat of Snake River fall Chinook salmon takes place in the Snake River and in the lower reaches of several major rivers. Spawning occurs from October through November and fry emerge from March through April. Downstream migration generally begins within several weeks of hatching. The fish spend 3 years at sea prior to returning to their birth streams. In the marine environment, they have a varied diet, feeding on herring, pilchard, sand lance, squid, and crustaceans (ADF&G 2010c).

3.6 SOCIOECONOMIC RESOURCES

The scope of this report limits the socioeconomic resources that were included for the consequences analysis. The resources included are those that would likely experience the greatest impacts resulting from an oil spill. This socioeconomic baseline includes an overview of the following socioeconomic resources within the study area:

- Commercial and recreational fisheries;
- Subsistence;
- Historic preservation sites;
- Marine recreation and tourism; and
- Coastal development and coastal infrastructure.

To provide a meaningful consequence analysis, the study area boundaries extend beyond lines of latitude and longitude to include communities potentially affected. The study area includes western portions of the Aleutians East Borough (AEB) and extends through the Aleutian Chain, which is in the Aleutian West Coastal Resource Service Area (AWCRSA). Table 3.3 lists the communities and the potentially affected populations in the study area.

Table 3.3 Communities and Populations in Study Area

Community	Population
Adak	165
Akutan	846
Atka	71
Cold Bay	84
False Pass	41
King Cove	744
Nikolski	33
Sand Point	1,001
Sheyma Station	27
Unalaska	3,662

Source: Alaska Department of Community and Regional Affairs (DCRA, Demographics Database) 2010.

Unalaska, as the largest community, is considered to have the most diverse economy and as such is an economic center of the region. Unalaska is also "recognized both as an international trade center and a regional transportation hub" (LaRoche and Associates 2005).

3.6.1 Commercial Fisheries

The US has exclusive fishery management authority over all marine fishery resources in the Exclusive Economic Zone (EEZ), the area extending between 3 and 200 miles offshore as established under the Magnuson-Stevens Act (US Code Title 16, Section 1801 *et seq.*). The fisheries within the Bering Sea–Aleutian Islands (BSAI) ecosystem are managed under a sophisticated multispecies framework that is based on extensive monitoring by both fishers and managers.

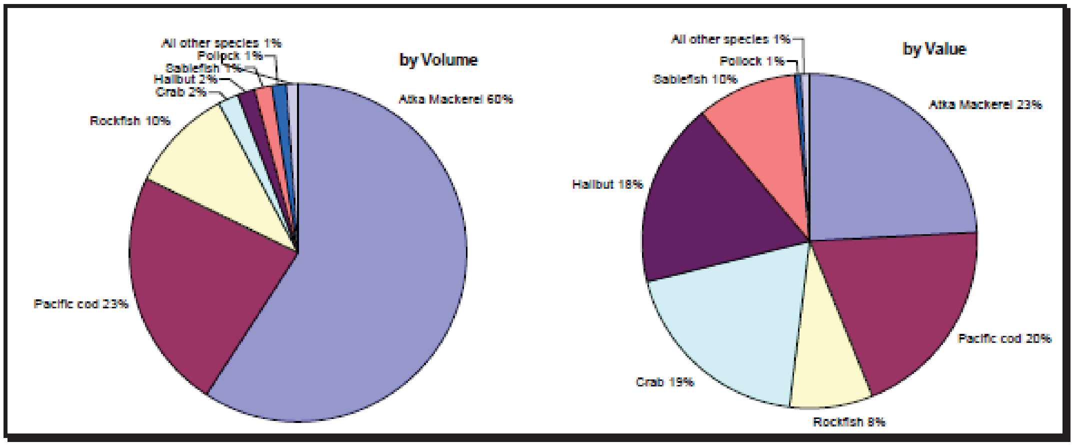
The groundfish fishery in Alaska is the largest commercial fishery in the world. In addition to groundfish, other key species harvested include but are not limited to crab, salmon, and halibut. About 80 stocks of groundfish are recognized and managed in the BSAI ecosystem (NPFMC 2006); chief among these are stocks of walleye pollock, Pacific cod, and Atka mackerel. The federal groundfish fisheries extend southward in the Aleutian Islands west of 170°W to the border of the EEZ. In addition, herring, crab, halibut and salmon are also fished. The ADF&G manages commercial fisheries near to shore, inside the 3-mile zone. Compared to the federal fisheries, the State-managed groundfish fisheries account for a small portion of the total and, in the project area, consist primarily of Pacific cod and black rockfish.

Commercial fleets operate out of most of the communities within the project area. Much of the seafood processing labor force comes from outside the region, although individual communities vary as to what portion of labor comes from local sources. The epicenter of commercial fishing in the region is unquestionably Unalaska/Dutch Harbor, with its large commercial fleet and processors, as well as offshore floating processors (Sepez et al. 2005).

In 2008, 1.7 million tons of groundfish was caught commercially, generating approximately $2.3 billion in gross value ($880 million in ex-vessel value). This huge volume of fish accounted for 46 percent of the weight and 20 percent of the ex-vessel value of total US domestic landings. The groundfish fisheries accounted for the largest share (51 percent) of the ex-vessel value of all commercial fisheries off Alaska in 2008, while the Pacific salmon fishery was second with $368 million or 21 percent of the total Alaska ex-vessel value. The value of the shellfish fishery amounted to $252 million or 15 percent of the total for Alaska and exceeded the value of Pacific halibut by about $43 million (NMFS 2009).

While these data represent the aggregated total for Alaska, the Alaska Peninsula/Aleutian Islands region is central to the Alaska groundfish fishery and accounts for the majority of the Alaskan groundfish catch (as percentage by volume) (NMFS 2004). Figure 3.6 shows the volume and value of fisheries resources harvested. Over the last 5 years, the volume of Atka mackerel extracted from the Aleutian Island ecosystem has ranged between 37,000 and 56,000 metric tons, Pacific cod between 22,000 and 38,000 metric tons, rockfish between 8,000 and 10,000 metric tons, halibut between 2,000 and 3,000 metric tons, crab between 2,000 and 3,000 metric tons, sablefish at 1,000 metric tons (plus or minus about 400), flatfish at 1,000 metric tons (plus or minus about 300), pollock at 1,000 metric tons (plus or minus 600) and other groundfish and other species ranging between 2 and 300 metric tons (Aleutian Islands Fishery Ecosystem Plan, December 2007). Table 3.4 presents the 2011 quotas and most current catch data by species or species group for this year in the BSAI. While these data are more recent, they are still considered preliminary as fishing continues to occur for this season.

Figure 3.6 Fishery Resources Harvested in the Aleutian Islands Ecosystem



Note: Selected Harvest Areas 541, 542, and 543, and Halibut Areas 4A and 4B, by volume and by value, in 2005

Table 3.4 NMFS 2011 Catch Report

Bering Sea Aleutian Islands Catch Report (includes CDQ) Through: 29-JAN-11	National Marine Fisheries Service Alaska Region, Sustainable Fisheries Catch Accounting

Bering Sea

Sea-sons	Account	Total Catch	Quota	Remaining Quota	% Taken	Last Wk Catch
	Other Rockfish (includes CDQ)	2	485	483	0%	1
	Pacific Ocean Perch (includes CDQ)	0	3,222	3,222	0%	0
	Sablefish (Hook-and-Line and Pot)	0	0	0	0%	0
	Sablefish CDQ (Hook-and-Line and Pot)	0	0	0	0%	0
	Sablefish (Trawl)	0	1,063	1,063	0%	0
	Sablefish CDQ (Trawl)	0	94	94	0%	0
	Greenland Turbot	1	3,145	3,144	0%	0
	Greenland Turbot CDQ	0	396	396	0%	0
X	Pollock, AFA Inshore	15,587	551,498	535,911	3%	13,703
X	Pollock, AFA Catcher Processor	9,123	443,448	434,325	2%	7,080
X	Pollock, AFA Mothership	2,539	110,550	108,011	2%	1,994
X	Pollock CDQ	5,573	127,100	121,527	4%	4,001
	Pollock, Incidental Catch, non-Bogoslof (includes CDQ)	2,246	33,804	31,558	7%	1,343
	Pollock, Incidental Catch, Bogoslof (includes CDQ)	0	150	150	0%	0

Bering Sea Aleutian Islands Catch Report (includes CDQ) Through: 29-JAN-11	National Marine Fisheries Service Alaska Region, Sustainable Fisheries Catch Accounting

Aleutian Islands

Sea-sons	Account	Total Catch	Quota	Remaining Quota	% Taken	Last Wk Catch
	Other Rockfish (includes CDQ)	4	472	468	1%	2
	Pacific Ocean Perch, Eastern	15	3,733	3,718	0%	3
	Pacific Ocean Perch, Eastern CDQ	0	447	447	0%	0
	Pacific Ocean Perch, Central	5	3,777	3,772	0%	5
	Pacific Ocean Perch, Central CDQ	0	453	453	0%	0
	Pacific Ocean Perch, Western	0	5,787	5,787	0%	0
	Pacific Ocean Perch, Western CDQ	0	693	693	0%	0
	Rougheye Rockfish (includes CDQ) - BS + Eastern	0	234	234	0%	0
	Rougheye Rockfish (includes CDQ) - Central + Western	0	220	220	0%	0
	Atka Mackerel, Eastern ICA	1	75	74	1%	0
	Atka Mackerel, Eastern (Jig)	0	180	180	0%	0
X	Atka Mackerel, Eastern (Trawl)	881	35,734	34,853	2%	480
	Atka Mackerel, Eastern CDQ	0	4,312	4,312	0%	0
X	Atka Mackerel, Central (Trawl)	178	9,998	9,820	2%	178
	Atka Mackerel, Central ICA	0	75	75	0%	0
	Atka Mackerel, Central CDQ	0	1,207	1,207	0%	0
X	Atka Mackerel, Western (Trawl)	0	1,300	1,300	0%	0
	Atka Mackerel, Western ICA	0	40	40	0%	0
	Atka Mackerel, Western CDQ	0	161	161	0%	0
	Sablefish (Hook-and-Line and Pot)	0	0	0	0%	0
	Sablefish CDQ (Hook-and-Line and Pot)	0	0	0	0%	0
	Sablefish (Trawl)	0	395	395	0%	0
	Sablefish CDQ (Trawl)	0	35	35	0%	0
	Greenland Turbot (includes CDQ)	0	1,420	1,420	0%	0
X	Pollock	0	3,000	3,000	0%	0
X	Pollock CDQ	0	0	0	0%	0
X	Pollock, Incidental Catch (includes CDQ)	1	1,600	1,599	0%	1

Bering Sea Aleutian Islands

Sea-sons	Account	Total Catch	Quota	Remaining Quota	% Taken	Last Wk Catch
	Alaska Plaice (includes CDQ)	1,331	42,500	41,169	3%	1,023
	Arrowtooth Flounder	198	63,750	63,552	0%	95
	Arrowtooth Flounder CDQ	8	8,025	8,017	0%	4
	Flathead Sole	409	53,580	53,171	1%	318
	Flathead Sole CDQ	23	6,420	6,397	0%	13
	Kamchatka Flounder (includes CDQ)	9	17,700	17,691	0%	5
	Northern Rockfish (includes CDQ)	23	7,290	7,267	0%	17
	Other Flatfish (includes CDQ)	100	14,705	14,605	1%	81
X	Pacific Cod, Catcher Processor (AFA)	578	4,682	4,104	12%	452
X	Pacific Cod, Catcher Processor (Amendment 80)	676	27,277	26,601	2%	569
X	Pacific Cod, Catcher Vessel (Trawl)	2,665	44,987	42,322	6%	2,320
X	Pacific Cod, Catcher Processor (Hook-and-Line)	10,776	98,733	87,957	11%	2,834
X	Pacific Cod, Catcher Vessel (Hook-and-Line >= 60 ft)	0	405	405	0%	0
X	Pacific Cod, Catcher Processor (Pot)	1,476	3,041	1,565	49%	105
X	Pacific Cod, Catcher Vessel (Pot >= 60 ft)	9,716	17,030	7,314	57%	0
X	Pacific Cod (Jig)	0	2,850	2,850	0%	0
	Pacific Cod (Hook-and-Line and Pot < 60 ft)	1,362	4,055	2,693	34%	221
	Pacific Cod, Incidental Catch (Hook-and-Line and Pot)	0	500	500	0%	0
X	Pacific Cod CDQ	314	24,391	24,077	1%	246
	Rock Sole	5,438	80,370	74,932	7%	4,119
	Rock Sole CDQ	31	9,630	9,599	0%	22
	Shortraker Rockfish (includes CDQ)	0	387	387	0%	0
	Yellowfin Sole	11,681	190,209	178,528	6%	8,581
	Yellowfin Sole CDQ	1	22,791	22,790	0%	0
	Octopus (includes CDQ)	90	150	60	60%	4
	Sculpin (includes CDQ)	328	5,200	4,872	6%	192
	Shark (includes CDQ)	11	50	39	22%	2
	Skate (includes CDQ)	2,014	16,500	14,486	12%	809
	Squid (includes CDQ)	0	1,675	1,675	0%	0
Total:		**85,412**	**2,119,186**	**2,033,774**	**4%**	**50,826**

Other flatfish: all flatfish except Pacific halibut, flathead sole, Greenland turbot, rock sole, yellowfin sole, Kamchatka and arrowtooth flounder, and Alaska plaice.

Other rockfish: all Sebastes and Sebastolobus species except for Pacific ocean perch, northern, shortraker, and rougheye rockfish.

For changes to the harvest specifications refer to http://alaskafisheries.noaa.gov/2011/hschanges.htm

Note: All weights are in metric tons. Report run on: February 4, 2011 5:15 AM

As described in the 2004 Alaska Groundfish Fisheries Programmatic Supplemental Environmental Impact Statement (NMFS 2004), the dependence of Aleutian Islands communities on the fishery varies from very little direct involvement to being Alaska's top fishing ports. Some of the larger fishing ports in the project area include Akutan, King Cove, and Sand Point. Adak is also a major fish processing community, particularly for Pacific cod. For communities within the AEB, revenue from the groundfish fisheries is distributed throughout borough communities due to the tax structure.

Unincorporated communities or those that are not within the AEB (i.e., west of Akutan) do not share this benefit and are perhaps more susceptible to activities or events that may result in economic impacts (NMFS 2004).

Employment in the Aleutian Islands communities is closely related to the commercial fishery, particularly the groundfish fishery. Communities with sizeable seafood processing operations (Akutan, King Cove, and Sand Point) typically have very low official unemployment rates. Seafood processing dominates employment in the manufacturing sector of this region, with almost five times as many persons (2,958) employed in 1999 compared to state and local government, the second highest sector (NMFS 2004).

Taxes from the fisheries are an important source of income for the region. Local raw fish taxes are collected in Akutan, King Cove, Sand Point, and Unalaska, and all but Unalaska are also subject to a borough raw fish landing tax. In 1999, over 99 percent of all shared taxes and fees in the region were fisheries-related taxes (NMFS 2004).

Processing is a major component of the economy in the Aleutian Islands. The offshore processing component paid more than $2 million in Fisheries Resource Landing tax in 1999. This tax is considerably more important in the Alaska Peninsula/Aleutian Islands region, than for any other Alaska region. Pollock comprises the majority of fish processed in the region (often approximately >90 percent), followed by Pacific cod, and other species such as Atka mackerel, rockfish, sablefish and other groundfish. The Alaska Peninsula/Aleutian Islands region does more inshore processing of groundfish (674,000 metric tons in 2001) than any other region (NMFS 2005). Most of the shore processing facilities in the region are owned by Washington-based individuals or firms; none of the shore processing plants are owned by resident entities (NMFS 2004).

In 1996, the Community Development Quota (CDQ) program was granted in perpetuity through the MSA authorized by the US Congress as a means to develop infrastructure and general well-being in rural Alaskan communities. The Aleutian/Pribilof Islands Community Development Association is a CDQ group that distributes a portion of commercial fishing proceeds to their various communities and sponsor economic and infrastructural development. There are also a number of regional Native corporations and Native village corporations with recognized status under the Alaska Native Claims Settlement Act (Sepez et al. 2005).

Depending on commercial fisheries revenue is both an asset and a liability for the Aleutian Island communities. Due to foreign competition in recent years, the market price of salmon in the US has declined, causing financial trouble for many Alaska communities. In 2003, the Aleutians East Borough received a total of $1,101,638 in federal disaster funds to compensate for falling salmon prices, while other communities received lesser amounts (Sepez *et al* 2005).

In addition, the decline of Steller sea lions, an endangered species in western Alaska, has resulted in new fishing regulations in areas where the sea lions haul out or breed (i.e., rookeries), displacing some fishing vessels resulting in lost revenue in some cases. A handful of communities in the region have received federal Steller sea lion compensation funds (Sepez *et al* 2005). Between 1999 and 2005, the Aleutian Islands pollock fishery was closed due to concerns about Steller sea lion survival. Areas surrounding Steller sea lion rookeries and haulouts remain closed, limiting fishing to two small areas with commercial concentrations of pollock within easy delivery distance to Adak Island (NMFS 2009). In January 2011, NMFS adjusted the 2011 total allowable catch (TAC) amounts for Atka mackerel in the BSAI management area. TAC for Atka mackerel in the Eastern Aleutian Island District and Bering Sea subarea was increased from 20,900 to 40,300 metric tons. NMFS also decreasing the Atka mackerel TAC from 26,000 to 11,280 metric tons in the Central Aleutian District and from 18,100 to 1,500 metric tons in the Western Aleutian District .

This action came after initial discussion of closing some of the fisheries (such as Statistical Area 541) due to concern over Steller sea lions (75 Federal Register 77535). NMFS 2010 North Pacific Groundfish Fishery Biological Opinion stated "data indicate that an adverse relationship between Steller sea lions and the commercial fisheries may exist in the western Aleutian Islands sub-region and portions of the central Aleutian Islands sub-region where two specific fisheries, for Atka mackerel and Pacific cod, target important Steller sea lion prey" (NMFS 2010a).

The Steller sea lion protection measures at Title 50 of the Code of Federal Regulations Part 679.20 require the seasonal apportionment of the annual TACs to reduce the potential for competition for prey species between Steller sea lions and the Atka mackerel fisheries. NMFS recently extended the comment period on the 2010 Biological Opinion, thus the future of fisheries in the western Aleutian Islands, specifically Atka mackerel and Pacific cod, are still to be determined.

The BSAI crab fisheries includes king (*Paralithodes* and *lithodes spp*.) and Tanner crab (*Chionoecetes spp*.). These species are most commonly found using the continental shelf and slope to depths of approximately 1,000 m (NMFS 2004). There are four species of king crab that support the BSAI fisheries including red king crab, blue king crab, golden king crab, and scarlet king crab. This report focuses on the following crab species due to their significance as a commercial species within the project area:

- Aleutian Islands red king crab – Red king crabs are taken in areas of all sediment types at depths of 20 to 100 fathoms (120 to 600 feet).
- Aleutian Islands golden king crab – Golden king crabs are taken in areas consisting of rough, uneven bottom and in compacted sand-cobble sediments at depths of 100 to 400 fathoms (600 to 2,400 feet). Fishery effort is concentrated at the entrances to passes between the islands, particularly in the eastern district. In the western district, the fishery occurs in steep rocky terrain, near passes between islands, and on moderately sloping mud/sand sediments in basins.
- Aleutian Islands Tanner crab – Tanner crabs are taken in areas of soft sediment types (silt and mud) at depths of 30 to 110 fathoms (180 to 660 feet) (NMFS 2004).

King crabs are most commonly fished using steel pots that are typically 5 to 8 feet square and 2 to 4 feet deep weighing 400 to 700 pounds. King crab fishing can be very dangerous due to the heavy gear, long hours, and severe weather encountered. Vessels fishing in the Bering Sea or Aleutian Islands average over 100 feet long (NMFS 2004).

The red king crab fishery has historically been Alaska's top shellfish fishery, with nearly 2 billion pounds of red king crab worth $1.6 billion harvested between 1959 and 2004 (NMFS 2004). While sockeye (red salmon), has been the most valuable species, red king crab is a close second. The Adak red king crab fishery was closed 1995-2005 for re-building. In the 2005-2006 fishery season, there were three vessels harvesting Western Aleutian Islands golden king crab and seven vessels harvesting Eastern Aleutian Islands golden king crab (NMFS 2007).

Following a peak harvest of red king crabs in the early 1980s, the fishery crashed, resulting from what biologists believe was intense predation and a warmer ocean environment and consequently poor recruitment. With the exception of southeastern Alaska, red king crab populations have remained depressed statewide since 1983 (NMFS 2004). Thus, commercial fisheries in the Aleutian Islands have targeted golden king crabs, which earned the industry $338 million between 1980 and 1995 (122 million pounds) (ADF&G 2010d). In 2009, the ex-vessel value for Aleutian Islands golden king crab was $15.6 million for approximately 5.9 million pounds of crab. The ex-vessel value of Eastern Aleutian bairdi Tanner crab was not reported due to confidentiality (ADF&G 2010e).

In 2005, the crab fishery was conducted under the newly implemented Crab Rationalization Program, which established a quota share system for allocating the harvest, including for Eastern Aleutian Islands golden king crab, Western Aleutian Islands golden king crab, and Western Aleutian Islands red king crab fisheries (NMFS 2007). The program also includes geographic landing requirements and transfer restrictions linking Processor Quota Shares (PQS) and Individual Processor Quota (IPQ) to specific fishery-dependent coastal communities with a history of participation in these fisheries. There are nine total Eligible Crab Communities, six of which are located within the project area or immediately adjacent to it including Adak, Akutan, Unalaska/Dutch Harbor, False Pass, King Cove, and Port Moller. Every community but Adak has a "Right of First Refusal" on proposed sales of PQS for use outside of the community.

In 2009, approximately 1,628,624 salmon (including Chinook, sockeye, chum, pink and coho) were harvested in the Aleutian Islands/Alaska Peninsula (ADF&G 2009). Under management by ADF&G, the Alaska Peninsula is divided into six districts including:

- Unimak District;
- Northwestern District;
- Southwestern District;
- South-central District;
- Southeastern District; and
- Northern District (located outside project area).

Likewise, the Aleutian Islands are divided into six districts as follows:

- Akutan District;

- Unalaska District;
- Umnak District;
- Atka-Amlia District;
- Adak District; and
- Pribilof Islands District (located outside project area).

In 2009, the value of salmon from the Aleutian Islands/Alaska Peninsula region totaled approximately $26.4 million (ADF&G 2009).

Dutch Harbor/Unalaska has been the nation's number-one fishing port since 1992 (NMFS 2004). Dutch Harbor/Unalaska has 10 major docks and over 200 moorage slips. In 2000, 50 residents held 103 commercial fishing permits, 17 resident vessel owners operating in the federal fisheries and six operated in the non-federal fisheries (Sepez et al. 2005). In 2005, there was a total of nine processors operating in Dutch Harbor/Unalaska representing a mix of shore plants, offshore, at-sea, and floating processors. Compared to other ports in the Aleutian Islands, Unalaska provides substantial support services for the Bering Sea fisheries. Unalaska can support all range of services for any vessel class in the pollock, crab, and other groundfish fisheries and, for this reason, the support services are heavily dependent upon the success of the groundfish and crab fisheries. To some extent, due to its involvement in a diverse number of fisheries, Unalaska is somewhat insulated from negative changes in individual fisheries (NMFS 2007).

According to EDAW, Inc. (2005), approximately 80 percent of the King Cove workforce is employed by the commercial fisheries. Several large processors are located in King Cove, with Peter Pan Seafoods being the only shore-based processor. Although King Cove once depended heavily on salmon, the community now processes groundfish, halibut, and crab from the Gulf of Alaska and BSAI. In addition, the community is home to several large crab vessels.

Akutan is a CDQ community, also heavily dependent on the commercial fisheries, that benefits from the allocation of BSAI groundfish and crab to the CDQ program. The largest shore-based processing plant in North America, operated by Trident Seafoods, is located in Akutan. The facility is self-sufficient (e.g., generates its own power) and can house as many as 825 Trident employees (Trident 2010). A floating processor is also based in Akutan. Fishing vessels delivering to Akutan focus primarily on pollock, crab, and Pacific cod.

Until recently, Adak was not significantly participating in the commercial fisheries because of the Naval Air Station located on the island. Limited small vessels are berthed in Adak. There is one processing plant which focuses mostly on cod, halibut, and black cod. However, the community does serve as the main marine refueling station for commercial shipping vessels transiting the North Pacific. Port facilities in Adak can support a wide variety of large vessels and as such, at-sea processors have used the port for transfer of product (NMFS 2007).

Sand Point, while outside the project area, is home to one of the largest fishing fleets in the Aleutian Chain. In 2000, approximately 116 commercial permit holders and 327 all-fisheries combined permits were from Sand Point (Sepez et al. 2005). Sand Point is also a CDQ community managed under the Aleutian Pribilof Islands Community Development Association (APICDA). Peter Pan Seafoods owns a storage and transfer station in the community. In 2009, 102 residents held commercial fishing permits (ADCED 2010). Trident Seafoods operates a processing facility in Sand Point year-round and processes cod, black cod, halibut, pollock, salmon and other groundfish and is capable of processing up to 1.2 million pounds of pollock per day or 350,000 pounds of salmon per day. Depending on the season, Sand Point employs between 50 and 400 employees (Trident 2010).

Atka is considered the westernmost fishing community in the Aleutian Islands chain (Sepez et al. 2005). According to the Alaska Commercial Fisheries Entry Commission (ACFEC), in 2000, there were nine permit holders who held 17 commercial fishing permits. Atka Pride Seafoods, a small on-shore processing plant, services the local fleet. In 2008, Atka Pride Seafoods owned and operated by APICDA, accomplished 100 percent hire of local residents for the processing plant (Global Food Collaborative 2010). Despite its limited support services, a number of offshore fish processors carry out crew changes through Atka (Sepez et al. 2005).

False Pass is heavily dependent on commercial fishing as part of the local economy. ADF&G and ACFEC reported that in 2000, 24 permits were held by 11 permit holders in False Pass (Sepez et al. 2005). At that time, for a population of 64, fishing permits were held by approximately 17 percent of the community. In addition, two vessel owners operated in the federal fishery while 10 vessel owners operated in the salmon fishery. In 2008, APICDA opened Bering Pacific Seafoods and produced headed and gutted fillets. As part of the CDQ program, the plant aims to benefit the region (Global Food Collaborative 2010).

Port Moller, while outside the project area, has been characterized by Sepez et al. (2005) as a seasonal (May-September) community and is the site of a salmon cannery owned and operated by Peter Pan Seafoods. In summer there are approximately 150 temporary residents (supporting the cannery) and there may be vessels that come to port in the area (Sepez et al. 2005).

3.6.2 *Sport Fisheries*

Sport fishing is not as extensive in this region as it is in the Alaska Peninsula and other parts of Alaska. Coho and sockeye are the two salmon species most frequently targeted in Dutch Harbor/Unalaska's freshwater and saltwater sport fisheries (ADF&G 2010f). In 2005, there were at least four charter boat companies operating out of Dutch Harbor/Unalaska and three registered freshwater and six saltwater fishing guides. In 2000, there were 833 sport fishing permits obtained for Unalaska (Sepez et al. 2005).

The small charter boat fleet in Dutch Harbor/Unalaska provides non-local anglers access to the area's best known sport fishery targeting halibut that travel in or through waters in the northwestern portion of the project area. In July and August, halibut is often taken in both the Bering Sea and Gulf of Alaska. Black and dusty rockfish are popular game species found in the Aleutians and are typically caught nearshore (ADF&G 2010f).

In 2000, 42 sport fishing permits were issued for Sand Point. As of 2000, there were five sport fishing guides operating out of Sand Point, four of which focused on freshwater activities (Sepez et al. 2005).

3.6.3 *Subsistence Use*

Subsistence activities include harvesting, sharing, and consuming vegetative and terrestrial and aquatic animal resources. Nearly all the residents in each of the communities take part in subsistence activities (ADCED 2010; Sepez et al. 2005). The communities in the study area depend heavily on subsistence resources such as (ADCED 2010):

- Salmon;
- Non-salmon fish species (e.g., cod, flounder, greenling, halibut, rockfish, sablefish, sculpin, sole, char, and trout);
- Shellfish;
- Marine mammals (e.g., seals);

- Land mammals (e.g., caribou, wild cattle, and reindeer);
- Birds and bird eggs (e.g., geese);
- Marine invertebrates; and
- Vegetation.

Federal subsistence fishery regulations require that a community be classified as rural "in order to harvest subsistence wildlife, fish, and shellfish on Federal lands" (Sepez et al. 2005, pg. 293). Adak residents cannot harvest subsistence resources on federal lands. The community requested rural status from the federal government, but was denied citing the naval base and the large population on the island at the time of the request. The community is classified as rural by the state, and salmon resources are harvested on state lands. State data include harvests for salmon, as that is the only resource the community can take due to its non-rural designation. In 1988, the non-commercial salmon net fishery was a subsistence fishery but was reclassified as a subsistence fishery in 1998. All freshwater on Adak Island is closed to federal subsistence salmon harvesting as it is all saltwater within 100 yards of a stream terminus resulting from the federal non-rural designation. Data from 1999 indicate five individual subsistence salmon permits and one household permit (Sepez et al. 2005).

Designated subsistence use areas within the study area have been well documented (LaRoche and Associates 2005). In addition to the communities highlighted in the Communities and Population table, the following communities and areas are known subsistence harvest areas of importance in and adjacent to the study area: Port Moller, Nelson Lagoon, Sand Point, Squaw Harbor, Unga, Belkofski, King Cove, Cold Bay, Sanak Island, Pauloff Harbor, and Umiak Island.

The extent of the subsistence use areas that have been documented include:

- Port Moller, Herendeen Bay, Bear River, Sandy River, Point Edward to Walrus Island and 3 miles offshore from Cape Kutuzof;
- Nelson Lagoon from Walrus Island to Spasuk River (and 3 miles offshore), including Kudobin Islands;
- Izembek Lagoon and Moffett Lagoon extending 3 miles offshore from the barrier islands;
- Pavlof Bay/Canoe Bay between Bluff Point and Cape Tolstoi;

- Bechevin Bay from the western boundary of Izembek Lagoon to the west of Swanson Lagoon including Cold Bay and offshore areas within a 3-mile limit including north of Bechevin Bay and Morzhovoi Bay;
- Unimak Pass from Seal Cape to Cape Sarichef and extending 3 miles offshore to the western boundary of the AEB and including the northern shore of Unimak Island and southern shore to False Pass and Deer Island;
- Sanak Islands and coastal waters;
- Krenitzin Islands including Hot Springs and Akutan Bays on Akutan Island, Lost Harbor, Surf Bay on Akun Island Akun Island;
- Unalaska Island including Wide Bay, Broad Bay, Nateekin Bay, Captains Bay, Iliuliuk Bay, Summer Bay and Hog Island in Unalaska Bay to Cape Wislow and Reese Bay;
- Umnak Island coastal waters including the Pancake and Adugak Islands;
- Samalga, Amutka, and Seguam islands and coastal waters;
- Atka and Amlia islands and coastal waters; and
- Adak Island and coastal waters.

3.6.4 Historic Preservation Sites

This study was limited to the places on the National Register of Historic Places (NPS 2010). There are 22 places on the registry in the study area, most located in upland areas that would not be affected by a spill. The following sites, by their location could be affected by oil spills:

- Adak Army Base and Adak Naval Operating Station --Roughly bounded by Cape Adagdak, Scabbard Bay, and Shagak Bay, Adak Station;
- Anangula Archeological District – Underwater Restricted location at Nikolski;
- Dutch Harbor Naval Operating Base and Fort Mears, US Army;
- Attu Battlefield and US Army and Navy Airfields on Attu;
- Japanese Occupation Site, Kiska Island; and
- S.S. NORTHWESTERN Shipwreck Site – Unalaska.

3.6.5 *Marine Recreation and Tourism*

The Shumagin Islands and Dutch Harbor/Unalaska are the two main areas of importance to tourism in the Aleutians.

Typically, these areas are rich in biodiversity, are relatively accessible and pristine. Caribou hunting, birding, beach combing, fishing, skiing and kayaking are popular tourist activities in the more established and accessible tourist areas. The tourism industry as a whole is largely dependent on the marine environment. Sport fishing, marine and terrestrial sightseeing, and boating are recreation and tourism activities that residents and visitors enjoy in the study area. Recreation and tourism is extremely limited in the communities in the study area, primarily because they do not have the facilities or resources to support such an industry.

Sepez et al. (2005) reports Dutch Harbor/Unalaska has four charter boat companies, three registered freshwater fishing guides, and six saltwater fishing guides. King Cove also has three saltwater sport fishing businesses and two cross over with freshwater.

Smaller communities like Adak have tourism activities on a much smaller scale such as visitors for sightseeing on cruise vessels or the Alaska Marine Highway System Ferry. The ferry and small tour boats also stop in Akutan, Sand Point, Cold Bay, King Cove and to a limited extent, False Pass.

The study area includes three national wildlife refuges within the study area including:

- Alaska Maritime National Wildlife Refuge, which includes the Aleutian Islands from approximately Unimak Island to Attu;
- Alaska Peninsula National Wildlife Refuge, which extends from False Pass along the southern portion of the peninsula to just east of Ugashik; and
- Izembek National Wildlife Refuge, which includes Umiak Wilderness Area and encompasses the area around the Izembek Lagoon from Morzhovoi Bay to areas north of Cold Bay on the Alaska Peninsula.

Although these large expanses of public lands are surrounding communities like False Pass and others, they do not add much to the local economies and accessibility is limited. Access to public and tribal lands is by cruise, tour, ferry, or chartered vessels and air and boat taxis from primarily Dutch Harbor.

3.6.6 *Coastal Development and Coastal Infrastructure*

Adak is a sub-regional hub with three deepwater harbors and fueling facilities. Sepez et al. (2005) indicates that the city has requested funding for expansion of the small boat harbor, specifically to include new breakwaters, new moorage fleets, and a 315-foot dock. Adak's existing port facilities can accommodate a large assortment of ships as it was designed for naval ships because of the naval base located there (Sepez et al. 2005). Adak also "provides a fueling port and crew transfer facility for foreign fishing fleets" (ADCED 2005).

Access to Akutan is limited to boat and amphibious craft. The community's primary employer, Trident Seafoods, operates its own vessel dock, water, sewer and electric facilities. The Akutan Electric Utility manages a hydroelectric facility that provides power to residents (Sepez et al. 2005). The community's public water supply is collected from a local stream and dam. Trident Seafoods processes cod, crab, pollock, and fish meal, and operates its own supply of water, sewer, and electricity (ADCED 2010).

The city of Atka operates a dock and port facility. The fishing industry along with the APICDA operates and maintains several other coastal facilities including Atka Pride Seafoods, the only processor in Atka and processes halibut and black cod (see Section 3.6.1) (Sepez et al. 2005; ADCED 2010). Atka Seafoods is powered by its own electric system. The public water supply is collected from a stream and wooden reservoir dam northwest of the city and stored in a 30,000-gallon tank (ADCED 2010).

Dutch Harbor/Unalaska is a regional container hub with 10 major docks, "three of which are managed by the city" (Sepez et al. 2005). In total, there is 5,200 feet of moorage and 1,232 feet of floating dock. "The small boat harbor has 238 moorage slips and 900 linear feet of dock space" (Sepez et al. 2005). Fish processors located in Dutch Harbor have saltwater intakes for process water.

False Pass does not have a boat harbor; however, a dock and boat ramp exist. Water from a nearby spring and reservoir is treated and stored in a 60,000-gallon tank for public use. The seafood processing plant discharges wastewater into an outfall line (ADCED 2010).

Sand Point is home to Trident Seafoods and Peter Pan Seafoods (see Section 3.6.1). The city also has a 25-acre boat harbor with docks, boat slips, a harbormaster office, a barge off-loading area, and a 150-ton lift (Sepez et al. 2005).

Attu and Shemya also have landings and other docks. Offshore development in the study area is limited to floating fish processors.

3.7 *INVASIVE SPECIES (RATS)*

Rats have been identified as the invasive species of concern that poses a threat to the islands' resources from the marine shipping industry and thus are the only invasive species included in the scope as part of the AIRA Phase A PRA.

Rats living in association with humans have been introduced to about 90 percent of the world's islands and are responsible for 40-60 percent of all recorded bird and reptile extinctions globally.

Rats, particularly the brown or Norway rat (*Rattus norvegicus*) and the black or roof rat (*Rattus rattus*), are highly adaptable, fast-breeding species. This makes them adept at colonizing new environments, and island ecologies have been devastated by such invasions throughout history. Rats are voracious predators on eggs, chicks, and even adult birds as large as albatrosses. For example, the extinction of such species as the great auk (*Pinguinus impennis*), the dodo (*Raphus cucullatus*), and several species of New Zealand moa were hastened by the introduction of rats; the list is lengthy. Rats can also cause more extensive ecosystem damage, as well as posing health risks to wildlife and humans.

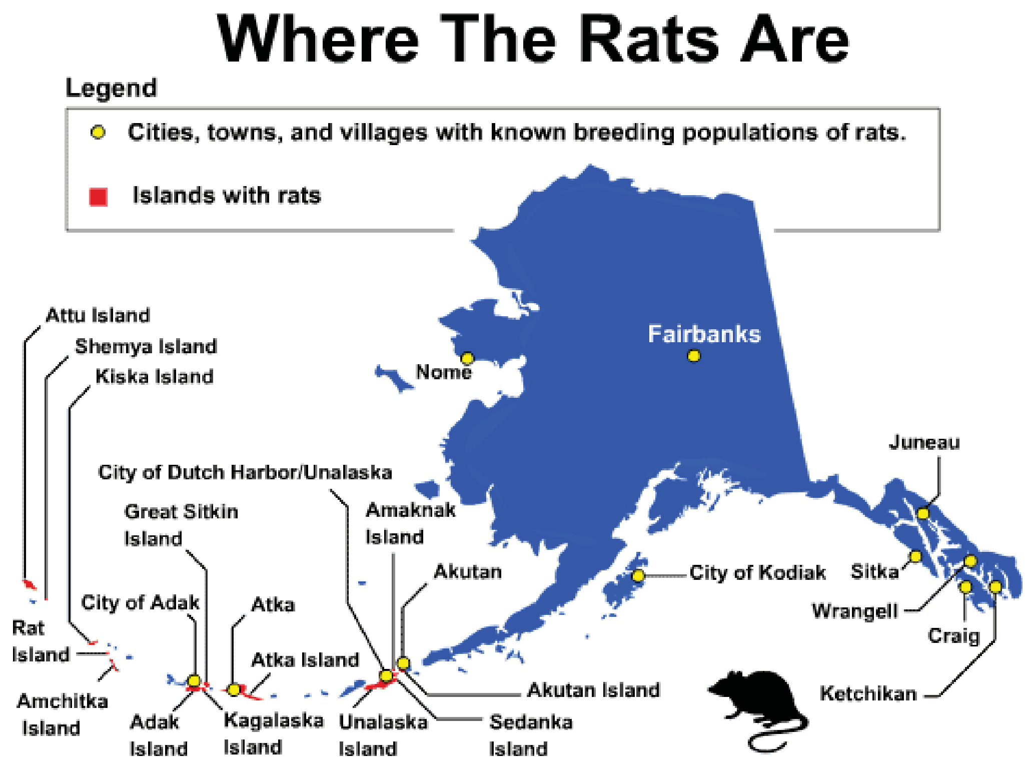
Norway rats have been identified as of greater concern as they are more widespread and better swimmers, thus more likely to successfully colonize new islands. Even in the cold waters of the Aleutians, Norway rats can survive for up to 15 minutes and swim up to 1 km (Russel et al. 2008). Roof rats are also strong swimmers, but their natural habitat is arboreal, possibly contributing to their relative scarcity in the treeless habitats characteristic of much of the Aleutians.

Rats are thought to have been introduced to Rat Island by shipwreck in the late 18th century. Norway rats (and, in one case, black rats) are established on at least 10 Aleutian Islands or island groups, and the diversity and numbers of breeding seabirds occurring on those islands are now conspicuously low (USFWS 2007). Rat-caused modifications to other components of the island ecosystems (e.g., other birds, plants, and invertebrates) are also evident. Islands known to have rat populations include (see Figure 3.7 below):

- Attu
- Shemya
- Kiska
- Little Kiska
- Amchitka
- Adak
- Kagalaska
- Great Sitkin
- Atka
- Unalaska
- Sedanka
- Amaknak
- Akutan

Of these, some islands, such as Unalaska, are believed to have been colonized by rats inadvertently introduced by early explorers and travelers. Rats were introduced to Adak, Amchitka, Attu, Kiska, and Shemya, around the time of World War II. Akutan, Atka, Kagalaska, Great Sitkin, and Little Kiska probably became infested sometime in the mid-20th century, although precisely when is not known. To date, Norway rats have constituted most of the rat infestations for which positive species identifications were made. Roof rats, however, are currently known to exist on Shemya and Kodiak islands.

Figure 3.7 Map of Aleutian Islands Currently with Rat Populations



Notes: Rat Island was determined to be rat-free in August 2010.
Source: Reprinted from www.stoprats.org.

3.8 *PROTECTED AREAS*

There are many national and international protected areas within the Aleutian Islands study area. These areas have been designated to protect the components of both the marine and terrestrial environment. Information on some of the key areas for this study is provided below.

Alaska Maritime National Wildlife Refuge is managed by the USFWS. The boundaries of this reserve encompass almost all the Aleutian Islands. The Alaska Maritime National Wildlife Refuge was established to conserve marine mammals, seabirds, and other migratory birds, and the marine resources upon which they rely. The 1980 Alaska National Interest Lands Conservation Act combined 11 previously established refuges, some of which have existed since the early 1900s, with an additional 1.9 million acres of land to form the Alaska Maritime National Wildlife Refuge. The refuge now comprises a total area of 4.9 million acres.

The Aleutian Islands and National Wildlife Refuge was designated as a Biosphere Reserve by the United Nations Educational, Scientific and Cultural Organization (UNESCO) in 1976. The reserve consists of the majority of the Aleutian Islands extending from the Alaska Peninsula about 1,600 km to the west. This reserve covers an area of 1,100,943 hectares, including both terrestrial and marine environments.

Alaska Peninsula National Wildlife Refuge has been established to conserve terrestrial mammals (including brown bears, caribou, moose), marine mammals, shorebirds, other migratory birds, raptors, and fish. The refuge is located on the Alaskan Peninsula, to the east of the Aleutian Islands. The refuge is divided into three units: Ugashik, Chignik, and Pavlot (from east to west).

The Steller Sea Lion Protection Areas, Gulf of Alaska – Groundfish, Pollock, and Pacific Cod Closures Federal Threatened/Endangered Species Protected Area. This area was designated in 1990.

Other protected areas include Bering Sea Habitat Conservation Area, Aleutian Island Coral Protection Area, and Gulf of Alaska Slope Habitat Conservation Areas.

3.9 DATA SOURCES

The sensitive features of the biological and socioeconomic environment of the Aleutian Islands characterized above were based on a range of publicly available information sources, primarily from information contained from NOAA ESI maps.

Table 3.5 shows the data sources and the types of data used for each resource/receptor for the purpose of the consequence analysis. Data sources that were not available in GIS format were georeferenced where possible.

Table 3.5 Data Sources Used for Each Resource/Receptor

Resource/ Receptor	Data Source	Data Type
Environmental		
Coastal habitats	NOAA ESI maps	GIS polyline; converted to area (acres)
Shallow sub-littoral benthic habitats	NOAA ESI maps	GIS polyline; converted to area (acres)
Birds	NOAA ESI maps	GIS point
Marine mammals	NOAA ESI maps	GIS point
Fish		GIS polygon
Socioeconomic		
Power stations and industrial abstraction	Power Plant Jobs. Website: http://www.powerplantjobs.com/ppj.nsf/powerplants1?openform&cat=ak&Count=500.	Not digitized
Subsistence	Alaska Department of Fish and Game. Website: http://www.subsistence.adfg.state.ak.us/. Robert J. Wolfe and Craig Mishler. 1997. The subsistence harvest of harbor seal and sea lion by Alaska Natives in 1996. ADF&G Division of Subsistence, Technical Paper No. 241.	Not digitized
Historic and cultural sites	National Register of Historic Places (NRHP). Website: http://www.nationalregisterofhistoricplaces.com/ak/Aleutian+Islands/state.html. Alaska National Historic Landmarks. Website: http://alaska.hometownlocator.com/features/landmarks,statefips,02.cfm.	Not digitized
Tourism and recreation	Aleutian Islands Fishery Ecosystem Plan. December 2007.	Not digitized
Fisheries	Alaska Fisheries Science Center. Website: http://www.afsc.noaa.gov/fma/spatial_data.htm. NMFS, 2004. Alaska Groundfish Fisheries Programmatic Supplemental Environmental Impact Statement.	Georeferenced raster data from fisheries catch rectangles

4.0 TASK 4 – PHASE A CONSEQUENCE ANALYSIS

Task 4 of the Phase A PRA includes two main components: 1) using the GEMSS® - COSIM models to provide mass balance of the key spill constituents and prepare useable model outputs to assess the consequence of a spill; and 2) to qualitatively identify the consequences of the hypothetical spill scenarios that have been modeled to five main receptor groups (habitat, mammals, seabirds, fish and socioeconomic).

The purpose of the consequence analysis is to gain an understanding of the relative impact of spill size; types of hazardous substance spilled, and spill location on environmental consequences. This analysis is a qualitative assessment of the potential ecological resource damage and socioeconomic impact of the hypothetical spill scenarios identified during Task 3 and provides a high-level assessment of vulnerability of identified natural resource(s).

The scope of the consequence analysis is limited to receptor groups as a whole, rather than individual species. As such, the main ecological receptor groups evaluated include habitat, fish, seabirds, and mammals. Under socioeconomic impacts, the key resources evaluated include fisheries, subsistence use, historical/archaeological landmarks, tourism and offshore developments. The analysis also includes a qualitative assessment of the potential introduction and associated impacts of invasive species (rats) from the marine traffic accident scenarios.

4.1 SPILL MODEL METHODS AND OUTPUT

The oil spill model that was developed during baseline spill modeling studies (Task 2B report; ERM/DNV 2010c) has been used for setting up hypothetical spill scenarios to get relevant outputs for conducting the consequence analysis. The baseline spill report establishes the basic model setup for performing spill modeling in the Aleutian Islands. During the baseline, basic input data specific to Aleutian Islands were gathered including current, winds, weather, waves and spilled substance. The model was tested during baseline spill studies by simulating six different scenarios that represented all seasons, type of spilled substance and release parameters, which are discussed in detail in the Task 2B report. The mass balance for affected media such as water surface, water column, and sediment is included as well as shoreline area.

4.1.1 *Behavior of Oil in Water*

The physical fates module of the Chemical and Oil Spill Impact Module (COSIM) computes the dynamic distribution of the spilled substance in the environment. The model creates a time series file of surface slick coverage and concentrations of the spilled substance in the water column, on the bottom, and along the shoreline. This corresponds to the three different output results that are presented in this report: probability of surface oiling, oil concentrations in the water column, and sediments. These oil conditions in the environment are then used in evaluation of impacts for the different receptor groups depending upon how/where they could be exposed to oil.

If the specific gravity of a spilled substance is less than or equal to that of water, the model employs surface spreading, advection, entrainment, and volatilization algorithms to determine transport and fate at the surface. A spill with specific gravity greater than water is modeled by a convective jet algorithm, which allows the contaminant plume to reach an equilibrium position in a stratified water column, or to sink to the bottom. In general, some fraction of any oil spilled will exist in both the water column and the sediments.

In the water column, horizontal and vertical advection and dispersion are simulated by random walk procedures. Partitioning between particulate adsorbed and dissolved states is calculated based on linear equilibrium theory. The contaminant fraction that is adsorbed to suspended particulate matter is assumed to settle at a rate typical for the environment. Oil at the bottom is mixed into the underlying sediments according to a simple bioturbation equation. Degradation in water and sediments is assumed as a first-order decay process.

The physical environment is divided into five general compartments: the atmosphere, the water surface, water columns, the bottom, and the shoreline. The model distributes the oil dynamically in three physical dimensions (two horizontal and one vertical) among these compartments. On the water surface and the shoreline, concentration has units of mass per unit area, whereas in the water column and sediments the units are mass per unit volume. Oil in the water column is carried to the sea floor primarily by adsorption to suspended particulates, and subsequent settling. The ratio of adsorbed to dissolved concentrations is computed from standard equilibrium partitioning theory. Diffusion spreads mass vertically and horizontally in the water column. In addition, the adsorbed fraction of the total mass settles through the water with a specific settling rate.

4.1.2 *Model Input Parameters and Assumptions*

A list of 16 scenarios identified in Task 3 has been used to obtain spill model output for the Task 4 consequence analysis. The list shown in Table 4.1 provides information about spill location, size and substance. The 16 spill scenarios are defined using a variety of vessels, oil types, and release volumes for potential releases at six locations. The release volumes have been chosen to provide a range of possible releases that may occur depending on the type of vessel and cause of the accident (collision versus bottom grounding). The vessels included in the spill scenarios are container ships, bulk carriers, crude oil tankers, product tankers, and tank barges. Simulated oil types include diesel fuel, Bunker C, and crude oil. As discussed in Section 2, the release volumes, vessel types and oil types were selected based on findings from Task 1 and 2 studies and outcome from the Task 3 webinars.

Based on the general scenarios, specific data was gathered to run the environmental spill modeling. Oil densities are from the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Type A Natural Resource Damage Assessment Model manual (French et al. 1996). Investigations were made into the carrying capacity of the vessels, ranging from tanks carrying fuel oil for its own engines, or those transporting large quantities of crude oil product. Dimensions of vessels and storage capacities have been obtained from literature (Michel and Winslow 1999) and researching physical dimensions of ships at websites such as: ships-info.info, shipbuildinghistory.com, and ec21.com. A summary of the ship dimensions and release scenarios is listed in Table 4.1.

For setting up a model simulation, additional information on season and release rate was needed. Information on season is based on Task 1 and 2A (ERM/DNV 2010b) baseline spill studies and also biological (sensitive species) activity in the study region. Spill release rate depends on the type of crack or tear that can happen on the hull of a ship due to different types of accidents described in Task 2A studies (ERM/DNV 2010b). Cracks and tears eventually result in small to large holes through which oil can spill out at a specific rate, which depends on location, hull configuration, and the density difference between seawater and oil. For modeling purposes, the shape of the hole is assumed to be circular.

For all scenarios except 8 and 12, it is assumed that a collision or grounding would cause a puncture in the side of the vessel. The release rate is based on methodology described by Fay (2002). The velocity is calculated as the square root of the product of the gravitational constant and the initial value of the height of oil in the cargo tank to the rupture's centerline. The release rate (flow) is calculated as the velocity multiplied by the cross-sectional area of the orifice. For guidance on assuming an orifice diameter, Pitblado et al. (2004) lists a range of typical rupture sizes (see Table 4.2). The number of tanks ruptured was assumed based on the scenario's release volume, number of tanks, and volume of each tank.

Table 4.1 Summary of 16 Spill Scenarios

Scenario	Location	Vessel	Oil	Density	Capacity	Incident	Season	Spill Vol MT (bbl)	Length (m)	Berth (m)	Depth (m)
1	1 - North Unimak Pass	Container Ship	Bunker C	0.820	3.5kDWT	Collision	Summer	391 (3049.79)	397	56	30
2	1 - North Unimak Pass	Bulk Carrier	Bunker C	0.981	60kDWT	Collision	Summer	2,339 (18244.2)	292	45	24.7
3	1 - North Unimak Pass	Crude Oil Tanker	Crude oil	0.863	110kDWT	Collision	Summer	54,882 (428079.6)	333	60	29
4	1 - North Unimak Pass	Product Tanker	Diesel	0.820	50kDWT	Collision	Winter	3,430 (26754)	180	32.2	19.3
5	1 - North Unimak Pass	Tank Barge	Diesel	0.820	30kDWT	Collision	Summer	5,215 (40677)	400	28.3	12.5
6	2 - Sanak Island	Container Ship	Bunker C	0.981	3.5kDWT	Drift Grounding	Summer	391 (3049.79)	397	56	30
7	2 - Sanak Island	Bulk Carrier	Bunker C	0.981	60kDWT	Drift Grounding	Summer	2,339 (18244.2)	292	45	24.7
8	2 - Sanak Island	Crude Oil Tanker	Crude oil	0.863	110kDWT	Drift Grounding	Summer	54,882 (428079.6)	333	60	29
9	2 - Sanak Island	Tank Barge	Diesel	0.820	30kDWT	Drift Grounding	Summer	5,215 (40677)	400	28.3	12.5
10	3 - Holtz Bay Attu Island	Container Ship	Bunker C	0.820	3.5kDWT	Drift Grounding	Winter	3,259 (25420.2)	397	56	30

Scenario	Location	Vessel	Oil	Density	Capacity	Incident	Season	Spill Vol MT (bbl)	Length (m)	Berth (m)	Depth (m)
11	3 - Holtz Bay Attu Island	Bulk Carrier	Bunker C	0.981	60kDWT	Drift Grounding	Summer	2,339 (18244.2)	292	45	24.7
12	3 - Holtz Bay Attu Island	Crude Oil Tanker	Crude oil	0.863	110kDWT	Drift Grounding	Spring	54,882 (428079.6)	333	60	29
13	3 - Holtz Bay Attu Island	Product Tanker	Diesel	0.820	50kDWT	Grounding	Spring	6,995 (54561)	180	32.2	19.3
14	4 - Adak Island	Tank Barge	Diesel	0.820	30kDWT	Grounding (powered/ drifting)	Summer	5,215 (40677)	400	28.3	12.5
15	5 - Amlia Island	Container Ship	Bunker C	0.981	3.5kDWT	Drift Grounding	Summer	5,215 (40677)	397	56	30
16	6 - Urilia Bay	Bulk Carrier	Bunker C	0.981	60kDWT	Drift Grounding	Spring	2,339 (18244.2)	292	45	24.7

Notes:

MT = metric tonnes

bbls = barrels

M = meters

K = thousand

DWT = deadweight tonnage

Source: Pitblado et al. 2004.

Table 4.2 Typical Orifice Sizes

Size (centimeters)	Description
25	Maximum credible puncture hole
75	Maximum credible hole from accidental operations event
150	Maximum credible hole from terrorist event

Source: Pitblado et al. 2004.

Table 4.3 Summary of 16 Spill Scenarios – Release Rates and Durations

Scenario	Fully Loaded Draft (m)	Tank Height (m)	Height above hole (m)	Hole Diameter (m)	Spill Velocity (m/s)	Spill Flow (m^3/s)	# Tank Leaks	Spill Load Rate (MT/hr)	Duration (hr)	Comments
1	15.5	15	3	0.04	5.7	0.01	1	21	19	Assume 2 tanks, 3500 MT total capacity. 1 tank loses 22% fuel
2	18.2	10.5	2	0.09	4.4	0.03	1	100	23	Assume 5 tanks, each holds 12kDWT. 19% loss in 1 tank
3	20.5	18	18	0.18	13.3	0.32	1	1000	55	Assume 110kMT capacity, 2 tanks, 1 loses 100% fuel
4	11.7	10	5.5	0.04	7.3	0.01	1	29	120	Assume 50kMT capacity, 8 tanks, 6250 MT each, 1 loses 55%
5	7.5	6	4.2	0.15	6.4	0.11	3	1000	5	Assume 30kMT capacity, 12 tanks, 2500 MT each, 3 lose 70%
6	15.5	15	3	0.04	5.7	0.01	1	25	15	Assume 2 tanks, 3500 MT total capacity. 1 tank loses 22% fuel
7	18.2	10.5	2	0.09	4.4	0.03	1	100	23	Assume 5 tanks, each holds 12kDWT. 19% loss in 1 tank
8	20.5	18	18	Large	-	-	1	19,210 -1st hr 171.5 - next 48 hrs	49	Assume 110kMT capacity, 2 tanks, 1 loses 100% fuel, massive rip in hull
9	7.5	6	4.2	0.15	6.4	0.11	3	1000	5	Assume 30kMT capacity, 12 tanks, 2500 MT each, 3 tanks lose 70%
10	15.5	15	3	0.04	5.7	0.01	2	42	77	Assume 2 tanks, 3500 MT total capacity. 2 tanks lose 93% fuel

Scenario	Fully Loaded Draft (m)	Tank Height (m)	Height above hole (m)	Hole Diameter (m)	Spill Velocity (m/s)	Spill Flow (m^3/s)	# Tank Leaks	Spill Load Rate (MT/hr)	Duration (hr)	Comments
11	18.2	10.5	2	0.09	4.4	0.03	1	100	23	Assume 5 tanks, each holds 12kDWT. 19% loss in 1 tank
12	20.5	18	18	Large	-	-	1	19210 -1st hr 171.5 - next 48 hrs	49	Assume 110kMT capacity, 2 tanks, 1 loses 100% fuel, massive rip in hull
13	11.7	10	5.5	0.04	7.3	0.01	2	57	122	Assume 50kMT capacity, 8 tanks, 6250 MT each, 2 lose 55%
14	7.5	6	4.2	0.15	6.4	0.11	3	1000	5	Assume 30kMT capacity, 12 tanks, 2500 MT each, 3 lose 70%
15	15.5	15	3	0.04	5.7	0.01	2	50	103	Assume 2 tanks, 6000 MT total capacity. 2 lose 87% fuel
16	18.2	10.5	2	0.09	4.4	0.03	1	100	23	Assume 5 tanks, each holds 12kDWT. (Ref 1) 19% loss in 1 tank

Notes:

m = meters

m/s = meters per second

m^3/s = cubic meters per second

MT/hr = metric tons per hour

hr = hour

k = thousand

DWT = deadweight tonnage

In cases of catastrophic grounding (Scenarios 8 and 12), where a large rupture is simulated to occur on the hull of the vessel, the release rates are based on the findings of Karafiath and Bell (1993), who note accidents of this type release 60 to 80 percent of the total volume relatively quickly into the environment. The remainder exits more slowly after the fluid level within the vessel forms a balance with the surrounding water; currents and wave action mingle with the remaining oil, pumping the oil-water mixture into the water column. For the grounding scenarios, 70 percent of the total release volume is assumed to exit in the first hour, with the remaining 30 percent exiting over the subsequent 48 hours. Release rates and durations for each scenario are provided in Table 4.3.

For each scenario, the wind probability Markov matrix was obtained using its location and seasonal conditions. All the external forcing data such as wind, current, salinity and temperature were applied for each scenario similar to baseline spill studies and is described in detail in the Task 2B report (ERM/DNV 2010c). All scenario simulations were run for 7 days and 25 stochastic runs were performed for each simulation.

The model grid domain used for each scenario is shown in Figure 4.1. The grid domain for Scenarios 1 to 6 (Location 1 – North Unimak Pass) has dimensions of 300 x 300 m along east-west and north-south directions with a far-field grid size of 750 x 650 m and near-field grid size of 94 x 81 m to resolve the shoreline. The grid domain for all the remaining scenarios (Location 2 to 6 – Sanak, Attu, Adak, Amlia and Urilia Bay) has dimensions of 400 x 400 m along east-west and north-south directions with a far-field grid size of 800 x 615 m and a near-field grid size of 134 x 100 m.

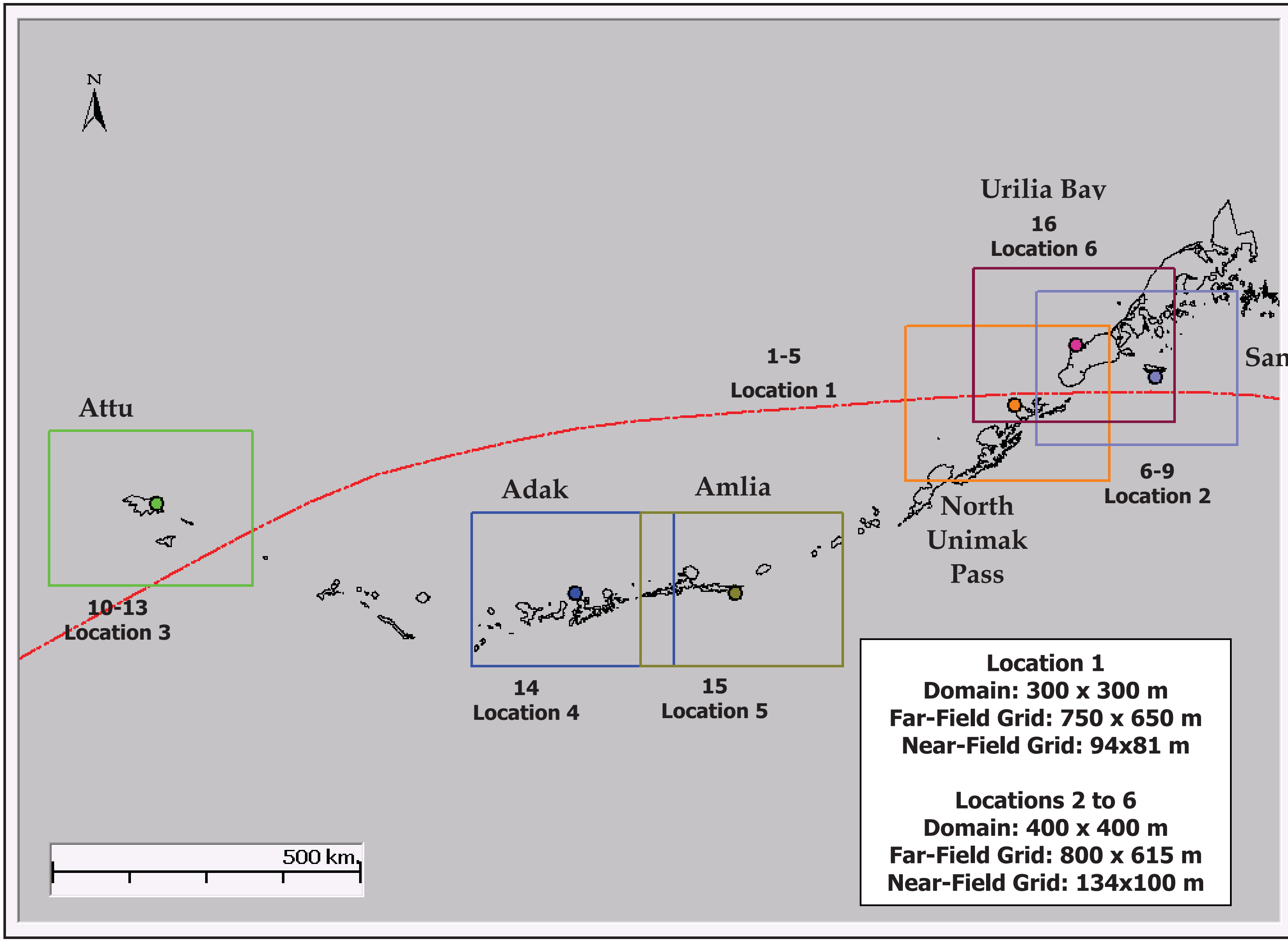
The model domain and grid dimensions were established by taking into consideration the computational efficiency and also the sensitiveness of variation of model results with grid dimensions. For this consequence analysis, sensitivity analysis was not performed since all the model parameters were kept the same as was used in the baseline spill studies (ERM/DNV 2010c). The purpose of the baseline spill study was to establish a defined set of input data and also model parameters so that they could be used for any other spill simulations for the Phase A risk analysis. Since we are analyzing the results using stochastic approach, any slight variation in the model parameters does not alter the probability values when analyzed at the 10% interval.

4.1.3 *Approach for Presenting Spill Modeling Impacts*

As described in the Task 2B Report (ERM/DNV 2010c), additional oil spill (as opposed to chemical spills) outputs produced by the model include the following:

- Travel time in hours on water surface and water column (chemical spills only);
- Probability of spill impact on the shoreline in percentage;
- Probability of spill impact in the water column for chemical spills;
- Probability of spill impact on the bottom sediments for chemical spills;
- Oil/chemical remaining on water surface in percentage;
- Oil/chemical lost by evaporation in percentage;
- Maximum averaged concentration over all iterations at any vertical location in parts per billion (ppb); and
- Maximum oil thickness in millimeters.

Figure 4.1 Model Grid Domain Used for Various Scenarios



To evaluate potential impacts to the five receptor groups (discussed in Section 4.2), spill model results from 16 scenarios have been analyzed in detail using the following contour outputs:

1. Probability of spill impact on the water surface in percentage;
2. Maximum water column concentration at any vertical location in ppb; and
3. Maximum sediment concentration in ppb.

Table 4.4 summarizes the model outputs and indications for evaluating impacts.

Table 4.4 Summary of Model Outputs for Evaluating Impacts

Model Output	Description	Use for Evaluting Impacts	Examples of Receptor Group(s)
Probability of spill impact on water surface	Provides estimated area of surface water oiling given probability (in 10% probability bands)	Calculated total area of surface oiling for each scenario above lowest probability band (e.g., <10%)	Habitat, birds, mammals
Maximum conc in water column (subsurface conc)	Provides maximum concentration from all the stochastic simulations per scenario in the water column	Calculated total area of lethal concentrations for biological impact analysis	Fish found primarily in water intakes
Maximum sediment conc	Provides maximum sediment concentration on ocean bed from all of the stochastic simulations performed for each scenario	Calculated total area of chronic concentrations for biological impact analysis	Fish and benthic organisms primarily inhabitating sediments

The results of the spill outputs are discussed in the subsequent section. The potential impacts to receptor groups are discussed in Section 4.2.

4.1.4 *Spill Modeling Results*

As described above, the surface oiling probability, maximum subsurface concentration, and sediment concentration were used for Task 4 consequence analysis. Results of each of the model outputs are described below.

Surface Oiling and Shoreline Probability

Table 4.5 provides a summary of the maximum surface oiling areas and shoreline lengths associated with two probability ranges: greater than 1 percent and greater than 90 percent. The surface impact probability contour maps are shown in Appendix A for all scenarios.

The top three scenarios exhibiting the greatest surface oil area at the lowest probability band (greater than 1%) are Scenarios 6, 8, and 9, which are all associated with Spill Location 2 – Sanak Island. The top three scenarios exhibiting the greatest area of surface oiling at the highest probability band (greater than 90%) are Scenarios 4 (Spill Location 1), 15 (Spill Location 5), and 13 (Spill Location 3).

The main drivers affecting the surface oiling output results are 1) environmental conditions associated with location of spill (e.g., wind, current, and wave); 2) oil type; and 3) oil properties. As indicated in the table above, Spill Location 2 presents the greatest impact for surface oiling within the areas evaluated. Scenarios 6 and 8 are represented by heavy oils while Scenario 9 is diesel fuel.

The top three scenarios associated with greatest shoreline impacts at the lowest probability band are Scenarios 14 (Spill Location 4), 1 (Spill Location 1), and 16 (Spill Location 6). Scenario 14 is a diesel spill, whereas Scenarios 1 and 16 are Bunker C.

Table 4.5 Maximum Surface Oiling and Shoreline Impact Area by Probability Ranges

Scenario Number	Season	Spill Vol MT (bbl)	Oil Type	Spill Load Rate (MT/hr)	Surface Oiling - Lowest Probability Band (area from <10% to 100%), Acres	Surface Oiling - Highest Probability Band (area from >90% to 100%), Acres	Shoreline Oiling - Lowest Probability Band (area from <10% to 100%), km	Shoreline Oiling - Highest Probability Band (area from >90% to 100%), km
1	Summer	391 (3049.79)	Bunker C	21	3,839,227	10,145	565	0
2	Summer	2,339 (18244.2)	Bunker C	100	3,679,967	35,812	425	0
3	Summer	54,882 (428079.6)	Crude oil	1000	3,125,919	36,056	492	4
4	Winter	3,430 (26754)	Diesel	29	3,071,162	99,736	141	0
5	Summer	5,215 (40677)	Diesel	1000	3,860,250	5,378	440	0
6	Summer	391 (3049.79)	Bunker C	25	6,371,639	4,008	459	0
7	Summer	2,339 (18244.2)	Bunker C	100	5,535,221	7,288	270	0
8	Summer	54,882 (428079.6)	Crude oil	19,210 -1st hr 171.5 - next 48 hrs	6,021,816	16,762	244	1
9	Summer	5,215 (40677)	Diesel	1000	5,872,048	2,672	325	0
10	Winter	3,259 (25420.2)	Bunker C	42	4,780,083	35,283	260	19
11	Summer	2,339 (18244.2)	Bunker C	100	5,186,878	8,912	338	9
12	Spring	54,882 (428079.6)	Crude oil	19210 -1st hr 171.5 - next 48 hrs	5,577,680	9,401	290	4

Scenario Number	Season	Spill Vol MT (bbl)	Oil Type	Spill Load Rate (MT/hr)	Surface Oiling - Lowest Probability Band (area from <10% to 100%), Acres	Surface Oiling - Highest Probability Band (area from >90% to 100%), Acres	Shoreline Oiling - Lowest Probability Band (area from <10% to 100%), km	Shoreline Oiling - Highest Probability Band (area from >90% to 100%), km
13	Spring	6,995 (54561)	Diesel	57	3,711,820	37,725	208	17
14	Summer	5,215 (40677)	Diesel	1000	2,512,492	13,470	718	0
15	Summer	5,215 (40677)	Bunker C	50	3,132,011	47,418	203	32
16	Spring	2,339 (18244.2)	Bunker C	100	4,317,274	16,704	549	6.1

Note: All measurements are estimated and approximate.

Maximum Subsurface Concentration

The maximum subsurface concentration at any location in the water column is plotted for all scenarios in Appendix B and is listed in Table 4.6. Even though the maximum subsurface concentration was obtained at any vertical location, it is normally located in the top few meters of the water column (e.g., 0 to 25 m below water surface).

The water column concentration is computed as the sum of dissolved concentrations of all fractions of oil, except the residual fraction (ERM/DNV 2010c). Maximum water column concentration observed is for Scenario 12 near Attu Island.

Table 4.6 Maximum Subsurface Concentrations of Petroleum Hydrocarbons

Scenario Number	Season	Spill Vol MT (bbl)	Oil Type	Spill Load Rate (MT/hr)	Maximum Predicted Subsurface Concentration, ppb
1	Summer	391 (3049.79)	Bunker C	21	8
2	Summer	2,339 (18244.2)	Bunker C	100	37
3	Summer	54,882 (428079.6)	Crude oil	1000	446
4	Winter	3,430 (26754)	Diesel	29	659
5	Summer	5,215 (40677)	Diesel	1000	47
6	Summer	391 (3049.79)	Bunker C	25	5
7	Summer	2,339 (18244.2)	Bunker C	100	52
8	Summer	54,882 (428079.6)	Crude oil	19,210 -1st hr 171.5 - next 48 hrs	865
9	Summer	5,215 (40677)	Diesel	1000	880
10	Winter	3,259 (25420.2)	Bunker C	42	20
11	Summer	2,339 (18244.2)	Bunker C	100	12
12	Spring	54,882 (428079.6)	Crude oil	19210 -1st hr 171.5 - next 48 hrs	10,951
13	Spring	6,995 (54561)	Diesel	57	48
14	Summer	5,215 (40677)	Diesel	1000	973
15	Summer	5,215 (40677)	Bunker C	50	70
16	Spring	2,339 (18244.2)	Bunker C	100	32

The key drivers for maximum subsurface concentration are low vapor pressure, high solubility, water column entrainment due to high winds and wave energy, droplet size distribution in the water column, and low viscosity with less emulsion.

To provide an example of effect of release rate, Figures 4.2 through 4.4 show the variation of subsurface hydrocarbon concentration with release rate for crude oil, diesel, and Bunker C, respectively. Scenario number and seasonal information are shown at the top and the right side of each bar plot, respectively. The hydrocarbon concentration in the water column increases with release rate, and proximity and location of the release location with respect to the shoreline. There is no specific correlation between seasonal variation and hydrocarbon concentration based on the scope of the analysis completed. That is, to analyze correlations further, the number of simulations performed for the consequence analysis would have to be increased to account for all the variables (locations, spill volumes, etc.) associated with each scenario.

Figure 4.2 Variation of Maximum Subsurface Concentration with Release Rate for Crude Oil

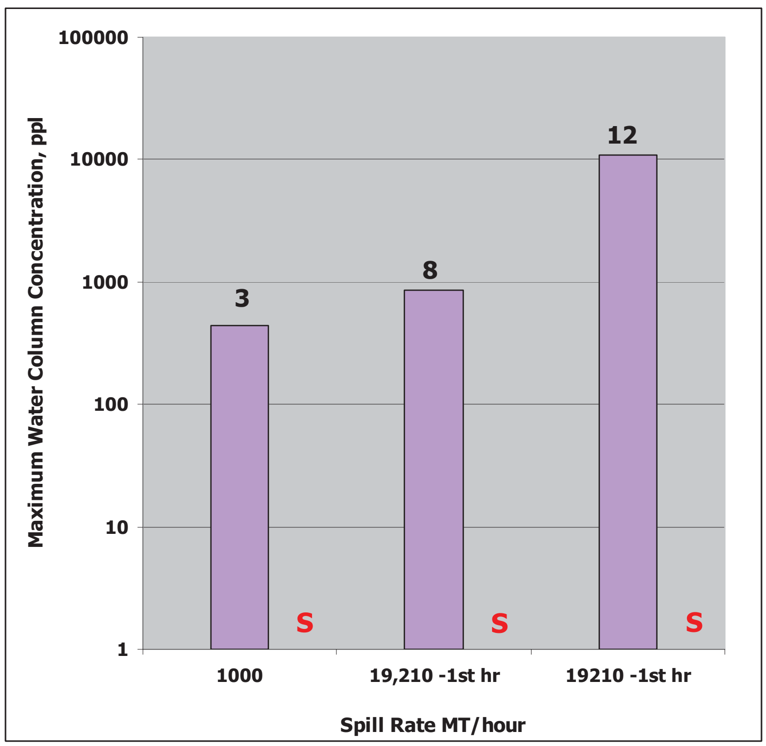


Figure 4.3 Variation of Maximum Subsurface Concentration with Release Rate for Diesel

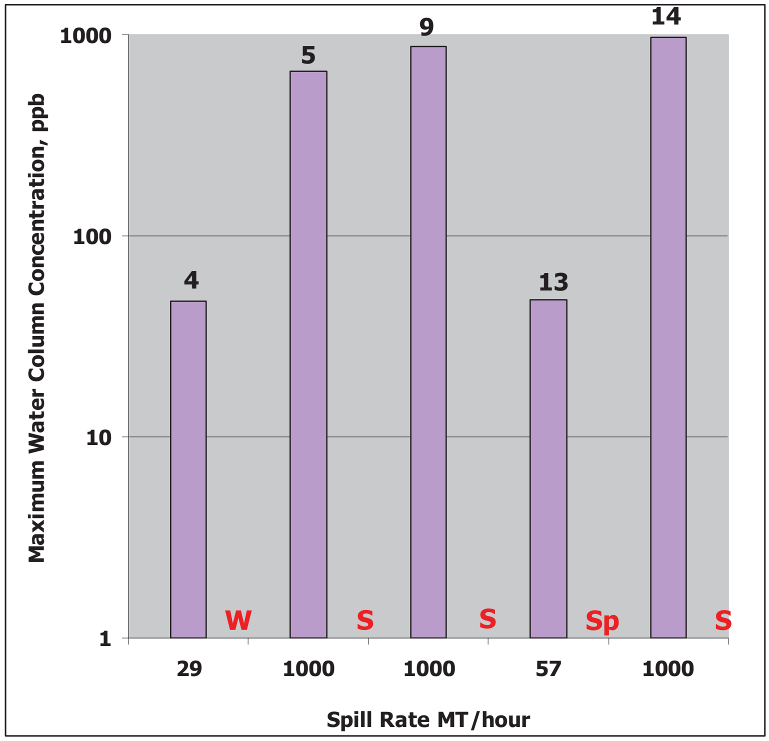
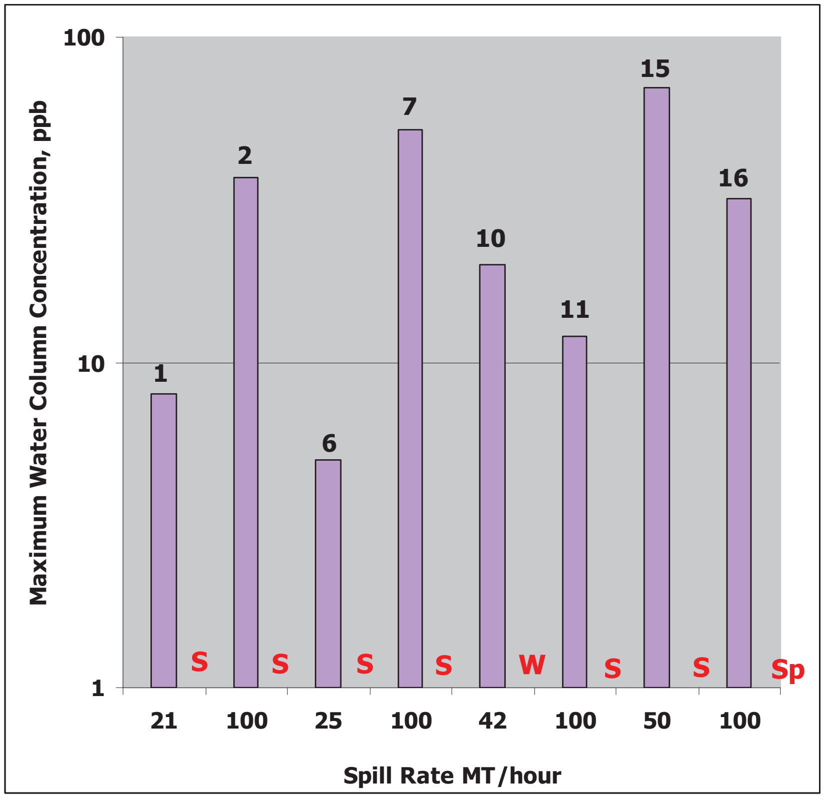


Figure 4.4 Variation of Maximum Subsurface Concentration with Release Rate for Bunker C



Maximum Sediment Concentration

The maximum sediment concentration plots for all scenarios are provided in Appendix C and listed in Table 4.7.

Table 4.7 Maximum Sediment Concentration of Petroleum Hydrocarbons

Scenario Number	Spill Vol MT (bbl)	Oil Type	Spill Load Rate (MT/hr)	Maximum Sediment Predicted Concentration, ppb
1	391 (3049.79)	Bunker C	21	318
2	2,339 (18244.2)	Bunker C	100	19
3	54,882 (428079.6)	Crude oil	1000	52
4	3,430 (26754)	Diesel	29	49
5	5,215 (40677)	Diesel	1000	558
6	391 (3049.79)	Bunker C	25	333
7	2,339 (18244.2)	Bunker C	100	24
8	54,882 (428079.6)	Crude oil	19,210 -1st hr 171.5 - next 48 hrs	1,470
9	5,215 (40677)	Diesel	1000	128
10	3,259 (25420.2)	Bunker C	42	158
11	2,339 (18244.2)	Bunker C	100	384
12	54,882 (428079.6)	Crude oil	19210 -1st hr 171.5 - next 48 hrs	417
13	6,995 (54561)	Diesel	57	228
14	5,215 (40677)	Diesel	1000	329
15	5,215 (40677)	Bunker C	50	400
16	2,339 (18244.2)	Bunker C	100	383

As shown in Table 4.7, the maximum sediment concentration was observed in Scenario 8 near Sanak Island (Location 2). There is no specific correlation between release rate and oil type. Oil concentration on sediments depends largely on total suspended solids concentration in the water column, bottom bathymetry, partitioning coefficient and release rate.

Table 4.8 summarizes the top three scenarios associated with the spill output results associated with surface oiling probability, maximum subsurface concentration, and maximum sediment concentration. For the surface oiling spill risk, the table summarizes the total area associated with the lowest (most conservative) and highest probability bands for the top three scenarios.

Table 4.8 Summary of Spill Model Output Results

Spill Model Output	**Top 3 Scenarios Exhibiting Greatest Area of Impact or Concentrations**		
	1	2	3
Surface oiling - Lowest probability band (includes area from <10% to 100%)	Scenario 6 – total area of 6,371,587 acres	Scenario 8 – total area of 6,021,934 acres	Scenario 9 – total area of 5,871,942 acres
Surface oiling - Highest probability band (includes area >90 to 100%)	Scenario 4 – total area of 99,831 acres	Scenario 15 – total area of 47,444 acres	Scenario 13 – total area of 37,807 acres
Shoreline length - Lowest probability band (includes area from <10% to 100%)	Scenario 14 – 718 km	Scenario 1 – 565 km	Scenario 16 – 549 km
Maximum Subsurface Concentration	Scenario 12 – 10,951 ppb	Scenario 14 – 973 ppb	Scenario 9 – 880 ppb
Maximum Sediment Concentration	Scenario 8 – 1,470 ppb	Scenario 5 – 558 ppb	Scenario 12 – 417 ppb

4.1.5 Uncertainty and Sensitivity Analysis

Oil spill modeling involves many variables and parameters that contribute to the accuracy of the results. These parameters can be divided into three categories: spill scenario, transport, and fate. Uncertainty in the model is affected by the combined uncertainties in each parameter.

Scenario variables include the location, volume, release rate, duration, and depth of the spill. The 16 scenarios evaluated include a range of these parameters that are feasible for the types of vessels and possible accidents in this region of the world. Naturally, model results are strongly affected by these parameters, especially the volume and location.

Release rates are dependent on diameter size and velocity of the leak. Based on literature reviews, average diameter sizes were used, which represents an average estimate. A continuous release was assumed during the duration of the spill period. This assumption represents a best estimate.

Differences in release rates do have an effect of oil spill modeling. A slower release rate increases the persistence of oil in the water column due to higher entrainment for slow release. In this analysis, release rates were used based on a certain number of hours depending on the hole size, and velocity of leak. This is a best estimate based on available literature. Effects of release rate also depend on currents and winds. For example, during the time of a slow release, wind and tide conditions change, resulting in a different impact than a faster release where tides and currents push the oil away from the shoreline or sensitive areas.

Transport variables include current speed and direction, wind speed and direction, water density, salinity, temperature, tidal heights and currents, freshwater flows, horizontal and vertical dispersion coefficients, thin and thick spreading rates, wind drift factor, wind drift angle, and bathymetry.

Model grid cell dimensions also affect the accuracy of the hydrodynamic predictions; the resolution of the grid cells used for the hydrodynamics were considered to be of sufficient resolution, although a finer grid and modeling could enhance near-field analysis in study areas less than 5 to 10 km in size.

Among these transport variables, there is good confidence in wind observations, water density, salinity, and temperature with depth, and bathymetry. Reasonable estimations were made for the dispersion coefficients; the model results are unlikely to be greatly impacted by choosing from the range of possible values. Greater uncertainty exists with the current speed and direction measurements, which are derived from model output.

Fate variables include oil type, oil composition and their properties (vapor pressure, boiling point, solubility, viscosity, atomic weight, partitioning coefficient, and density), evaporation and emulsification rate variables, biodegradation rates, evaporation/volatilization rate variables, dissolution rate variables, suspended solids, organic carbon fraction of suspended solids, shoreline classifications, and others.

Oil compound properties are well documented; however, the exact composition within each oil is variable, so there is some degree of uncertainty in the fate processes. For example, some crude oils may have more waxy components than others, increasing the amount of residual material that will be slow to degrade and weather.

Sedimentation by sorption to suspended solids is presumably low in the ocean due to insufficient concentrations of suspended solids to remove a significant amount of organic components; therefore, uncertainty in solids, organic fractions, and partition coefficients should have little influence over the outcome of the modeling.

Shoreline classifications are important for estimations of the amount of oil that can reflect or remain when contact is made. While there can be uncertainty in the exact properties of specific shorelines, the impacts on the results of this modeling exercise will likely be small.

Loss rates such as biodegradation and photodegradation may have a significant degree of uncertainty, but the relative impacts on this study of knowing the exact rates will be small due to the comparatively small oil mass reductions by these processes over the duration of the model simulation.

4.2 *CONSEQUENCE ANALYSIS – APPROACH FOR ASSESSMENT*

This section describes the methodology used to evaluate the relative impacts of each of the hypothetical oil spill scenarios using the output of the stochastic and trajectory oil spill modeling in relation to the location of environmental and socioeconomic receptors sensitive to oil spills.

In general, the approach for conducting the consequence analysis was undertaken in the following broad steps:

- Identify resources/receptors (indicator species) within six environmental (habitat is assessed under two categories) and socioeconomic categories and determine the sensitivity of each to oil spill effects;
- Using the stochastic modeling output, identify the likelihood that the resource/receptor will be affected (the spill risk area is defined by the greater than 1 percent probability contour from the stochastic modeling output); and
- Collate and analyze the data for each scenario.

Determination of sensitivity, i.e., the tendency for the receptor to suffer harm if exposed to oil, is discussed in Section 4.2.1 below.

Determination of the potential risk and data analysis for each of the resources/receptors for each of the spill scenarios from the stochastic modeling output is described in Section 4.4.

4.2.1 Assessment of Sensitivity

Sensitivity depends on a number of factors including:

- The mechanism of exposure (i.e., ingestion, oiling of skin, fur or feathers);
- The life stage of an organism or season during which the oil spill occurs;
- The effect of hydrocarbon exposure on the receptor (i.e., mortality or serious impairment for biological resources or loss of income for socioeconomic receptors); and
- The ability of the receptor to recover from hydrocarbon exposure.

For the environmental resources/receptors considered, the Sensitivity Factors (SFs) for each receptor group are based on the NOAA ESI, the most widely used approach to sensitive environment mapping in the US. The NOAA ESI approach systematically compiles information in standard formats for coastal shoreline sensitivity, biological resources, and human-use resources.

There are some exceptions to the sensitivity indices presented in the following sections due to rare habitat qualities or species that may be listed as threatened or endangered under the ESA. For example, the sensitivity index for marine mammals, Steller sea lions, and sea otters have a sensitivity ranking of 5 (i.e., most sensitive) given their protected status (see Section 4.2.5).

The subsequent sections describe the approach taken to define the sensitivity of each resource/receptor.

4.2.2 Littoral/Coastal Habitat

The sensitivity of a particular shoreline area to oil damages depends substantially on the physical characteristics of the environment and the sensitivity of the different species and their role in the community living in the respective shoreline area. Typically, oil causes more damage in low-energy coastal areas where weathering is slower and oil can become entrapped in sediment, i.e., bays and marshes. In contrast, the more rapid weathering associated with more energetic environments such as exposed rocky shores reduces exposure to oil and consequent impacts.

The habitat SFs developed for this assessment are based on the ESI, which ranks the sensitivity of estuarine shoreline types to an oil spill. The ESI system uses a scale from 1 to 10 as shown in Table 4.9 For the purposes of this assessment, the shoreline habitats have been categorized into five groups based upon the ESI ranking system. An SF of 1 represents shorelines that are least sensitive to oil and includes steep, exposed rocky shores. At these locations, the oil cannot penetrate into the rock and will be washed off quickly by waves and tides. A ranking of 5 represents shorelines most sensitive to oil. Examples include protected, vegetated wetlands such as saltwater marshes. Oil in these areas will remain for long periods of time; therefore, it can penetrate deeply into the substrate.

Table 4.9 Sensitivity Factors – Littoral Habitats

ESI Rank	Physical Characteristics	Sensitivity Factor
• **1A** Exposed rocky shores • **1B** Exposed, solid man-made structures • **1C** Exposed rocky cliffs with boulder talus base	This is the least sensitive classification. A shoreline that has regular exposure to wave and tidal energy, no potential for subsurface oil penetration, and a slope of 30°or greater is included into this ranking. Because of the impermeable substrate and its exposure to waves, oil remains on the surface, thus allowing natural forces to remove the oil. Little or no cleanup is usually required.	**1**
• **2A** Exposed wave-cut platforms in bedrock, mud, or clay • **2B** Exposed scarps and steep slopes in clay	This shoreline is similar to that above, except the slope is less than 30°. Cleanup is made easy because of the exposure to high wave energy and the impermeable substrate.	
• **3A** Fine to medium-grained sand beaches • **3B** Scarps and steep slopes in sand • **3C** Tundra cliffs	This shoreline is composed of low-sloping, well-compacted sediment, which limits oil penetration. Cleanup is simplified by a hard substrate, permitting both foot and vehicle traffic.	**2**

ESI Rank	Physical Characteristics	Sensitivity Factor
• **4** Coarse-grained sand beaches	The grain of this shoreline is much coarser than that in Rank 3. Oil is able to penetrate up to 10 inches (25 cm) below the surface, and its slope is between 5° and 15°. Cleanup efforts are hindered because erosional and deposition cycles are rapid, and vehicles tend to push oil *farther* into the loosely packed sediment.	
• **5** Mixed sand and gravel beaches	Penetration of oil can go as deep as 20 in (50 cm) into the substrate, and the slope is between 8° and 15°. Contaminated sediment is difficult to remove without causing significant erosion and disposal problems.	**3**
• **6A** Gravel beaches, Gravel beaches (granules and pebbles)* • **6B** Riprap, Gravel beaches (cobbles and boulders)* • **6C** Riprap	Because of the large grained sediments, oil can penetrate up to 40 inches (100 cm) below the surface. An intermediate slope, between 10° and 20°, restricts vehicles from assisting in the cleanup efforts. Riprap, a man-made break wall to limit wave and tidal energy, has added problems. Riprap usually is constructed at the high-tide line, which is where oil concentrations are strongest. Because of the large size of riprap boulders, oil penetrates deeply, and flushing is not always effective. Only by removing and replacing it can one ensure it is completely clean.	
• **7** Exposed tidal flats	The sediments on this shoreline are water saturated, which limits the oil from penetrating. Low traffic, high infaunal densities, and a slope of less than 10°are also characteristics of this rank. Cleanup can be difficult because of a potential to penetrate oil deeper into the substrate because of increased foot traffic.	**4**
• **8A** Sheltered scarps in bedrock, mud, or clay, Sheltered rocky shores • **8B** Sheltered, solid man-made structures • **8C** Sheltered riprap • **8D** Sheltered rocky rubble shores • **8E** Peat shorelines	This shoreline is similar to that in Rank 2 except that it is sheltered from the wave and tidal forces. The substrate is compacted and hard, composed of bedrock, man-made materials, or stiff clay, and the slope is greater than 15°. High algae and organism coverage is usually present. Shoreline cleanup can be difficult and intrusive, usually done for aesthetic reasons.	

ESI Rank	Physical Characteristics	Sensitivity Factor
• **9A** Sheltered tidal flats • **9B** Vegetated low banks • **9** Hypersaline tidal flats	Again, this shoreline classification is sheltered from wave and tidal energy, with a slope less than 10°. The sediment is water saturated, limiting oil penetration. Cleanup efforts face the same difficulties as in ESI Rank 7.	**5**
• **10A** Salt- and brackish-water marsh • **10B** Freshwater marshes • **10C** Swamps • **10D** Scrub-shrub wetlands • **10D** Inundated low-lying tundra	The substrate is generally flat, with a high concentration of organic, muddy soil. Grassy or woody vegetation frequently covers this classification. Cleanup tends to cause significant damage and long-term impacts to this delicate ecosystem.	

4.2.3 *Shallow Sublittoral/Benthic Habitats*

Shallow sublittoral habitats are generally less vulnerable to oil contamination than intertidal habitats. However, weathered oil can sink and can become entrained with suspended material and deposited on the seabed. Also, volatile water-soluble fractions can affect the water column below the surface. The sensitivity of shallow sublittoral habitats (>65-foot depth) follows the same general trend as found in intertidal habitats with shallow, low energy waters being more sensitive than rocky substrate. In general, shallow sublittoral habitats are dominated by algal (and in some cases eelgrass) habitats. Animal-dominated communities are prevalent at greater depths depending on the clarity of the water and light penetration.

The waters of the Aleutian Islands Archipelago support a diverse subtidal benthic community. Different nearshore and offshore habitats can be identified in the waters surrounding the Aleutian Islands, each characterized by distinct species assemblages. The key shallow sublittoral benthic communities include the following habitat types:

- Eelgrass; and
- Kelp forests.

Eelgrass habitat is typically found in low intertidal and shallow subtidal sandy mudflats along sheltered coastlines. Eelgrass is particularly sensitive to turbidity and changes in water quality, which can result in smothering of the community or cause toxic effects. Oil spills pose serious threats to these communities, which tend to retain oil for long periods of time, becoming chronically contaminated. If a spill occurs in the spring, seed production and viability could be affected (Beak Consultants 1975) and impact the population. Surfactants applied to mitigate oil spills have a more significant detrimental effect on eelgrass than the actual oil.

Subtidal kelp forests are less sensitive to a spill, but may be affected by toxic oils dissolved in the water column.

Deeper sublittoral benthic communities include coral and sponges. The sensitivity of corals to oil spills is heavily dependent on the type of oil spilled. Subtidal corals or sponges may experience harmful exposure when oil mixes into the water column. If a heavy fuel spill takes place, this is less of a concern to subtidal communities such as kelps or corals while it remains on the water surface. However, heavy oils can also weather or mix with sediment material and increase in density to the point where they may actually sink, at which point they could potentially result in the smothering of corals, sponges, or kelp communities.

In addition to the sensitivity of the general habitat types there are specific, sublittoral resources that are important in terms of their ecology or socioeconomic value, such as demersal fish spawning areas, breeding areas, food resources for marine mammals, etc. These are discussed in the subsequent sections.

Fish may be impacted by spills at any depth: shallow zones, intermediate depth zones, and in surface waters. Fish are impacted through direct uptake through the gills and ingestion of oil or oiled prey. Fish can also rapidly metabolize and excrete oil products that have built up in their tissues due to an effective Mixed Function Oxygenase system (Law and Hellou 1999). However, fish kills may occur as a result of high exposure to emulsified oil in shallow waters and gross oil pollution may clog fish gills causing asphyxiation. While oil exposure may cause some individuals to die, a population level effect is not likely due to the persistence of healthy individuals unaffected by contamination.

The most serious effects are to territorial or species that are reliant on specific habitats for a stage in their life cycle (e.g., critical spawning and rearing habitats) as fish eggs and larvae cannot actively avoid or escape a pollution event. Fish eggs and larvae are mostly present in the upper planktonic layers, and hence are affected by all early stages of a spill. Cleanup techniques often result in high mortality of larvae and eggs (GESAMP 1993). Demersal spawners and egg-guarding species are more likely to be affected in shallow waters and enclosed areas once the oil has dispersed through the water column. Lethal effects on the population as a whole are rare but long-term, sub-lethal effects are possible, particularly if a major spawning area is affected.

NOAA ESI data were used to identify the areas of shallow sublittoral habitats that exist within the study area. A sensitivity ranking system for shallow sublittoral habitats to spills is provided in Table 4.10.

Table 4.10 Sensitivity Factors – Shallow Sublittoral Habitats

Description	Example habitats	Sensitivity Factor
• Very high energy habitat, widespread	Barren sand or extremely exposed rocky shores	**1**
• Locally important • High energy habitat that does not support an important resource or species • Widely distributed and common	Exposed rock and boulders with common species	**2**
• Regionally important Moderate energy sea bed where sediment is likely to be mobile but that supports some important but widespread resources	Shallow kelp habitat	**3**
• Nationally important • Low energy soft sediment, shallow diverse reef areas, or rare species found at moderate depth (~20 ft or 6 m)	Eelgrass beds Fish and shellfish breeding/spawning and nursery areas Corals (seapens, seafans) Food resources for predator fish, marine mammals and seabirds	**4**
• Extremely sheltered areas with rare diverse faunal and floral communities • Supports ESA-listed species • Internationally important/protected areas	Lagoons Marine protected areas and habitat that support ESA-Listed species	**5**

4.2.4 *Seabirds*

Seabirds (i.e., auks, gulls and waterfowl) are highly sensitive to oil spills, primarily during critical periods (e.g., breeding and migration) when birds have a tendency to congregate in high-density aggregations and therefore have direct exposure to oil on the water surface. Similarly, birds that forage at sea are sensitive to oil exposure, which could be particularly damaging to the population during the breeding season when parent birds are feeding unfledged young .

The oil principally affects birds by removal of the natural buoyancy and thermal insulating properties of the feathers and by ingestion during feeding and grooming. The species most likely to be affected by a spill depends on the circumstances of the incident, e.g., the time of year, location, size, and type of oil and type of habitat affected. Severe events can be harmful at the population level (Piatt et al. 1990). However, due to positive population growth rates and natural compensatory mechanisms, many populations can recover following a one-time mortality event (e.g., a localized oil spill) if the fraction of the total population affected remains small. Declining populations or populations with a limited capacity for growth would be at greater risk. Many of the species that could be exposed to oil spilled in the Bering Sea are of this type. All loons, eiders, and other sea ducks have a relatively low capacity for population growth. Long-tailed ducks, scoters, and all species of eider and loons are declining in at least some portions of their ranges in Alaska (USFWS 1999; Conant et al. 2000).

Williams et al. (1995) proposed a method for assessment of seabird vulnerability to surface pollutants, which used the following factors to generate a vulnerability score for the United Kingdom (UK) coastal waters and the North Sea:

- Reliance on the marine environment;
- Proportion of each species that was oiled and found dead to the proportion of the time that the species spent on the surface of the sea (based on UK survey data);
- Biogeographical population; and
- Potential rate of recovery following a reduction in number.

This approach provides a useful insight into the potential effects of oil spills on the Aleutian Island's seabirds and is used below to indicate the general vulnerability of the main types of seabirds.

Figure 4.5 provides detail of the feeding strategy of the main breeding seabirds in the Aleutian Islands. The feeding habits of seabirds gives an indication of the vulnerability of these species to a particular spill, with divers tending to be more vulnerable than surface feeders.

Figure 4.5 Feeding Strategies of Breeding Seabirds in the Aleutian Islands

Species	Nearshore/offshore	Fish/plankton	Dive/surface
Northern fulmar	Offshore	Fish	Surface
Storm-petrel spp.	Offshore	Plankton	Surface
Cormorant spp.	Nearshore	Fish	Dive
Glaucous-winged gull	Nearshore	Fish	Surface
Black-legged kittiwake	Offshore	Fish	Surface
Red-legged kittiwake	Offshore	Fish	Surface
Arctic tern	Nearshore	Fish	Surface
Aleutian tern	Nearshore	Fish	Surface
Murre spp.	Offshore	Fish	Dive
Pigeon guillemot	Nearshore	Fish	Dive
Brachyramphus murrelet	Nearshore	Fish	Dive
Ancient murrelet	Offshore	Plankton	Dive
Cassin's auklet	Offshore	Plankton	Dive
Parakeet auklet	Nearshore	Plankton	Dive
Least auklet	Offshore	Plankton	Dive
Whiskered auklet	Nearshore	Plankton	Dive
Crested auklet	Offshore	Plankton	Dive
Horned puffin	Nearshore	Fish	Dive
Tufted puffin	Offshore	Fish	Dive

Source: Byrd et al. 2005.

4.2.4.1 *Gulls and Terns*

Because gulls tend to be less reliant on the sea and use more terrestrial habitat than alcids, they can also recover quickly from losses. As a consequence, gulls are amongst the least sensitive of seabird species (Williams et al. 1995). Aleutian and Arctic terns (*Sterna aleutica* and *S. paradisaea*, respectively), by contrast, have lower clutch sizes, are more reliant on the sea for the entire year, and are considered to be slightly more vulnerable to oil spills than gulls, but less so than ducks. The mid-Aleutian Islands are particularly important breeding areas for terns, with the largest concentrations found at Amchitka Island, in the Rat Islands (Byrd et al. 2005). Gulls and terns are used to represent the types of species with an SF of 2.

4.2.4.2 *Waterfowl*

Divers, such as cormorants, are relatively vulnerable to the effects of oil, mainly due to the amount of time they spend in contact with the water and their low reproductive rate. Cormorants are nearshore divers, usually foraging within 2 miles of land (Wehle 1976), although red-faced cormorants apparently can feed in deeper water than pelagic cormorants, and they occasionally have been seen up to 12 miles offshore (Causey 2002). Most ducks, however, have a potential for rapid recovery (Williams et al. 1995) and considered less vulnerable. These species are used as indicator species for an SF of 3.

4.2.4.3 *Auks*

Auks (alcids) such as auklets, puffins, and guillemots feed by catching fish and can be affected by surface oil while foraging. Populations are sensitive due to the low number of young produced per year by each nesting pair and the time to reach maturity (Piatt et al. 1990). Some auks (e.g., puffins) come ashore only to breed, spending most of their year at sea. They are therefore particularly sensitive and were amongst the most vulnerable to oil spills using the method of Williams et al. (1995), described above. Auks *spp*. are representative of species with an SF of 4.

4.2.4.4 *ESA-Listed Species*

Steller's eiders (*Polysticta stelleri*) use the eastern Aleutian Islands as winter and molting habitat. The USFWS estimates the wintering population of Steller's eider at 150,000 birds, the majority of the world's population (USFWS 2010c). They have been listed as threatened by the USFWS and thus are used to represent the highest SF of 5. However, there are insufficient data on this habitat to perform a quantitative analysis. Given that Scenario 4 is the only winter spill in the eastern Aleutian portion of the study area, a qualitative analysis will be performed.

4.2.4.5 *Nesting Areas*

Nesting areas and areas important to feeding birds in the Aleutian Islands study area have been identified using NOAA ESI data and represent the highest SF of 5.

A sensitivity ranking system for birds was developed based on several factors including the feeding behavior and vulnerability to surface pollutants. These factors are summarized in Table 4.11 below.

Table 4.11 Sensitivity Factors – Bird Populations

Description	Example Groups	Sensitivity Factor
• Species affected are not present in large numbers and are widely distributed	Very low specific sensitivity to birds identified	**1**

Description	Example Groups	Sensitivity Factor
• Habitat is locally important • Species are not fully dependent on sea • Lay more than 1 egg and have more than 1 brood	Gulls and terns	**2**
• Habitat is regionally important • Species are dependent on the sea for most of the year • Can have more than one brood and generally have multiple young	Ducks, waterfowl	**3**
• Nationally important habitat • Species are highly dependent on the sea for feeding and fledging young, have a small number of young in one brood • Migratory birds in nationally important numbers	Auks and divers Some migratory waders and water fowl	**4**
• ESA-Listed species • As above but present in internationally important numbers (e.g., Ramsar sites, etc.) Nesting areas for pelagic and diving birds	Auks and auklets, ducks, cormorants, Aleutian Canada geese, other ESA-Listed species such as Steller's eiders As above but in internationally important numbers	**5**

4.2.5 *Mammals*

The Aleutian Islands provide suitable breeding habitat for a number of seasonal visitors and resident species of marine mammal including Steller sea lions, northern sea otters, and northern fur seals. Of all the marine mammals present within the vicinity of the Aleutian Islands, it is considered that species typically associated with nearshore are likely to be most sensitive to an oil spill (e.g., sea otters and Steller sea lions). Many of these species haul out or breed along the coast of the Aleutian Islands. Mobile species that are generally found offshore, for example whales and dolphins, are less likely to be affected by an oil spill as they are typically benthic or pelagic feeders.

In summary, marine mammals may be exposed to chemicals in oil in two ways:

- Internally through consumption or swallowing of oil, or prey containing oil-based chemicals, or inhaling of volatile oil-related compounds; and
- Externally through swimming in oil, and the direct contact of the oil with the skin.

The various sensitivities to spills of the different groups of marine mammals in the Aleutian Islands are described below.

4.2.5.1 Pinnipeds

The following pinnipeds are found within waters of the Aleutian Islands:

- Steller sea lion (*Eumetopias jubatus*);
- Northern fur seal (*Callorhinus ursinus*);
- Pacific harbor seal (*Phoca vitulina richardsi*);
- Spotted seal (*Phoca largha*);
- Ribbon seal (*Histriophoca fasciata*); and
- Pacific walrus (*Odobenus rosmarus divergens*).

The following causes of harm to seals from oil have been identified based on Engelhardt (1983):

- Damage to sensitive tissue through direct contact with lungs following inhalation or eyes through direct contact;
- Toxic effects following ingestion;
- Effects on thermoregulation;
- Impairment of locomotion in viscous oil; and
- Behavioral modifications due to avoidance.

Seals may be exposed to surface oil through inhalation, absorption through the skin and ingestion with food. Seals rely on their blubber for thermal insulation and do not suffer from a reduction in core temperature due to changes in the thermal properties of their fur following contamination by oil (Engelhardt 1983).

Direct mortality of seals following oil spills has been reported, but is based on anecdotal evidence. No causal link has been confirmed. Following the Exxon Valdez spill, there is some evidence that disappearance of harbor seals from haul-out sites is consistent with avoidance behavior rather than mortality (Hoover-Miller et al. 2001).

It is thus generally accepted that pinnipeds, except for very young juveniles, are not highly sensitive to oil contamination, although the potential for mortality cannot be discounted.

The sensitivity of pinnipeds will depend on the following factors:

- Habitat – Physical contact with oil will be greater where the spill affects the coast or ice used by seals to breed or haul out. Species that spend proportionately more of their time hauled out will have a greater exposure to oil than those that spend a greater proportion at sea. Oil spilled amid floating ice is likely to take longer to weather.
- Gregariousness – A larger proportion of a population could be affected if a spill contaminates locations where gregarious species congregate.
- Feeding habit – Oil spills have the potential to affect inshore, shallow water food resources. Deeper benthic and pelagic resources are less likely to be contaminated. Pinnipeds that feed on shallow benthic infaunal prey are more likely to ingest oil or be affected by a reduction in the availability of their food.
- Population status – Population size within a biogeographical area is an important factor that affects the potential for recovery from natural or anthropogenic impacts. Larger populations are more robust against mortality and/or lowered rates of breeding success.

4.2.5.2 Cetaceans

The following cetaceans are found within waters of the Aleutian Islands at various times of the year:

- Killer whale (*Orcinus orca*);
- Pacific white-sided dolphin (*Lagenorhynchus obliquidens*);
- Harbor porpoise (*Phocoena phocoena*);
- Sperm whale (*Physeter macrocephalus*);
- Baird's beaked whale (*Berardius bairdii*);
- Cuvier's beaked whale (*Ziphius cavirostris*);
- Stejneger's beaked whale (*Mesoplodon stejnegeri*);
- Gray whale (*Eschrichtius robustus*);

- Humpback whale (*Megaptera novaeangliae*);
- Fin whale (*Balaenoptera physalus*);
- Minke whale (*Balaenoptera acutorostrata*); and
- North Pacific right whale (*Eubalaena japonica*).

A number of potentially harmful effects of oil on cetaceans have been postulated as follows (Geraci and Aubin 1988; Engelhardt 1983):

- Damage to sensitive tissue through direct contact with lungs (following inhalation) or eyes;
- Toxic effects following ingestion;
- Blocking of blow hole;
- Fouling of baleen plates; and
- Behavioral modifications due to avoidance.

There is evidence that cetaceans may accumulate hydrocarbon residues in their blubber (Engelhardt 1983) and that the smaller-toothed whales accumulate more than baleen whales. Under experimental conditions dolphins (*Tursiops truncatus*) can detect oil, but in the field, cetaceans do not tend to avoid oil spills. There is no evidence that any of the identified potential effects of oil have resulted in death or harm to a cetacean species (Geraci and Aubin 1988; Engelhardt 1983), although it has been suggested that a dolphin may have died from a blocked blow hole following a spill of viscous oil (Brownwell 1971). Circumstantial evidence also suggests that the Exxon Valdez incident was responsible for mortality in resident killer whales living in the vicinity of the spill (Exxon Valdez Oil Spill Trustee Council [EVOS] 2010a). The potential for individual animals to be harmed by exposure to oil certainly exists.

4.2.5.3 Sea Otters

Northern sea otters (Enhydra *lutris kenyoni*) are particularly sensitive to oil spills. They rely on air trapped in their fur for warmth and buoyancy. Contamination with oil drastically reduces the insulative value of the pelage and, consequently, sea otters are among the marine mammals most likely to be detrimentally affected by contact with oil (Angliss and Allen 2009). It is believed that sea otters can survive low levels of oil contamination (<10% of body surface), but that greater levels (>25%) will lead to death (Costa and Kooyman 1981; Siniff et al. 1982). Vulnerability of sea otters to oiling was demonstrated by the 1989 Exxon Valdez oil spill in Prince William Sound. It was estimated that 3,905 sea otters (range 1,904 -

11,257) died in Alaska as a result of the spill (DeGange et al. 1994). Evidence suggests that sea otters and the nearshore ecosystem have not yet fully recovered from the spill, with populations remaining below pre-spill levels (Bodkin et al. 2002; Stephenson et al. 2001).

The Southwest Alaska Distinct Population Segment was listed as threatened by the USFWS in 2005 and designated critical habitat in 2009. A Draft Recovery Plan was published in August 2010 (USFWS 2010b).

The SFs used for marine mammals are summarized in Table 4.12 below.

Table 4.12 Sensitivity Factors – Marine Mammal Habitat

Group	**Example Species/Habitat**	**Sensitivity Factor**
• No specific importance to marine mammals • Shoreline not used habitually	Transient species or species migrating through the area	**1**
• Locally important marine mammal habitat • Species present have low reliance on rocky haulout sites • Non-gregarious breeders • Pelagic feeders • Widely distributed and large population numbers • Not dependent on fur for insulation	Cetacean species such as minke whales Habitat Conservation Areas (NOAA Fisheries)	**2**
• Regionally important marine mammal habitat • Species present use rocky haulouts for a significant part of the year • Gregarious breeding colonies/locations • Benthic feeders	Resident cetacean populations such as some killer whales Pinniped areas and locations, rookeries	**3**

Group	Example Species/Habitat	Sensitivity Factor
• Nationally important marine mammal habitat • Species are very dependent on rocky haul-out sites • Very gregarious breeding colonies comprising a significant proportion (>10%) of regional population • Dependent on fur for insulation • Benthic feeders • Nationally important location for species or species present are protected	Pacific walrus Gray whales Harbor seals Steller sea lion haulouts Aleutian Island Open Areas	**4**
• ESA-Listed Species • Marine Mammal Protection Act Depleted Species • Internationally important area for sensitive/protected species	Steller sea lions & SSL Conservation Areas Northern sea otters (Distinct Population Segment) Northern fur seals Blue whales Sperm whale	**5**

4.2.6 Fish

Oil spills can cause direct impacts to fish by physical contamination and tainting and toxic effects resulting in fish kills. The three main fish groups of cultural and commercial interest in the study area include:

- Salmon;
- Shellfish (e.g., crab, scallops, shrimp); and
- Groundfish (e.g., rockfish, walleye pollock, halibut, lingcod).

Toxic effects of an oil spill will generally not affect adult pelagic or demersal fish (Deslauriers et al. 1982), but may affect spawning, nursery areas, and shallow-water shell fisheries. There are spawning and nursery areas of numerous species of economic importance within the Aleutian Islands. Portions of the lifecycles of a number of fish species are associated with shallow waters; for example, following spawning, the Pacific cod move into shallower waters (less than 100 m deep), and Atka mackerel deposit their eggs in rock crevices in shallow coastal waters. As herring eggs are deposited on intertidal and subtidal vegetation, herring are particularly vulnerable to oils spills at the time of spawning, as noted following the Exxon Valdez oil spill. The SFs used for fish are summarized in Table 4.13.

Table 4.13 Sensitivity Factors – Fish Species

Group	Example species	Sensitivity Factor
• Water column and seabed (>200 m)	Transient species found at depths > 200 m	**1**
• Water column and seabed (>100 m)	Transient species found at depths > 100 m	**2**
• Water column and seabed (50 - 100 m)	Adults of pelagic species (e.g., Pacific cod, pollock, Atka mackerel). Groundfish (flatfish, rockfish, shellfish)	**3**
• Water column and seabed (< 50 m) spring & summer	Eggs, larvae, juveniles of pelagic species (e.g., Pacific cod, pollock, Atka mackerel); adult salmon, herring, and crab	**4**
• Intertidal / subtidal / spring and summer; NMFS-designated "Savings Areas"	Eggs, larvae, juveniles of any species of salmon, crab, and herring; adult Chinook salmon in the Savings Areas, summer herring in the Savings Areas.	**5**

See Section 4.2.8 for the sensitivity criteria developed for fisheries, including important areas for fixed nets and trawling.

4.2.7 *Invasive Species – Rats*

Risk assessment considers the likelihood and potential impact of an invasive species establishing in a new location (Andersen et al. 2004). It has been presented that establishment of invasive species usually follows a process of uptake, transport, release, survival and spread (Colautti and MacIsaac 2004). The *farther* along this pathway invasive rats survive, the greater the likelihood of adverse impacts. Unfortunately, there are currently few data available to quantify the relative survival rates of invasive rats through each of these stages.

For transport routes very close to shore (1 to 2 km), invasive rat transport can occur by local transportation on vessels or by swimming. It can be quite difficult to distinguish the mechanisms by which invasive rats are arriving on islands and very few data exist on the rates of vessel infestation for local transportation (Russel et al., 2008).

The approach for evaluating the potential impacts and risk from invasive species includes an evaluation of the following:

- Potential sources of invasive rats;

- Pathways for release;
- Assessment for introduction following an accident; and
- Potential for impact following release.

The assessment of impacts from invasive rats is presented in Section 4.4.7.

4.2.8 *Socioeconomic Resources*

The sensitivity to oil spills of socioeconomic resources is expressed using the same scale as the other receptors, i.e., a scale of 1 to 5, with 1 being least sensitive and 5 being most sensitive for each as shown in Table 4.14.

The following categories of socioeconomic resources/receptors are considered in this study:

- Commercial and recreational fisheries;
- Subsistence;
- Historic preservation sites;
- Marine recreation and tourism; and
- Coastal development and coastal infrastructure.

Each of these receptors is described in more detail in the sections below. Identification of these resources/receptors within the study area was undertaken through a careful study of publicly available literature sources listed in Table 3.5. For the purposes of the consequence analysis, sensitivity criteria that encompass all socioeconomic receptors, with the exception of fisheries, have been developed as shown in Table 4.14.

Table 4.14 Overview of Sensitivity Factors for Socioeconomic Resources

General Group	Comments	Commercial Fisheries Avg. Annual Catch	Sensitivity Factors
• No specific socioeconomic activity other than communications • No commercial fisheries interest	• Locations in the open sea.	• **No historic catch.**	**1**
• Resource is locally important but widespread and common or species has low average annual catch • Commercial harvest in the area not significant or fisheries are widespread • Alternative fishing grounds are available • Small proportion of population reliant • Recovery likely to be complete and effective within 1 to 2 months • Effects on people will be localized and short lived	• Pelagic fishing areas (exclusion likely but effects on resources not significant so fishing can continue when oil has been dispersed).	• Pollock trawl <30,000 metric tons • Pacific cod fixed <1,000 metric tons • Pacific cod trawl <2,500 metric tons • Tanner crab <1,200,000 lbs. • Bristol Bay king crab <300,000 lbs. • Flatfish trawl <4,000 metric tons • Salmon <12,000,000 lbs.	**2**
• Resource is regionally significant, widespread but of relatively high value or species has moderate average annual catch • Alternative fishing grounds are available but distant (i.e., requiring significant travel time) • Recovery likely to be complete and effective within 6 months to 1 year • Large proportion of moderately important fishing grounds affected	• Fishing areas where the average annual catch is of moderate important. • Area used for tourism. • Offshore fish processing or catcher processing.	• Pollock trawl 30,000 – 50,000 metric tons • Pacific cod fixed 1,000 – 2,500 metric tons • Pacific cod trawl 2,500 – 5,000 metric tons • Tanner crab 1,200,000 – 4,800,000 lbs. • Bristol Bay king crab 600,000 – 1,500,000 lbs. • Flatfish trawl <4,000 metric tons • Salmon <12,000,000 lbs.	**3**

General Group	Comments	Commercial Fisheries Avg. Annual Catch	Sensitivity Factors
• Resources are high (national) value or not widely distributed or species has moderate to high average annual catch • Alternative fishing grounds are not available and large numbers of people are reliant • Recovery likely to be greater than 1 year	• Area important for commercial fishing (State or Federal) • Area used for shore-based, floating inshore or mothership processing. • Community Development Quota (CDQ) Fishery.	• Pollock trawl 50,000 - 70,000 metric tons • Pacific cod fixed 2,500 - 3,000 metric tons • Pacific cod trawl 5,000 - 7,500 metric tons • Tanner crab 4,800,000 - 8,400,000 lbs. • Bristol Bay king crab 1,500,000 - 2,100,000 lbs. • Flatfish trawl 8,000 - 12,000 metric tons • Salmon 24,000,000 - 30,000,000 lbs.	**4**
• Resources are of national value upon which very sensitive economies and communities are totally reliant. • Impacts are likely to be difficult to mitigate. • Sites listed on the NRHP. • Sites identified as culturally significant to communities. • Worker and community health and safety. • Majority of all fishing grounds for any one species affected. • Species has very high average annual catch.	• Areas used for subsistence fishing or hunting. • Small rural communities with few options for economic activity. • Local community fisheries or shore-based processors NRHP sites. • Communities located near spill area (includes potential risks associated with culturally significant areas as well as worker and community health and safety).	• Pollock trawl >70,000 metric tons • Pacific cod fixed >3,000 metric tons • Pacific cod trawl >7,500 metric tons • Tanner crab >8,400,000 lbs. • Bristol Bay king crab >2,100,000 lbs. • Flatfish trawl >12,000 metric tons • Salmon >30,000,000 lbs.	**5**

4.2.8.1 *Fisheries*

Oil spills can cause direct damage to fishing resources by physical contamination, toxic effects and tainting, and disrupting normal fishing activities. For Alaska fisheries in particular, the downstream economic effects of tainting and loss of marketplace due an oil spill is well documented (EVOS 1992). A description of the commercial fisheries in the Aleutian Islands and the significance of the fisheries to the economy are described in more detail in Section 3.6.1.

Direct economic losses to the fishing industry due to an oil spill can be significant and have both long- and short-term effects. For example, area closings and restrictions on all the commercial fisheries immediately following the Exxon Valdez spill in 1989 resulted in a estimated net loss of $136.5 million to commercial fishermen in that year alone. Estimates of the long-term losses to the fishing industry since then are approximately $580 million (Dorsett 2010).

For the purposes of this analysis, potential impacts of oil spills on fish and commercial fisheries have been characterized based on the following four types of impacts:

- Direct mortality of fish stocks;
- Exclusion or displacement of fleets from the fishing grounds;
- Contamination of fish catch and fishing gear; and
- Potential decline in market value due to concerns of contamination (i.e., avoidance of Alaska fish products due to fear of contamination whether true or not).

Direct impacts on fish are described in Section 4.2.6. An oil spill can adversely affect the fishing industry through the creation of exclusion zones around the pollution source, thus limiting the ability of fishing vessels to track and capture target fish. An oil spill may also result in displacement of fishing fleets to areas that are further away, resulting in additional fuel costs, time, and other supplies needed to maintain fleets. Depending on the extent of the spill, the impacts on the fishing industry could be extensive.

Other effects to the fishing industry from a spill likely to result in extensive economic loss to the sector include contamination of catch and fishing gear. Contamination of fishing gear is likely to be more important for static fishing methods such as potting or drift netting. Such contamination is then easily transferred to the catch.

The sensitivity of the commercial fisheries receptors have been qualitatively evaluated based on maps showing average annual catch by statistical area 2006-2008 (NMFS 2008) and categorized according to the scheme provided in Table 4.14. While 2011 catch data are available, these data are preliminary and thus less reliable then the catch averages from 2006-2008.

4.2.8.2 Subsistence

Subsistence fishing and hunting play an important role in communities located in the Aleutian Islands. A 1997 report prepared by the ADF&G Division of Subsistence (ADF&G 1997) indicated that the percentage of households harvesting marine mammals ranged from approximately 20 to 90 percent (Wolfe and Mishler 1997). Communities in the Alaska Peninsula and Aleutian Islands consume on average about 200 to over 450 pounds per capita of subsistence resources annually. Salmon, groundfish, Steller sea lions, and harbor seals are some of the more significant species harvested in the Aleutian Islands, though several other species are also important (e.g., halibut, birds, bird eggs, and marine invertebrates) (NMFS 2004).

The significance of subsistence to the nutritional and cultural wellbeing of communities in the Aleutian Islands cannot be overstated. Given that subsistence activities occur throughout the region, for the purposes of this analysis, it is assumed that potential oil spill locations near communities in the Aleutian Islands would affect subsistence activities and that these effects would be significant. For these reasons, the sensitivity ranking for potential impacts to subsistence resources is considered high as shown in Table 4.14.

The Aleutians East Borough Coastal Management Plan (AEBCMP) indicates that "subsistence" can have multiple meanings in Alaska. According to Alaska Administrative Code, Title 11 Chapter 112.990(38) (adopted the definition for subsistence uses in Alaska Statute 16.05.940):

> "Subsistence uses" means the noncommercial, customary and traditional uses of wild, renewable resources by a resident domiciled in a rural area of the state for direct personal or family consumption as food, shelter, clothing, tools or transportation, for the making and selling of handicraft articles out of nonedible by-products of fish and wildlife resources taken for personal or family

> consumption, and for the customary trade, barter, or sharing for personal or family consumption; in this paragraph, "family" means persons related by blood, marriage, or adoption, and a person living in the household on a permanent basis.

According to the AEBCMP, "subsistence in Alaska comprises a diverse set of localized systems of food production and distribution, representing relatively unique combination of ecology, community, culture and economy." Subsistence could include aquatic hunting, fishing and trapping and terrestrial plant resource gathering. The resources harvested include waterfowl and bird eggs, crab, salmon, shrimp, halibut, seals, sea lions, clams, cod, mussels, sea urchins, and octopus.

The AEB identifies three types of subsistence use areas under Alaska Administrative Code Title 11, Chapter 114.250(g):

- Marine-Based Subsistence Area includes all non-federal coastal waters within its boundaries as important for subsistence use;
- Land and Freshwater Based Subsistence Areas include all non-federal lands and aquatic areas within its coastal zone as important for subsistence use; and
- Special Use Areas important for subsistence.

In addition to these areas, the AEB identifies Specific Geographic Subsistence Designations within the coastal zone.

For this study, the subsistence use areas identified in the AEBCMP and AWCRSA Coastal Resource Inventory and Environmental Sensitivity Maps were referenced. For the impact analysis, subsistence-use area boundaries were extended to the coastal zone boundaries (3 miles from mean high water, which generally excludes federal lands) to reflect the definition of Marine-Based Subsistence and the definitions of the Specific Geographic Subsistence Designations.

4.2.8.3 Historic and Cultural Sites

Based on the National Register of Historic Places (NRHP), there are over 20 sites in the Aleutian Islands that have been classified as historic places (NPS 2010). Most of these sites are located on land, away from the sea, and are therefore not likely to be directly impacted by a spill. Potential impacts to sites offshore, or along the coastline of the Aleutians, are considered high due to their national significance.

While the NRHP lists several sites in the study area, there are likely to be additional sites in the Aleutian Islands characterized as culturally significant to Aleutian Islands communities. Impacts to culturally significant sites are considered high, given their unique value to these communities, many of which have been inhabited for hundreds or thousands of years.

4.2.8.4 *Tourism and Recreation*

The two main areas of importance to tourism in the Aleutians are:

- The Shumagin Islands; and
- Unalaska/Dutch Harbor.

Typically, these areas are rich in biodiversity, relatively accessible, and pristine. Caribou hunting, birding, beach combing, fishing, skiing and kayaking are popular tourist activities in the more established and accessible tourist areas such as Dutch Harbor and the Shumagin Islands. The tourism industry as a whole is largely dependent on the marine environment.

A spill could have an adverse effect on tourism through a direct impact on coastal areas where tourists are present, or through a belief that the Aleutian Islands are no longer a desirable destination because of a real or perceived loss in pristine wilderness values. Negative effects of an oil spill could also include decreased resident and non-resident visitor traffic, labor shortages in the visitor industry as local workers are recruited for the response/cleanup effort, and so on. On the other hand, spill-related businesses would be strengthened (EVOS 1990).

4.2.8.5 *Power Stations and Industrial Abstraction*

Industrial facilities that utilize seawater for cooling and other process functions are at risk from oil spills through damage of water circulation and heat-exchange equipment, due to need to clean and possibly replace equipment. The International Tanker Owners Pollution Federation suggests that damage to power stations is not usually serious; however, this would depend on the consequences of temporary closure of the facility. If there are no alternatives or the closure occurs at a critical time, then impacts could be more significant.

4.2.8.6 *Coastal Development and Offshore Development*

Key coastal infrastructure includes ports, harbors and fish processors in the communities of Unalaska/Dutch Harbor, Sand Point, King Cove and Adak. Important offshore development includes floating fish processors. Of greatest importance is the intake water locations for fish processors, whether at a fixed location or floating.

4.3 *APPROACH FOR ASSESSING RECEPTOR IMPACTS*

As described in Section 4.1, the surface oiling probability, maximum subsurface concentration, and sediment concentration were used for Task 4 consequence analysis. These outputs from stochastic modeling comprise information on the areas at which oil is estimated to impact water surface and the coastline, as well as the probability of its occurrence.

Exposure expressed in terms of surface water oiling and shoreline oiling was used to provide an indicator of impact on the physical, seabirds and mammal receptors by estimating total area of intersection between spill plots and receptor location maps. To provide an indicator of impact on fish and invertebrates receptors, the subsurface concentration in the water column and the area of bottom sediment contamination affected above thresholds of concern was used from the stochastic model. Again, the estimated area of potential impact was estimated by overlaying fish receptor maps with spill plots. This process is described in more detail in the Appendix D.

For the two media, water column and sediment, a level of concern or threshold concentration was utilized to identify the potential impact to groundfish and benthic-dwelling organisms (e.g., scallops, and crabs). These are typically represented by lethal concentrations (LC50) or lethal doses (LD50) where 50 percent of population dies, or alternatively, effect concentrations (EC50) where 50 percent of the population experiences adverse effect (e.g., limited growth). While LC50 and EC50 values vary by species, age and life stage, not enough information is available to obtain toxicity data (LC50 and EC50) for each species and age group of fish or other biota. In addition, an exhaustive review of toxicity data is not within the scope of this study. Therefore, several sources were reviewed for species that fall into 5 broad taxonomic life stage categories: fish (juvenile and adult), eggs and larvae of fish, benthic invertebrates, zooplankton, and plants. Representative threshold values were selected to assess fish and benthic organisms.

For the purposes of this study, probability bands which indicate the probability of a resource/ receptor coming into contact with a spill were considered. These were:

- 0-10% (where 0% is where the resource/receptor will not be affected);
- 10-20%;
- 20-30%;
- 30-40%;
- 40-50%;
- 50-60%;
- 60-70%;
- 70-80%;
- 80-90%; and
- 90-100% (where 100% is where the resource/receptor is guaranteed to be affected).

Where the resource/ receptor data was available in GIS format (i.e., NOAA ESI data), then the probability of oil effects were determined by interrogating the GIS to select probability values corresponding to the data points. This method was undertaken for the following environmental resource/receptor categories:

- Sublittoral habitat;
- Benthic habitat;
- Seabirds;
- Marine mammals; and
- Fish

For each scenario where data was available in GIS format, the resources/ receptors and associated sensitivity value (discussed in Section 4.2) and vulnerability in terms of the probability value were tabulated into a worksheet for each resource/receptor type.

Overview tables of vulnerability and sensitivity were then produced to identify the most sensitive receptors with the highest vulnerability. These tables and associated graphical output were used to interpret the output from the sensitivity analysis.

Where the data was digitized rasta data then the interpretation of the probability was undertaken by eye, using the stochastic modeling output overlaid with maps showing the receptor location. A conservative estimation was made where the boundary was difficult to determine. This method was undertaken for the socioeconomic receptors, including fisheries.

For digitized rasta data, the location of the resource (including fisheries) was plotted on ArcMap GIS and the overlaid with the 1 percent probability envelope derived from the stochastic modeling. A conservative assumption was made that if the 1 percent probability plume overlapped an area where receptor/resource is expected to be present, then unacceptable effects would occur. For receptors that covered a large area (e.g., fisheries resources) the proportion and relative value of the area over which oiling may occur was taken into account. For example if a given fishery has only one highly productive location within an area of coast then it is likely that if this was affected the viability of the fishery would be much more seriously affected than if there where alternative fishery grounds of the same or similar productivity near by. Accessibility was also taken into account if, for example, a resource such as a fishery is separated by an island then it may take a considerable period for a fishing fleet to travel to an alternative location.

A detailed description of the process used to evaluate the intersection of spill area and receptors for each scenario is provided in Appendix D.

4.4 CONSEQUENCE ANALYSIS - RESULTS OF IMPACTS

The results of the consequence analysis at the six spill locations and 16 scenarios are discussed in this section. The results are based on the methodology described in the previous sections, as well as Appendix D. For each location, the probability of the various environmental and socioeconomic resources/receptors coming into contact with a spill is discussed and, where relevant, the extent of the habitats affected are noted. Detailed evaluation data tables and figures of the assessment of potential impacts is provided in Appendix E. The spill-receptor impact overlays for each scenario are included in Appendix F.

4.4.1 Location 1 - Northern Side of Unimak Pass

An oil spill in North Unimak Pass is postulated to occur to the northwest of Akutan Island, within 10 miles of the coast. The spills resulting from Scenarios 1 through 5 are predicted to affect the northern coasts of

Akutan, Atun, and the western end of Unalaska islands. For all scenarios, oil reaches the Akutan and North Unimak passes, but there is generally a low probability of impacts to the southern coasts of the islands, particularly for Scenario 3. In all cases of a spill during the summer, i.e., Scenarios 1, 2, 3 and 5, there is a higher probability of the oil moving to the northeast. For Scenario 4, a diesel spill during the winter, the model predictions indicate the plume moving slightly further north and west and barely reaching the end of Unimak Island.

4.4.1.1 *Coastal Habitats*

Between 19,574 (Scenario 4) and 52,100 acres (Scenario 3) of coastal habitat are affected by Scenarios 1 through 5.

The majority of the coastline comprises slightly sensitive gravel beaches (38%) with moderately sensitive coarse-grained sandy beaches (58%) in more sheltered embayments and exposed headlands. Scenario 4 is the only scenario with areas of highly sensitive tidal flats (1,809 acres), with the probability of impact fairly evenly distributed across the entire range (>1% to >90%). However, the area of sheltered tidal flats affected is less than 1 percent of the potentially impacted littoral habitat as shown in Table 4.15.

Table 4.15 Coastal (Littoral) Habitat Affected (Acres) for Scenarios 1 through 5

Receptor	Sensitivity Factor	Total Area (acres)
Coarse-grained Sand	2	95,368
Gravel Beaches	3	62,275
Exposed Tidal Flats	4	3,655
Sheltered Tidal Flats	5	1,810
Total area of littoral habitat		163,108

4.4.1.2 *Benthic Habitats*

There are extensive areas of very sensitive eelgrass habitat and sheltered rocky shores in and around the Krenitzin Islands, Akutan Island, and Unalaska Bay in all five scenarios. Scenarios 3 and 4 each have over 15,000 acres of eelgrass habitat and a probability of impact of over 90 percent. Nearly half (46% or 872,085 acres) of the total eelgrass habitat has a 0 to 10 percent probability of being impacted. Scenario 3 has over 40,000 acres (15% of the total) of sheltered rocky shores with a 60 percent probability of impact. Fifty-six percent (56%) of the eelgrass has a 0 to 10 percent probability of impact.

Smaller areas of highly sensitive marshes, lagoons and soft sediment habitats exist in all Location 1 scenarios, ranging from 617 acres in Scenario 3 to 35 acres in Scenario 5. Overall, 71 percent of marshy areas are impacted in the 0 to 10 percent probability band. The total acreage of sublittoral habitat with potential impact for Scenarios 1 through 5 at all levels of impact probability can be found in Appendix D.

4.4.1.3 Seabirds

In general, the areas around the Krenitzin Islands, Akutan Island, and Akun Island are important habitat for all marine bird resources in the study area, i.e., gulls and terns, alcids, diving birds, and pelagic birds. Total areas of bird resources for all five scenarios range from 415,198 acres for Scenario 5 to 576,146 acres in Scenario 3. Moderately sensitive (SF 3) resources, represented by waterfowl such as ducks and cormorants, have the highest total area (1.9 million acres or 77.4% of all receptors). Nearly 75 percent of waterfowl have a low (0-10%) to moderately low (<30%) probability of impact. Only 4 percent of waterfowl resources have a greater than 80 percent chance of impact.

Nesting sites are defined as points in the GIS database, rather than areas or polygons. For the purposes of analysis and display, these points have been assigned a value of 1 (acre) but are more accurately discussed in terms of the number of sites rather than an area. For example, the value 2,891 for "Nests-Pelagic Birds" represents the number of nests within the study area location and is not the total acreage of the nests. This means that direct comparison of amount of nesting sites to often much larger values for the true polygon or area receptors is not possible. However, nesting sites can be discussed relative to each other.

All five scenarios also have areas of very sensitive (SF 4) alcid receptors, with low probability to moderately low probability of impact. Just over 3 percent of these auk and diving bird resources may be affected by an oil spill at a probability of 90 percent or higher.

One-third of highly sensitive bird nesting sites (SF 5), i.e., the diving bird nesting sites on the northern shores of Akutan and Akun islands and the pelagic bird nesting sites on Unalga Island, northeast of Unalaska, have a low probability of impact (< 20%); 6 percent of nesting sites in all scenarios have more than a 90 percent chance of impact from a potential spill in the area. No nesting sites exist in Scenario 5 with a 90 percent or greater probability of being impacted.

Steller's eiders have winter and molting habitat in the eastern Aleutians. Shape files were unavailable for modeling; however, a map of Steller's eider wintering habitat, available from the USFWS (2010b), was used to approximate potential impact to this ESA-listed species. Scenario 4 models a diesel oil spill in the winter approximately 5 miles northwest of Akutan Island and is therefore the only winter scenario with potential to impact Steller's eiders.

The area in red inside the box marked "2" on the detail of the USFWS map are known concentrations of 1,000 or more birds. The overlay plot for Scenario 4 shows that the area on Akutan Island has a 0 percent probability of impact. The Steller's eider population in Unalaska overlaps with alcid. The data indicate there is a 20 to 30 percent probability of impact in the same area; therefore, this probability is inferred for Steller's eiders.

4.4.1.4 Mammals

As with birds, marine mammal receptors are of two types: points and polygons. The point receptors for marine mammals are:

- Stellar sea lion haulouts;
- Pinniped locations; and
- Rookeries.

The polygon receptors are:

- Sea otters;
- Stellar sea lion conservation areas;
- Pinniped areas;
- Habitat conservation areas; and
- Aleutian Island open areas.

The discussion of the results for marine mammals distinguishes between these two types.

In Scenarios 1 to 5, there are consistently very large areas of highly sensitive marine mammal habitat with a SF 5 that may be impacted by a potential oil spill, as well as a number of SF 3 and SF 4 sites.

The total area in acres of SF 5 habitat for each scenario in each impact probability band can be found in Appendix D. The amount of potentially impacted habitat is roughly the same for each scenario at this location, i.e., just under 3.5 million acres. Scenarios 3 and 4 have 2 and 3 percent, respectively, of areas with over 90 percent probability of impact. In each scenario, the majority (> 60%) of SF 5 has a low probability of impact.

The potential impacts to SF 4 marine mammal receptors (e.g., Steller sea lion haulout sites) for Scenarios 1 through 5 can be found in Appendix D. A low to moderate chance of impact to these receptors exists in all scenarios, with a small amount with a high to very high probability of being affected.

The potential impacts to SF 3 receptors for Scenarios 1 through 5 can be found in Appendix D. The probability of impact is low (0-10%) to moderate (30-40%) for most scenarios. Scenarios 1, 3, 4 and 5 have a higher percentage of sites impacted between 10 and 40 percent. All scenarios could impact a small proportion of these receptors at moderately high to very high probabilities.

The relative vulnerability of these receptors to a potential spill can be found in Appendix D. Receptors with the same SF have been combined. For example, pinniped locations and rookeries have an SF of 3; sea otters and the Steller sea lion conservation area have an SF of 5.

4.4.1.5 Fish

The result of the model predictions of aqueous phase hydrocarbons indicates that levels will only exceed toxic levels for adult fish, shell fish and fish larvae/eggs for Scenarios 3 and 5. The area affected is greatest for Scenario 5, with a moderate probability of impact (46%).

4.4.1.6 Socioeconomic Receptors

Representative commercial fisheries located within the region affected by Spill Scenarios 1 through 5 include pollock (trawl gear), Pacific cod (fixed and trawl gear), Tanner crab, Bristol Bay kin crab, flatfish (trawl) and salmon (all gear). Scenarios 1 and 2 affect all fisheries except Bristol Bay kin crab. Scenario 2 is not expected to directly affect salmon fisheries.

Scenarios 3 through 5 are not expected to affect the Tanner crab or Bristol Bay king crab fisheries.

The Pacific cod fixed gear fishery is potentially the fishery most affected by Scenarios 1 through 5. Based on historic catch, the fishery is considered highly productive in this area. Based on NOAA data from 2006 through 2008, historical catch of Pacific cod (fixed gear) in this region was greater than 3,000 metric tons and is therefore considered a significant contribution to the BSAI groundfish fishery. With the exception of Scenario 2, Scenarios 1 through 5 may have a significant effect (sensitivity rating of 5) on the Pacific cod fixed gear fishery. Historical catch for the pollock trawl fishery ranges between 30,000 and 50,000 metric tons in areas near Scenarios 2 and 5 and therefore are given a sensitivity rating of 3 for those scenarios.

According to the Alaska Department of Commerce, Community and Economic Development (ADCCED), there are 11 shore-based processors located in Dutch Harbor. Trident Seafoods is a large processing plant located in Akutan and, while it is only one facility, the probability of oil reaching the shore is very high for all scenarios at this location. The water intakes for fish processing facilities at Dutch Harbor and Akutan are potentially affected by Scenarios 1 through 5 given their location. Oil passing into fish-processing water systems has the potential to contaminate lines, resulting in total shutdown of facilities for unknown periods of time. Although there are processing plant spill prevention plans in place to protect the intakes, the possibility exists that water intakes could be affected by spills. Consequently, given the number of fish-processing plants located in Dutch Harbor and Akutan, and the significance of these facilities to the overall success of the Alaska groundfish and salmon fisheries, the sensitivity rating for fish processors for these Scenarios is 5.

Communities and community resources at various locations exist within the footprint of the 1 percent probability contour. The most sensitive of these are subsistence hunting and fishing areas. At least one area of importance would be affected by Scenarios 1 through 5. The potentially affected communities include Akutan on Akutan Island and subsistence use areas on both Akutan and Akun islands including, but not limited to, Open Bight, Hot Springs Bay, Akutan Bay, Lost Harbor, and Surf Bay. The community of Unalaska/Dutch Harbor and subsistence use areas of Unalaska Bay could be affected by Scenario 3. Loss of subsistence areas could impact the cultural heritage of these communities, as subsistence resources are necessary for their livelihoods and the practice is integral to their cultural identity. Indirect impacts to cultural identity could include increasing and/or reinforcing individual vulnerabilities (Cf. Bjerregaard, Berner, and Odland 2008). Possible impacts include a range of public health concerns including mental health issues, substance abuse, and violence, as well as outmigration, which could accelerate a loss of cultural heritage.

Oil reaching such areas would result in exclusion, potential contamination of boats and equipment, and exposure of people. The consequences would be serious because the ability to hunt and fish would be affected for potentially more than 1 month. Subsistence areas are assigned the highest level of sensitivity.

NRHP sites identified in Dutch Harbor include (but are not limited to) the Dutch Harbor Naval Operating Base and Fort Mears and the SS Northwestern Shipwreck Site. NPHP sites could be adversely affected by the oil spill Scenario 3.

Tourism and recreation include boating, hunting, fishing, and wildlife viewing. These activities are important in the potentially affected areas depicted in Scenarios 1 through 5. The potentially affected areas are likely to recover within 6 to 12 months after the oil has been cleaned up. The economic significance of these resources is reflected in the sensitivity score of 3.

4.4.2 *Location 2 – Off Sanak Island on Southern Side of Unimak Pass*

An oil spill in the Sanak Islands is postulated to occur due south of the island, within 10 miles of the coast. Spills from Scenarios 6, 7, 8, and 9 are all summer spills and behave in a similar way, with the plume moving in a predominantly southwest-to-northeast direction with little predicted north or south movement. Consequently, the majority of the impacts from these scenarios are in the vicinity of the Sanak Islands and Unimak Island. The coast of the Alaskan Peninsula is only affected by Scenario 6 and, to a lesser extent, Scenario 9.

The intertidal habitats of Sanak Islands include areas of sheltered tidal flats, exposed tidal flats, fine-to-medium grained sand beaches, coarse-grained sand beaches, and gravel beaches. The relative effects on intertidal resources for all scenarios with a release point in the Sanak Islands have similar potential impacts on coastal habitat resources.

The total impacted acreage for each receptor type are presented in Appendix D. The overall impacted acreage for all receptor types are fairly consistent, ranging from 23,465 acres (Scenario 6) to 31,234 acres (Scenario

9). Coarse-grained sand beaches have a low sensitivity to a spill (SF 2) and are the most prevalent of all receptor types for Location 2 scenarios. The majority of these beaches have a low (0-10%) probability of impact, with less than 2 percent having a potential impact of 80 percent or higher. All scenarios have areas of high and very highly sensitive beaches with a low (0-10%) probability of impact.

4.4.2.1 *Benthic Habitat*

Scenarios 6 through 9 have significant areas of highly sensitive eelgrass habitat (SF 4) that range between 315,709 acres for Scenario 7 and 500,929 acres for Scenario 6. Scenario 6 has the highest amount of all benthic habitat. All scenarios have some areas of highly sensitive brackish marsh (SF 5), with Scenario 8 having the greatest amount.

All scenarios with a release point in the Sanak Islands have similar potential impacts on benthic habitat resources, although Scenario 8 has more acreage (53,594 acres) and a higher percentage of its habitat (19%) with greater potential impact (>80%) than the others. For all scenarios, the probability of impact for eelgrass beds and brackish marshes is low (i.e., 0-10%).

4.4.2.2 *Birds*

There are large areas of moderately sensitive waterfowl (SF 3) habitat in all scenarios at Location 2, the Sanak Islands, ranging between 285,310 acres in Scenario 8 and 511,375 acres in Scenario 6. Scenario 9 affects more sensitive bird habitat across all sensitivity levels than any of the scenarios examined.

For all scenarios, the majority of waterfowl receptor areas have a low to moderately low probability of impact, although in Scenarios 7 and 8 there is a higher percentage of habitat with a greater than 70 percent chance of an effect. The percentage of waterfowl receptor areas within each scenario for each impact probability band is evaluated in Appendix D.

The percentage of nesting sites within each scenario for each probability band is tabulated in Appendix D. The most sensitive bird habitat within the area potentially affected, pelagic and diving bird nesting areas, have a low probability of oiling (less than 20%) for Scenarios 6, 7, and 9. For Scenario 8, this probability drops to 10 percent.

The sensitivity to nesting birds would be confined to the period from early spring to late summer.

4.4.2.3 *Marine Mammals*

The southern side of the Sanak Islands as well as to the east-northeast provides important marine mammal habitat areas. Between 270,734 acres (Scenario 7) and 425,134 acres (Scenario 6) are identified as sea otter habitat specifically. Steller sea lion conservation areas are not present for any scenario in Location 2. Around half of the sea otter receptor areas in all scenarios have a low-impact probability of 0 to 10 percent; however, some areas have a probability greater than 60 percent. The less sensitive pinniped locations, rookeries (both SF 3), and Steller sea lion haulouts (SF 4) show a slightly higher percentage of sites with low probabilities of impact, while there are a few sites where the probability is greater than 90 percent.

4.4.2.4 *Fish*

The result of the model predictions of aqueous-phase hydrocarbons indicates that levels will only exceed toxic levels for adult fish, shell fish and fish larvae/eggs for Scenarios 8 and 9. The area affected is greater for Scenario 8 than for Scenario 9. The probability of impact is 46 percent and 39 percent respectively.

4.4.2.5 *Socioeconomic Receptors*

Both Pacific cod fisheries (fixed and trawl gear) as well as the salmon fisheries are potentially affected by Scenarios 6 through 9. Of those, the Pacific cod fixed gear fishery would be the most sensitive based on ratings shown in Table 4.11. Pacific cod fixed gear catch near Scenarios 6 through 9 ranges between 2,500 and 3,000 metric tons and is therefore given a rating of 4. Pacific cod trawl gear catch has not been as high as the fixed gear fishery in this location (catch ranges between 1,000 and 2,500 metric tons) and has a rating of 3 for these Scenarios. While the salmon fishery may be affected by Scenarios 6 through 9, the amount of salmon historically harvested in this location has been less than 12 million pounds resulting in a sensitivity rating of 2. There are no fish processors near Location 2 and, therefore, are not expected to be impacted by Scenarios 6 through 9.

For Scenarios 6 through 9 in the vicinity of Sanak Islands, those residents who travel to subsist on the islands would be affected. For each scenario, highly sensitive subsistence areas fall within the 1 percent probability band. Potentially affected communities that may visit Sanak Islands for subsistence harvesting include False Pass, King Cove, and Sand Point. The impacted subsistence use areas appear to be limited to Sanak Islands and the coastal areas to the 3-mile coastal boundary. Subsistence areas lost could impact the cultural heritage of those communities affected. Communities in the region depend on subsistence resources for their livelihoods and it is integral to their cultural identity. Indirect impacts to cultural identity could include increasing and/or reinforcing individual vulnerabilities (Cf. Bjerregaard, Berner, & Odland 2008). Possible impacts include a range of public health concerns including mental health issues, substance abuse, and violence, as well as outmigration, which could accelerate a loss of cultural heritage.

Significant coastal infrastructure sites are not present in the vicinity of the Sanak Islands presented in Scenarios 6 through 9. However, highly sensitive subsistence communities fall within the 1 percent probability band. Tourist and recreational receptors would be affected in Scenarios 8 and 9 and be considered moderately sensitive and score 3. NRHP sites are nonexistent in the area of the Sanak Islands that would be affected by a spill.

4.4.3 Location 3 – Holtz Bay on Attu Island

Location 3 scenarios postulate an oil spill just off Holtz Bay on Attu Island, the largest of the Near Islands in the Aleutian chain, traveling mainly to the east with some northerly and southerly spread. Scenario 10 occurs in winter, Scenario 11 is a summer spill, and Scenarios 12 and 13 are based in the spring.

Spills in all scenarios could affect the eastern shore of Attu Island with greater than 80 percent probability, mostly impacting the north-facing shoreline from Chichagof Harbor and Sarana Bay to Chirikof Point. The northern coast of Agattu Island has a 20 percent probability of impact in Scenario 10, which falls to less than 10 percent in Scenarios 11 and 12. Only the northern tip of the island may be affected in Scenario 13 at low probability. Shemya Island, to the east, has up to a 30 percent chance of being impacted in Scenarios 10, 12 and 13; this probability is reduced to 10 to 20 percent in Scenario 11.

4.4.3.1 Coastal Habitat

The coastal habitat in the areas potentially affected are all exposed rocky shores, and characterized with low sensitivity (SF 1). Most have a less than a 20 percent probability that the coast will be affected. Scenario 12 has the highest area of coastal habitat affected at 1,692 acres.

4.4.3.2 *Benthic Habitat*

The benthic habitats in the areas potentially affected are all high energy habitat with low sensitivity (SF 1) and are affected in comparatively small areas (1,510 acres for Scenario 13 to 2,180 acres for Scenario 10). There is a low probability that these resources will be affected.

4.4.3.3 *Birds*

All four scenarios at this location have potentially impacted areas of moderately sensitive (SF 3) waterfowl habitat, ranging from 51,643 acres in Scenario 10 to 36,382 acres in Scenario 13. Scenario 11 has a higher percentage of waterfowl habitat with lower probability than the other three scenarios. Scenarios 10 and 13 have over 20 percent of habitat with greater than 70 percent chance of impact, and both have 8 percent of waterfowl areas with over a 90 percent chance of being affected.

Alcid habitat does not exist at this location.

Impacts to nesting birds would be confined to the period from early spring to late summer. Scenarios 10 and 13 have 13 percent and 12 percent, respectively, of nesting sites with a very high probability of impact, otherwise the range of potential impact is evenly distributed across all bands.

4.4.3.4 *Marine Mammals*

The amount of highly sensitive sea otter habitat affected ranges between 45,050 acres (Scenario 13) to 3,218,600 acres (Scenario 11). There are no areas of Steller sea lion conservation areas in this location.

4.4.3.5 *Fish*

Scenarios 10, 11, and 13 do not cause levels of hydrocarbon residues to exceed toxicity thresholds in the water column. Scenario 12 results in 9,656 acres being affected by levels of hydrocarbons, which are acutely toxic to adult groundfish and levels sufficient to cause acute toxicity to mature shell fish and groundfish larvae/eggs will occur over an area of 19,296 acres. The probability of impact is 65 percent.

4.4.3.6 *Socioeconomic Receptors*

Commercial fisheries are the only socioeconomic resources affected by Scenarios 10 through 13. For these scenarios, historical catch data indicate that the potential spills may affect areas where less than 1,000 metric tons of Pacific cod fixed gear and less than 2,500 Pacific cod trawl gear are harvested. Similarly, the pollock trawl gear fishery, which has harvested less than 30,000 metric tons in these areas historically, may also be affected. Both flatfish and salmon fisheries also occur in this area, though they are not expected within areas where oil would disperse due to the spills projected. While the fisheries are likely to be affected, the relatively low level of catch results in a sensitivity rating of 2 for commercial fisheries potentially affected by Scenarios 10 through 13. Neither the Tanner crab nor Bristol Bay king crab fisheries would be impacted by these scenarios.

4.4.4 Location 4 – North of Adak (Scenario 14)

Only one scenario has been modeled for a spill at Location 4: Adak Island. Scenario 14 is postulated to occur during summer and potentially affects the northern side of the Andreanof Islands, from Tanaka Island in the west to Great Sitkin Island in the east. The probability is low for oil to reach the southern side of the islands passing between Tanaga and Kanaga islands. Atka Island on the far eastern edge of the impact zone may not be affected.

4.4.4.1 Coastal Habitat

Scenario 14 has 24,419 acres of low sensitivity, high energy shoreline that may be impacted. The northern exposed areas around Cape Adagak on Adak Island, representing 6 percent of the total area, has a 50 to 60 percent chance of being impacted. The western edge of Great Sitkin Island and the northern capes of Kanaga Island, representing 13 percent of the total habitat, has a 30 to 40 percent chance of being affected. Many of the smaller islands in the impact zone have anywhere from 0-10 percent to 20-30 percent chance of being affected.

4.4.4.2 Benthic Habitat

Scenario 14 has 12,252 acres of low sensitivity habitat. Almost 80 percent of the habitat has up to a 40 percent probability of being impacted.

4.4.4.3 Birds

All of the bird resources within the predicted impact zone are of very high sensitivity (SF 5) and the majority have a low-to-moderate chance of being affected. Approximately 4.5 percent of nesting sites have a 90 to 100 percent chance of impact.

4.4.4.4 *Marine Mammals*

Compared to other scenarios, Scenario 14 has less potentially affected habitat (90,768 acres) of very high sensitivity (SF 5). Over 60 percent of the SF 5 habitat has less than 10 percent probability of impact. However, there are some areas with a moderate probability of impact (up to 50-60%). There are larges areas of SF 4 (Aleutian Island Open Areas) and SF 2 (Habitat Conservation Areas) around in Adak Strait.

4.4.4.5 *Fish*

This scenario results in 98 acres being affected by levels of hydrocarbons, which are acutely toxic to adult groundfish; levels sufficient to cause acute toxicity to mature shell fish and groundfish larvae/eggs will occur over an area of 152 acres. The probability of impact is 56 percent.

4.4.4.6 *Socioeconomic Receptors*

While according to ADCCED (2010), Adak hosts just one fish processing plant, the contribution of this facility to the region cannot be underestimated (NMFS 2007). Given the contribution of the processor and the importance of local fueling services to the economy and the fisheries, a sensitivity rating of 5 has been given for this Scenario. While each of the seven representative fisheries are known to occur at this location, historical levels of reported catch have been relatively low compared to other areas and thus are considered to have a sensitivity of 2 for Scenario 14.

Scenario 14 is anticipated to affect the northern portion of Adak Island, which is a sensitive subsistence community. As previously mentioned, Adak residents can only subsist on private or State lands due to its non-rural federal designation for subsistence. Loss of already limited subsistence areas could impact the cultural heritage of Adak, as subsistence resources are necessary for their livelihoods and the practice is integral to their cultural identity. Indirect impacts to cultural identity could include increasing and/or reinforcing individual vulnerabilities (Cf. Bjerregaard, Berner, & Odland 2008). Possible impacts include a range of public health concerns including mental health issues, substance abuse, and violence, as well as outmigration, which could accelerate a loss of cultural heritage.

Tourism resources would also be affected, which would be moderately sensitive and score 3. Adak's coastal infrastructure of three deepwater docks and marine fueling facility could also be affected. The Naval

Operating Station is on the NRHP and it too could be affected by Scenario 14.

4.4.5 Location 5 - South of Amlia Island (Scenario 15)

Scenario 15 postulates a summer spill near the southeastern edge of Amlia Island, spreading mostly in a northwesterly direction past Seguam Island and across Seguam Pass, but also spreading south to a lesser degree. The highest impact, with more than 90 percent probability, would occur along the southern shoreline at the eastern end of Amlia Island and the ocean area immediately to the south. Seguam Island has 0 to 10 percent chance of being affected.

4.4.5.1 Coastal Habitat

All of the coastal habitat within the impact zone for Scenario 14 is exposed rocky shoreline with very low sensitivity and includes 1,820 acres of beach. Almost 90 percent of this habitat has less than a 20 percent chance of impact.

4.4.5.2 Benthic Habitat

Relatively small amount of benthic habitat (2,338 acres) is within the area potentially affected by a Scenario 15 spill. These areas are of low sensitivity and have a low probability of impact.

4.4.5.3 Birds

There are a small number of highly sensitive bird receptors potentially affected in Scenario 15; most (75%) have a low probability of impact. There are two sites that have a very high probability of impact.

There are 10,849 acres of SF 3 habitat in Scenario 15; over 90 percent have a low probability of impact.

4.4.5.4 Marine Mammals

There are high and very high sensitive areas of marine mammal habitat within the potential impact zone for Scenario 15, particularly on the southern side of Amlia Island. The majority (62%) of the estimated 15,847 acres of SF 5 habitat has a low to moderately low chance of impact, but there are 3,778 acres (>20%) of the total habitat that have a high to very high chance of being affected.

The large area (1,267,120 acres) of SF 4 has a low probability of impact. There are also 23 Steller sea lion haulout sites (SF 4) within the impact zone; almost 40 percent (10) have a greater than 50 percent chance of being impacted.

SF 3 point receptors, represented by pinniped locations and rookeries, also have a moderate to high probability of impact.

There are almost 2 million acres of low sensitivity habitat in Scenario 15, the majority have a low probability of impact. However, over 160,00 acres (approximately 8%) have a greater than 50 percent chance of being affected.

4.4.5.5 *Fish*

This scenario does not result in contamination of the water column with hydrocarbon residues in sufficient concentrations to cause acute toxicity.

4.4.5.6 *Socioeconomic Receptors*

Each of the representative commercial fisheries (Pacific cod, pollock, flatfish, crab and salmon) occurs within or near the spill area. Of these fisheries, the Pacific cod and pollock trawl fisheries are the most sensitive given catch levels ranging from 2,500 to 5,000 metric tons for cod and 30,000 to 50,000 metric tons for pollock. Based on the sensitivity criteria presented in Table 4.11, these levels of catch warrant a rating of 3. While other fisheries do occur at this location, the low levels of catch have resulted in a rating of 2. No processors are likely to be affected by this scenario.

The subsistence resources used by the community of Atka would be affected in Scenario 15, because the land and water surrounding Amlia Island would be impacted. Loss of subsistence areas could impact the cultural heritage of Atka, as subsistence resources are necessary for their livelihoods and the practice is integral to their cultural identity. Indirect impacts to cultural identity could include increasing and/or reinforcing individual vulnerabilities (Cf. Bjerregaard, Berner, & Odland 2008). Possible impacts include a range of public health concerns including mental health issues, substance abuse, and violence, as well as outmigration, which could accelerate a loss of cultural heritage.

4.4.6 *Location 6 - 2 Miles North of the Shores of Urilia Bay (Scenario 16)*

The most likely outcome of a spill in Urilia Bay is for the oil to remain in the vicinity of Urilia Bay with a slight bias to the northeast. The footprint of the <10 percent probability contour, extends southwest to northeast, affecting the northern coasts of Unimak Island, the Krenitzin Islands and the western end of the Alaskan Peninsula; two small bands of oil (0-10% probability) also appear to enter the southwestern corner of the Izembek Lagoon.

4.4.6.1 *Coastal Habitat*

There are 294,437 acres of very highly sensitive coastal habitat (SF 5) in Scenario 16; the majority (80%) has less than a 20 percent chance of being impacted. Approximately 4 percent or 12,145 acres have a greater than 70 percent probability of impact.

There are 38,522 acres of highly sensitive coastal habitat (SF 4) in Scenario 16; the majority (68%) has less than a 20 percent chance of being impacted. Approximately 7 percent or 2,750 acres have a greater than 70 percent probability of impact.

There are 39,128 acres of moderately sensitive coastal habitat (SF 3) in Scenario 16; the majority (81%) has less than a 20 percent chance of being impacted. Approximately 3 percent or 1,254 acres have a greater than 70 percent probability of impact.

There are 118,538 acres of moderately low sensitive coastal habitat (SF 2) in Scenario 16; the majority (71%) has less than a 20 percent chance of being impacted. Approximately 3 percent or 6,172 acres have a greater than 70 percent probability of impact.

4.4.6.2 *Benthic Habitat*

There are 102,356 acres of very highly sensitive benthic habitat (SF 5) in Scenario 16; the majority (68%) has less than a 20 percent chance of being impacted. Approximately 7 percent or 7,303 acres have a greater than 70 percent probability of impact.

There are 367,345 acres of very highly sensitive benthic habitat (SF 4) in Scenario 16; the majority (68%) has less than a 20 percent chance of being impacted. Approximately 16 percent or 58,278 acres have a greater than 50 percent probability of impact.

4.4.6.3 *Birds*

Waterfowl habitat covering 42 acres contributes to 35 sites identified with moderate sensitivity. Mostly, these sites have a probability of <10 percent of being affected. However, highly sensitive diving bird nesting sites exist with a probability of <40 percent of being affected. Only 45 acres of sensitive bird habitat is anticipated to have a probability of >1 percent of being affected.

The sensitivity to nesting birds would be confined to the period from early spring to late summer.

Scenario 16 is a modeled as a spring spill and there is a probability, albeit low (i.e., less than 30 percent probability of impact on surface water inside the lagoon), that some of the spill will enter Izembek Lagoon, which lies within the Izembek National Wildlife Refuge. According the USFWS (2010), as many as 50,000 Steller's eiders winter in the area. Therefore, there is the potential for this ESA-listed species (SF 5) to be in the area before migrating to their traditional breeding grounds in the north. Using the same method described for Scenario 4, it was determined there is a low (<10%) probability of impact to these receptors.

The area along the shoreline bordering and within Izembek Lagoon has a large concentration of Steller eiders. Comparing this to the spill impact zone in Appendix A, it was determined that the potential impact is likely to be low (<10%), but may be as high as 20 to 30 percent as one approaches Bechevin Bay on the northeastern portion of Unimak Island.

4.4.6.4 *Marine Mammals*

There are 4,367,540 acres of very highly sensitive (SF 5) marine mammal habitat within the potential impact zone. The majority (63% or 2,767,828 acres) of the acreage has a low probability of impact (<10%), but there are still 100,000 to 120,000 acres of the total habitat that have a high to very high chance of being affected.

Sixteen sites are present in the potential impact zone with a high (SF 4) sensitivity (e.g., Steller sea lion haulouts). The 16 sites have a low probability of impact (<10%). The highest probability of impact for this receptor is 60 to 70 percent.

A relatively small amount (5,121 acres) of moderately sensitive (SF 3) marine mammal habitat (e.g., pinniped areas) is found in Scenario 16, all of the habitat has a 0 to 10 percent probability of impact.

In addition, there are 41 moderately sensitive (SF 3) sites, represented by pinniped locations and rookeries, within the impact zone, almost half of which have a low probability of impact. The highest impact probability for these receptors is 60 to 70 percent,

4.4.6.5 *Fish*

This scenario does not result in contamination of the water column with hydrocarbon residues in sufficient concentrations to cause acute toxicity.

4.4.6.6 *Socioeconomic Receptors*

Bering Pacific Seafoods is a shore-based processor based in False Pass, located on the eastern end of Unimak Island in Isanotski Straight, which would be directly impacted by oil reaching the shore, as depicted by Scenario 16. For this reason, a sensitivity rating of 5 has been given for fish processors at this location. There are two fisheries with relatively high levels of catch, pollock trawl gear (greater than 70,000 metric tons) and Pacific cod trawl gear (greater than 7,500), within this area that have been given a sensitivity rating of 5, given their significance.

Both flatfish and Pacific cod fixed gear fisheries also occur within this area and have had historical catch levels between 8,000 and 12,000 metric tons and 2,500 and 3,000 metric tons, respectively. The flatfish and Pacific cod fixed gear fisheries were rated with a sensitivity of 4 for Scenario 16 based on catch. While Tanner crab, Bristol Bay king crab and salmon fisheries all occur in this area, the levels of catch are relatively low, resulting in a sensitivity rating of 2.

The northern shore of Unimak Island is designated a subsistence use area, with trapping and salmon harvesting as the primary subsistence activities that take place in the affected area. The potential loss of the northern shore of Unimak Island could impact the cultural heritage of the communities of Cold Bay and False Pass, as subsistence resources are necessary for their livelihoods and the practice is integral to their cultural identity. Indirect impacts to cultural identity could include increasing and/or reinforcing individual vulnerabilities (Cf. Bjerregaard, Berner, & Odland 2008). Possible impacts include a range of public health concerns including mental health issues, substance abuse, and violence, as well as outmigration, which could accelerate a loss of cultural heritage.

4.4.7 *Potential Risks from Invasive Species – Rats*

This section presents a discussion of the potential impacts and risks due to introduction of invasive rats from shipping accidents. As described in Section 4.2.7, this assessment used the following four general components for evaluating potential impacts and associated principles were considered:

- Potential sources of rats: Is there a potentially viable population of an invasive species on a ship?
- Pathways of Release: Does the ship accident occur sufficiently close to a shoreline where the invasive species could be a new (that is, an additional) concern?
- Potential for introduction following an accident: Is the accident and the environmental conditions such that a potentially viable population of the invasive species could be transferred to the shoreline?
- Potential for impact following release: Does the hinterland behind the shoreline contain significant environmental resources that might be significantly impacted by the newly-introduced invasive species?

In addition to the assessment of impacts, this section presents a brief overview of the existing control measures in place to reduce the potential for release and risks from invasive rats.

4.4.7.1 *Possible Sources of Rats*

There are two ways rats might colonize previously rat-free islands, either by swimming from neighboring infested areas or being transported by man. In the case of the Aleutians, this essentially means rats on board ships.

There would first need to be a viable population of rats on a ship. This would depend on the cargos carried by the ship and the type of controls applied by the ship's crew and their shipping company to control the population of potentially invasive species onboard the ship.

Rats could be present on virtually any vessel, including bulk cargo, grain or container ships, and oil tankers. In addition, rats frequent smaller vessels operating between islands as well as fishing boats. Few data are currently available on the rate of ship infestation by rats, thus it must be considered that all shipping is a potential source of rat infestation. In Alaska, single rats (but not breeding populations) have been detected on large fishing vessels.

4.4.7.2 *Pathways of Release*

Aleutian ports receive approximately 400 ships and Alaskan harbors continue to expand, increasing the opportunity for ship-borne rats to come ashore.

Even where there are no port facilities where ship-borne rats might disperse, shipping poses a threat of rat infestation. Rats are strong swimmers and are easily able to escape from stricken ships in the event of an accident. Assuming there is a shoreline with a potential vulnerability, the most likely release pathway would only involve grounding accidents, as this would be the likely accident type to deliver an invasive rat to a new environment. Accidents that occur at a significant distance from the shoreline, such as collisions, will probably not result in a viable population of invasive species becoming established.

Despite improved navigation and mechanical equipment, the Aleutian Islands remain vulnerable to rat "spills" from vessels plying the Great Circle Route between the Pacific Coast of North America and Asia due to their remote location. The same is true during fishing seasons when fishing fleets, processors, freighters, and fuel barges concentrate near land.

4.4.7.3 *Potential for Rat Introduction Following a Marine Accident*

The risk of rat introduction is determined by the risk of several other factors as follows:

- The likelihood of a vessel being infested with rats. There are no current data on the levels of rat infestation in modern ship types, but it is reasonable to assume that vessels carrying foodstuffs or those with ample hiding space (e.g., container ships) might harbor a higher rat population than, for example, a modern liquefied natural gas carrier.
- The likelihood of an accident. This is in turn determined by location, weather, vessel type, *etc*.
- The location of the accident. Risk is proportional to the proximity of a rat-free island and the distance from the accident site to land. Rats escaping a stricken vessel nearshore will be more likely to survive. As has been previously mentioned, in the cold waters of the Aleutians, it has been estimated that rats can survive on the order of 15 minutes in the water and swim several hundred meters. Clearly accidents occurring several miles offshore are less of a risk, unless there is a significant volume of flotsam generated.

- Ambient conditions. In extreme weather (which is also often in winter months when water is colder), rats are also more likely to drown. The local tide and current regime will also have a significant bearing on the ability of rats to make landfall.

In summary, only groundings in non-stormy conditions will likely result in a significant probability of the transfer of a viable population of invasive rats ashore. In stormy conditions the wave energy at the shoreline is likely to prevent significant numbers of individuals from reaching the hinterland. Thus it is likely that powered groundings in non-stormy weather will be mainly responsible for the establishment of invasive species, though a drift grounding that occurs in non-stormy weather may also give a similar result (though such an accident is less likely because ships often do not drift far in non-stormy weather).

4.4.7.4 Potential for Impact Following Introduction

Alaska has more than 40 million breeding seabirds, about half of all the seabirds in North America. Most of these breed on the islands within the Alaska Maritime National Wildlife Refuge (AMNWR). While many areas in Alaska, including several islands in the Aleutian chain, are rat-free, existing seabird colonies are highly vulnerable to the possibility of a rat invasion. At least 14 seabird species on Audubon Alaska's Watchlist for declining species nest on islands at risk of rat introductions, including whiskered auklet (Aethia pygmaea), red-legged kittiwake (*Rissa brevirostris*), Aleutian tern (*Onychoprion aleuticus*), Aleutian song sparrow (*Melospiza melodia maxima*), and McKay's bunting (*Plectrophenax hyperboreus*).

There is direct observational and experimental evidence of rat predation on seabirds in the Aleutians (USFWS 2007). For example, predation impacts on seabirds are documented for Kiska Island, where rats prey on crested auklets (*Aethia pusilla* and *A. cristatella*). Food caches from rats near the Kiska auklet colony have been found to contain up to 150 auklet carcasses in a single cache.

Experiments in the Bay of Islands, located off Adak Island, indicated very high egg predation rates on artificial alcid nests, demonstrating that invasive rat impact to nesting seabirds can be severe and that the removal of the rat population has the potential to provide measurable increases in the nesting success of impacted seabirds.

Rat invasions are not only of concern to bird populations. Introduced rats feed opportunistically on plants, and alter the floral communities of island ecosystems, in some cases degrading the quality of nesting habitat for birds that depend on the vegetation.

Recent research suggests that rat predation on nesting marine birds such as glaucous-winged gulls (*Larus glaucescens*) and black oystercatchers (*Haematopus bachmani*) might also indirectly alter intertidal community structure. Shorebirds and some seabirds forage heavily on intertidal invertebrate grazers, and are capable of significantly altering both the species assemblage and algal abundance of intertidal communities. Significant predation by rats on intermediate marine predators has shifted the intertidal community structure of islands with introduced rats. Other research suggests that predation on seabirds also has the potential to broadly impact the terrestrial ecosystem through removal of marine-derived nutrients formerly supplied by seabirds (e.g., in the form of guano) (USFWS 2007).

4.4.7.5 Existing Control and Prevention Measures

Prevention

Prevention is the most effective strategy for managing impacts from invasive rats. This includes managing the level of infestation on vessels, minimizing accidents as well as shore-side control measures to prevent any escaped rats establishing populations ashore. Prevention relies on:

- Improving public awareness to change human behaviors that contribute to rat problems (both on vessels and ashore);
- Regulatory control and response capability; and
- Inspection and monitoring plans to detect the presence of rats on vessels, to document the need for control actions and assess the effectiveness of any actions taken.

Much of this approach is embodied in the Alaska Department of Fish and Game's rodent plan for Alaska

Control

Where rats escape stricken vessels, eradication is generally considered the best strategy for addressing them. Although eradication of rats from islands was once believed to be impossible, it is now an accepted conservation management tool. Nevertheless, the reliance on pesticides for most rat eradication programs raises some concerns around the risk to non-target species.

Eradication programs may be limited by logistical and cost considerations; however, it is much easier to eradicate rats if they can be eliminated before a breeding population becomes established. Eradication has advantages over long-term pest control programs as it does not need to be repeated and often requires the use of less pesticide than control with repeated applications.

Research suggests that although difficult, eradication is feasible if six fundamental criteria can be met:

- There is no immigration;
- All target animals are placed at risk;
- Rate of removal exceeds rate of increase at all population densities;
- Animals can be detected at low densities;
- Cost/benefit analysis favors eradication over control; and
- A suitable socio-political environment for eradication exists.

Rugged terrain and difficult logistics make eradication particularly challenging in the Aleutians;, however, the benefits of meeting those challenges may be substantial.

Existing Rodent Management Plans in Alaska

There are several plans for rat control in Alaska. Though it is outside the scope of this document to discuss these in detail, key plans and programs are summarized below.

- In 1988, the AMNWR published a Comprehensive Conservation Plan that prioritized restoration of Aleutian Island ecosystems. Though the plan is not yet fully implemented, the AMNWR began a rodent invasion prevention program in 1993. As a follow-up to this, the AMNWR published an environmental assessment of a plan to restore Rat Island that may serve as model for future restoration plans.
- An intensive rat control program was conducted on Adak in the early 1990s, but declined following the US Navy's withdrawal from the island. Recently, the community of Adak has become more involved in rat control to reduce the habitat available for rats. Akutan has implemented a similar rat control program.

- In 1995, the USFWS with AMNWR started implementing a shipwreck response program. This program includes the formation of a "Rat Response Strike Team" composed of agency, industry, and tribal community personnel, in a state of readiness to respond to groundings near a rodent-free island.
- The USFWS has also assembled a number of response kits, placed with agency personnel on salvage ships and with local oil spill response organizations. The community on Adak has such a response kit available to them.
- In 2008, the ADF&G published a manual for waterfront rat control. Though intended to provide operators with tools to minimize risks to human health and to property, many of the management techniques therein are also relevant to vessel owners and operators.
- The USFWS leads the ongoing Stop Rats! campaign to help ships, harbors, and towns prevent the spread of rats.

International Plans

Over the past 45 years, rat eradication programs have been successfully undertaken on more than 332 islands around the world, from the tropics to much higher latitudes (Howald et al. 2007). Though the majority of these programs have been on islands smaller than 500 hectares, land area has become less of determining factor in recent years.

To prevent invasive rats from arriving in new locations from ocean-going vessels, the International Health Regulations (2005) require vessels to hold either a current Ship Sanitation Control Certificate or a Ship Sanitation Control Exemption Certificate, which have a lifetime of six months. These certificates are issued on behalf of the World Health Organization in order to prevent the spread of contagions, and incorporate the previous (1969) De-Rat Certification requirement.

4.4.7.6 Summary

Rats escaping stricken vessels pose a significant risk to certain Aleutian Islands. The risks relate to the level of infestation on ships, the likelihood of an accident, and the time and location of the accident.

This issue needs to be managed through a combination of preventive measures onboard vessels, maritime safety measures, and where necessary, onshore response.

Targeted outreach should be developed for vessel operators, crews and coastal communities in the understanding that many people may be uninterested and some may even be resistant particularly in communities that don't currently have rats.

5.0 SUMMARY

The AIRA study area spans a wide range of environmental conditions, receptors, and resources. The North Pacific's Great Circle Route between western North America and eastern Asia is a high-volume shipping lane that passes through the Aleutian chain near large aggregations of animals, important ecological resources and sensitivity areas, as well as valuable socio-economic resources important to local and global communities (see Section 3). The intersection of a high-volume and international shipping lane and an area of global importance for ecological and socioeconomic resources creates the potential for increased risks.

The Risk Analysis Team (ERM and DNV) prepared this Consequence Analysis Report, on behalf of the MT, as part of the AIRA Phase A PRA. Phase A includes the following main phases:

1. Establishing the Advisory Panel (completed);
2. Contracting a Risk Analysis Team (completed);
3. Selecting a Peer Review Panel (completed);
4. Drafting a spill risk report on vessel traffic and spill likelihood (completed);
5. Developing a risk matrix and consequence analysis (this submittal); and
6. Conducting a qualitative assessment and prioritization of risk reduction options (Risk Reduction Options Evaluation Report).

The Consequence Analysis report covers Task 3 – Characterizing High Risk Scenarios and Task 4 – Consequence Analysis of the Phase A PRA.

The purpose of this consequence analysis is to gain an understanding of the relative impact of spill size, types of hazardous substance spilled, and spill location on environmental consequences. This analysis is a qualitative assessment of the potential resource damage and socioeconomic impact of select high-risk spill scenarios and provides a high-level assessment of vulnerability of identified natural resource(s).

In order to qualitatively evaluate the potential impacts to these resources (consequence analysis), hypothetical high-risk scenarios were developed as part of Task 3. Sixteen scenarios were selected based on spill location, type of material and spill volumes (see Section 2). These are summarized below.

Location 1: Northern side of Unimak Pass - High risk due to groundings, collisions, and other accident types. Spills at this location are modeled five times (two different materials and three different spill volumes).

Location 2: - Off Sanak Island on the southern side of Unimak Pass - Great Circle Route intersection with the eastern Aleutians is at high risk. Spills at this location are modeled four times (two different materials and two different spill volumes).

Location 3: Holtz Bay on Attu Island – Great Circle Route intersection with the eastern Aleutians is at high risk. The spill volumes for this location are based on upper bounds for the associated vessel and material type combination because of the response time required to assist vessels in this area.

Location 4: Adak – Near-shore locations are high risk due to groundings; a scenario releasing 40,000 bbl of non-persistent oil.

Location 5: Amlia Island – Near-shore locations are high risk due to groundings; a scenario releasing 40,000 bbl of non-persistent oil.

Location 6: Urilia Bay – Near-shore locations are high risk due to groundings; a scenario releasing 15,000 bbl of persistent oil.

The 16 representative scenarios were selected as "reasonable worst case spill scenarios." This means they are neither the most likely outcome of a given marine accident (this is normally no spill), nor are they always the worst case outcome (which would be all cargo and all bunker fuel oil carried by the ship spilled into the marine environment).

The oil spill model (COSIM) that was developed during baseline spill modeling studies (Task 2B report; ERM/DNV 2010c) was used for setting up hypothetical spill scenarios to get relevant outputs for conducting the consequence analysis (see Section 4.1). The model creates a time series file of surface slick coverage and concentrations of the spilled substance, in the water column, on the bottom, and along the shoreline. This corresponds to the three different output results that are presented in this report: probability of surface oiling plots (Appendix A), oil concentrations in the water column (Appendix B), and sediment concentrations (Appendix C).

Table 5.1 provides a summary of the main spill model outputs for each scenario. The top five largest values for each output are represented in bold text. Hence the top five scenarios associated with spill output results are listed below.

Surface oiling – Lowest Prob Range	Surface oiling – Highest Prob Range	Shoreline Impact - Lowest Prob Range	Max Subsurface Concentration	Max Sediment Concentration
Scenarios 6, 8, 9, 12, and 7	Scenarios 4, 15, 13, 3, and 2	Scenarios 14, 1, 3, 6, and 16	Scenarios 12, 14, 9, 8, and 4	Scenarios 8, 5, 12, 15, and 11

The oil spill outputs into the environment are then used in evaluation of impacts for the different receptor categories depending upon how/where they could be exposed to oil using the approaches described in Sections 4.2 and 4.3. The potential environmental (Section 5.1) and socioeconomic impacts (Section 5.2) are summarized below.

Table 5.1 Summary of Spill Model Output Results for Each Scenario

Scenario Number	Season	Spill Vol MT (bbl)	Oil Type	Spill Load Rate (MT/hr)	Surface Oiling - Acres		Shoreline Oiling - Lowest Probability Band (area from <10% to 100%), km	Maximum Predicted Concentrations, ppb	
					Lowest Probability Band (<10% to 100%)	Highest Probability Band (>90% to 100%)		Subsurface	Sediment
1	Summer	391 (3049.79)	Bunker C	21	3,839,227	10,145	**565**	8	318
2	Summer	2,339 (18244.2)	Bunker C	100	3,679,967	**35,812**	425	37	19
3	Summer	54,882 (428079.6)	Crude oil	1000	3,125,919	**36,056**	**492**	446	52
4	Winter	3,430 (26754)	Diesel	29	3,071,162	**99,736**	141	**659**	49
5	Summer	5,215 (40677)	Diesel	1000	3,860,250	5,378	440	47	**558**
6	Summer	391 (3049.79)	Bunker C	25	**6,371,639**	4,008	**459**	5	333
7	Summer	2,339 (18244.2)	Bunker C	100	**5,535,221**	7,288	270	52	24
8	Summer	54,882 (428079.6)	Crude oil	19,210 -1st hr 171.5 - next 48 hrs	**6,021,816**	16,762	244	**865**	**1,470**
9	Summer	5,215	Diesel	1000	**5,872,048**	2,672	325	**880**	128

Scenario Number	Season	Spill Vol MT (bbl)	Oil Type	Spill Load Rate (MT/hr)	Surface Oiling - Acres		Shoreline Oiling - Lowest Probability Band (area from <10% to 100%), km	Maximum Predicted Concentrations, ppb	
					Lowest Probability Band (<10% to 100%)	Highest Probability Band (>90% to 100%)		Subsurface	Sediment
		(40677)							
10	Winter	3,259 (25420.2)	Bunker C	42	4,780,083	35,283	260	20	158
11	Summer	2,339 (18244.2)	Bunker C	100	5,186,878	8,912	338	12	**384**
12	Spring	54,882 (428079.6)	Crude oil	19210 -1st hr 171.5 - next 48 hrs	**5,577,680**	9,401	290	**10,951**	**417**
13	Spring	6,995 (54561)	Diesel	57	3,711,820	**37,725**	208	48	228
14	Summer	5,215 (40677)	Diesel	1000	2,512,492	13,470	**718**	**973**	329
15	Summer	5,215 (40677)	Bunker C	50	3,132,011	**47,418**	203	70	**400**
16	Spring	2,339 (18244.2)	Bunker C	100	4,317,274	16,704	**549**	32	383

Note: All measurements are estimated and approximate.

5.1 *ENVIRONMENTAL IMPACT SUMMARY*

The potential impact of spill scenarios to coastal, benthic, marine mammals, seabird and fish communities are summarized in this section.

Location 1 (Scenarios 1 - 5)

Spill Location is on the northern side of Unimak Pass. Spill scenarios at this location include three different materials (Bunker C, crude oil, and diesel) and five different spill volumes (3,000 bbl, 15,000 bbl, 400,000 bbl, 25,000 bbl, and 40,000 bbl).

Generally, the areas around the Krenitzin Islands, Akutan Island, and Akun Island are important habitat for all seabird resources in the study area, i.e., gulls and terns, alcids, diving birds, and pelagic birds. Likewise, there are consistently very large areas of highly sensitive marine mammal habitat with a SF 5 that may be impacted by a potential oil spill (e.g., sea lion and sea otter on the northern coast of Akutan and Akun Islands), as well as a number of SF 3 and SF 4 sites within the Krenitzin Island, Unalaska and Unimak Islands.

Based on the model and spill location of Scenarios 1 through 5, the following generalizations are made:

- Potential impacts to bird habitats, shoreline and benthic receptors are most significant for the large crude oil spill in the Summer season (Scenario 3).
- Potential impact to marine mammal habitat was the most significant for Scenario 4, assuming the receptors are present during winter season and exposed. Additionally, this scenario assumes a diesel spill, which as a non-persistent oil, represents less potential for long term impacts.
- Concentrations of hydrocarbons are not predicted to reach levels greater than representative threshold values for Scenarios 1, 2 and 4; which are all spill volumes less than 25,000 bbl. The most significant potential impact to fish, including shell fish and fish larvae, was Scenario 5 (a diesel spill of 40,000 bbl) and Scenario 3 (a crude oil spill of 400,000 bbl).

Location 2 (Scenarios 6 – 9)

Spill location is off Sanak Island on the south side of Unimak Pass. Spill scenarios at this location include three different materials (Bunker C, crude oil, and diesel) and four different spill volumes (3,000 bbl, 15,000 bbl, 400,000 bbl, and 40,000 bbl).

Based on the model and spill location of Scenarios 6 through 9, the following generalization are made:

- Potential impacts to shoreline and benthic receptors were most significant for Scenario 8.
- Potential impacts to marine mammal habitat and haul out and rookeries was most significant for Scenarios 7 and 8.
- Bird habitat were least affected for spill scenarios at this location.
- The most significant potential impact to fish including shell fish and fish larvae was Scenario 8.

Scenario 8 assumes a large spill, consisting of 400,00 bbl of crude oil. These findings indicate that the fuel type and the volume in the Scenarios are of greatest possible concern for determining environmental impacts at this spill location.

Location 3 (Scenarios 10 – 13)

This spill location is Holtz Bay on Attu Island - Great Circle Route intersection with the eastern Aleutian Islands. The spill volumes associated with the three scenarios for this location are based on upper limits for the associated vessel/material type combination because of the response time required to assist vessels in this area.

Based on the model and spill location of Scenarios 10 through 13, the following generalization are made

- Shoreline and benthic receptors and bird habitat are not significantly impacted from the three scenarios at this location.
- Potential impacts to marine mammal habitat, haul out and rookeries and nesting bird sites are most significant for a 50,000 bbl of diesel fuel spill in the spring (Scenario 13) and smaller spill (25,000 bbl) of Bunker C oil in the winter (Scenario 10).
- The most significant potential impact to fish including shell fish and fish larvae was Scenario 12, consisting of a very large spill (400,000

bbl) of crude oil. Levels of hydrocarbon do not reach levels predicted to cause acute toxicity for the other scenarios.

The large spill volume associated with Scenario 12 drives the greatest potential for environmental impacts at this spill location. Of note, the sensitivity to nesting birds would be confined to the period from early spring to late summer.

Location 4 (Scenario 14)

This scenario consists of location, Adak - near shore locations, of a grounding accident releasing 40,000 bbl of non-persistent oil (diesel fuel).

The potential impacts to all receptors for Scenario 14 is not as great a environmental concern due to the lack of significant habitats with high sensitivity factors.

Location 5 (Scenario 15)

Scenario 15 is located near shore of Amlia Island and consists of a spill of 40,000 bbl of persistent oil.

The potential impacts to marine mammal habitat and bird nesting sites for Scenario 15 are the most significant environmental concern. The sensitivity to nesting birds would be confined to the period from early spring to late summer.

Location 6 (Scenario 16)

Urilia Bay - near shore locations are high risk due to groundings; a scenario releasing 15,000 bbl of persistent oil (Bunker C).

The potential impact to marine mammal habitat for Scenario 16 is of significant environmental concern.

5.2 SOCIOECONOMIC IMPACT SUMMARY

The potential impact of spill scenarios to commercial fisheries, cultural resources including subsistence use areas are summarized in this section.

5.2.1 *Commercial Fisheries Impact Summary*

Representative commercial fisheries located within the region that were chosen to evaluate potential commercial fisheries impacts of oil spill Scenarios 1 through 16 include pollock (trawl gear), Pacific cod (fixed and trawl gear), Tanner crab, Bristol Bay kin crab, flatfish (trawl gear) and salmon (all gear). As described in Section 4.2.8.1, historical NOAA catch data from 2006 through 2008 were used to evaluate the sensitivity of these fisheries to potential spills. The higher the level of historical catch in the area, the higher the sensitivity rating for each scenario. The evaluation of potential impacts to fish processors was based on 2010 ADCCED data, which indicate where shore-based, fish-processing plants are located within the study area. If a fish-processing plant was located in an area where oil was projected to reach the shore, an SF of 5 was given based on the potential for the plant water intake could be contaminated with oil. The results of the sensitivity analyses are summarized in Tables 5.2 and 5.3 below.

Table 5.2 Sensitivity Analysis by Scenario for Representative Commercial Fisheries Using NMFS Average Annual Catch Data (2006-2008) for Probability Bands Greater than 50%

Fishery	Scenario 1 - North Unimak Pass	Scenario 2 - North Unimak Pass	Scenario 3 - North Unimak Pass	Scenario 4 - North Unimak Pass	Scenario 5 - North Unimak Pass	Scenario 6 - Sanak Island	Scenario 7 - Sanak Island	Scenario 8 - Sanak Island	Scenario 9 - Sanak Island	Scenario 10 - Holtz Bay Attu Island	Scenario 11 - Holtz Bay Attu Island	Scenario 12 - Holtz Bay Attu Island	Scenario 13 - Holtz Bay Attu Island	Scenario 14 - Adak Island	Scenario 15 - Amlia Island	Scenario 16 - Urilia Bay
Pollock trawl gear	2	3	2	2	3	-	-	-	-	2	2	2	2	2	3	5
Pacific cod fixed gear	2	5	5	5	5	4	4	4	4	2	2	2	2	2	2	4
Pacific cod trawl gear	2	2	2	2	2	3	3	3	3	2	2	2	2	2	3	5
Tanner crab	2	2	-	-	-	-	-	-	-	-	-	-	-	2	2	2
Bristol Bay king crab	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	2
Flatfish trawl	2	2	2	2	2		-	-	-	2	2	2	2	2	2	4
Salmon*	2	-	2	2	2	2	2	2	2	2	2	2	2	2	2	2

Note: (-) No Processor Near Location

Table 5.3 Sensitivity Analysis by Scenario for Representative Commercial Processors by Community

Community	Scenario 1 - North Unimak Pass	Scenario 2 - North Unimak Pass	Scenario 3 - North Unimak Pass	Scenario 4 - North Unimak Pass	Scenario 5 - North Unimak Pass	Scenario 6 - Sanak Island	Scenario 7 - Sanak Island	Scenario 8 - Sanak Island	Scenario 9 - Sanak Island	Scenario 10 - Holtz Bay Attu Island	Scenario 11 - Holtz Bay Attu Island	Scenario 12 - Holtz Bay Attu Island	Scenario 13 - Holtz Bay Attu Island	Scenario 14 - Adak Island	Scenario 15 - Amlia Island	Scenario 16 - Urilia Bay
Adak	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-
Akutan	4	4	4	4	4	-	-	-	-	-	-	-	-	-	-	-
Dutch Harbor	4	4	4	4	4	-	-	-	-	-	-	-	-	-	-	-
False Pass	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5
King Cove	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sand Point	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Point Moller	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chinig	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Note: (-) No Processor Near Location

Based on catch data, the Pacific cod fixed gear fishery is the most sensitive to a potential spill projected by Scenarios 2 through 5, near North Unimak Island. The levels of Pacific cod catch harvest using trawl gear in this location is high and, therefore, may be significantly impacted by a potential oil spill. While other fisheries in this area may also be affected (Pacific cod trawl gear had a sensitivity rating of 3), the levels of catch for other fisheries is lower and, therefore, may result in a moderate impact to pollock, Tanner crab, flatfish and salmon. The Bristol Bay king crab fishery is not likely to be impacted by Scenarios 1 through 5. Similarly, Scenario 16 is projected to result in a sensitivity rating of 5 for both pollock and Pacific cod trawl gear fisheries based on catch data (NOAA 2008). In addition, the Pacific cod fixed gear fishery may be moderately impacted (rating of 4), while all other fisheries are expected to have minor impacts (rating of 2) under Scenario 16.

Scenarios 4 through 9 at Location 2, Sanak Island, are rated as having an SF of 2 based on 2006-2008 catch data and the projected dispersion of oil as depicted in Appendix F *Spill-Receptor Impact Overlays*. Specifically, the Pacific cod fixed gear fishery is the most sensitive at this location though the impact rating is not as significant as under Scenarios 2 through 5. While impacts to the Pacific cod trawl gear fishery (rating of 3) and the salmon fishery (rating of 2) are likely under Scenarios 6 through 9, the impacts are not as significant when compared to Scenarios 2 through 5. The pollock, Tanner crab, Bristol Bay king crab and the flatfish fisheries are not likely to be impacted by Scenarios 6 through 9.

While Scenarios 10, 11, 12, 13, and 15 may result in impacts to the pollock, Pacific cod (both gear types), flatfish trawl and salmon fisheries, these impacts are not expected to be significant (rating of 2) because historical catch data at these locations have been lower when compared to other spill locations evaluated. Pacific cod trawl gear fisheries did result in an impact rating of 3 under Scenario 15; however, catch data indicate the potential impact would be moderate compared to other scenarios modeled.

Potential impacts to fish processing plants resulting from Scenarios 1 through 5 are significant. Due to the high number of fish processing plants located in Dutch Harbor and Akutan and their significant contribution to the overall success of the Alaska groundfish and salmon fisheries, oil that may reach shore at this location under these scenarios would result in a sensitivity rating of 5. Only Scenarios 14 (Adak Island) and 16 (Urilia Bay) are located in areas where fish processors are based onshore. Oil is expected to reach shore under Scenarios 14 and 16; therefore, potential impacts to fish-processing plants at these locations are rated as a 5. Scenarios 6 through 13 and 15 are not likely to result in impacts to fish processors resulting from an oil spill.

5.2.2 *Cultural/Historic Resources and Subsistence Impact Summary*

The Aleutian Islands have extensive historic resources as defined by the National Historic Preservation Act of 1966, as well as cultural resources and cultural heritage. This risk assessment is not a "federal undertaking" as defined by 16 US Code Section 470W(7), and thus it is beyond the scope of this report to inventory all cultural and historic resources throughout the study area. From the perspective of evaluating potential risk to socioeconomic resources including historic and cultural resources within the study area, it is likely there would be persisting and perhaps irretrievable impacts experienced by some or all of the communities, especially those in closest proximity to the spill.

During a spill cleanup of any kind, it is likely there would be some level of disturbance (malicious and non-malicious) and/or loss to known and unknown historic and cultural resources. Damage could occur from increased levels of human presence resulting from pedestrian traffic, worker camps, materials staging areas, and general cleanup techniques. Vandalism is of potential concern because the location of cultural and historic sites would become more known in an effort to protect those sites. When more people know about sites, there is an increased risk of vandalism. However, it is likely that the impacts to historic and cultural resources from a spill in the Aleutian Islands would be similar to those experienced from EVOS.

History records that cultural sites in the area of effect for EVOS experienced less direct effects (i.e., impacts from the spill) than indirect effects (*i.e.*, impacts resulting from actions associated with, but not the actual spill event such as cleanup worker pedestrian traffic) (Bittner 1996). NRHP sites are located on Adak Island (Scenario 14/Location 4) and in Dutch Harbor (Location 1). Unknown and known historic and cultural resources not fully inventoried in this report would also have the greatest sensitivity, and effects would need to be mitigated in a coordinated manner with the appropriate agencies and with the greatest level of anonymity to the sites as practicable.

It was noted in post-EVOS reports that the ability to date artifacts (not yet dated) was compromised because of hydrocarbon contamination (Bittner 1996). Although there is conflicting evidence to support this claim, it should still be noted as a possible consequence from a spill. Losing the ability to date artifacts, found and unfound, could contribute to a sense of loss of cultural heritage because a piece of the historical record would be absent.

A potential spill coincident with the varied subsistence harvest seasons, would directly affect a community's access to those resources. Loss of subsistence areas could impact the cultural heritage of these communities, as subsistence resources are necessary for their livelihoods and the practice is integral to their cultural identity. Indirect impacts to cultural identity could include increasing and/or reinforcing individual vulnerabilities (Cf. Bjerregaard, Berner, and Odland 2008). Possible impacts include a range of public health concerns including mental health issues, substance abuse, and violence, as well as outmigration, which could accelerate a loss of cultural heritage.

5.3 *SPILL MODEL AND CONSEQUENCE ANALYSIS SUMMARY*

The oil spill modeling output results, and ecological and socioeconomic impacts, for each of the 16 scenarios are summarized in the attached Table 5.4.

Based on the findings of the consequence analysis, the ecological receptors potentially at greatest risk include seabirds and marine mammals while the socioeconomic resources at greatest risk are subsistence use areas and fisheries. Clearly, an oil spill of a notable amount has the potential to result in ecological and/or socioeconomic impacts depending on the relation to important receptors of the study area.

To provide another perspective of the scenarios evaluated, the spill scenarios are mapped below based on material type and spill release rates.

Material Type and Spill Volumes	**Spill Load Rates (MT/hr)**		
	~ ≤ 50	**100**	**1000 or greater**
Diesel Oil / 25,000 – 40,000 bbl	Scenario 4 (25,000) Scenario 13 (50,000)		Scenario 5 (40,000) Scenario 9 (40,000) Scenario 14 (40,000)
Bunker C / 3,000 – 40,000 bbl	Scenario 1 (3,000) Scenario 6 (3,000) Scenario 10 (25,000) Scenario 15 (40,000)	Scenario 2 (15,000) Scenario 7 (15,000) Scenario 11 (40,000) Scenario 16 (15,000)	
Crude Oil / 400,000 bbl			Scenario 3 19210 -1st hr 171.5 - next 48 hrs: Scenario's 8 and 12

Even Scenario 4, characterized as a 25,000 barrel diesel fuel spill North of Unimak Pass (Location1), has the potential to result in impacts to marine mammal habitat if receptors are present during the winter season. Of additional note, scenarios associated with large spills (400,000 barrels) of persistent oil at high release rates (e.g., Scenario's 3, 8, and 12) indicate the greatest potential of ecological and socioeconomic impacts.

The effects of oil spills in the marine environment depend on the oil type, release rates and associated fate mechanisms as well location, receptors present, and season. As demonstrated in the Phase A consequence analysis, a large amount of persistent oil spilled in a resource rich area at critical times is likely to create more damage than a small amount. Although, as also demonstrated with Scenario's 4 and 13, smaller spill volumes of non persistent oil near sensitive receptors (marine mammal habitats, fisheries and subsistence use communities) can also have significant impacts.

Release rate is an important variable to assessing impacts, in addition to the distance to shore. If more oil deposits, then less oil is available for surface spread. In general, heavy oil with a higher release rate results in more likelihood of affecting a large area; whereas medium and lighter oil with lower release rate results in more likelihood of affecting a large area. Also, for larger wind speeds, more oil gets into the water column resulting in less oil available at the surface. These are several examples to demonstrate that many factors are interdependent and must be considered when evaluating impacts.

Table 5.4 Summary of 16 Spill Scenarios and Potential Impacts

Scenario	Location	Vessel/Oil Type and Capacity	Spill Load Rate (MT/hr)	Incident/ Season	Summary of Oil Modeling Impacts	Summary of Ecological and Socioeconomic Impacts
1	1 - North Unimak Pass	Container Ship/ Bunker C 3.5kDWT	21	Collision Summer	Spills resulting from Scenarios 1 through 5 are predicted to affect the northern coasts of Akutan, Atun, and the western end of Unalaska islands. For all scenarios, oil reaches the Akutan and North Unimak passes, but there is generally a low probability of impacts to the southern coasts of the islands, particularly for Scenario 3. Scenarios 1, 2, 3 and 5, there is a higher probability of the oil moving to the north east. For Scenario 4, a diesel spill during the winter, the model predictions indicate the plume moving slightly farther north and west and barely reaching the end of Unimak Island.	Ecological • Potential impacts to bird habitats, shoreline and benthic receptors are most significant for the large crude oil spill in the summer season (Scenario 3). • Potential impact to marine mammal habitat was the most significant for Scenario 4, assuming the receptors are present during winter season and exposed. Additionally, this scenario assumes a diesel spill, which as a non-persistent oil, represents less potential for long term impacts. • Concentrations of hydrocarbons are not predicted to reach levels greater than representative threshold values for Scenarios 1, 2 and 4; which are all spill volumes less than 25,000 bbl. The most significant potential impact to fish, including shell fish and fish larvae, was Scenario 5 (a diesel spill of 40,000 bbl) and Scenario 3 (a crude oil spill of 400,000 bbl). Socioeconomic • Water intakes for fish processing facilities at Dutch Harbor are potentially affected by Scenarios 1 through 5. • Subsistence hunting and fishing areas: potentially affected communities include Akutan on Akutan Island. • The Pacific cod fishery (specifically the trawling areas): potentially the fishery most affected by Scenarios 1 through 5. This fishery is considered the most productive and is situated within the 1% oil spill probability footprints in
2	1 - North Unimak Pass	Bulk Carrier/ Bunker C/ 60kDWT	100	Collision Summer		
3	1 - North Unimak Pass	Crude Oil Tanker/ Crude oil/ 110kDWT	1000	Collision Summer		
4	1 - North Unimak Pass	Product Tanker/ Diesel 50kDWT	29	Collision Winter		
5	1 - North Unimak Pass	Tank Barge / Diesel 30kDWT	1000	Collision Summer		

Scenario	Location	Vessel/Oil Type and Capacity	Spill Load Rate (MT/hr)	Incident/ Season	Summary of Oil Modeling Impacts	Summary of Ecological and Socioeconomic Impacts
						each case.
6	2 - Sanak Island	Container Ship/ Bunker C 3.5kDWT	25	Drift Grounding Summer	Spills from Scenarios 6, 7, 8, and 9 are predicted to behave in a similar way, with the plume moving in a predominantly southwest to northeast direction with little predicted north or south movement. Consequently, the majority of the impacts from these scenarios are in the vicinity of the Sanak Islands and Unimak Island. The coast of the Alaskan Peninsula is only affected by Scenario 6 and, to a lesser extent, Scenario 9.	Ecological • Potential impacts to shoreline and benthic receptors were most significant for Scenario 8. • Potential impacts to marine mammal habitat and haul out and rookeries was most significant for Scenarios 7 and 8. • Bird habitat were least affected for spill scenarios at this location. • The most significant potential impact to fish including shell fish and fish larvae was Scenario 8. Socioeconomic • No communities or significant coastal infrastructure sites are present in the vicinity of the Sanak Islands. • There is a potential to affect the coastal salmon fishery if the spill occurred during the salmon run.
7	2 - Sanak Island	Bulk Carrier/ Bunker C/ 60kDWT	100	Drift Grounding Summer		
8	2 - Sanak Island	Crude Oil Tanker/ Crude oil 110kDWT	19,210 -1st hr 171.5 - next 48 hrs	Drift Grounding Summer		
9	2 - Sanak Island	Tank Barge/ Diesel / 30kDWT	1000	Drift Grounding Summer		
10	3 - Holtz Bay Attu Island	Container Ship/ Bunker C 3.5kDWT	42	Drift Grounding Winter	Spills in all scenarios could affect the eastern shore of Attu Island with greater than 80% probability, mostly impacting the north-facing shoreline from Chichagof Harbor and Sarana Bay to Chirikof Point. The northern coast of Agattu Island has a 20% or less probability of impact. Only the northern tip of the island may be affected in Scenario 13 at low probability. Shemya Island, to the east, has a 30% or less chance of being impacted.	Ecological • Shoreline and benthic receptors and bird habitat are not significantly impacted from the three scenarios at this location. • Potential impacts to marine mammal habitat, haul out and rookeries and nesting bird sites are most significant for a 50,000 bbl of diesel fuel spill in the spring (Scenario 13) and smaller spill (25,000 bbl) of Bunker C oil in the winter (Scenario 10). • The most significant potential impact to fish including shell fish and fish larvae was Scenario 12, consisting of a very
11	3 - Holtz Bay Attu Island	Bulk Carrier/ Bunker C/ 60kDWT	100	Drift Grounding Summer		
12	3 - Holtz Bay Attu Island	Crude Oil Tanker/ Crude oil 110kDWT	19210 -1st hr 171.5 - next 48 hrs	Drift Grounding Spring		

Scenario	Location	Vessel/Oil Type and Capacity	Spill Load Rate (MT/hr)	Incident/ Season	Summary of Oil Modeling Impacts	Summary of Ecological and Socioeconomic Impacts
13	3 - Holtz Bay Attu Island	Product Tanker/ Diesel/ 50kDWT	57	Grounding Spring		large spill (400,000 bbl) of crude oil. Levels of hydrocarbon do not reach levels predicted to cause acute toxicity for the other scenarios. Socioeconomic • The Pacific cod fishery is the most sensitive socioeconomic resource in all scenarios.
14	4 - Adak Island	Tank Barge/ Diesel / 30kDWT	1000	Grounding (powered/ drifting) Summer	Scenario 14 potentially affects the northern side of the Andreanof Islands, from Tanaka Island in the west to Great Sitkin Island in the east. The probability is low for oil to reach the southern side of the islands passing between Tanaga and Kanaga Islands.	Ecological • Potential impacts to all receptors for Scenario 14 are not as great an environmental concern due to the lack of significant habitats with high sensitivity factors. Socioeconomic • Scenario 14 is anticipated to affect the northern portion of Adak Island, which is a highly sensitive subsistence hunting and fishing community. • Tourism resources, historical sites (due to the Naval Operating Station) and fisheries are predicted to be affected and these resources are assigned a moderately sensitive score 3.
15	5 - Amlia Island	Container Ship/ Bunker C 3.5kDWT	50	Drift Grounding Summer	Modeling predicts the spill to travel mostly in a northwesterly direction past Seguam Island and across Seguam Pass, but also spreading south to a lesser degree. The highest impact, with more than 90% probability would occur along the southern shoreline at the eastern end of Amlia Island and the ocean area immediately to the south.	Ecological • The potential impacts to marine mammal habitat and bird nesting sites for Scenario 15 are the most significant environmental concern. • The sensitivity to nesting birds would be confined to the period from early spring to late summer. Socioeconomic • Resources potentially affected include the subsistence resources used by the community of Atka and the docking facilities and a small processing facility.

Scenario	Location	Vessel/Oil Type and Capacity	Spill Load Rate (MT/hr)	Incident/ Season	Summary of Oil Modeling Impacts	Summary of Ecological and Socioeconomic Impacts
16	6 - Urilia Bay	Bulk Carrier/ Bunker C/ 60kDWT	100	Drift Grounding Spring	In Scenario 16, the oil to predicted to remain in the vicinity of Urilia Bay with a slight bias to the north east. The footprint of the <10% probability contour, extends southwest to northeast, affecting the northern coasts of Unimak Island, the Krenitzin Islands and the western end of the Alaskan Peninsula; two small bands of oil (0-10% probability) also appear to enter the southwest corner Izembek Lagoon.	Ecological • There is minimal bird habitat area; however, highly sensitive diving bird nesting sites exist with a probability of <40% of being affected. However - if the spill occurs in the spring, there is a low probability that some of the spill will enter Izembek Lagoon, which lies within the Izembek National Wildlife Refuge. There is the potential for the Steller's eiders (SF 5) to be in the area before migrating to their traditional breeding grounds in the north resulting in a low (<10%) probability of impact to these receptors. • There is a very large area of very highly sensitive (SF 5) marine mammal habitat within the potential impact zone, thus a significant potential for impacts. Socioeconomic • The north shore of Unimak Island has been designated a subsistence use area which could result in a significant impact to the nearby communities of Cold Bay and False Pass. • Other socioeconomic resources predicted to be affected is the fin fish fisheries (pacific cod both trawl and fixed gear, Pollock and flatfish).

SF = Sensitivity Factor

HCA = Habitat Conservation Area

5.4 *UNCERTAINTY DISCUSSION/LIMITATIONS*

This study represents a qualitative assessment of potential environmental and socioeconomic impacts associated with selected high-risk scenarios to receptor categories present within the Aleutian Islands. Existing information forms the basis for this qualitative study; that is, primary data collection did not occur. The scenarios, spill locations, and consequence analysis reflect best professional assessments based on experience, existing data, and modeling outputs. The spill scenarios, of course, are not exhaustive of all possible spills; however, they do provide a wide spectrum of high-risk scenarios with which to evaluate the relative risk and potential consequences to the study area's resources should a spill occur. Notably, a potential spill event would likely have greater socioeconomic consequences than could be evaluated in this study because region-wide impacts were not evaluated due to the scope constraints.

While not intended to be an exhaustive list, the following is a list of notable assumptions and uncertainty associated with approaches used in the analysis:

- Consequences were based on an oil spill as opposed to a spill of another sort.
- Uncertainties and assumptions associated with the oil spill modeling are discussed in Section 4.1.
- Most scenarios were modeled during the season most sensitive to the receptor (e.g., nesting birds are only present in the spring or summer). In addition, receptors were assumed to be present if the spill reached the designated receptor areas.
- In contrast to the above, shipping accidents tend to occur when weather is bad as in winter months. High sea states, cold temperatures and shorter days may delay response and/or cleanup time, thus creating the potential for increased impacts though the receptor density at the time of a spill is lower.
- Linear data output from GIS was converted to an Access database to an area unit of measure. The beach area was calculated using the slope angle of the respective shoreline evaluated. This enabled a consistent unit of measure for comparison to other area outputs.
- For the two media, water column and sediment, a level of concern or threshold concentration (e.g., LC50) was utilized to identify the

potential impact to groundfish and benthic-dwelling organisms (e.g., scallops, and crabs). While LC50 and EC50 values vary by species, age and life stage, not enough information is available to obtain toxicity data (LC50 and EC50) for each species and age group of fish or other biota. Therefore, several sources were reviewed for representative marine species.

- Salmonid eggs and larvae, although normally present in freshwater, were used as a representative receptor to provide a notional toxicity level for other highly sensitive species.
- Socioeconomic resources relied on manually overlapping scenario maps to visually compare the proximity of receptors to the potential spill plume.
- A conservative approach was taken to err on the side of greater probability of impact or sensitivity, and as such may overestimate potential impacts.
- For all receptors, less fisheries, adverse impact is assumed to occur if oil spill area was predicted to coincide with a receptor area.
- Commercial fisheries data were used for the assessment of effects of a spill on the fishery resources of the study area. Available NOAA data, reported as average annual catch in metric tons, pounds, or kilograms, were used for the assessment.

Caution should be exercised in interpreting the findings of the consequence analysis. The results of this report are not intended to represent absolute terms of impacts regarding spill scenarios in the study area. Rather, this Consequence Analysis Report provides a high level assessment of the relative environmental and socioeconomic impacts associated with the high-risk scenarios identified for the Aleutian Island study area. To address the complex and challenging nature of this task within the limits of scope and resources, both qualitative and quantitative techniques where appropriate were applied and enhanced and supplemented by available data and local expertise and judgment.

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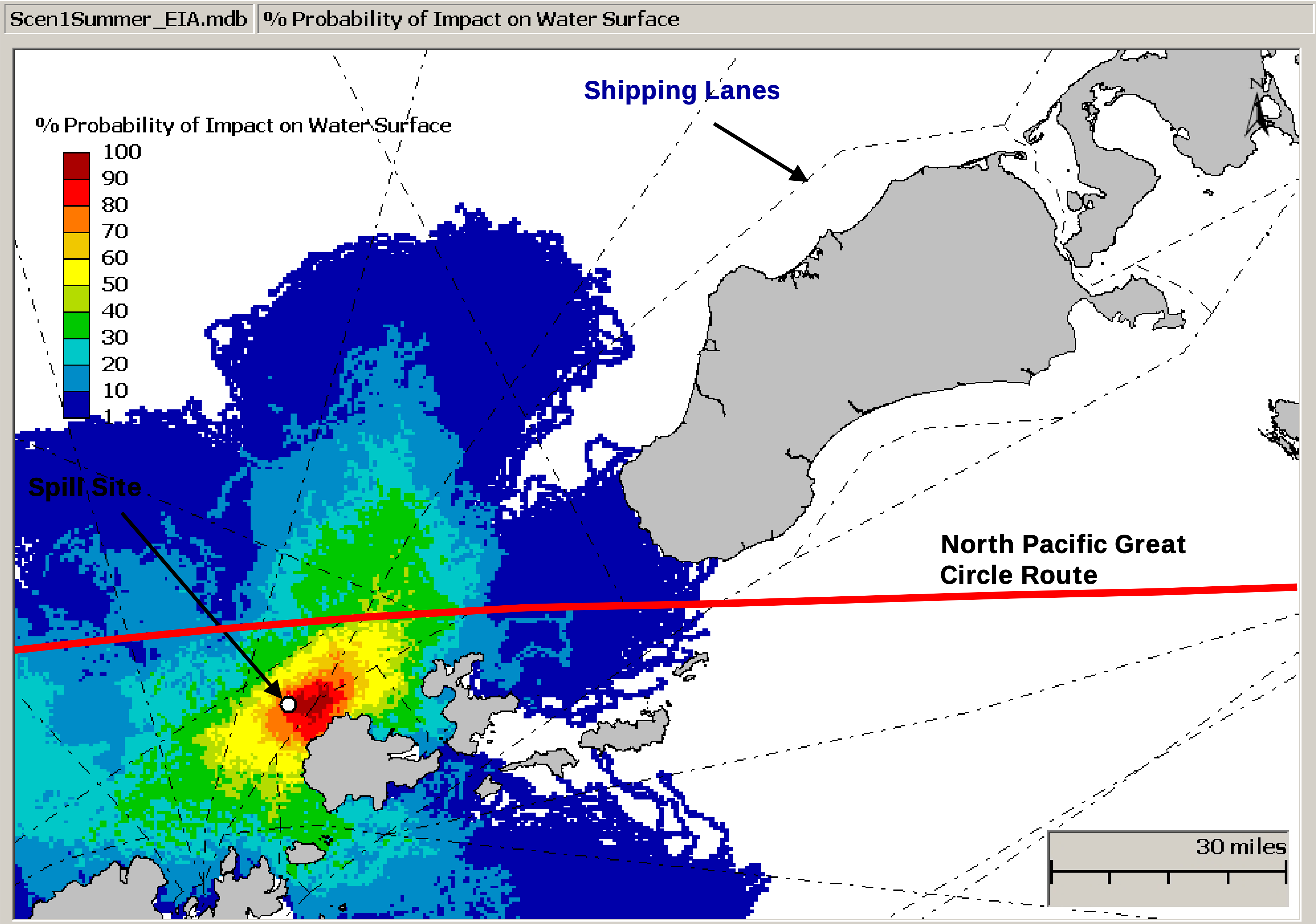
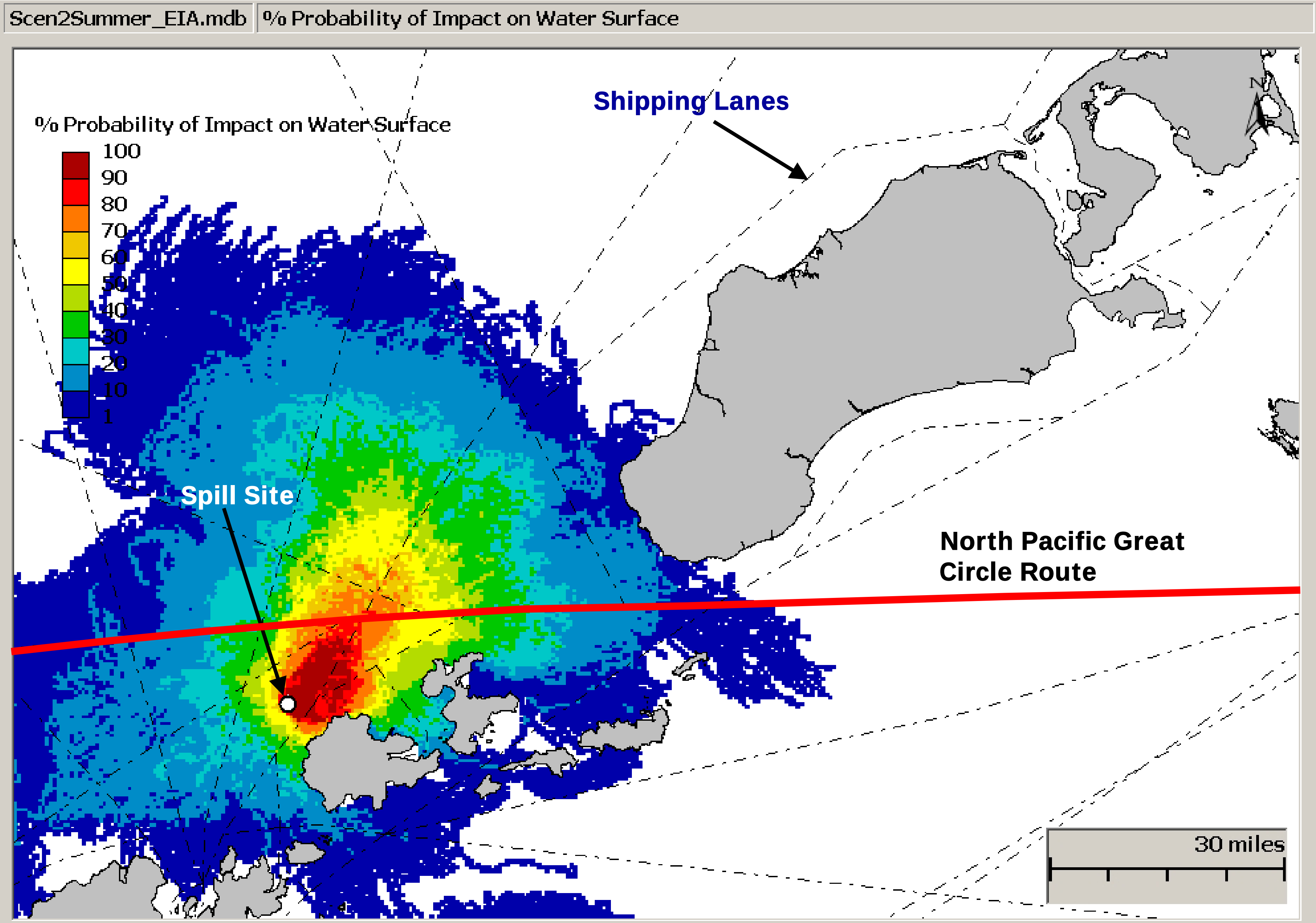
Appendix A
Spill Model Surface Oiling Outputs

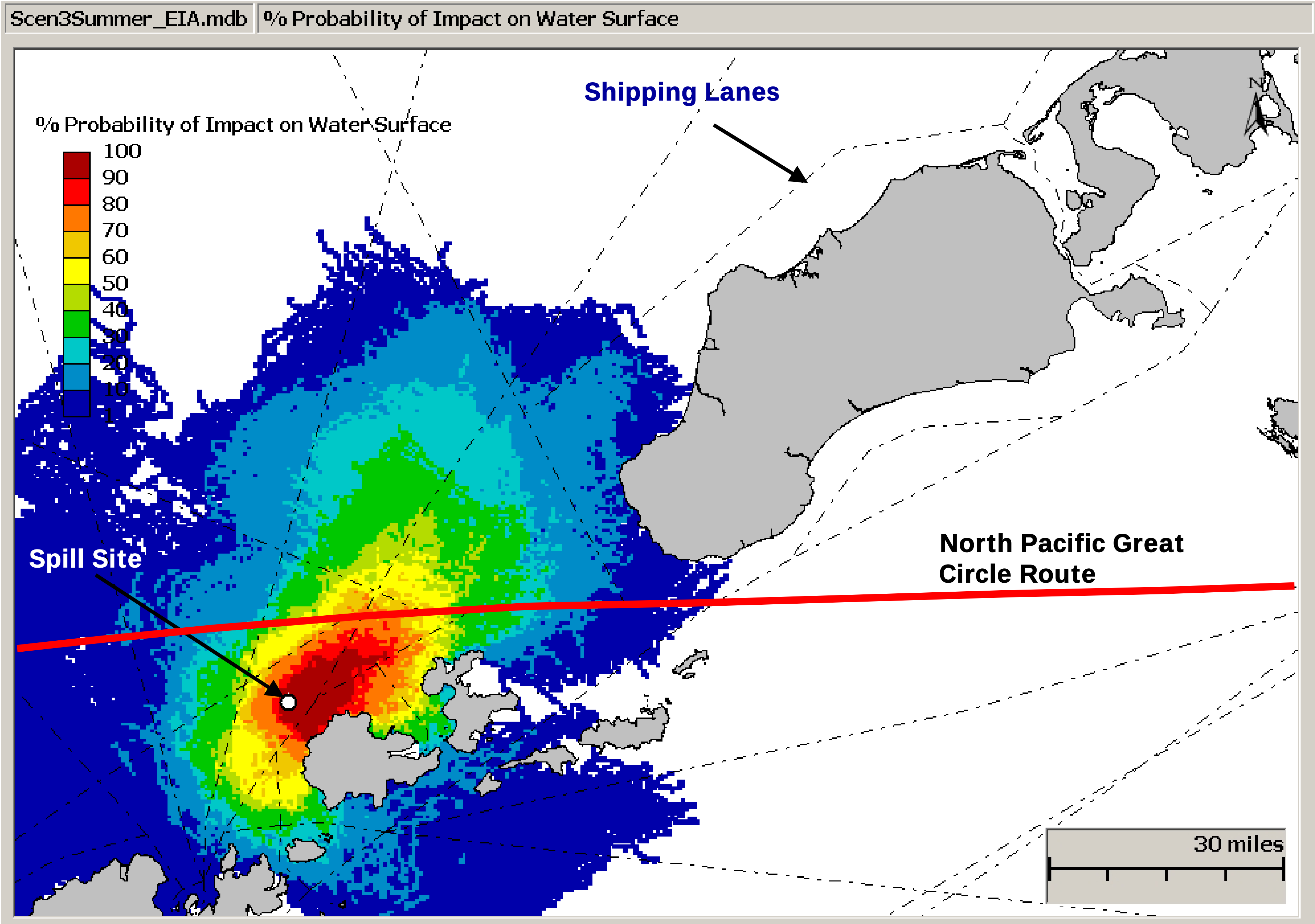
Scenario 1 - Summer



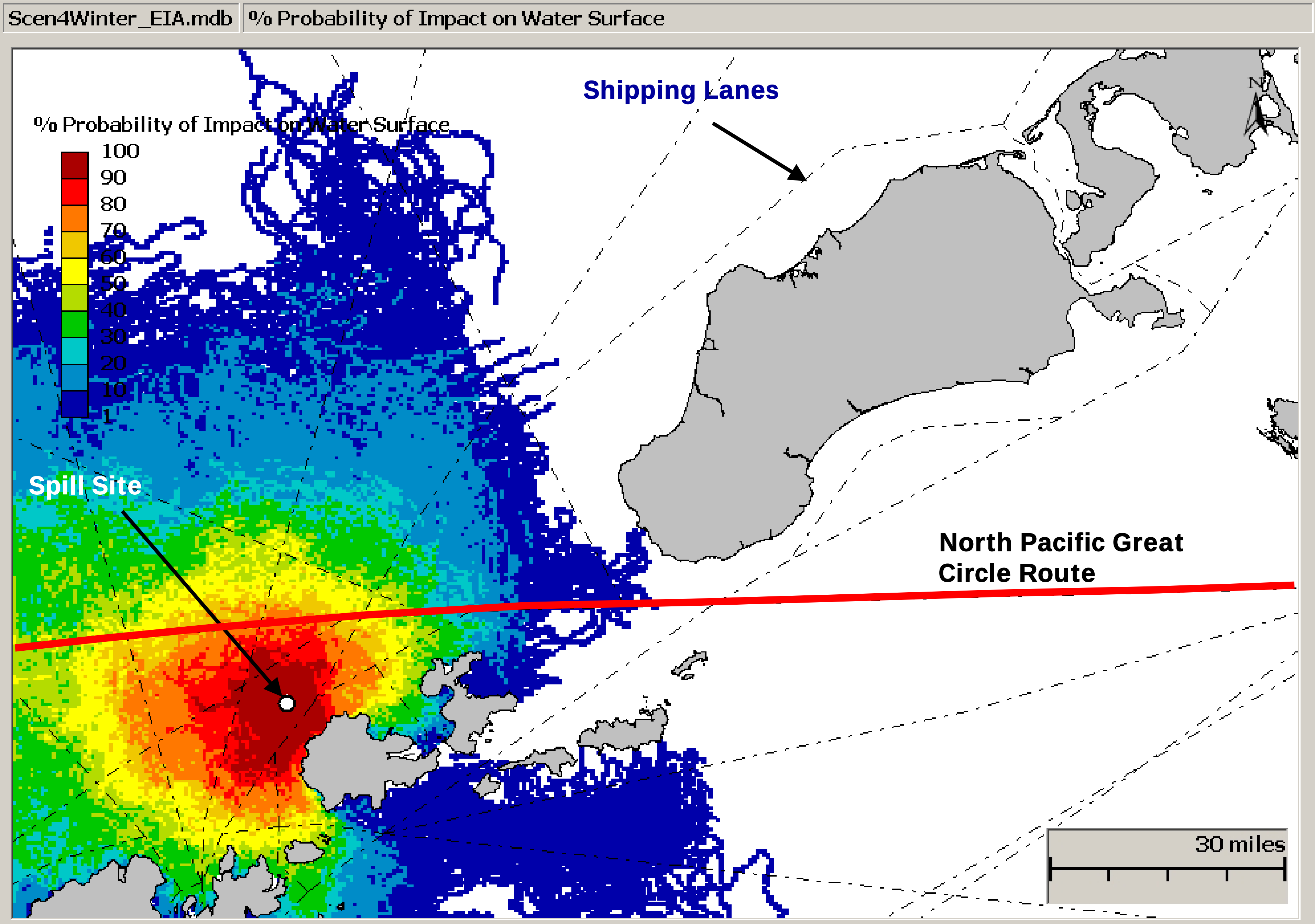
Scenario 2 - Summer



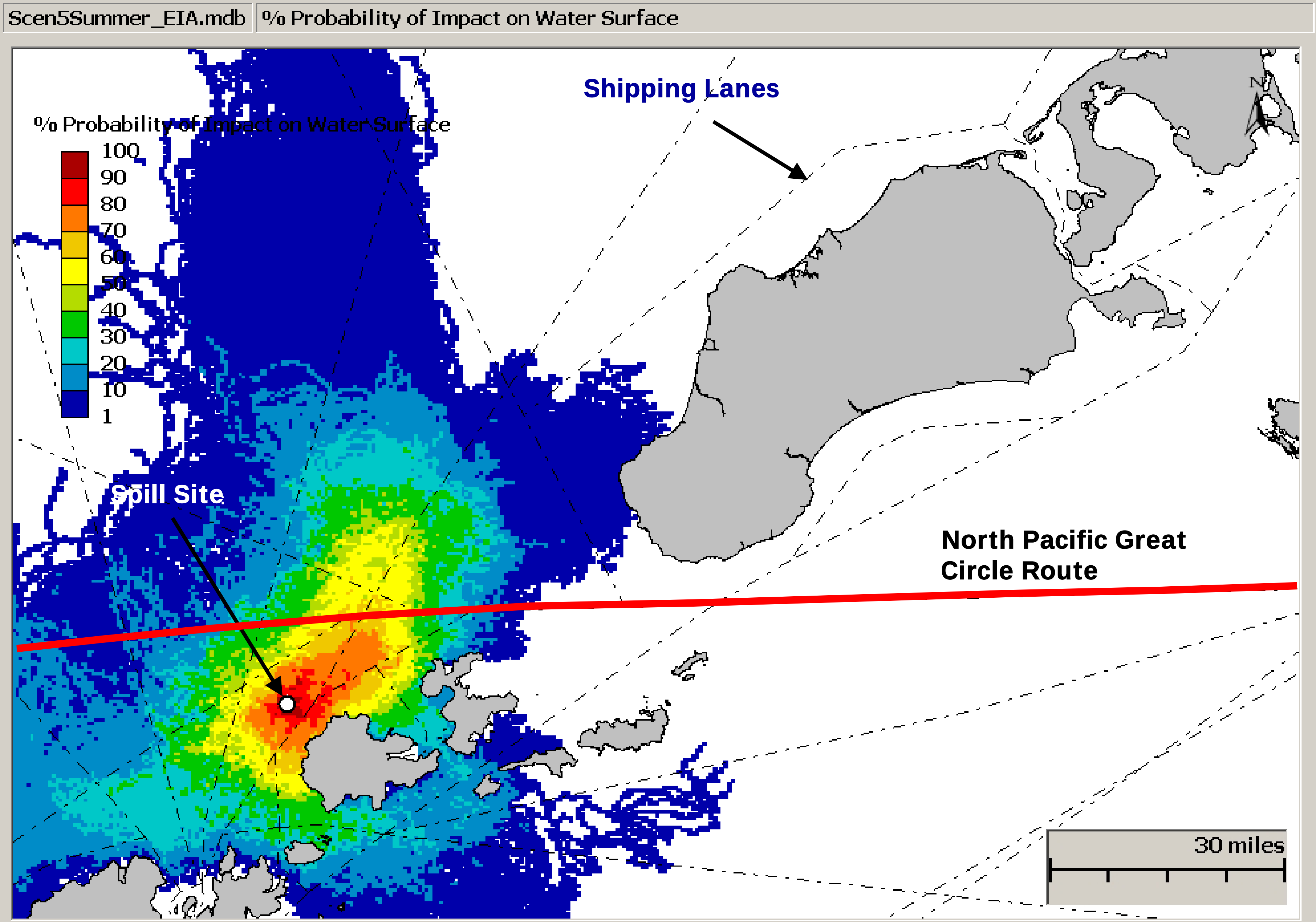
Scenario 3 - Summer



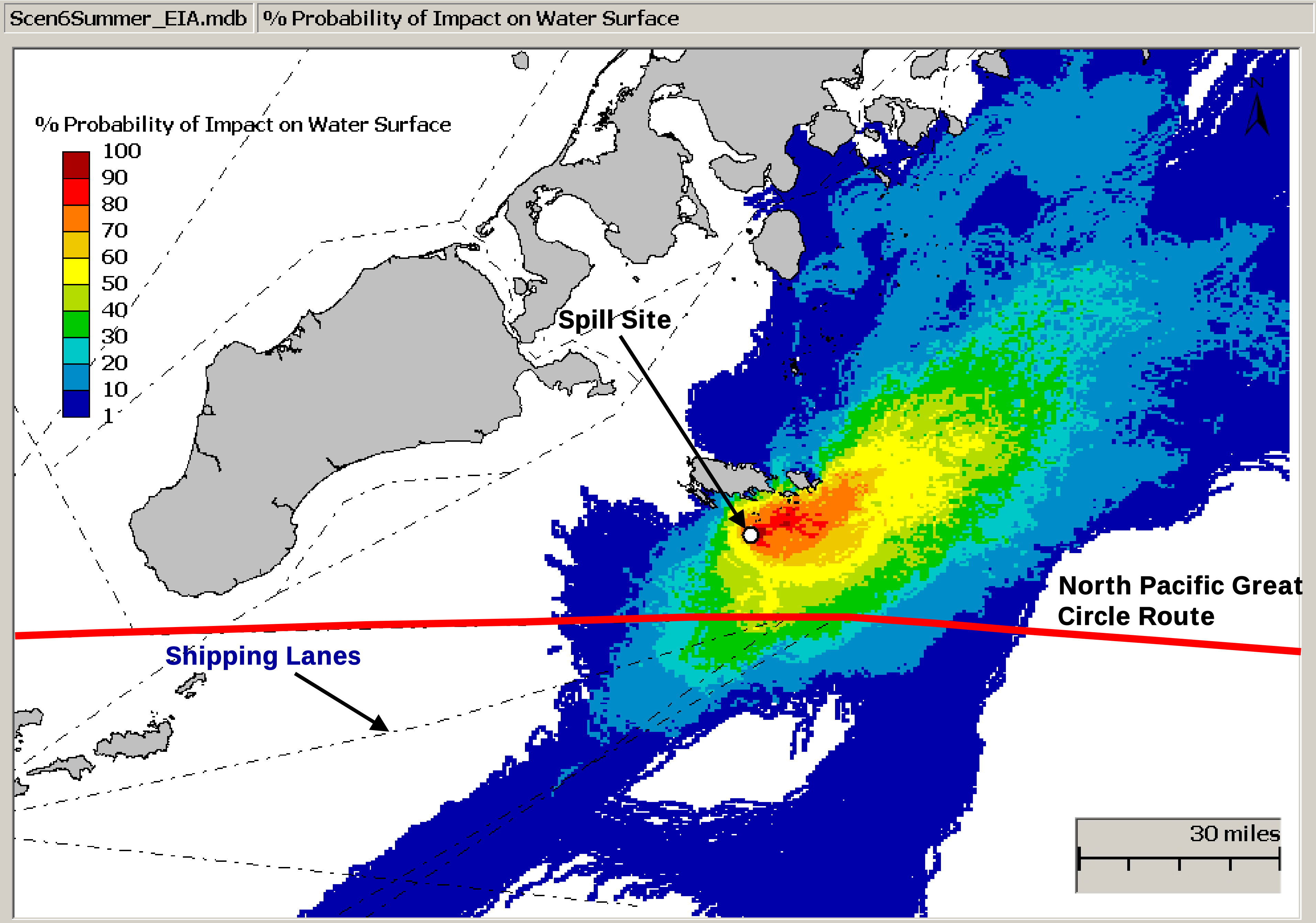
Scenario 4 - Winter



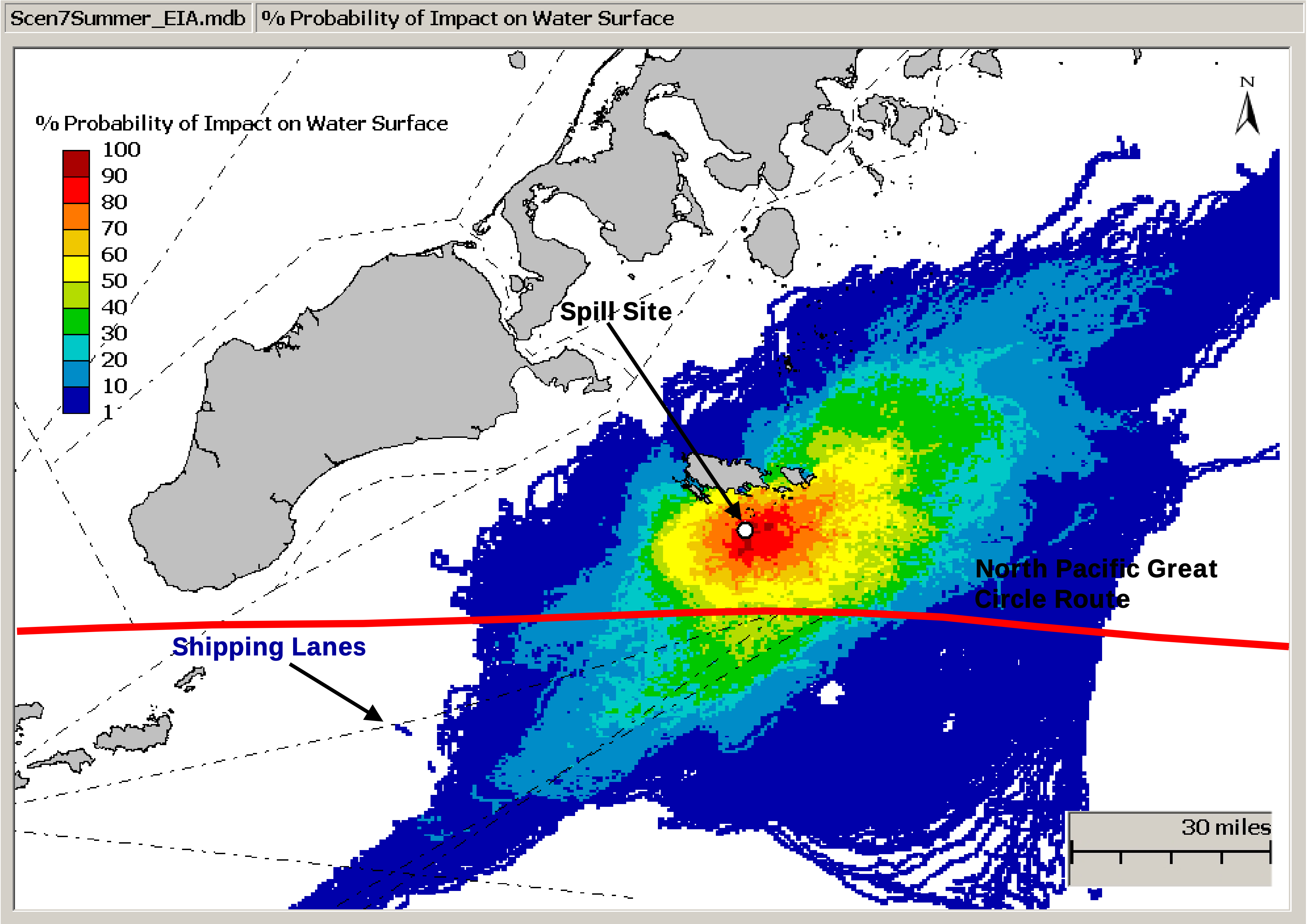
Scenario 5 - Summer



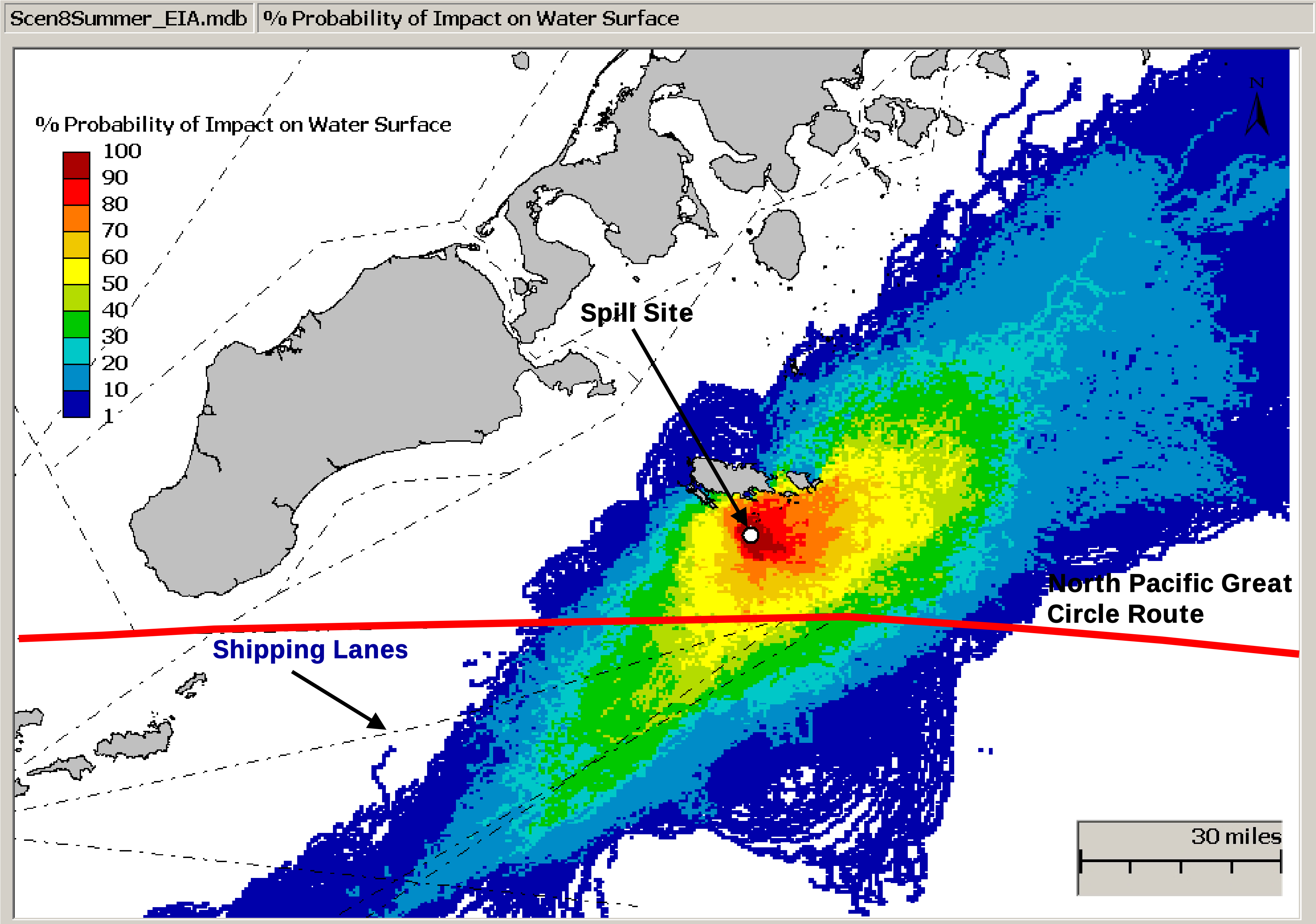
Scenario 6 - Summer



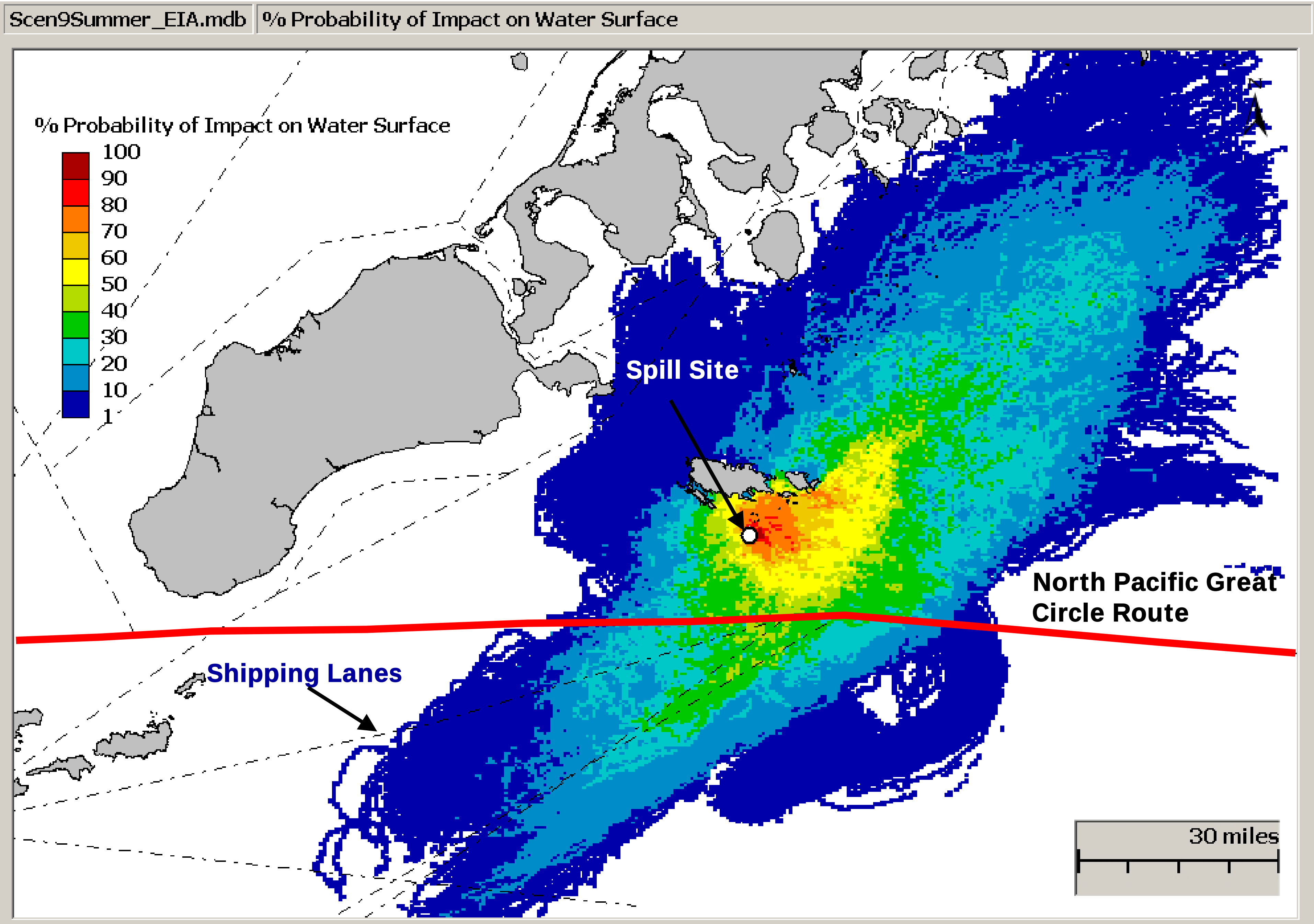
Scenario 7 - Summer



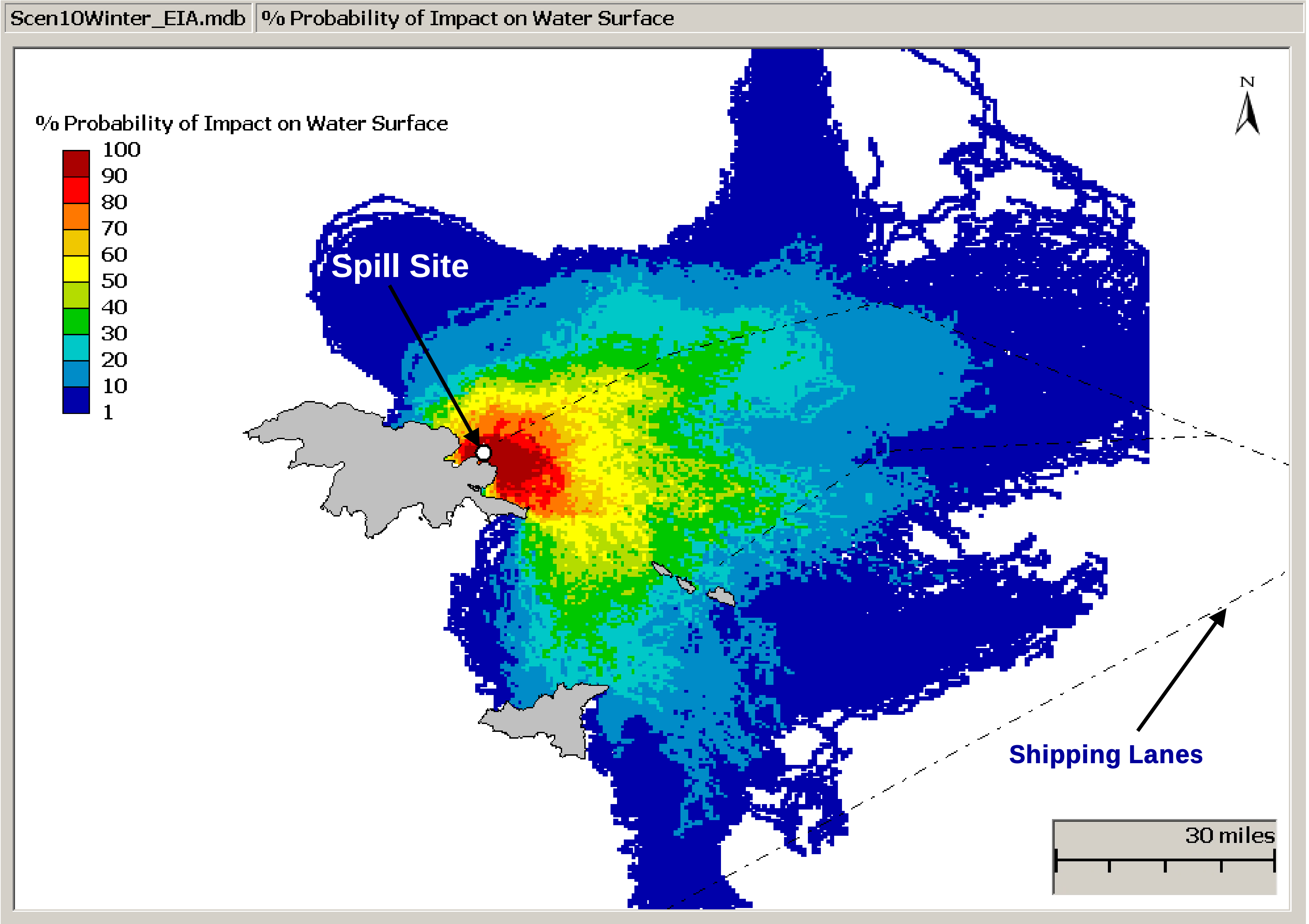
Scenario 8 - Summer



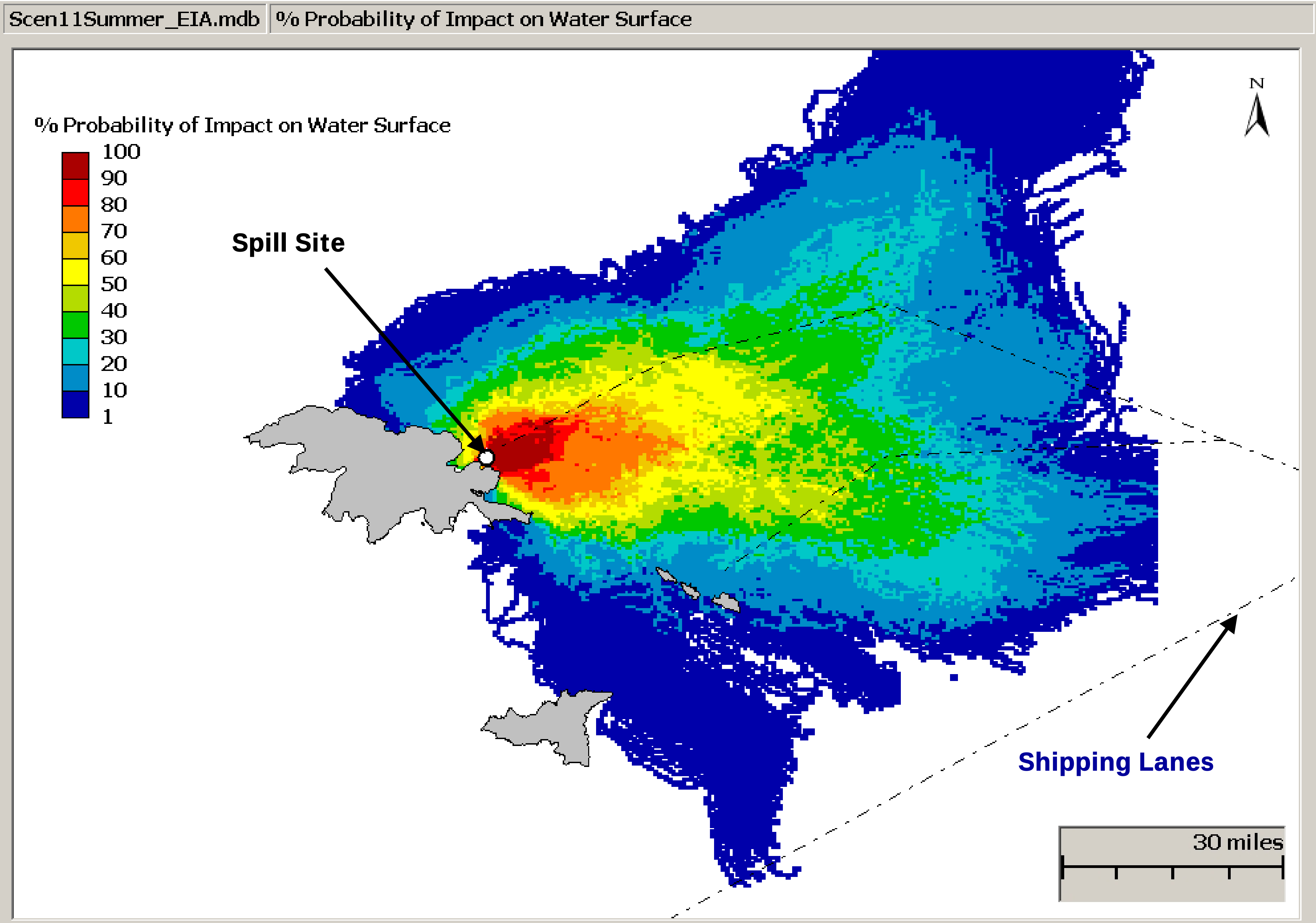
Scenario 9 - Summer



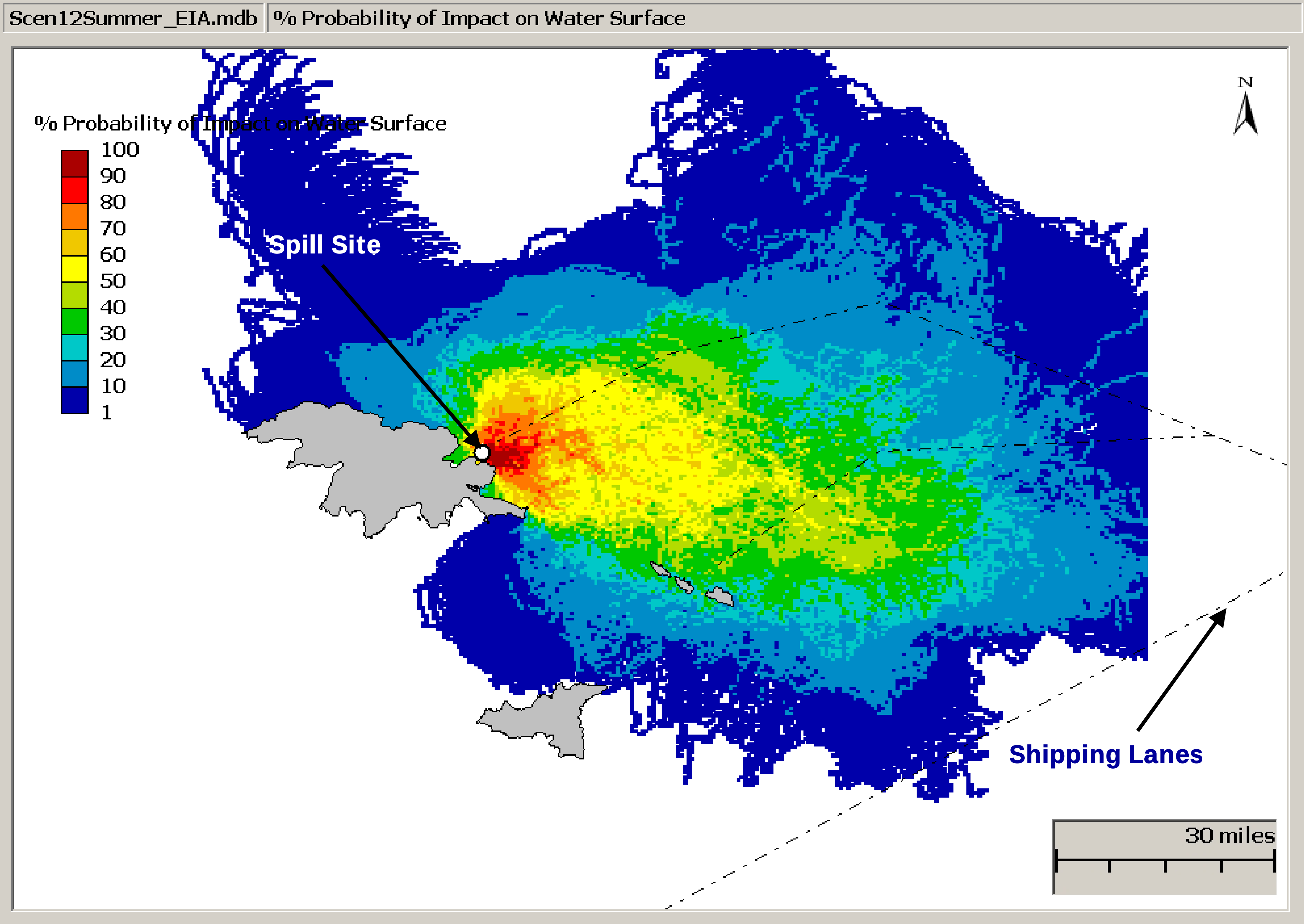
Scenario 10 - Winter



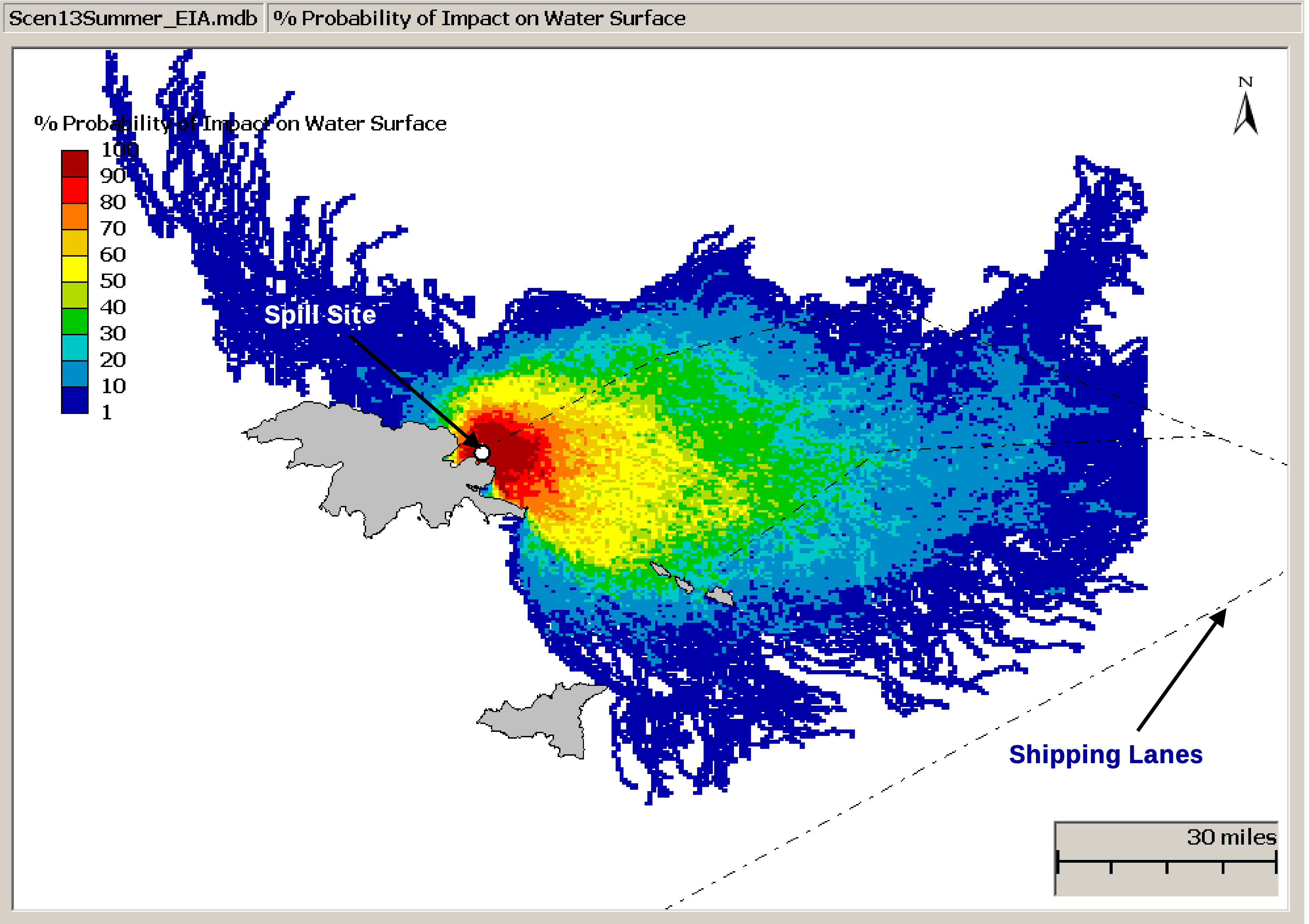
Scenario 11 - Summer



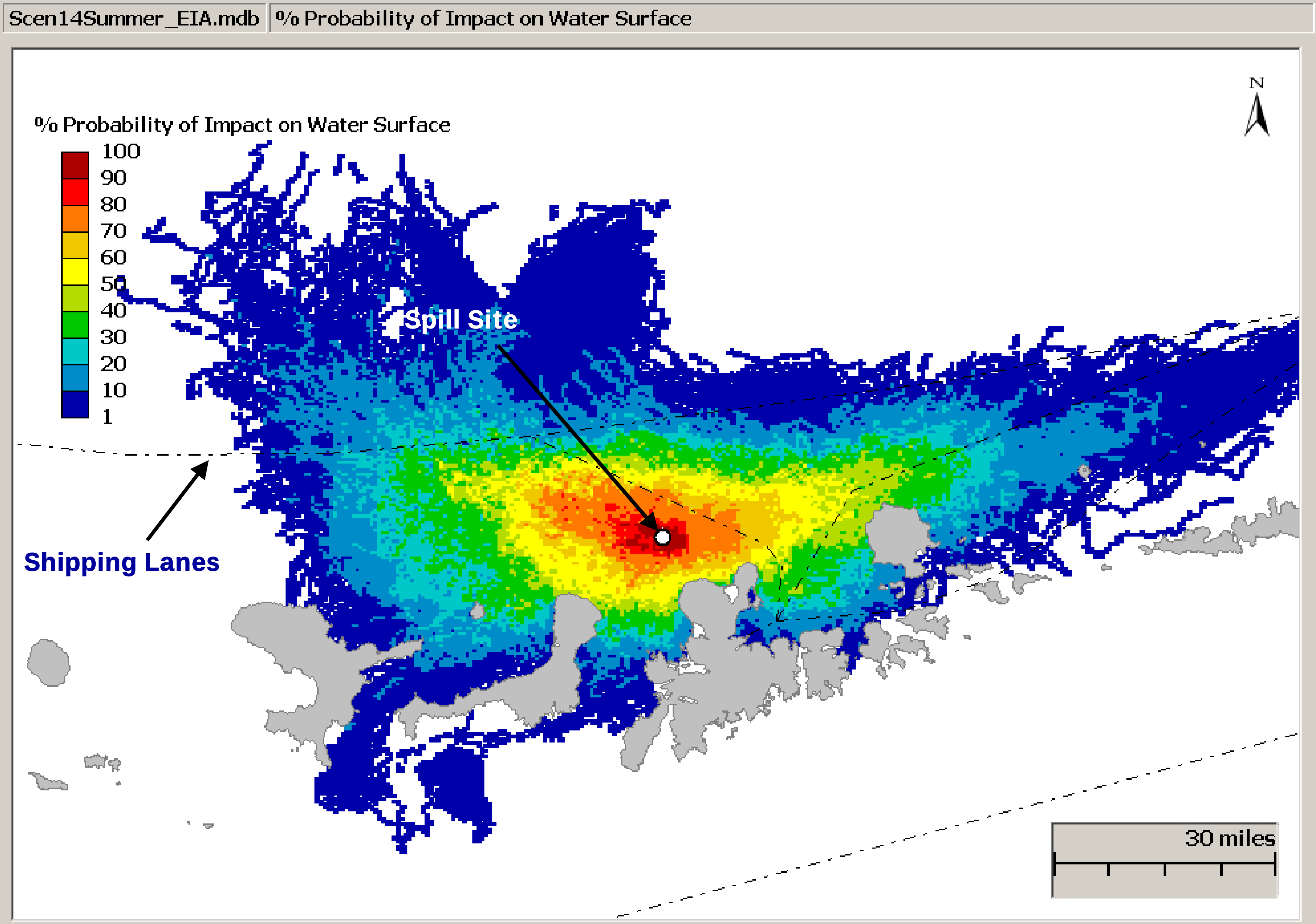
Scenario 12 - Spring



Scenario 13 - Spring

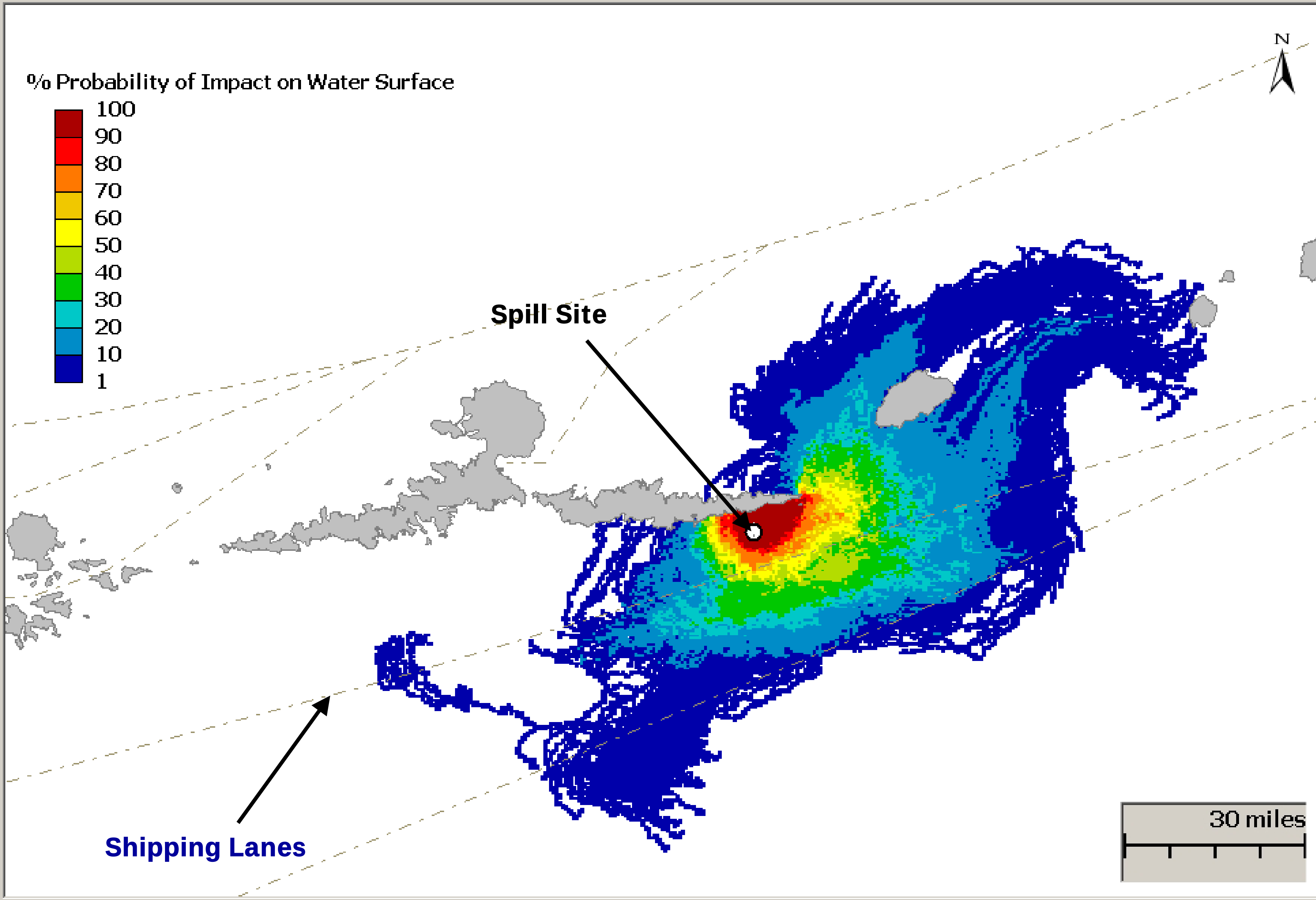


Scenario 14 - Summer

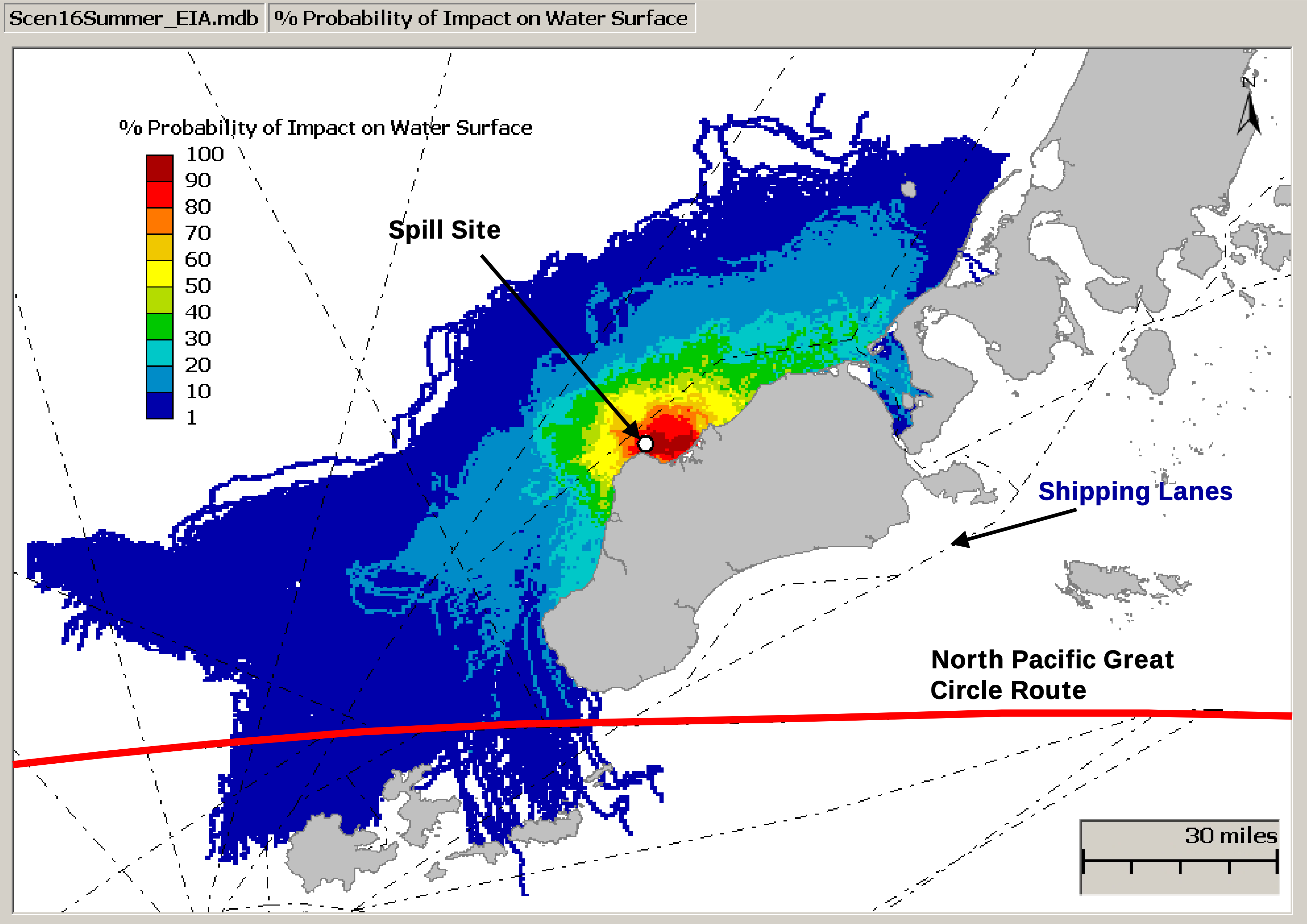


Scenario 15 - Summer

Scen15Summer_EIA.mdb | % Probability of Impact on Water Surface

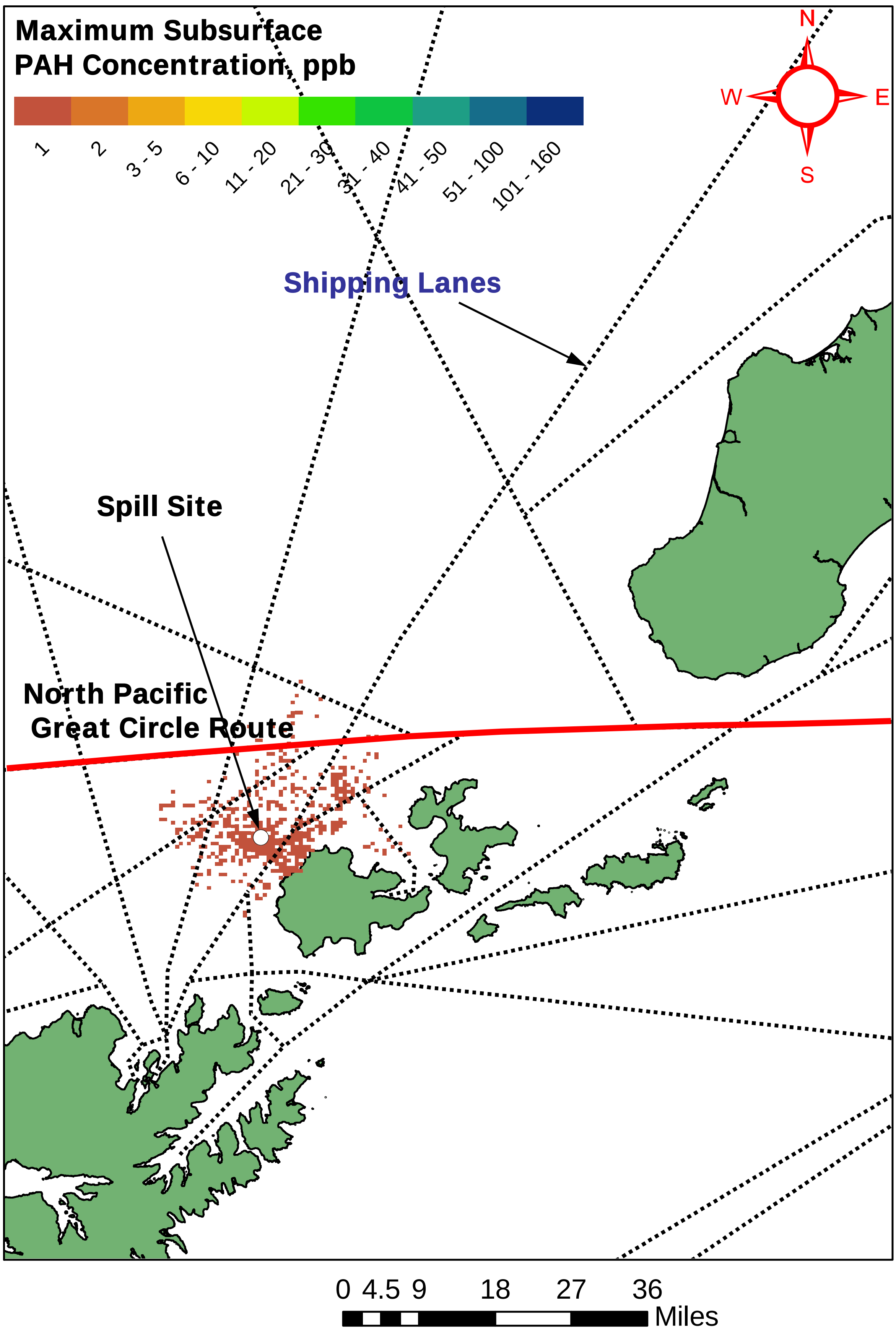


Scenario 16 - Spring

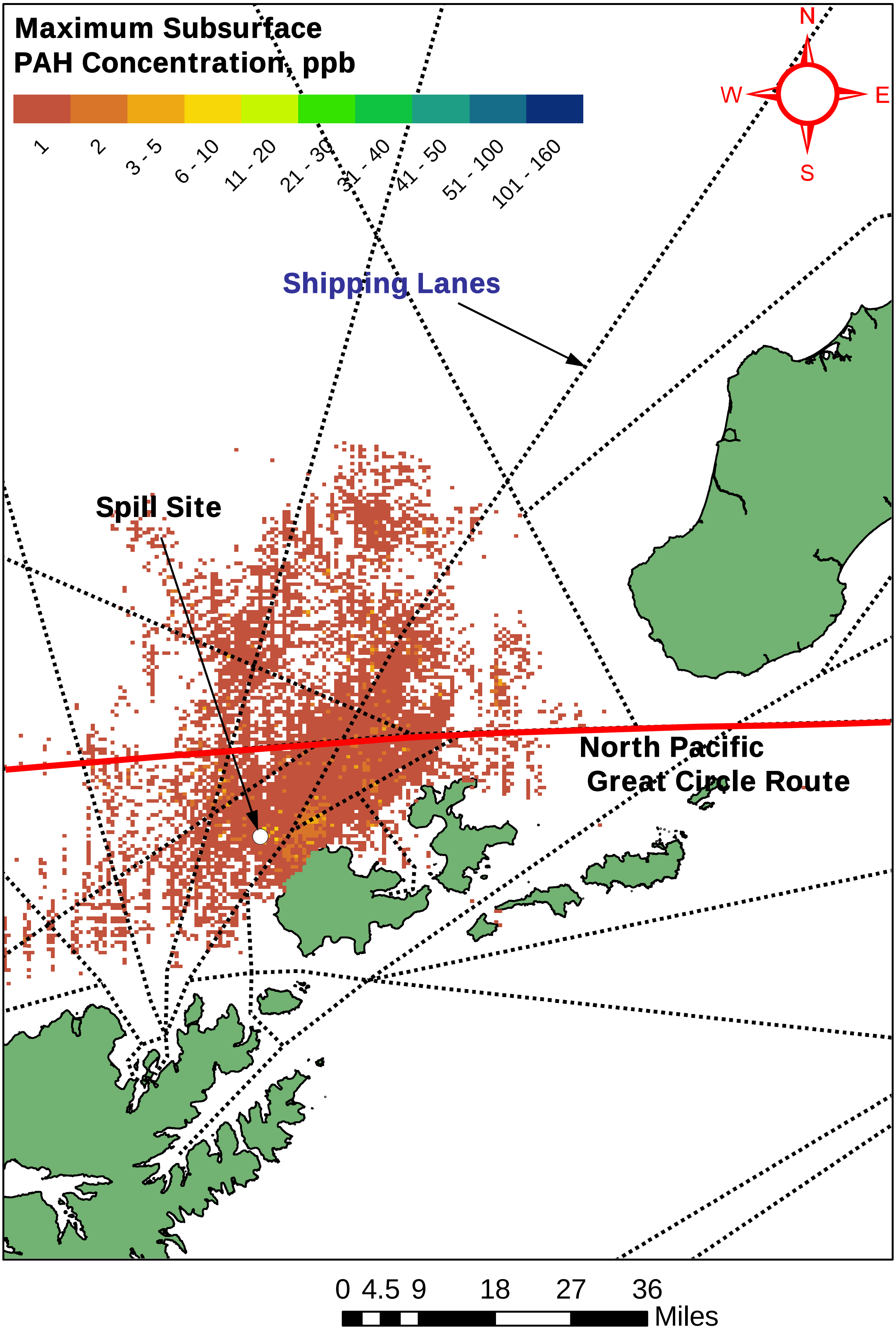


Appendix B
Maximum Subsurface Concentration Outputs

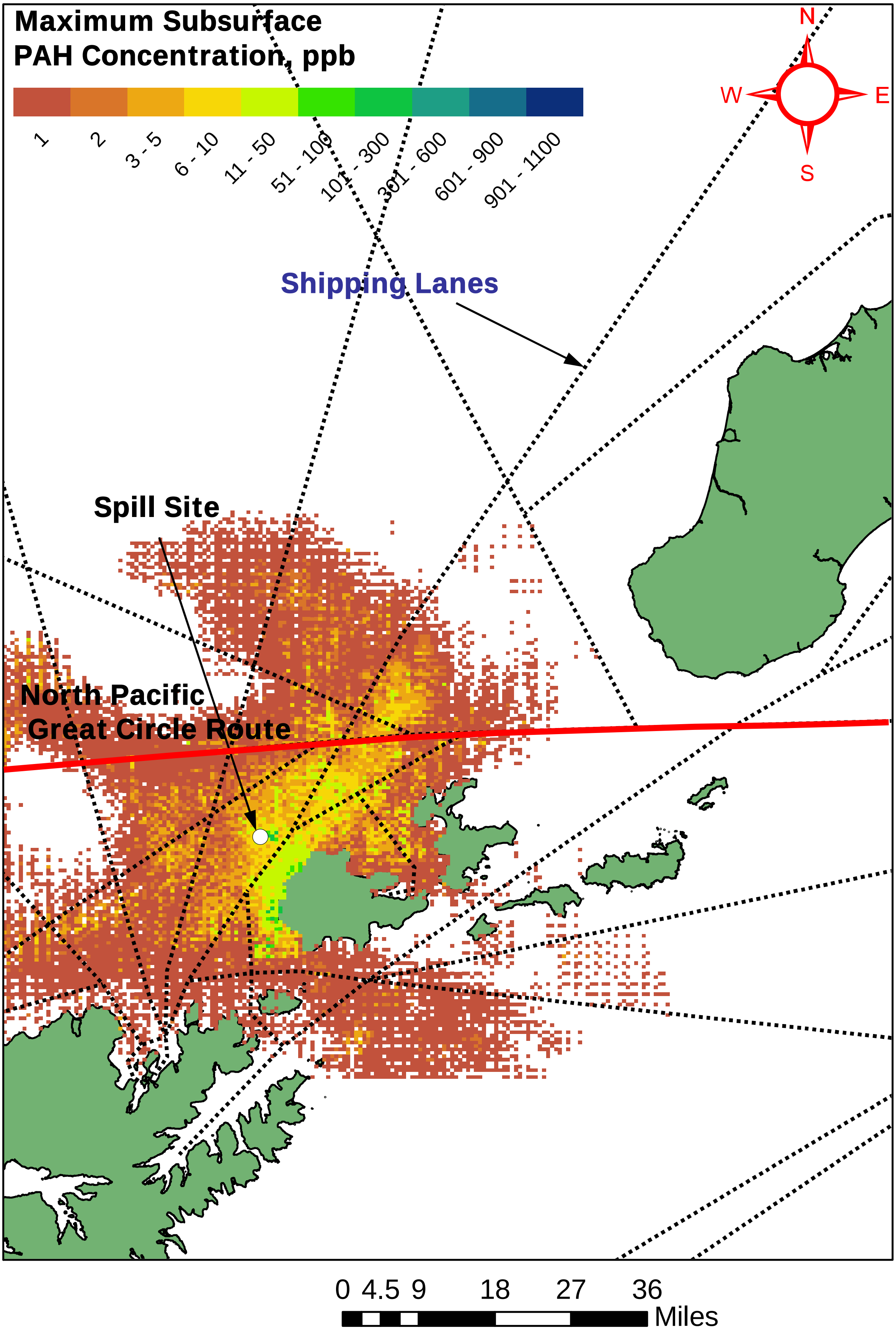
Scenario 1 - Summer



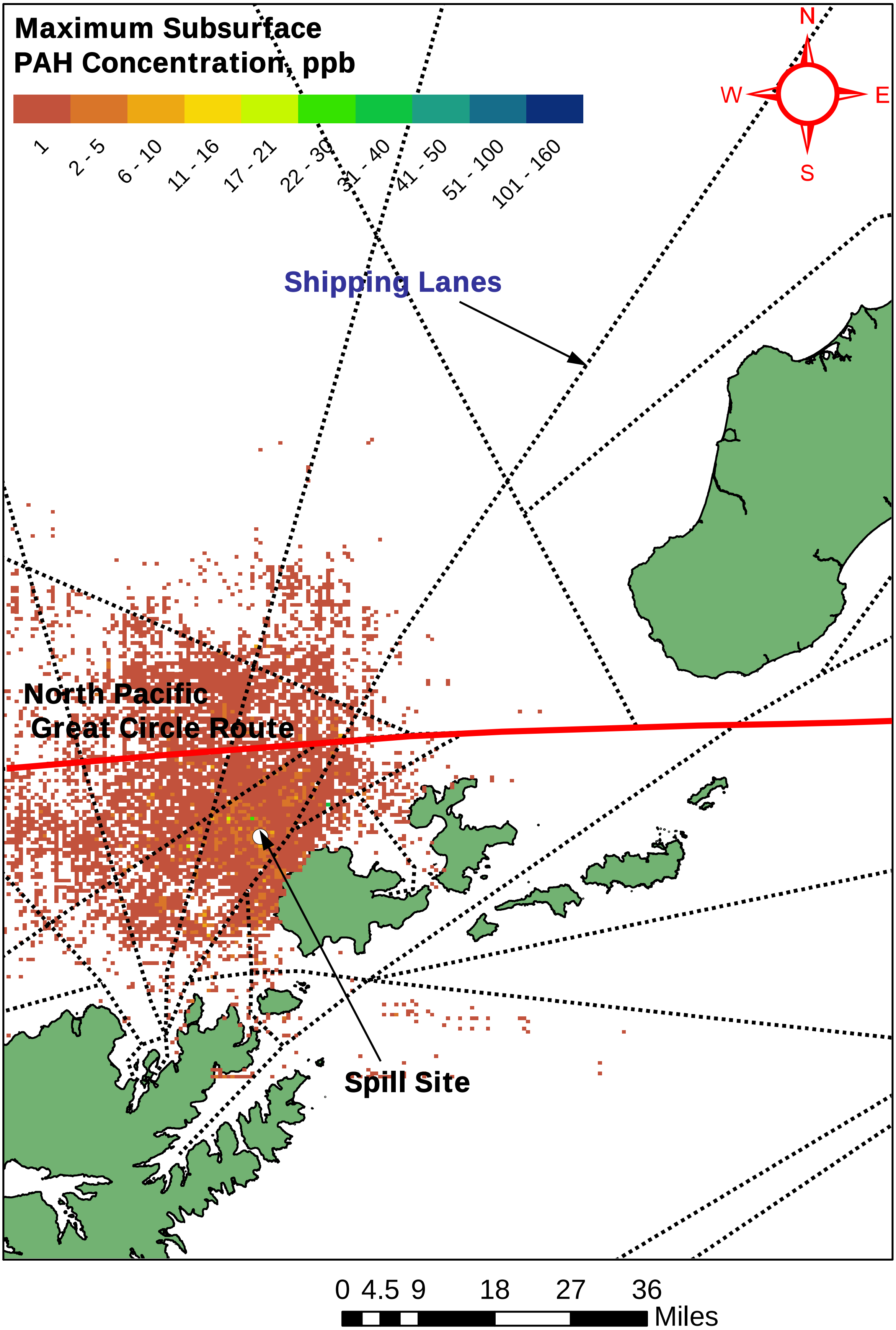
Scenario 2 - Summer



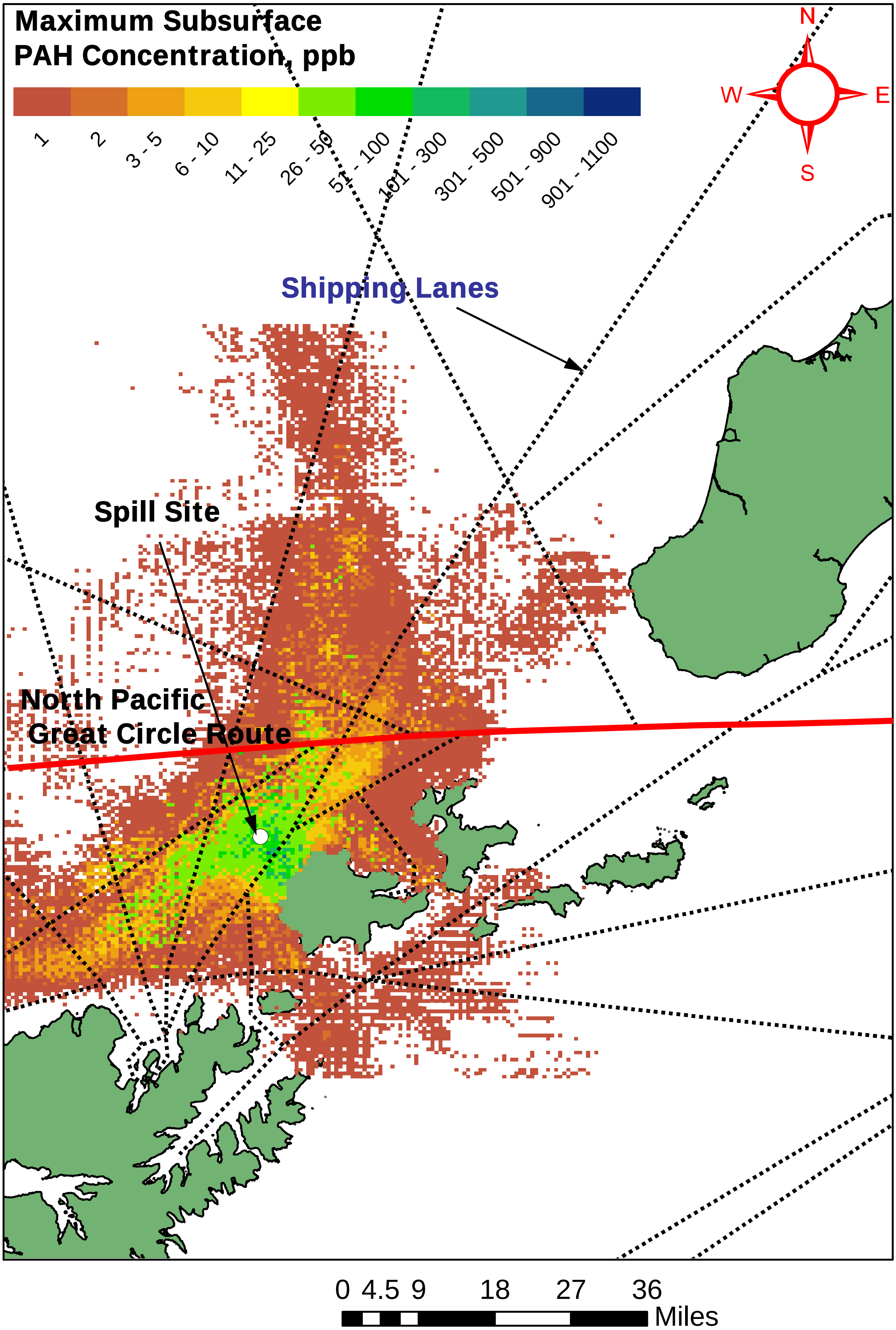
Scenario 3 - Summer



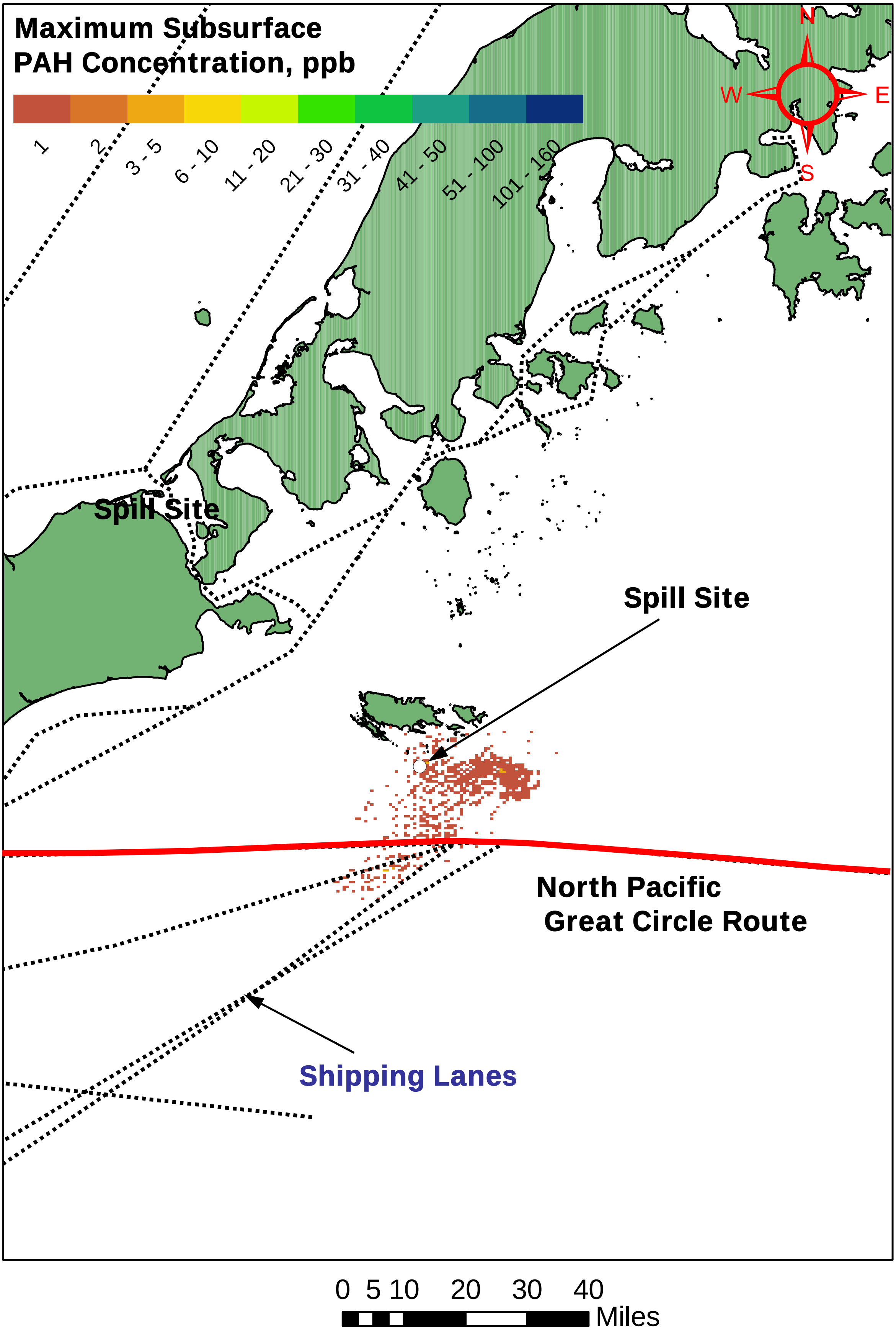
Scenario 4 - Winter



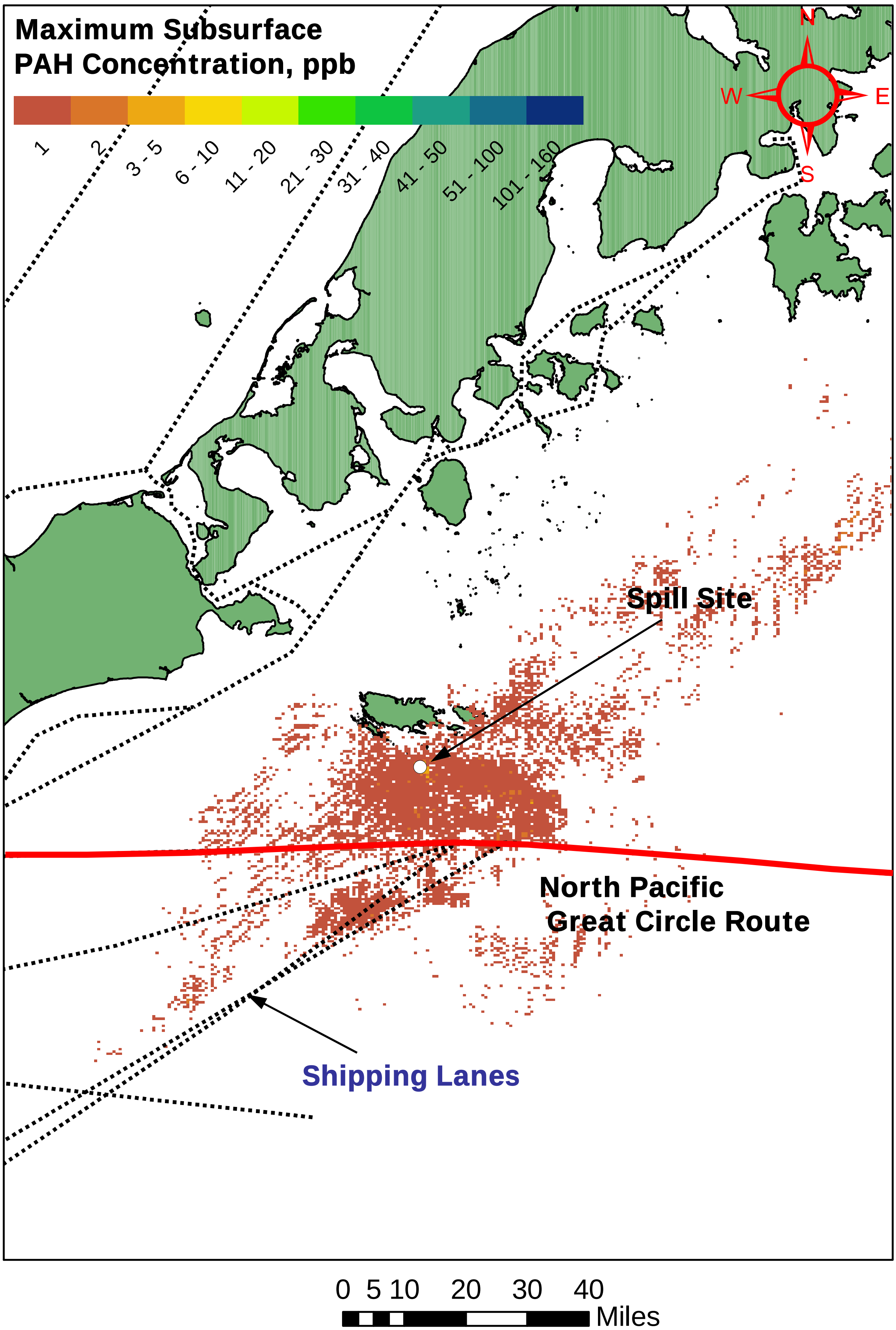
Scenario 5 - Summer



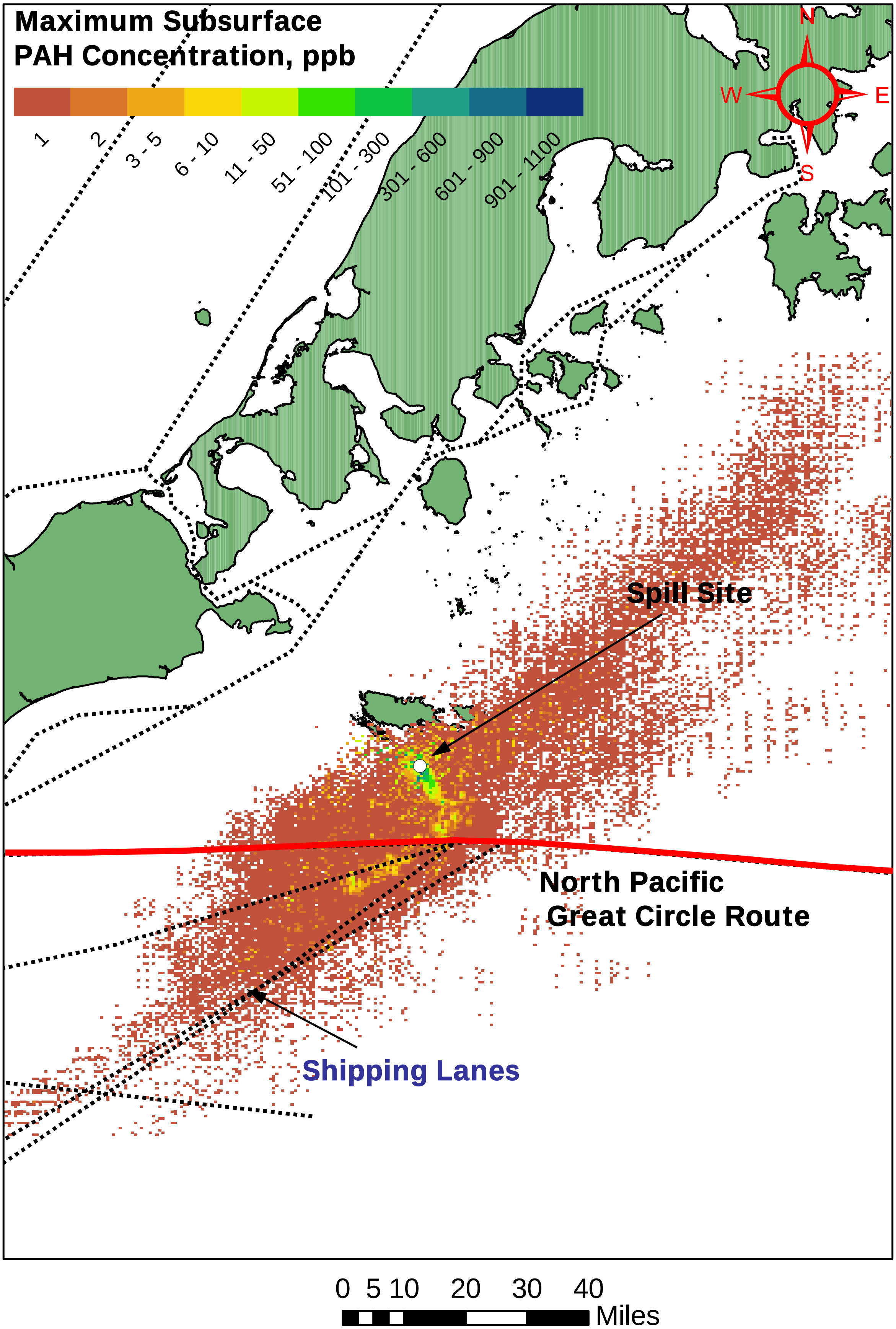
Scenario 6 - Summer



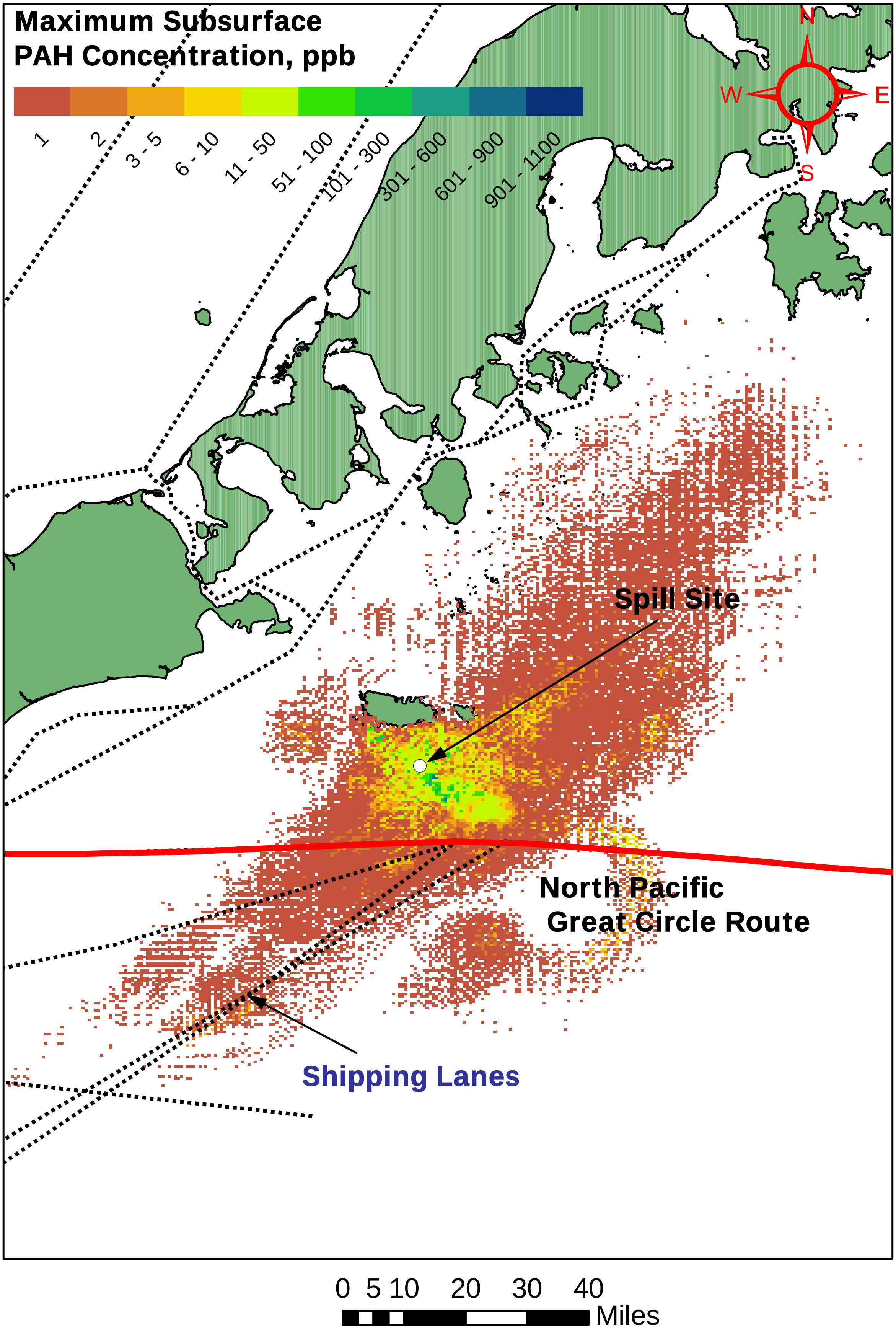
Scenario 7 - Summer



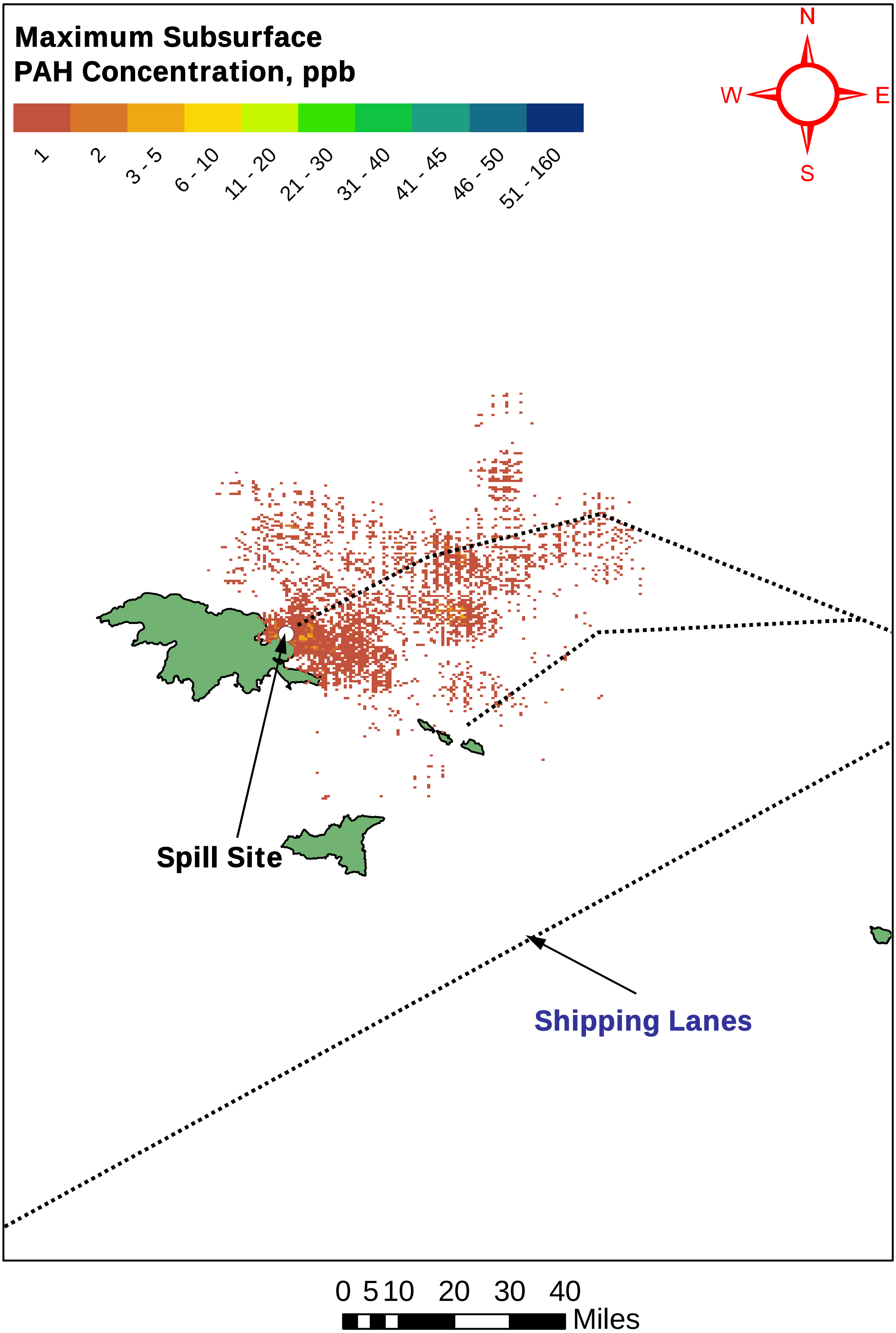
Scenario 8 - Summer



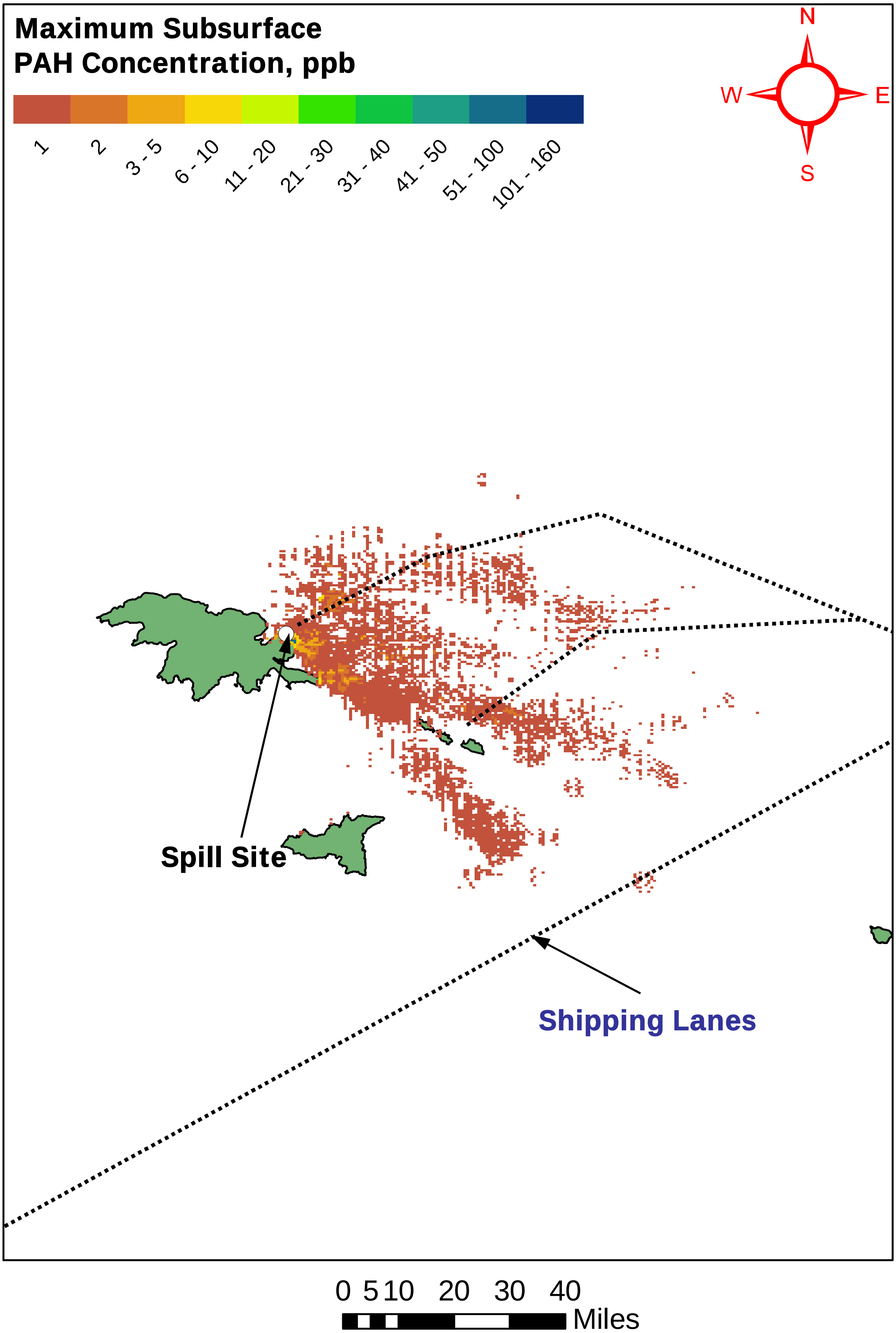
Scenario 9 - Summer



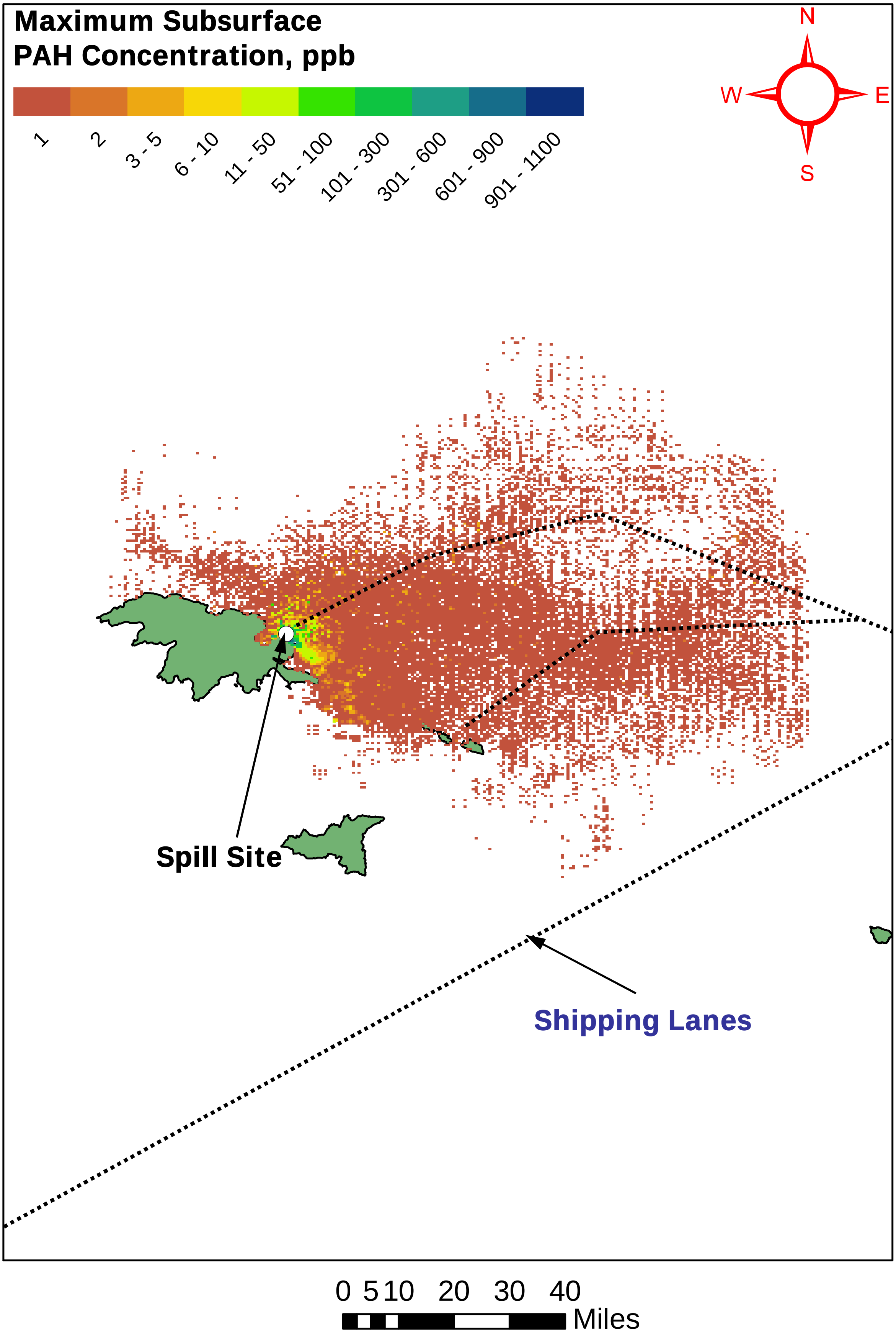
Scenario 10 - Winter



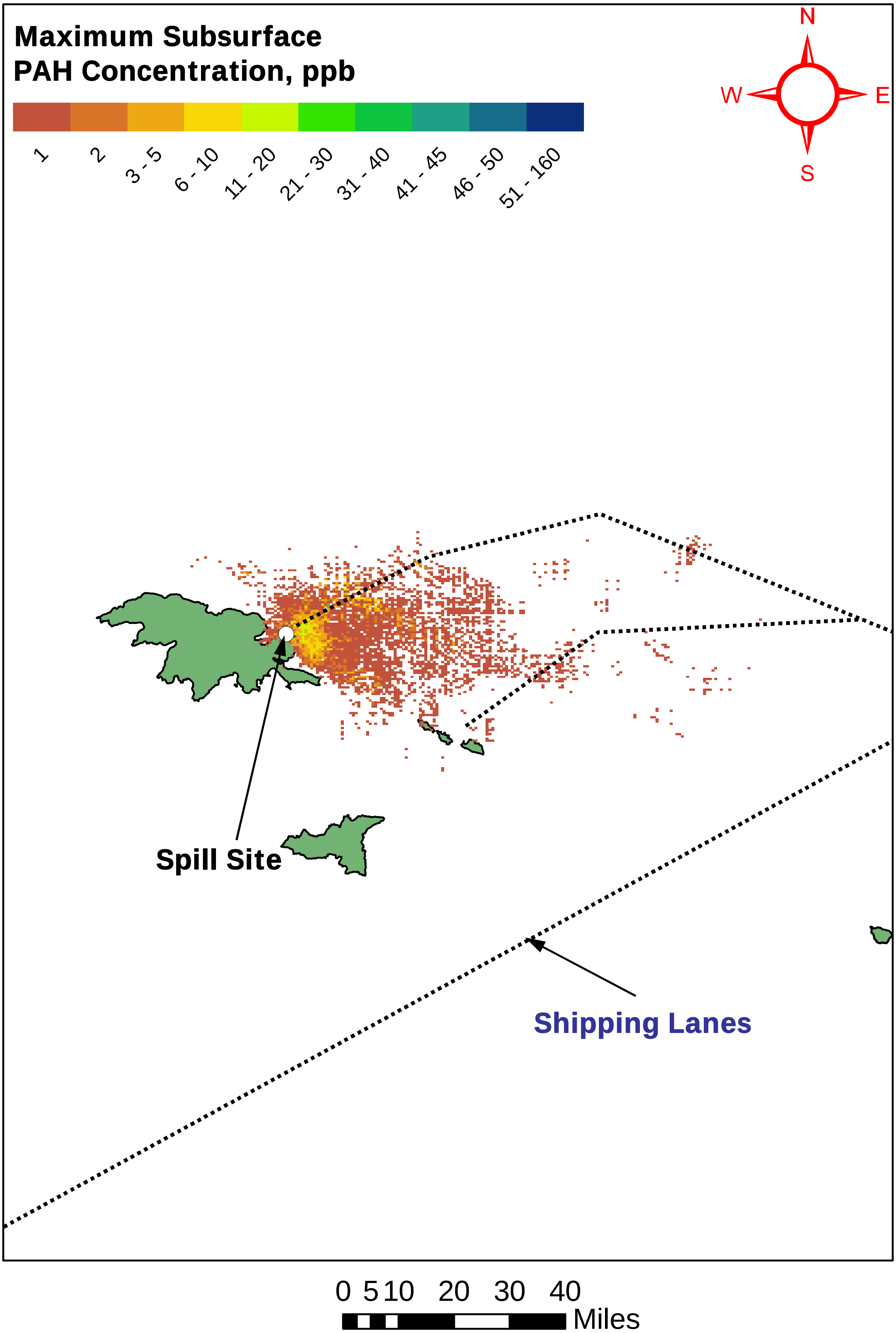
Scenario 11 - Summer



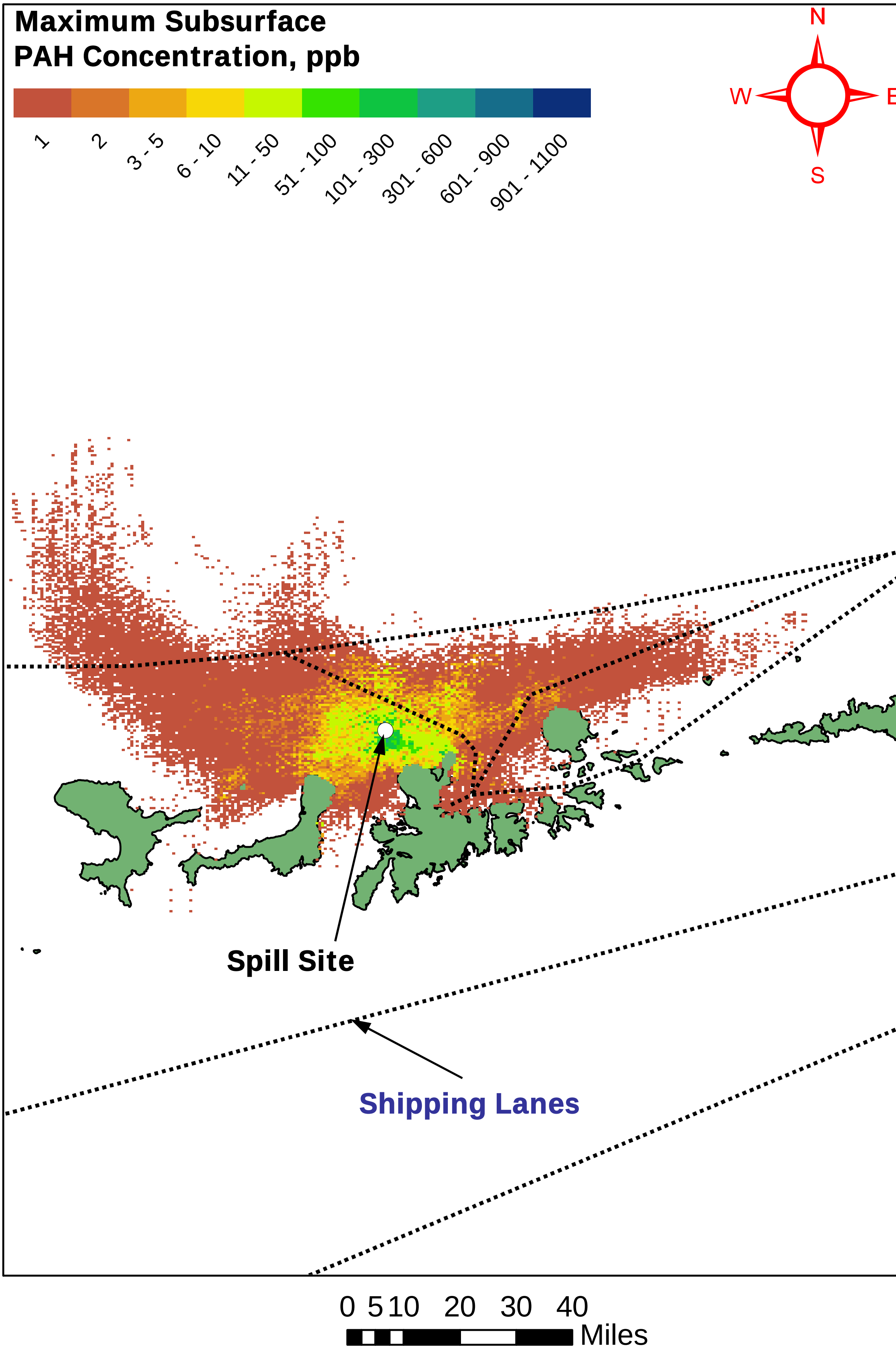
Scenario 12 - Spring



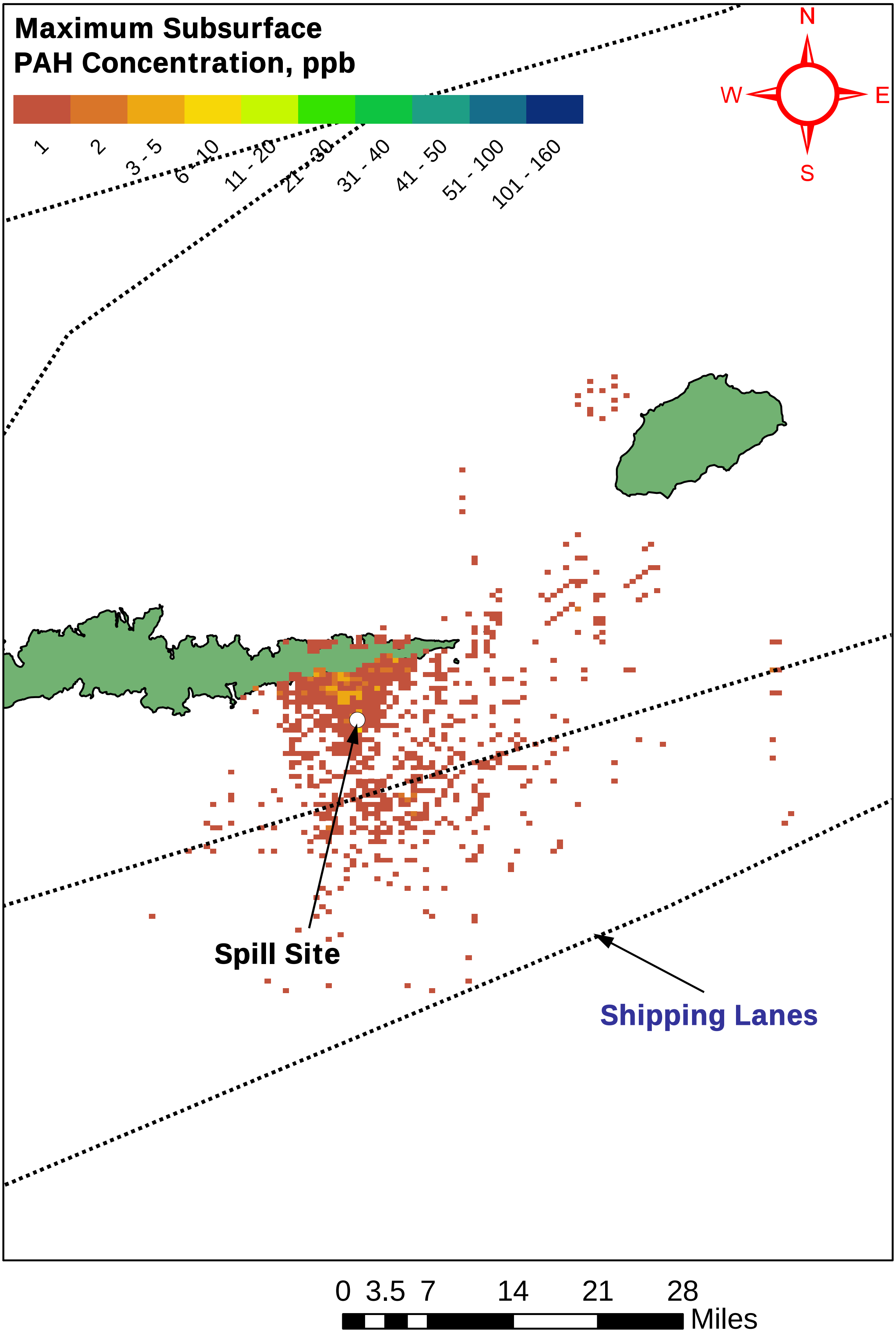
Scenario 13 - Spring



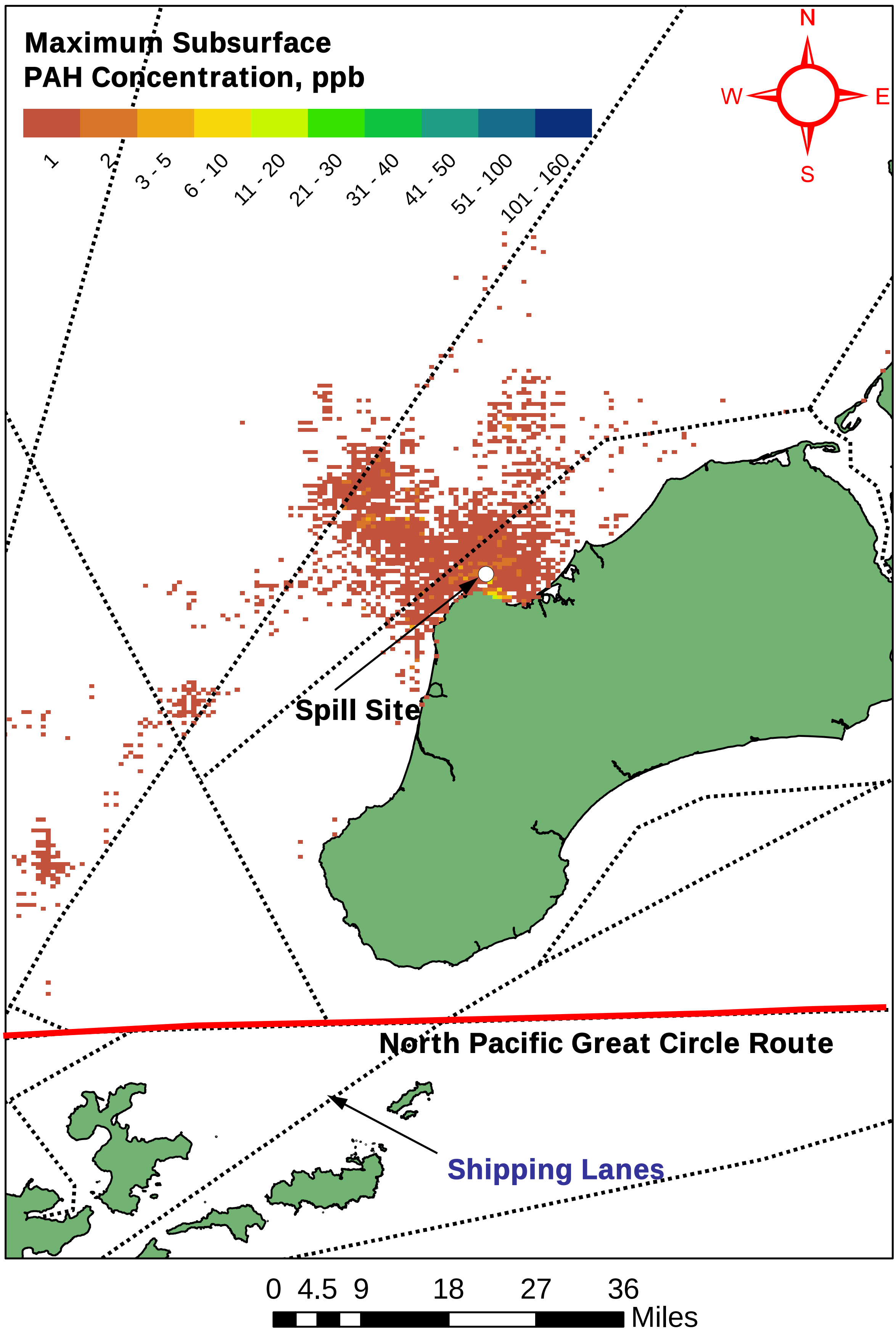
Scenario 14 - Summer



Scenario 15 - Summer

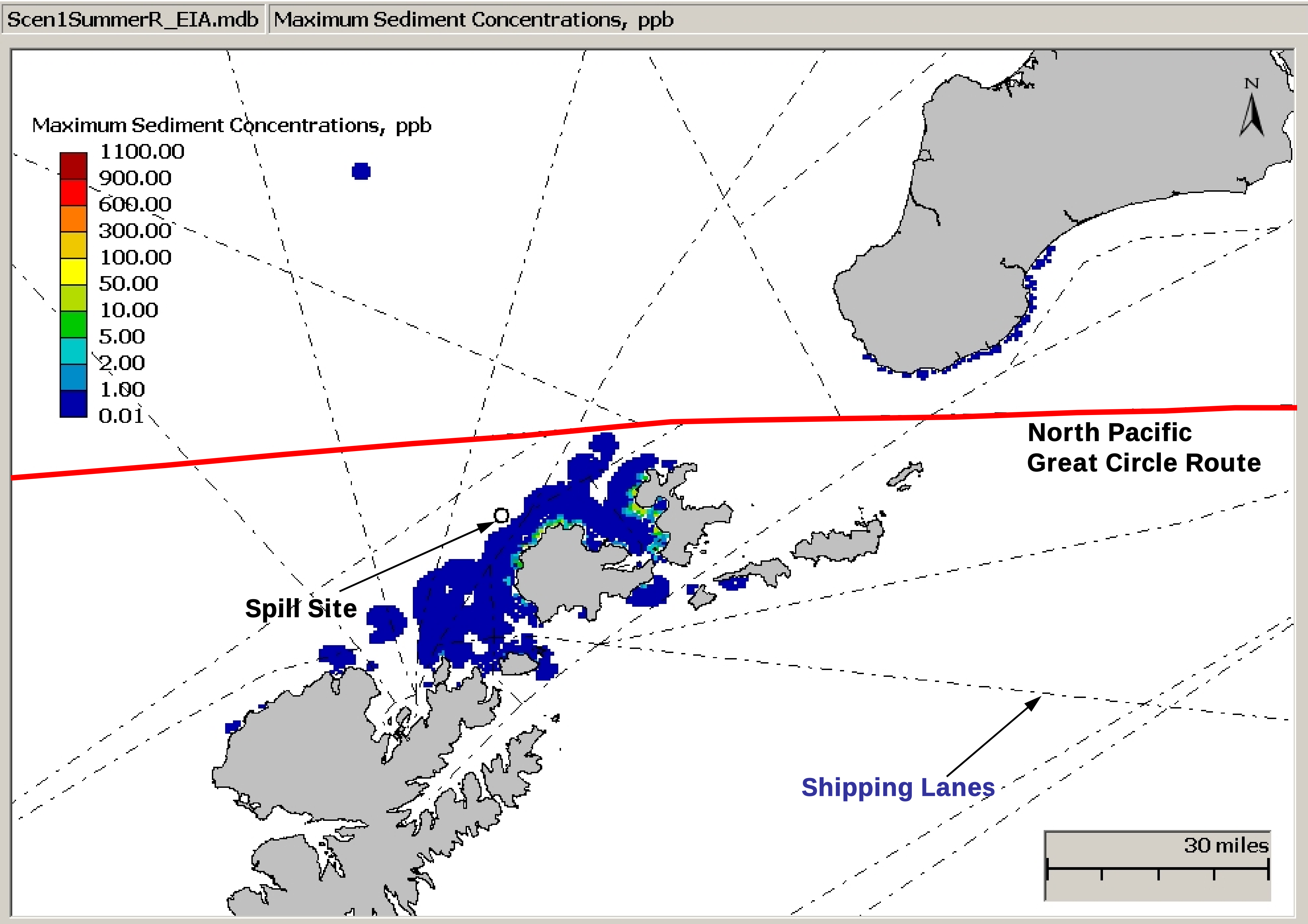


Scenario 16 - Spring

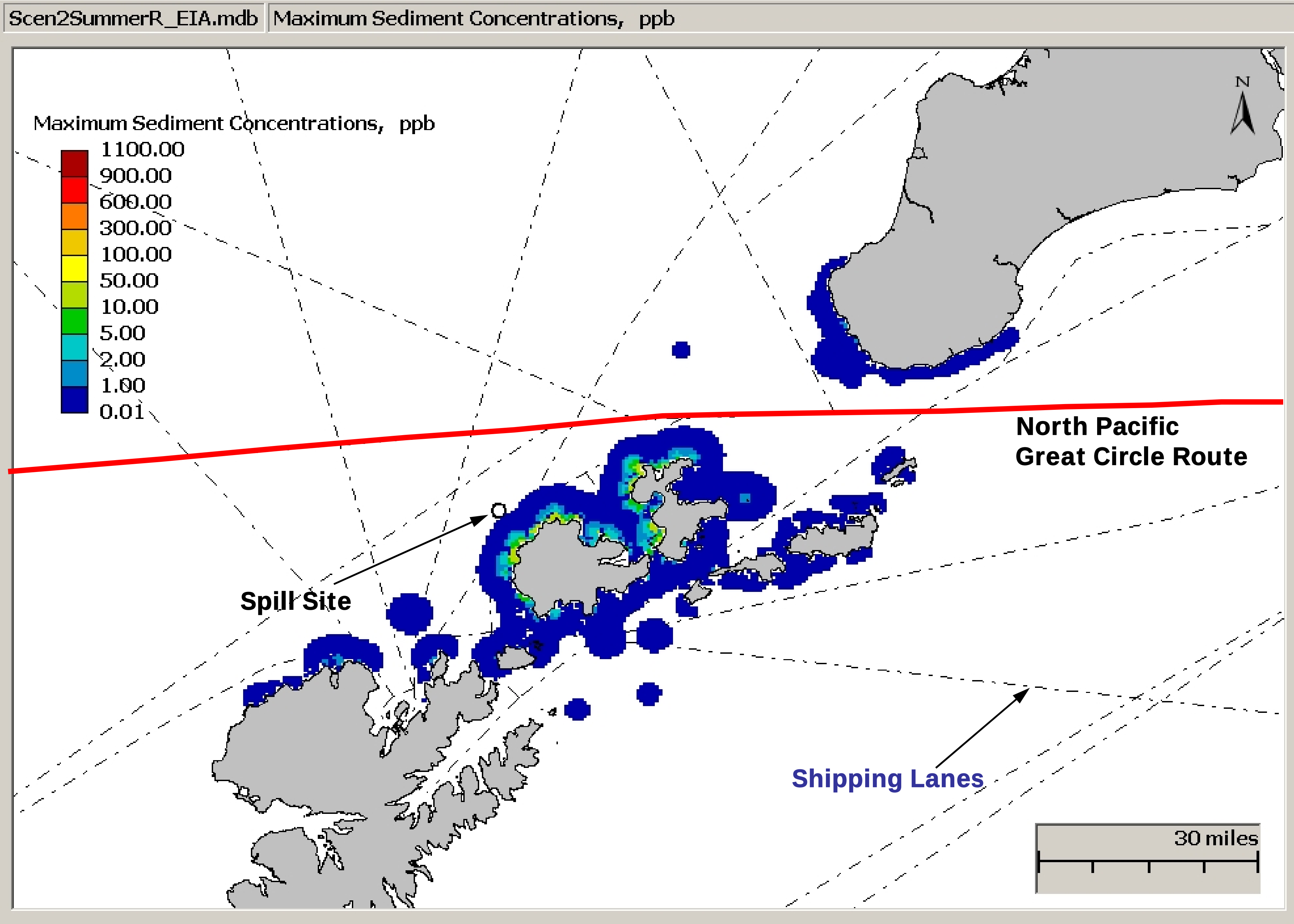


Appendix C
Maximum Sediment Concentration Outputs

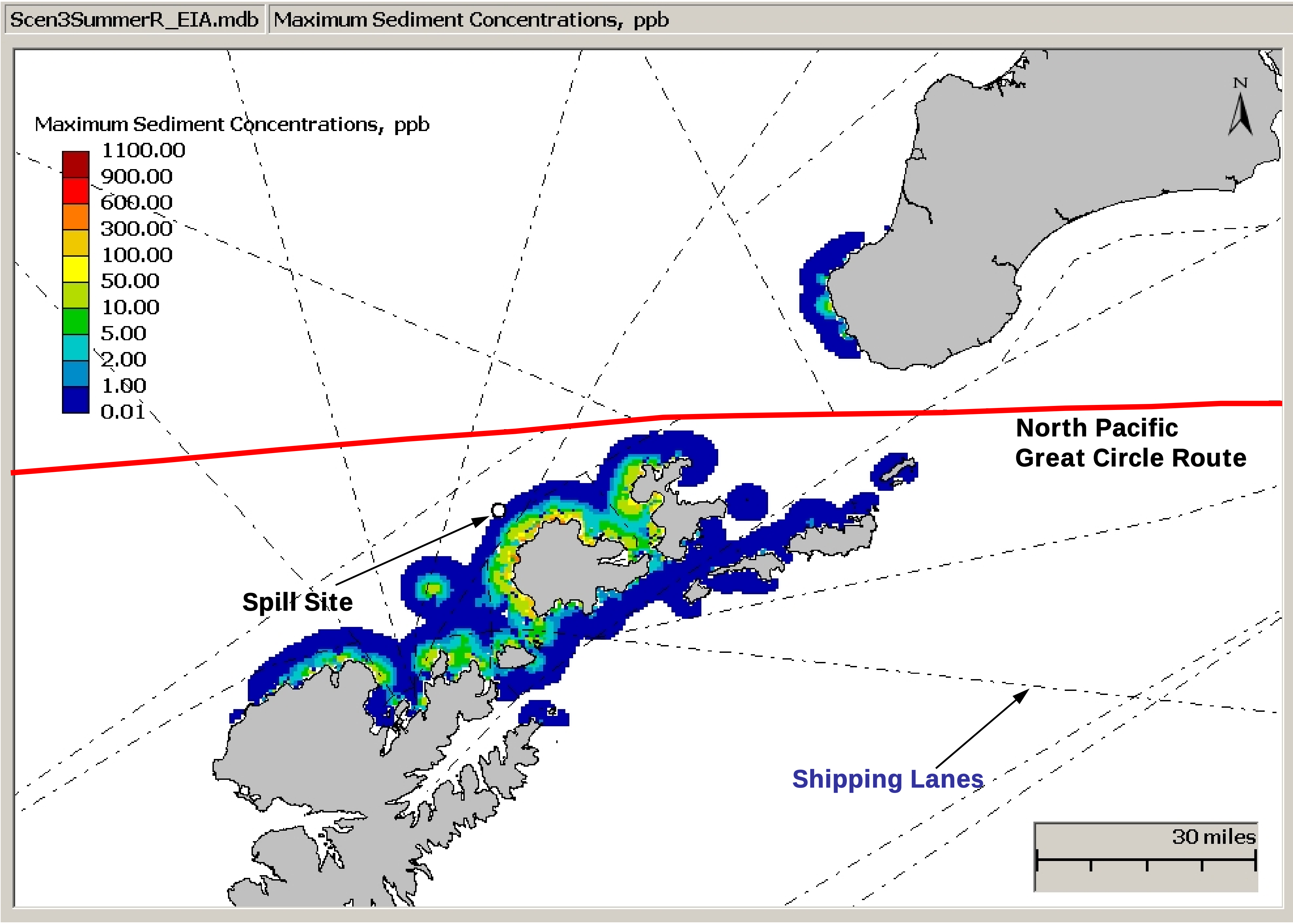
Scenario 1 - Summer



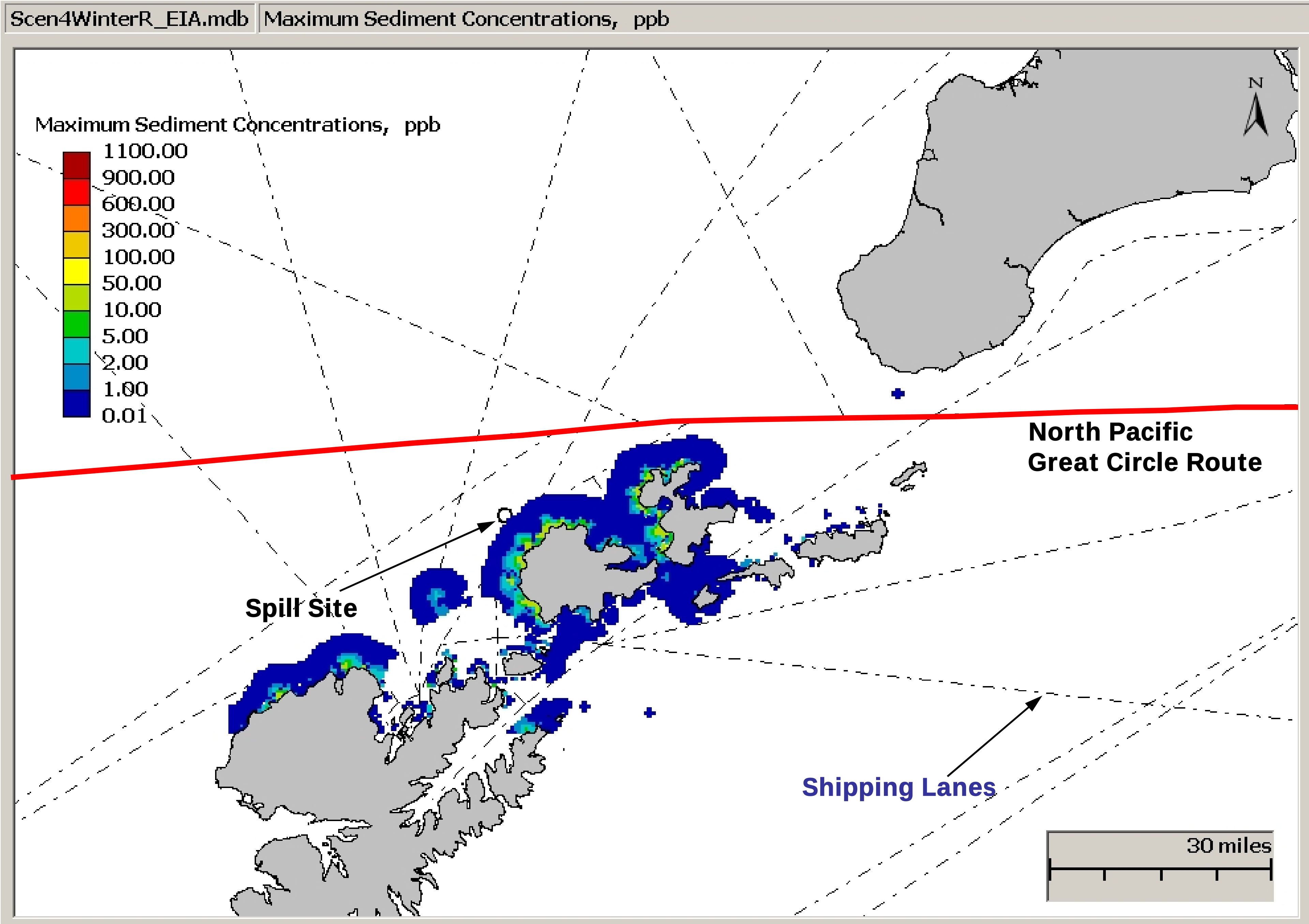
Scenario 2 - Summer



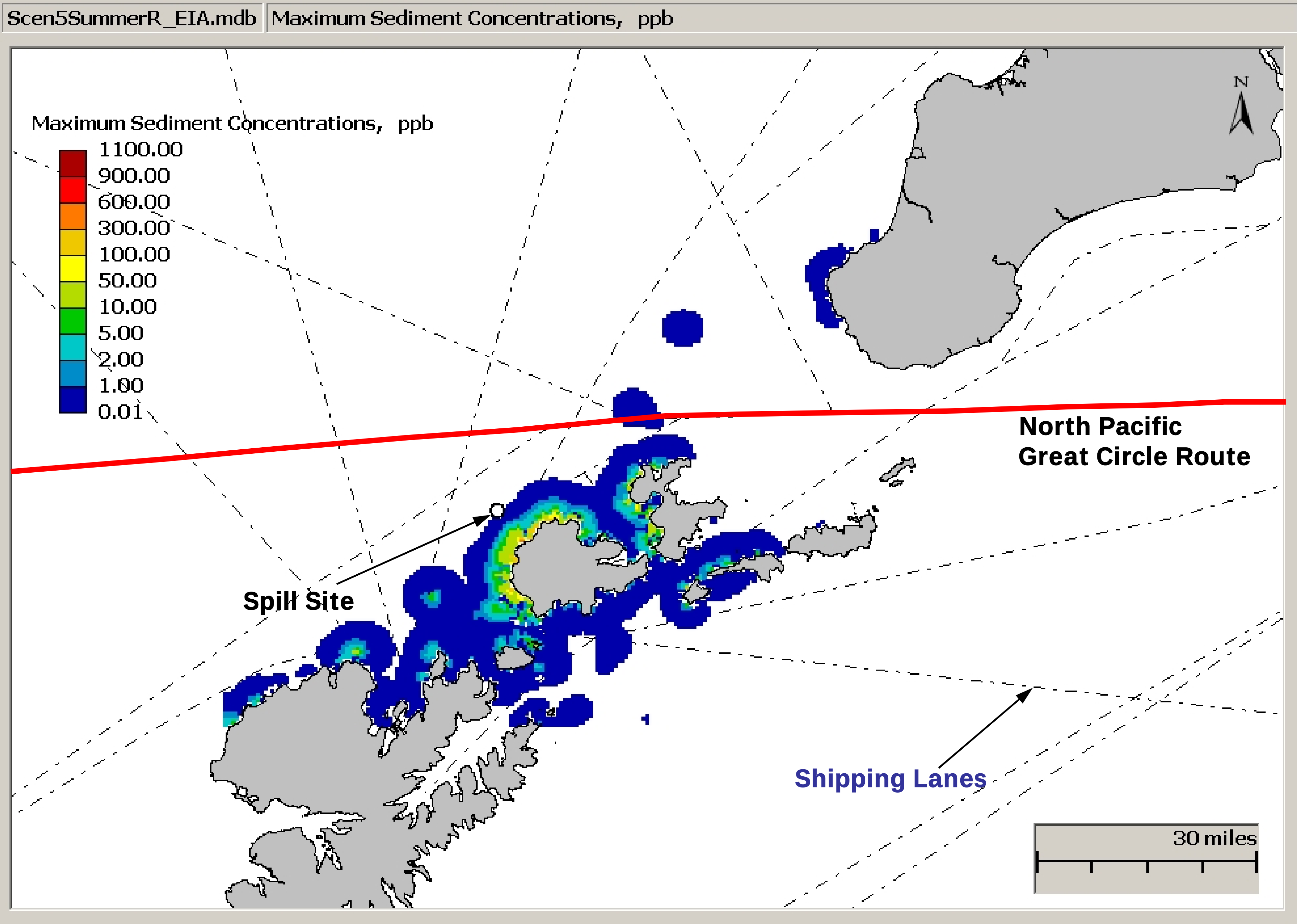
Scenario 3 - Summer



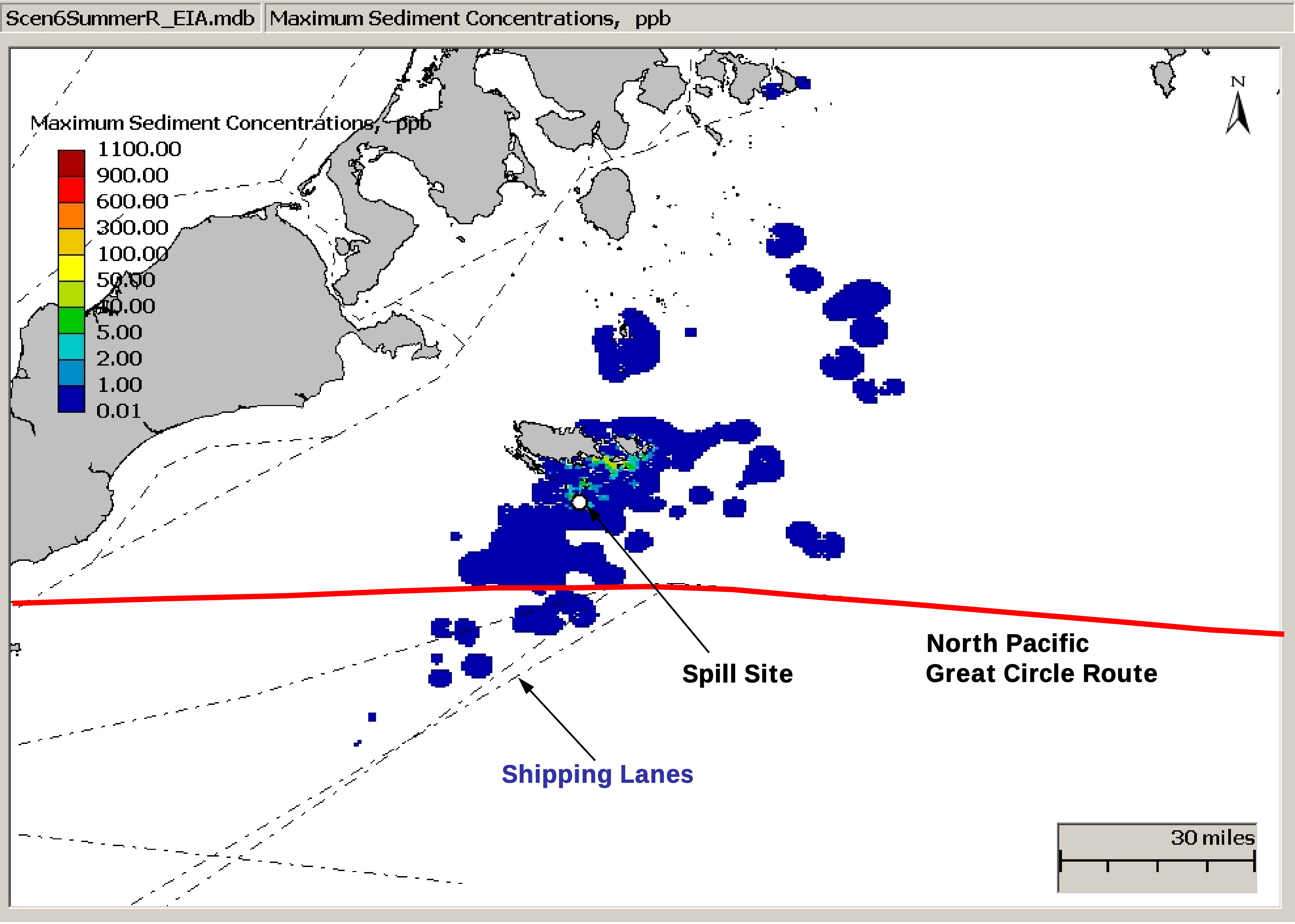
Scenario 4 - Winter



Scenario 5 - Summer

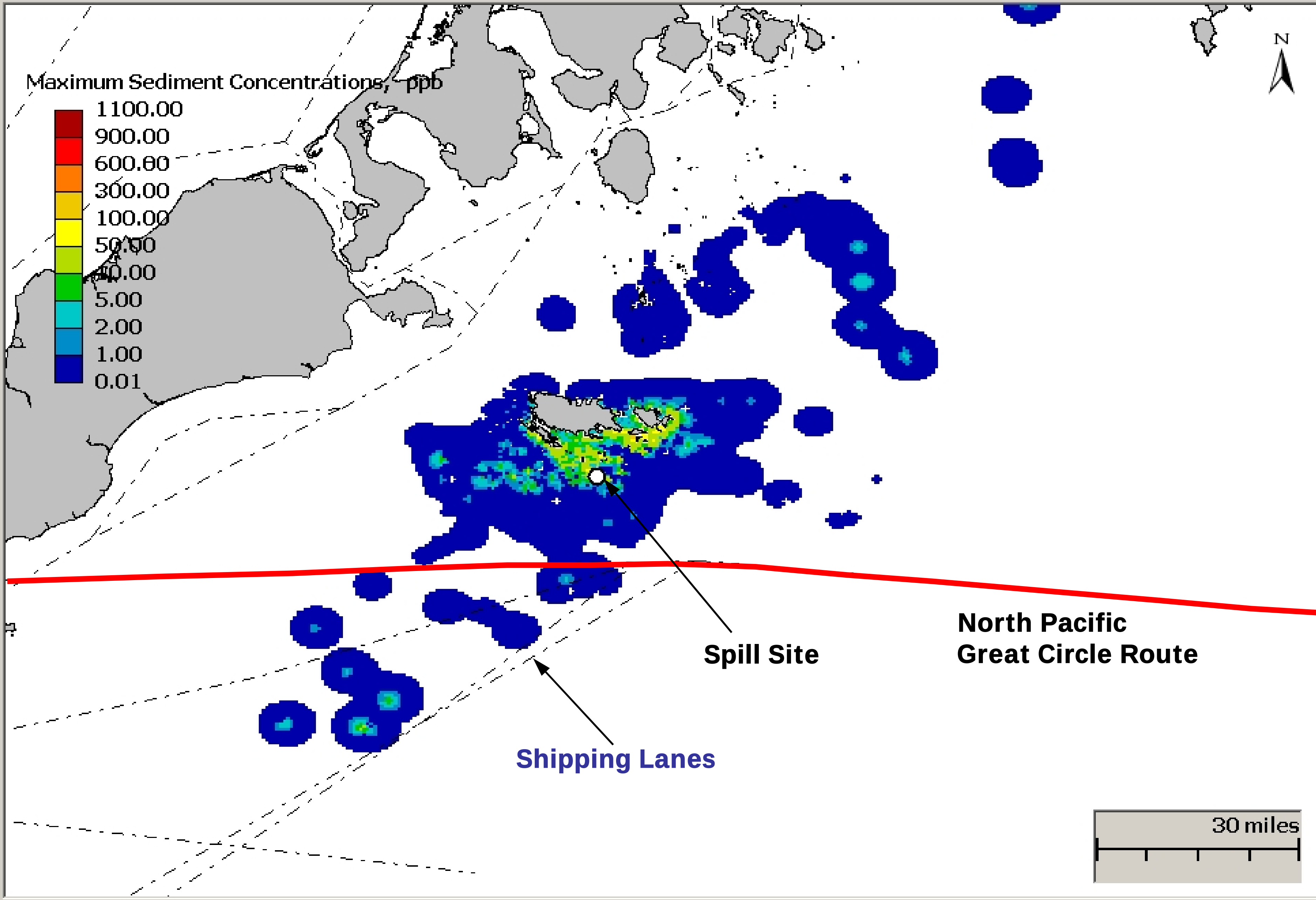


Scenario 6 - Summer

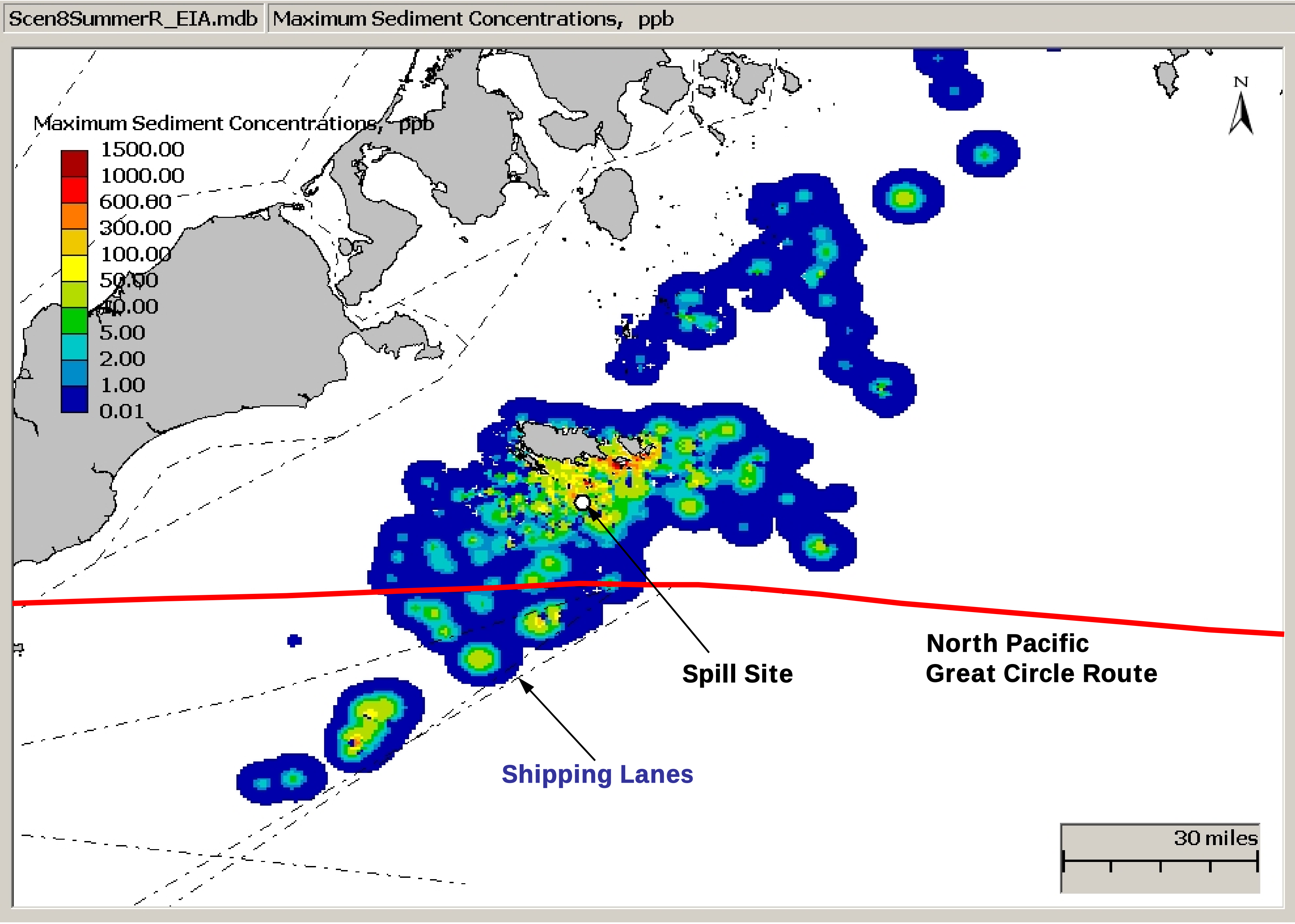


Scenario 7 - Summer

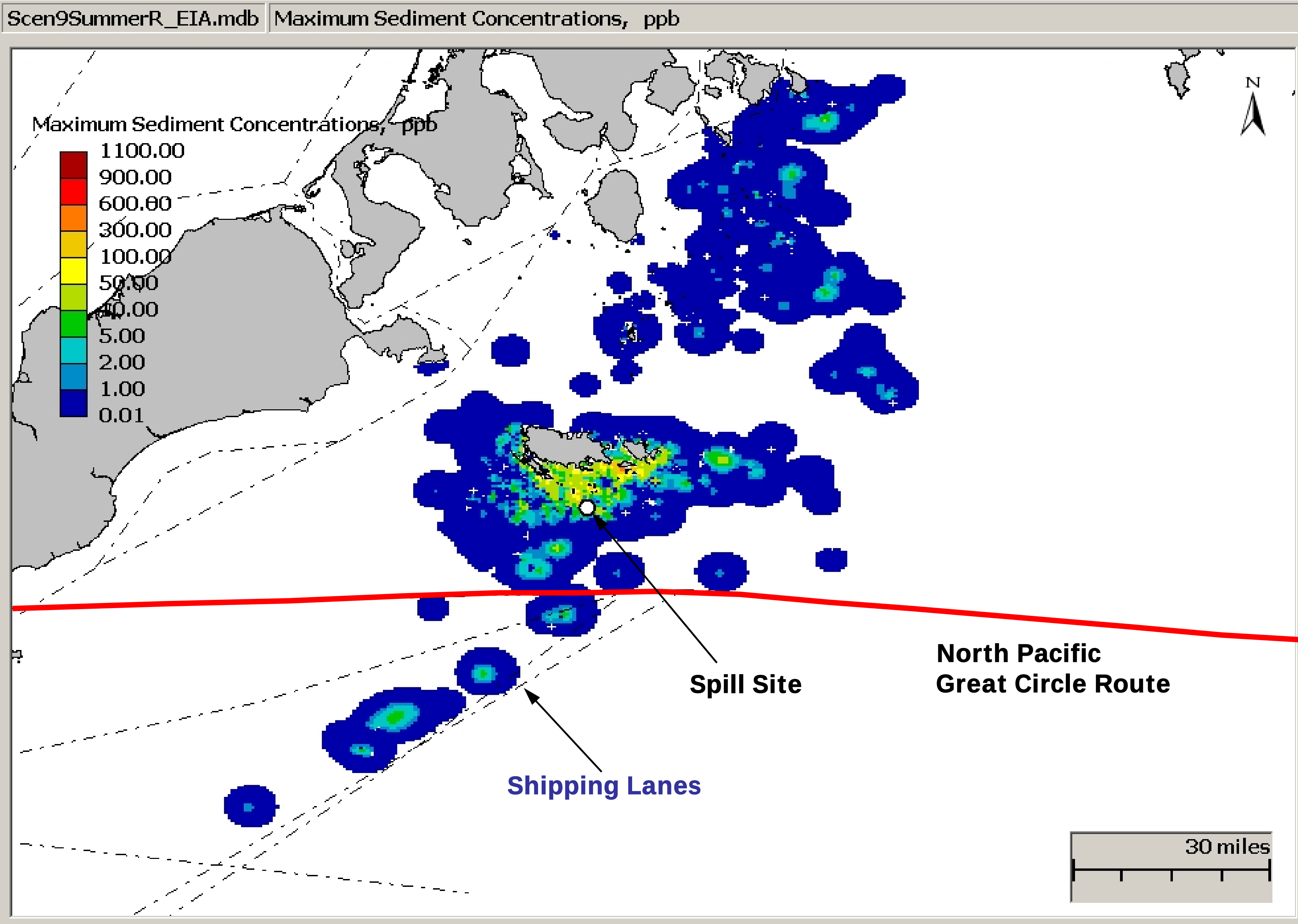
Scen7SummerR_EIA.mdb | Maximum Sediment Concentrations, ppb



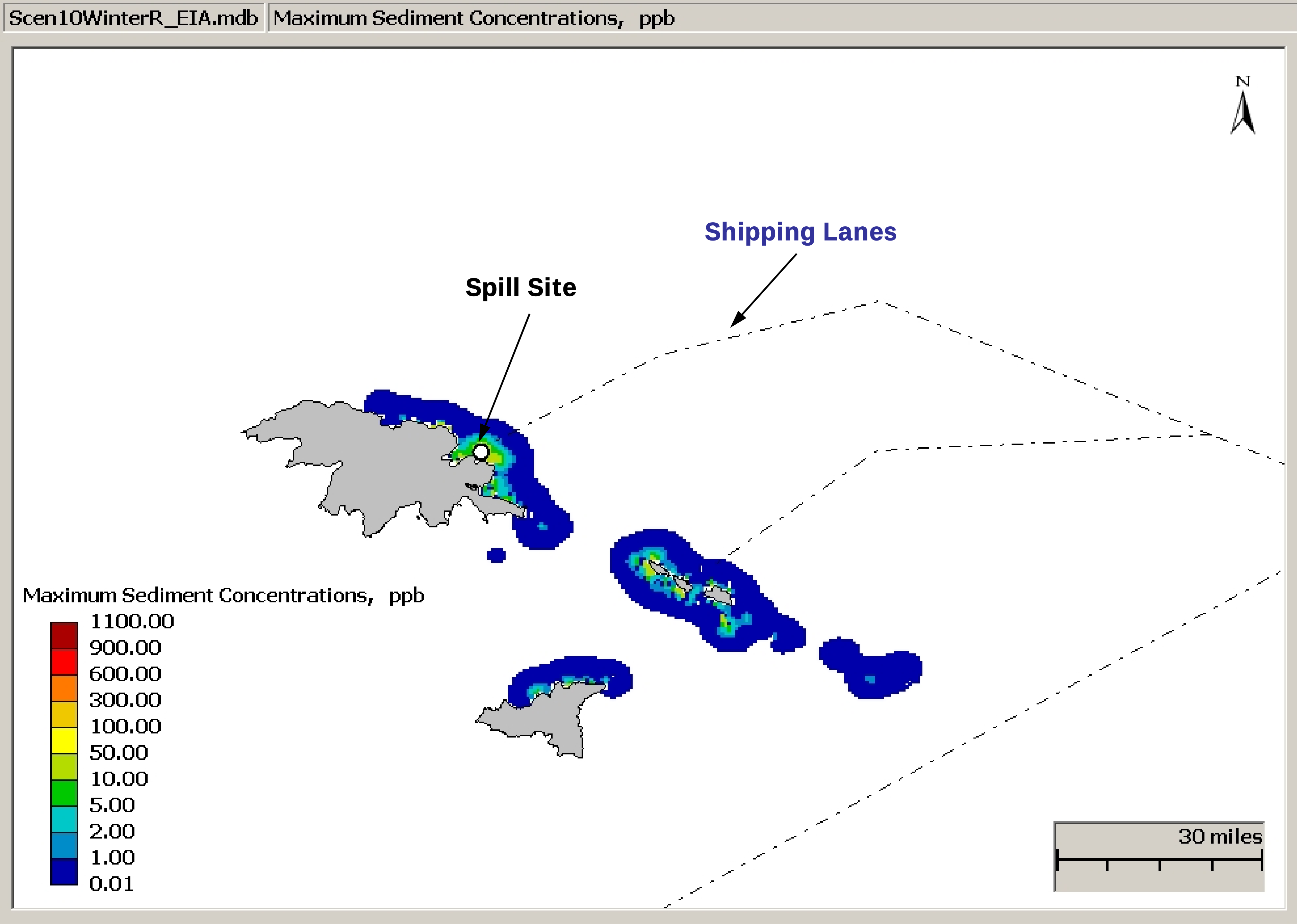
Scenario 8 - Summer



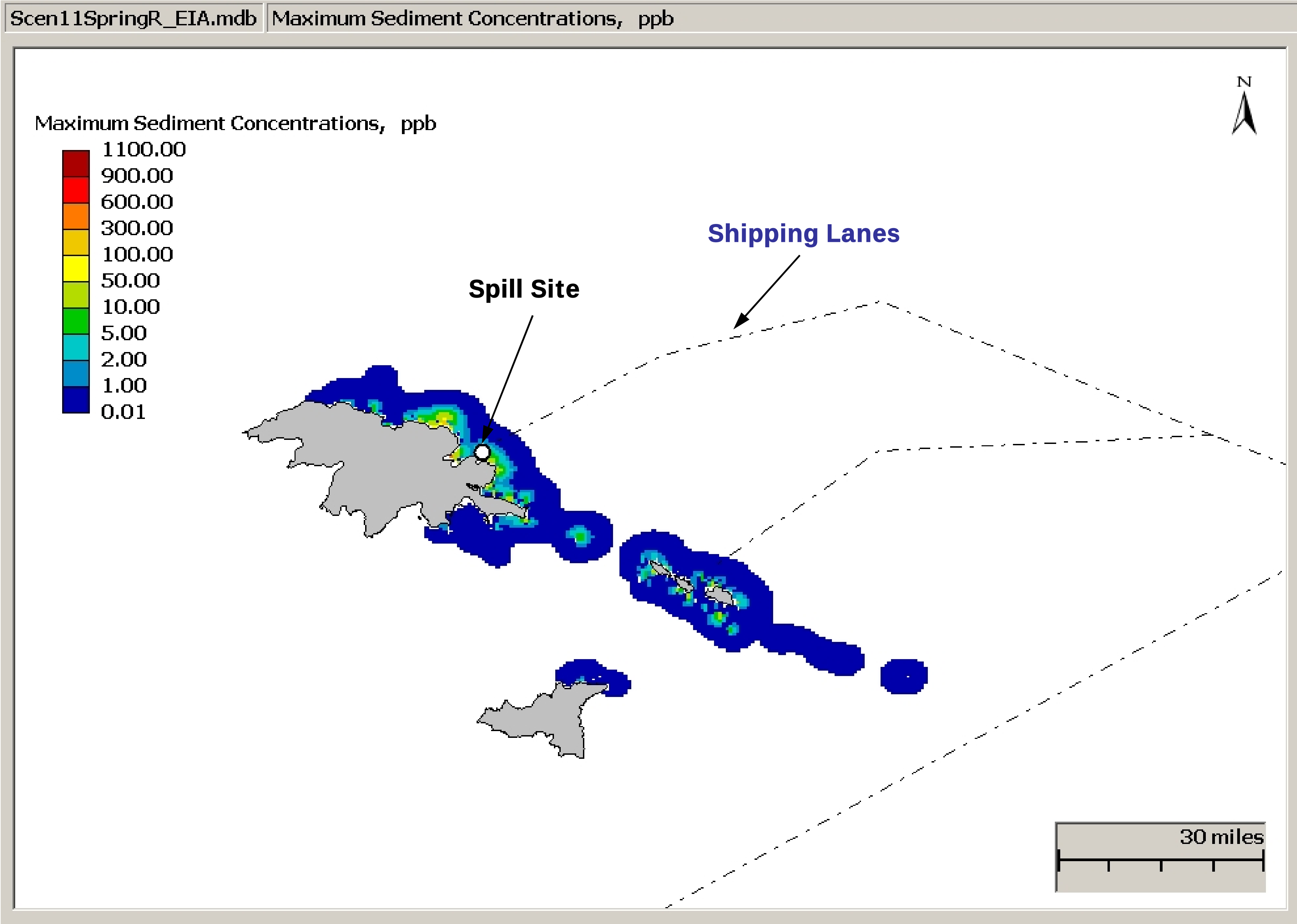
Scenario 9 - Summer



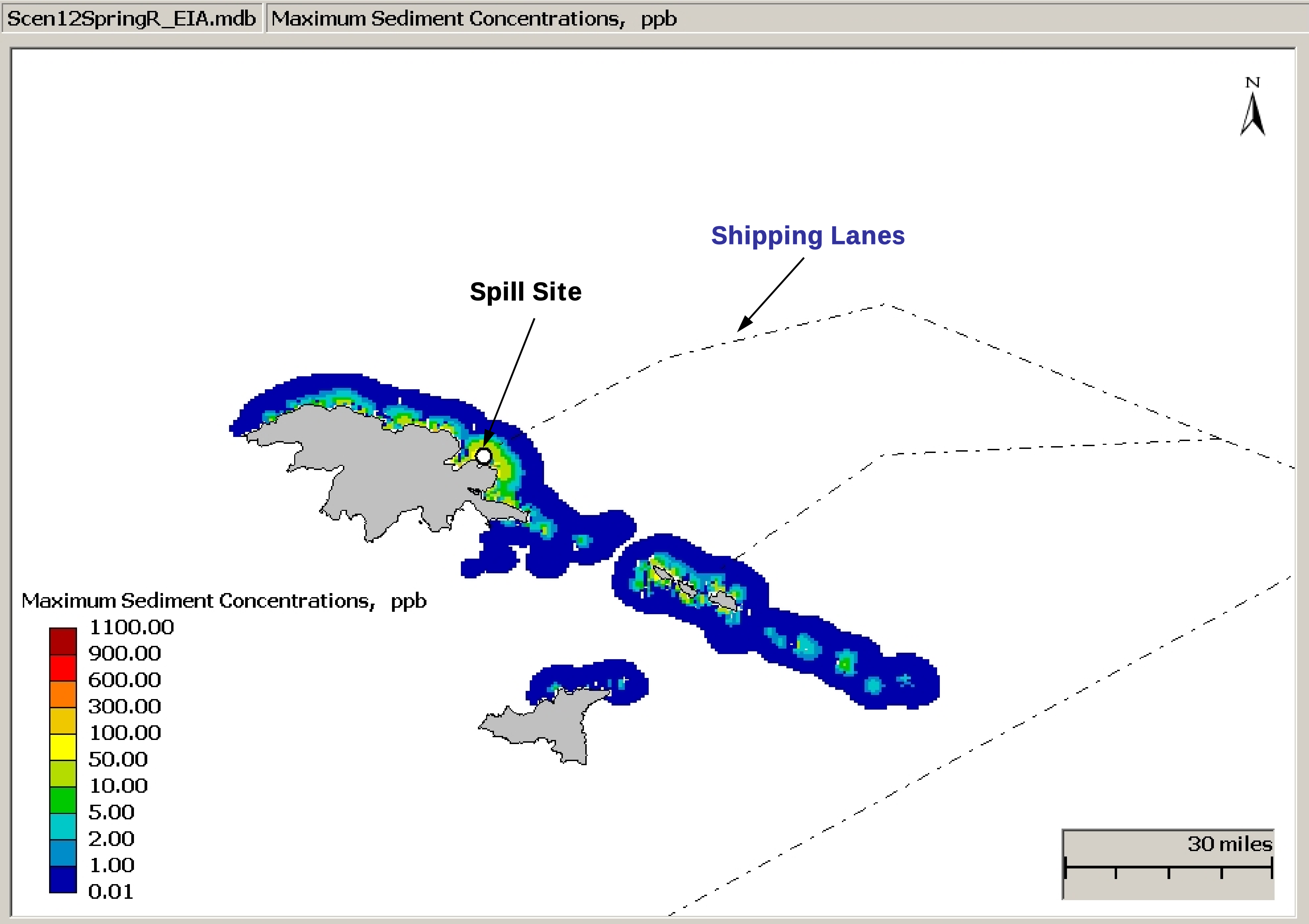
Scenario 10 - Winter



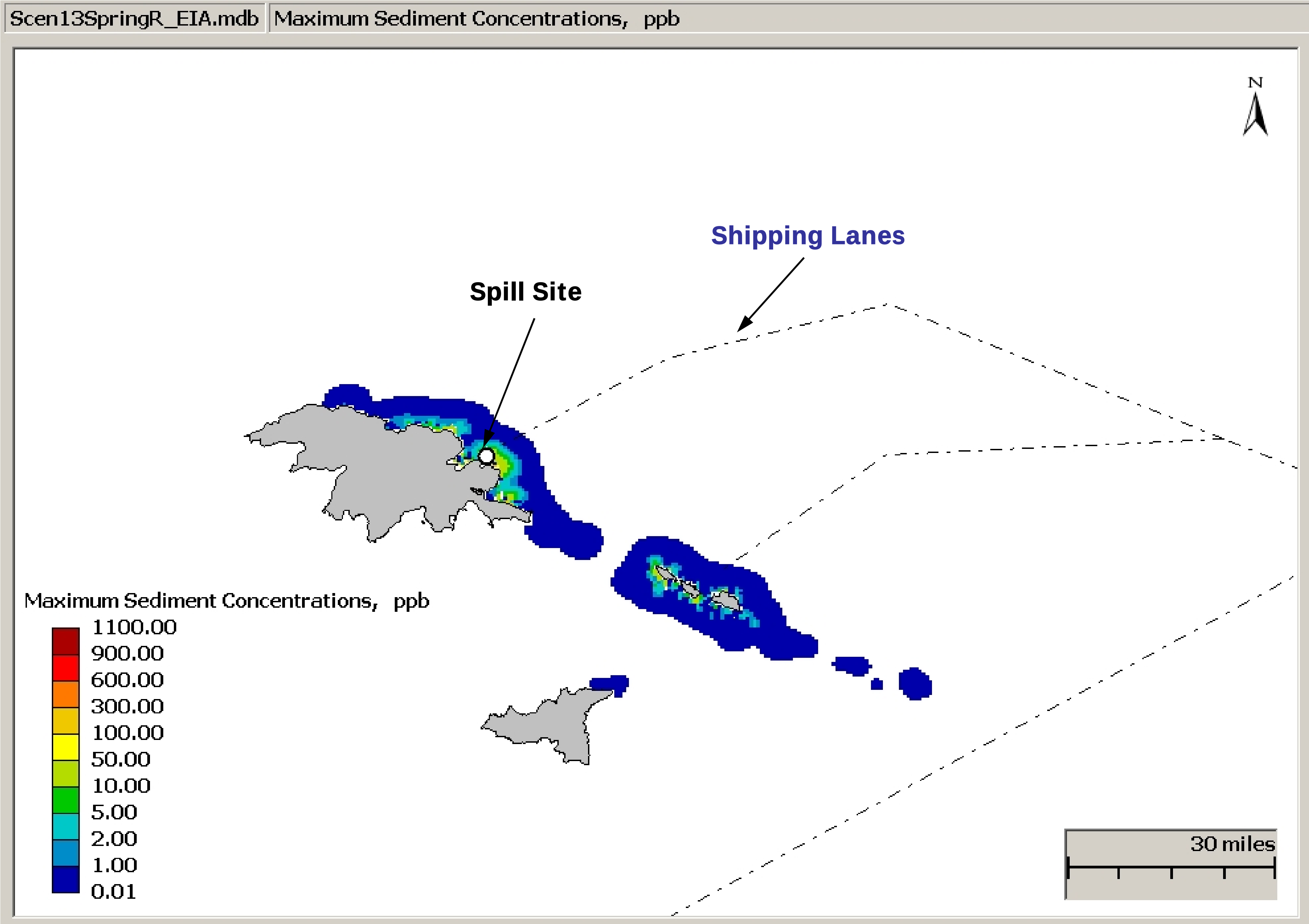
Scenario 11 - Summer



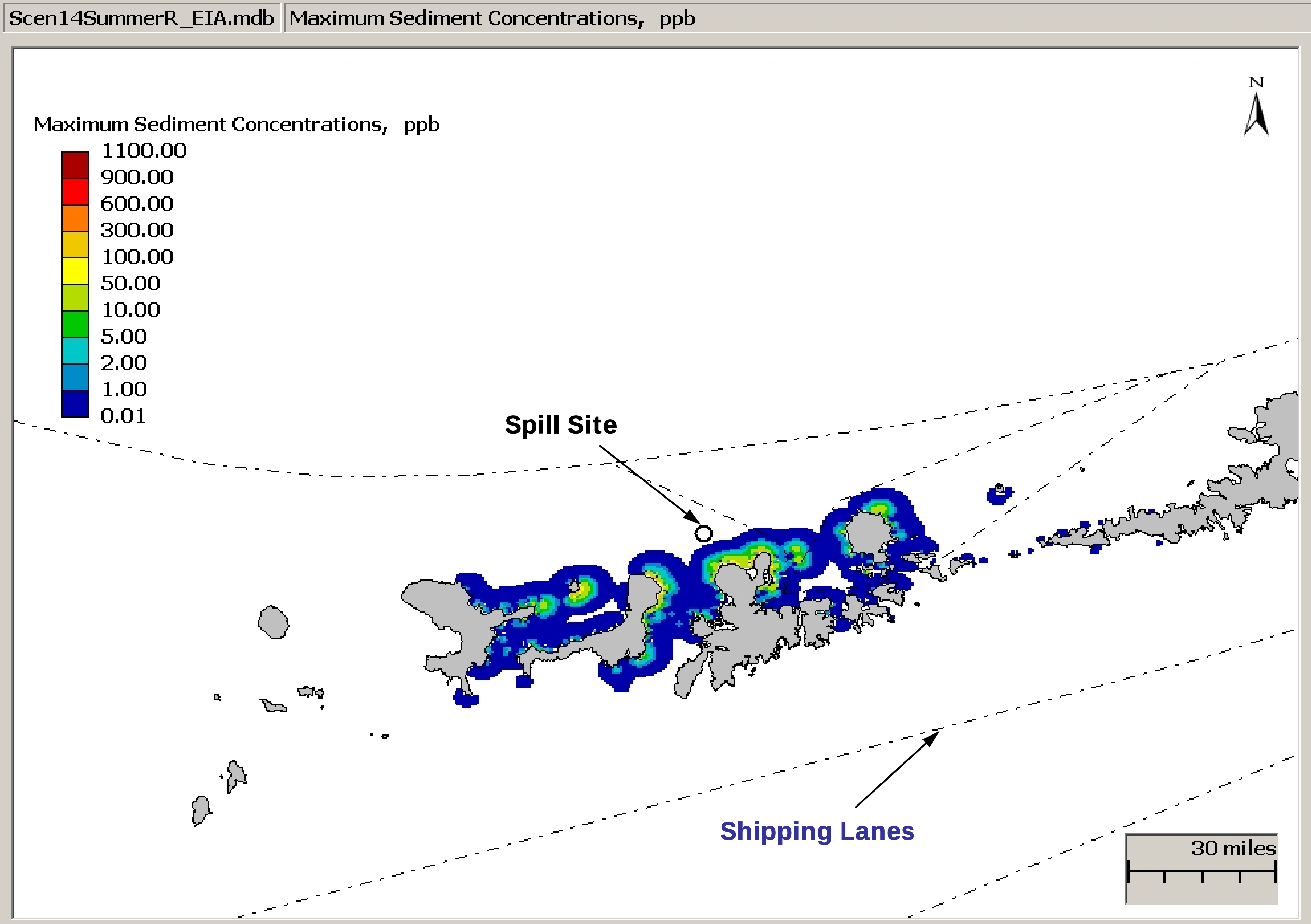
Scenario 12 - Spring



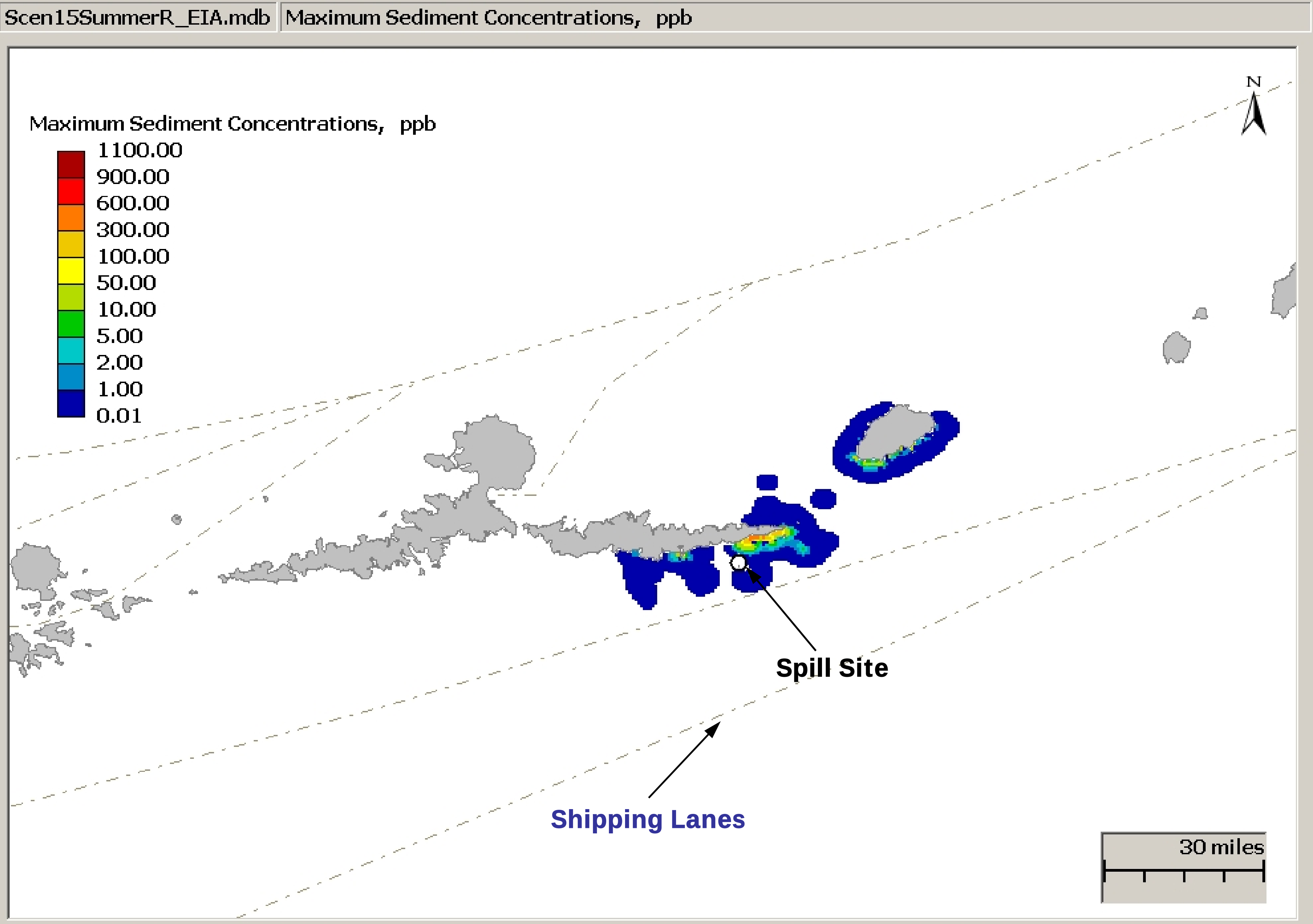
Scenario 13 - Spring



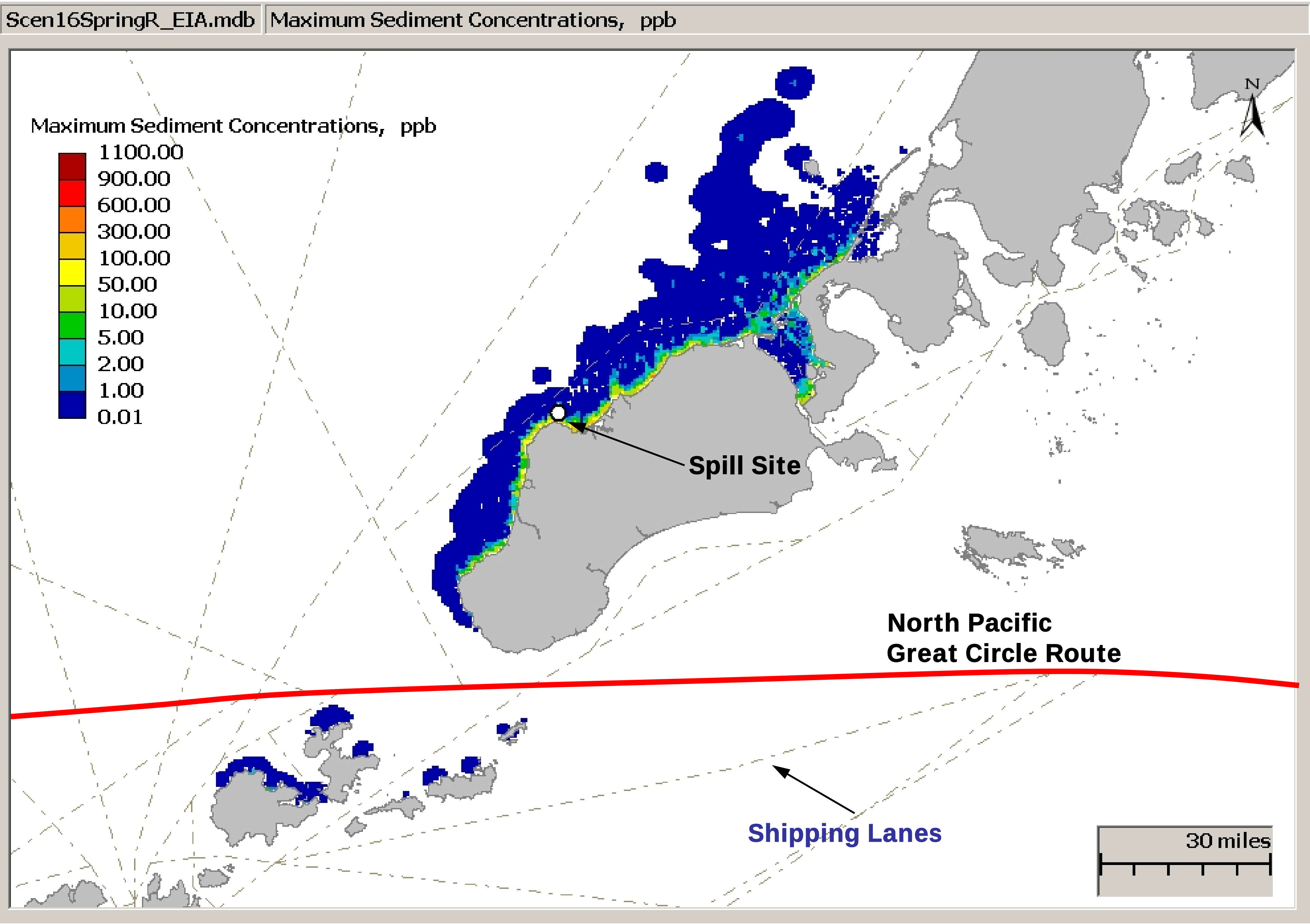
Scenario 14 - Summer



Scenario 15 - Summer



Scenario 16 - Spring



Appendix D
Description of Spill Output-Receptor Overlay Assessment

Appendix D: Description for Assessing Spill Model Outputs and Receptor Overlays

This appendix provides additional information on the approach used to assess potential impacts to the receptor categories evaluated as part of the Task 4 Consequence Analysis; which include physical (habitats), seabirds, mammals, fish and socioeconomic receptors. As described in Section 4.3, the surface oiling probability, maximum subsurface concentration, and sediment concentration were used for this assessment. These outputs from stochastic modeling comprise information on the areas at which oil is estimated to impact water surface and the coastline, as well as the probability of its occurrence.

Exposure expressed in terms of surface water oiling and shoreline oiling was used to provide an indicator of impact on the physical, seabirds and mammal receptors by estimating total area of intersection between spill plots and receptor location maps. To provide an indicator of impact on fish and invertebrates receptors, the subsurface concentration in the water column and the area of bottom sediment contamination affected above thresholds of concern was used from the stochastic model. This process is described in more detail in the subsequent sections.

Map Overlays

To assess areas of exposure from the spill model outputs to the receptor groups, relevant Geographic Information System (GIS) files were obtained. Specifically, the Environmental Sensitivity Index (ESI) maps and National Marine Fisheries Service Essential Fish Habitat (EFH) dataset were used. The GIS files includes hundreds of species level data files for multiple receptors, such as Alcids, Steller Sea Lions, Groundfish, Salmon, etc, which were identified from each of their respective files and extracted for use in further GIS assessment as described below. Although the scope of the Phase A consequence analysis was to assess receptors groups at a family level, indicator species were selected for each receptor group (physical, seabirds, mammals, fish) based on the sensitivity analysis.

For each of the 16 scenarios, three types of intersections between receptors and oil were developed: on-land, surface water, and subsurface water. The estimation of area of intersection (i.e., spill-receptor overlap) was conducted using ESRI’s ArcGIS Version 10.

Physical, Seabird and Mammal Receptors Analysis

The ESI maps, where available, were used for the physical, seabird and mammal receptor analysis. The ESI maps, which were provided as GIS shapefiles, included three main components: sensitive biological resources, shoreline habitats, and human-use resources. For this project, the sensitive biological resources used were:

Alcids	Nesting diving birds	Salt marshes
Coral	Aleutian Islands Open	Sea mounts
Eel grass	Areas	Sea otters
Gulls and Terns	Pinniped as a point	Steller sea lions
Steller sea lion Haul outs	Pinniped as polygons	Waterfowl
HCA	Rookeries	

Note: HCA = Habitat Conservation Area

Spatial distribution of the resources or habitats was represented by polygons, polylines, or points. Each polygon, polyline, or point also had an embedded reference identification number and data associated with it, such as receptor type and name. The on-land receptor analysis consisted of intersecting the oil spill results from the COSIM modeling with the ESI GIS files to identify the area, length, or point or the above resource affected by the release of oil from each Scenario release location.

Sensitive Biological Resources

For each biological resource, a separate GIS shape file was created by extracting all the respective data from the ESI GIS data files and used to identify the resource, location, and area or point of impact. Thus 17 individual shape files, one for each of the biological receptor types as noted above, were prepared from the single ESI shape file. The single ESI datasets were each separated into several smaller files to reduce processor time and facilitate the management of the overall assessment.

Each separate shape file was created by extracting polygon or point data for each receptor/resource while retaining the original embedded data such as location and name of the receptor. Using the ArcGIS intersect function, the polygon or point representing the receptor was overlaid with the COSIM spill model polygons that were also created as GIS shape files. The intersection of the two files (COSIM spill and on-land resource) resulted in a new shape file that contained combined polygons that retained the embedded data from the original polygons in the original shape files.

Because all the shapefiles used in the project are georeferenced, a new data field termed Shape_Area or Point was created, and the area of each intersection polygon was calculated. If a point from the original dataset was intersected, the area was assigned a numerical value of 1. The area was calculated in acres.

The area calculated represented the area of each of the above resources that shared the same location where oil was projected to migrate to for each Scenario release location. The sum of the polygon areas, or sum of the points, in each shape file represented the total area where the Scenario's oil release was projected to be in contact with that receptor/resource. Thus, the total area is the intersection of the projected oil spill mass and designated receptor/resources areas in the study region. For the consequence analysis, it was assumed that the receptors are present at the designated areas at the time of the oil spill release.

Physical (Habitats)

Habitats were treated in a similar fashion as the Sensitive Biological Resources except that habitats in the ESI datasets were identified as polygons and polylines only. For this project, the sensitive physical (habitat) resources used were

Coarse grained sand beaches	Fine to medium grained beaches	Sheltered rocky shores
Exposed shorelines	Gravel beaches	Sheltered tidal flats
Exposed tidal flats	Rocky shorelines	

A separate shape file was created for each of the above habitats by extracting polygon or polyline data while retaining the original embedded data. Using the ArcGIS intersect function, the polygon or polyline representing the habitat was overlaid with the COSIM spill model polygons. The intersection of the two files (COSIM spill and habitat) resulted in a new shape file that contained combined polygons, or the length of shoreline affected if the habitat was defined as a polyline. The new file retained the embedded data from the original polygon or polyline in the original shape files.

Similar to the sensitive biological resource work, a new data field termed Shape_Area or Length was created and the area was calculated if polygons were intersected or lengths (calculated in feet) were calculated if polylines were intersected.

The area calculated represented the area of each of the above habitats shared the same location where oil was projected to migrated to from each Scenario release location. The sum of the polygon areas in each shape file represented the total area where the Scenario's oil release was projected to be in contact with that habitat. The sum of the lengths in the respective file represented the total length of shoreline where the Scenario's oil release was projected to be in contact with the habitat. In the consequence analysis, the length was converted to yield an estimated area for the habitat based on slope angle and mean tidal range for the given shorelines.

Fish and Benthic Receptors Analysis

The 2005 Essential Fish Habitat (EFH) GIS file obtained from National Marine Fisheries Service was used for the off-shore receptor analysis. The EFH file provided spatial distribution of the pelagic and benthic resources as polygons. Each polygon also has an embedded reference identification number and data associated with it, such fish type, common name, area. The dataset type category for each resource used for this receptor analysis included groundfish, salmon, scallops, and crabs.

The fish receptor analysis was conducted differently than the other receptor analysis because oil constituent occurrence and behavior, and exposure terms are not similar to that of surface water impacts. Two constituent distribution types created by the COSIM model were developed and employed for the fish (and benthic) receptor analysis. These two distributions are subsurface concentration (water column) and sediment concentration. The subsurface concentrations represent the concentration of oil dissolved in the water column. The sediment concentration represents the concentration of oil constituents in the near sediment layer of the sea bed.

For the two media, water column and sediment, a level of concern or threshold concentration was utilized to identify the potential impact to groundfish and benthic-dwelling organisms (e.g., scallops, and crabs). These are typically represented by lethal concentrations (LC50) or lethal doses (LD50) where 50% of population dies, or alternatively, effect concentrations (EC50) where 50% of the population experiences adverse effect (e.g. limited growth). While LC50 and EC50 values vary by species, age and life stage, not enough information is available to obtain toxicity data (LC50 and EC50) for each species and age group of fish or other biota. Therefore, several sources were reviewed for species that fall into 5 broad taxonomic life stage categories: fish (juvenile and adult), eggs and larvae of fish, benthic invertebrates, zooplankton, and plants. Several sources are provided in the reference section; however this is not meant to be an exhaustive list.

A dissolved concentration of equal to or greater than 600 parts per billion (ppb) was used to assess impact to groundfish. This concentration is an LC50 for amphipods and was selected as a conservative value to represent the threshold value for evaluating groundfish. A threshold concentration of 300 ppb was used to assess impact to scallops and crabs. This concentration is an (LC50) was selected as a conservative value to represent the threshold value for evaluating potential impacts to sediment receptors such as benthic organisms, scallops and crabs.

For the groundfish, salmon, scallop, and crab resource, one GIS shape file was created extracting all the respective data from the EFH GIS data files and utilized to identify the resource, location, and area of impact. Extracting the groundfish and salmon EFH data reduced the file size and improved computer processor time and facilitated the management of the overall assessment.

Subsurface (Water Column) Receptor Analysis

Using the ArcGIS intersect function, the reduced EFH shapefile was overlaid with the COSIM subsurface concentration result shapefiles. The intersection of the two files (COSIM subsurface concentration and groundfish and salmon resource) resulted in a new shapefile that contained combined polygons that retained the embedded data for each polygon in each shapefile. This intersection file was then filtered to highlight those polygons that had a modeled and projected concentration equal to or greater than 600 ppb and coincident with the groundfish or salmon polygons.

Similar to the sensitive biological resource and habitat analysis, the shape files used are georeferenced, so a new data field termed True_Area was created and the area of each intersection polygon calculated. The area was calculated as acres within the framework of the ArcGIS platform.

The calculated area of each polygon represented the area of groundfish or salmon that shared the same location where dissolved oil concentration in the water column was equal to or greater than 600 ppb. The sum of the polygon areas represented the total areal extent where the Scenario’s oil release was projected to exceed the threshold value (LC50) for groundfish or salmon to survive.

Sediment Receptor Analysis

The sediment concentration assessment was done in the same way as the water column assessment, except that the COSIM sediment concentration output was utilized to identify the location and area where the oil concentration in sediment would exceed the threshold level for sediment receptors, such as scallops and crabs. Using the ArcGIS intersect function, the EFH shapefile was overlaid with the COSIM sediment concentration result shapefile. The intersection of the two files (COSIM subsurface concentration and EFH scallop and crab resource) resulted in a new shapefile that retained the embedded data for each polygon in each shapefile. This intersection file was then filtered to highlight those polygons that had a modeled and projected concentration equal to or greater than 300 ppb and coincident with the scallop or crab polygons.

Similar to the sensitive biologic resource and habitat analysis, the shapefiles used are georeferenced, so a new data field termed True_Area was created and the area of each intersection polygon calculated. The area was calculated as acres within the framework of the ArcGIS platform.

The calculated area of each polygon represented the area of scallops or crabs that shared the same location where oil concentration in sea-bed sediment was equal to or greater than 300 ppb. The sum of the polygon areas represented the areal extent where the Scenario’s oil release (in terms of concentration) was projected to exceed the threshold value for scallops or crabs.

Consequence Analysis

The attribute table for each intersection shape file that contained oil spill data from the COSIM model, resource data from the EFH or ESI dataset, and the new area calculation results for each polygon/polyline/point was exported to Microsoft Access for further use in the consequence analysis.

The graphical representation of the spill model outputs and receptor overlays for each scenario are provided in Appendix E.

References:

Buchman, M. F., 2008. NOAA Screening Quick Reference Tables, NOAA OR&R Report 08-1, Seattle, WA, Office of Response and Restoration Division, National Oceanic and Atmospheric Administration, 34 pages.

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Appendix E
Evaluation Data Tables and Figures

Littoral Habitat (Area in acres)

Scenario	SF	Probability of Impact 0-10%	10-20%	20-30%	30-40%	40-50%	50-60%	60-70%	70-80%	80-90%	90-100%	Total Scenario
10	1	3	7	0	0	x	x	x	x	x	x	11
11	1	691	258	21	21	15	5	1	3	1	5	1,021
12	1	835	490	230	115	12	5	0	1	0	4	1,692
13	1	121	456	179	91	28	16	6	11	6	12	925
14	1	6,280	5,987	3,165	3,211	1,391	1,994	1,139	926	184	143	24,419
15	1	1,060	573	134	4	3	10	5	7	2	23	1,820
1	2	6,546	2,885	2,845	3,096	1,611	1,242	281	285	361	14	19,165
2	2	9,339	6,778	2,103	2,119	575	1,028	172	467	252	94	22,928
3	2	11,202	6,342	1,952	4,082	1,672	2,581	2,614	2,111	1,296	2,402	36,253
4	2	438	553	248	901	389	601	218	706	626	185	4,864
5	2	3,081	2,649	1,976	1,394	271	479	1,544	746	17		12,159
6	2	4,201	2,706	1,661	1,033	226	664	547	1,284	168	84	12,574
7	2	5,987	2,735	2,016	791	380	1,341	1,261	2,147	517	137	17,312
8	2	4,822	4,109	2,314	2,407	709	1,650	734	724	1,055	822	19,346
9	2	9,942	4,818	1,819	1,234	670	426	394	1,636	229	62	21,230
16	2	69,188	26,789	5,757	3,289	3,709	3,207	427	1,203	2,169	2,799	118,538
1	3	3,938	3,683	1,758	1,535	687	363	61	44	64	3	12,136
2	3	9,884	1,706	574	722	155	269	37	105	74	33	13,560
3	3	8,934	2,358	838	775	354	665	546	328	105	181	15,084
4	3	2,510	2,997	989	2,100	850	807	355	877	509	92	12,086
5	3	4,046	1,757	1,440	930	208	348	464	207	9	x	9,409
6	3	4,837	4,378	x	x	x	x	x	x	x	x	9,215
9	3	4,624	195	x	x	x	x	x	x	x	x	4,819
16	3	20,008	11,882	1,726	2,183	1,262	722	92	276	553	425	39,128
1	4	176	136	108	181	96	57	16	3	3		776
2	4	288	116	31	159	24	7					625
3	4	302	66	43	33	41	77	130	64		7	763
4	4	91	125	26	154	70	86	38	82	89	53	814
5	4	134	101	150	117	47	42	65	21			677
6	4	529	59	52	36	9	27	11	38	23	10	794
7	4	1,129	1,285	289	315	221	84	46	42	33	20	3,464
8	4	1,272	788	367	364	34	40	44	20	41	30	2,999
9	4	875	628	379	77	39	15	16	43	16	5	2,093
16	4	16,092	9,383	3,532	2,553	1,761	2,166	286	658	943	1,149	38,522
4	5	130	167	97	438	119	203	93	240	223	100	1,810
6	5	885	x	x	x	x	x	x	x	x	x	885
7	5	3,856	765	198	148	x	x	x	x	x	x	4,967
8	5	1,433	348	24	x	x	x	x	x	x	x	1,805
9	5	2,502	548	43	x	x	x	x	x	x	x	3,093
16	5	157,467	78,023	14,322	10,826	11,952	9,334	368	3,059	4,695	4,390	294,437

Only Scenarios where there is a potential impact to a receptor are shown.

Sublittoral Habitat (Area in acres)

		Probability of Impact										
Scenario	SF	0-10%	10-20%	20-30%	30-40%	40-50%	50-60%	60-70%	70-80%	80-90%	90-100%	Total Scenario
10	**1**	483	382	242	628	359	15	16	18	9	28	2,180
11	**1**	965	562	31	30	18	12	1	7	5	6	1,639
12	**1**	1,224	752	380	213	12	7	3	5	6	2	2,602
13	**1**	193	445	324	435	40	12	5	25	8	22	1,510
14	**1**	4,053	2,841	1,402	1,306	559	808	572	507	128	76	12,252
15	**1**	1,431	729	108	4	1	9	2	8	4	42	2,338
1	**4**	139,599	82,168	54,658	34,483	9,789	9,049	4,278	5,989	9,411	3,300	352,725
2	**4**	254,162	62,723	23,842	34,835	18,212	6,845	2,689	6,356	6,356	5,011	421,030
3	**4**	373,686	101,835	31,294	48,312	31,709	58,266	14,178	13,444	6,478	15,766	694,969
4	**4**	104,638	29,831	17,730	50,972	26,890	15,278	5,500	12,712	8,923	15,034	287,506
5	**4**	103,423	71,524	46,700	32,152	9,295	12,108	10,511	12,711	5,378	244	304,046
6	**4**	302,331	114,543	11,661	10,082	7,167	12,390	10,082	18,341	10,325	4,008	500,929
7	**4**	156,625	28,514	12,875	21,741	8,259	21,498	22,227	25,021	13,361	5,587	315,709
8	**4**	139,679	29,029	12,389	13,118	7,652	18,826	11,053	25,992	16,397	11,174	285,310
9	**4**	218,692	128,667	21,863	16,033	14,332	15,547	14,454	26,357	4,615	2,672	463,232
16	**4**	193,121	56,449	41,575	10,607	7,315	16,093	8,047	8,778	9,876	15,484	367,345
1	**5**	329	109	x	x	x	x	x	x	x	x	438
2	**5**	184	x	x	x	x	x	x	x	x	x	184
3	**5**	436	x	x	x	x	x	x	x	x	x	436
4	**5**	223	263	60	59	12	x	x	x	x	x	617
5	**5**	35	x	x	x	x	x	x	x	x	x	35
6	**5**	68	17	21	13	3	9	3	14	8	2	159
7	**5**	58	24	24	10	3	15	14	18	10	7	183
8	**5**	147	38	30	26	9	17	15	6	14	10	312
9	**5**	110	45	24	13	12	6	3	16	8		237
16	**5**	43,047	25,070	9,422	6,008	5,112	5,804	591	1,823	2,348	3,132	102,356

Only Scenarios where there is a potential impact to a receptor are shown.

Bird Habitat (Area in acres)

Scenario	SF	Probability of Impact										
Scenario	SF	0-10%	10-20%	20-30%	30-40%	40-50%	50-60%	60-70%	70-80%	80-90%	90-100%	Total Scenario
1	**2**	12,223	29,456	16,867	3,667	x	x	x	x	x	x	62,213
2	**2**	43,146	x	x	x				x	x	x	43,146
3	**2**	54,510	9,778	x	x	x	x	x	x	x	x	64,288
4	**2**	3,789	8,678	4,522	26,401	12,467	8,678	489	x	x	x	65,024
5	**2**	11,366	18,455	10,144	x	x	x	x	x	x	x	39,966
1	**3**	139,949	86,658	69,791	47,057	9,778	9,045	4,278	5,989	9,411	3,300	385,256
2	**3**	275,986	66,369	23,834	34,834	18,212	6,845	2,689	6,356	6,356	5,011	446,492
3	**3**	220,729	90,443	27,988	27,377	13,811	17,355	14,178	13,444	6,478	15,766	447,570
4	**3**	104,870	30,068	18,578	64,291	39,723	20,656	5,867	12,712	8,923	15,034	320,721
5	**3**	109,515	79,569	57,324	38,501	9,289	12,100	10,511	12,712	5,378	244	335,144
6	**3**	312,777	114,543	11,661	10,082	7,167	12,390	10,082	18,341	10,325	4,008	511,375
7	**3**	156,076	28,422	12,875	21,741	8,259	21,498	22,227	25,021	13,361	5,587	315,067
8	**3**	139,679	29,029	12,389	13,118	7,652	18,826	11,053	25,992	16,397	11,174	285,310
9	**3**	218,264	128,626	21,863	16,033	14,332	15,547	14,454	26,357	4,615	2,672	462,763
10	**3**	9,401	14,651	7,081	5,494	1,099	1,221	1,953	3,296	3,418	4,029	51,643
11	**3**	12,941	13,063	1,221	4,517	3,663	2,808	977	366	122	244	39,923
12	**3**	1,953	3,663	10,133	14,406	2,930	3,174	1,343	366	122	x	38,091
13	**3**	4,273	7,569	5,372	6,471	977	1,587	977	3,418	2,930	2,808	36,382
15	**3**	10,117	366	366	x	x	x	x	x	x	x	10,849
16	**3**	185,684	49,865	40,965	10,607	7,315	16,093	8,047	8,778	9,876	15,484	352,715
1	**4**	12,223	29,456	16,867	3,667	x	x	x	x	x	x	62,213
2	**4**	47,546	244	x	x	x	x	x	x	x	x	47,790
3	**4**	54,510	9,778	x	x	x	x	x	x	x	x	64,288
4	**4**	3,789	8,678	4,522	26,401	12,467	8,678	489	x	x	x	65,024
5	**4**	11,366	18,577	10,144	x	x	x	x	x	x	x	40,088

Only Scenarios where there is a potential impact to a receptor are shown.

Bird Nesting Sites (points)

Scenario	SF	Probability of Impact										Total Scenario
		0-10%	10-20%	20-30%	30-40%	40-50%	50-60%	60-70%	70-80%	80-90%	90-100%	
1	5	30	30	26	25	13	13	8	7	7	x	159
2	5	30	30	26	25	13	13	8	7	7	x	159
3	5	29	24	22	13	12	12	10	9	6	7	144
4	5	27	28	27	25	22	14	14	13	11	7	188
5	5	35	29	25	21	13	13	9	8			153
6	5	20	13	x	x	x	x	x	x	x	x	33
7	5	5	2	x	x	x	x	x	x	x	x	7
8	5	1	x	x	x	x	x	x	x	x	x	1
9	5	18	8	x	x	x	x	x	x	x	x	26
10	5	1	1	3	2	3	3	3	3	2	3	24
11	5	1	5	5	3	3	3		1	x	1	22
12	5	1	3	3	6	3	3	2	x	x	1	22
13	5	3	1	4	4	2	1	3	1	3	3	25
14	5	8	7	7	5	4	4	3	3	2	2	45
15	5	2	2	2	x	x	x	x	x	1	1	8
16	5	14	6	4	4	3	3	2	x	x	x	36

Only Scenarios where there is a potential impact to a receptor are shown.

Marine Mammal Habitat (Area in acres)

Scenario	SF	Probability of Impact										Total Scenario
		0-10%	10-20%	20-30%	30-40%	40-50%	50-60%	60-70%	70-80%	80-90%	90-100%	
10	2	2,288,291	835,447	349,659	260,413	119,890	92,787	33,330	28,691	25,028	35,283	4,068,819
11	2	1,451,379	1,121,865	478,950	464,666	236,728	173,243	56,282	93,397	21,487	28,324	4,126,322
12	2	2,198,434	1,204,884	379,205	498,606	277,261	220,735	74,596	40,533	11,598	9,401	4,915,254
13	2	1,591,414	726,056	255,041	283,244	105,728	110,001	51,521	38,336	21,976	35,283	3,218,600
14	2	1,575,941	624,819	230,196	253,981	108,242	119,770	78,391	93,316	20,993	13,470	3,119,118
15	2	1,193,251	342,287	103,491	99,102	50,709	43,395	27,305	32,059	12,921	47,418	1,951,938
16	3	5,121	x	x	x	x	x	x	x	x	x	5,121
10	4	296,795	193,265	81,921	81,188	50,422	38,458	18,924	20,877	4,517	x	786,367
11	4	463,567	41,876	23,197	26,005	24,784	16,482	8,790	11,720	5,616	2,442	624,479
12	4	357,229	210,235	38,458	42,364	29,057	28,569	11,720	11,354	1,953	x	730,939
13	4	323,533	51,765	13,796	27,958	26,249	51,399	21,976	13,796	8,180	4,151	542,802
14	4	317,931	135,545	75,478	66,256	37,982	43,806	26,575	10,557	x	x	714,131
15	4	612,533	388,486	114,583	99,224	34,375	15,115	1,950	731	122	x	1,267,120
1	5	1,510,836	716,733	435,858	334,044	75,291	79,569	26,890	25,301	17,112	10,145	3,231,779
2	5	1,159,192	1,050,044	334,166	285,031	122,837	109,392	53,657	58,424	27,745	35,934	3,236,423
3	5	1,431,074	762,775	308,483	312,883	98,509	109,387	60,254	72,354	36,910	53,655	3,246,285
4	5	1,029,999	707,933	234,185	440,625	246,408	225,385	127,971	180,650	101,203	100,103	3,394,462
5	5	1,868,988	645,566	320,461	255,195	93,376	124,542	61,721	65,999	19,066	5,378	3,460,293
6	5	218,154	129,362	7,652	9,231	6,316	11,904	9,839	18,341	10,325	4,008	425,134
7	5	133,970	20,405	8,988	14,089	7,288	19,919	22,106	25,021	13,361	5,587	270,734
8	5	118,302	20,284	7,531	10,810	7,045	17,490	11,053	25,992	16,397	11,174	246,078
9	5	191,299	114,537	14,818	14,940	14,211	15,183	14,454	26,357	4,615	2,672	413,085
10	5	9,645	10,866	7,692	4,395	2,564	2,198	2,686	3,174	2,320	6,349	51,887
11	5	24,662	10,500	1,953	3,174	4,639	3,296	488	977	977	3,174	53,841
12	5	16,238	13,063	7,203	10,500	1,709	2,686	610	977	1,465	2,320	56,771
13	5	14,040	6,226	5,250	4,517	610	1,831	855	4,395	1,465	5,860	45,050
14	5	56,184	20,508	5,097	3,034	1,820	2,670	1,456	x	x	x	90,768
15	5	4,023	5,363	488	609	731	853	x	853	975	1,950	15,847
16	5	2,767,828	899,038	267,005	173,736	59,009	74,737	32,796	30,114	31,090	32,187	4,367,540

Only Scenarios where there is a potential impact to a receptor are shown.

Marine Mammal Haul-outs & Rookeries (points)

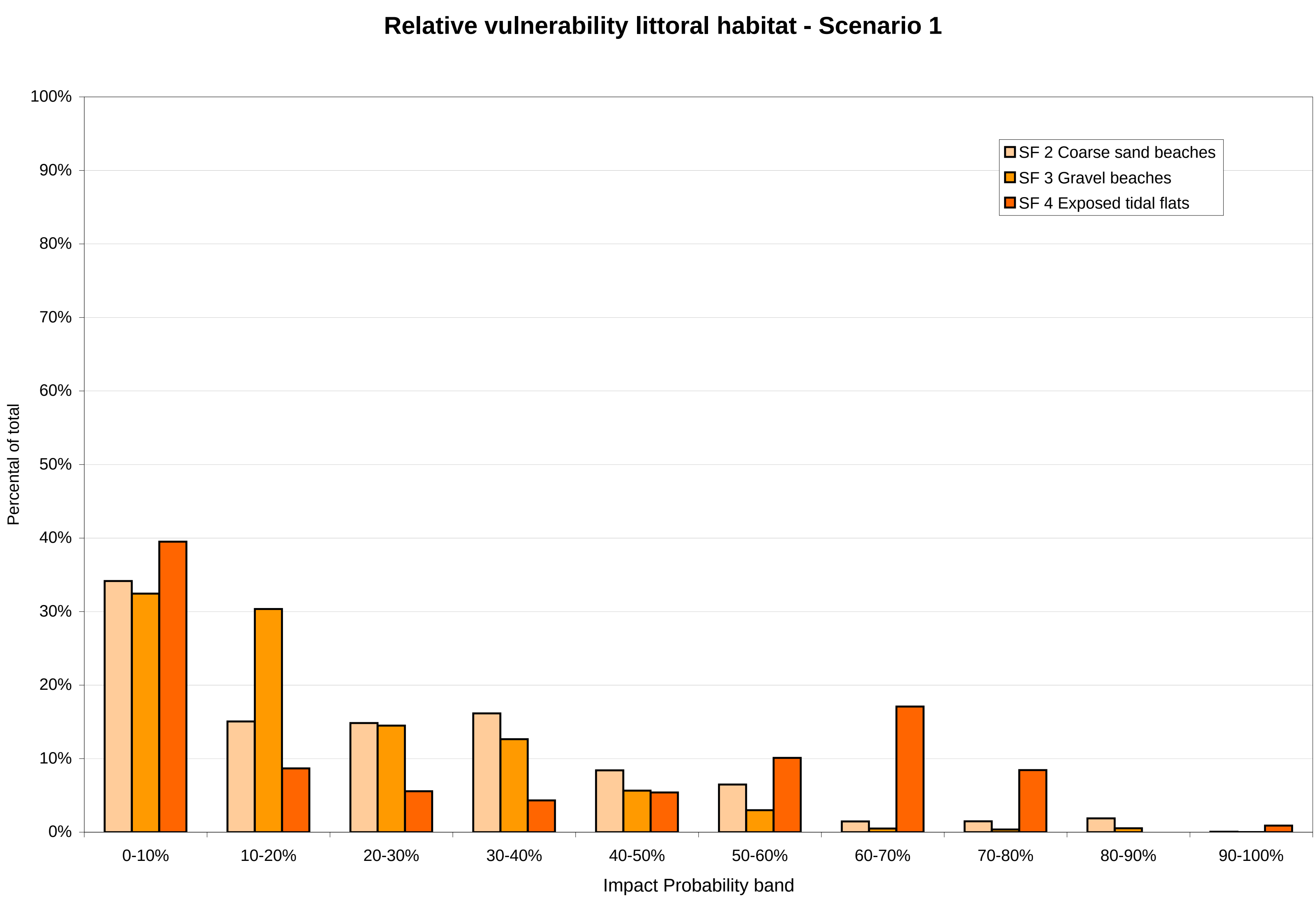
		Probability of Impact										
Scenario	SF	0-10%	10-20%	20-30%	30-40%	40-50%	50-60%	60-70%	70-80%	80-90%	90-100%	Total Scenario
1	**3**	55	53	38	27	15	15	6	6	6	0	221
2	**3**	52	20	15	15	7	7	4	3	2	0	125
3	**3**	55	42	21	16	14	14	10	8	4	6	190
4	**3**	33	40	38	32	20	11	9	9	8	3	203
5	**3**	47	33	28	15	10	10	5	4	x	x	152
6	**3**	29	17	2	2	2	2	2	2	1	1	60
7	**3**	10	6	5	2	2	2	2	2	2	2	35
8	**3**	11	5	2	2	2	2	2	2	2	2	32
9	**3**	27	19	2	2	2	2	1	1	1	1	58
10	**3**	21	19	19	19	15	3	2	1	1	x	100
11	**3**	21	21	5	2	1	1	x	1	x	1	53
12	**3**	21	16	20	14	2	1	x	x	x	1	75
13	**3**	17	16	18	12	5	2	1	1	1	1	74
14	**3**	45	36	26	20	17	13	9	7	3	2	178
15	**3**	18	15	10	4	4	7	2	8	5	7	80
16	**3**	19	7	5	5	2	2	1	0	0	0	41
2	**4**	10	7	4	3	2	1	1	1	1	x	30
3	**4**	8	5	4	4	3	3	3	2	1	1	34
4	**4**	2	3	4	3	1	1	1	1	1	x	17
5	**4**	7	4	4	3	2	2	2	1	x	x	25
6	**4**	8	5	2	2	2	2	2	2	1	1	27
7	**4**	4	3	3	2	2	2	2	2	2	2	24
8	**4**	5	4	2	2	2	2	2	2	2	2	25
9	**4**	8	7	2	2	2	2	1	1	1	1	27
10	**4**	3	3	3	3	2	x	x	x	x	x	14
11	**4**	3	3	x	x	x	x	x	x	x	x	6
12	**4**	3	2	3	2	1	x	x	x	x	x	11
13	**4**	2	1	2	1	1	1	x	x	x	x	8
14	**4**	6	5	4	3	3	2	2	1	1		27
15	**4**	5	5	2	1	1	2	1	2	2	2	23
16	**4**	6	3	2	2	1	1	1	x	x	x	16

Only Scenarios where there is a potential impact to a receptor are shown.

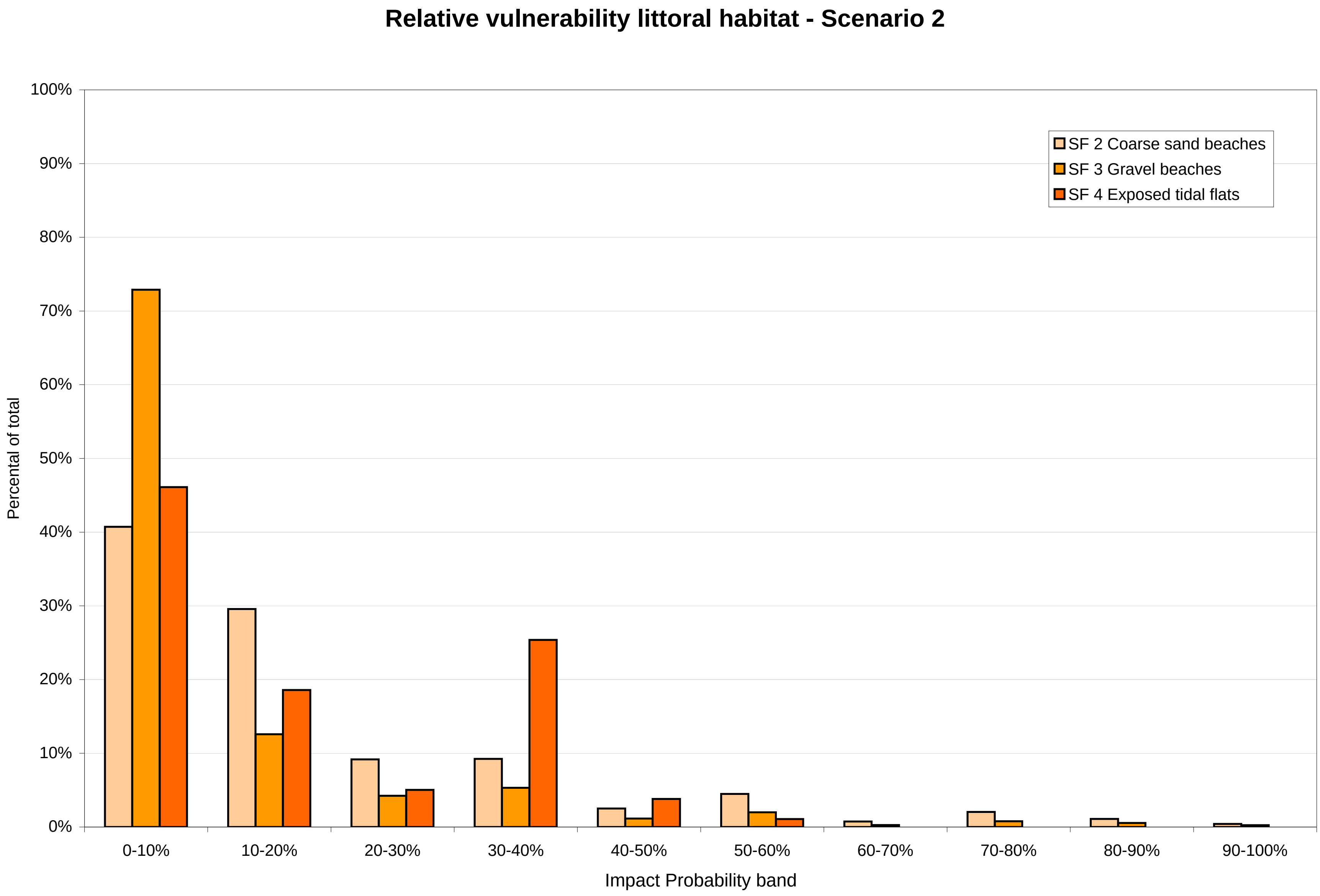
Fish Data

(Only those scenarios where there was potential impact to fish are shown. See text for desrciption)

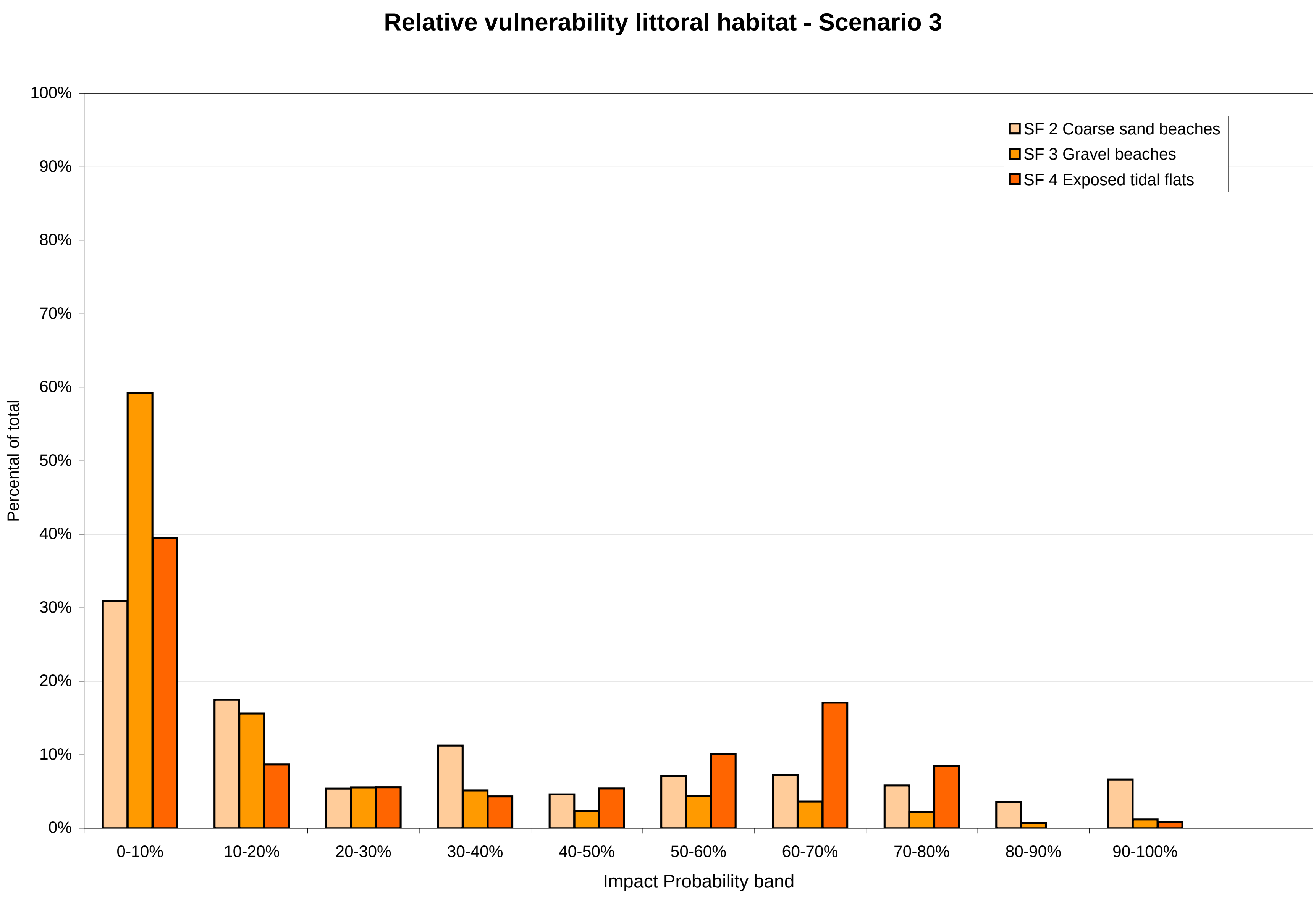
	Sensitivity	Indicator species	Total area	Probability		Total Acreage
Scenario 3	3	Adult Groundfish	0.02	56		
Crude Oil					**Total SF 3**	**0.02**
North Umiak Pass	4	Immature Groundfish	0.02	56		
	4	Adult Salmon	0.02	56		
					subtotal (immature groundfish,adult	0.04
	4	Mature shellfish	9.16	92	subtotal Mature shellfish (sediments)	9.16
					Total SF 4	**9.20**
	5	Immature shellfish	9.164199			
					Total SF 5	**9.16**
Scenario 5	3	Groundfish (adult)	859.83	64		
Diesel					**Total SF 3**	**859.83**
North Umiak Pass	4	Groundfish (Eggs, larvae, juveniles)	859.83	64		
	4	Salmon (adult)	28.51	64		
					subtotal (immature groundfish,adult	888.34
	4	Mature shellfish (sediments)	120	64	subtotal Mature shellfish (sediments)	120.00
					Total SF 4	**1008.34**
	5	Eggs, larvae salmon,	120	64		
					Total SF 5	**120.00**
Scenario 8	3	Groundfish (adult)	8080.00	46		
Bunker C					**Total SF 3**	**8080.00**
Sanak Island	4	Immature groundfish (Eggs, larvae, juveniles)	8080.00	46		
	4	Salmon (adult)	8080.00	46		
					subtotal (immature groundfish,adult	16160.00
	4	Mature shellfish (sediments)	6174.122996	46	subtotal Mature shellfish (sediments)	0.00
					Total SF 4	**22334.12**
	5	Eggs, larvae salmon,	6174.122996	46		
					Total SF 5	**6174.12**
Scenario 9	3	Groundfish (adult)	595.61	39		
Diesel					**Total SF 3**	**595.61**
Sanak Island	4	Immature groundfish (Eggs, larvae, juveniles)	595.61	39		
	4	Salmon (adult)	406.34	39		
					subtotal (immature groundfish,adult	1001.95
	4	Mature shellfish (sediments)	0.000146		subtotal Mature shellfish (sediments)	0.000146
					Total SF 4	**1001.95**
	5	Immature salmon,	0.000146	39		
					Total SF 5	**0.000146**
Scenario 12	3	Groundfish (adult)	9656.80	65		
Crude Oil					**Total SF 3**	**9656.80**
Holtz Bay Attu Island	4	Immature groundfish (Eggs, larvae, juveniles)	9656.80	65		
	4	Salmon (adult)	9639.95	65		
					Total SF 4	**19296.74**
Scenario 14	3	Groundfish (adult)	98.88	56		
Diesel					**Total SF 3**	**98.88**
Adak Island	4	Immature groundfish (Eggs, larvae, juveniles)	98.88	56		
	4	Salmon (adult)	53.66	56		
					Total SF 4	**152.53**



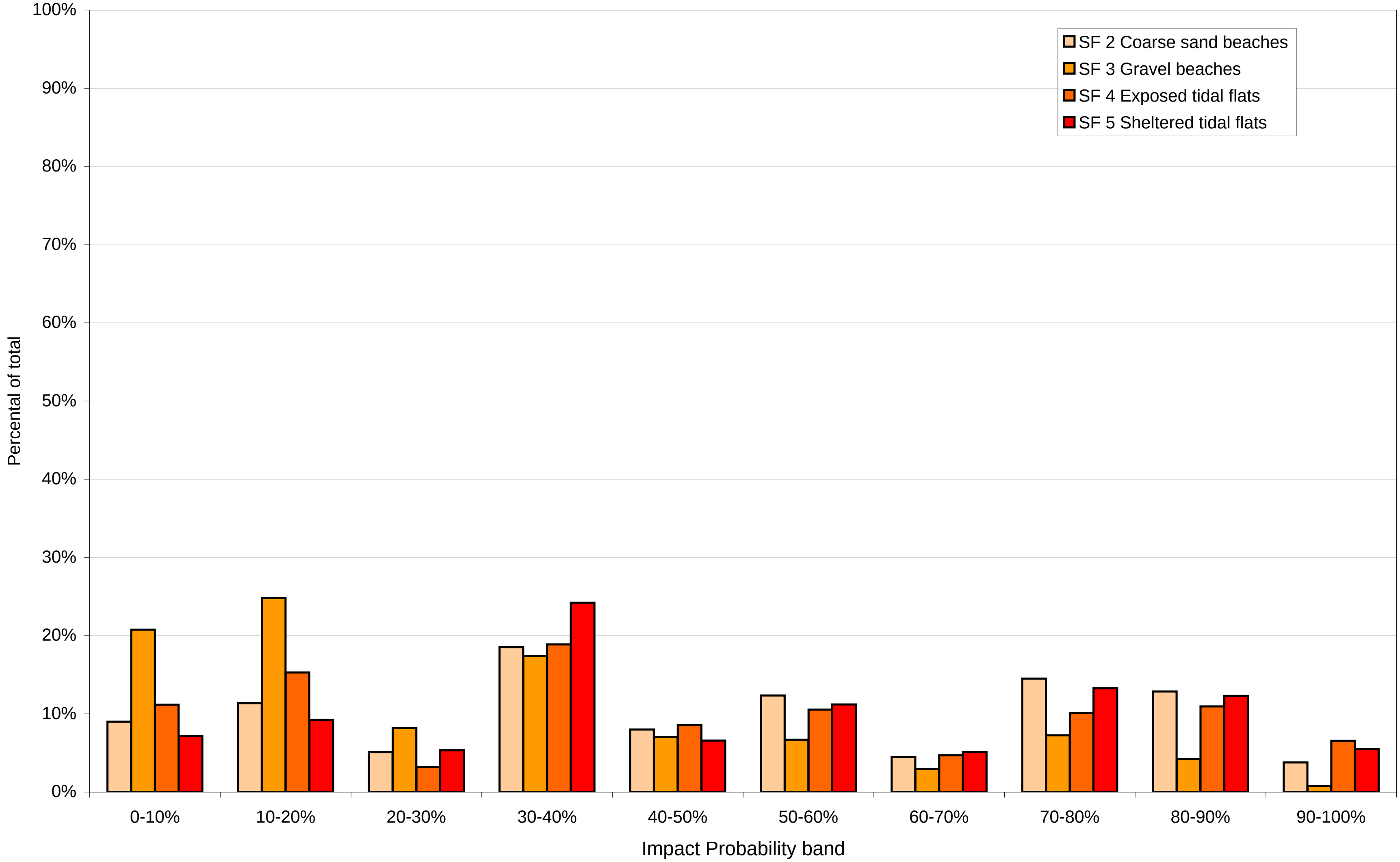
Relative vulnerability littoral habitat - Scenario 1
SF 2 Coarse sand beaches
SF 3 Gravel beaches
SF 4 Exposed tidal flats
Percental of total
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability band

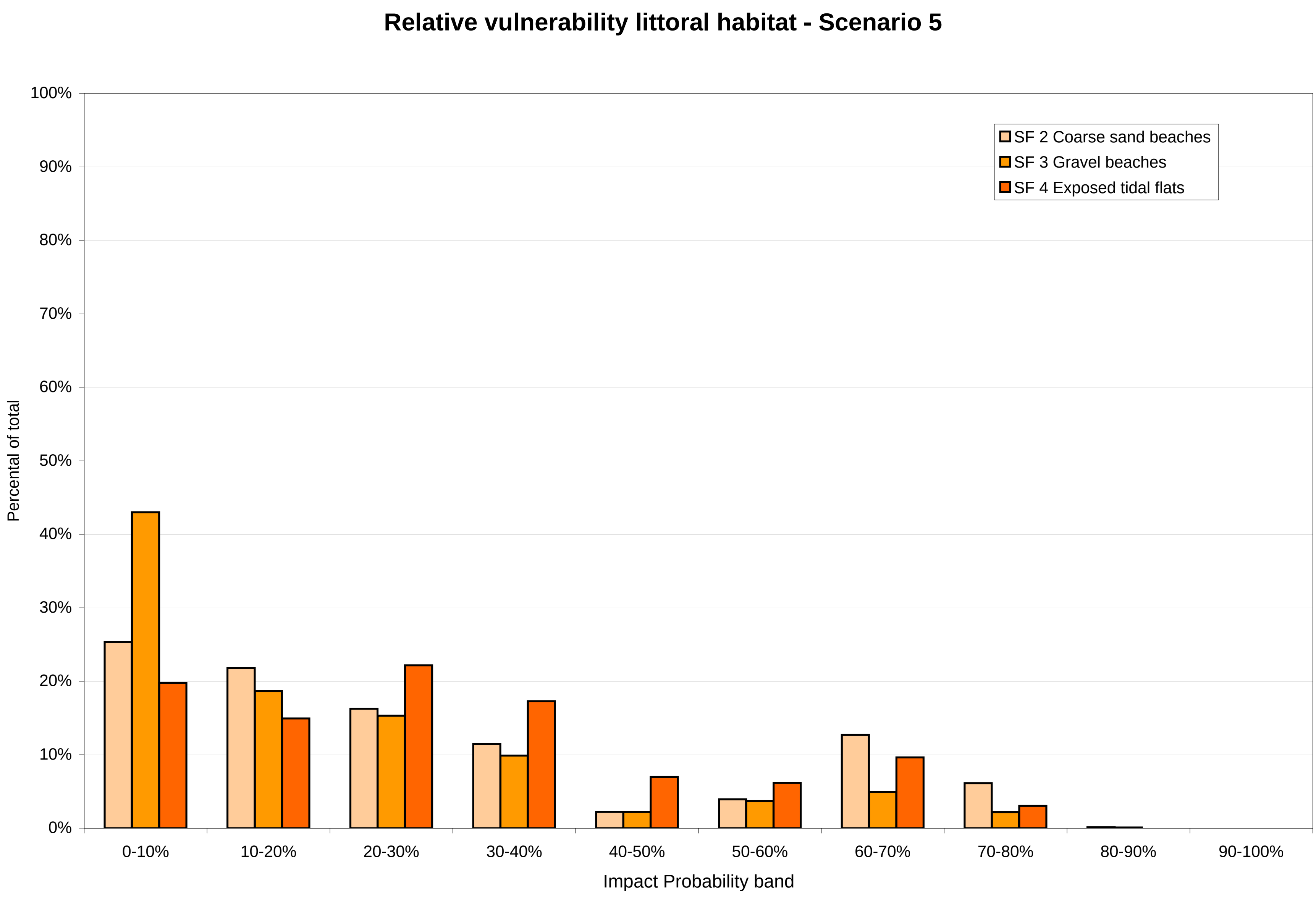


Relative vulnerability littoral habitat - Scenario 2
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percental of total
SF 2 Coarse sand beaches
SF 3 Gravel beaches
SF 4 Exposed tidal flats
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability band

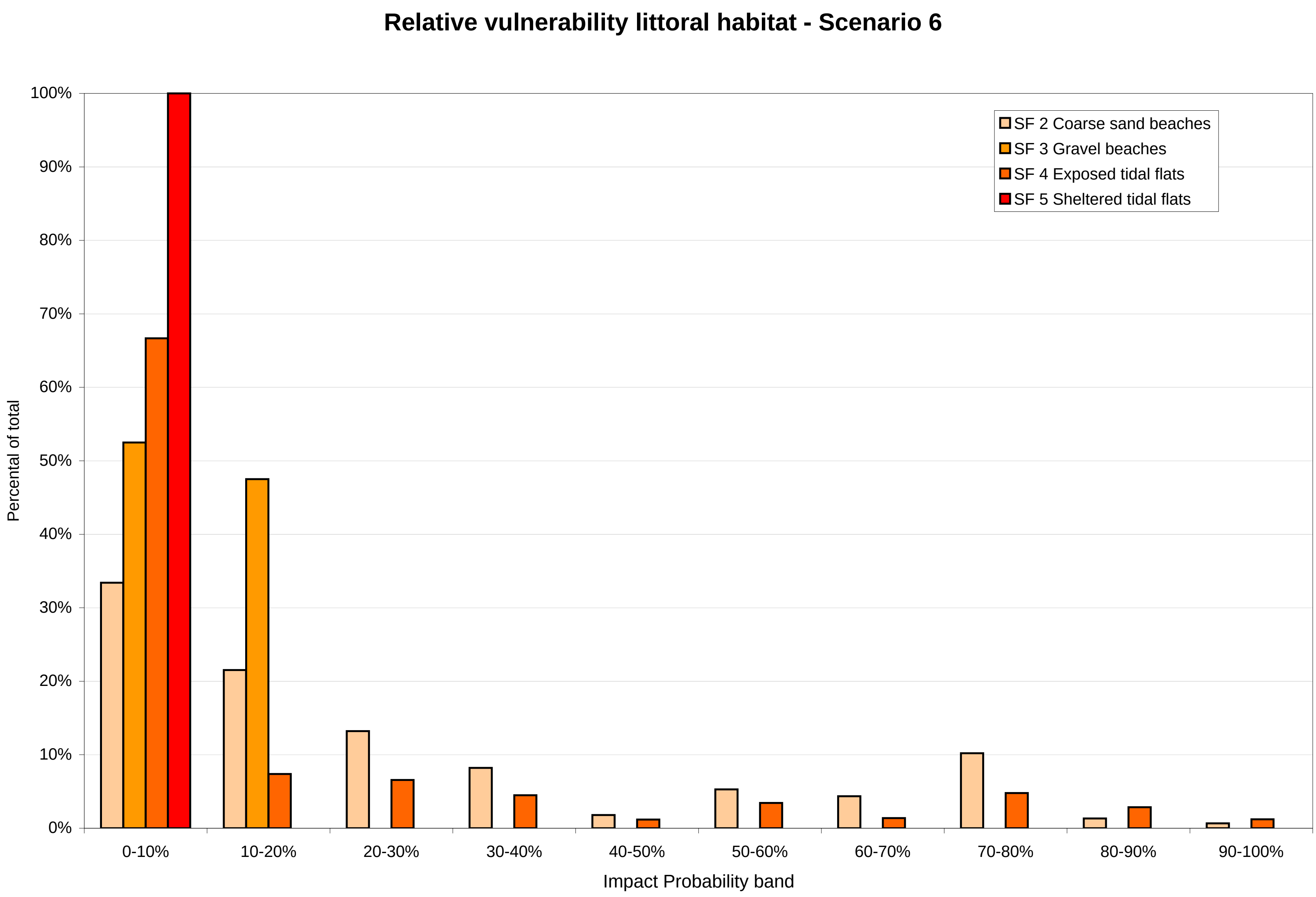

Relative vulnerability littoral habitat - Scenario 3
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percental of total
SF 2 Coarse sand beaches
SF 3 Gravel beaches
SF 4 Exposed tidal flats
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability band

Relative vulnerability littoral habitat - Scenario 4

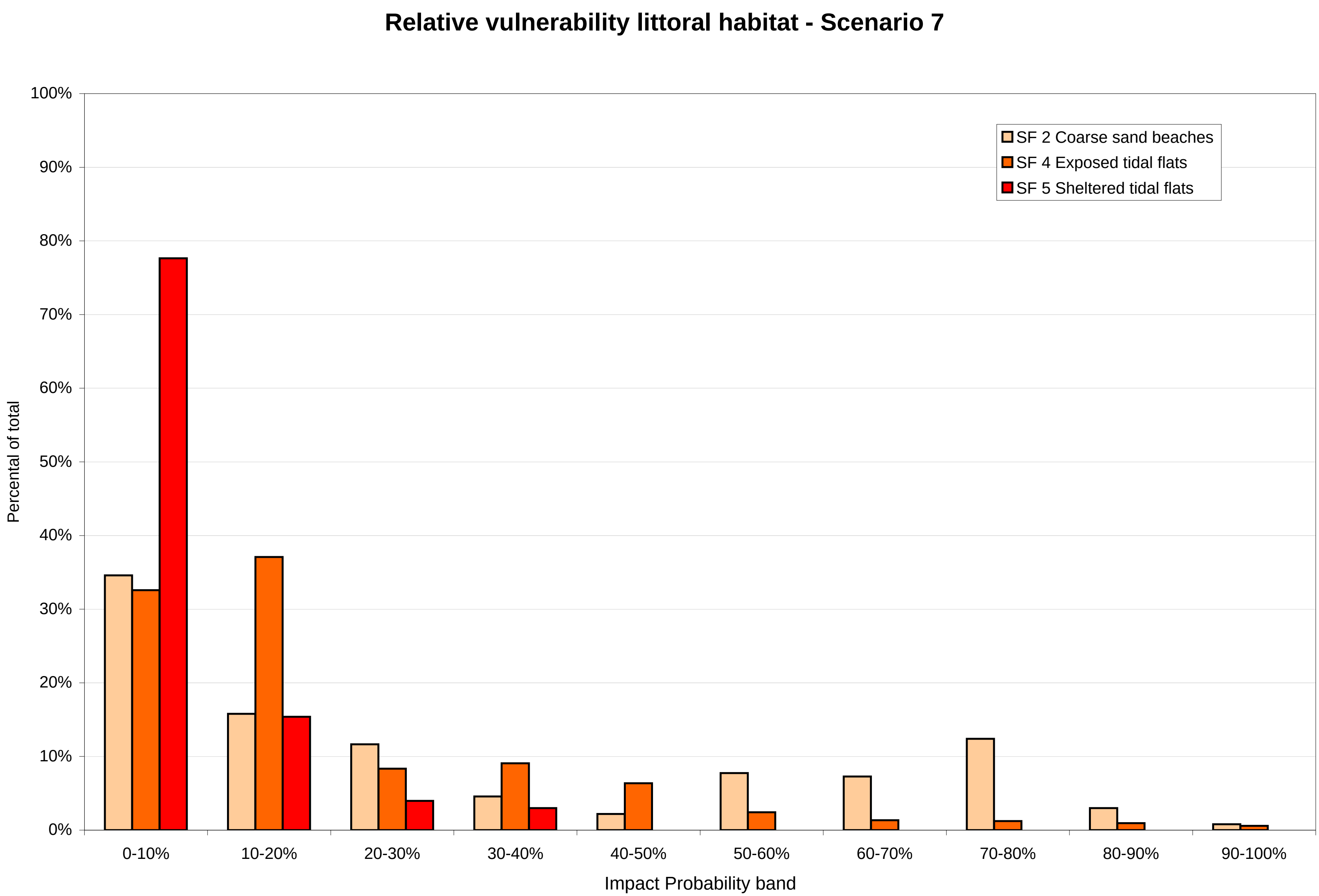


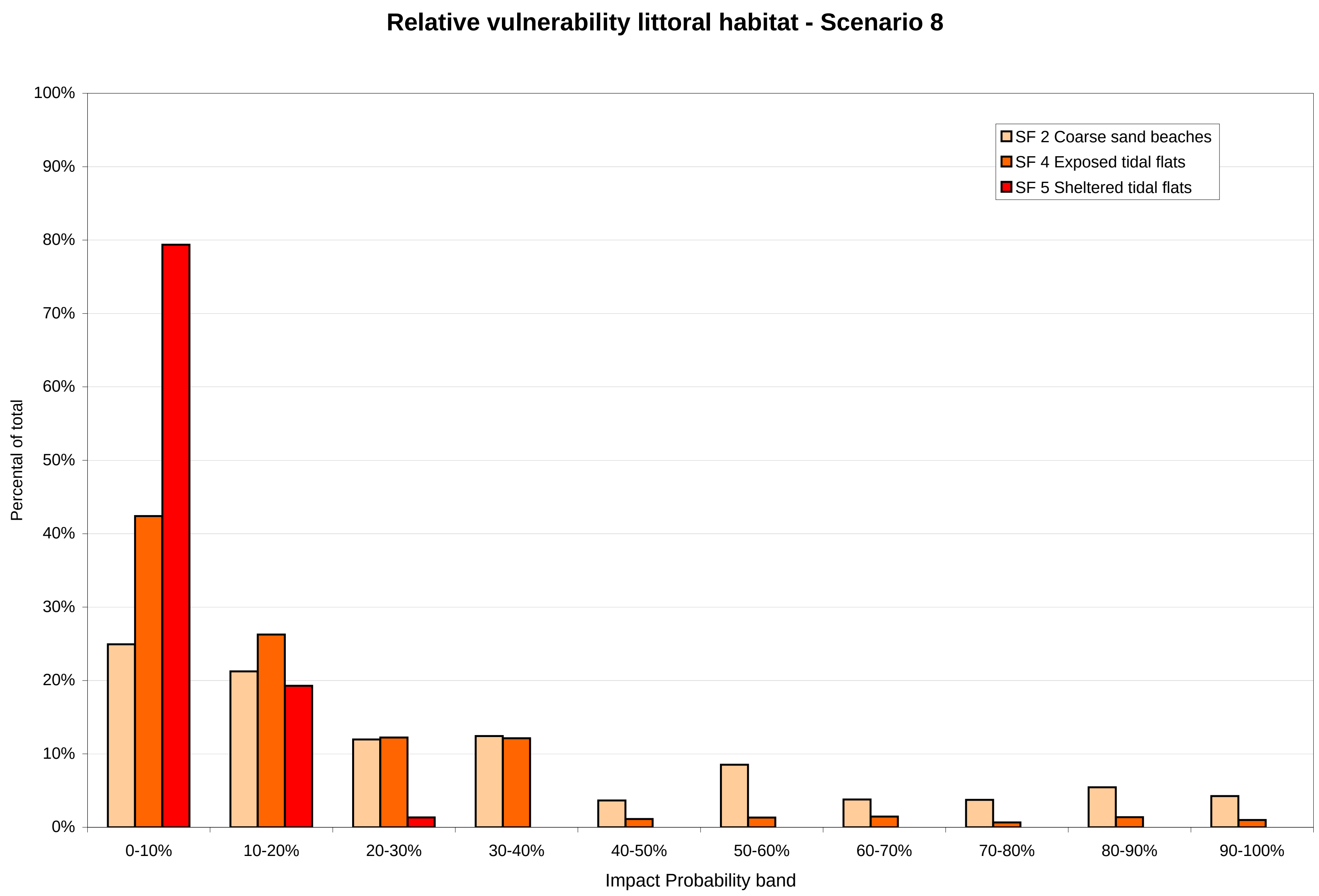


Relative vulnerability littoral habitat - Scenario 5
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percental of total
SF 2 Coarse sand beaches
SF 3 Gravel beaches
SF 4 Exposed tidal flats
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability band

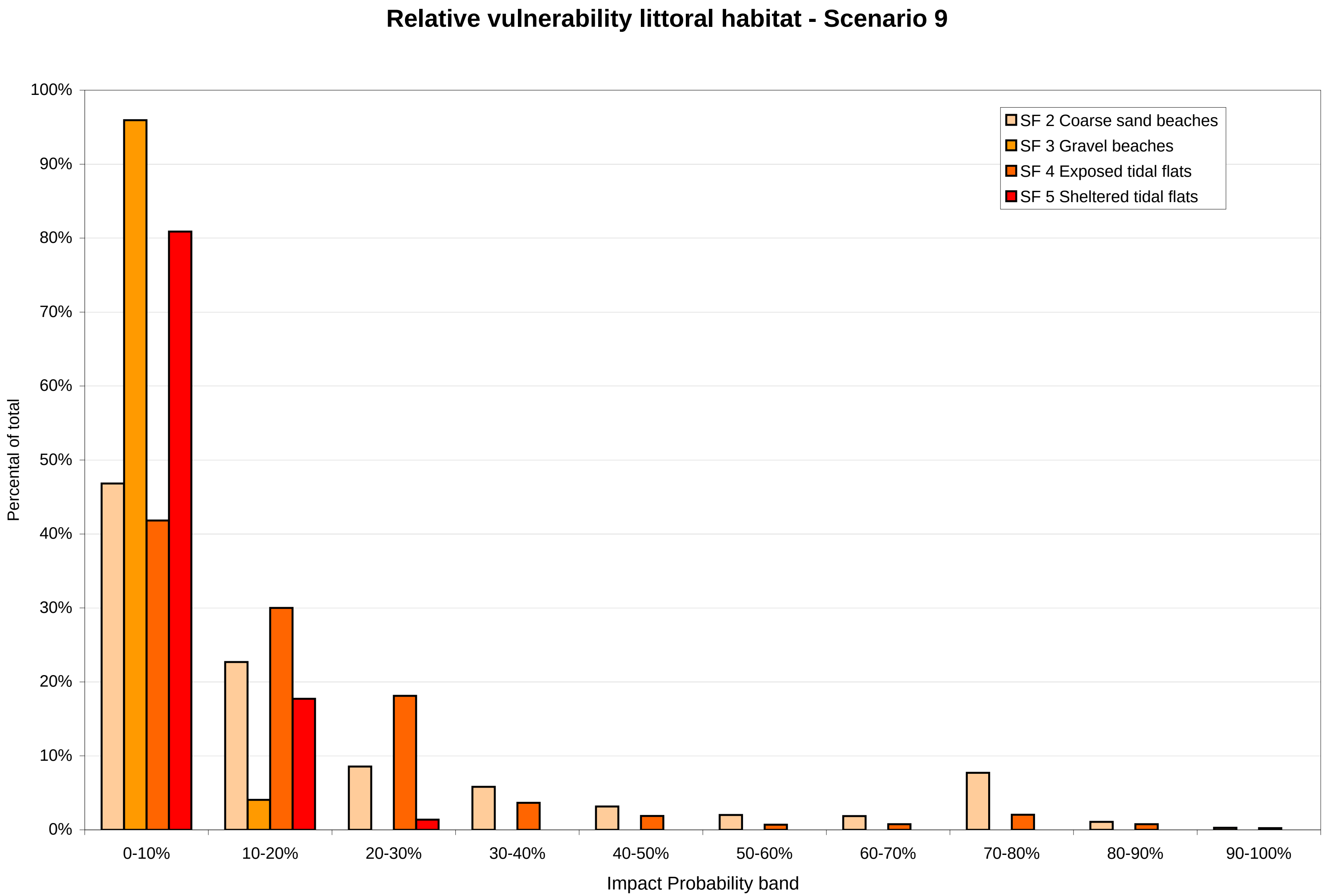


Relative vulnerability littoral habitat - Scenario 6
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percental of total
SF 2 Coarse sand beaches
SF 3 Gravel beaches
SF 4 Exposed tidal flats
SF 5 Sheltered tidal flats
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability band

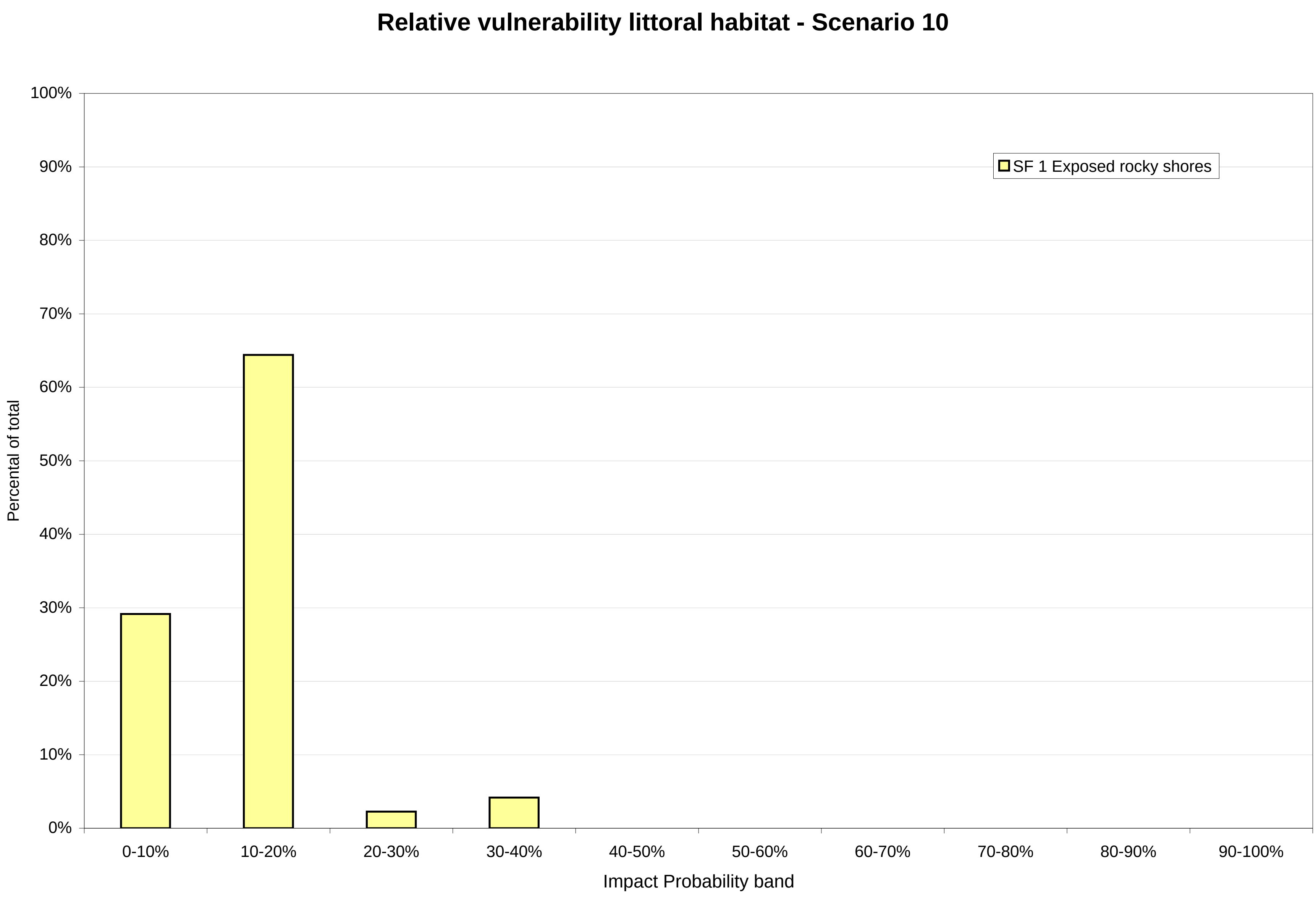

Relative vulnerability littoral habitat - Scenario 7
SF 2 Coarse sand beaches
SF 4 Exposed tidal flats
SF 5 Sheltered tidal flats
Percental of total
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability band



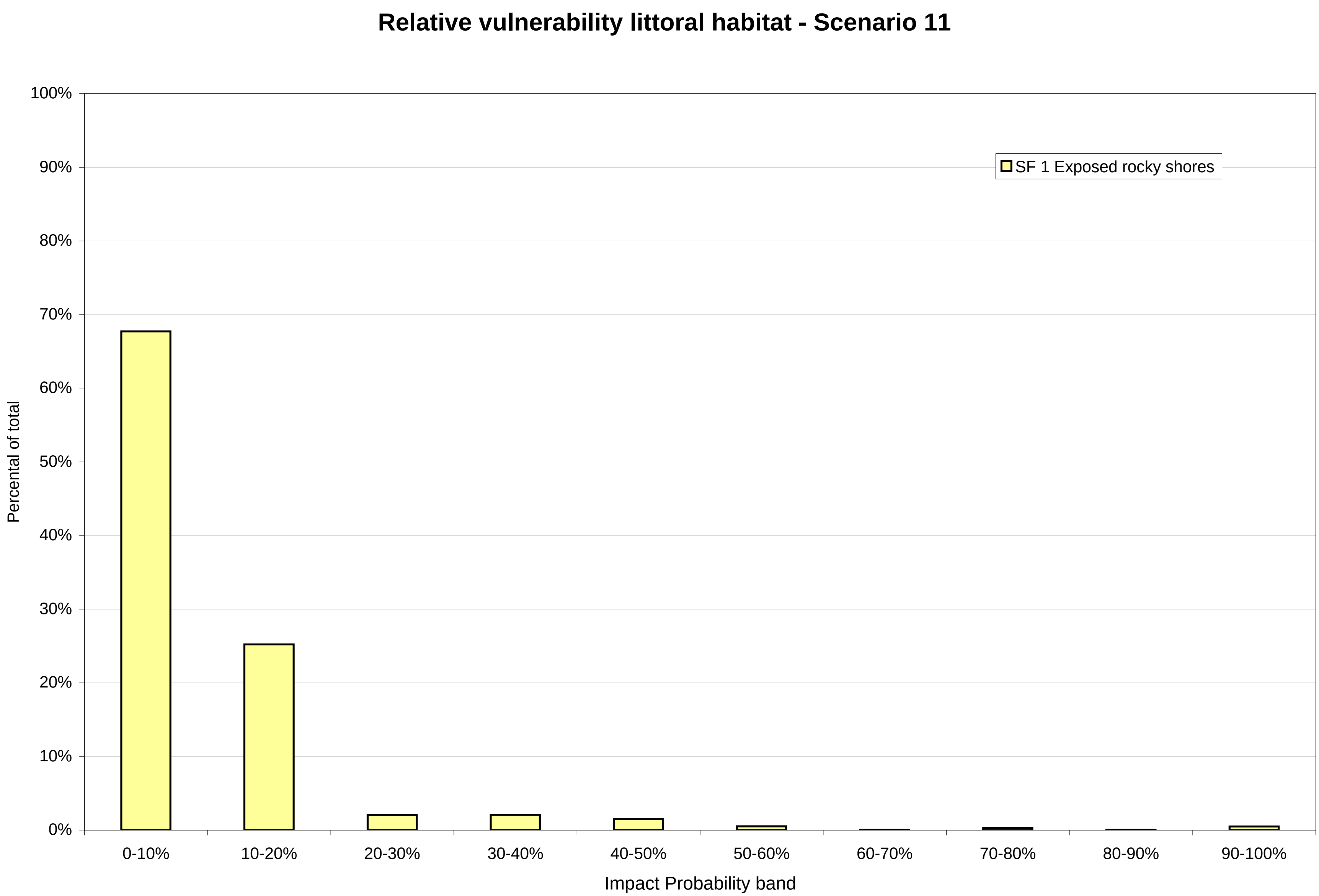
Relative vulnerability littoral habitat - Scenario 8
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percental of total
SF 2 Coarse sand beaches
SF 4 Exposed tidal flats
SF 5 Sheltered tidal flats
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability band

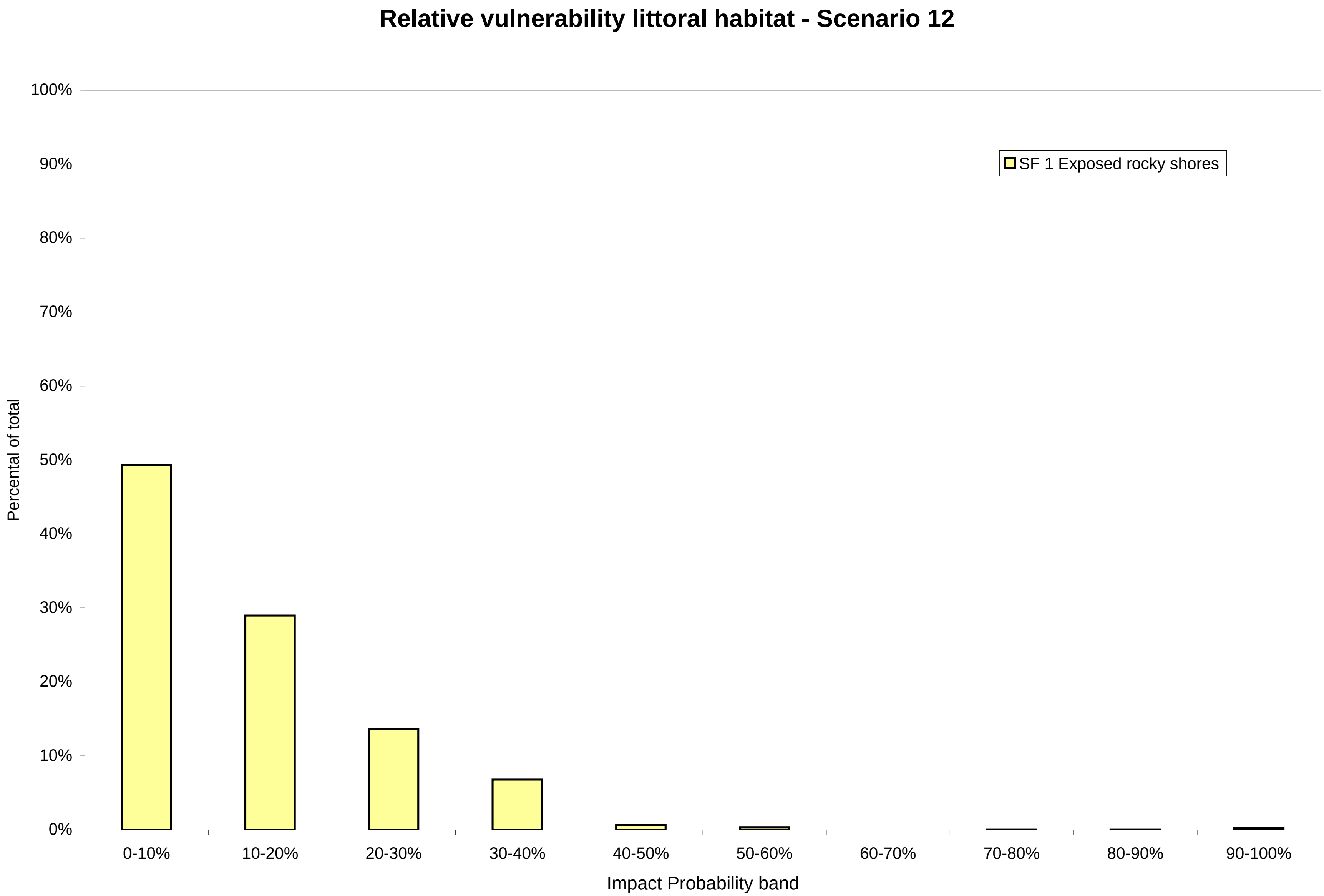


Relative vulnerability littoral habitat - Scenario 9
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percental of total
SF 2 Coarse sand beaches
SF 3 Gravel beaches
SF 4 Exposed tidal flats
SF 5 Sheltered tidal flats
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability band

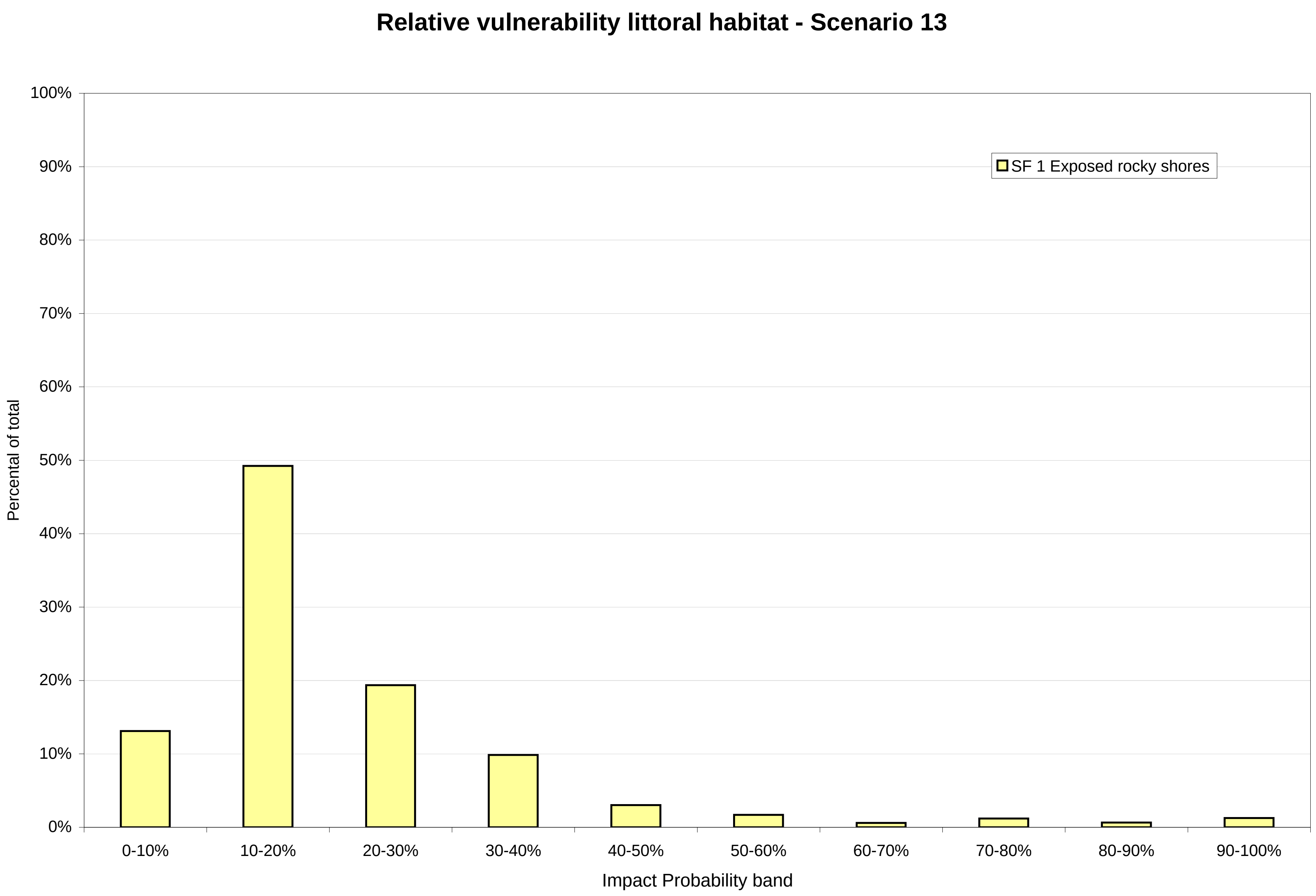


Relative vulnerability littoral habitat - Scenario 10
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percental of total
SF 1 Exposed rocky shores
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability band


Relative vulnerability littoral habitat - Scenario 11
SF 1 Exposed rocky shores
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percental of total
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability band

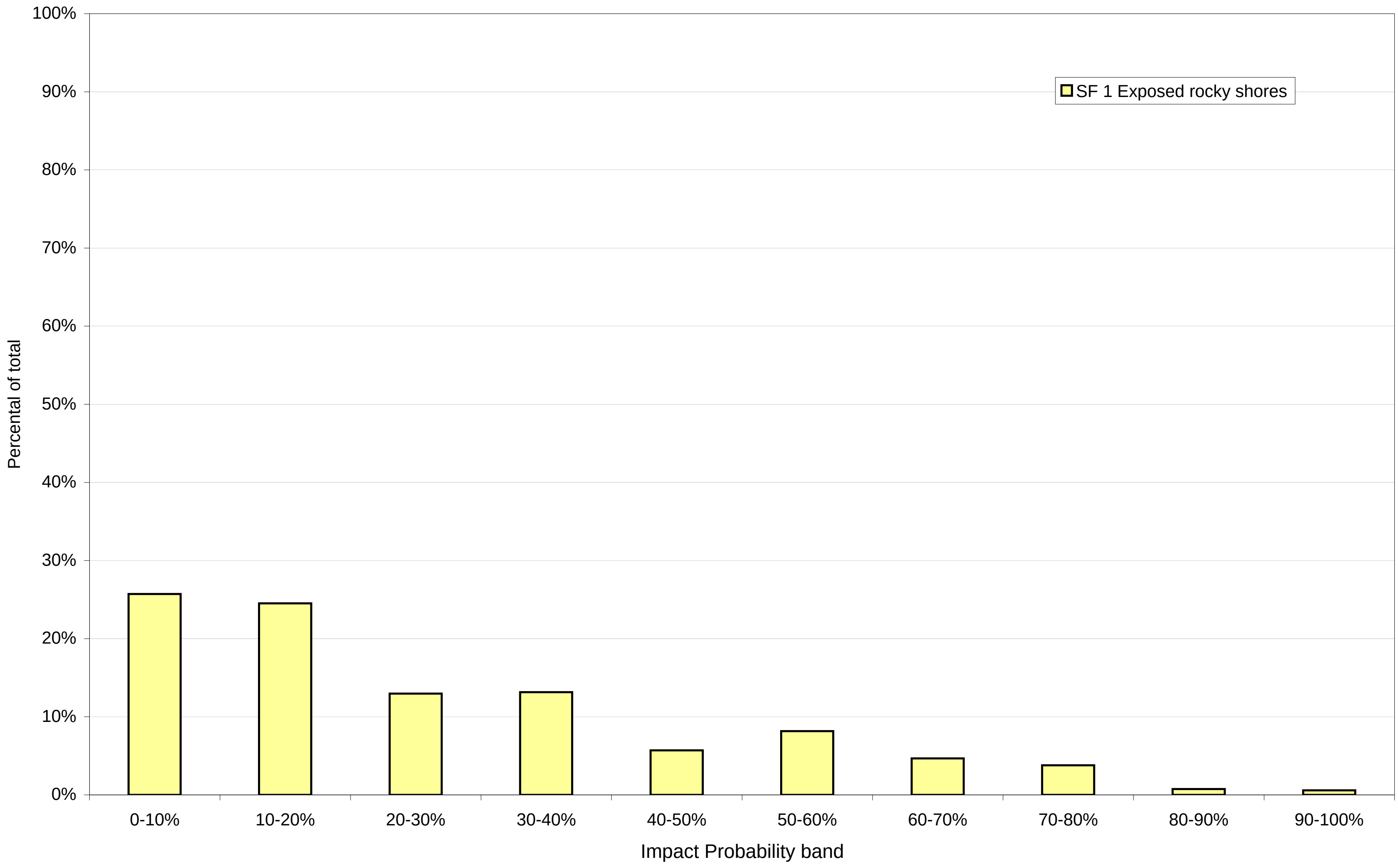


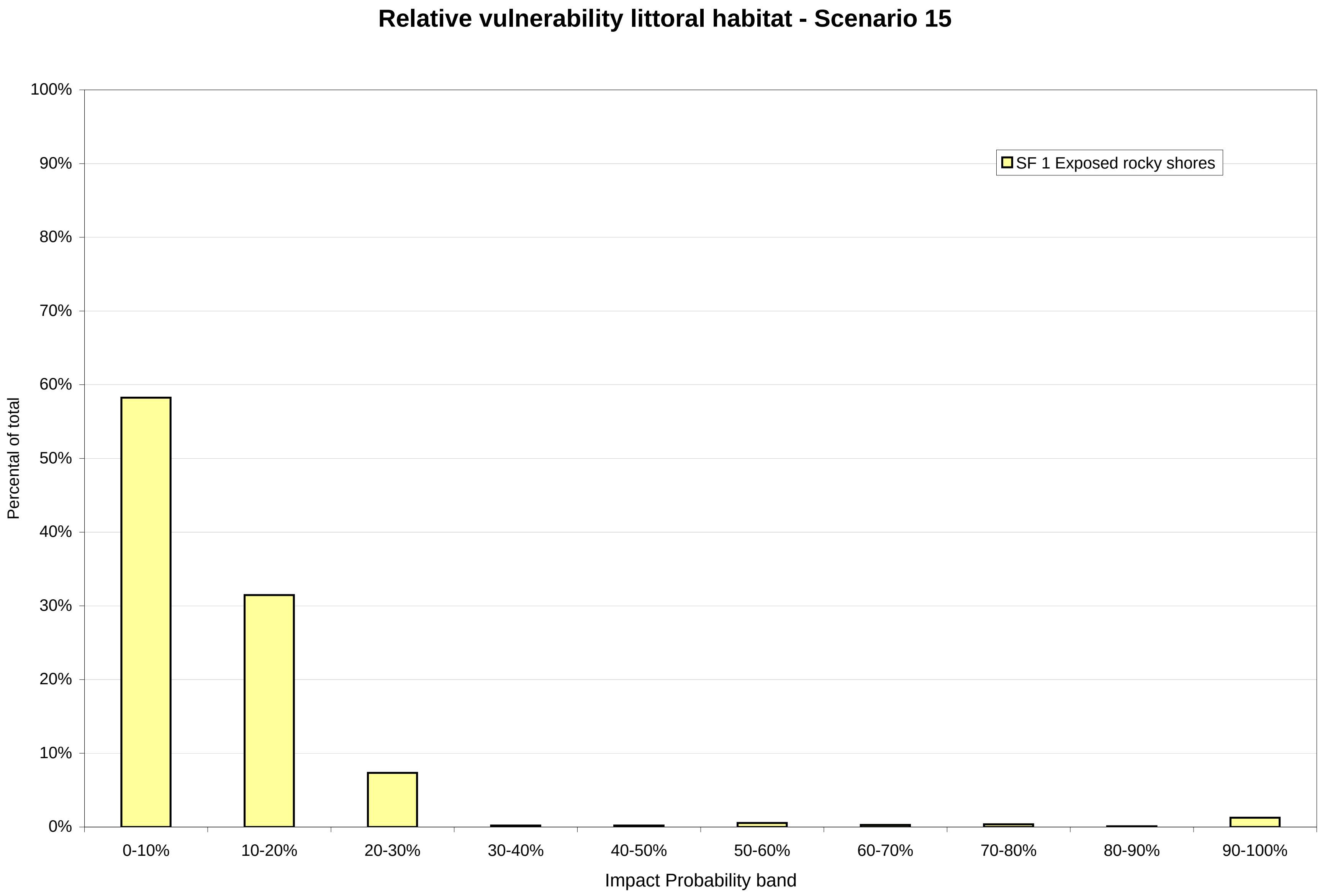
Relative vulnerability littoral habitat - Scenario 12
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percental of total
SF 1 Exposed rocky shores
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability band

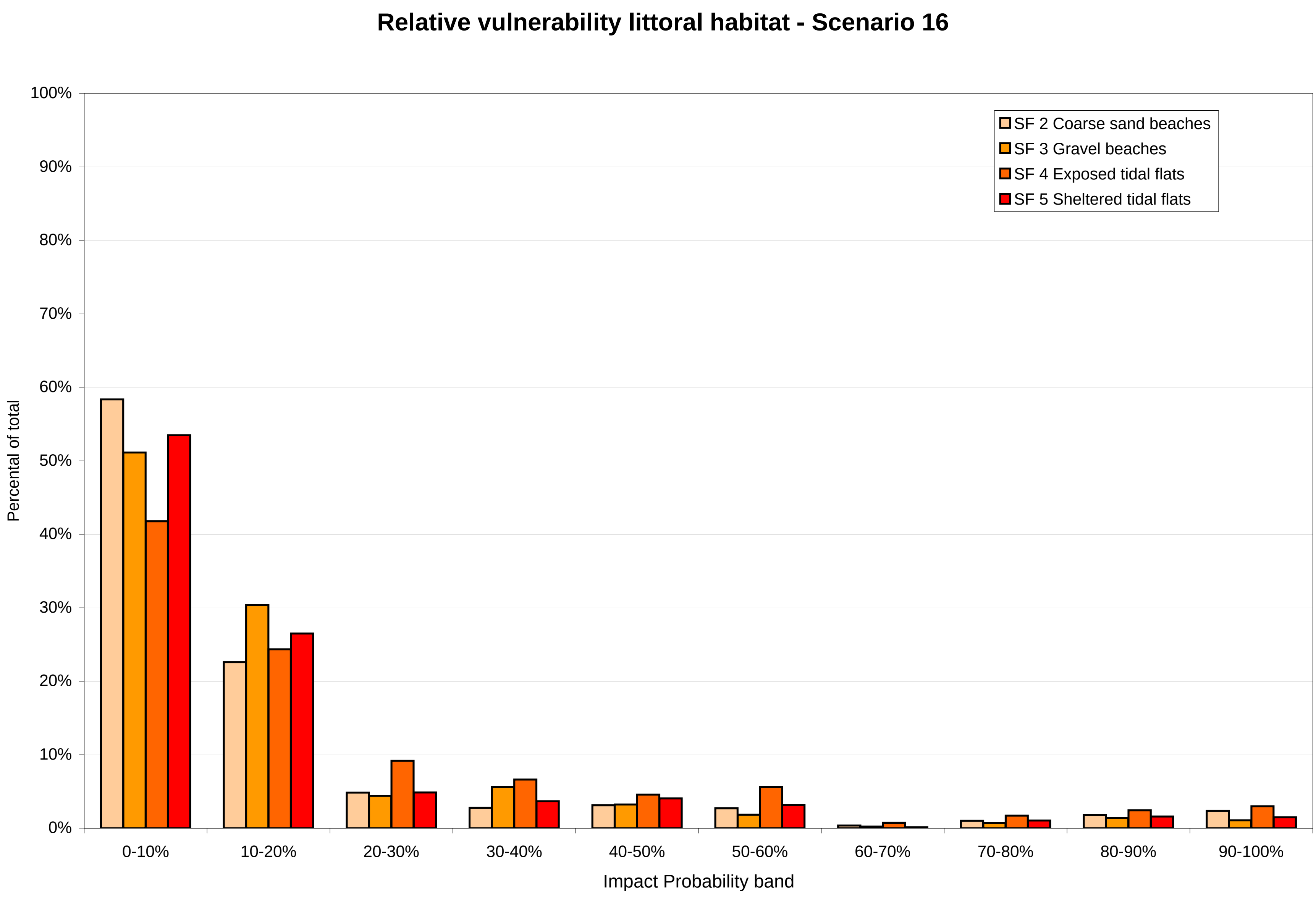


Relative vulnerability littoral habitat - Scenario 13
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percental of total
SF 1 Exposed rocky shores
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability band

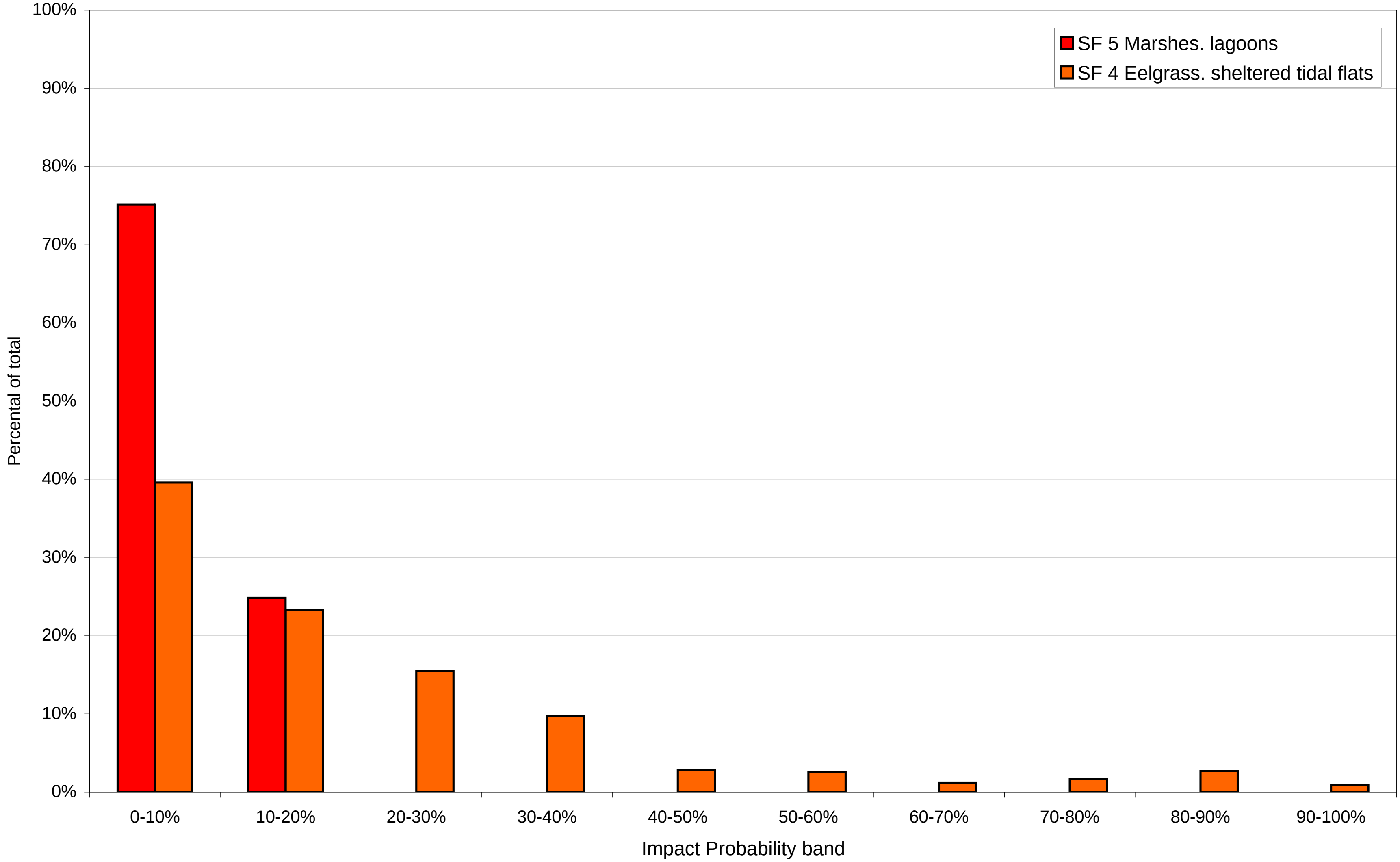
Relative vulnerability littoral habitat - Scenario 14

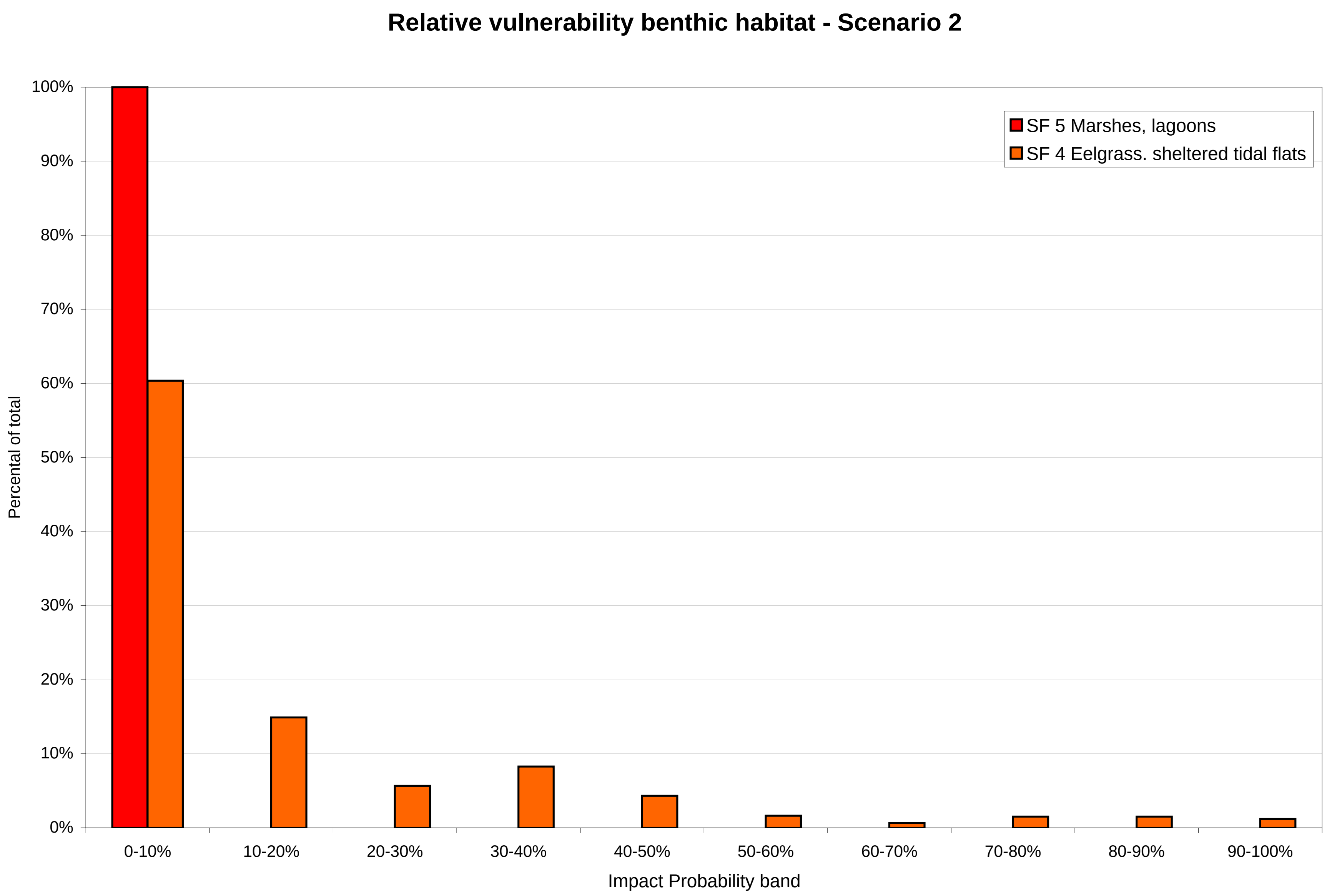



Relative vulnerability littoral habitat - Scenario 15
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percental of total
SF 1 Exposed rocky shores
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability band

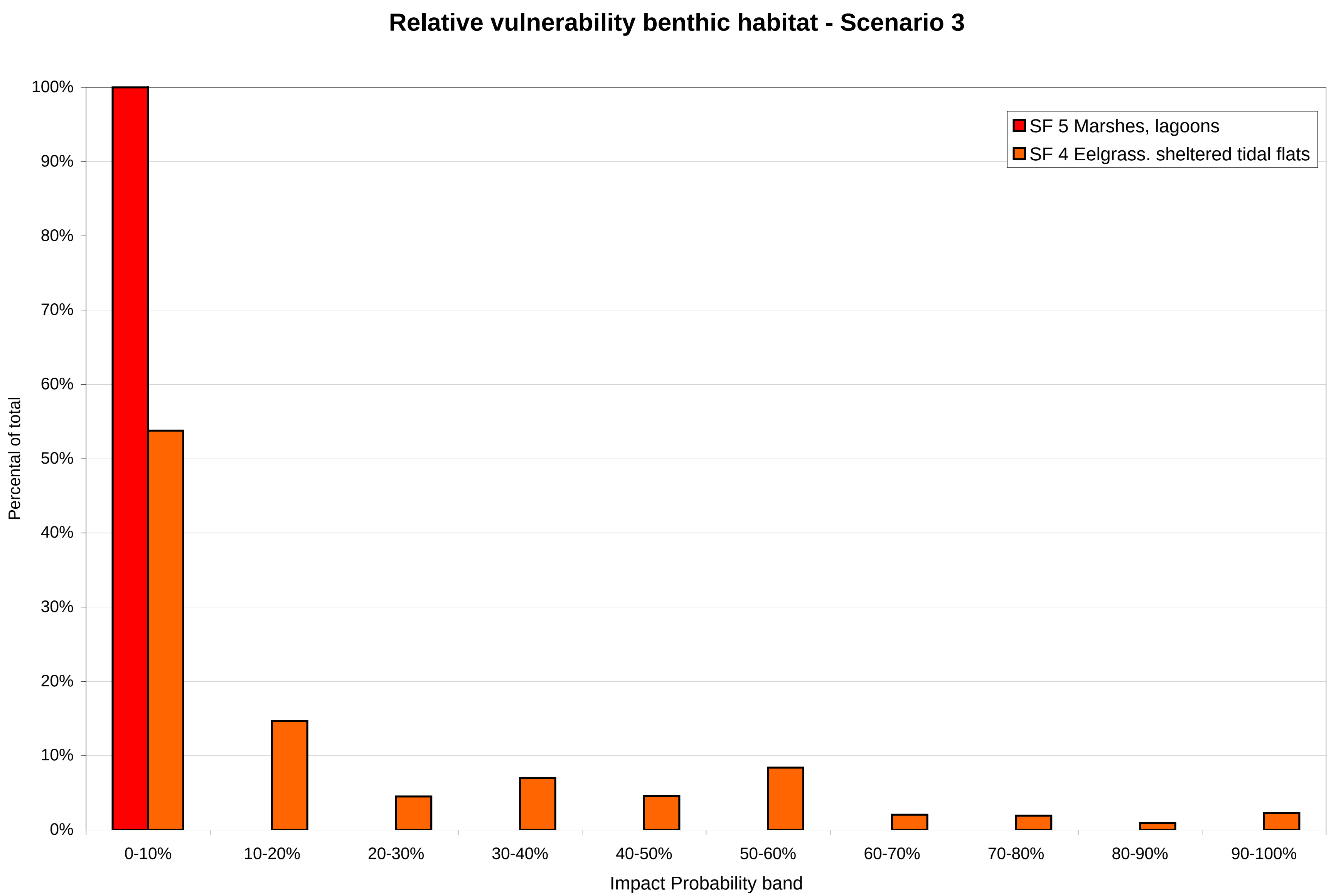

Relative vulnerability littoral habitat - Scenario 16
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percental of total
SF 2 Coarse sand beaches
SF 3 Gravel beaches
SF 4 Exposed tidal flats
SF 5 Sheltered tidal flats
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability band

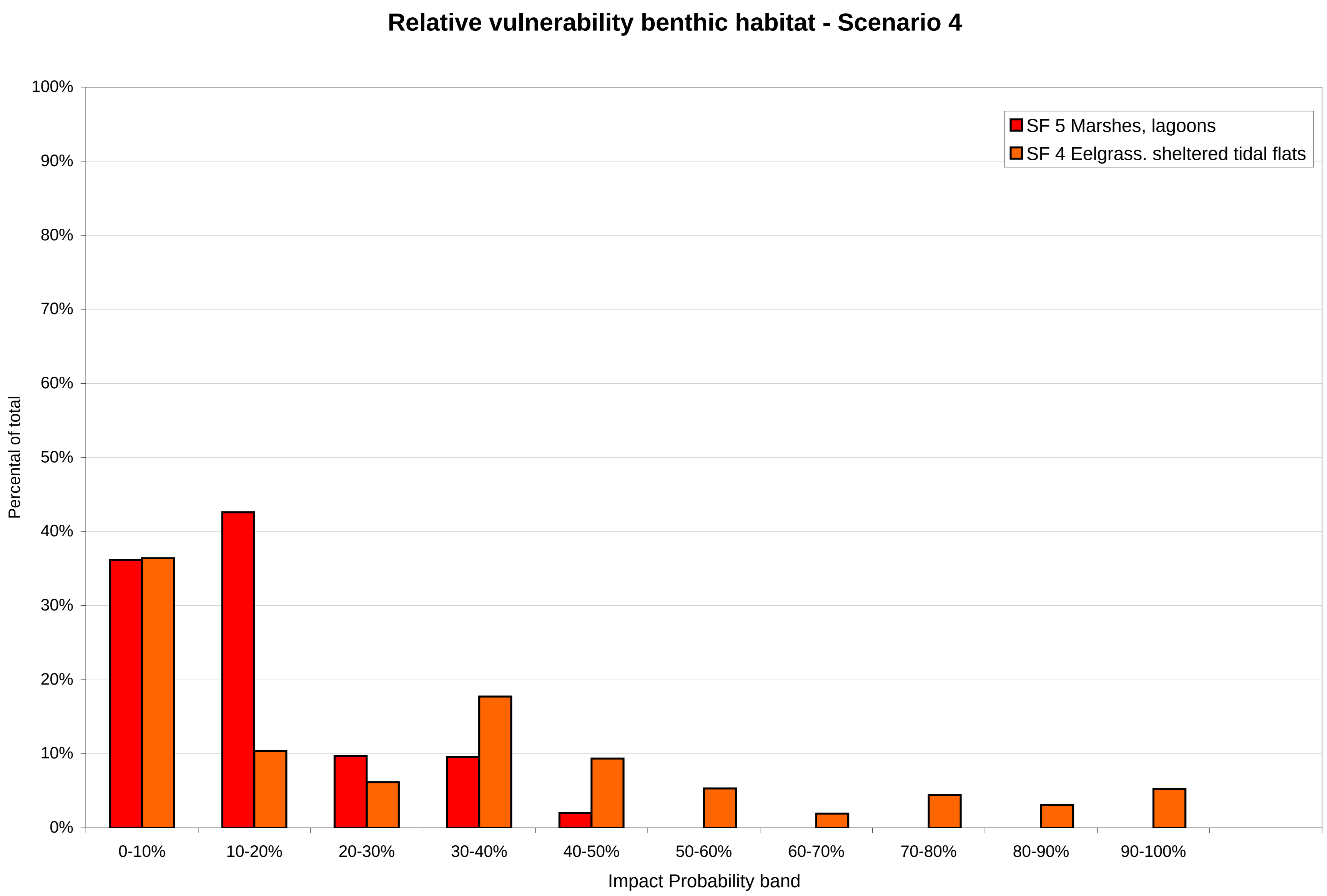
Relative vulnerability benthic habitat - Scenario 1

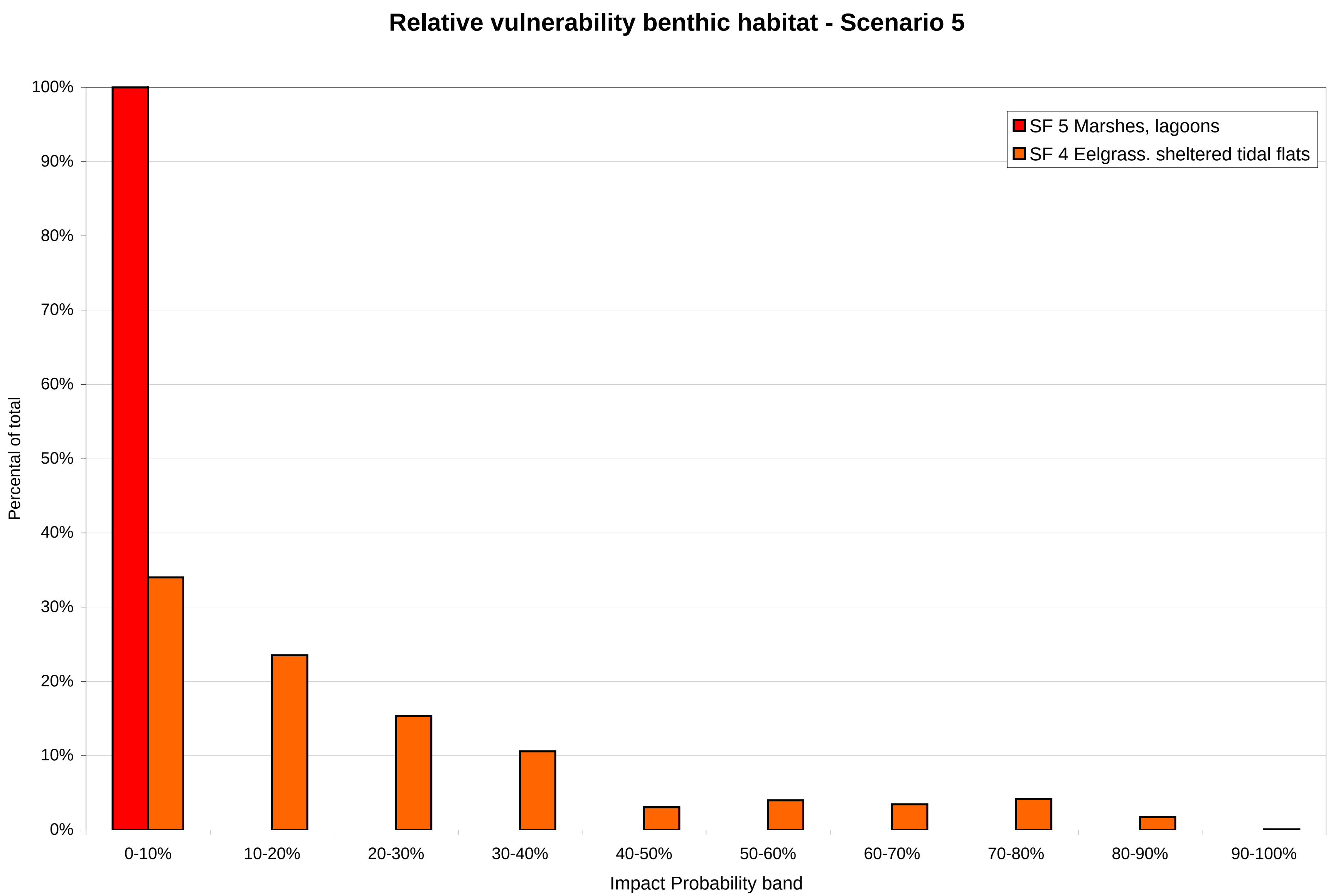




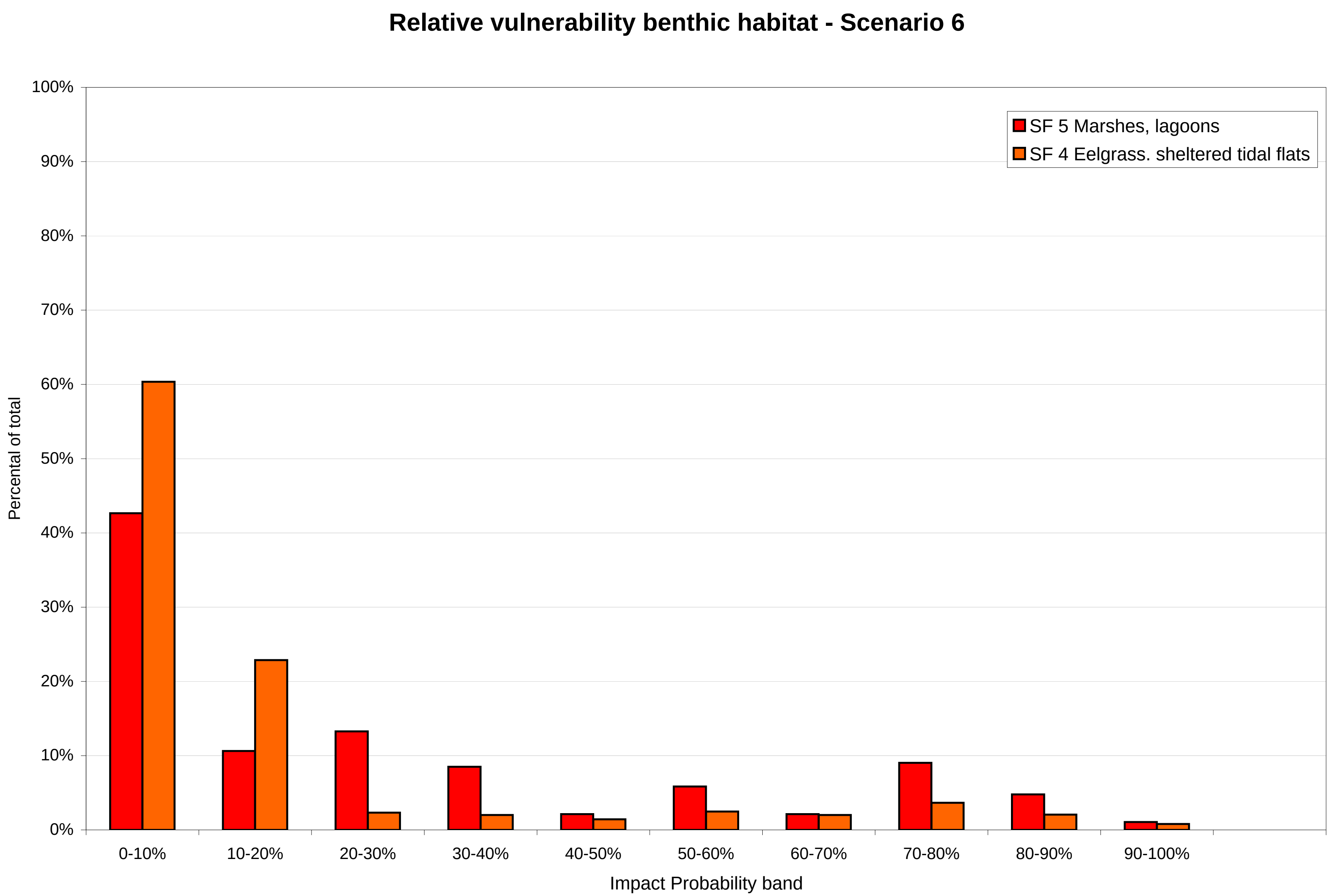
Relative vulnerability benthic habitat - Scenario 2
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percental of total
SF 5 Marshes, lagoons
SF 4 Eelgrass. sheltered tidal flats
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability band

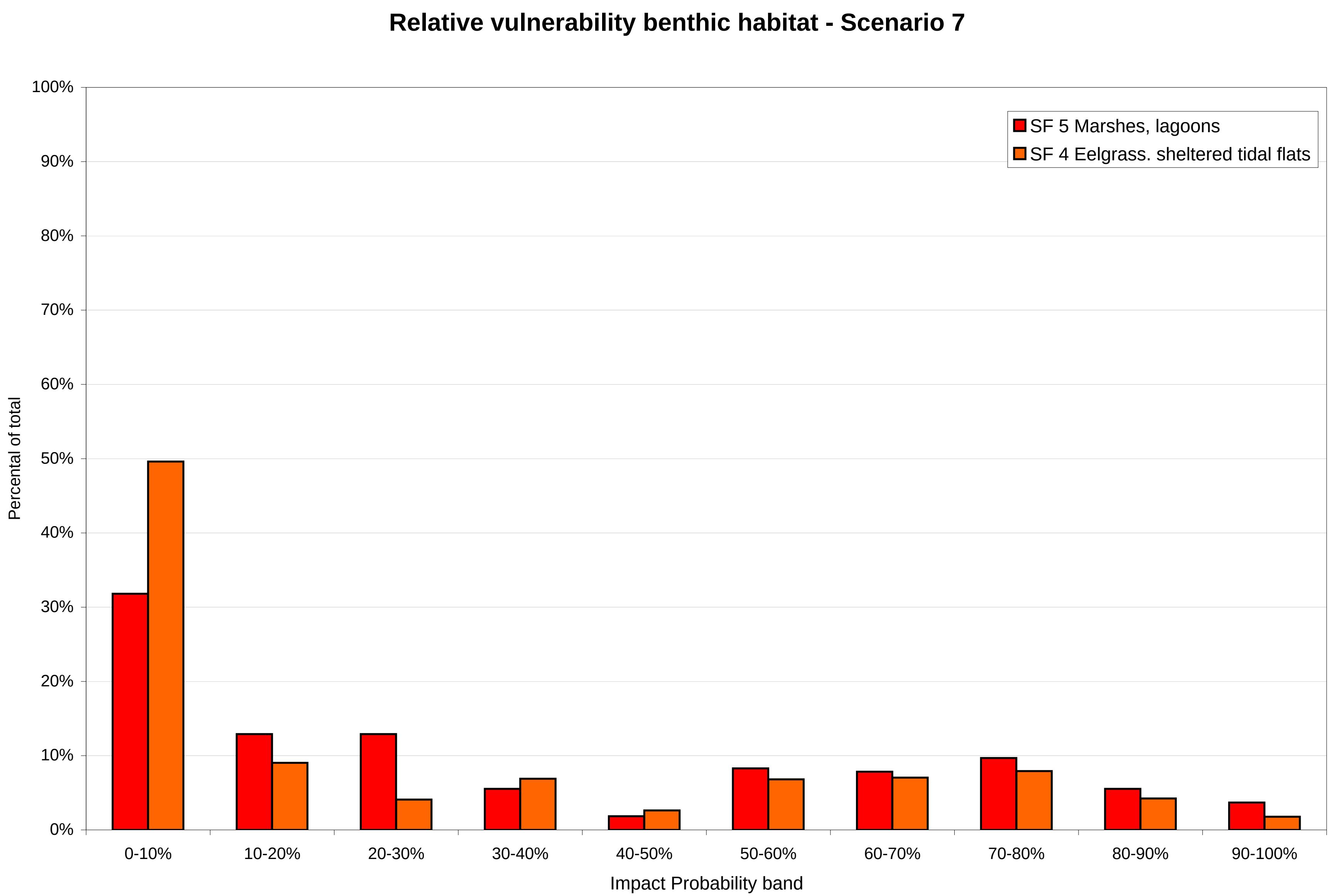

Relative vulnerability benthic habitat - Scenario 3
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percental of total
SF 5 Marshes, lagoons
SF 4 Eelgrass. sheltered tidal flats
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability band

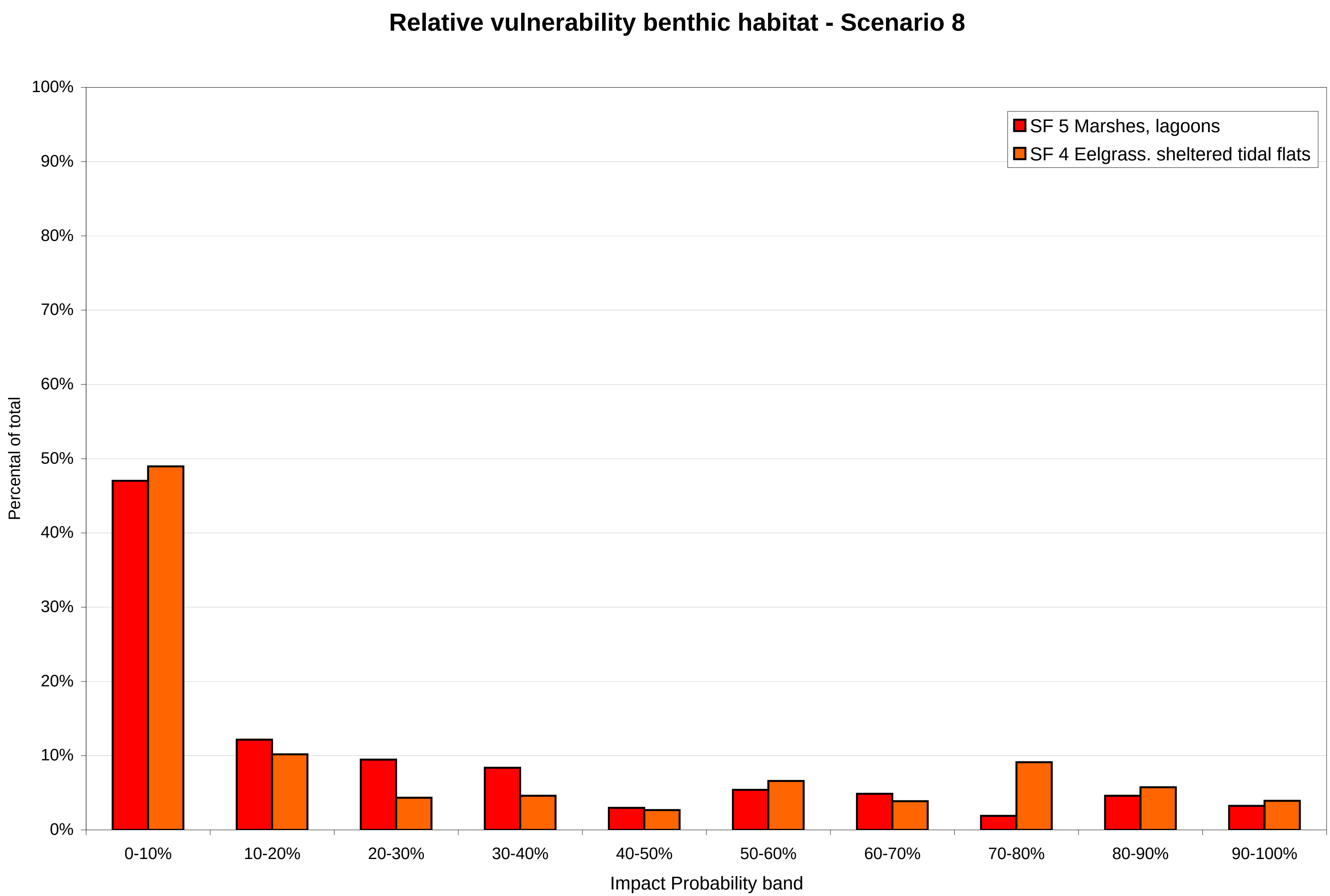

Relative vulnerability benthic habitat - Scenario 4
SF 5 Marshes, lagoons
SF 4 Eelgrass. sheltered tidal flats
Percental of total
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability band



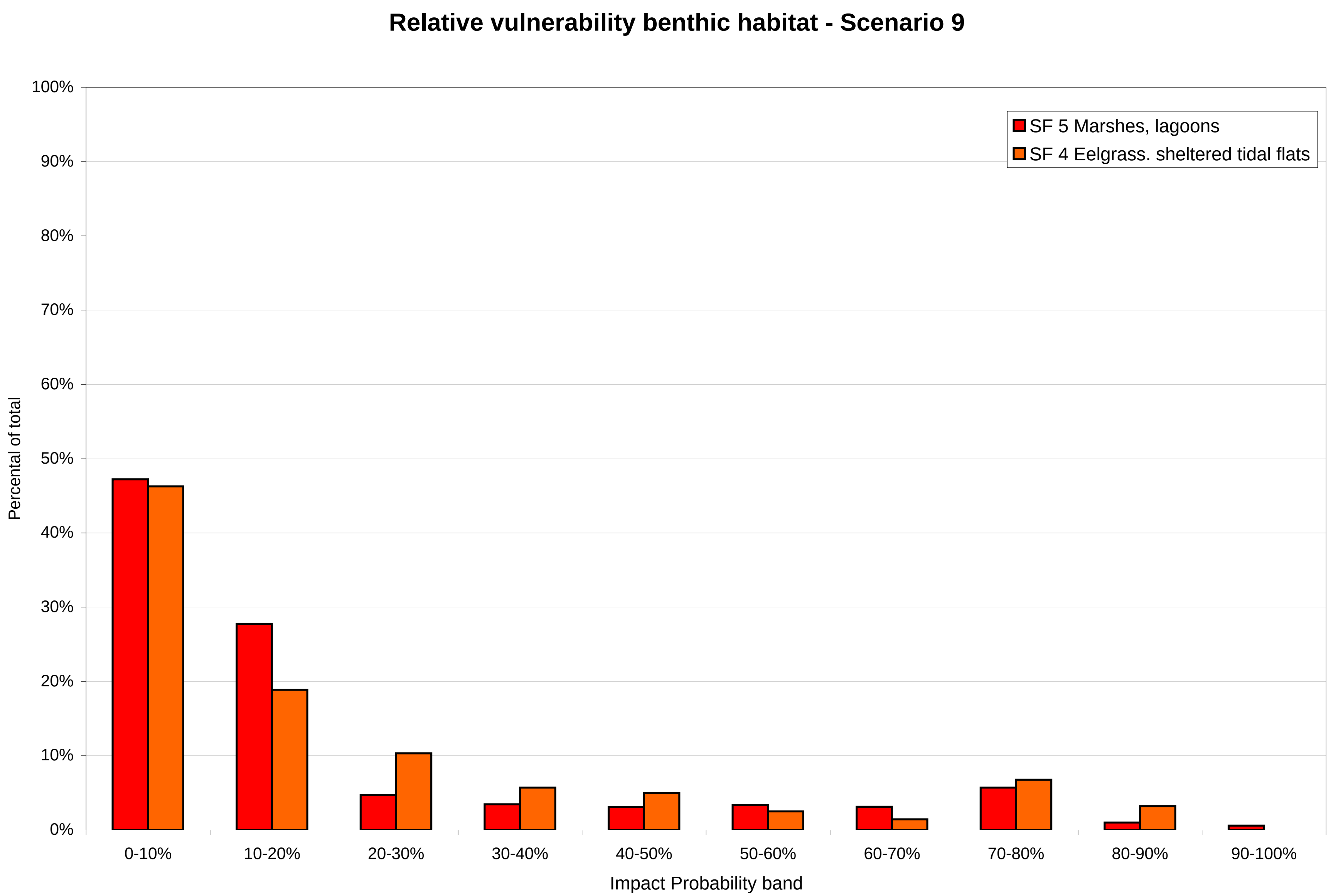
Relative vulnerability benthic habitat - Scenario 5
SF 5 Marshes, lagoons
SF 4 Eelgrass. sheltered tidal flats
Percental of total
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability band


Relative vulnerability benthic habitat - Scenario 6
SF 5 Marshes, lagoons
SF 4 Eelgrass. sheltered tidal flats
Percental of total
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability band

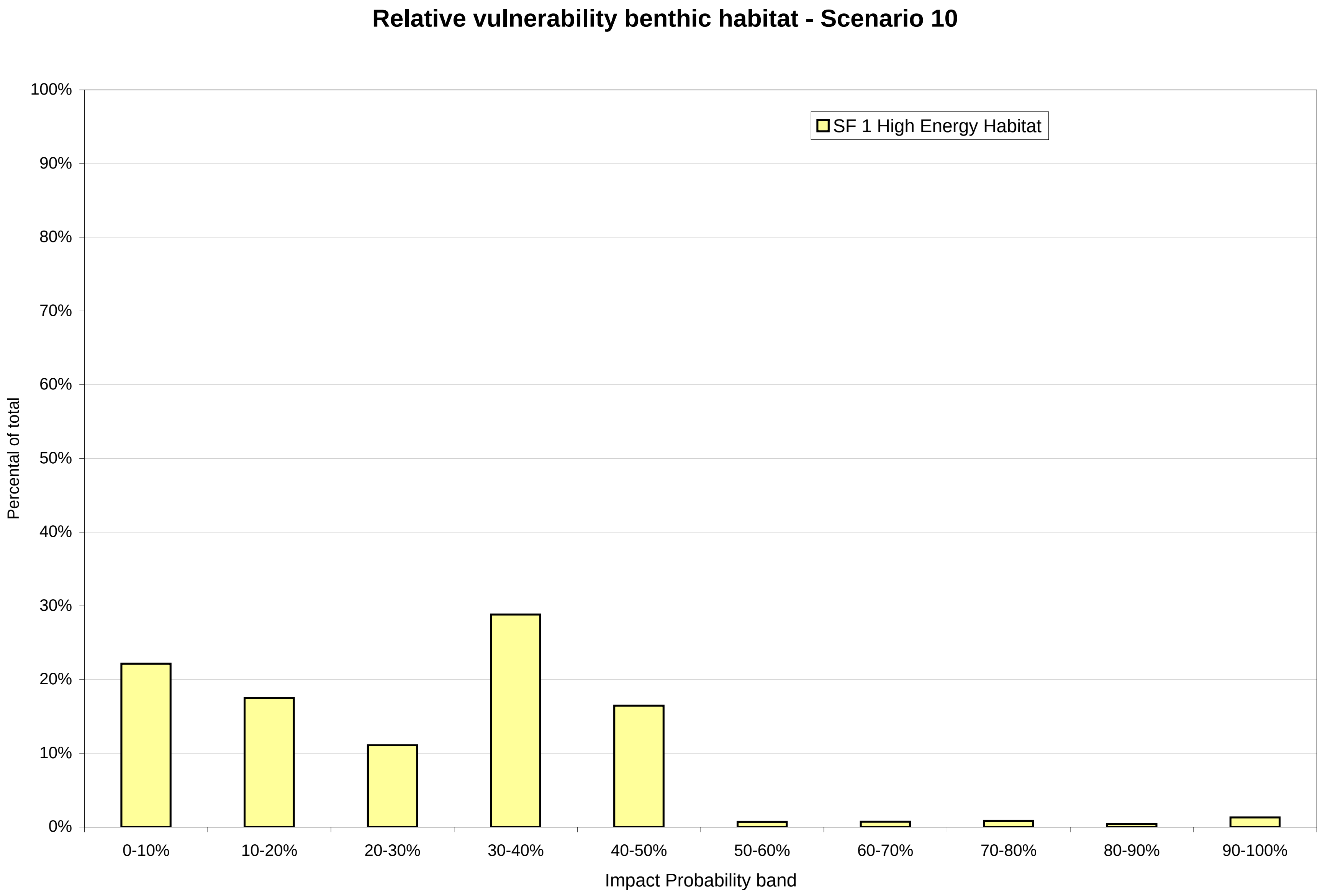

Relative vulnerability benthic habitat - Scenario 7
SF 5 Marshes, lagoons
SF 4 Eelgrass. sheltered tidal flats
Percental of total
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability band

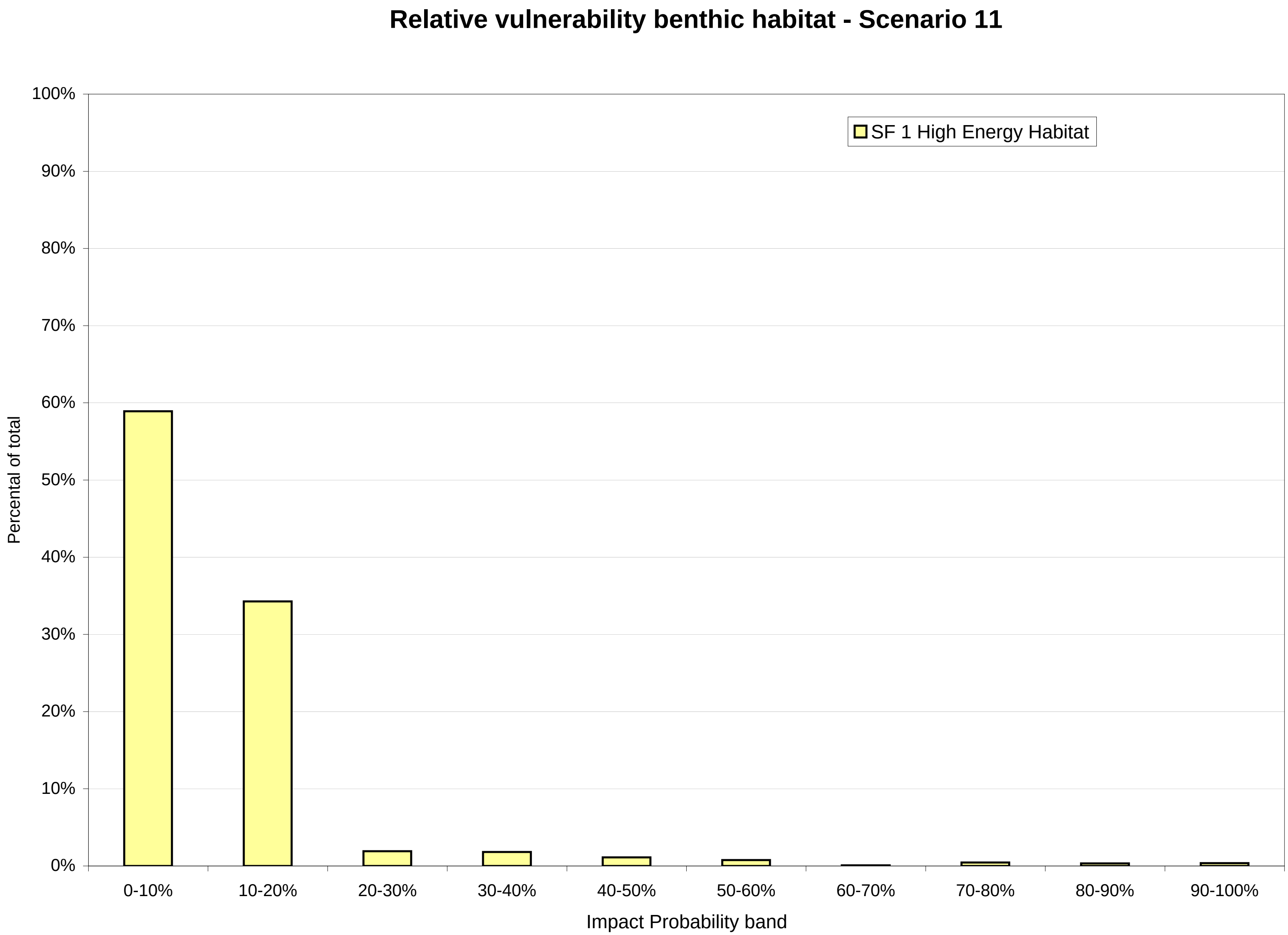


Relative vulnerability benthic habitat - Scenario 8
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percental of total
SF 5 Marshes, lagoons
SF 4 Eelgrass. sheltered tidal flats
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability band

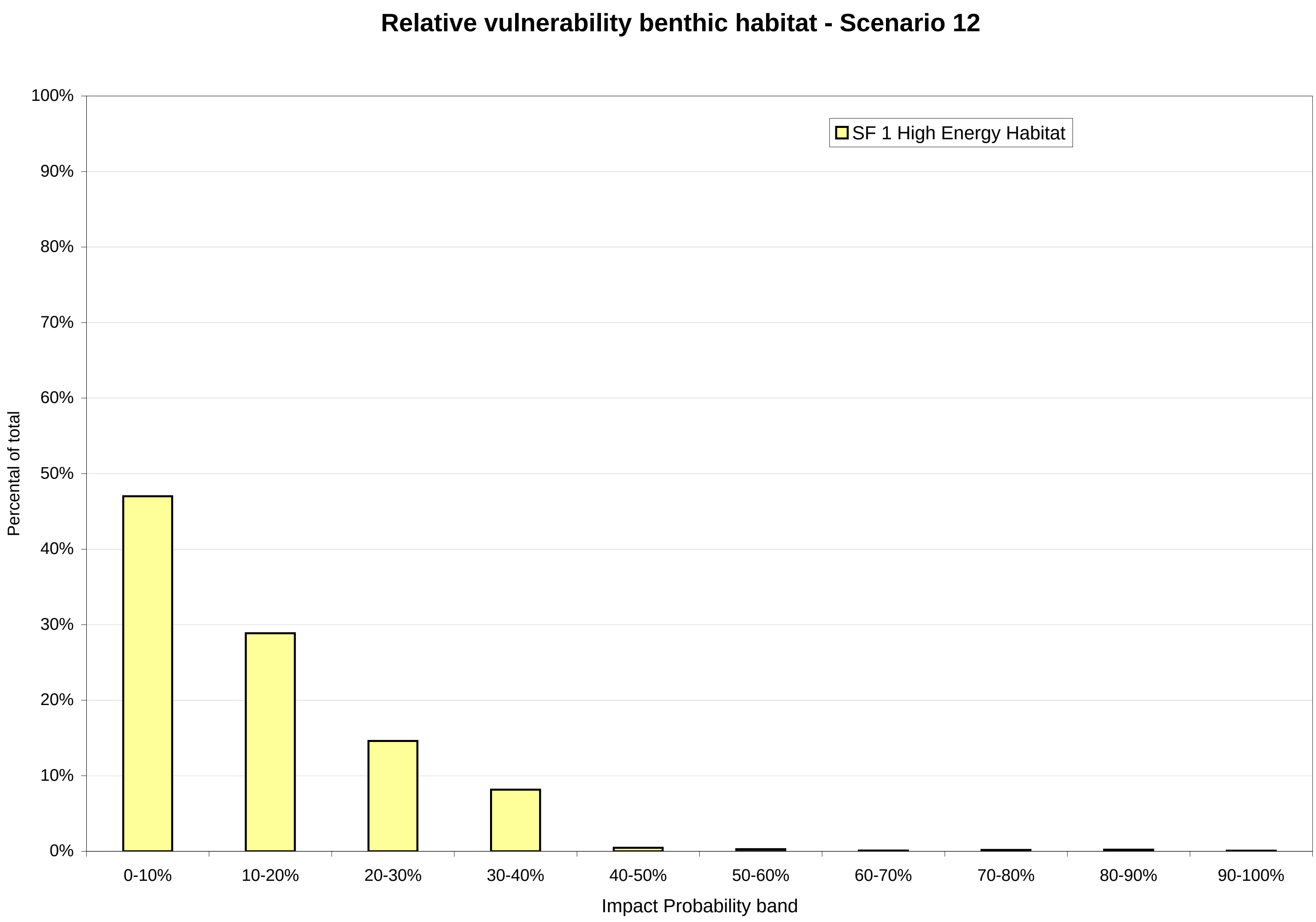


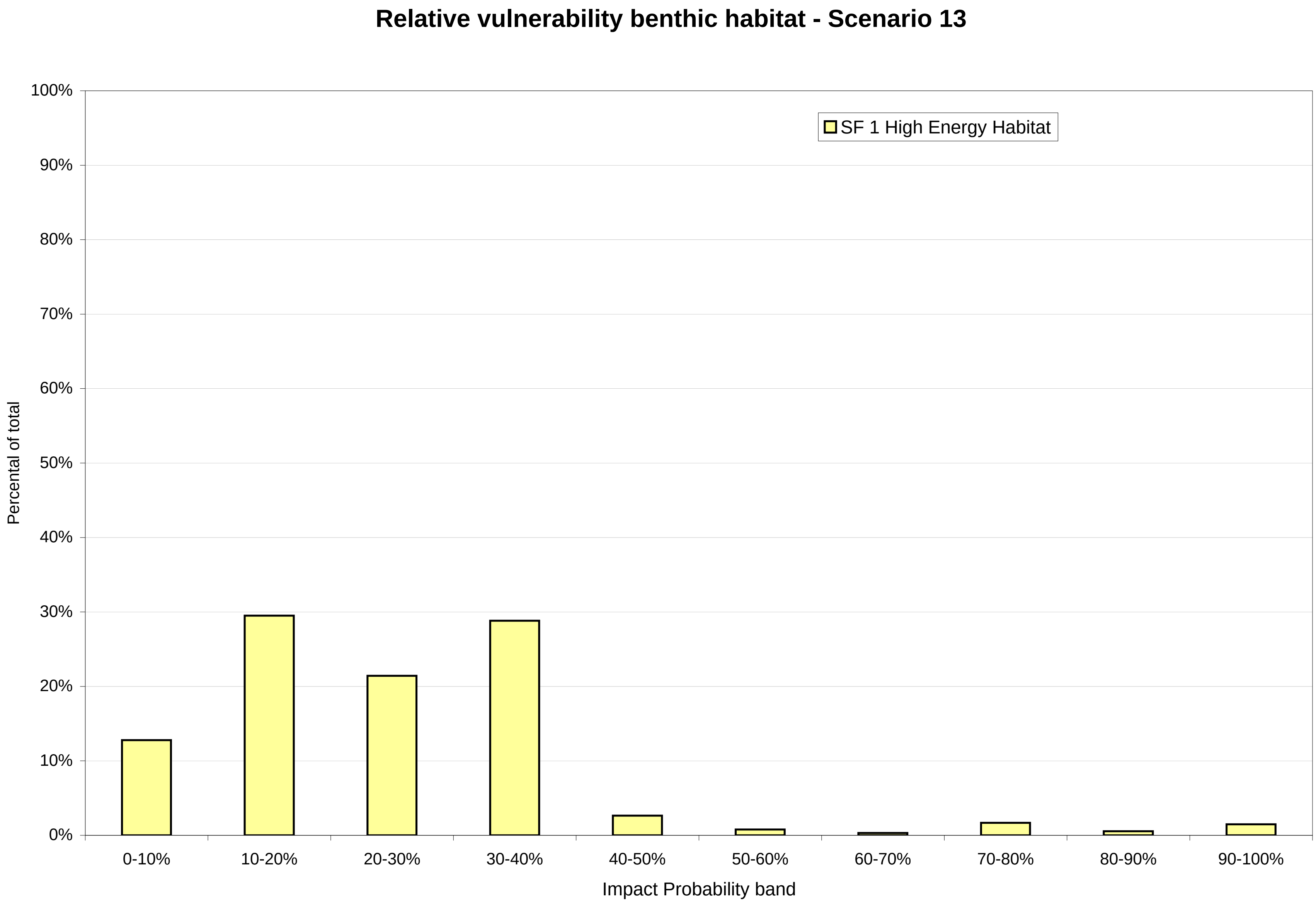
Relative vulnerability benthic habitat - Scenario 9
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percental of total
SF 5 Marshes, lagoons
SF 4 Eelgrass. sheltered tidal flats
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability band


Relative vulnerability benthic habitat - Scenario 10
SF 1 High Energy Habitat
Percental of total
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability band

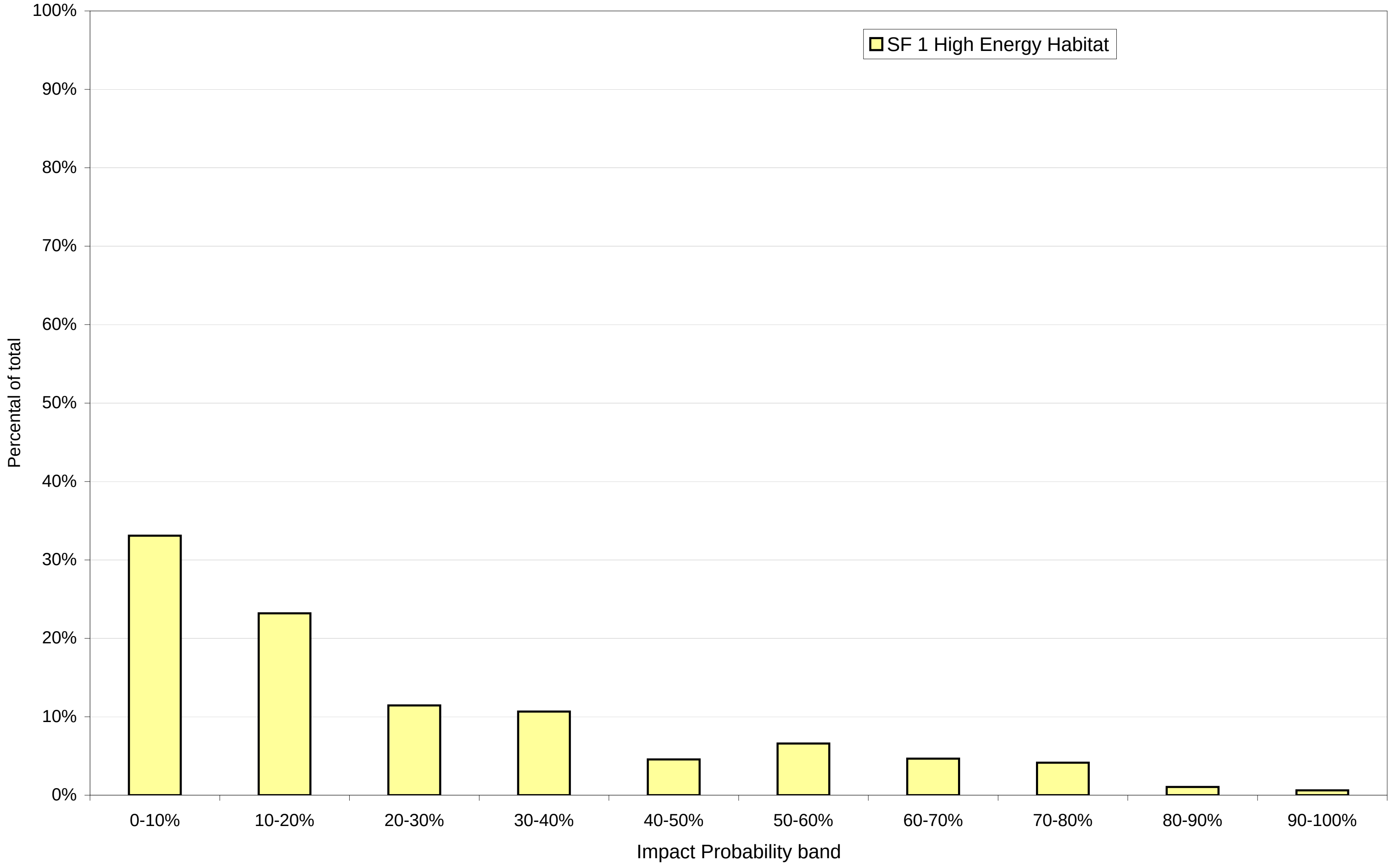


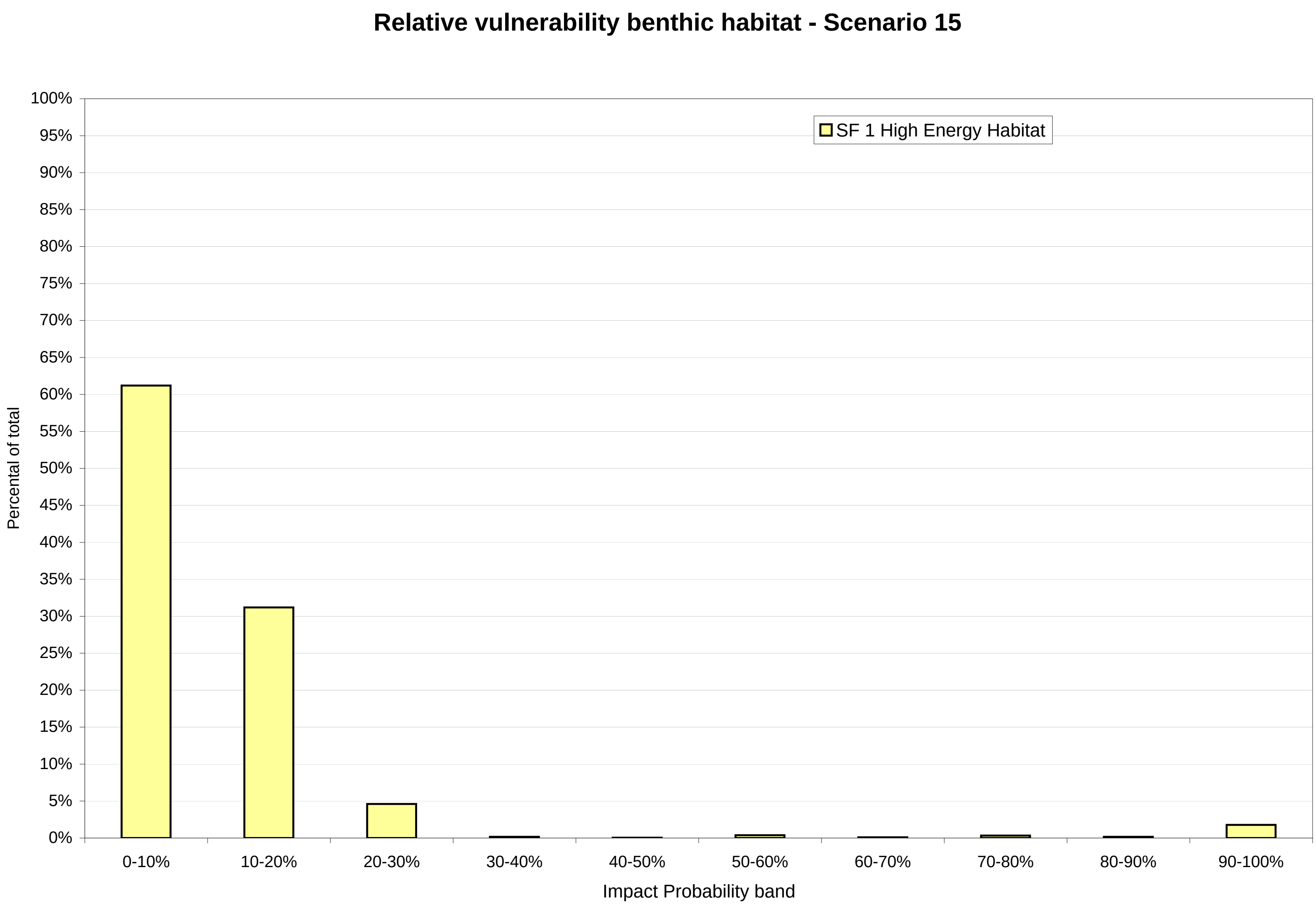
Relative vulnerability benthic habitat - Scenario 11
SF 1 High Energy Habitat
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percental of total
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability band


Relative vulnerability benthic habitat - Scenario 12
SF 1 High Energy Habitat
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percental of total
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability band


Relative vulnerability benthic habitat - Scenario 13
SF 1 High Energy Habitat
Percental of total
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability band

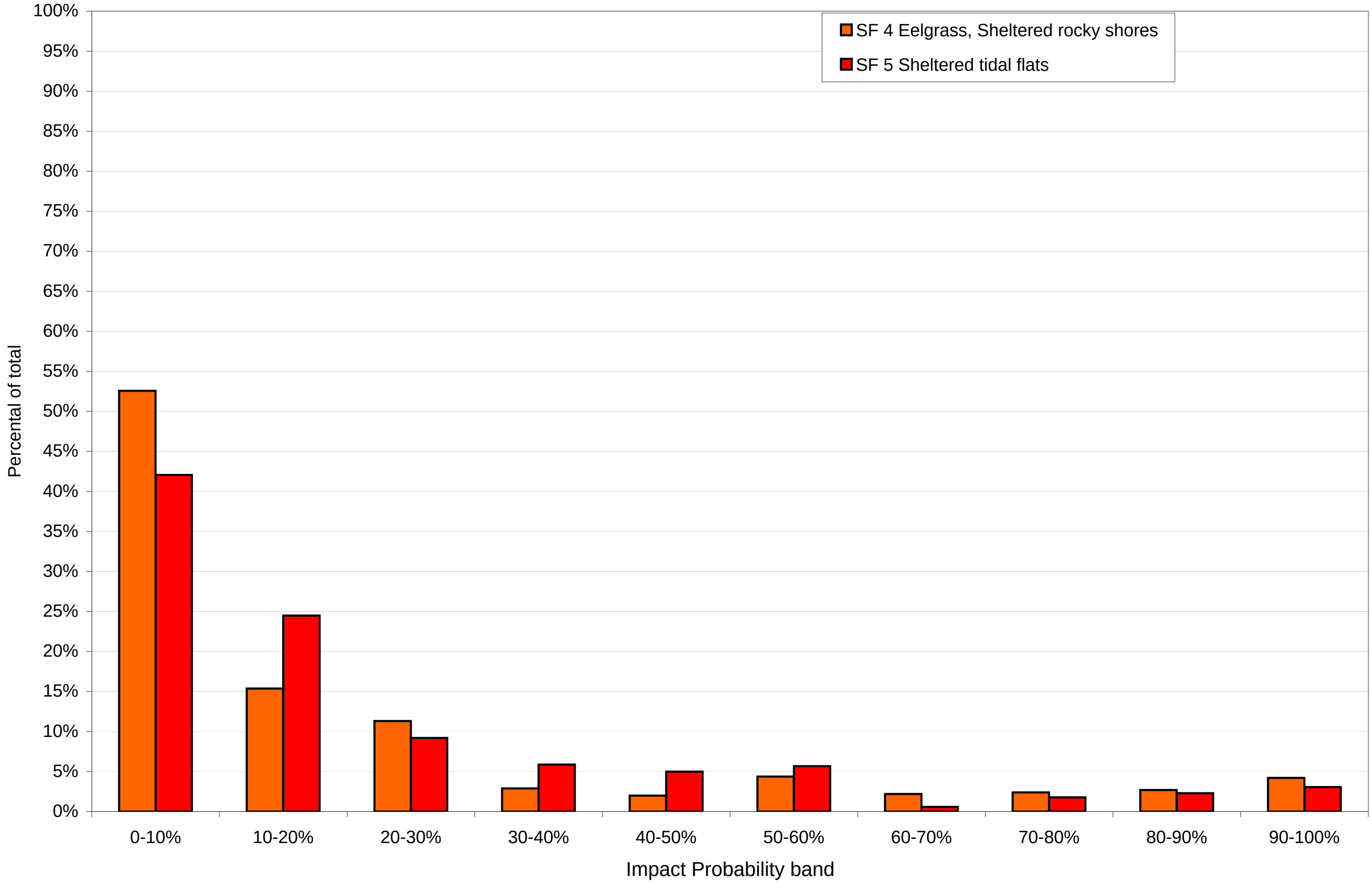
Relative vulnerability benthic habitat - Scenario 14

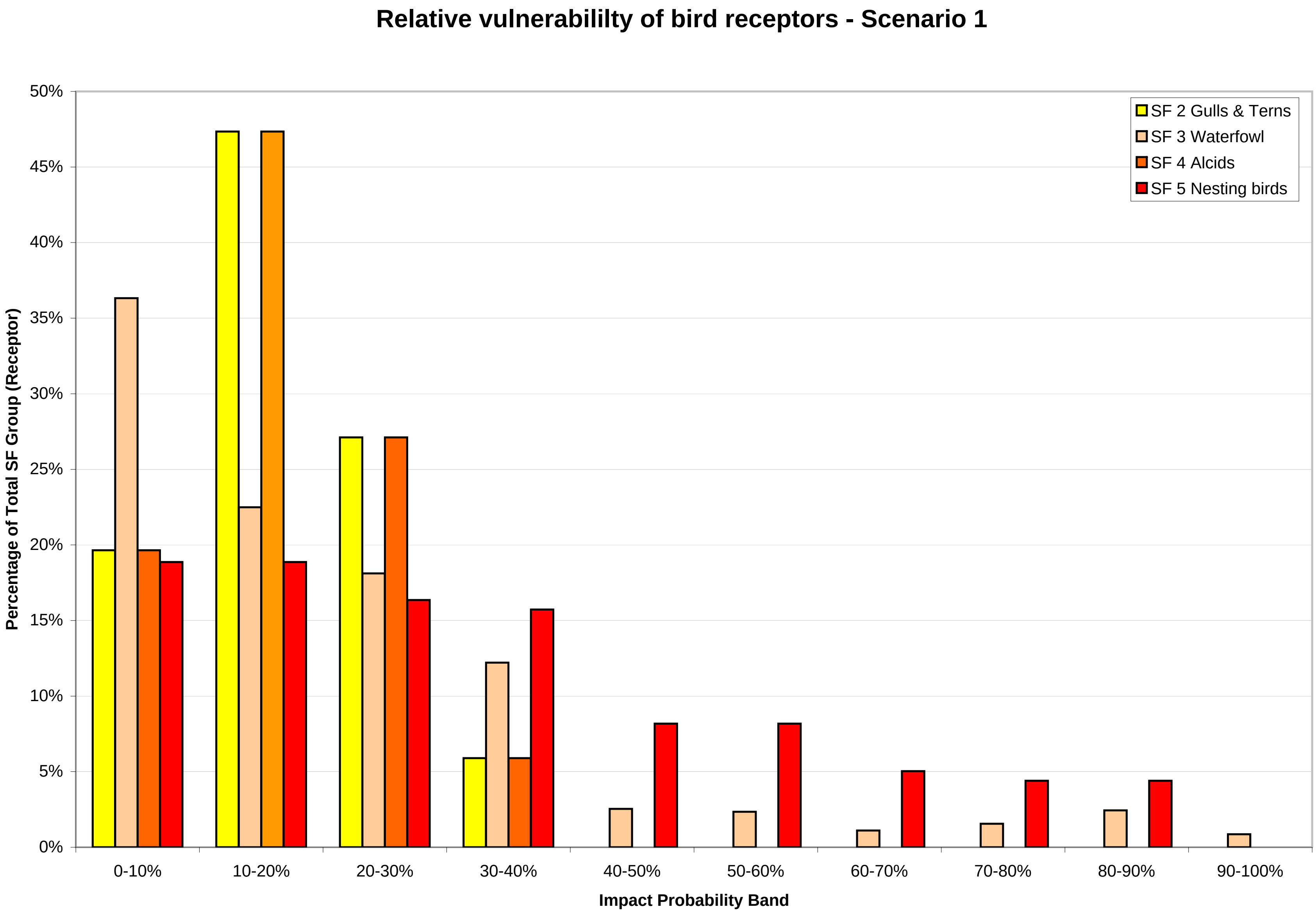


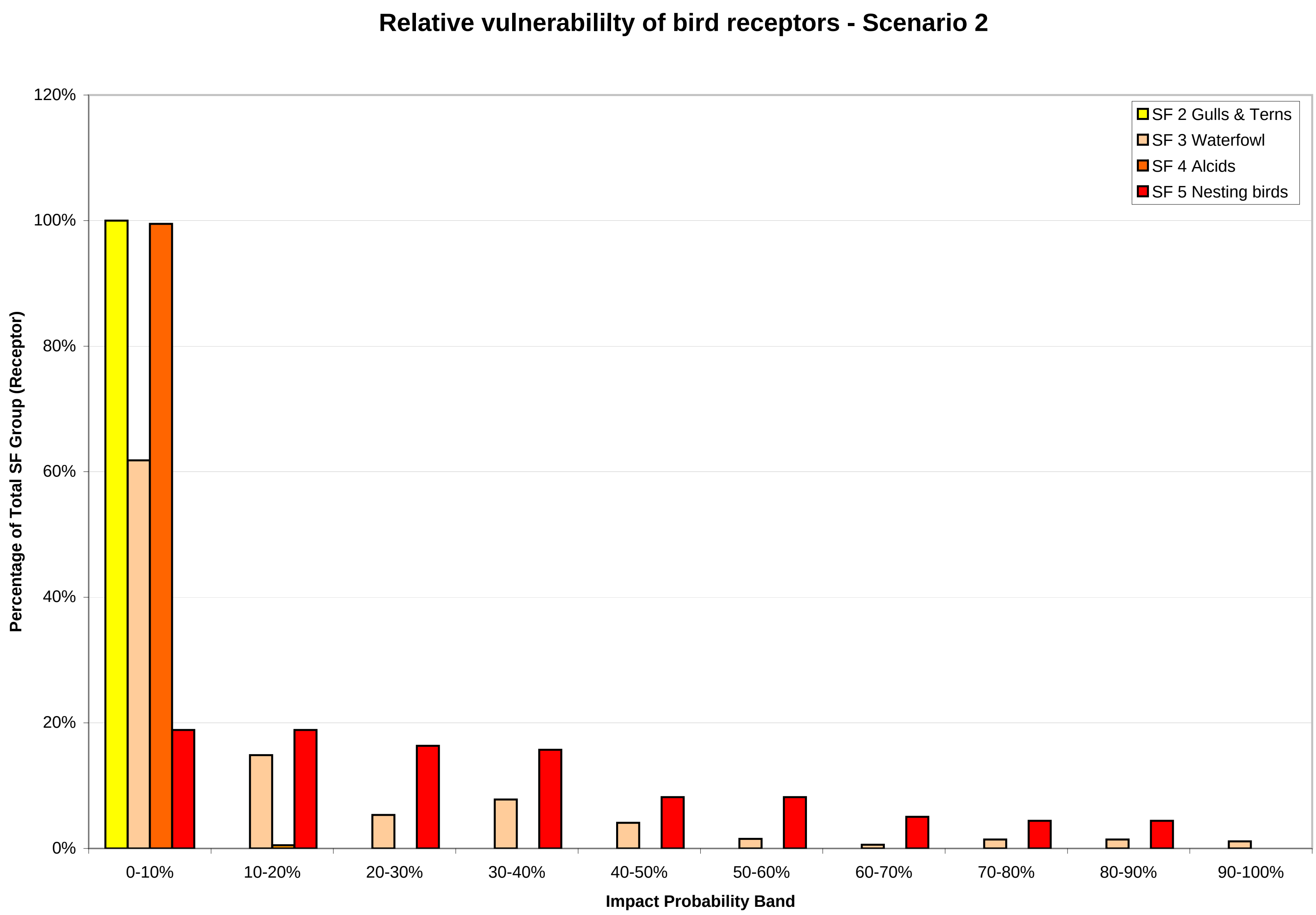


Relative vulnerability benthic habitat - Scenario 15
SF 1 High Energy Habitat
Percental of total
100%
95%
90%
85%
80%
75%
70%
65%
60%
55%
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability band

Relative vulnerability benthic habitat - Scenario 16

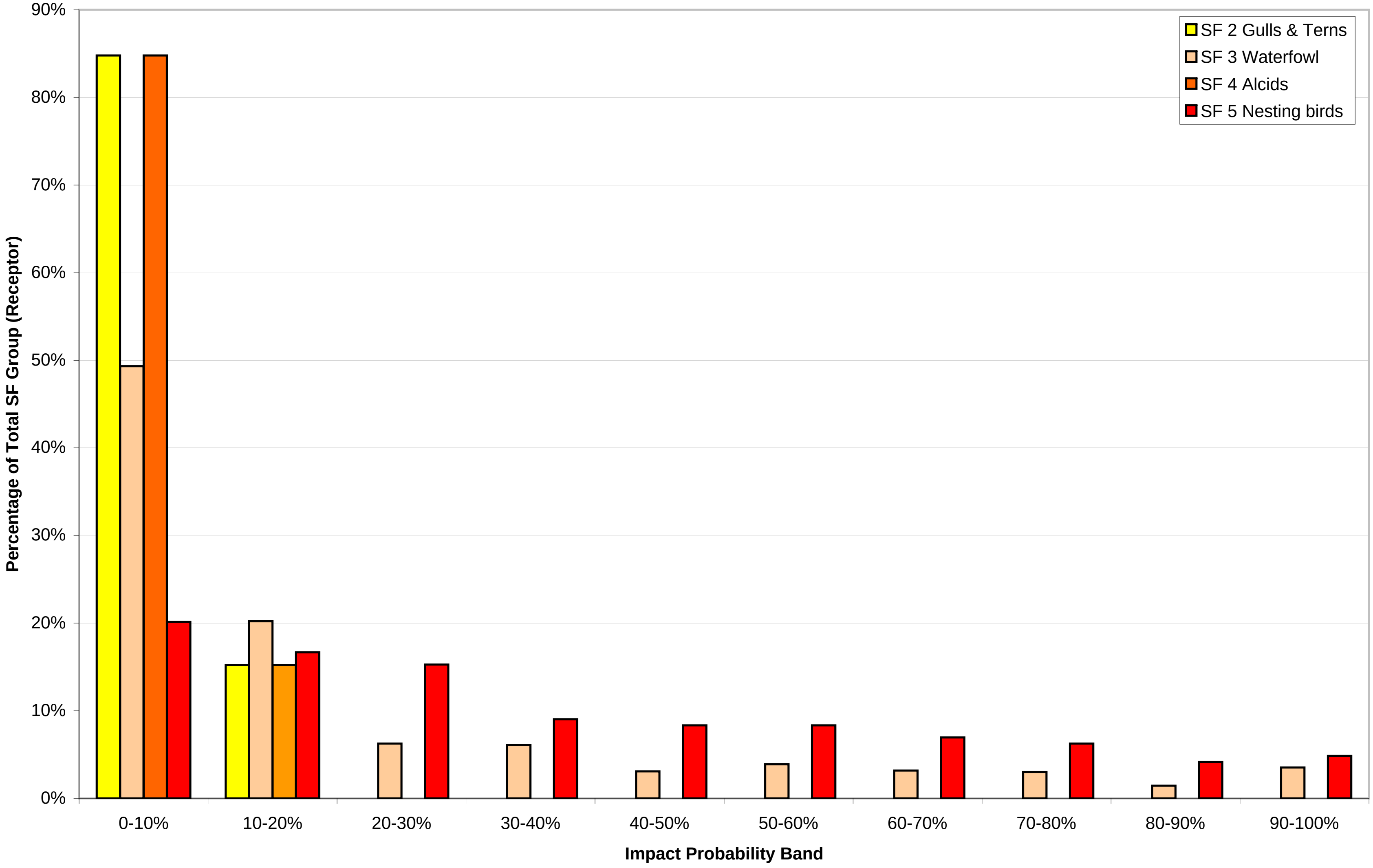


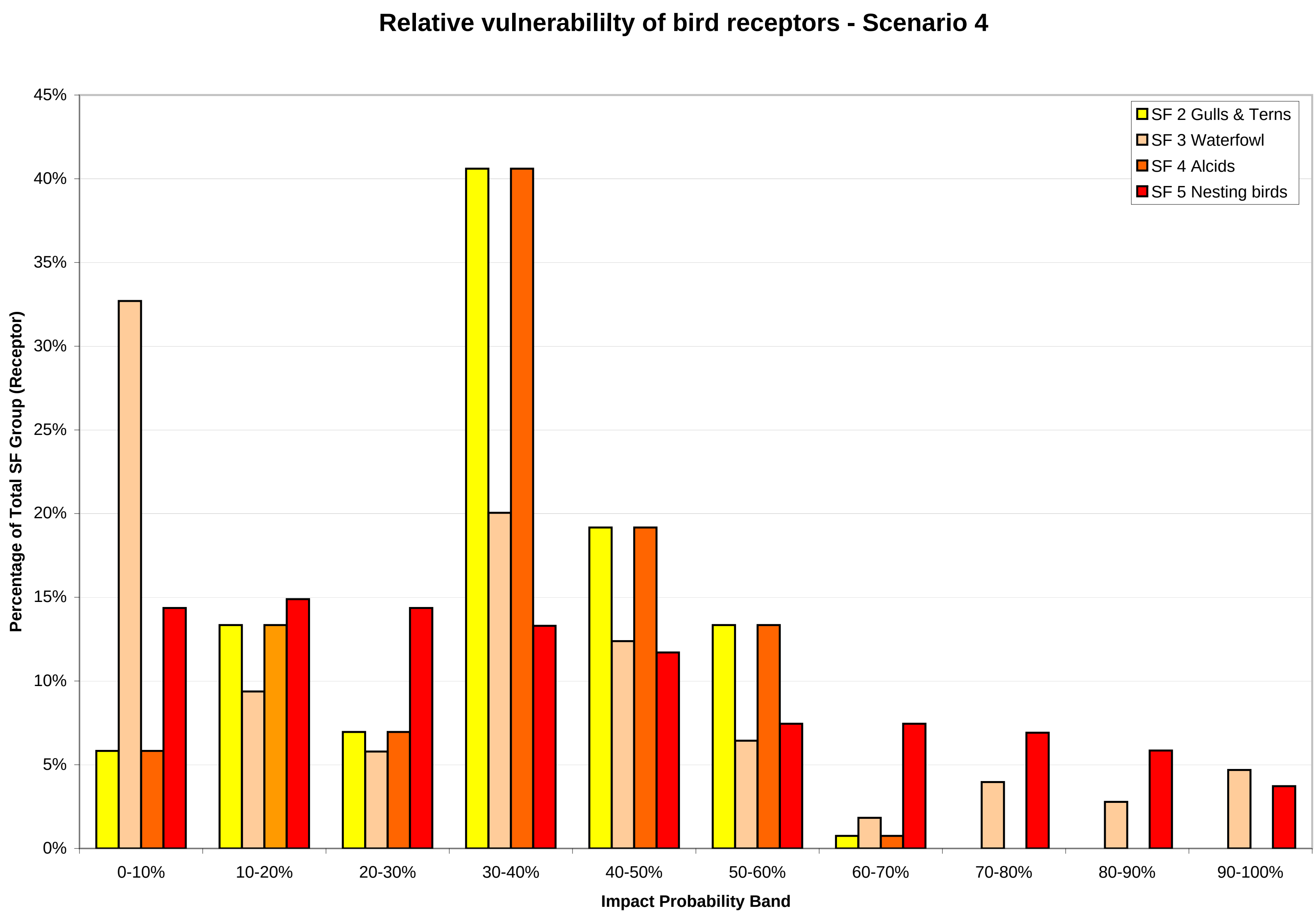

Relative vulnerabililty of bird receptors - Scenario 1
Percentage of Total SF Group (Receptor)
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability Band
SF 2 Gulls & Terns
SF 3 Waterfowl
SF 4 Alcids
SF 5 Nesting birds

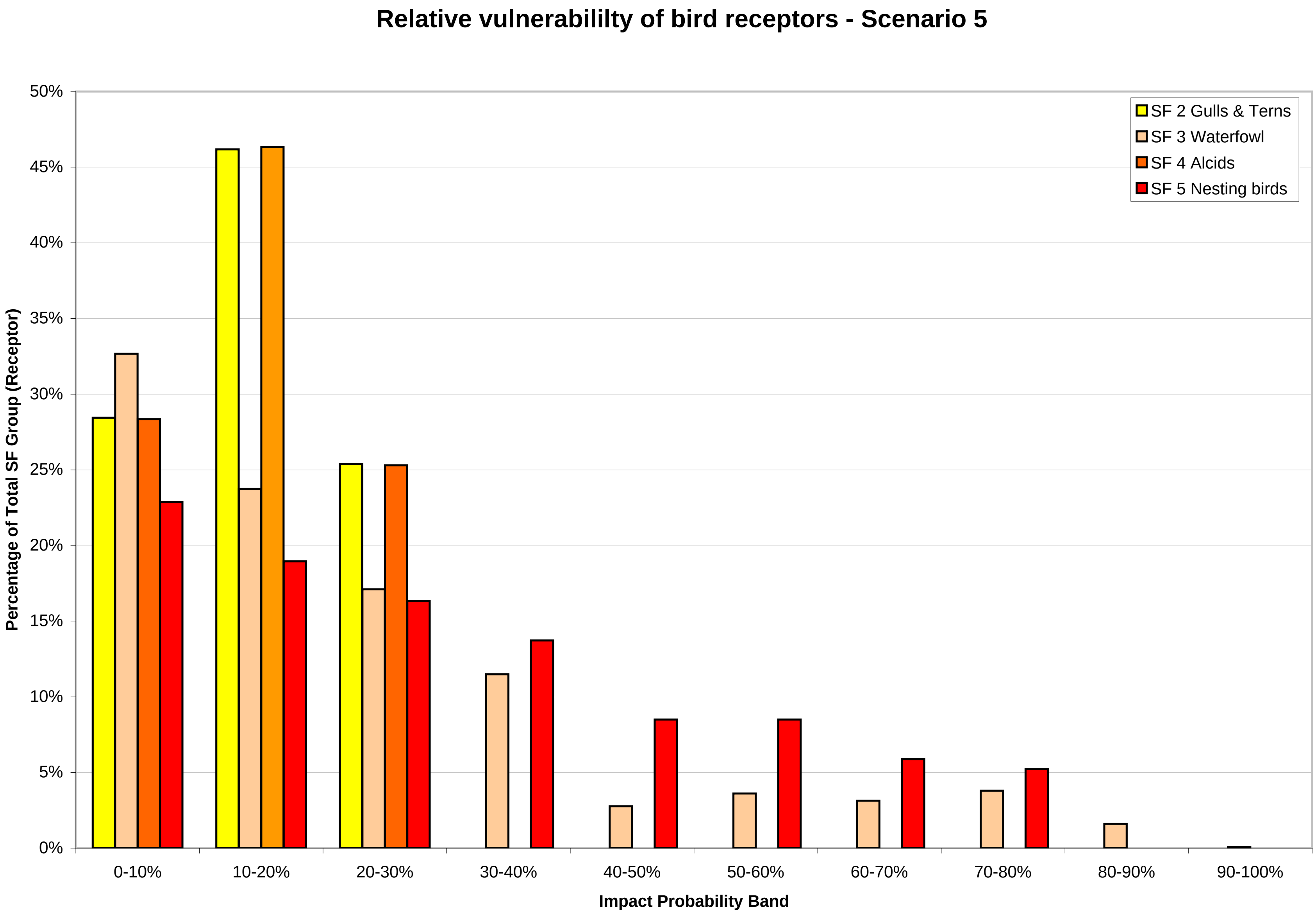


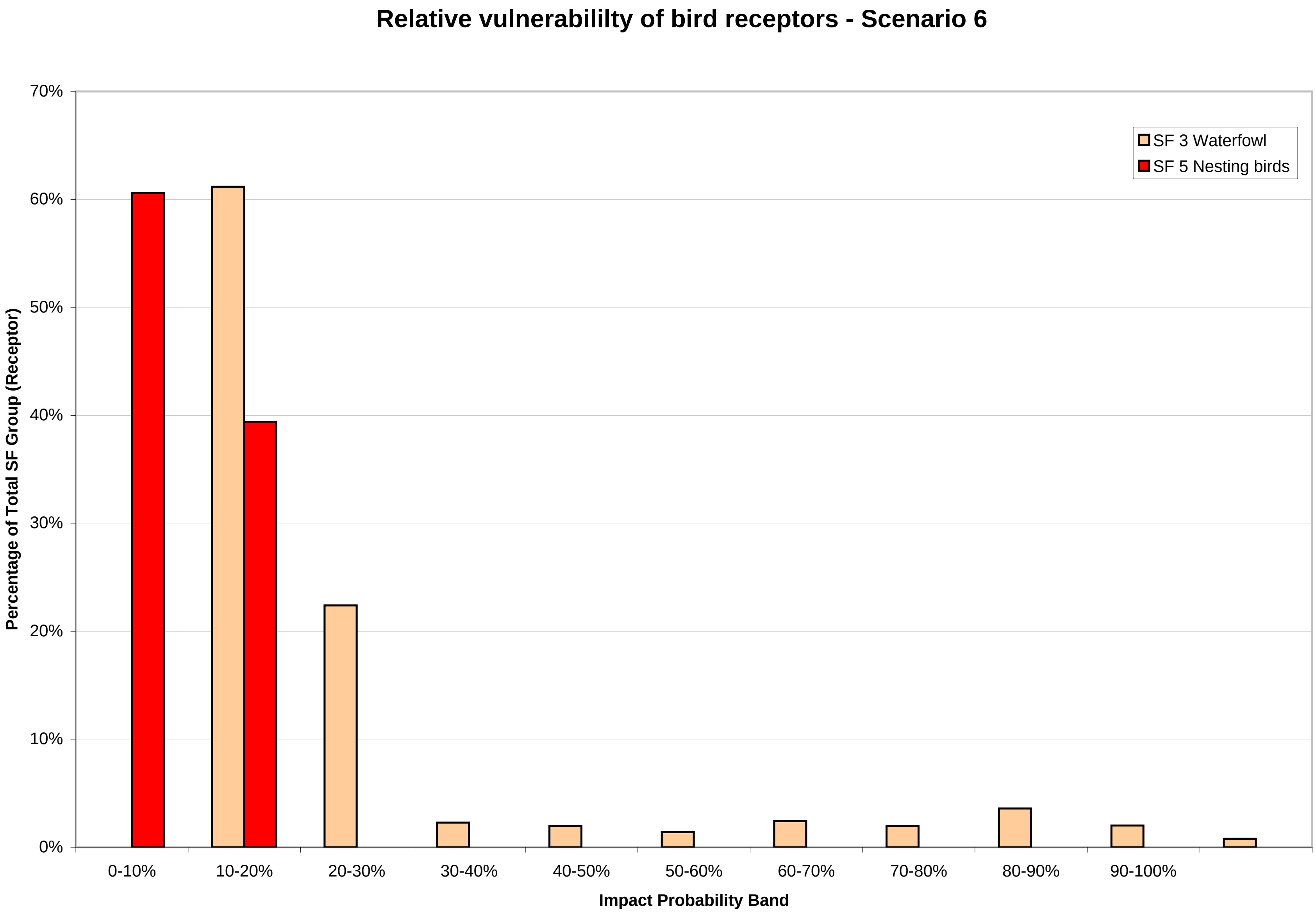
Relative vulnerabililty of bird receptors - Scenario 2
120%
100%
80%
60%
40%
20%
0%
Percentage of Total SF Group (Receptor)
SF 2 Gulls & Terns
SF 3 Waterfowl
SF 4 Alcids
SF 5 Nesting birds
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability Band

Relative vulnerabililty of bird receptors - Scenario 3

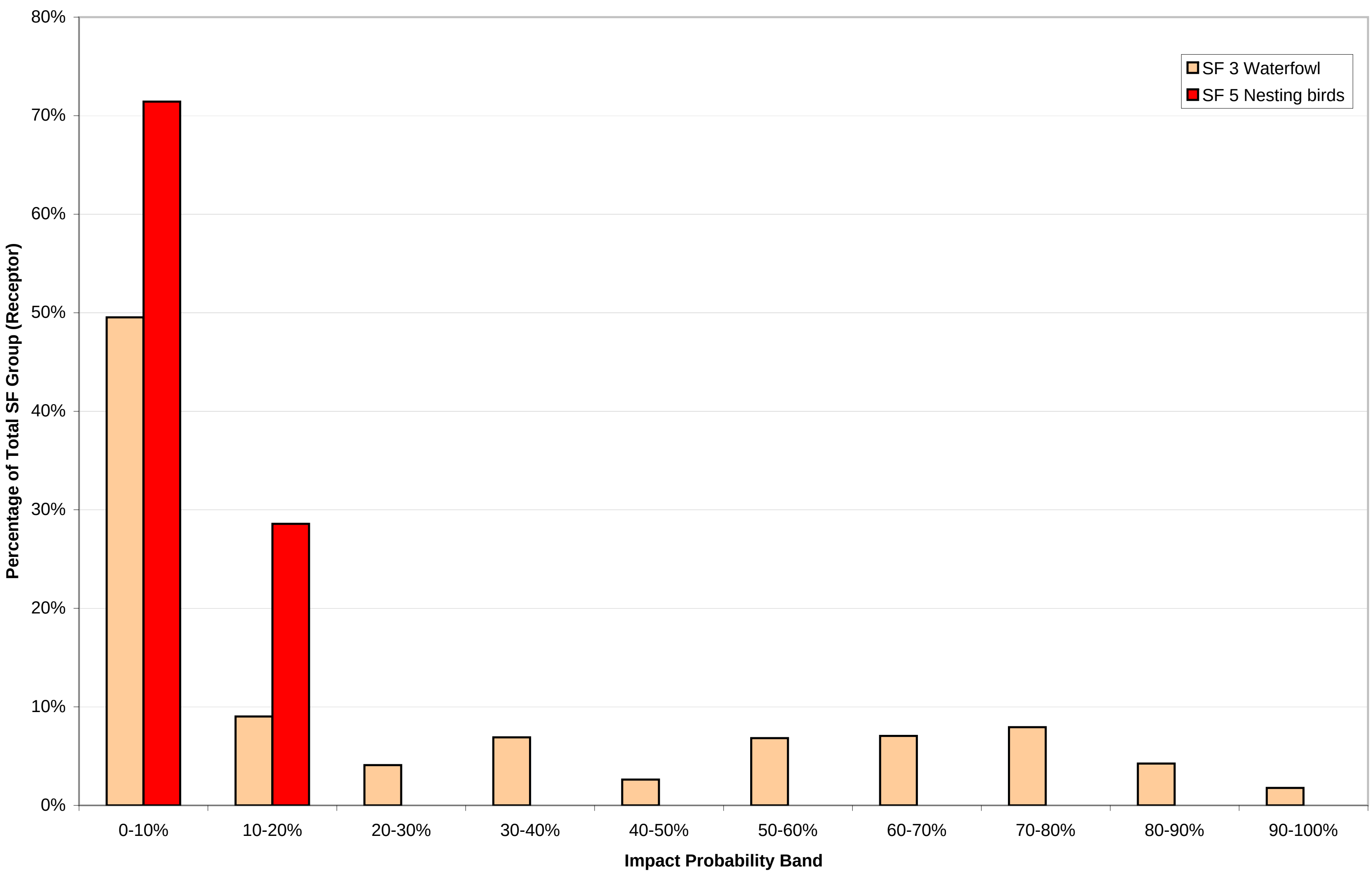


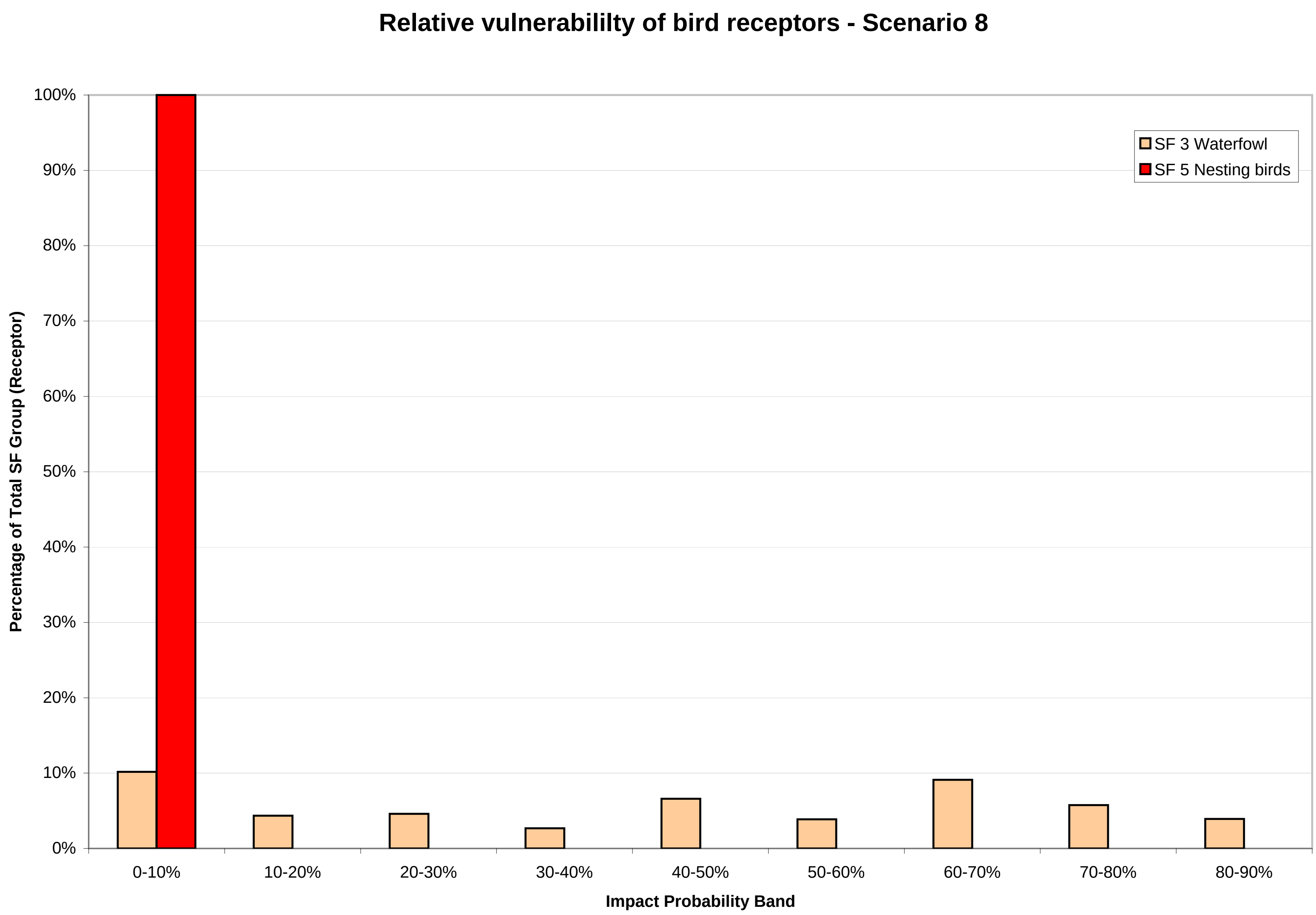

Relative vulnerabililty of bird receptors - Scenario 4
SF 2 Gulls & Terns
SF 3 Waterfowl
SF 4 Alcids
SF 5 Nesting birds
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
Percentage of Total SF Group (Receptor)
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability Band

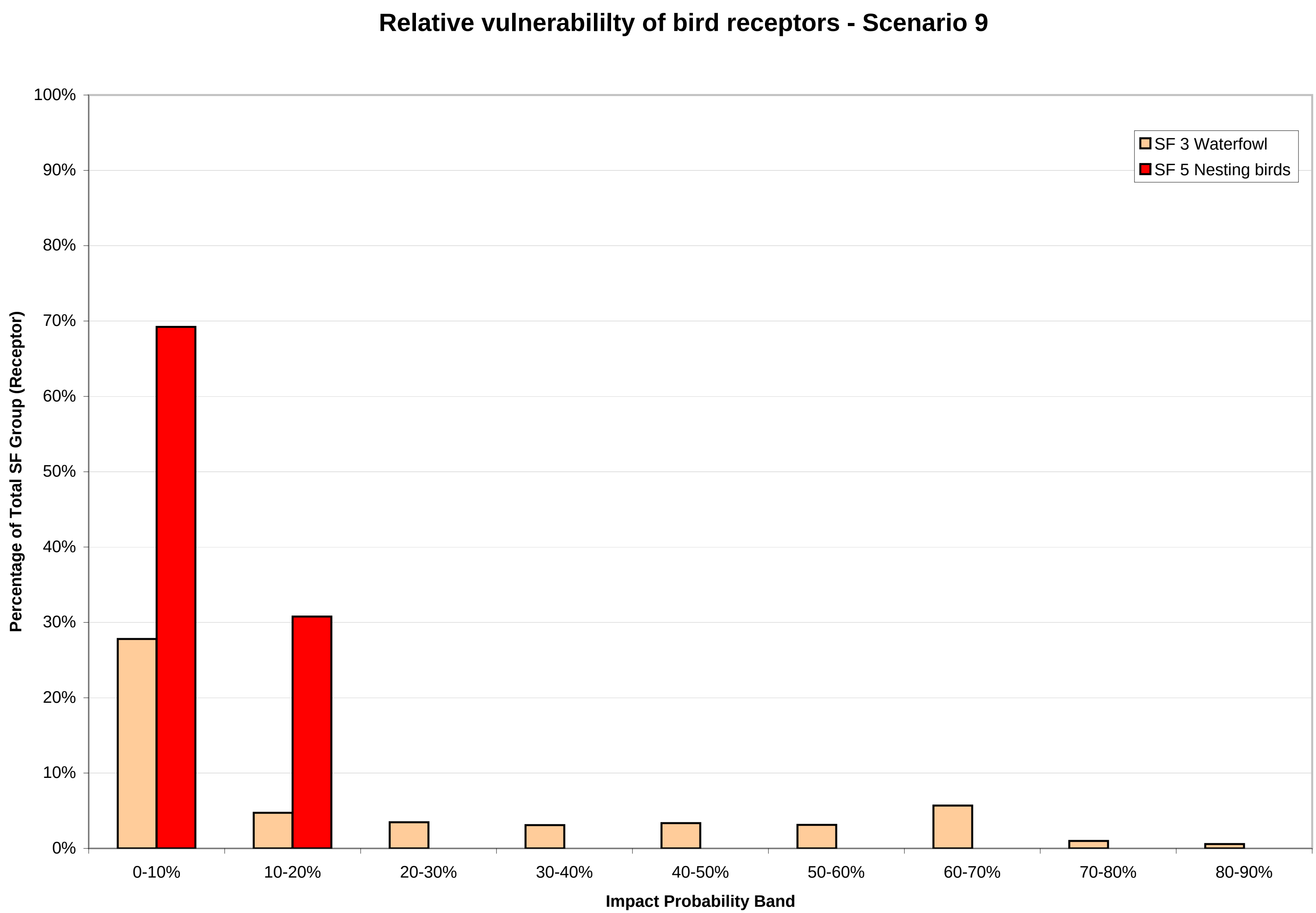

Relative vulnerabililty of bird receptors - Scenario 5
Percentage of Total SF Group (Receptor)
0%
5%
10%
15%
20%
25%
30%
35%
40%
45%
50%
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability Band
SF 2 Gulls & Terns
SF 3 Waterfowl
SF 4 Alcids
SF 5 Nesting birds

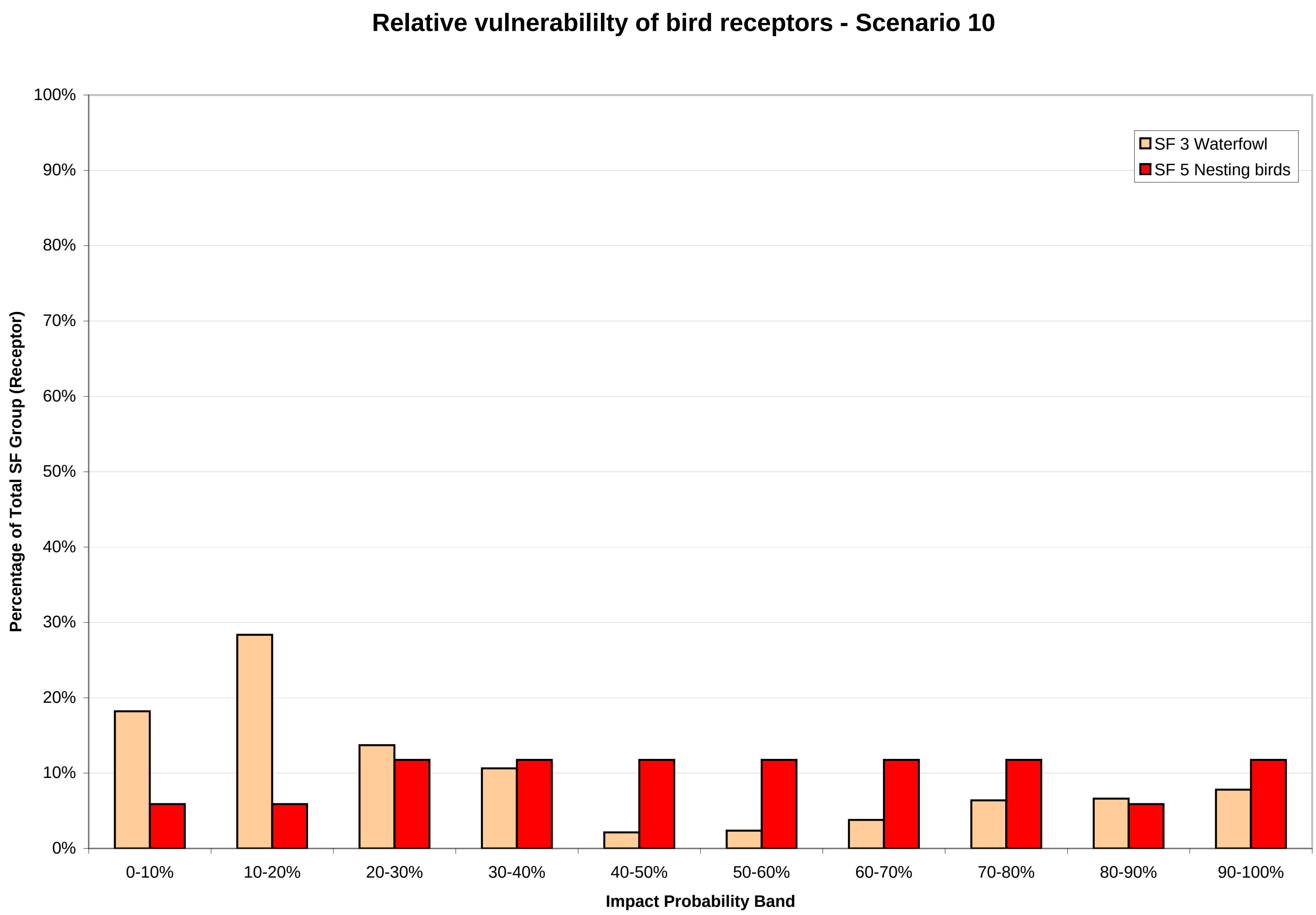

Relative vulnerabililty of bird receptors - Scenario 6
70%
60%
50%
40%
30%
20%
10%
0%
Percentage of Total SF Group (Receptor)
SF 3 Waterfowl
SF 5 Nesting birds
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability Band

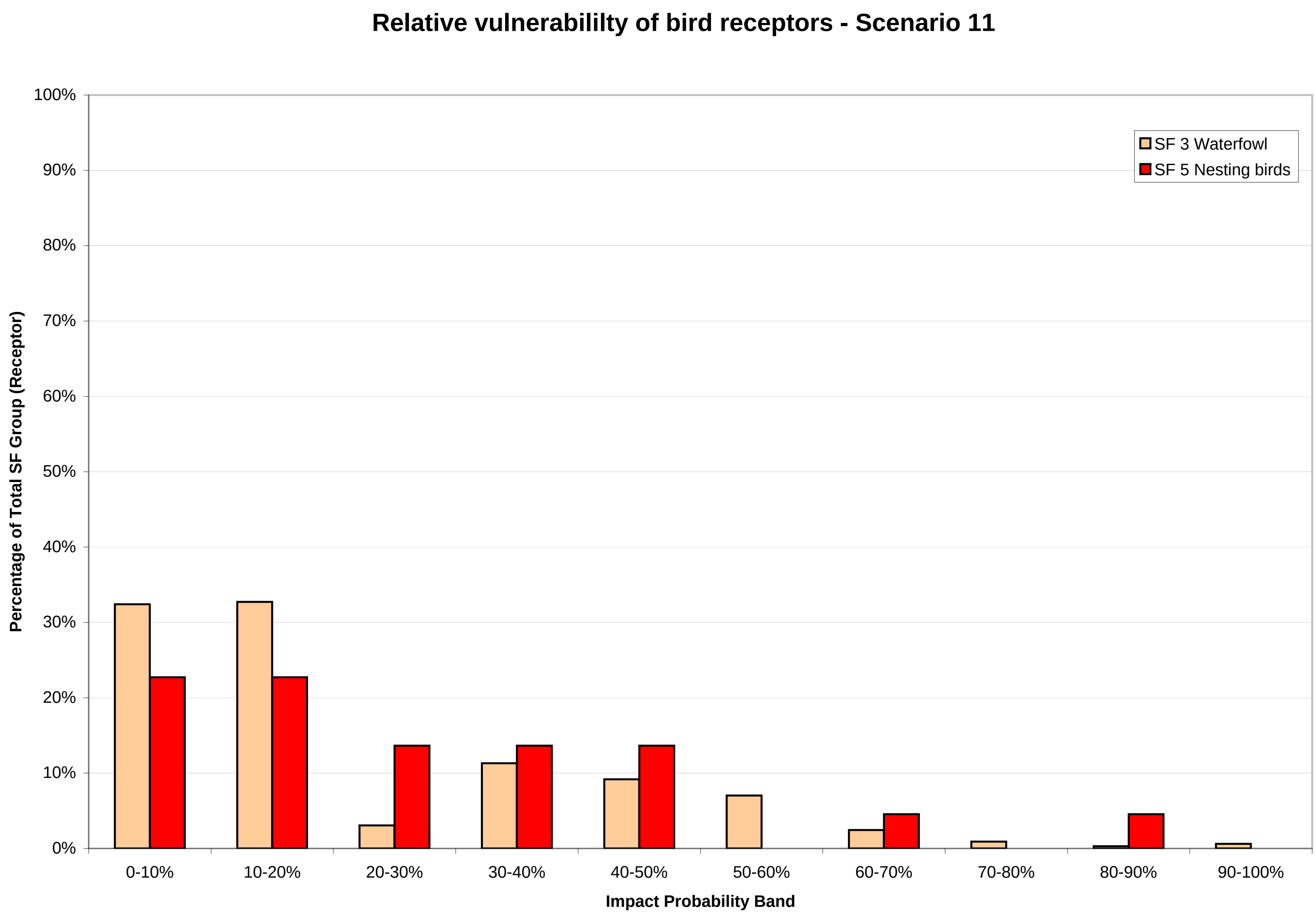
Relative vulnerabililty of bird receptors - Scenario 7

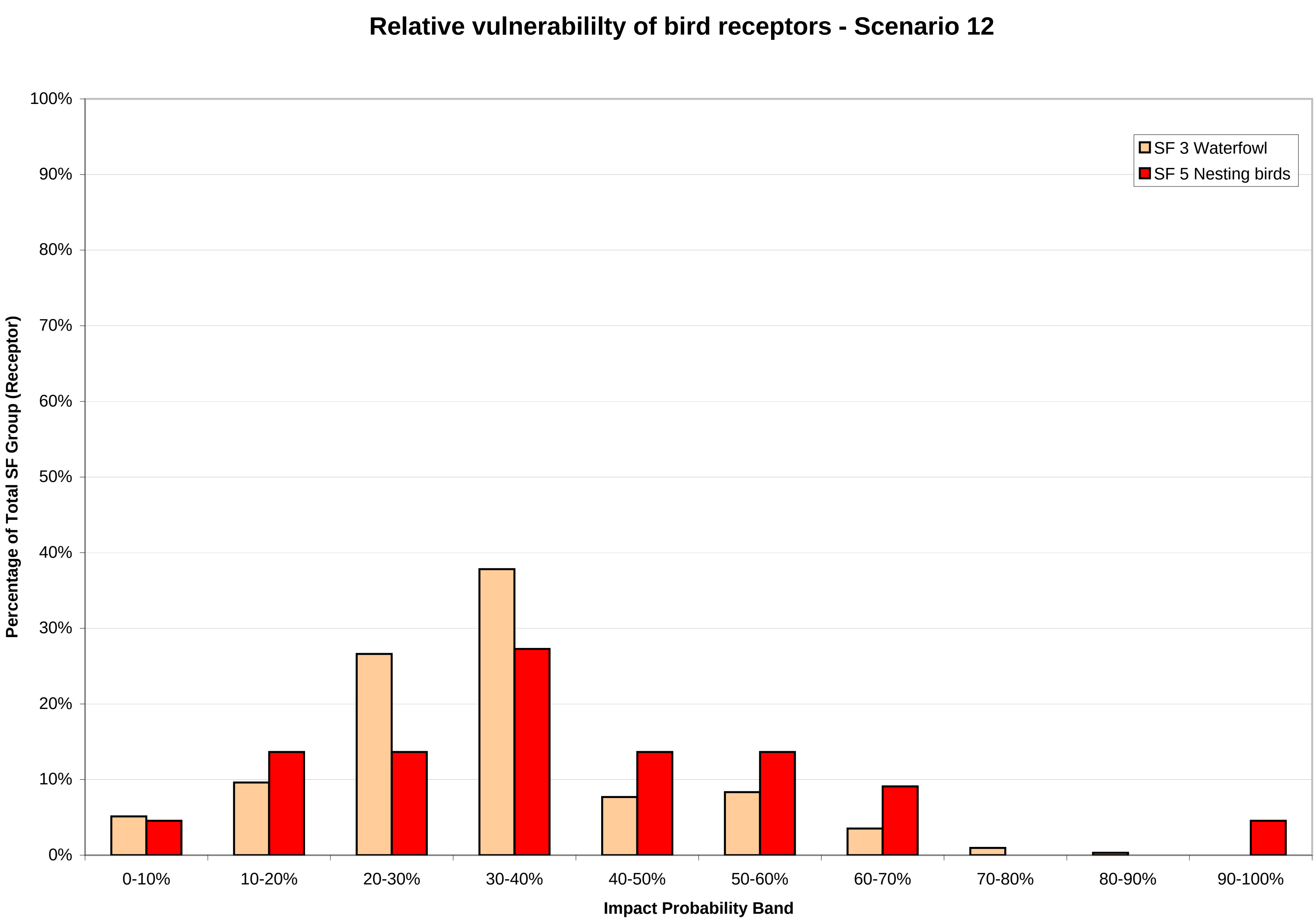



Relative vulnerabililty of bird receptors - Scenario 8
Percentage of Total SF Group (Receptor)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
Impact Probability Band
SF 3 Waterfowl
SF 5 Nesting birds

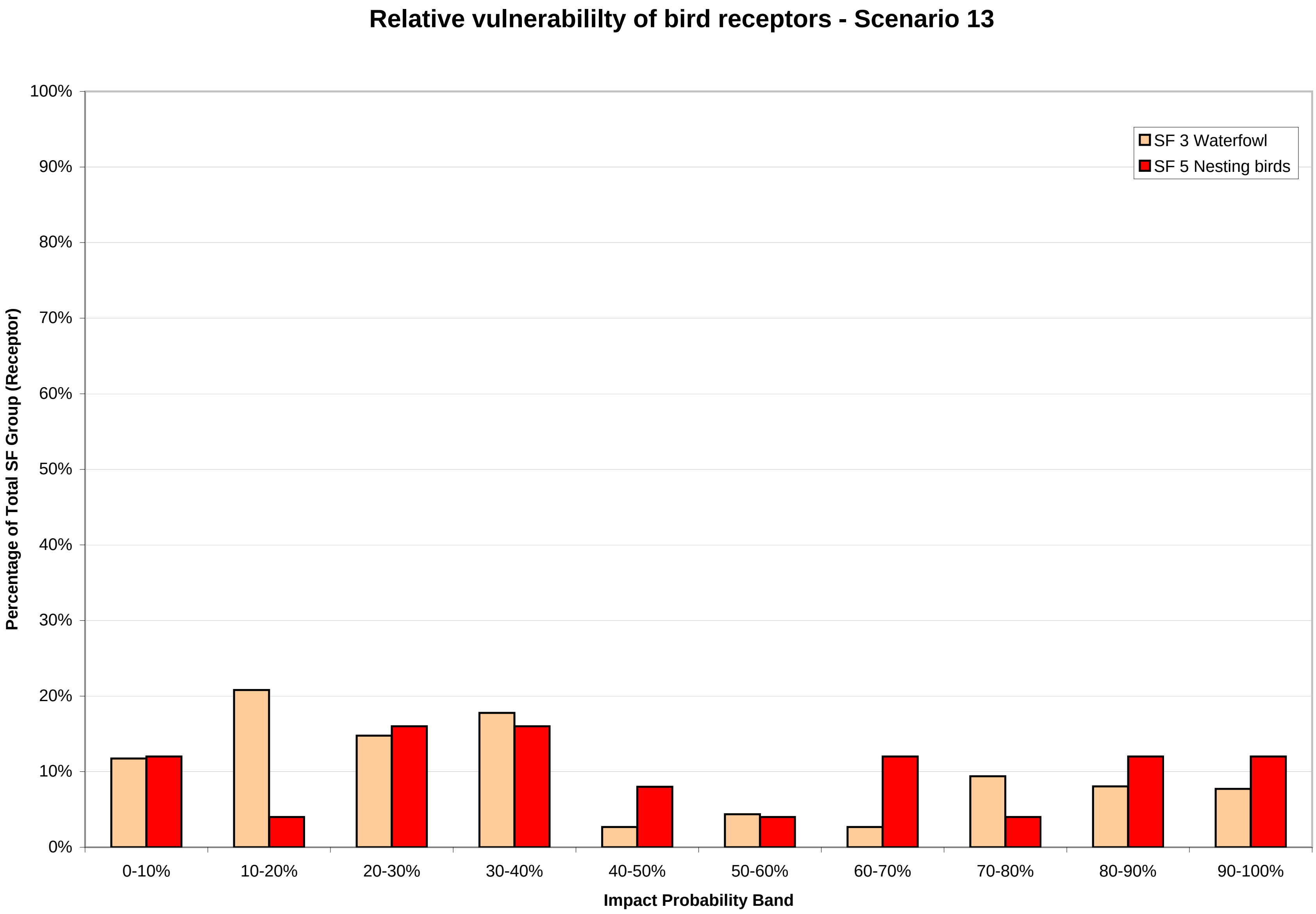

Relative vulnerabililty of bird receptors - Scenario 9
Percentage of Total SF Group (Receptor)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
SF 3 Waterfowl
SF 5 Nesting birds
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
Impact Probability Band

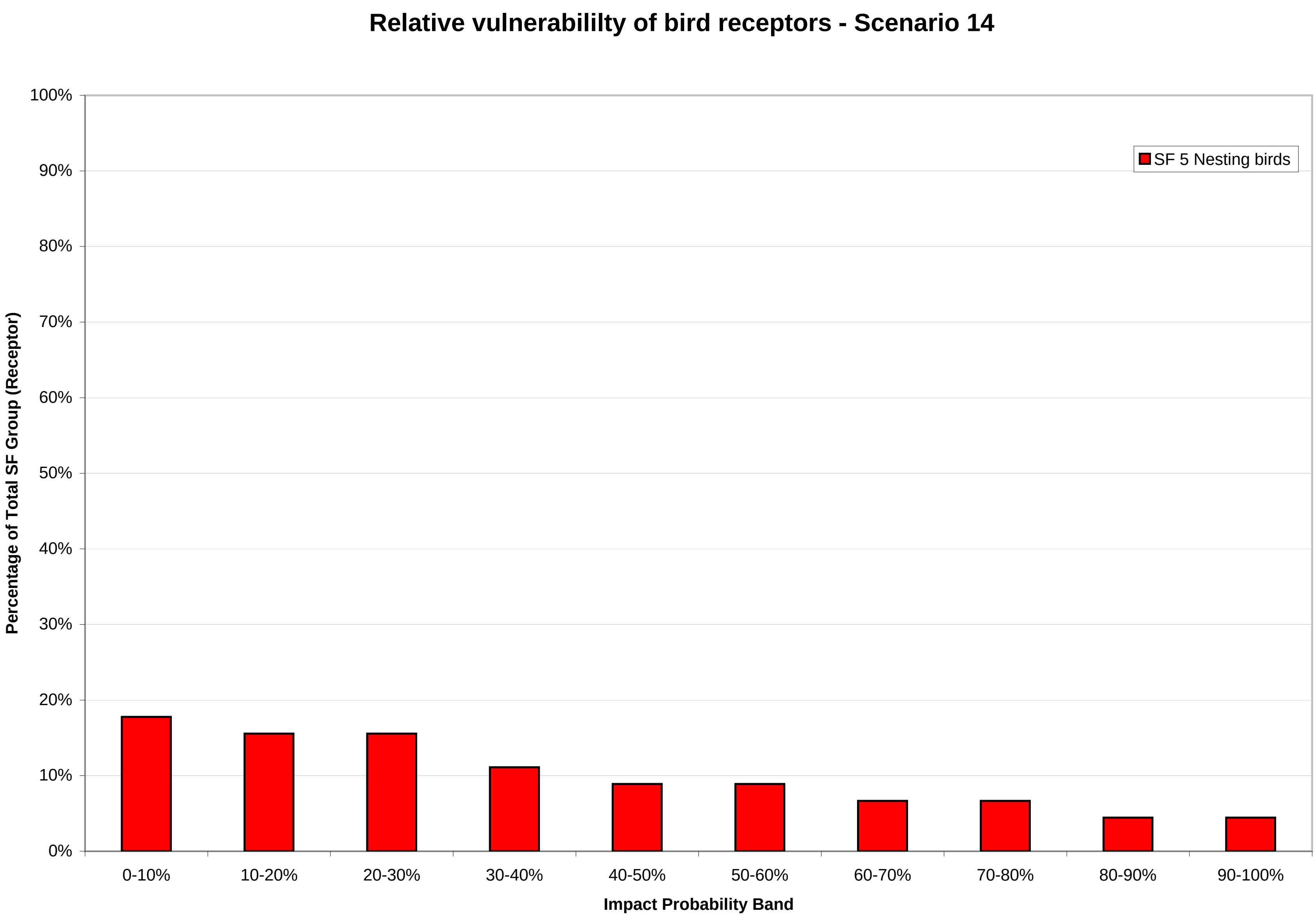

Relative vulnerabililty of bird receptors - Scenario 10
SF 3 Waterfowl
SF 5 Nesting birds
Percentage of Total SF Group (Receptor)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability Band

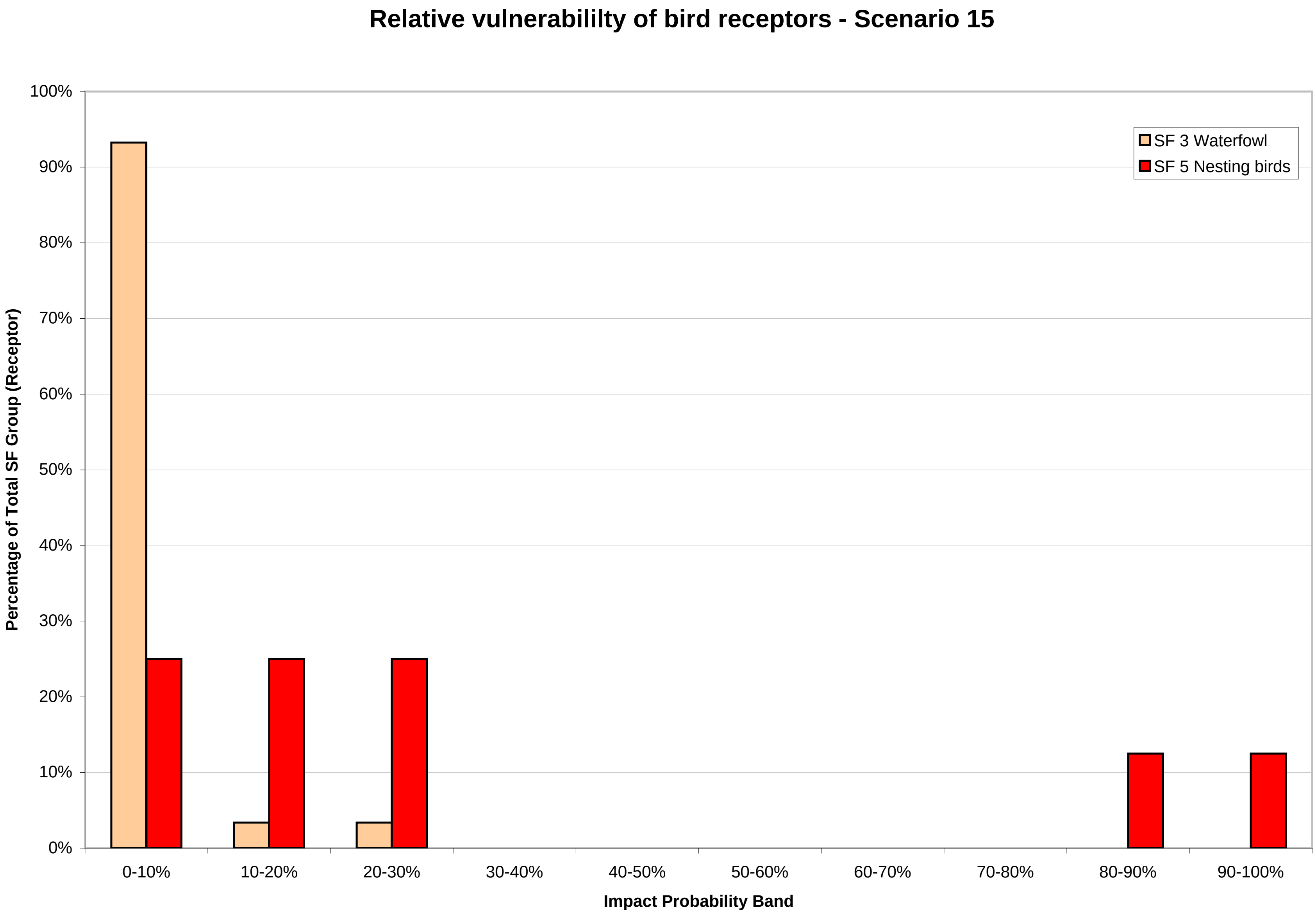

Relative vulnerabililty of bird receptors - Scenario 11
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percentage of Total SF Group (Receptor)
SF 3 Waterfowl
SF 5 Nesting birds
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability Band

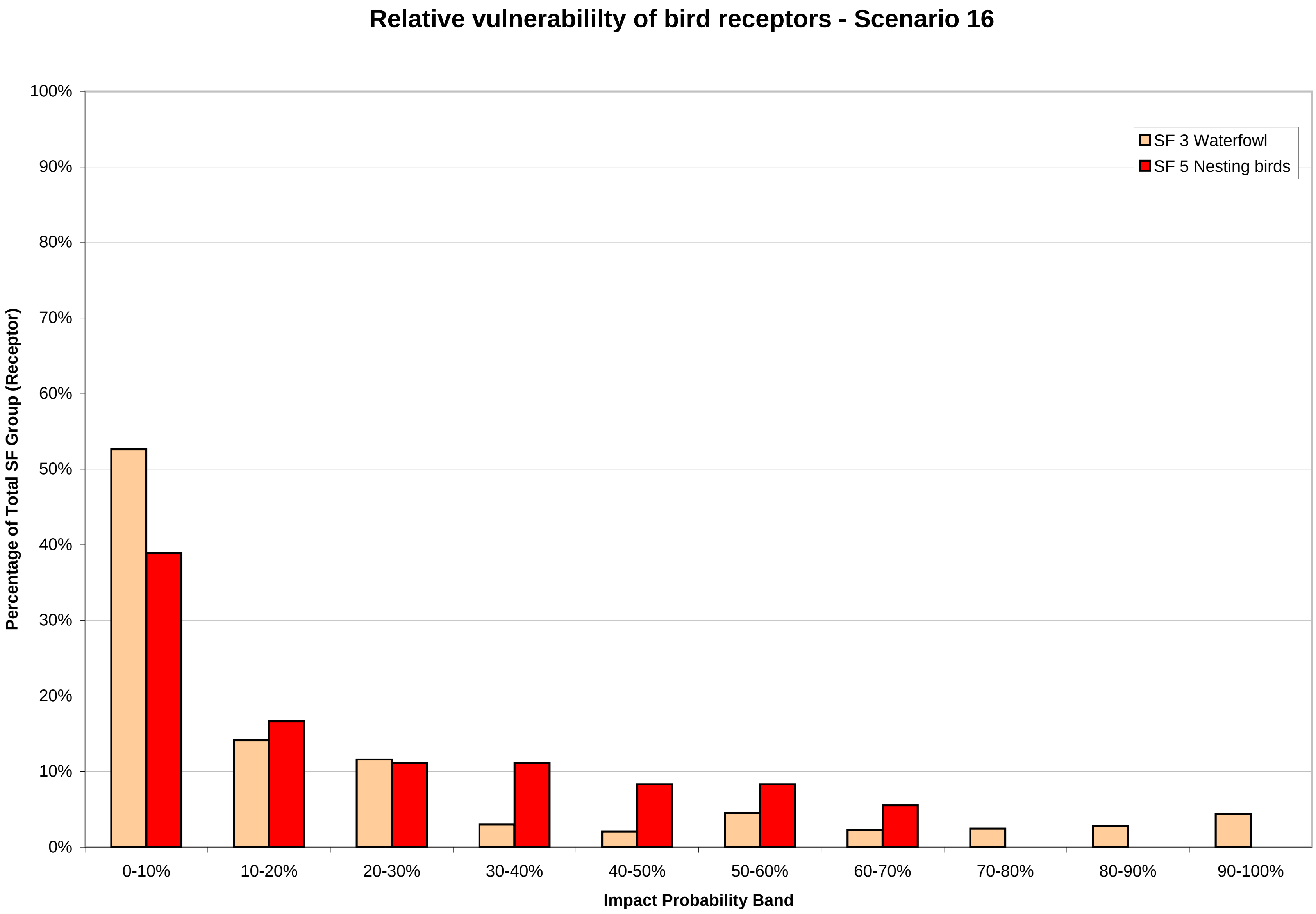


Relative vulnerabililty of bird receptors - Scenario 12
SF 3 Waterfowl
SF 5 Nesting birds
Percentage of Total SF Group (Receptor)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability Band


Relative vulnerabililty of bird receptors - Scenario 13
SF 3 Waterfowl
SF 5 Nesting birds
Percentage of Total SF Group (Receptor)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability Band

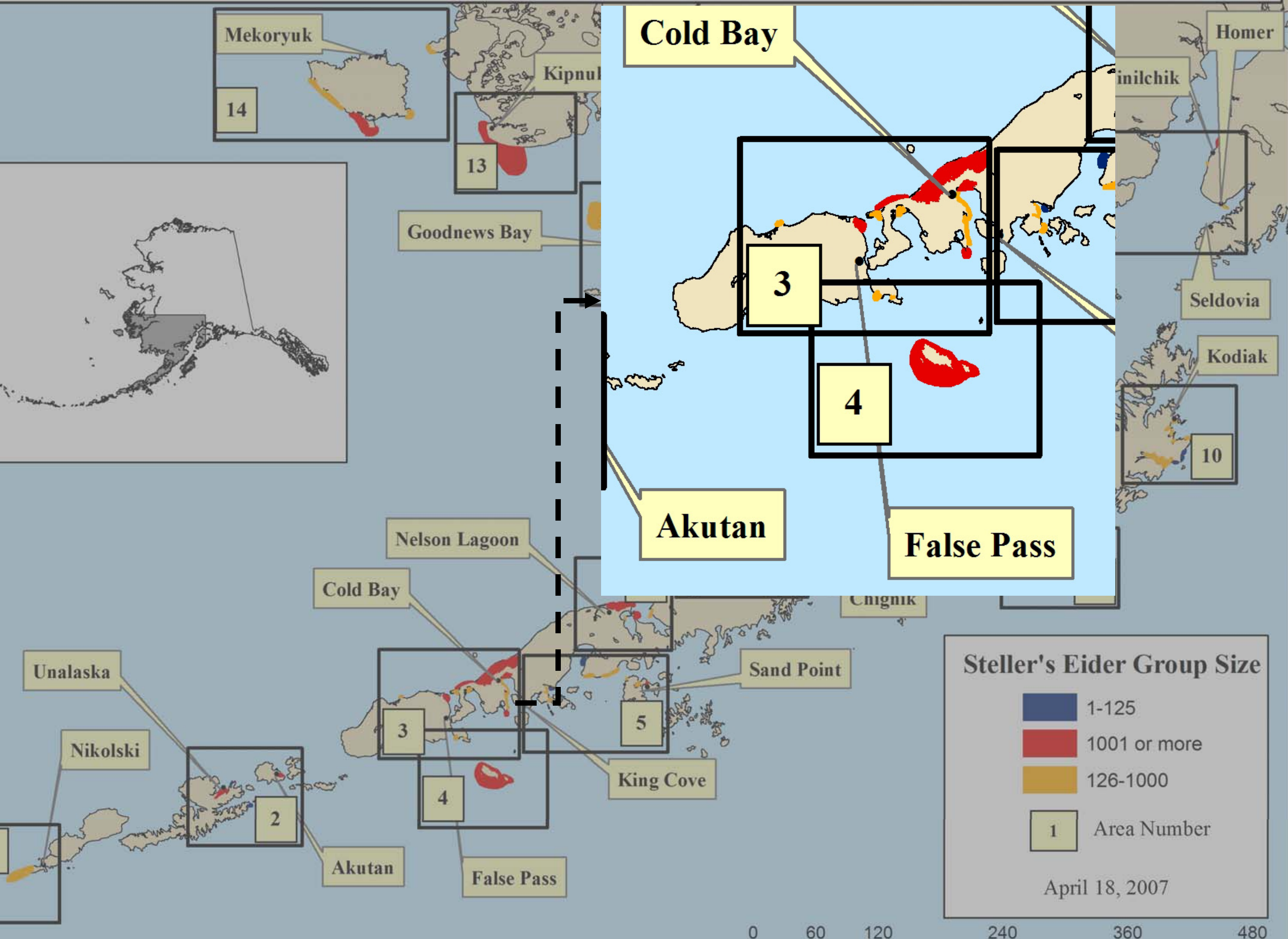

Relative vulnerabililty of bird receptors - Scenario 14
SF 5 Nesting birds
Percentage of Total SF Group (Receptor)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability Band


Relative vulnerabililty of bird receptors - Scenario 15
SF 3 Waterfowl
SF 5 Nesting birds
Percentage of Total SF Group (Receptor)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability Band

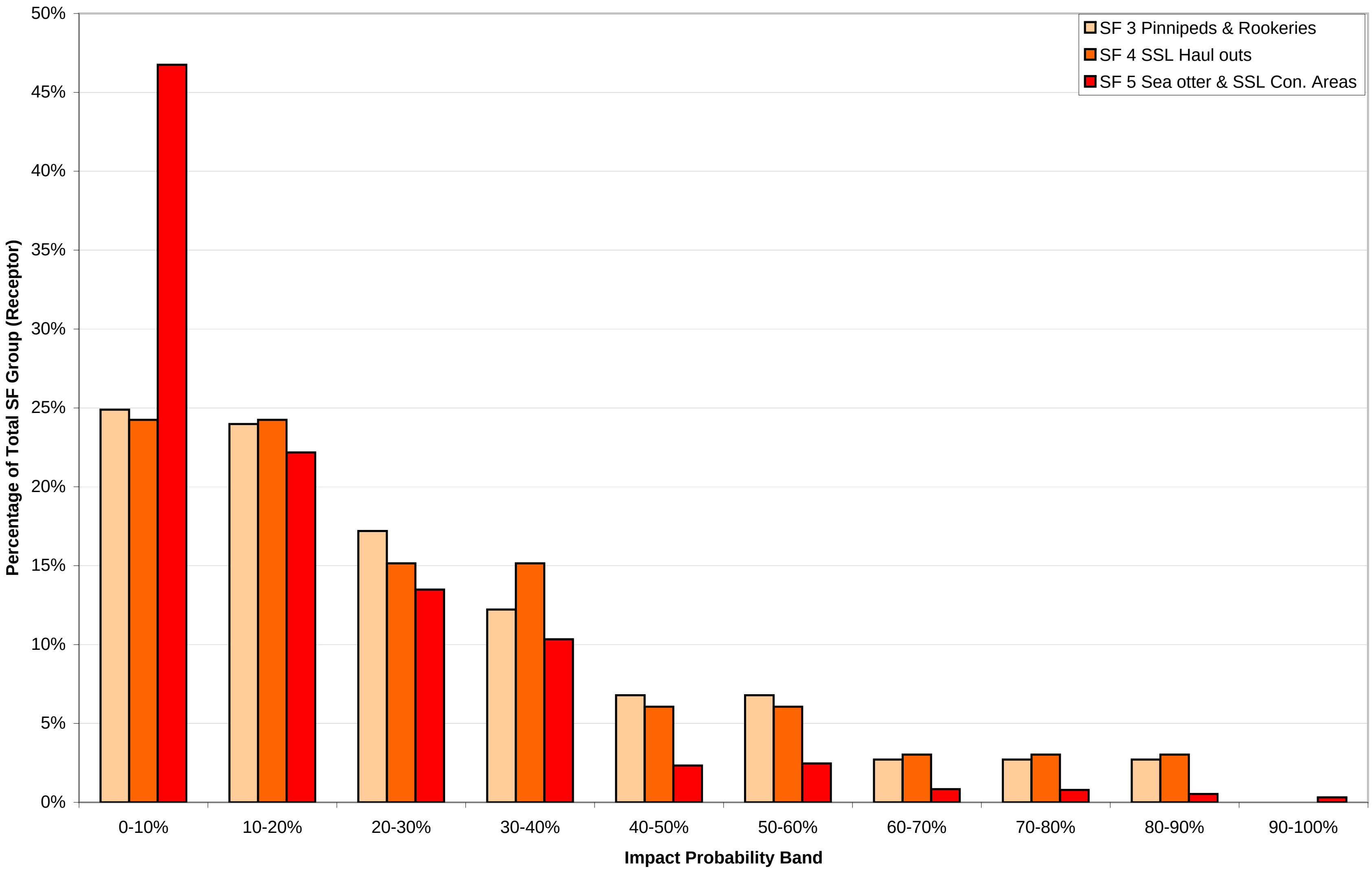


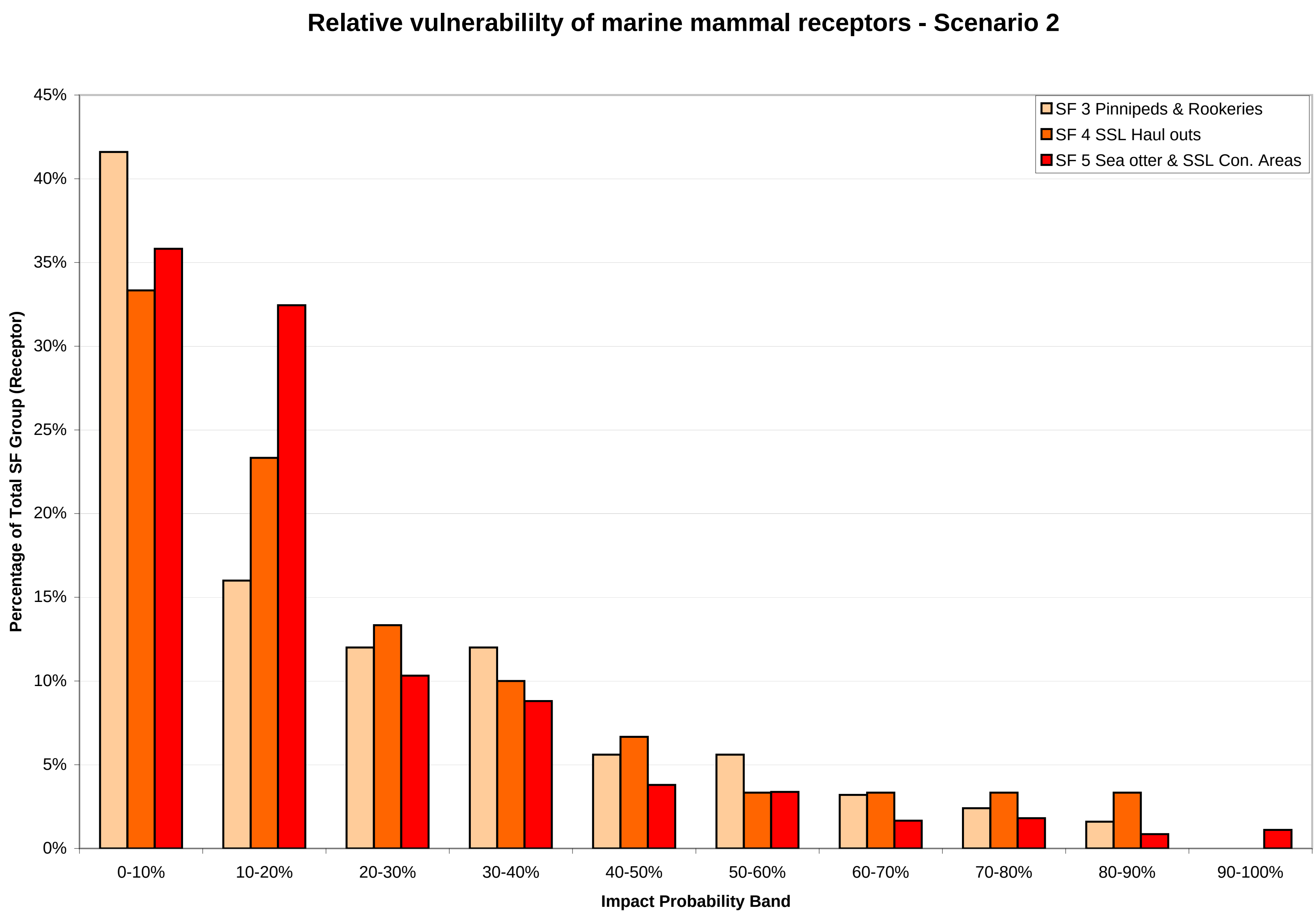
Relative vulnerabililty of bird receptors - Scenario 16
Percentage of Total SF Group (Receptor)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
SF 3 Waterfowl
SF 5 Nesting birds
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability Band

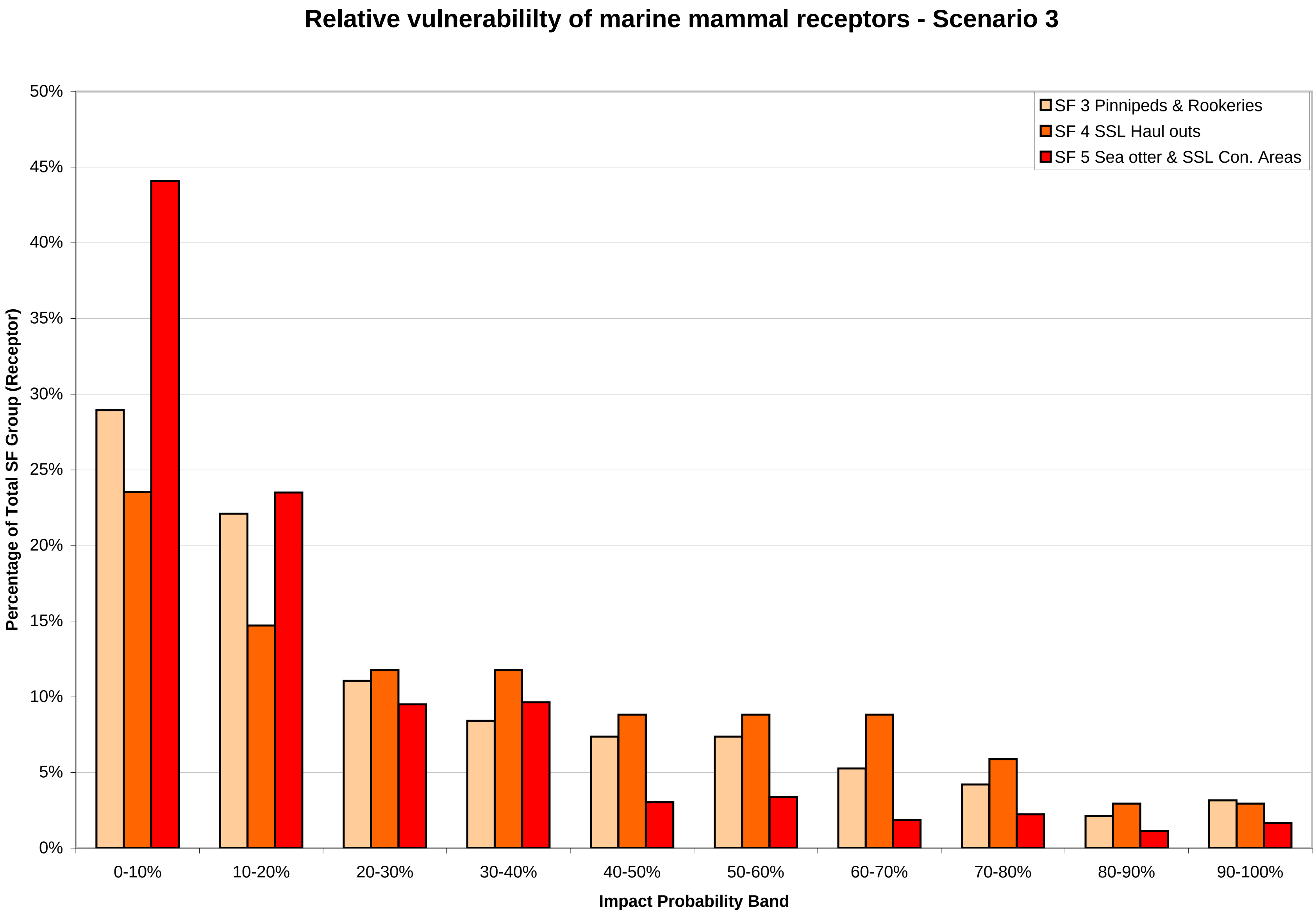
Known Steller's Eider Winter and Molting Distribution - Reference Map



Relative vulnerabililty of marine mammal receptors - Scenario 1

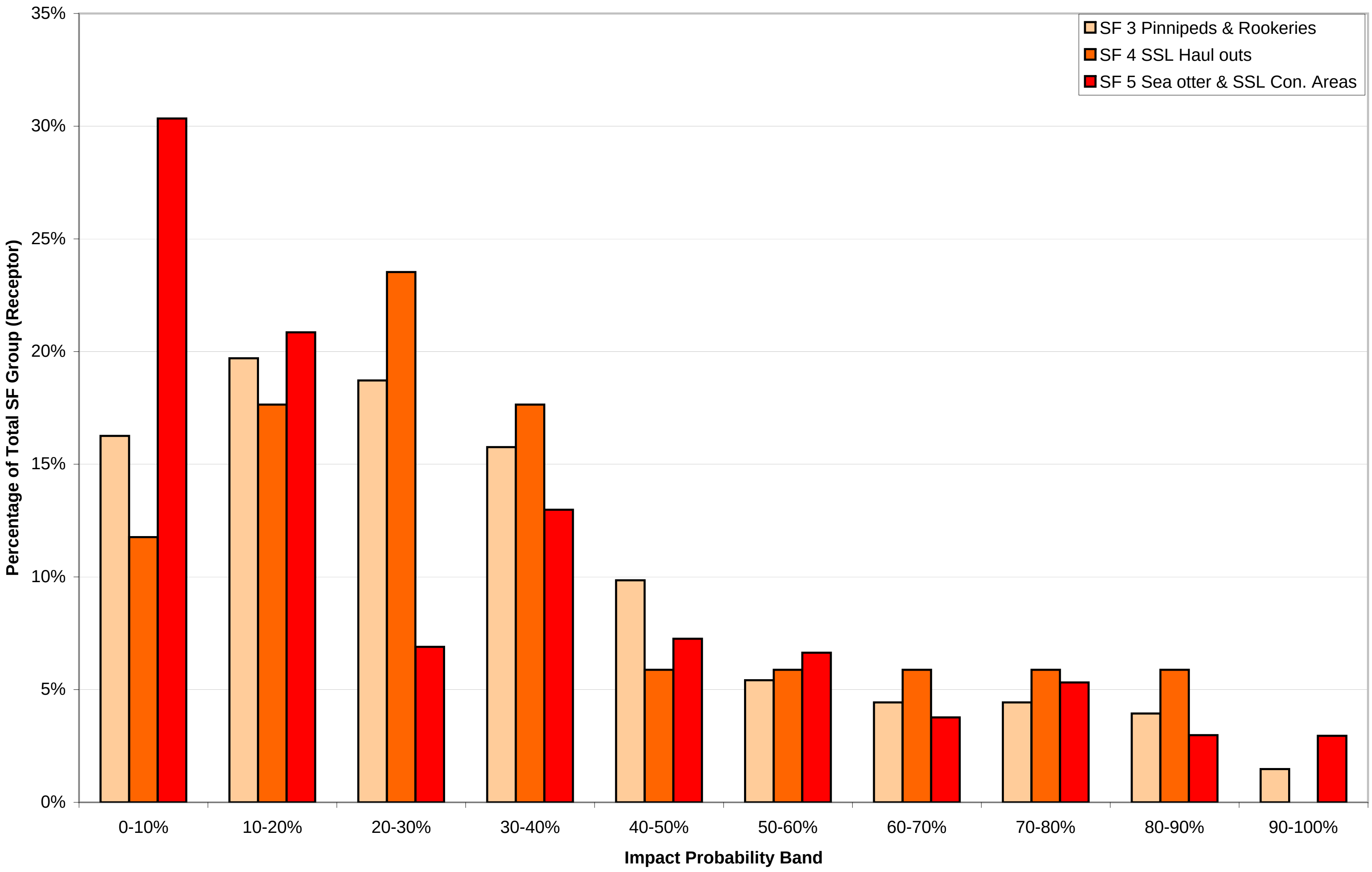


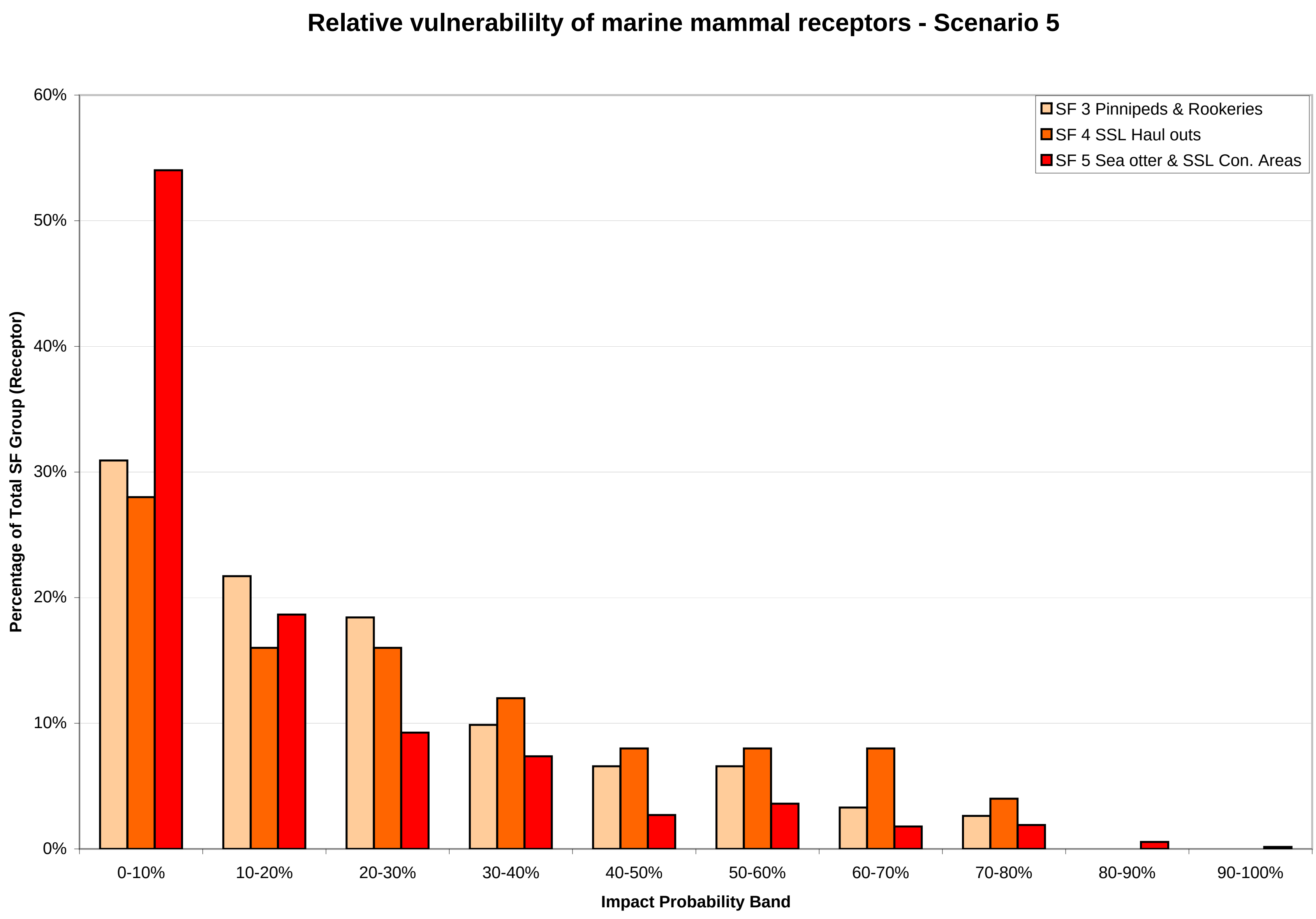

Relative vulnerabililty of marine mammal receptors - Scenario 2
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
Percentage of Total SF Group (Receptor)
SF 3 Pinnipeds & Rookeries
SF 4 SSL Haul outs
SF 5 Sea otter & SSL Con. Areas
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability Band

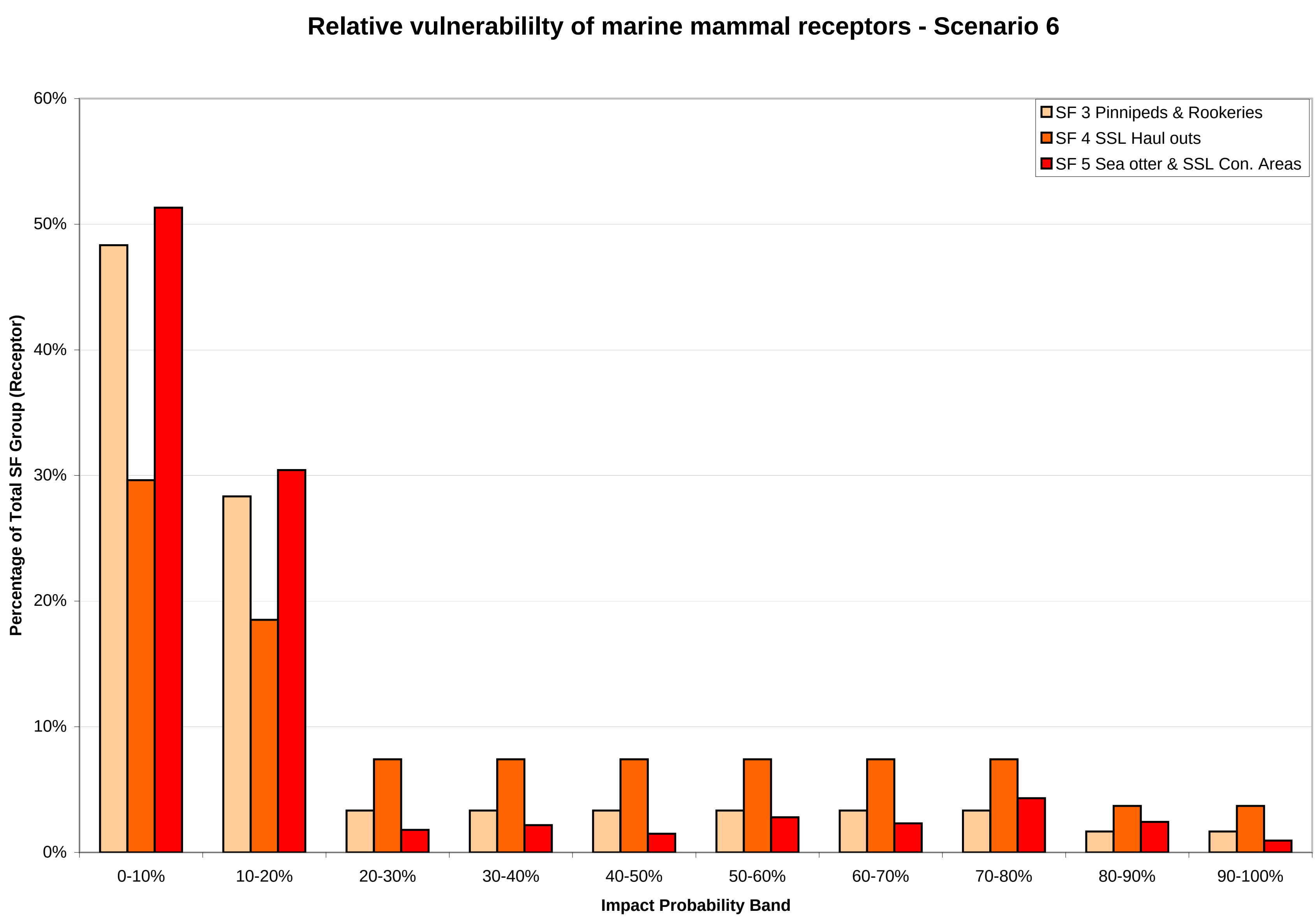


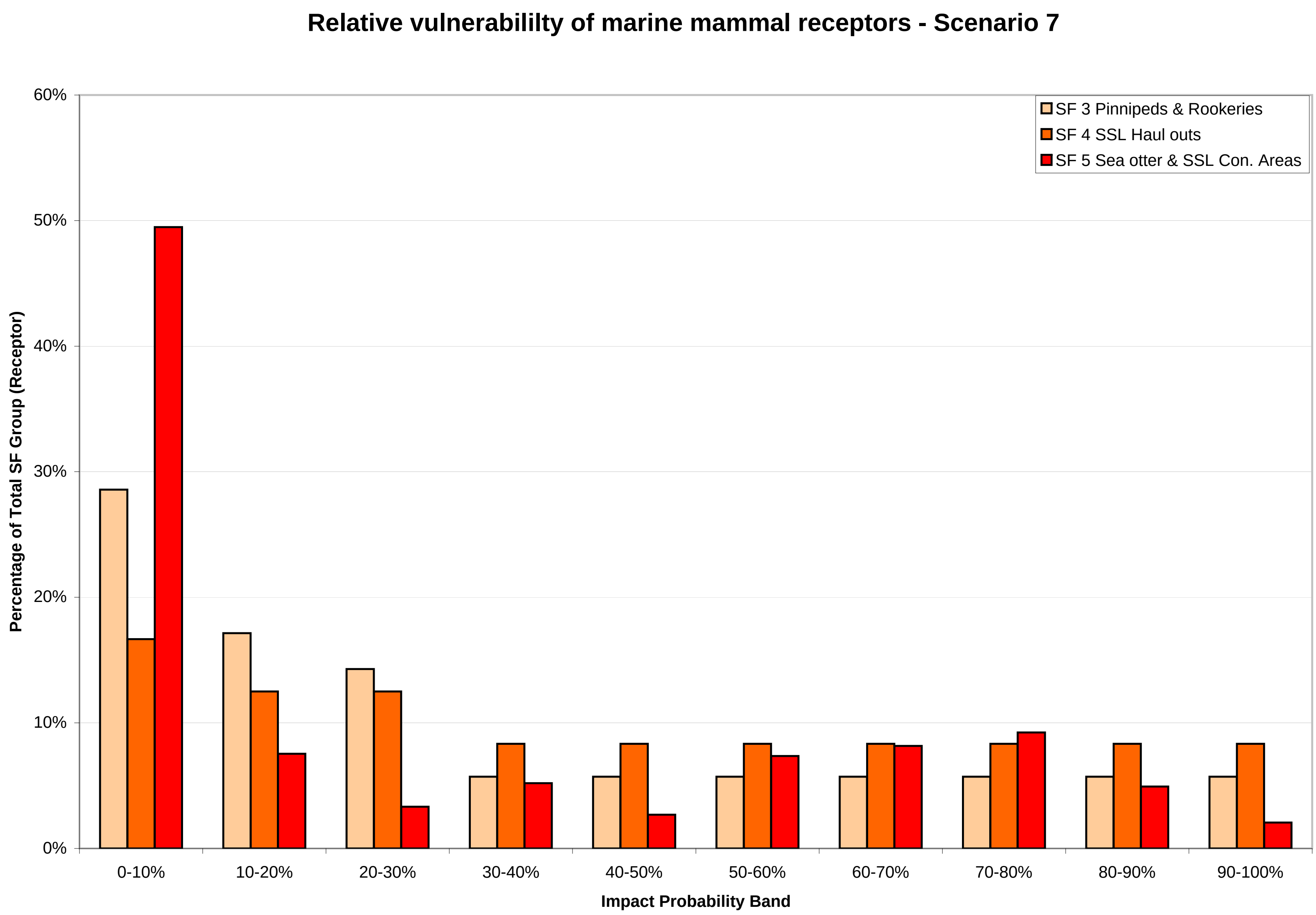
Relative vulnerabililty of marine mammal receptors - Scenario 3
Percentage of Total SF Group (Receptor)
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
SF 3 Pinnipeds & Rookeries
SF 4 SSL Haul outs
SF 5 Sea otter & SSL Con. Areas
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability Band

Relative vulnerabililty of marine mammal receptors - Scenario 4

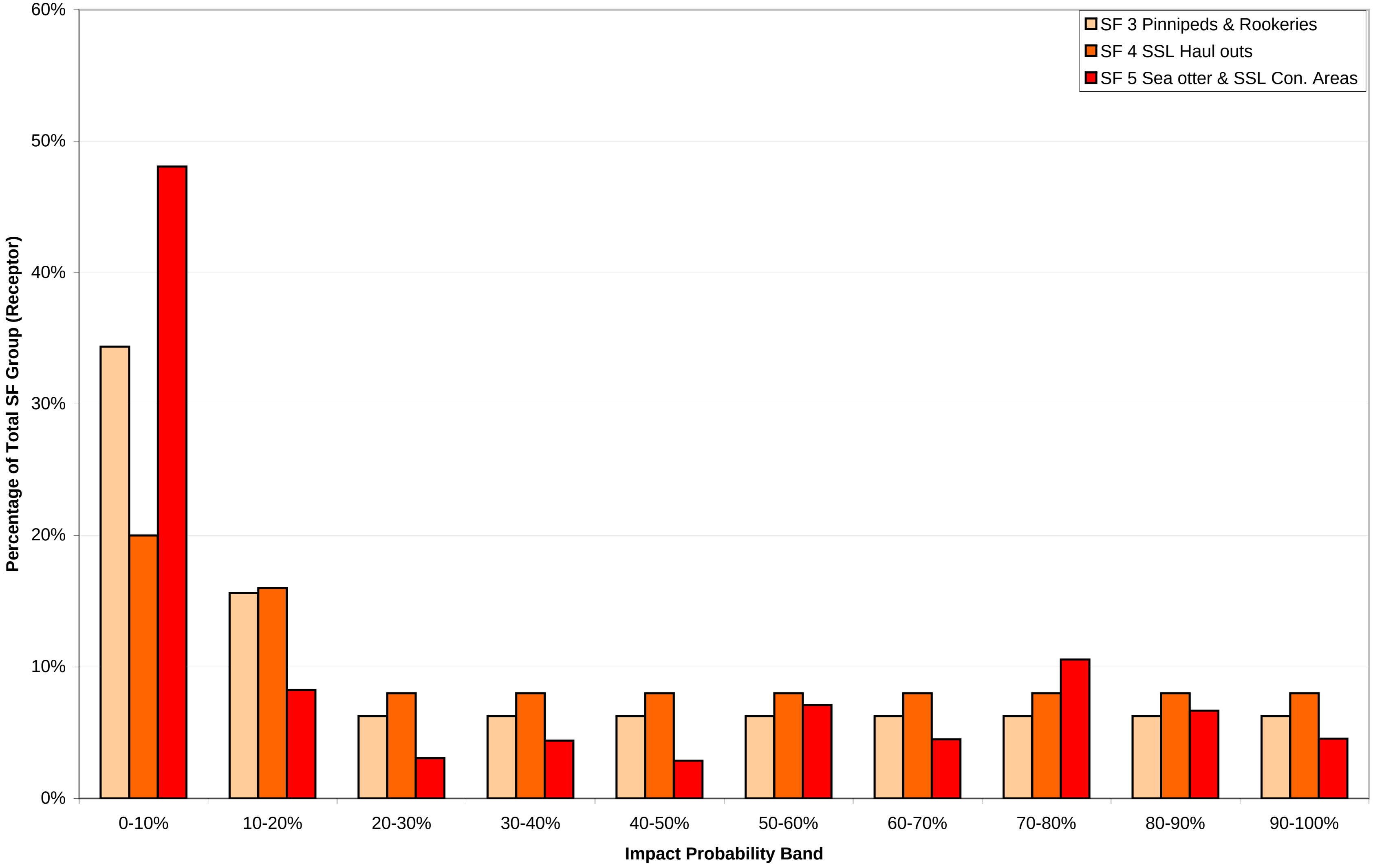



Relative vulnerabililty of marine mammal receptors - Scenario 5
Percentage of Total SF Group (Receptor)
60%
50%
40%
30%
20%
10%
0%
SF 3 Pinnipeds & Rookeries
SF 4 SSL Haul outs
SF 5 Sea otter & SSL Con. Areas
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability Band

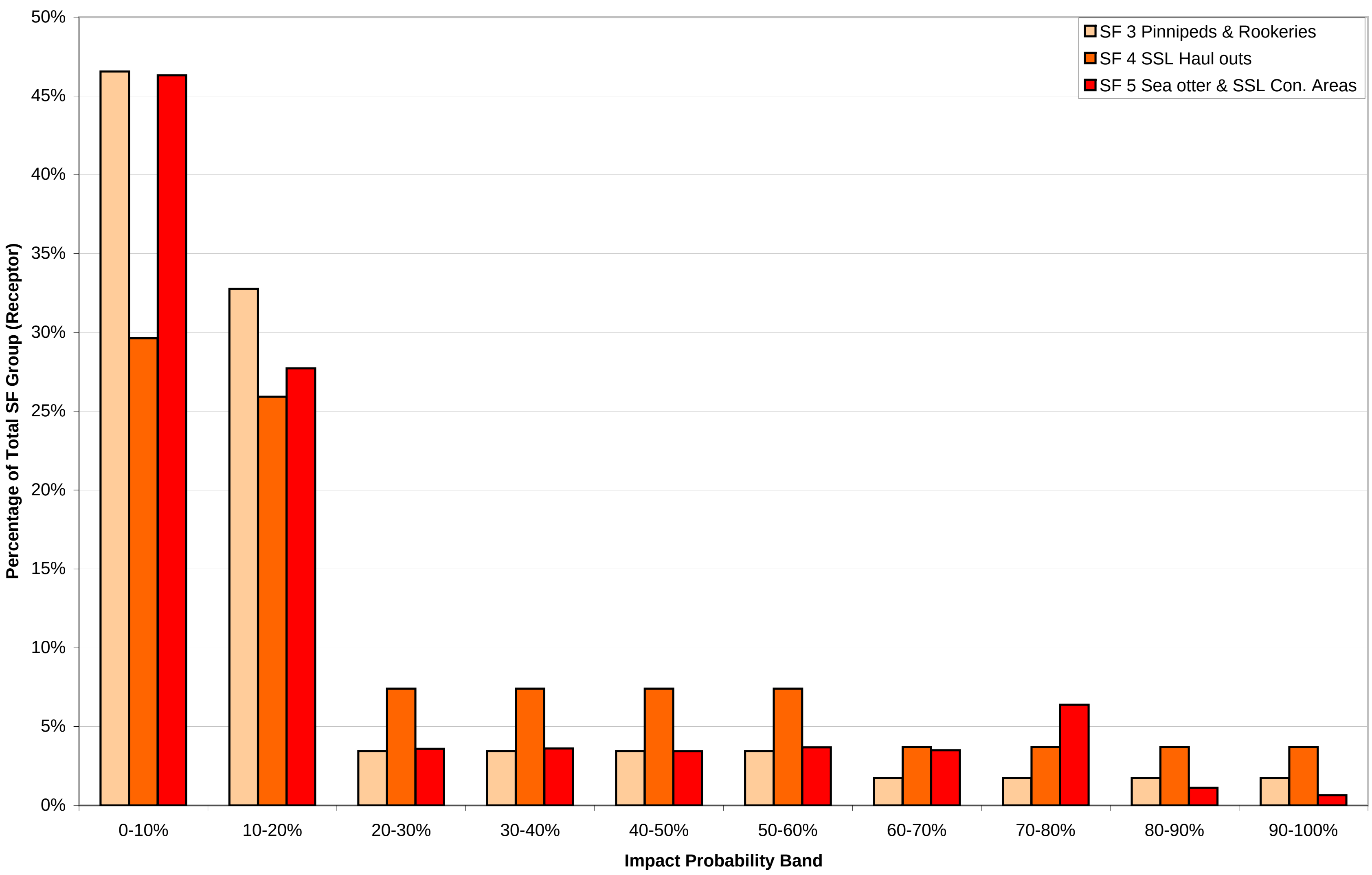

Relative vulnerabililty of marine mammal receptors - Scenario 6
SF 3 Pinnipeds & Rookeries
SF 4 SSL Haul outs
SF 5 Sea otter & SSL Con. Areas
Percentage of Total SF Group (Receptor)
60%
50%
40%
30%
20%
10%
0%
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability Band

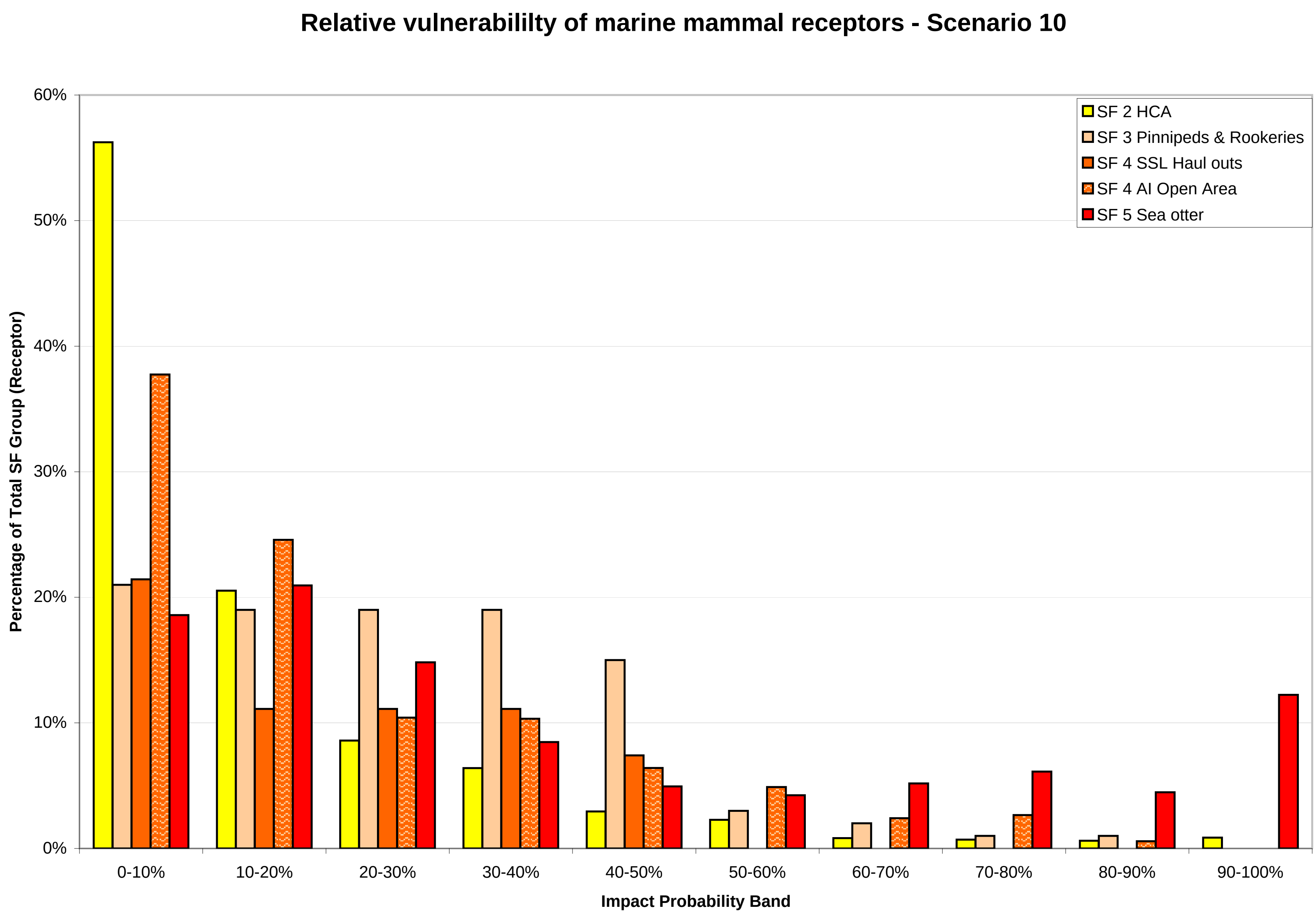

Relative vulnerabililty of marine mammal receptors - Scenario 7
SF 3 Pinnipeds & Rookeries
SF 4 SSL Haul outs
SF 5 Sea otter & SSL Con. Areas
60%
50%
40%
30%
20%
10%
0%
Percentage of Total SF Group (Receptor)
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability Band

Relative vulnerabililty of marine mammal receptors - Scenario 8

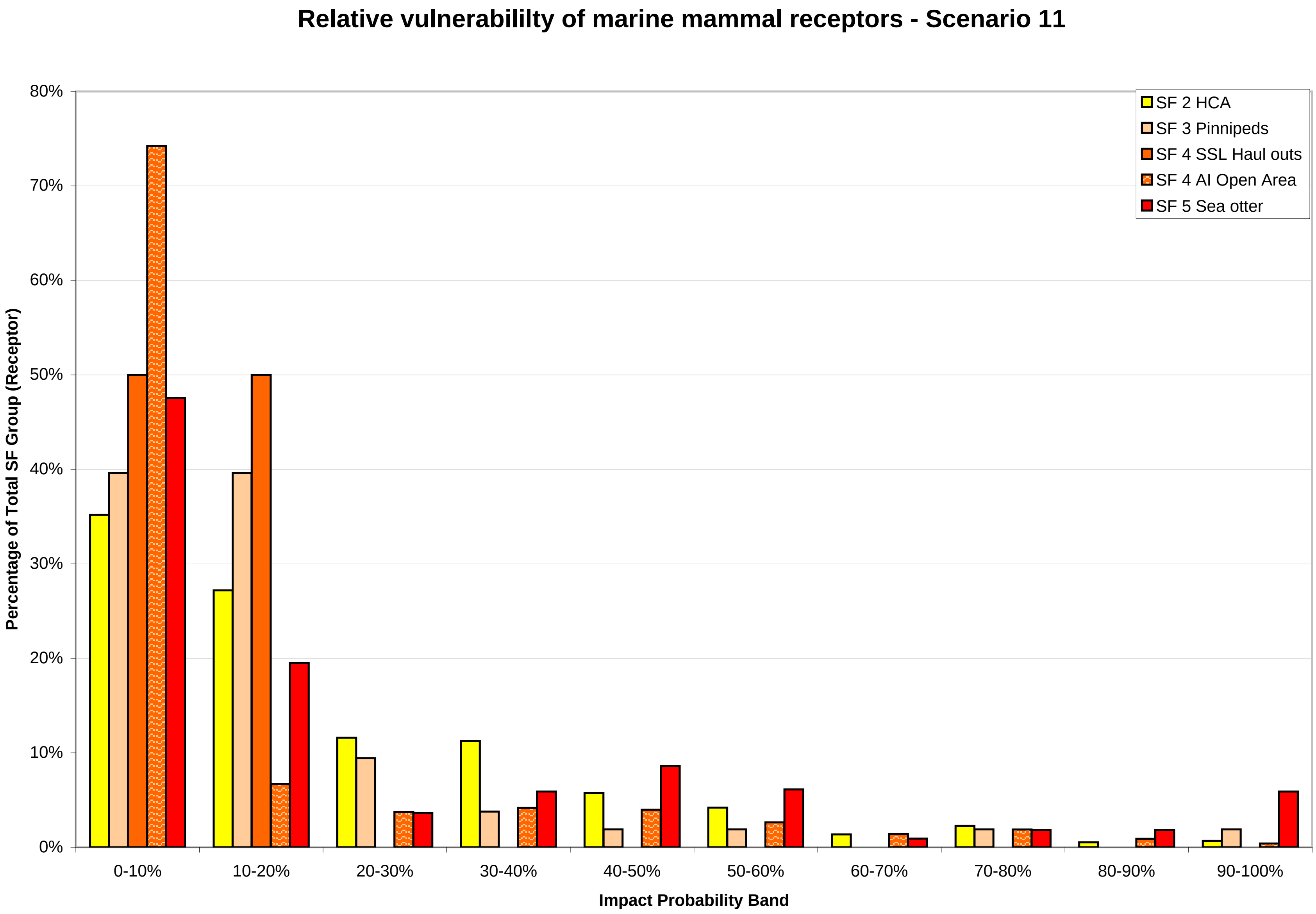


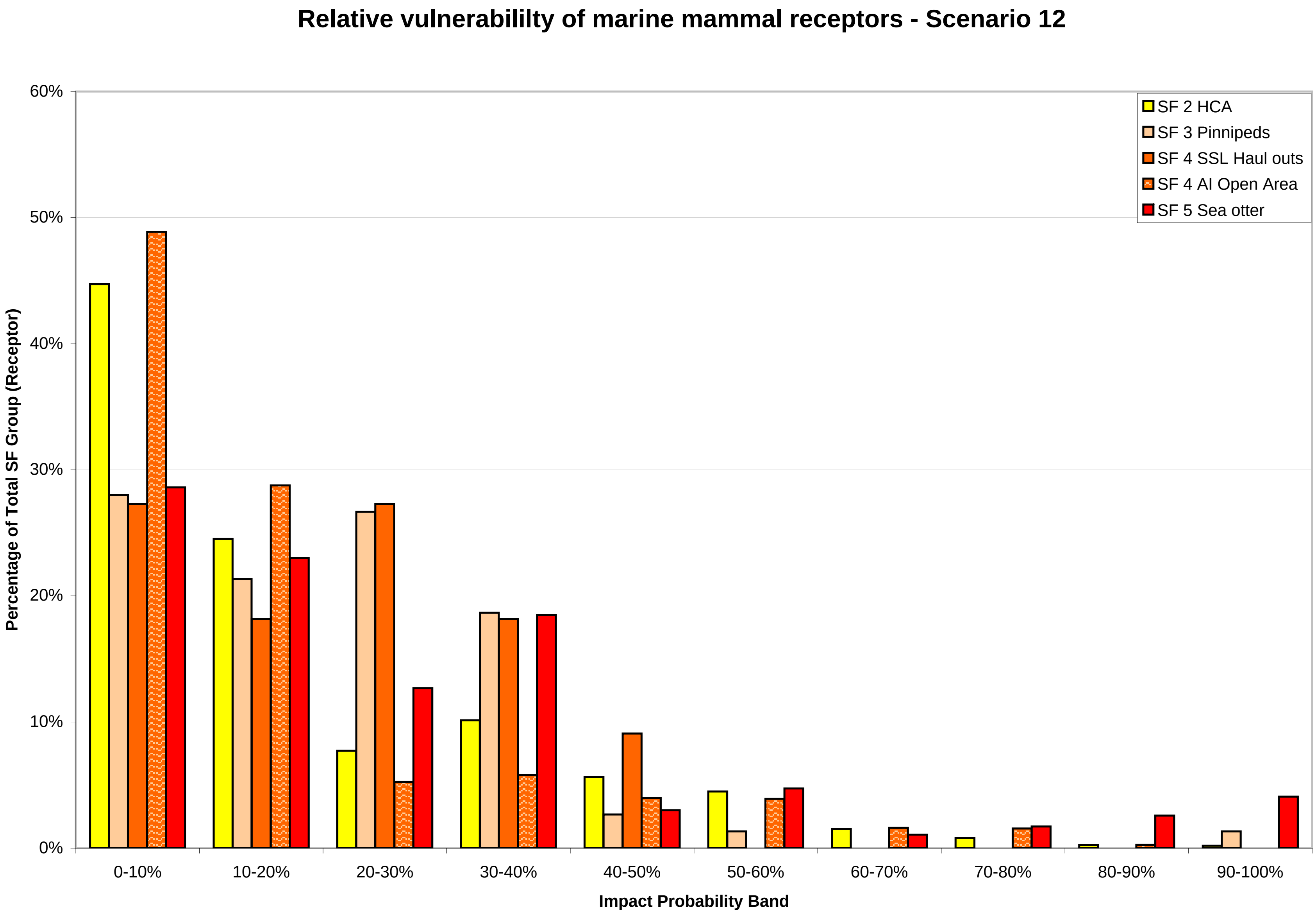
Relative vulnerabililty of marine mammal receptors - Scenario 9



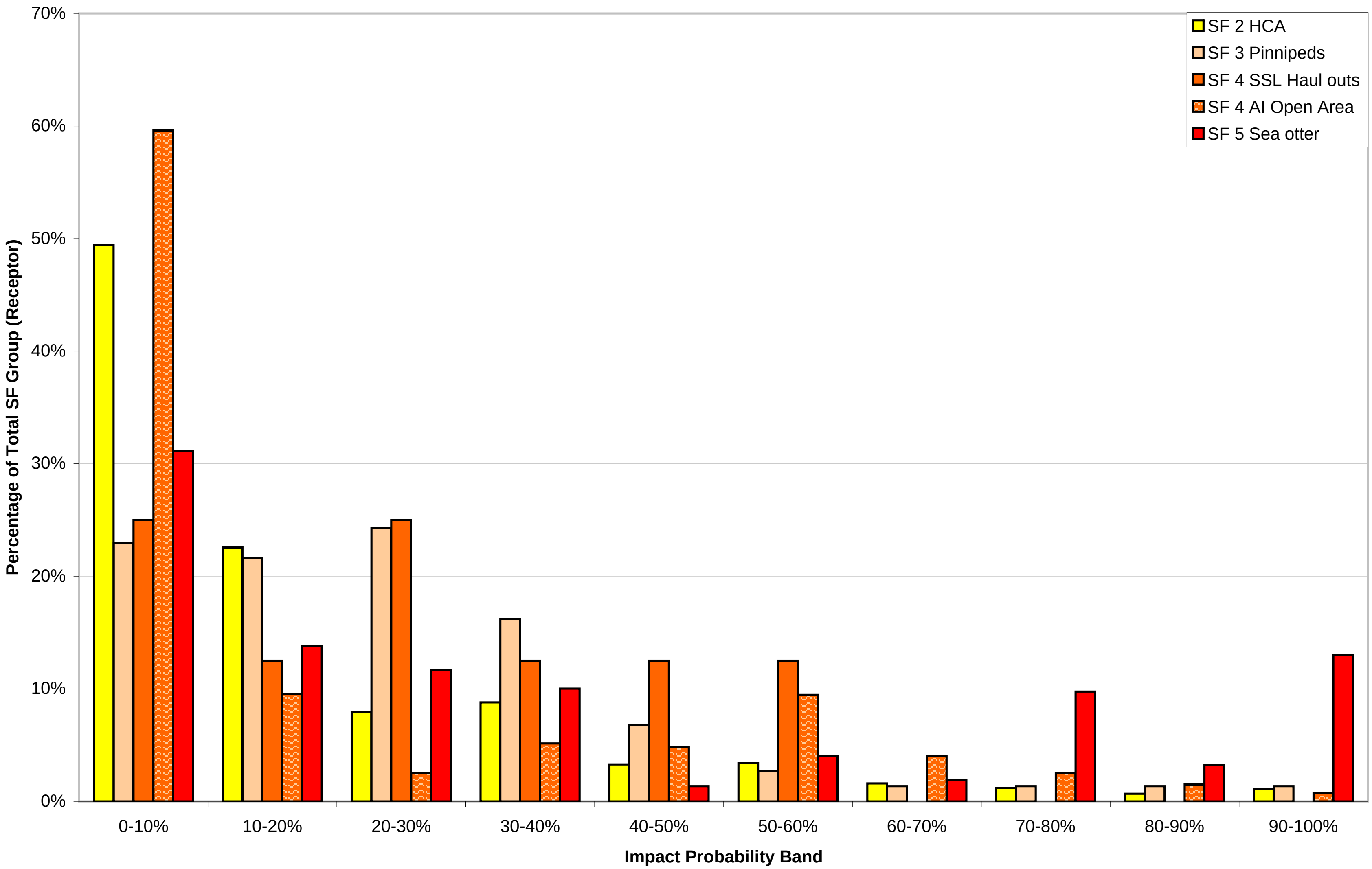


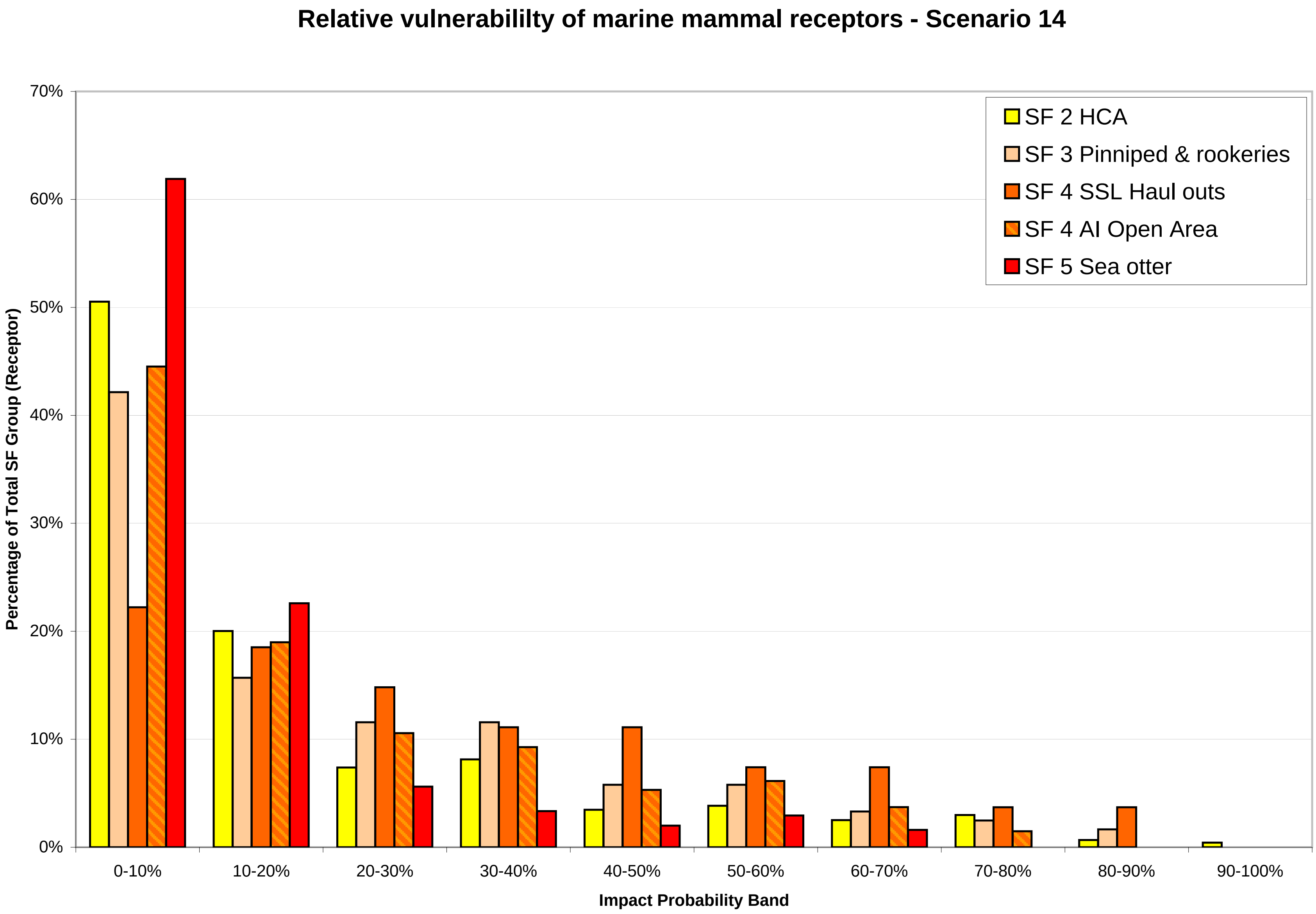
Relative vulnerabililty of marine mammal receptors - Scenario 10
60%
50%
40%
30%
20%
10%
0%
Percentage of Total SF Group (Receptor)
SF 2 HCA
SF 3 Pinnipeds & Rookeries
SF 4 SSL Haul outs
SF 4 AI Open Area
SF 5 Sea otter
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability Band


Relative vulnerabililty of marine mammal receptors - Scenario 11
Percentage of Total SF Group (Receptor)
80%
70%
60%
50%
40%
30%
20%
10%
0%
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability Band
SF 2 HCA
SF 3 Pinnipeds
SF 4 SSL Haul outs
SF 4 AI Open Area
SF 5 Sea otter

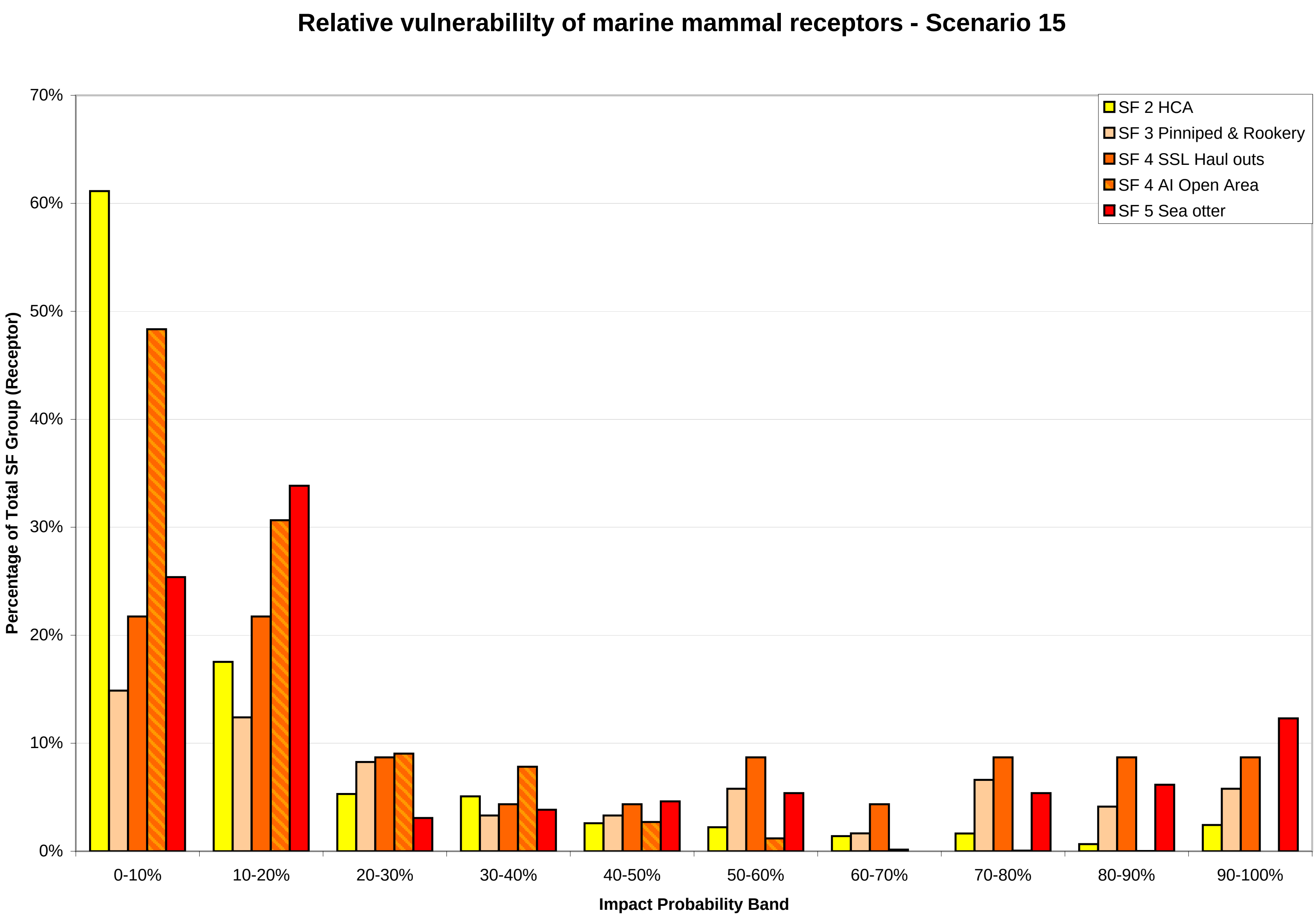

Relative vulnerabililty of marine mammal receptors - Scenario 12
Percentage of Total SF Group (Receptor)
0%
10%
20%
30%
40%
50%
60%
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability Band
SF 2 HCA
SF 3 Pinnipeds
SF 4 SSL Haul outs
SF 4 AI Open Area
SF 5 Sea otter

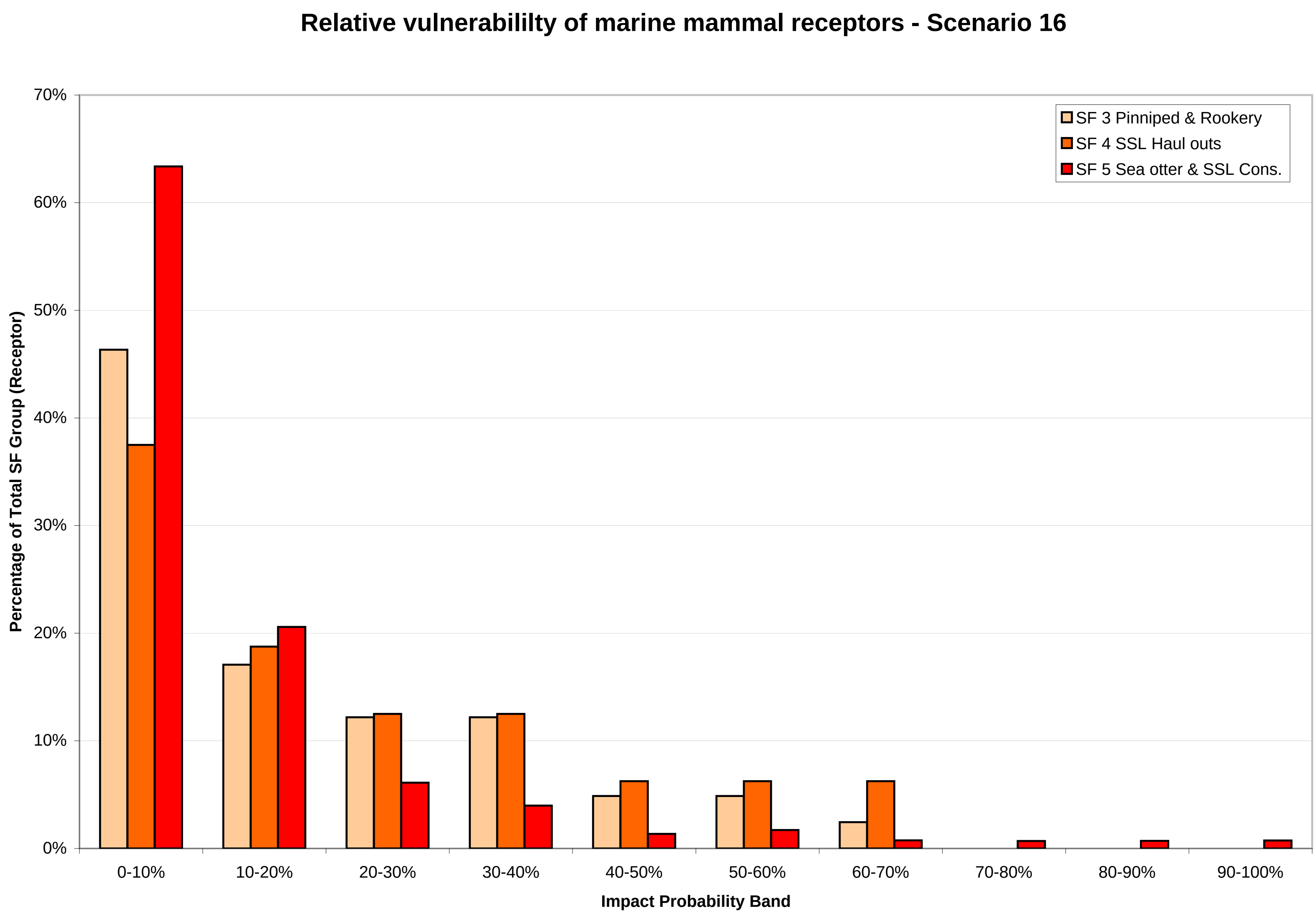
Relative vulnerabililty of marine mammal receptors - Scenario 13



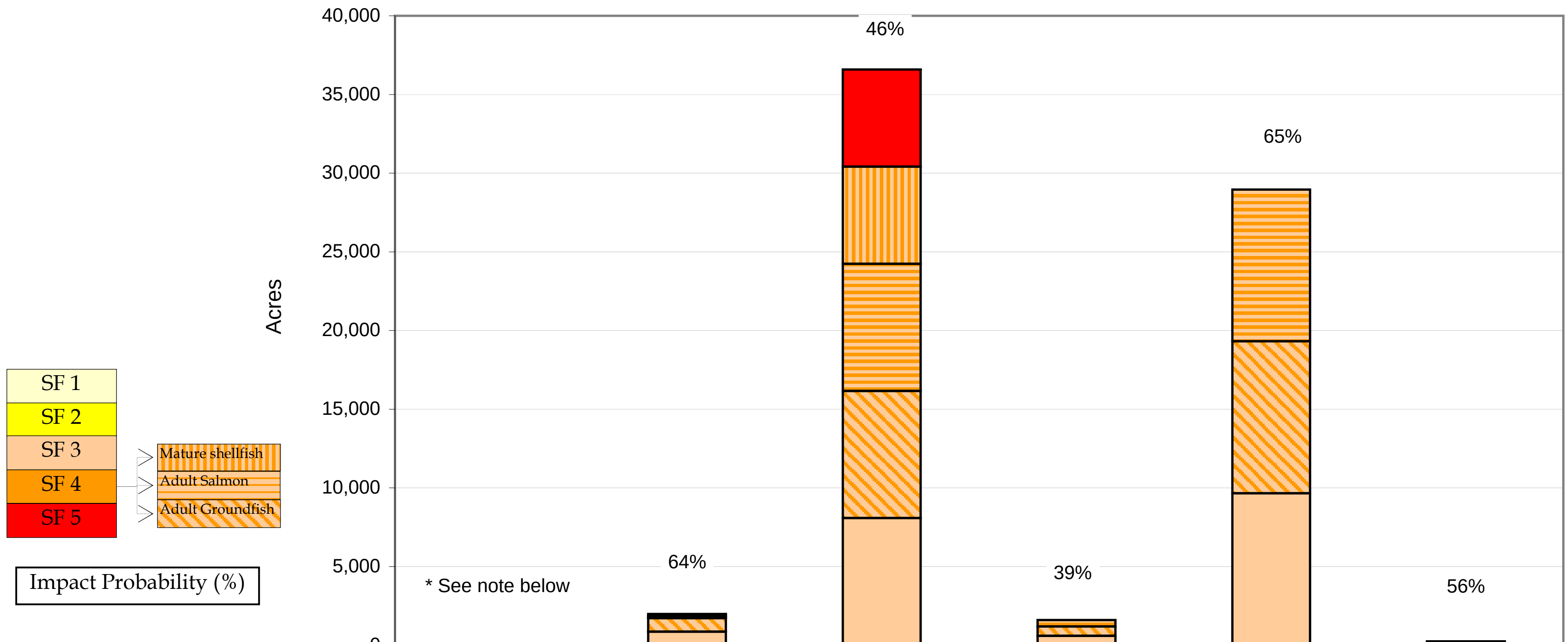


Relative vulnerabililty of marine mammal receptors - Scenario 14
70%
60%
50%
40%
30%
20%
10%
0%
Percentage of Total SF Group (Receptor)
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability Band
SF 2 HCA
SF 3 Pinniped & rookeries
SF 4 SSL Haul outs
SF 4 AI Open Area
SF 5 Sea otter


Relative vulnerabililty of marine mammal receptors - Scenario 15
Percentage of Total SF Group (Receptor)
0%
10%
20%
30%
40%
50%
60%
70%
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability Band
SF 2 HCA
SF 3 Pinniped & Rookery
SF 4 SSL Haul outs
SF 4 AI Open Area
SF 5 Sea otter


Relative vulnerabililty of marine mammal receptors - Scenario 16
70%
60%
50%
40%
30%
20%
10%
0%
Percentage of Total SF Group (Receptor)
SF 3 Pinniped & Rookery
SF 4 SSL Haul outs
SF 5 Sea otter & SSL Cons.
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80-90%
90-100%
Impact Probability Band

Total Impact Area - Fish Species/Sensitivity



	Scenario 3	Scenario 5	Scenario 8	Scenario 9	Scenario 12	Scenario 14
Immature shellfish and immature salmon	9.16	120	6174	0.00015		
Mature shellfish	9.16	120	6174	0.00015		
Adult Salmon	0.02	29	8080	406	9640	54
Immature Groundfish	0.02	860	8080	596	9657	99
Adult Groundfish	0.02	860	8080	596	9657	99

* **For Scenario 3 only** the Impact Probability for Mature Shellfish (SF 4) is 92%. All other species in this scenario have an impact probability of 56%.
See text for description of methodology.

Table 1. Sensitivity Analysis By Scenario for Representative Commercial Fisheries Using NMFS Average Annual Catch Data (2006-2008) for Probability Bands Greater Than 50%

Fishery	Scenario 1 - North Unimak Pass	Scenario 2 - North Unimak Pass	Scenario 3 - North Unimak Pass	Scenario 4 - North Unimak Pass	Scenario 5 - North Unimak Pass	Scenario 6 - Sanak Island	Scenario 7 - Sanak Island	Scenario 8 - Sanak Island	Scenario 9 - Sanak Island	Scenario 10 - Holtz Bay Attu Island	Scenario 11 - Holtz Bay Attu Island	Scenario 12 - Holtz Bay Attu Island	Scenario 13 - Holtz Bay Attu Island	Scenario 14 - Adak Island	Scenario 15 - Amlia Island	Scenario 16 - Urilia Bay
Pollock trawl gear	2	3	2	2	3					2	2	2	2	2	3	5
Pacific cod fixed gear	2	5	5	5	5	4	4	4	4	2	2	2	2	2	2	4
Pacific cod trawl gear	2	2	2	2	2	3	3	3	3	2	2	2	2	2	3	5
Tanner crab	2	2												1	1	2
Bristol Bay king crab														1	1	2
Flatfish trawl	2	2	2	2	2					1	1	1	1	1	2	4
Salmon*	2		2	2	2	2	2	2	2	1	1	1	1	1	1	2

(Shaded) No fishery near location.

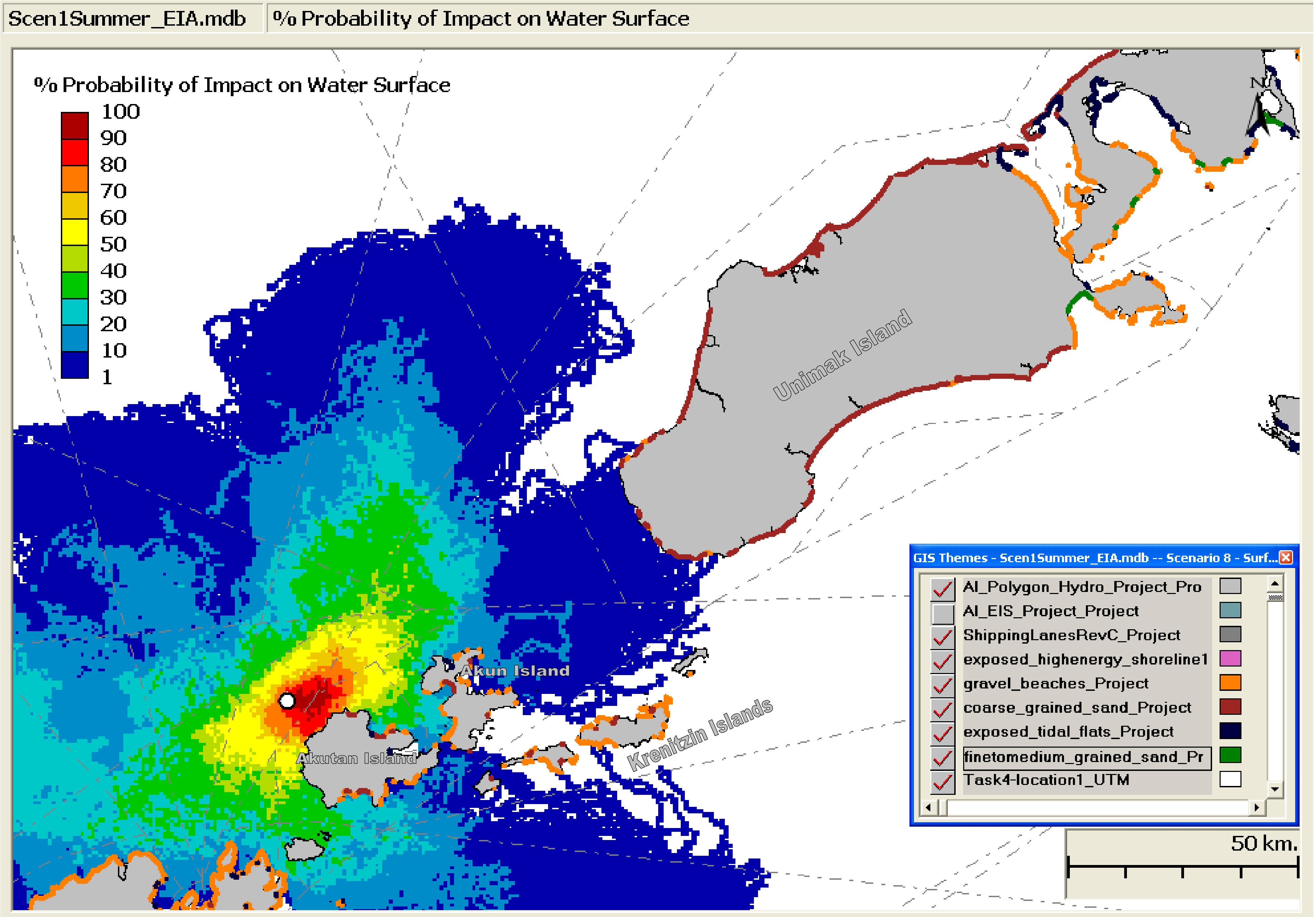
Table 2. Sensitivity Analysis By Scenario for Representative Commercial Processors by Community

Community	Scenario 1 - North Unim	Scenario 2 - North Unim	Scenario 3 - North Unim	Scenario 4 - North Unim	Scenario 5 - North Unim	Scenario 6 - Sanak Islan	Scenario 7 - Sanak Islan	Scenario 8 - Sanak Islan	Scenario 9 - Sanak Islan	Scenario 10 - Holtz Bay	Scenario 11 - Holtz Bay	Scenario 12 - Holtz Bay	Scenario 13 - Holtz Bay	Scenario 14 - Adak Islan	Scenario 15 - Amlia Islan	Scenario 16 - Urilia Bay
Adak														5		
Akutan	4	4	4	4	4											
Dutch Harbor	4	4	4	4	4											
False Pass																5
King Cove																
Sand Point																
Point Moller																
Chinig																

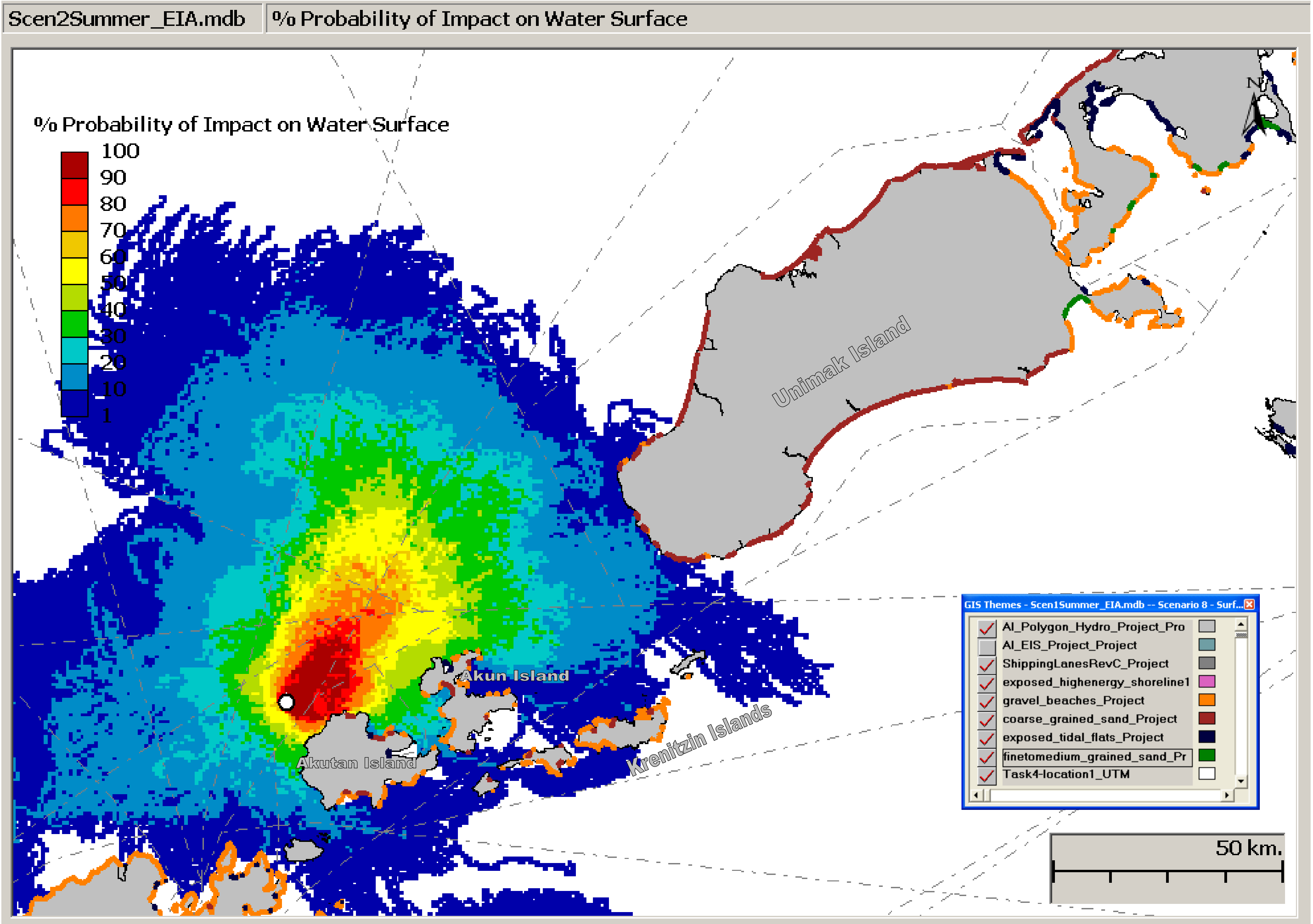
(shaded) No processor near location.

Appendix F
Spill Impact Overlays For Each Scenario

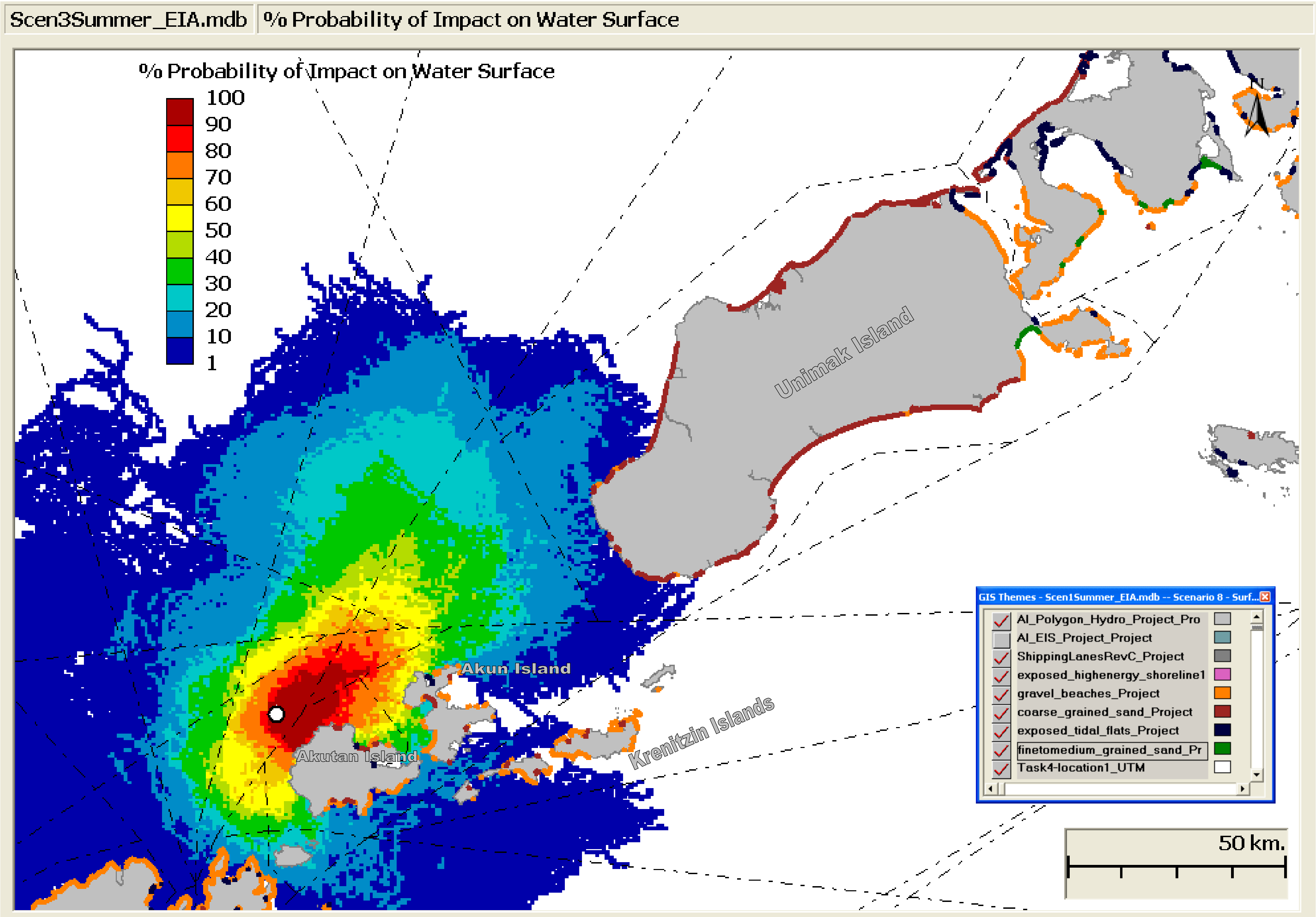
Scenario 1 – Summer – Littoral



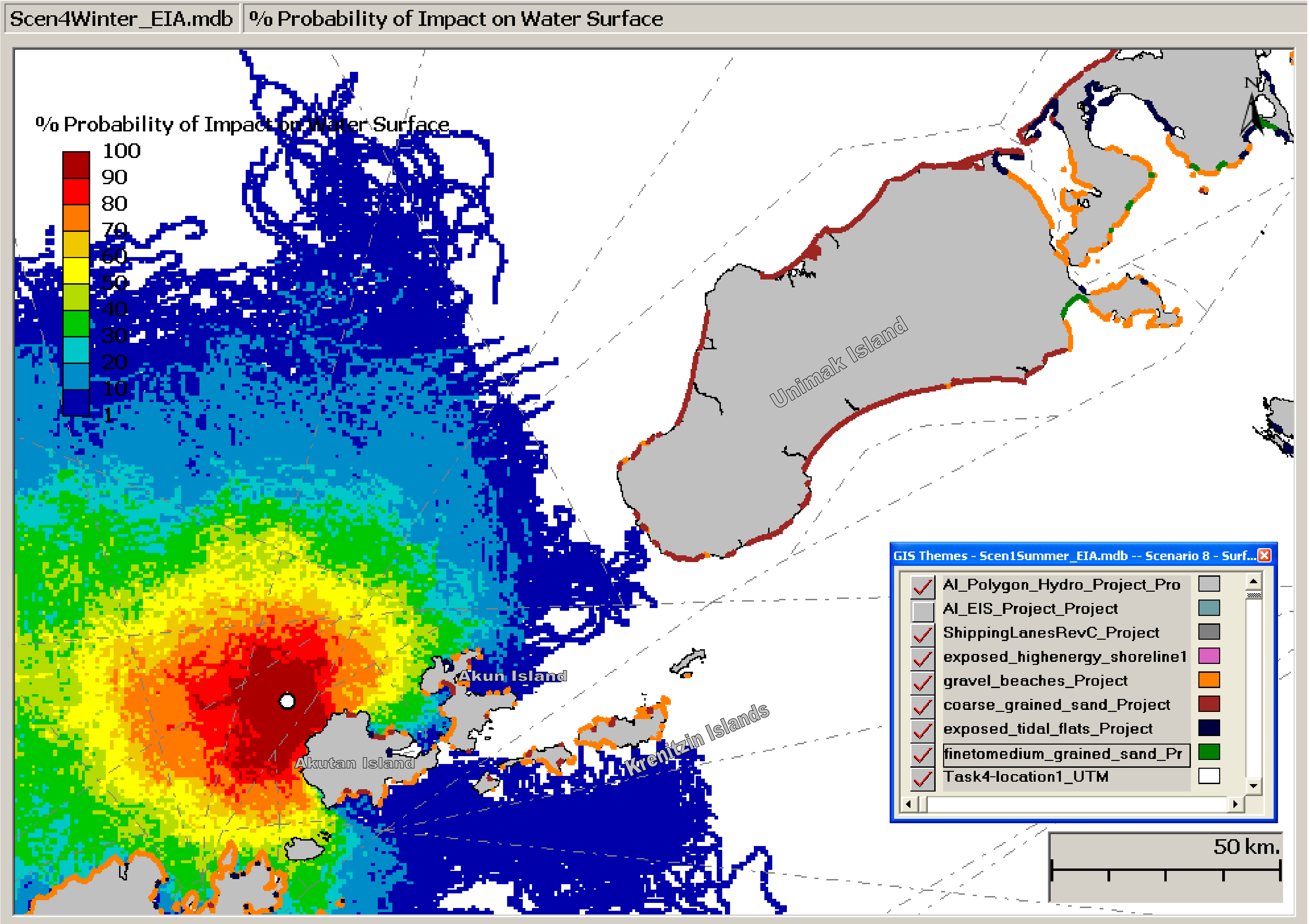
Scenario 2 – Summer – Littoral



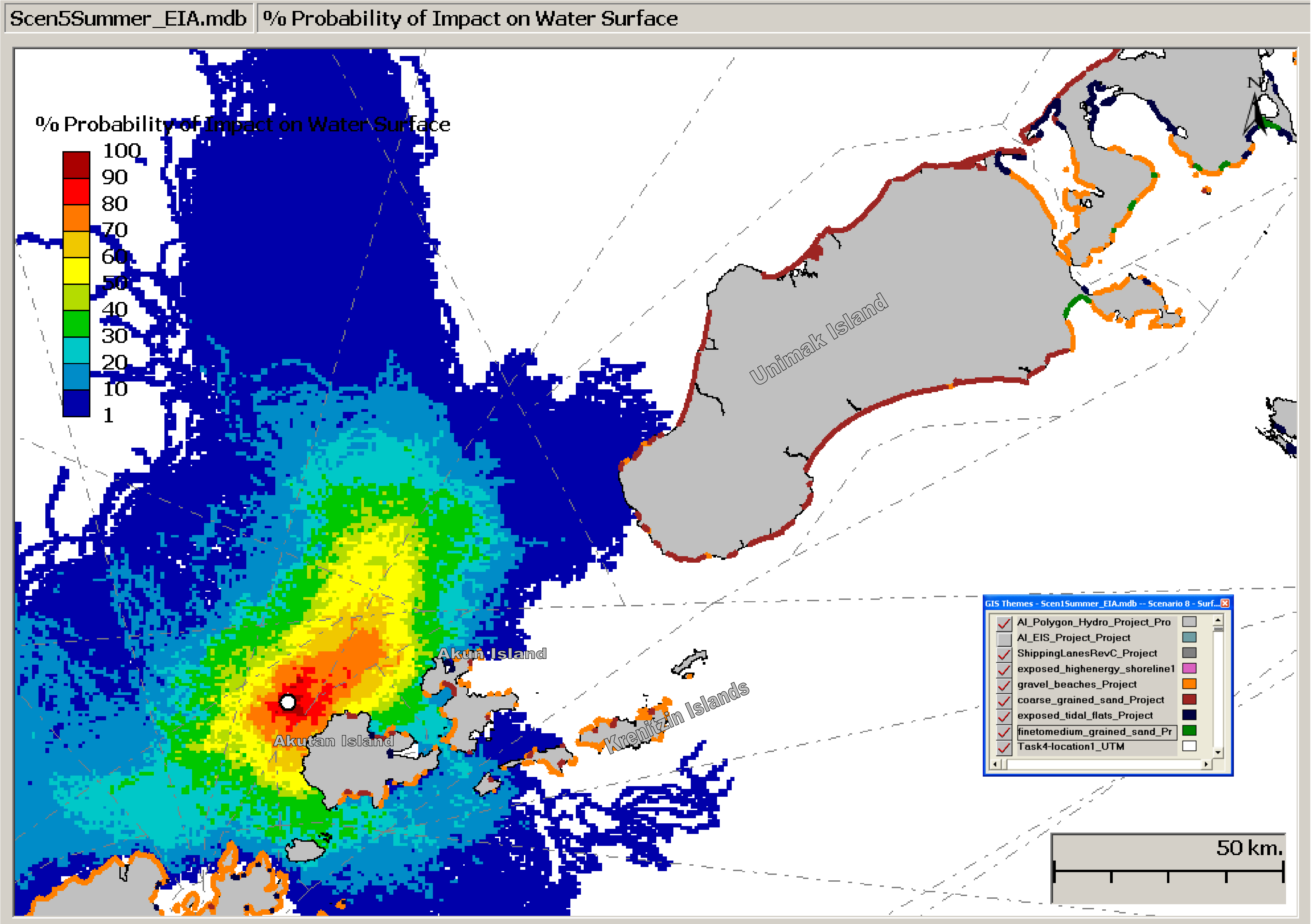
Scenario 3 – Summer – Littoral



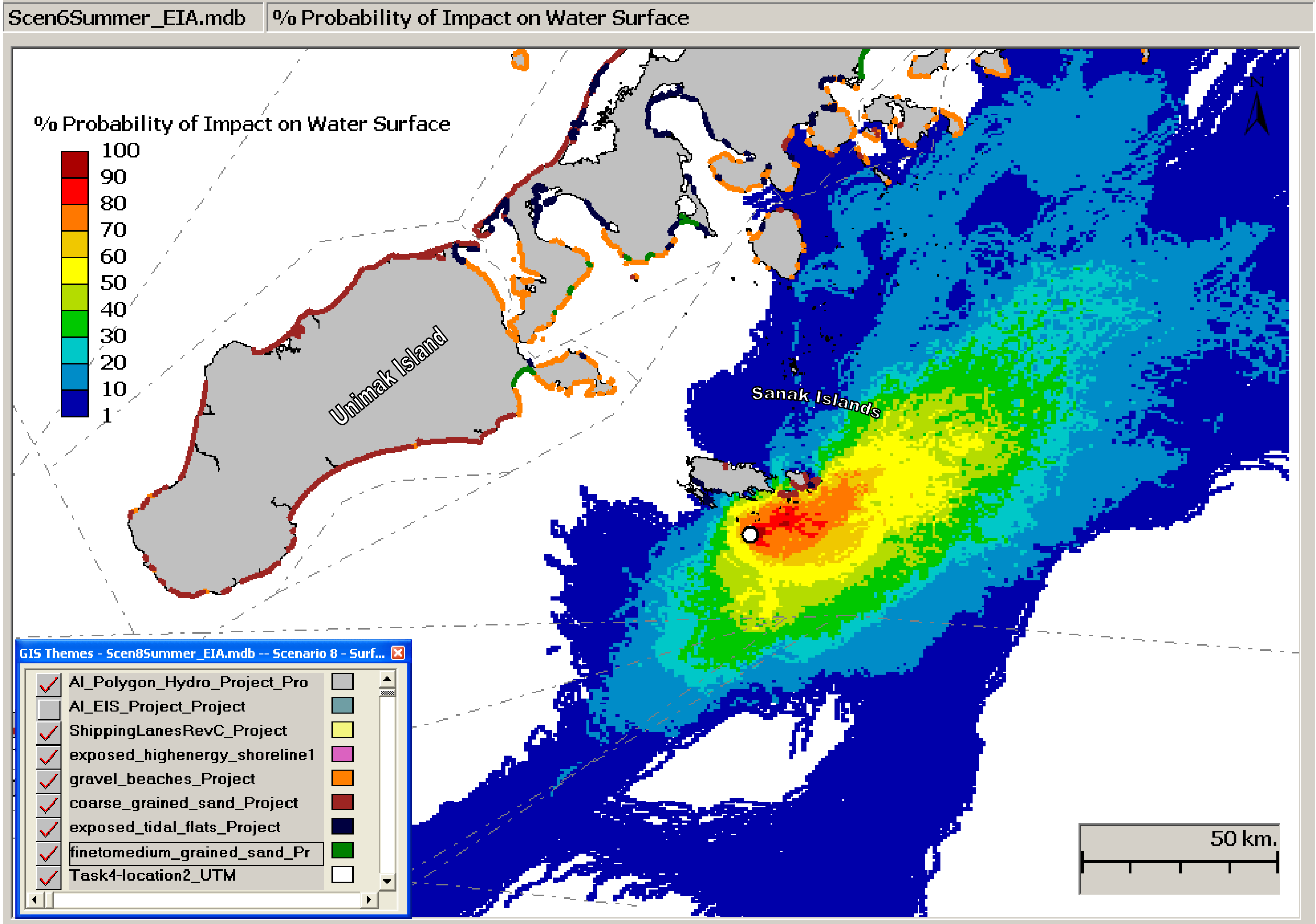
Scenario 4 - Winter - Littoral



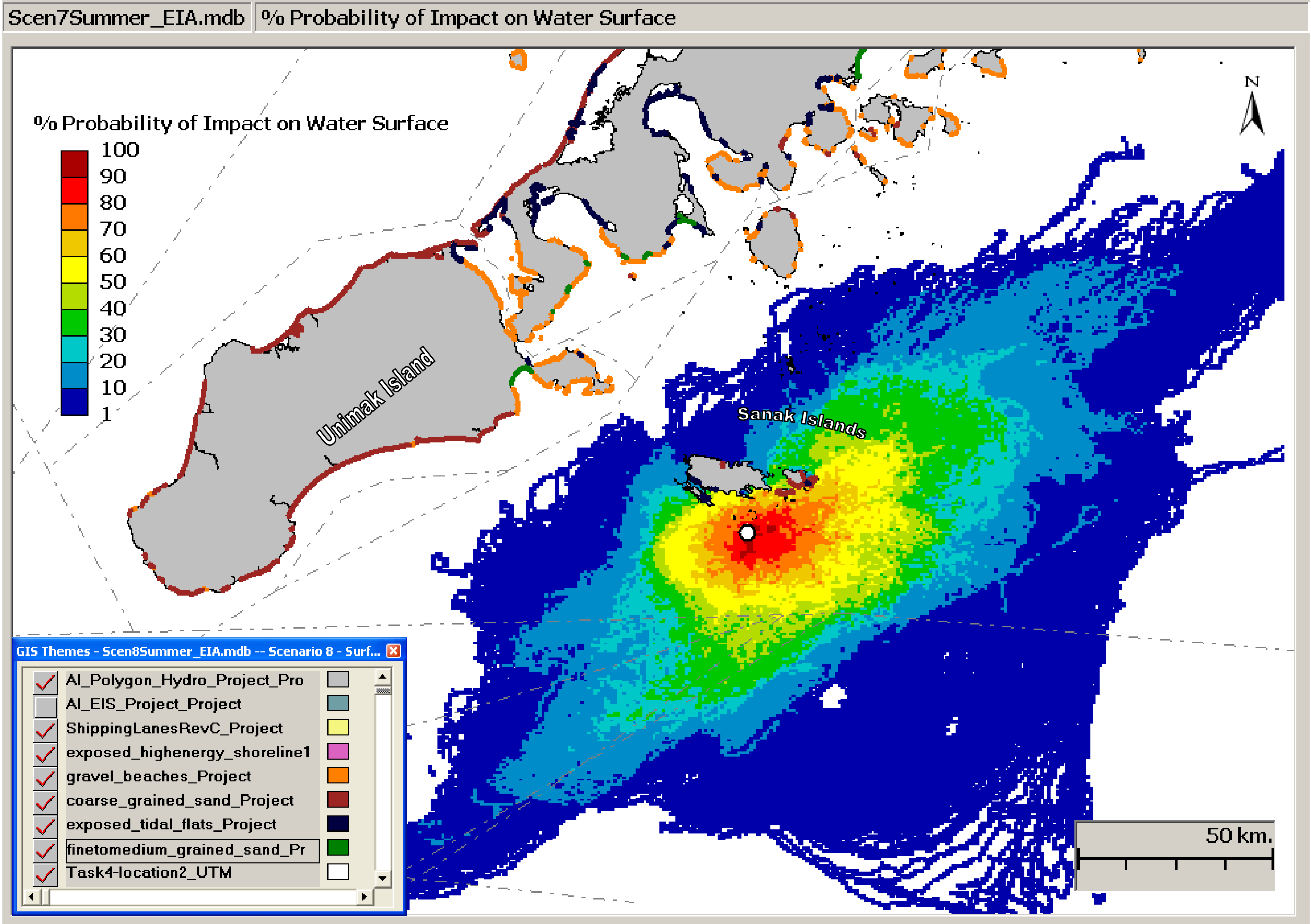
Scenario 5 - Summer - Littoral



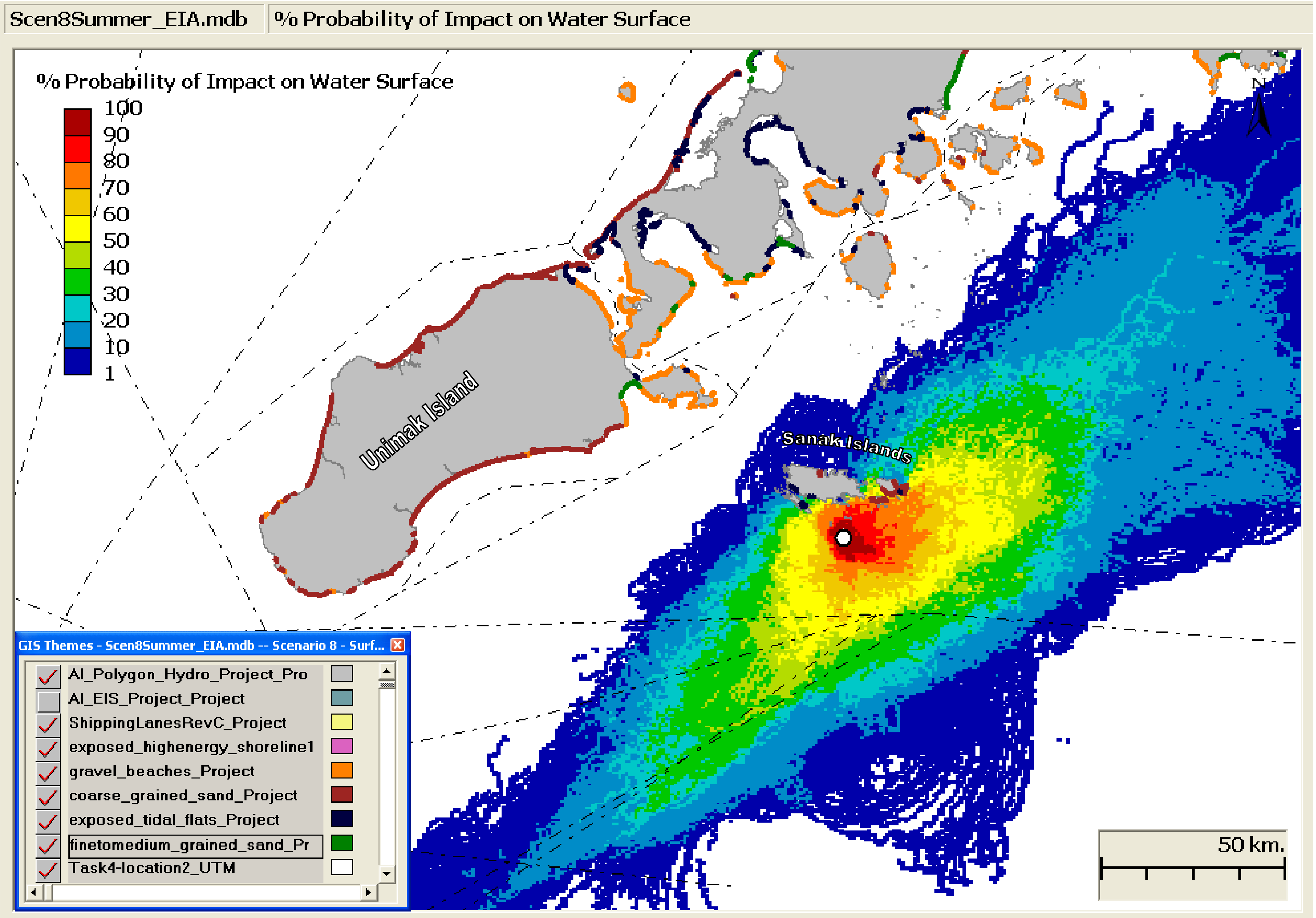
Scenario 6 - Summer - Littoral



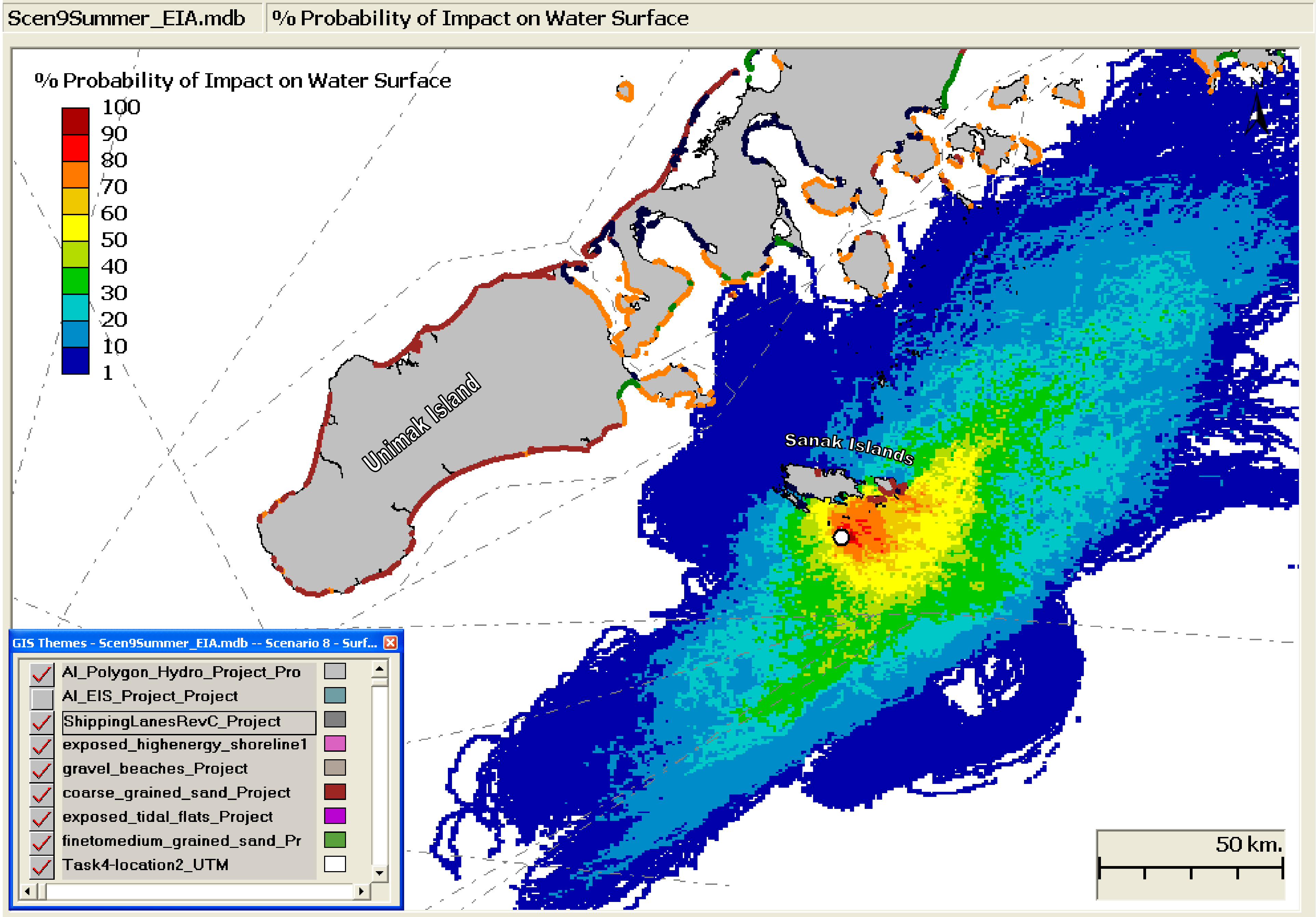
Scenario 7 - Summer - Littoral



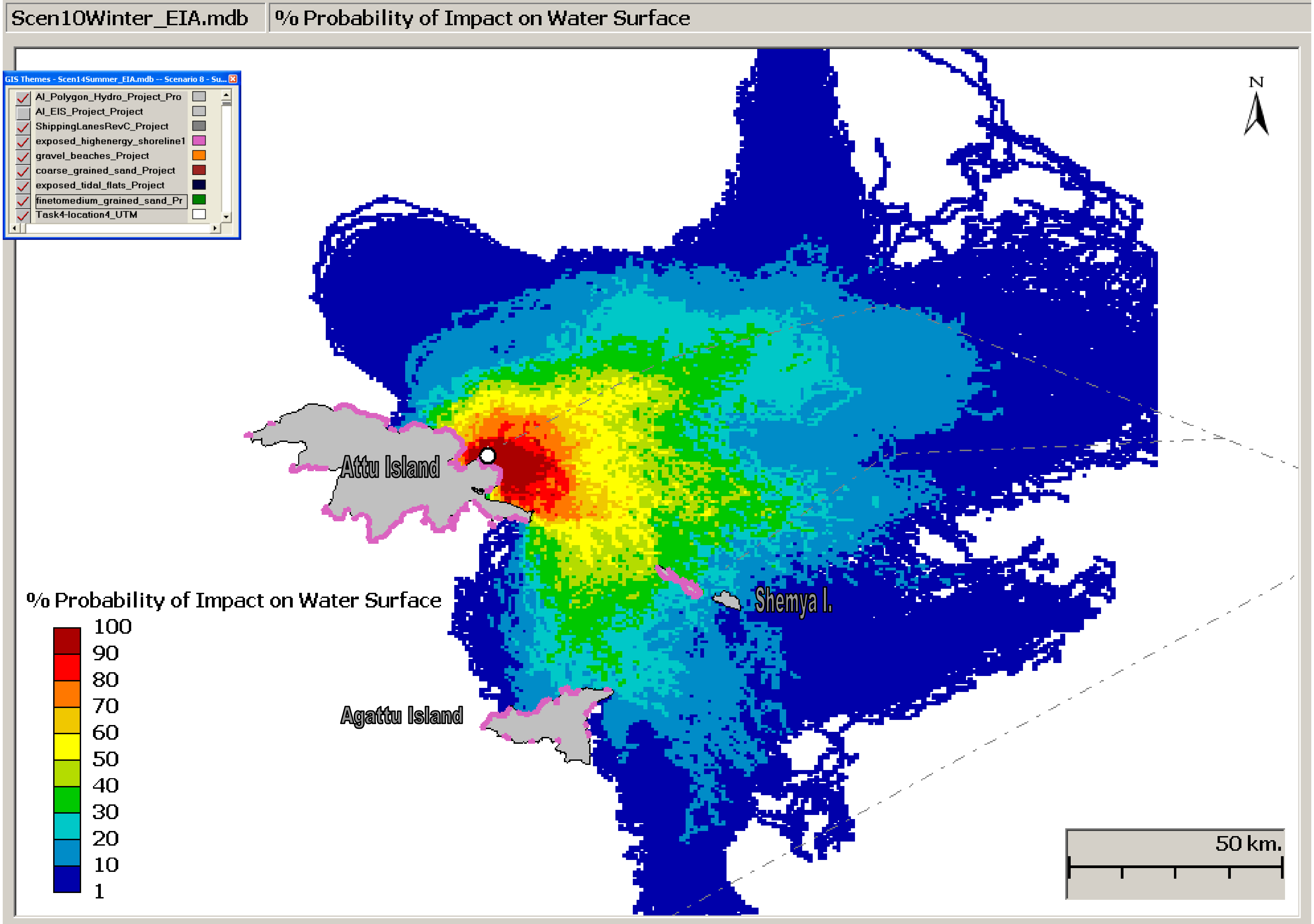
Scenario 8 - Summer - Littoral



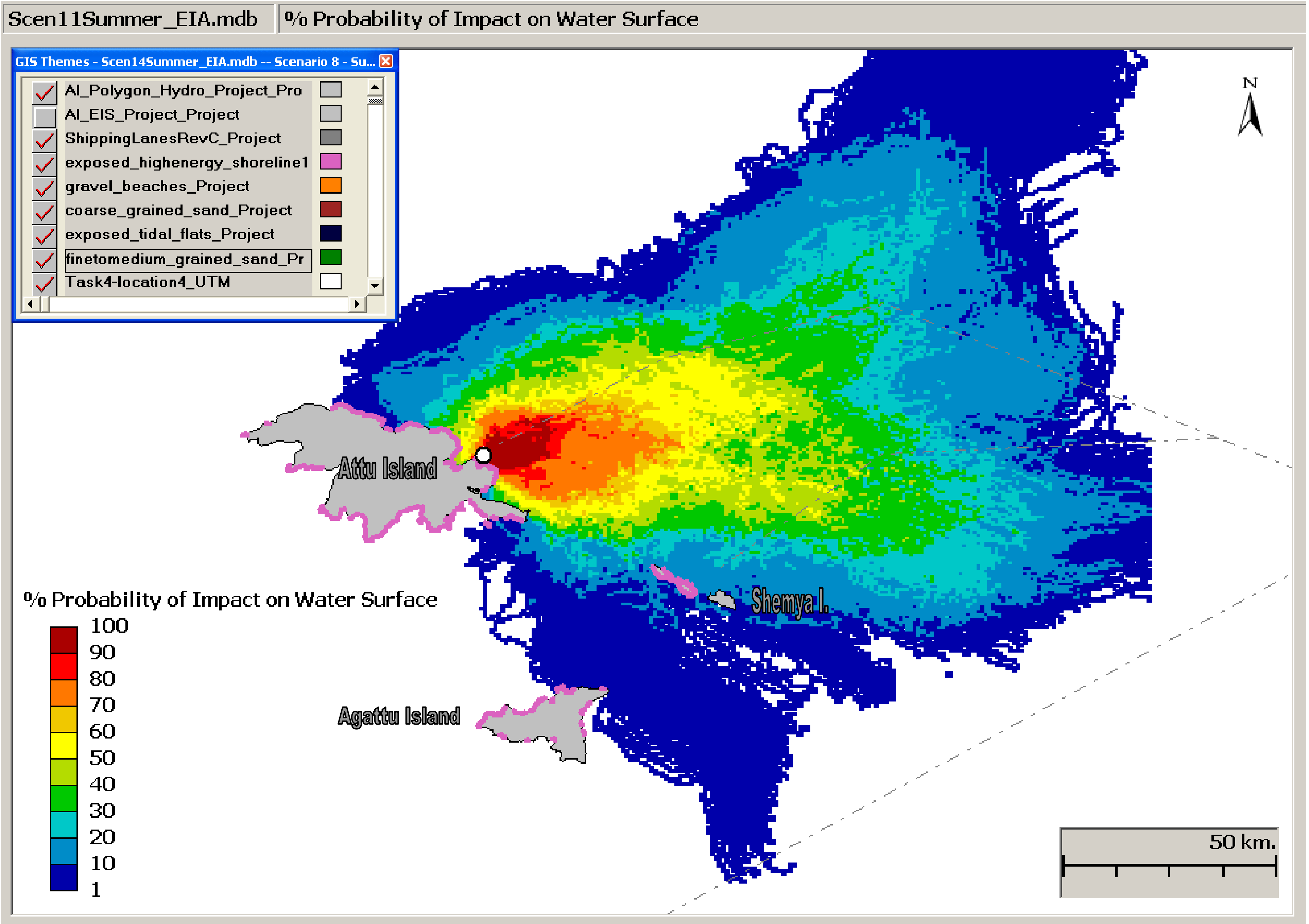
Scenario 9 - Summer - Littoral



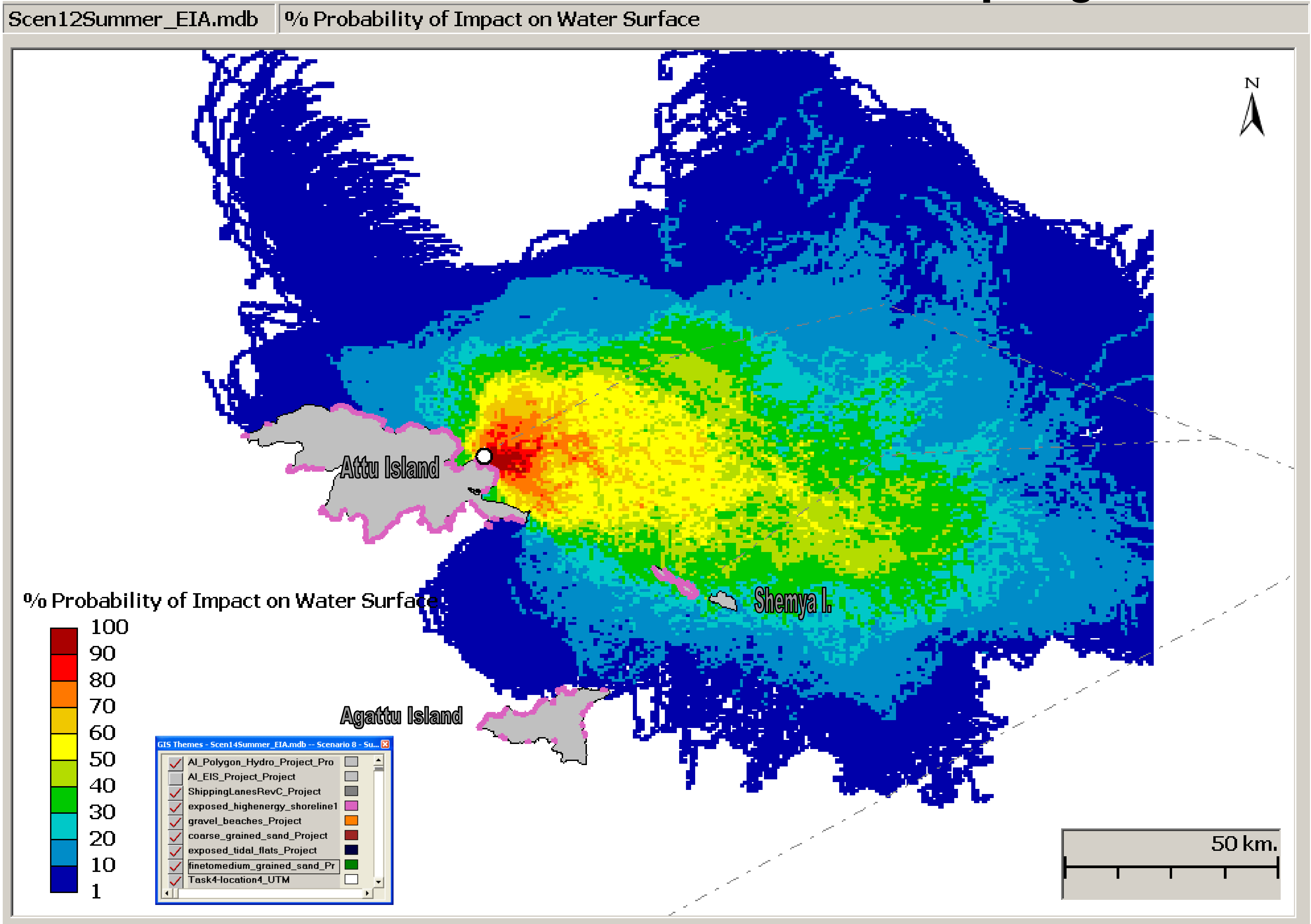
Scenario 10 - Winter - Littoral



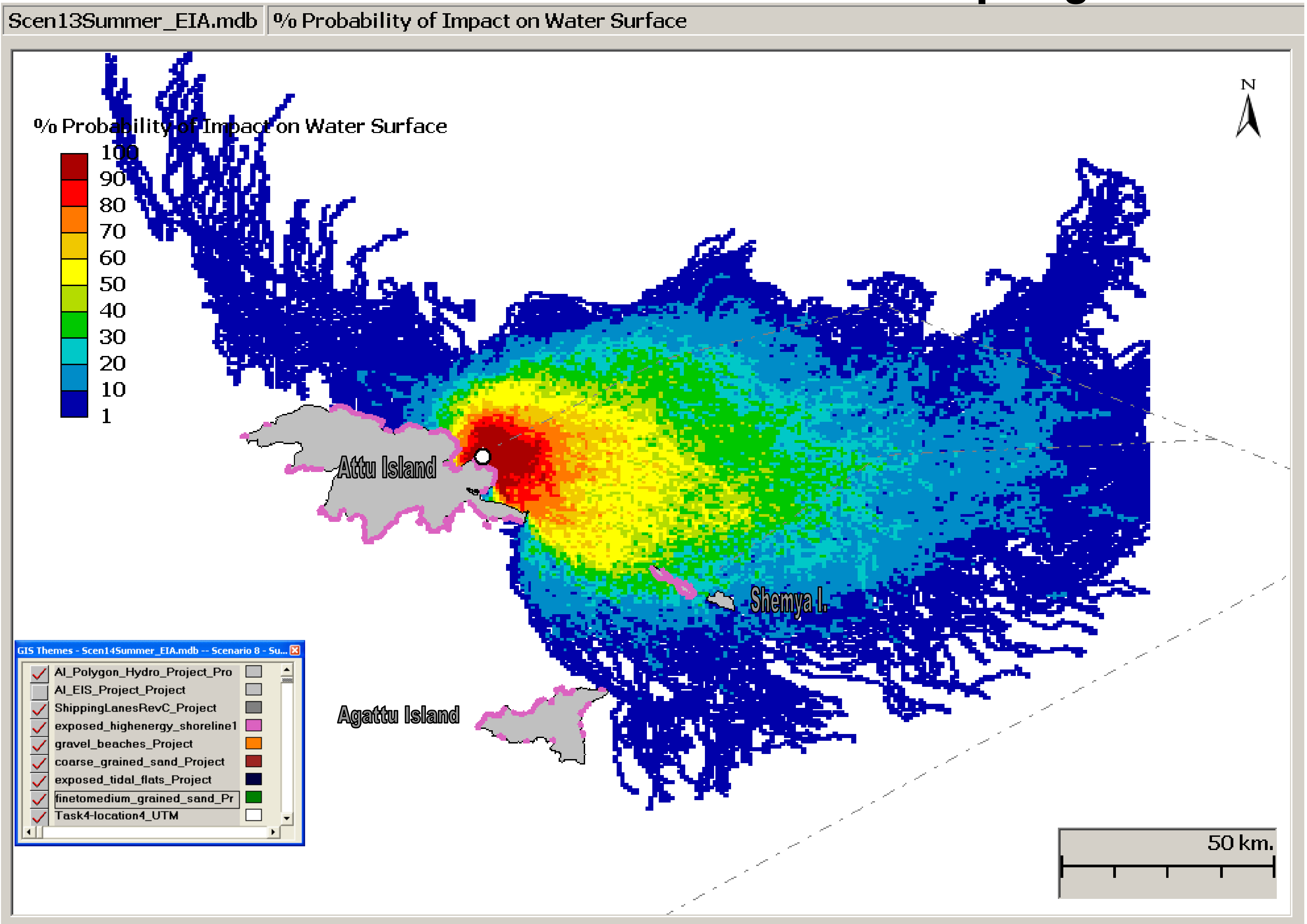
Scenario 11 - Summer - Littoral



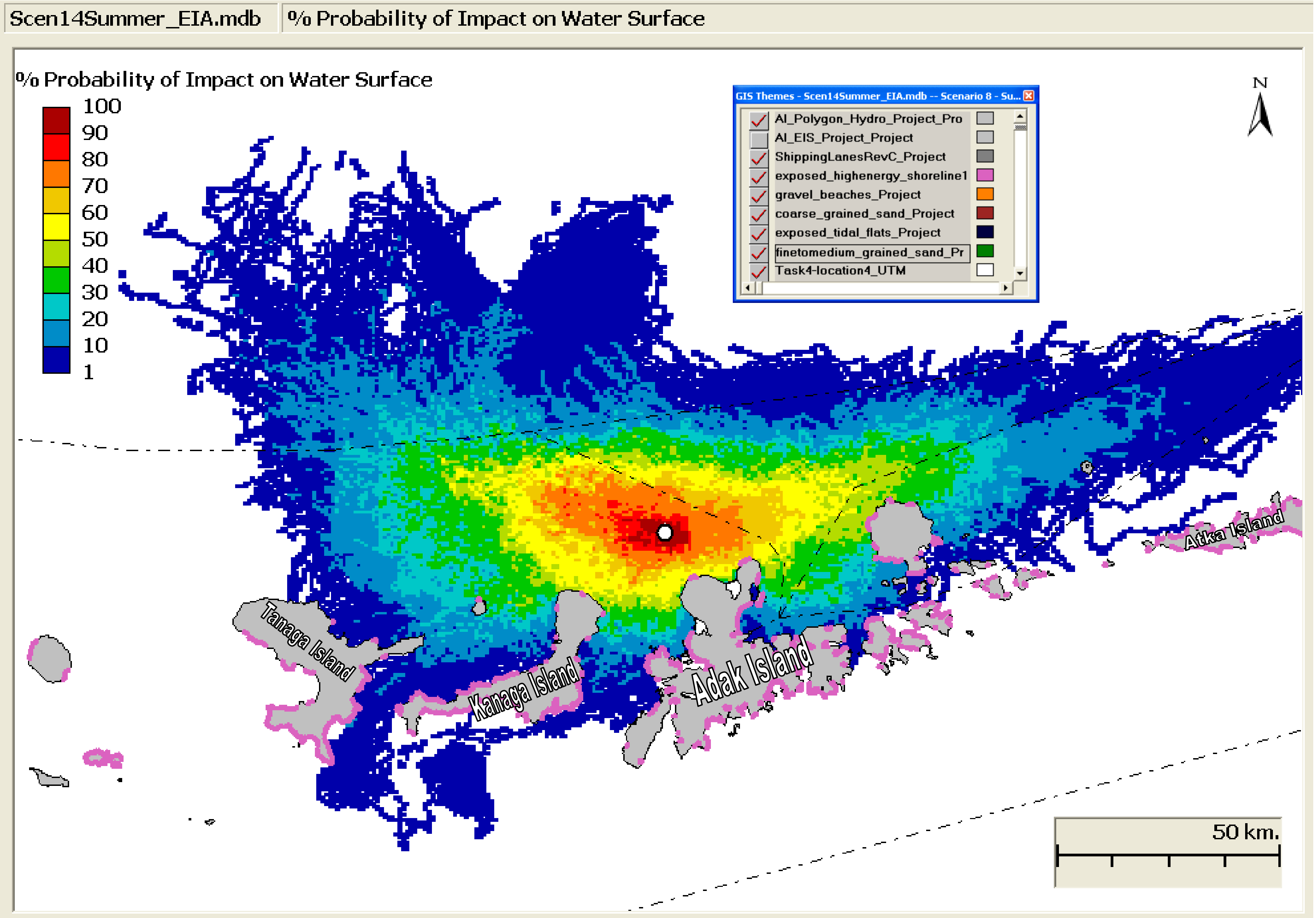
Scenario 12 - Spring - Littoral



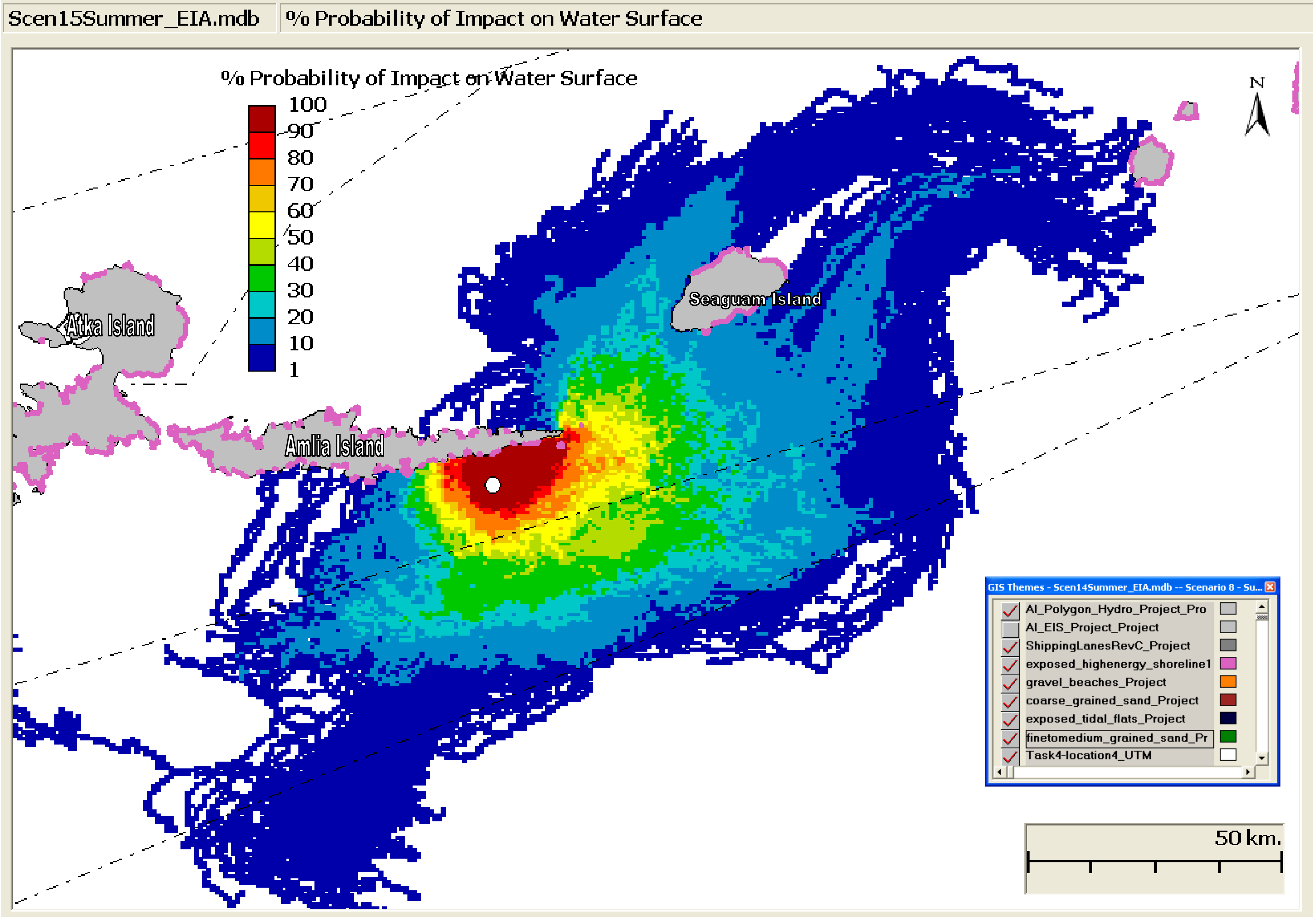
Scenario 13 - Spring - Littoral



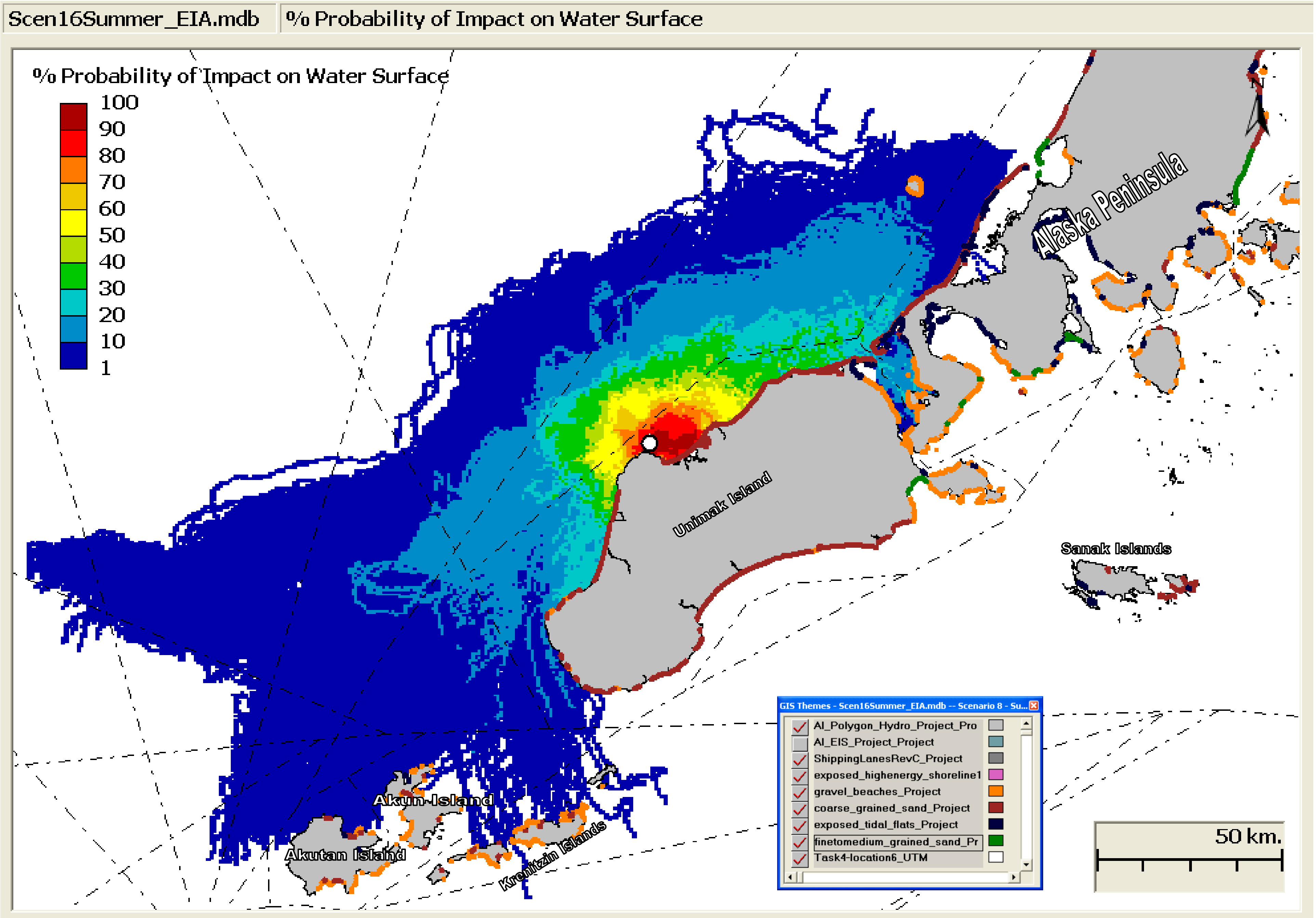
Scenario 14 - Summer - Littoral



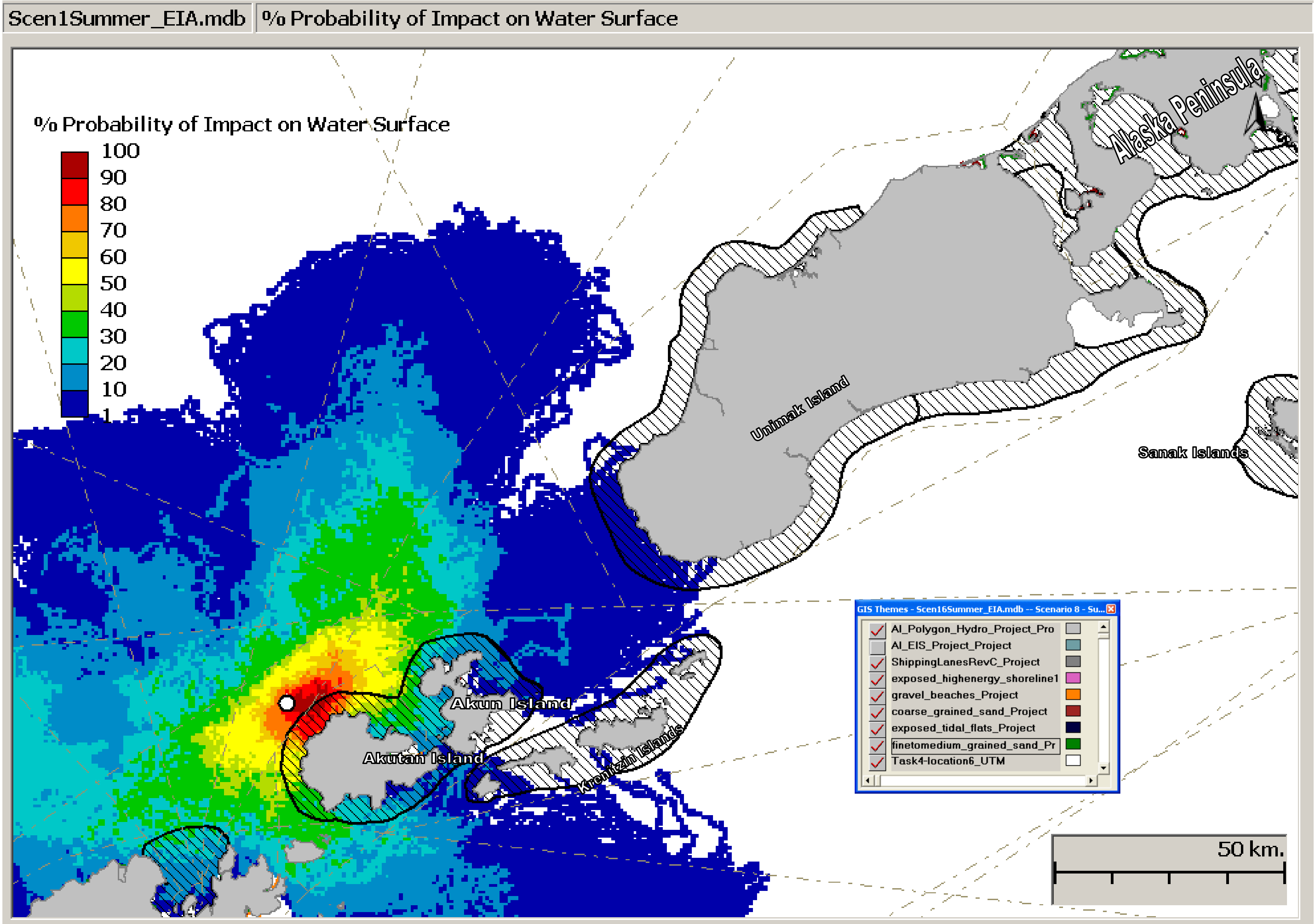
Scenario 15 - Summer - Littoral



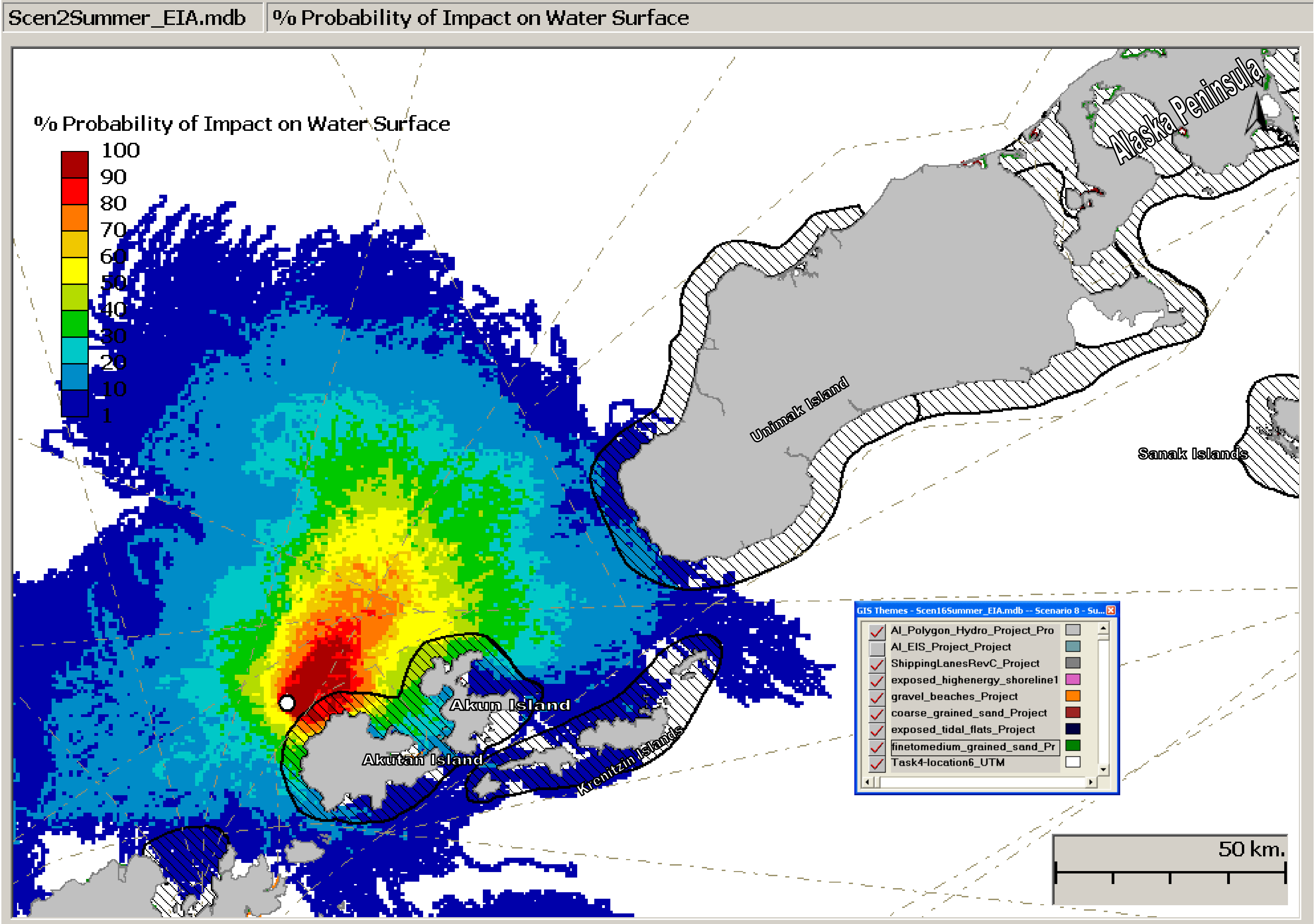
Scenario 16 - Spring - Littoral



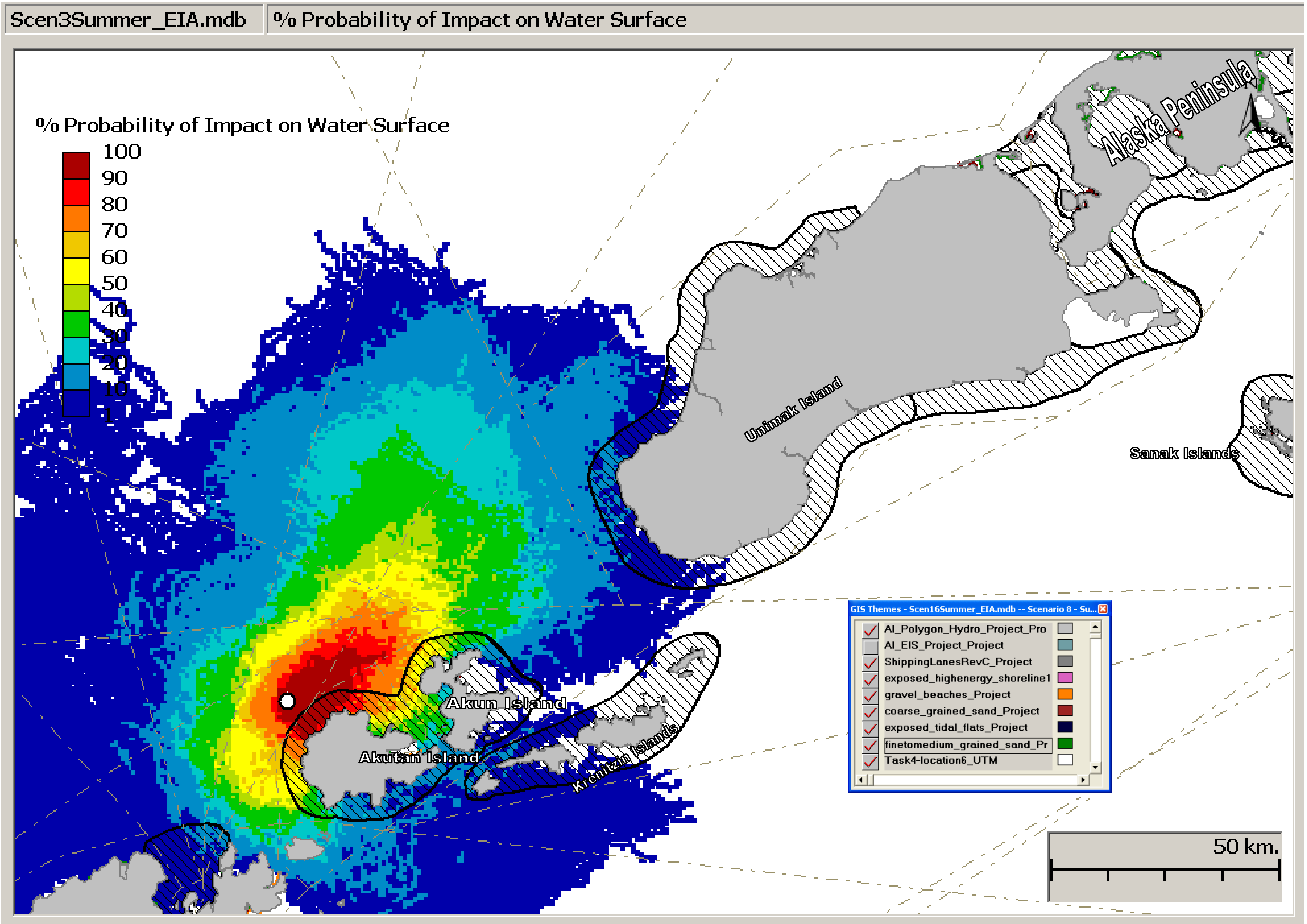
Scenario 1 - Summer - Sublittoral



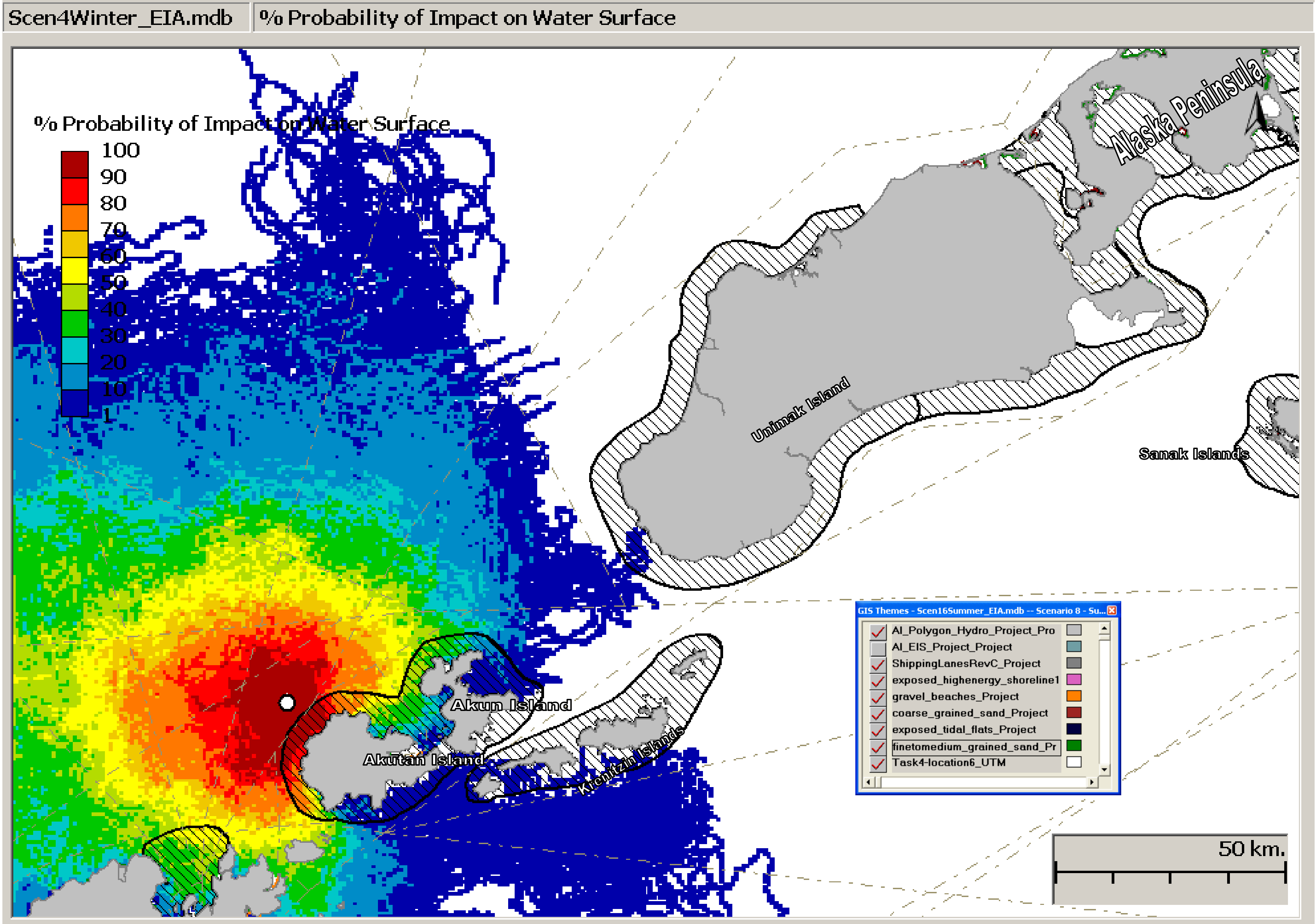
Scenario 2 - Summer - Sublittoral



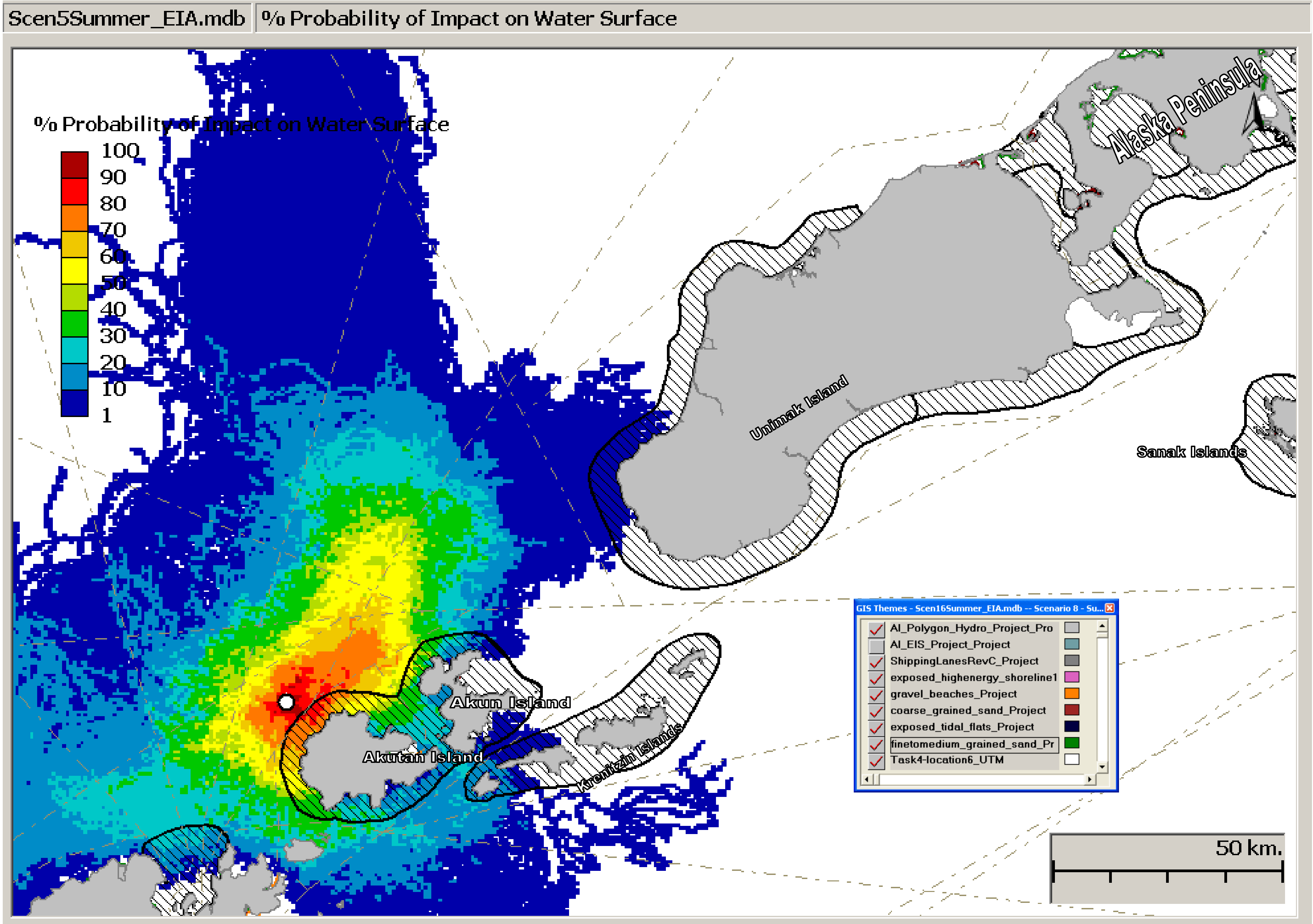
Scenario 3 - Summer - Sublittoral



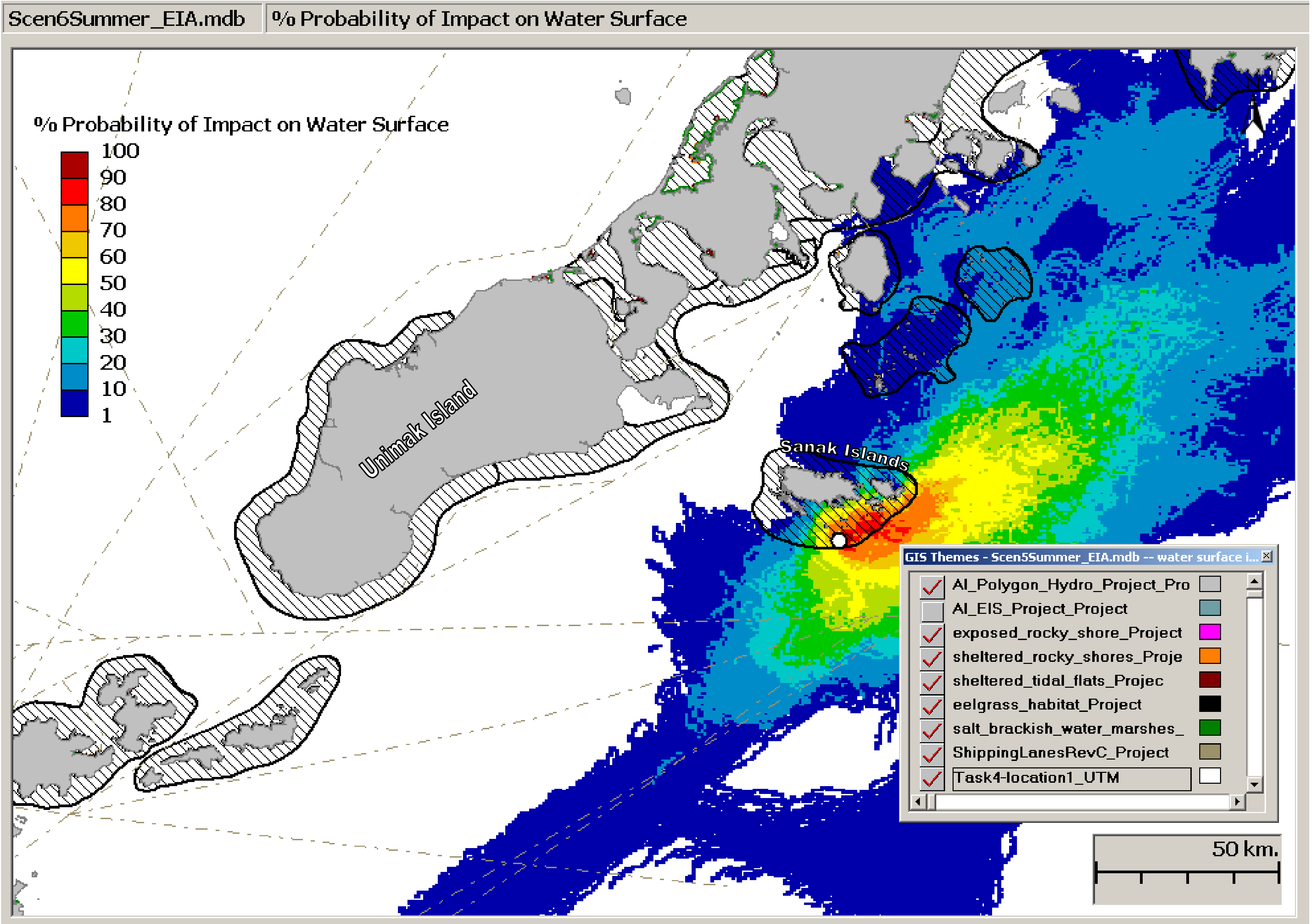
Scenario 4 - Winter - Sublittoral



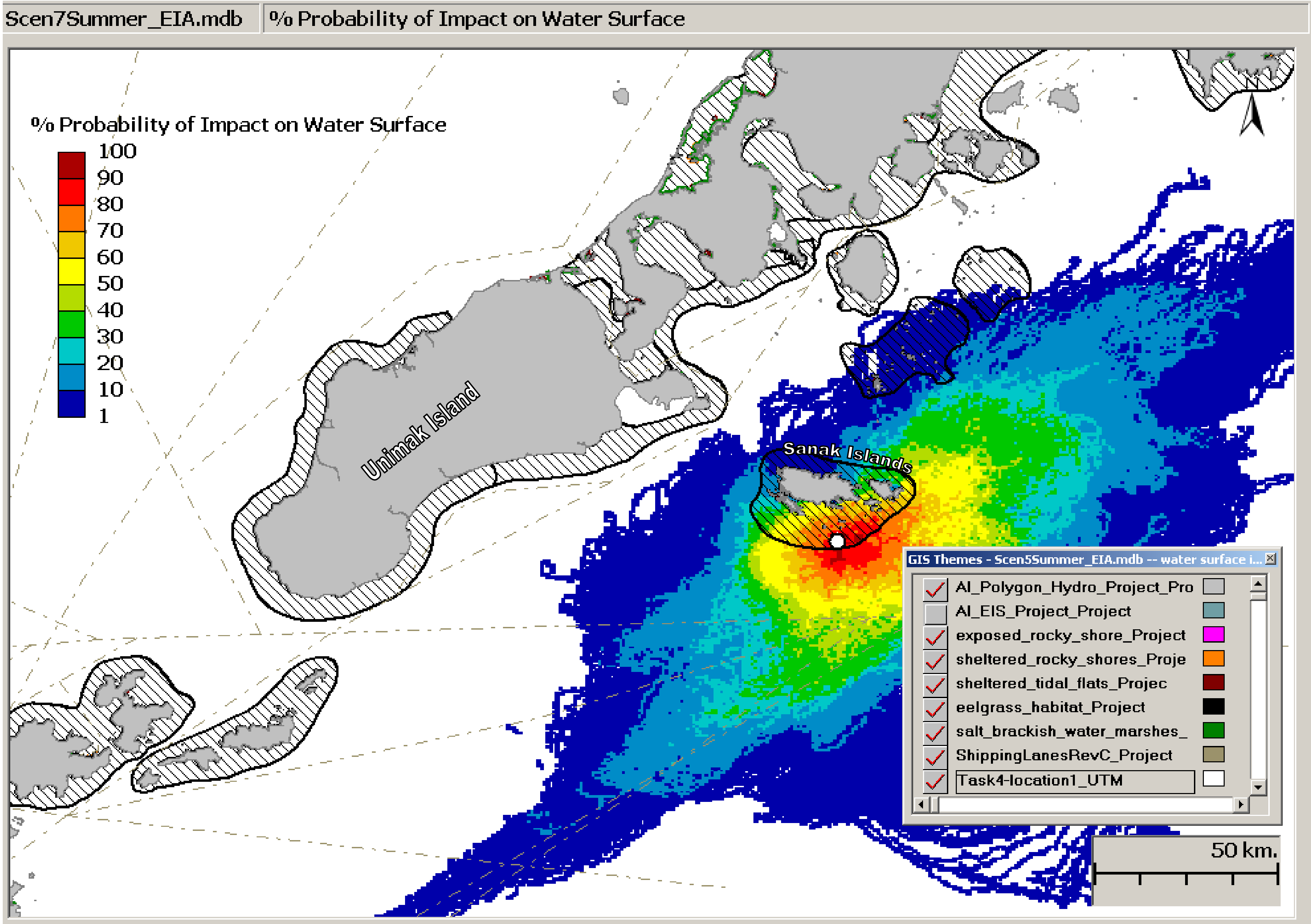
Scenario 5 - Summer - Sublittoral



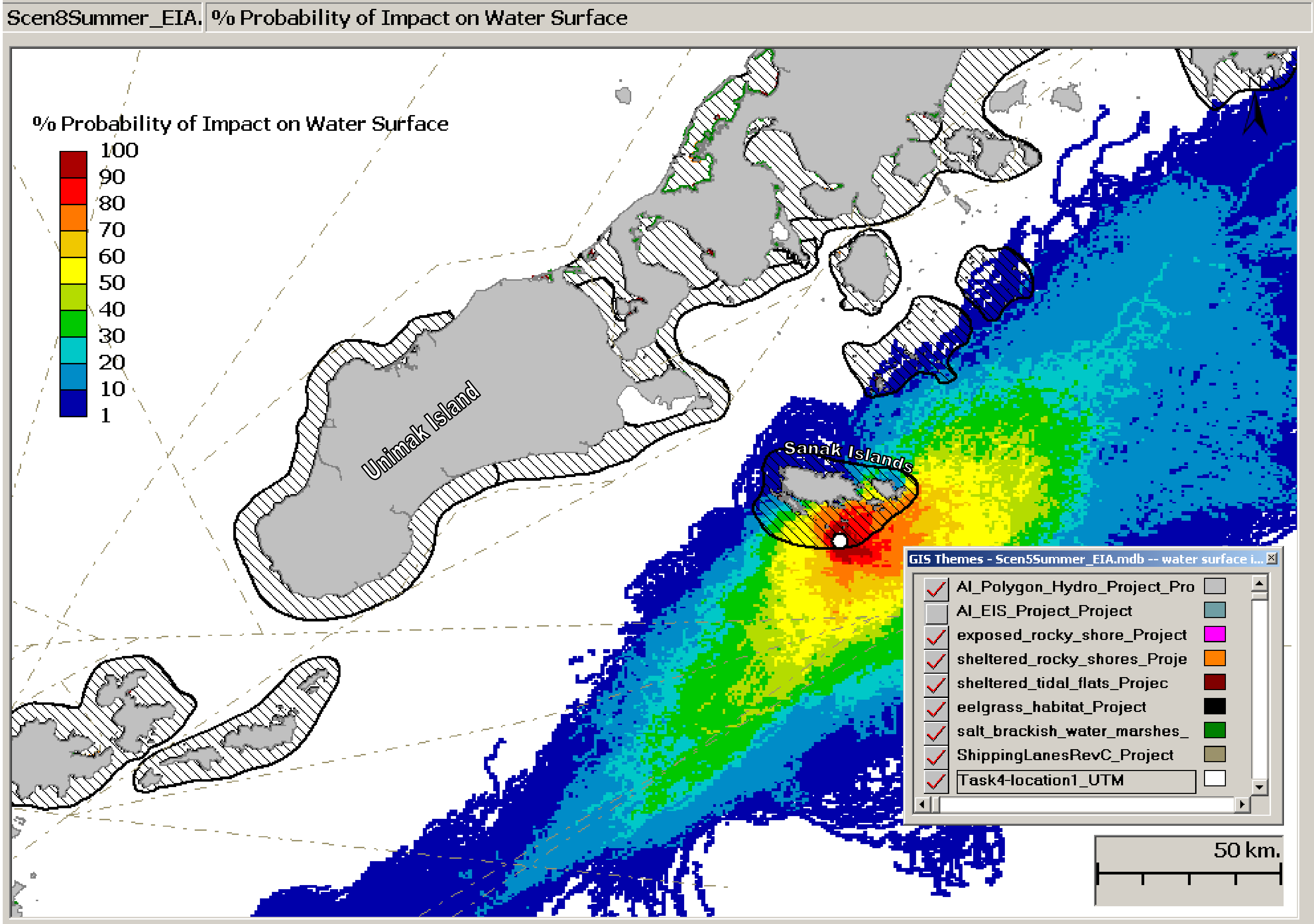
Scenario 6 - Summer - Sublittoral



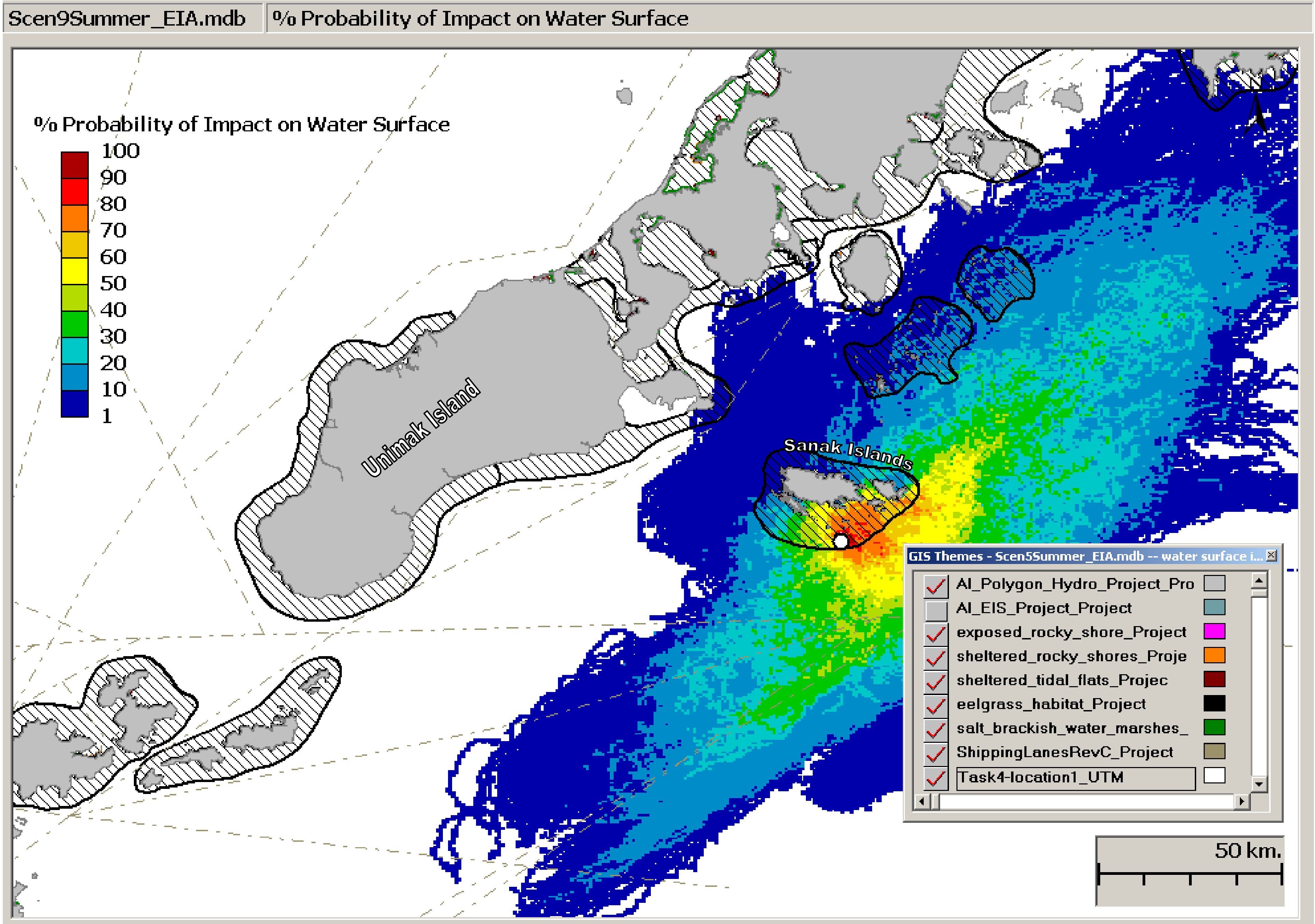
Scenario 7 - Summer - Sublittoral



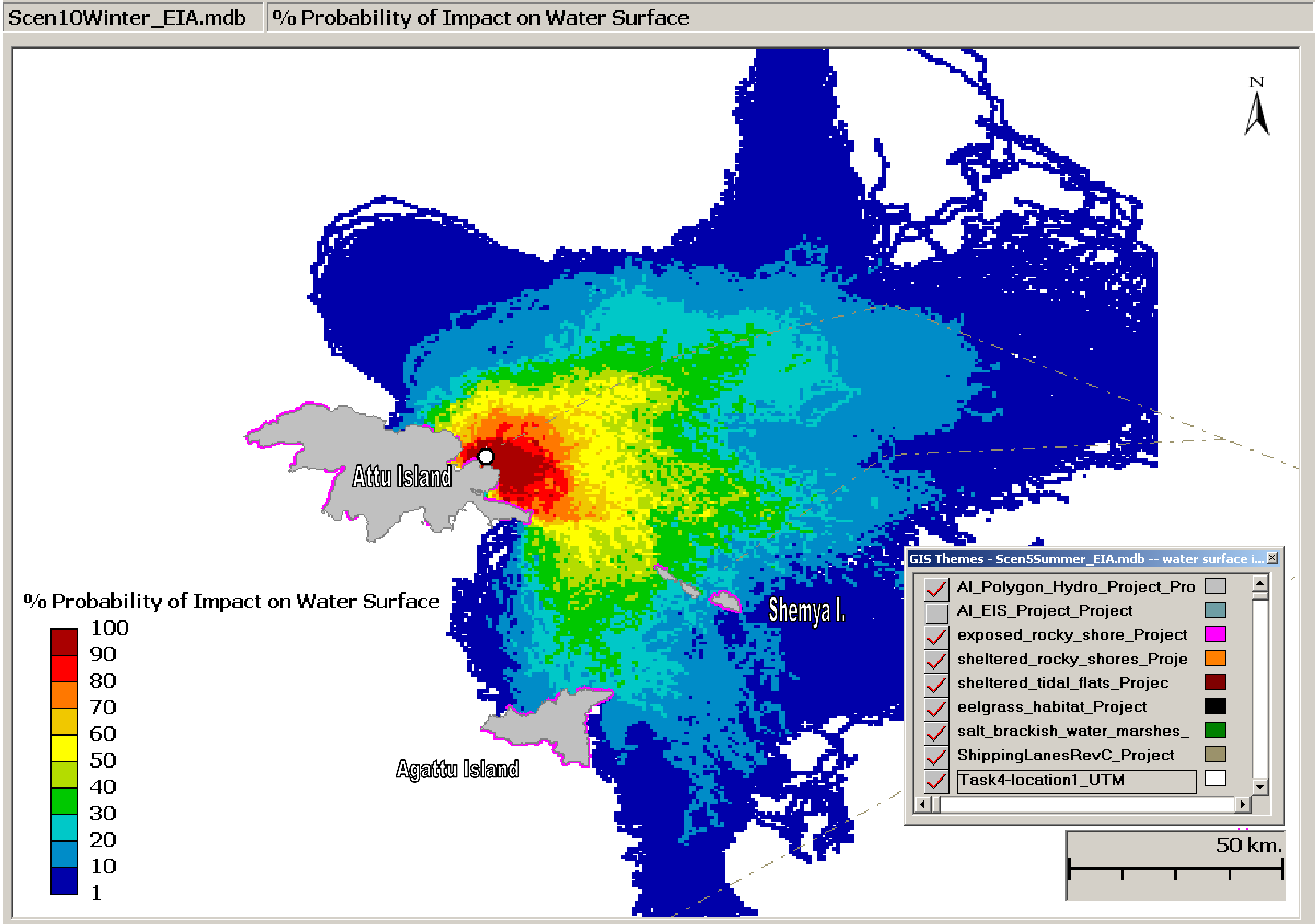
Scenario 8 - Summer - Sublittoral



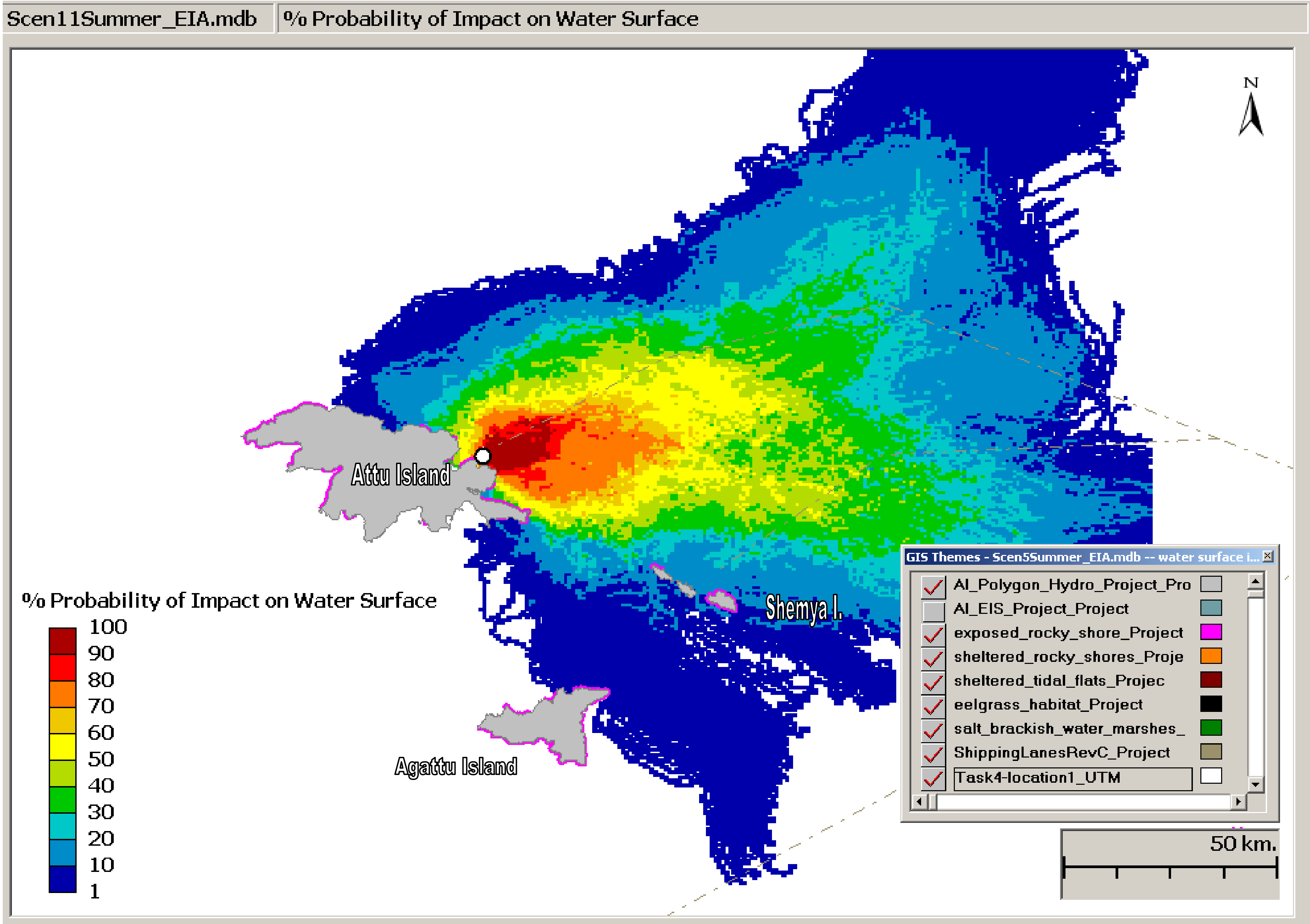
Scenario 9 - Summer - Sublittoral



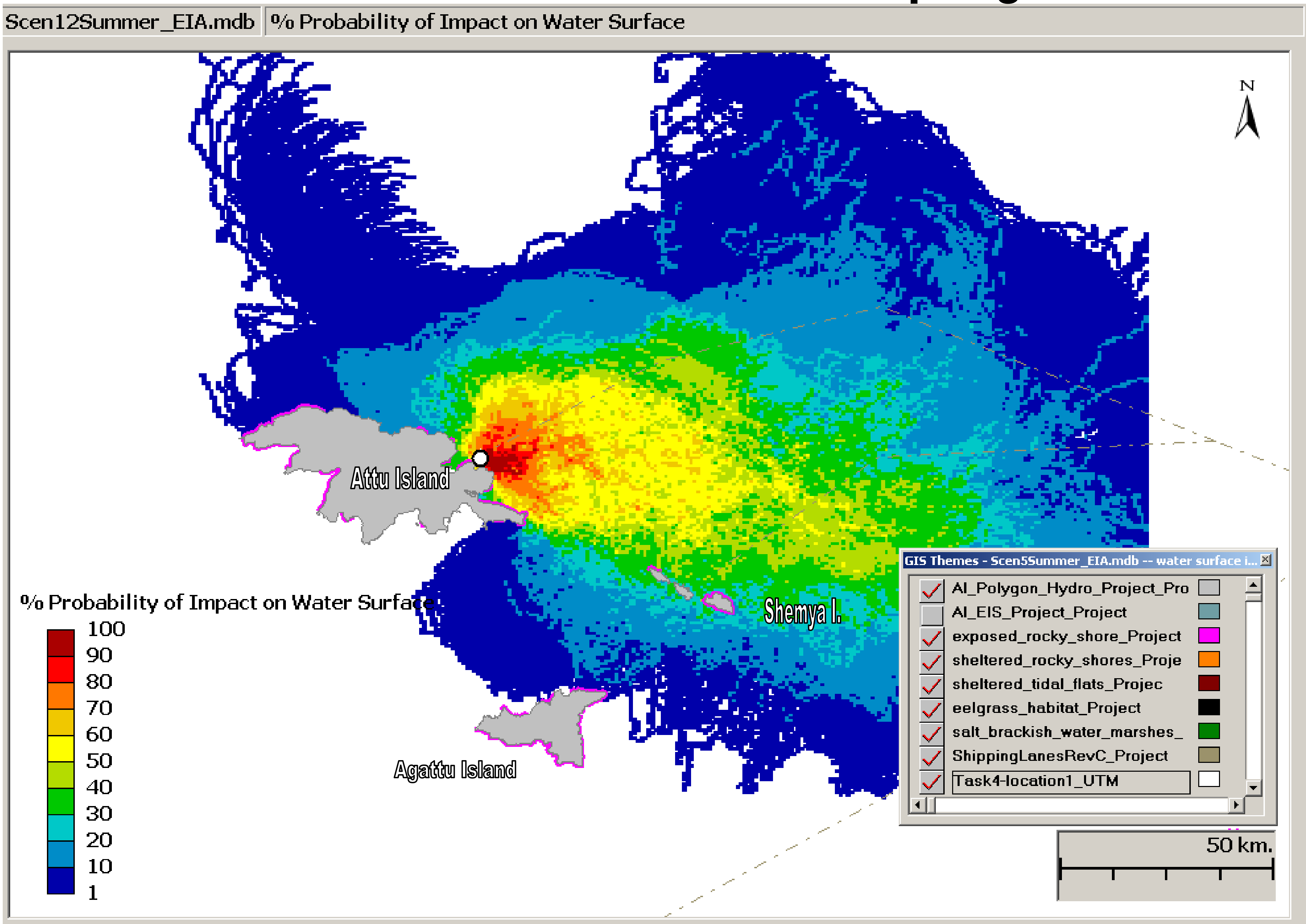
Scenario 10 - Winter - Sublittoral



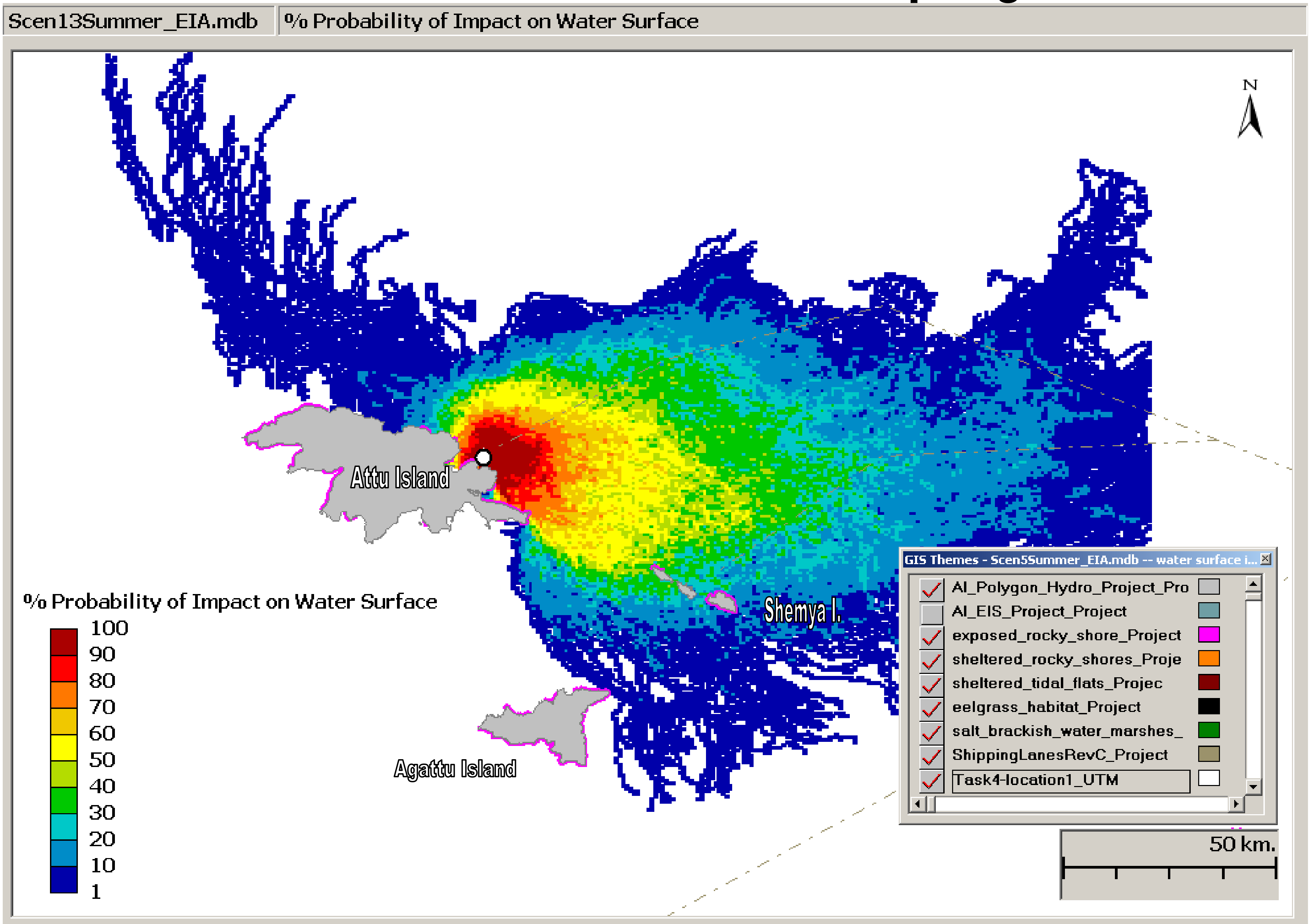
Scenario 11 - Summer - Sublittoral



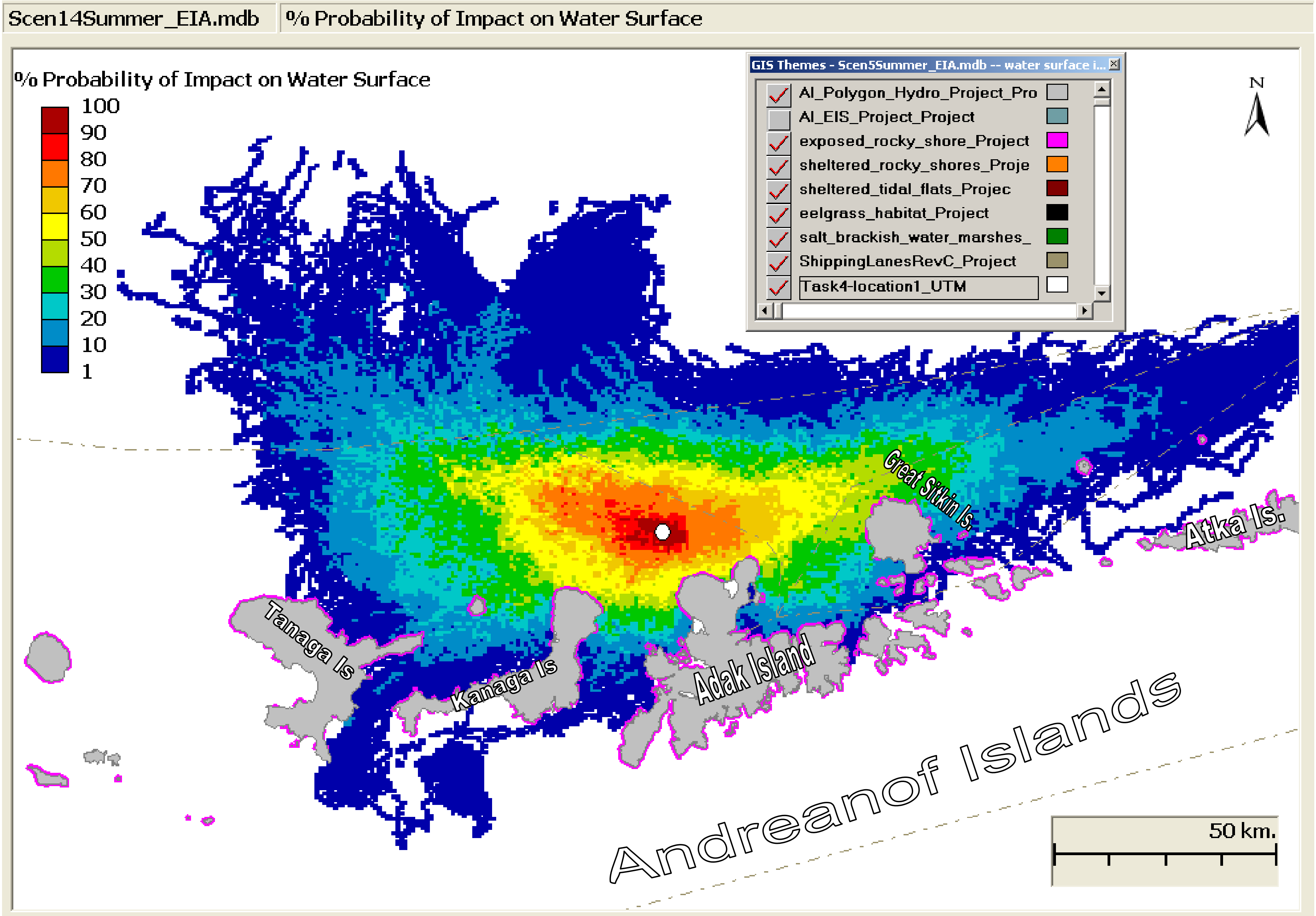
Scenario 12 - Spring - Sublittoral



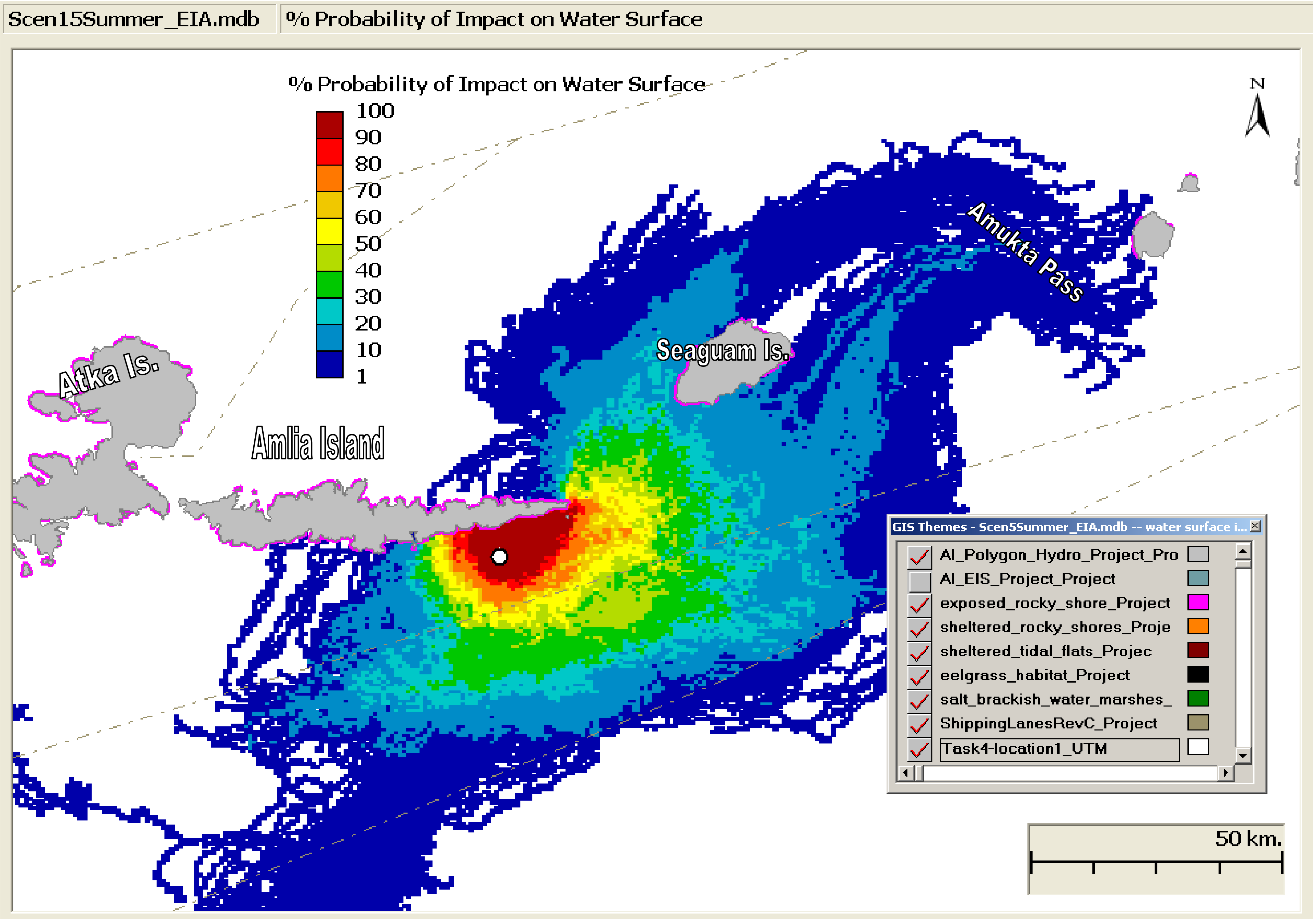
Scenario 13 - Spring - Sublittoral



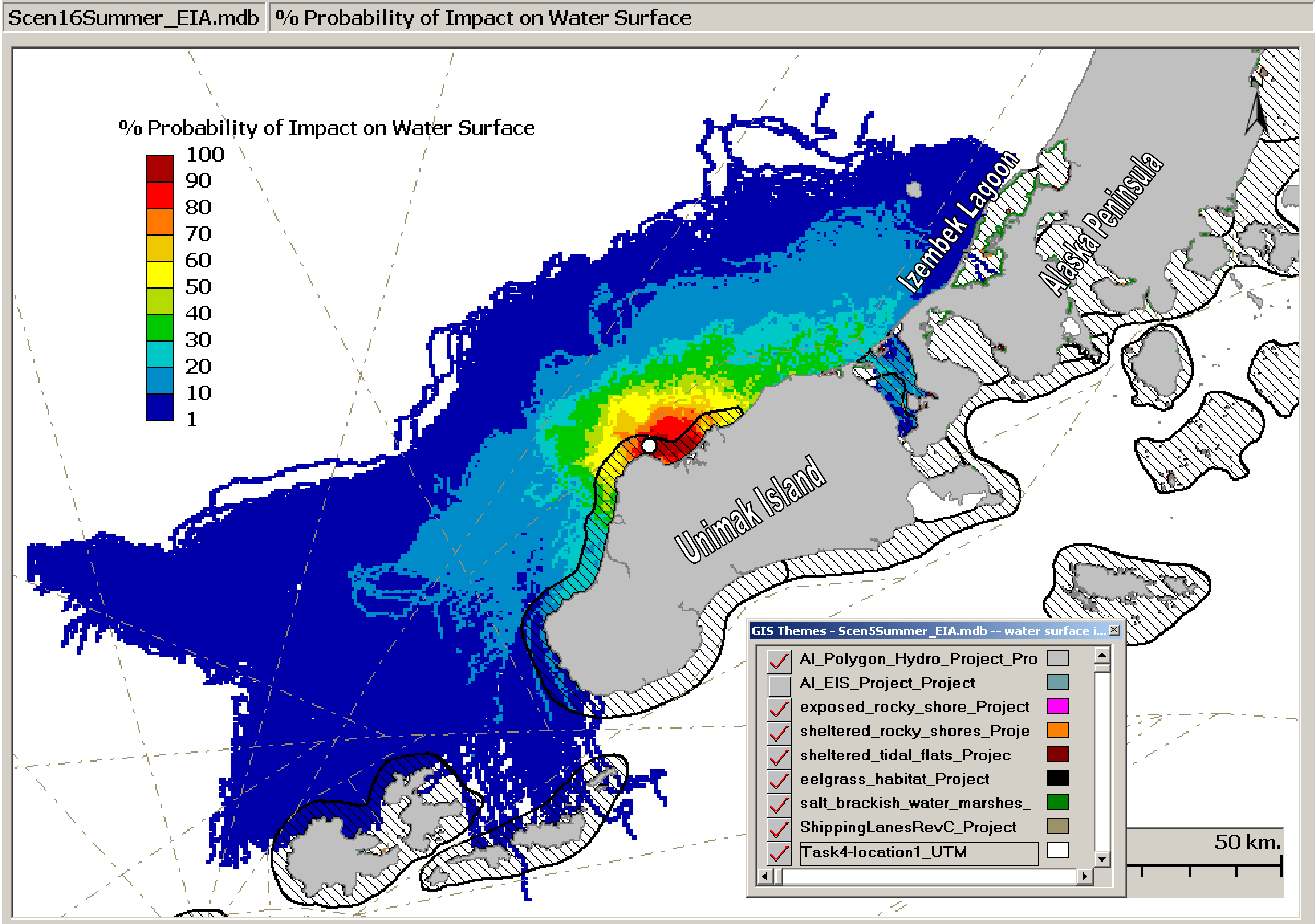
Scenario 14 - Summer - Sublittoral



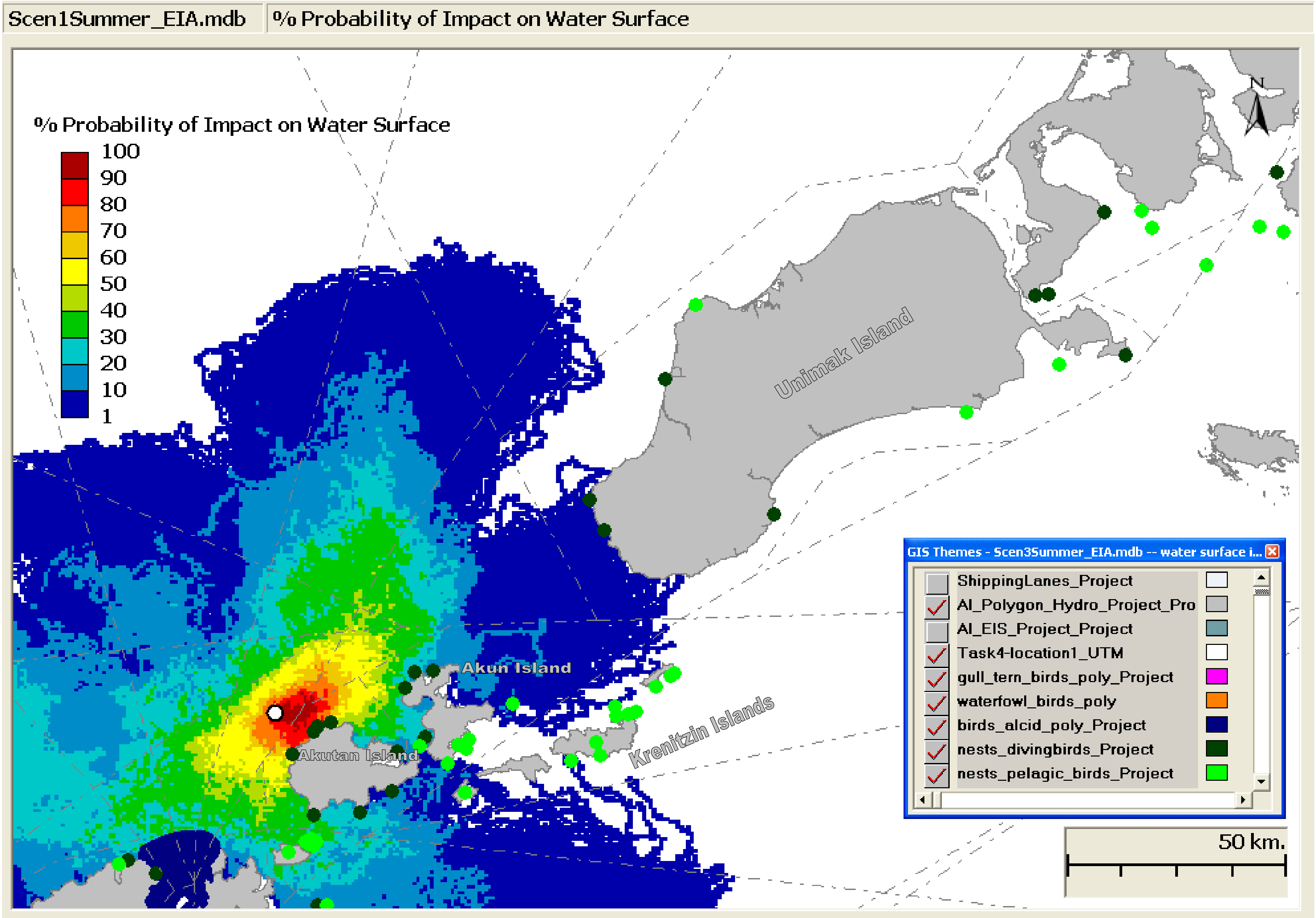
Scenario 15 - Summer - Sublittoral



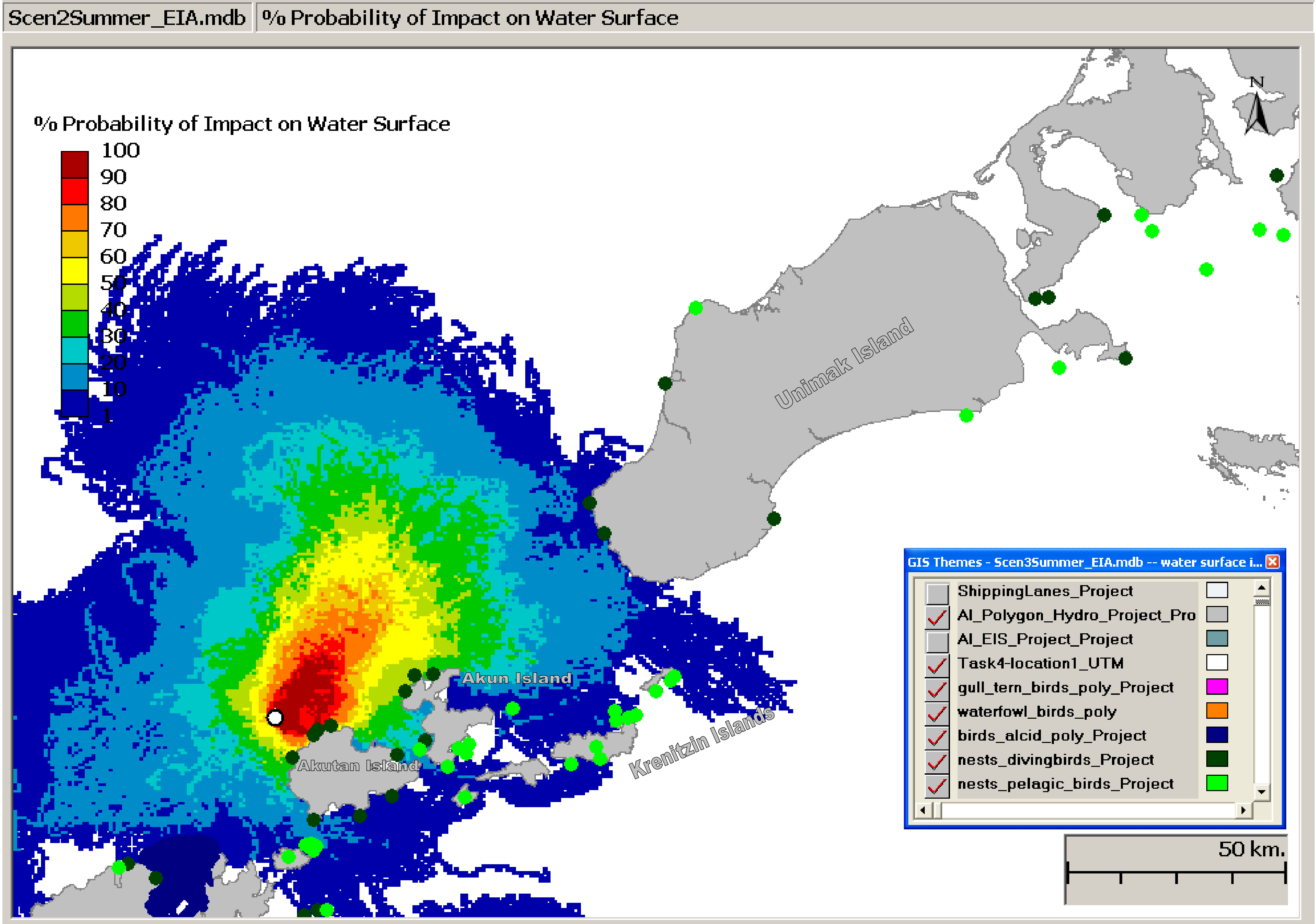
Scenario 16 - Spring - Sublittoral



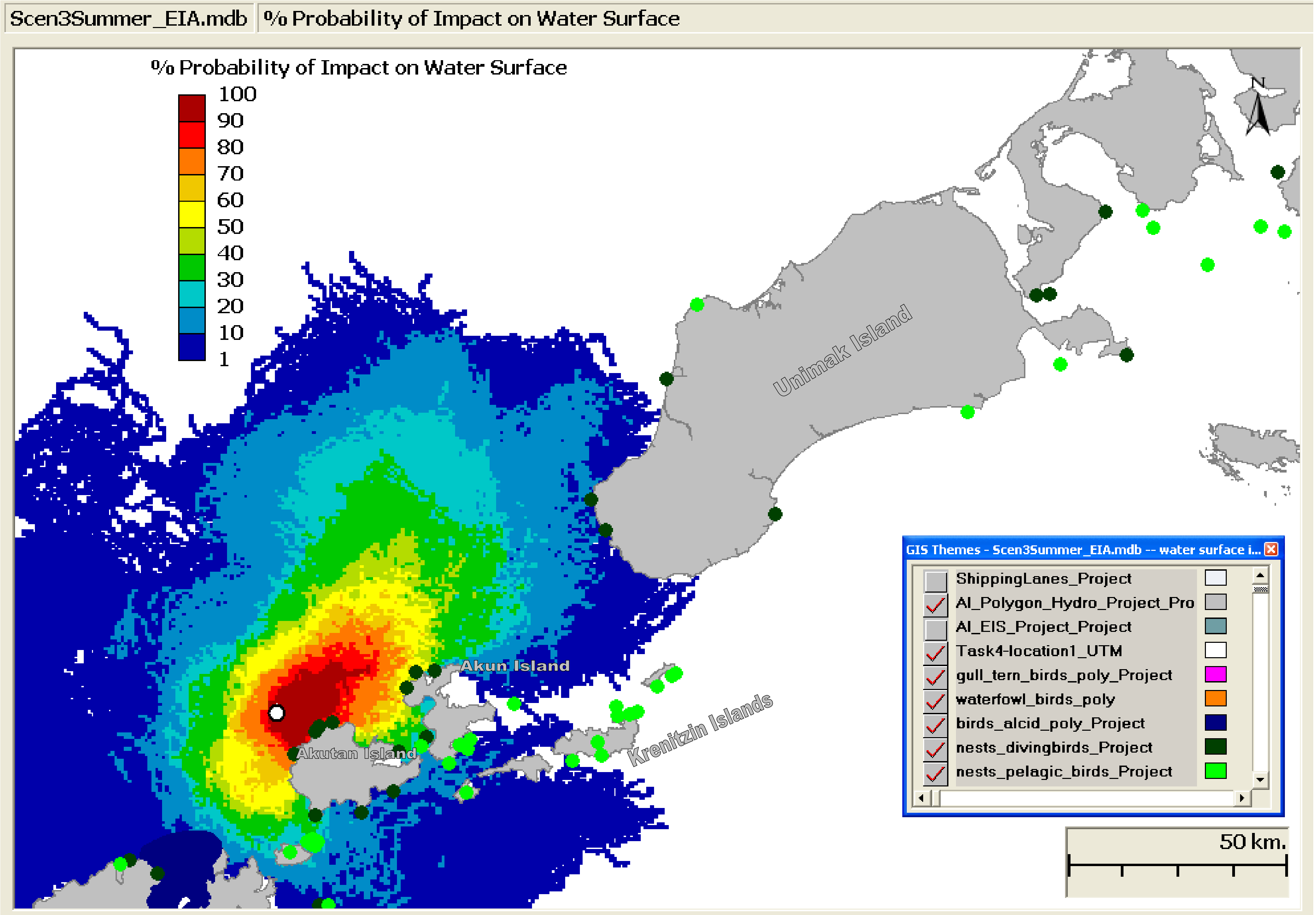
Scenario 1 - Summer - Birds



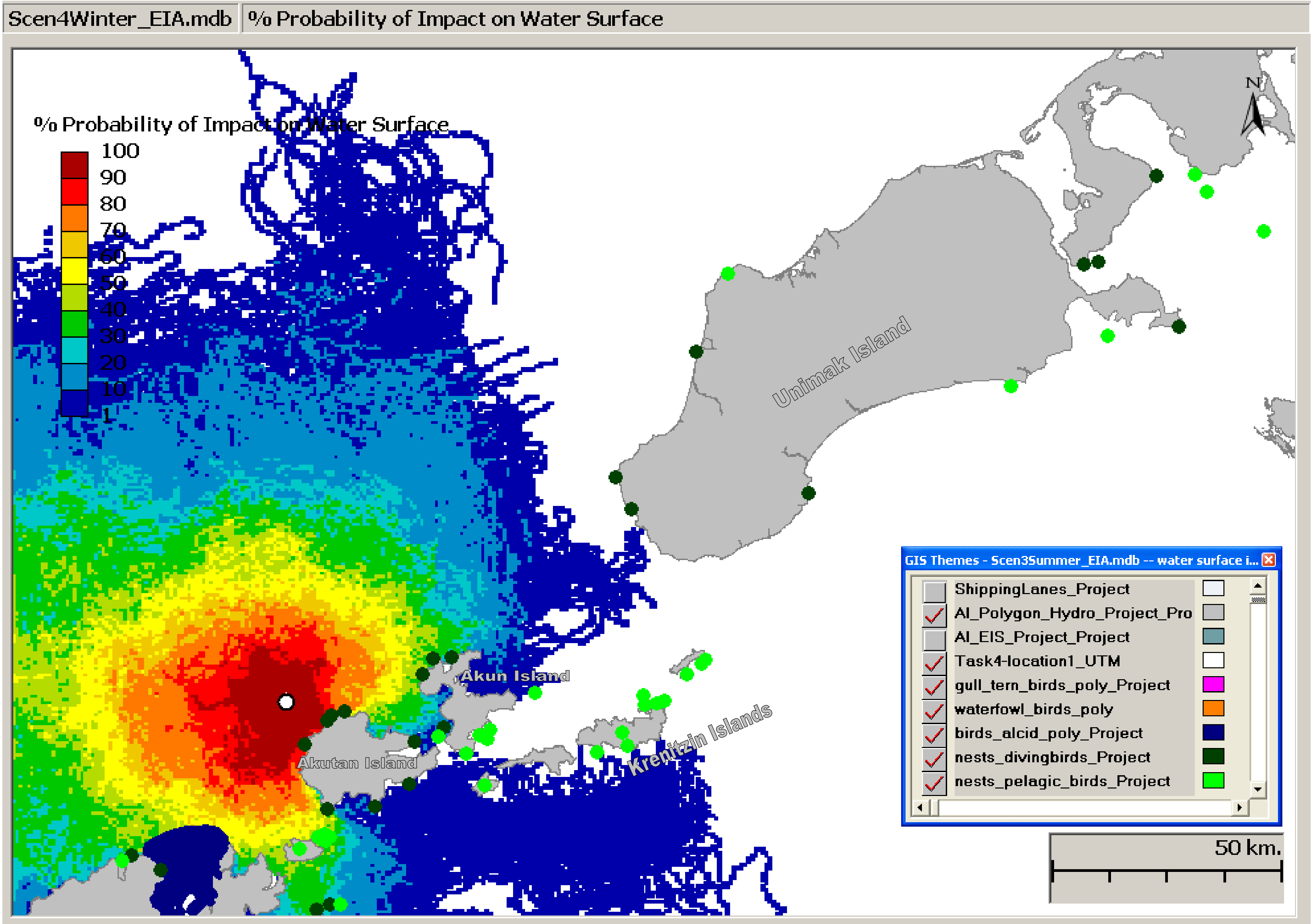
Scenario 2 - Summer - Birds



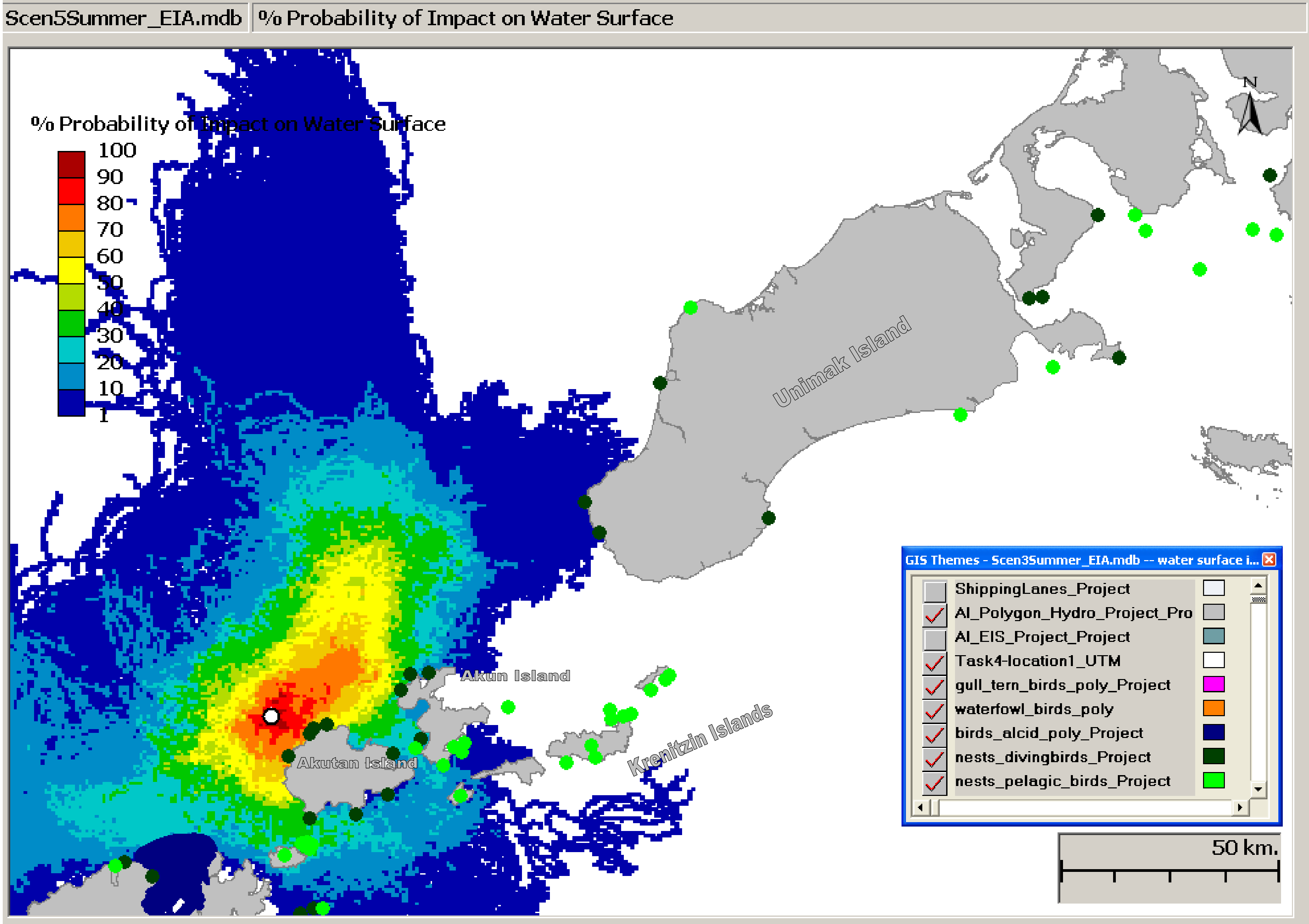
Scenario 3 - Summer - Birds



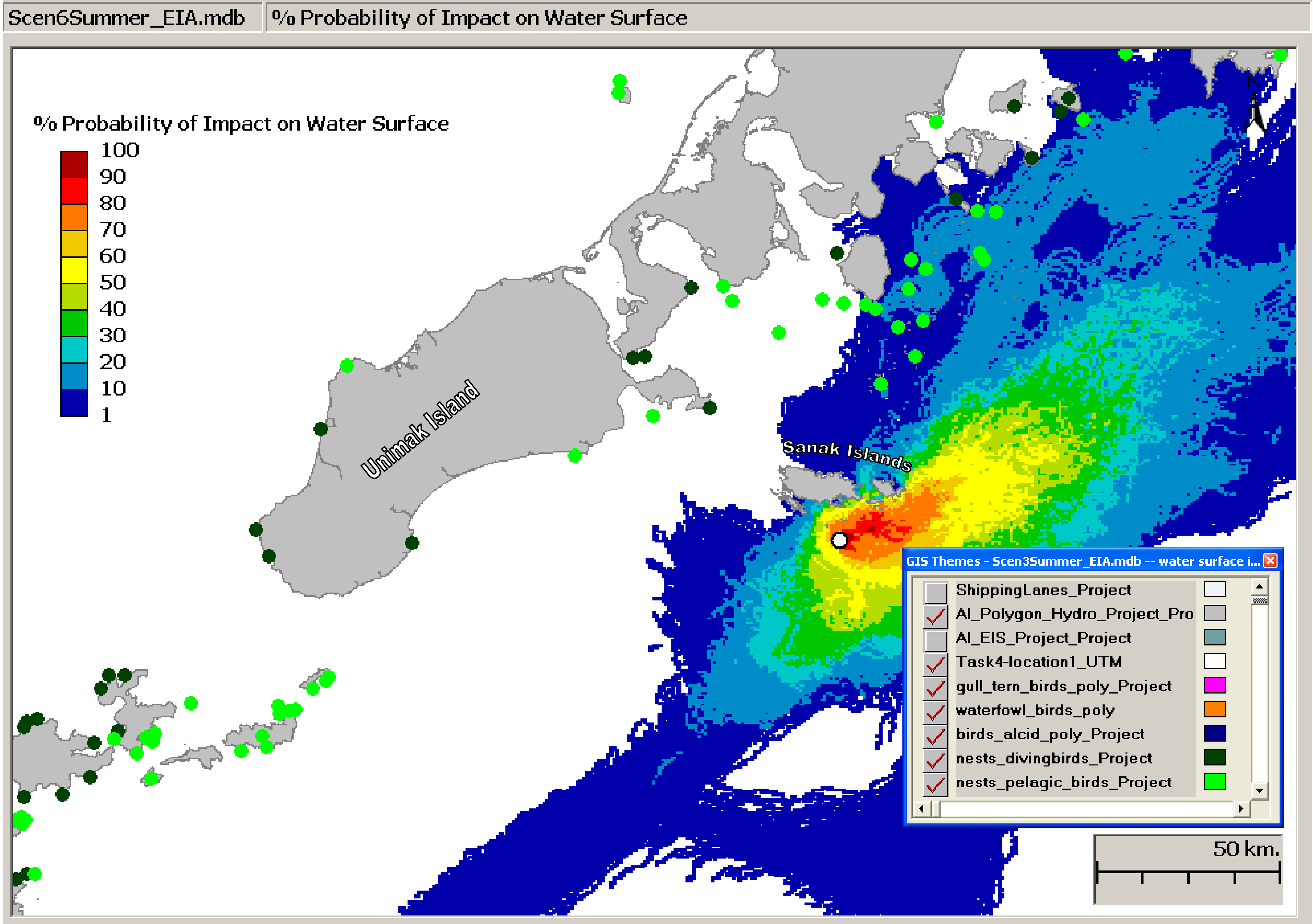
Scenario 4 - Winter - Birds



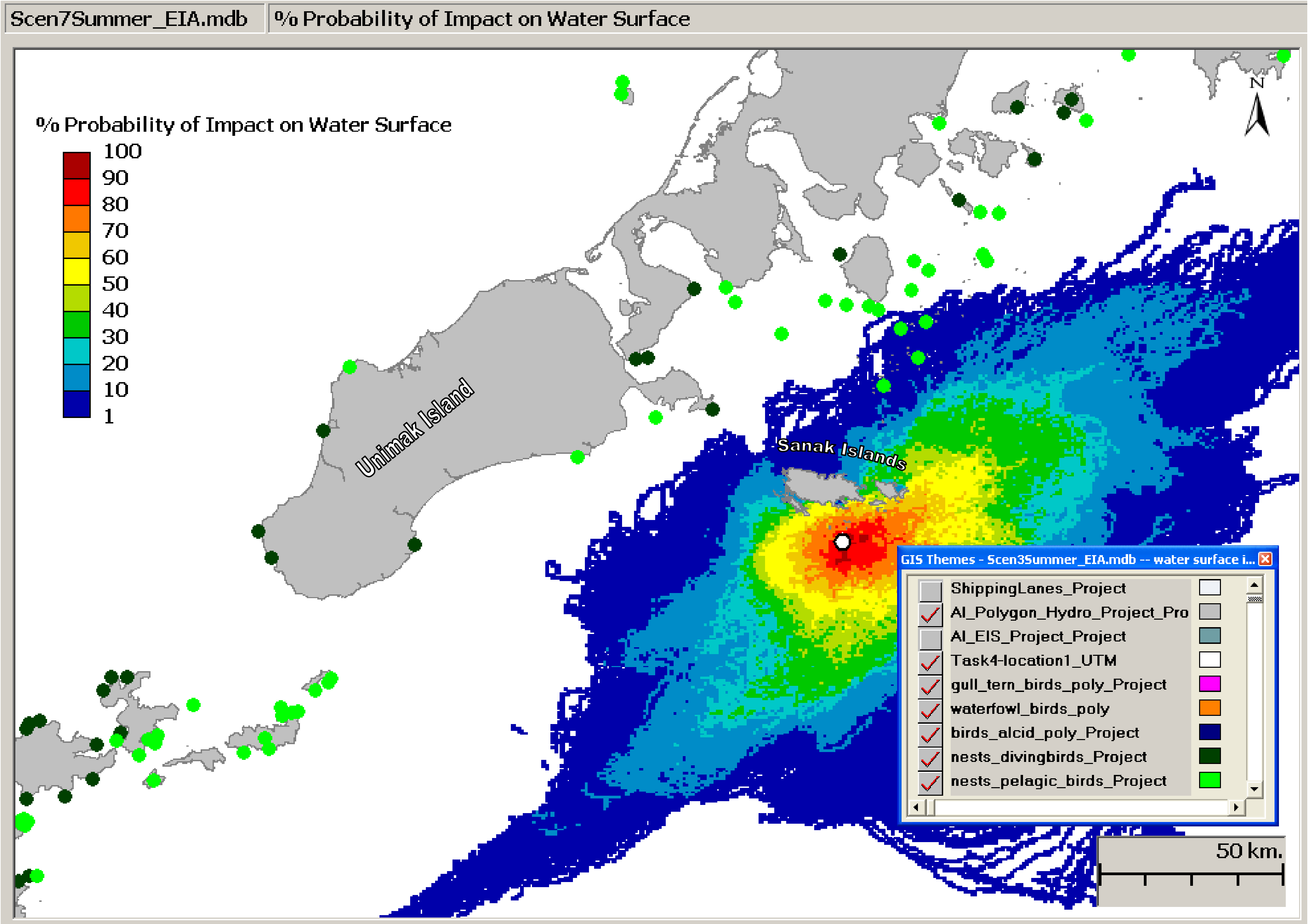
Scenario 5 - Summer - Birds



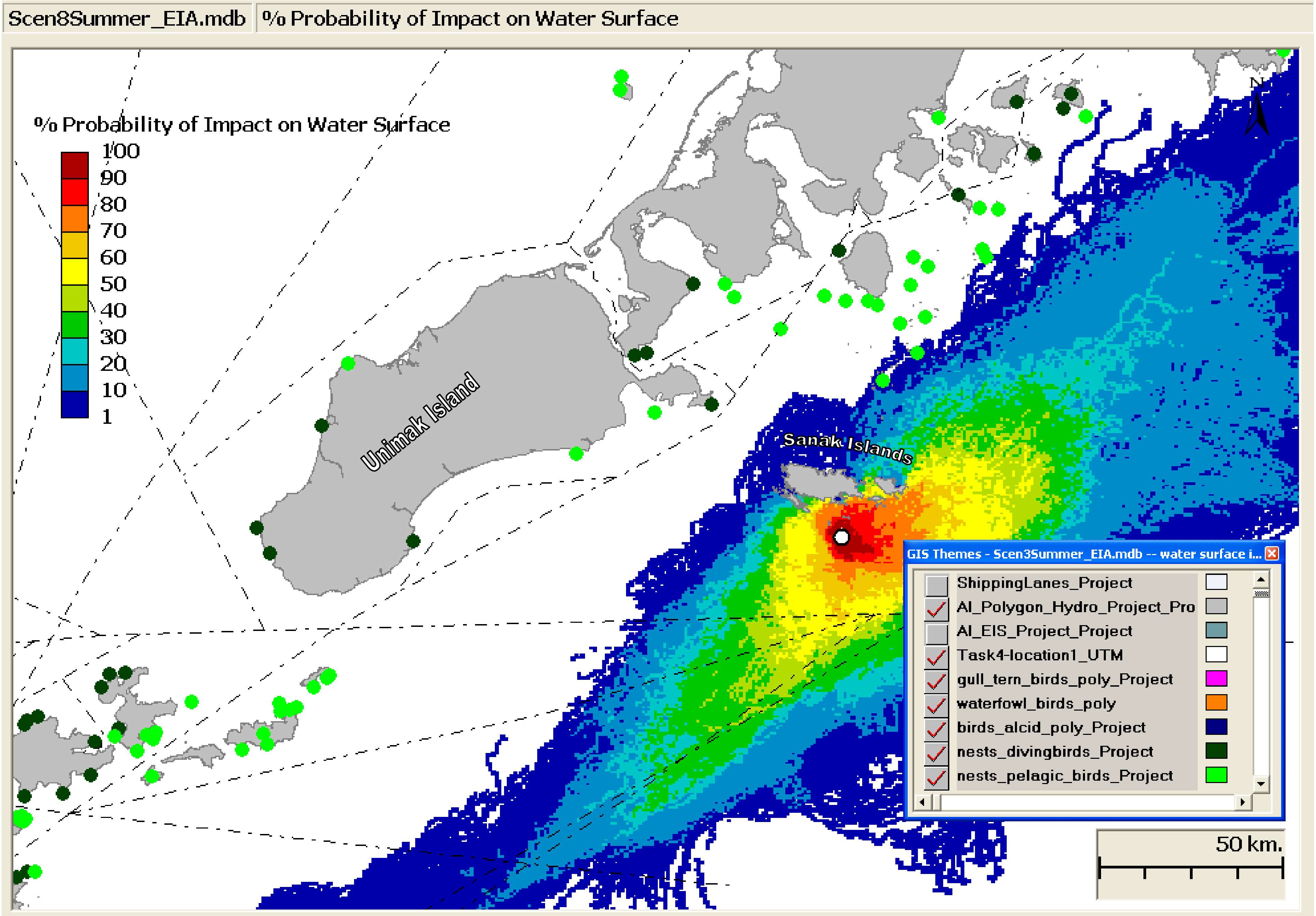
Scenario 6 - Summer - Birds



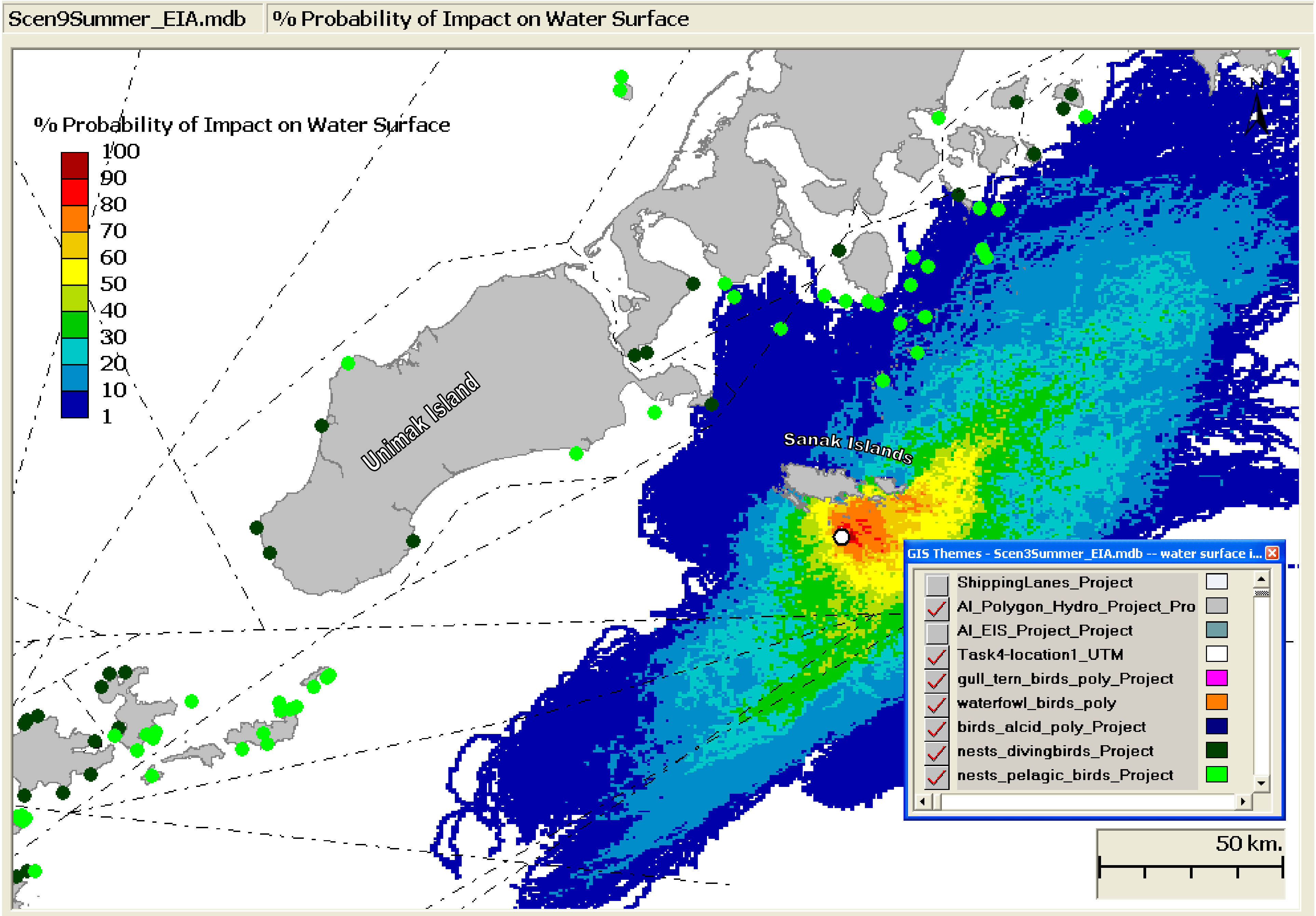
Scenario 7 - Summer - Birds



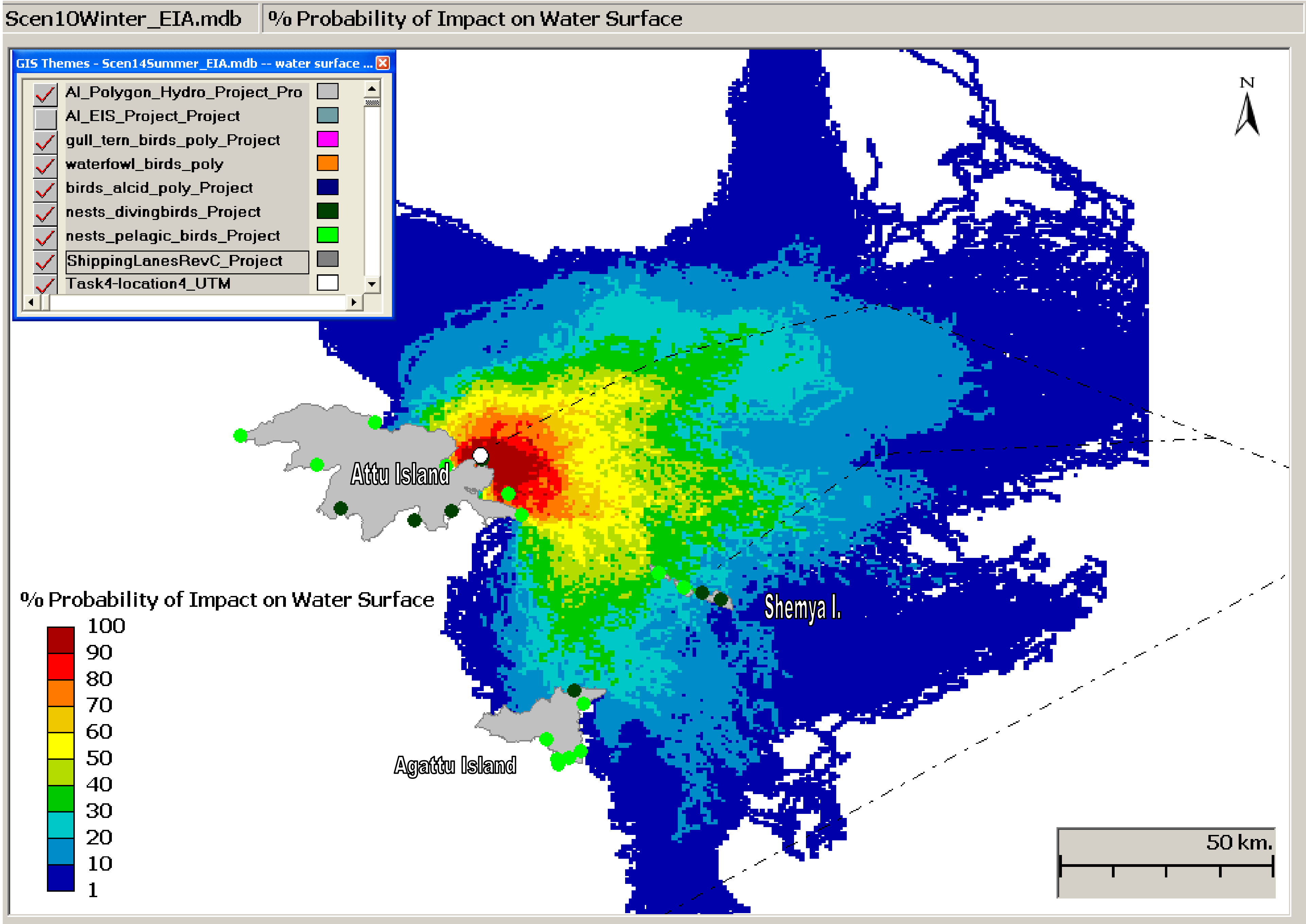
Scenario 8 - Summer - Birds



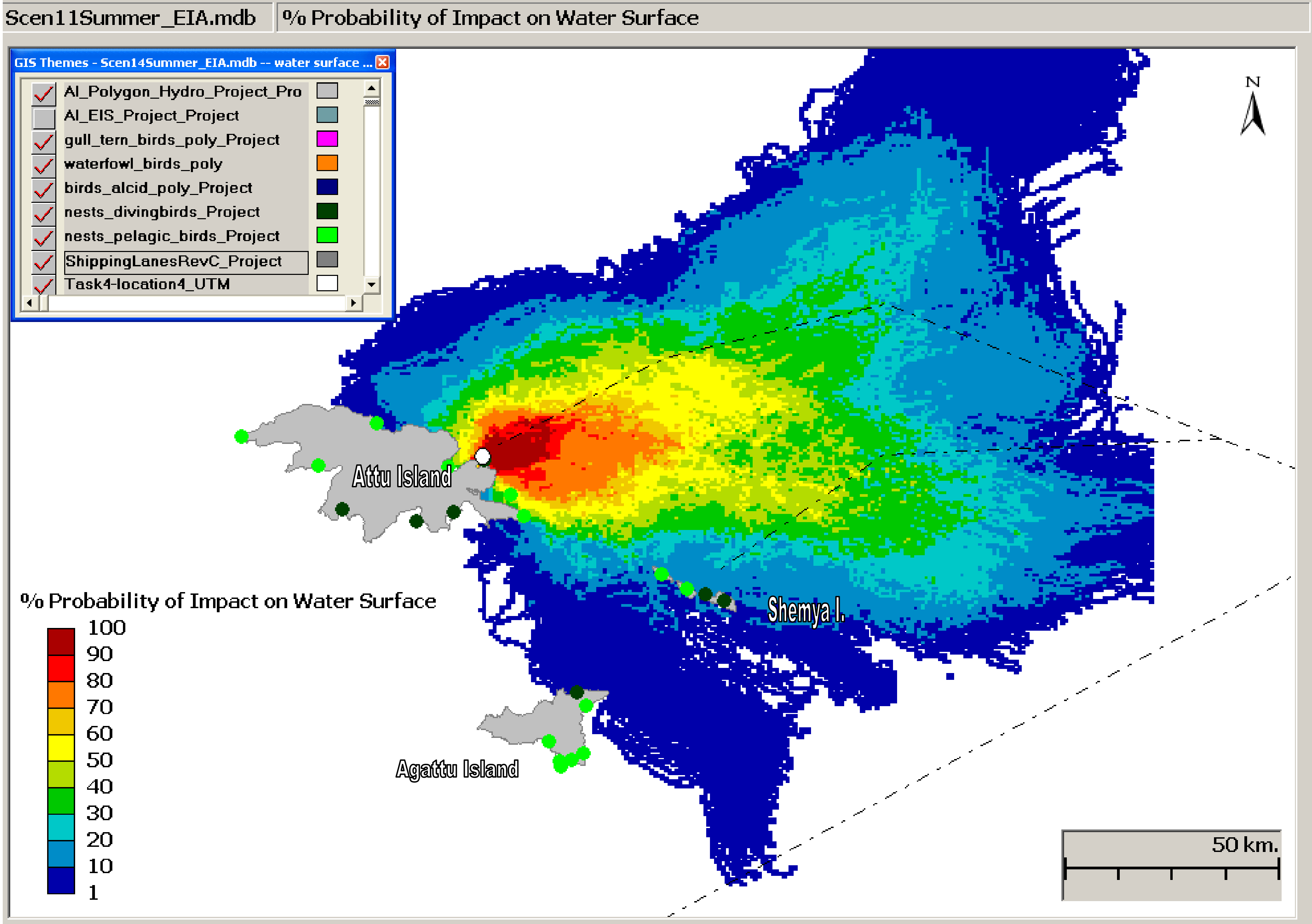
Scenario 9 - Summer - Birds



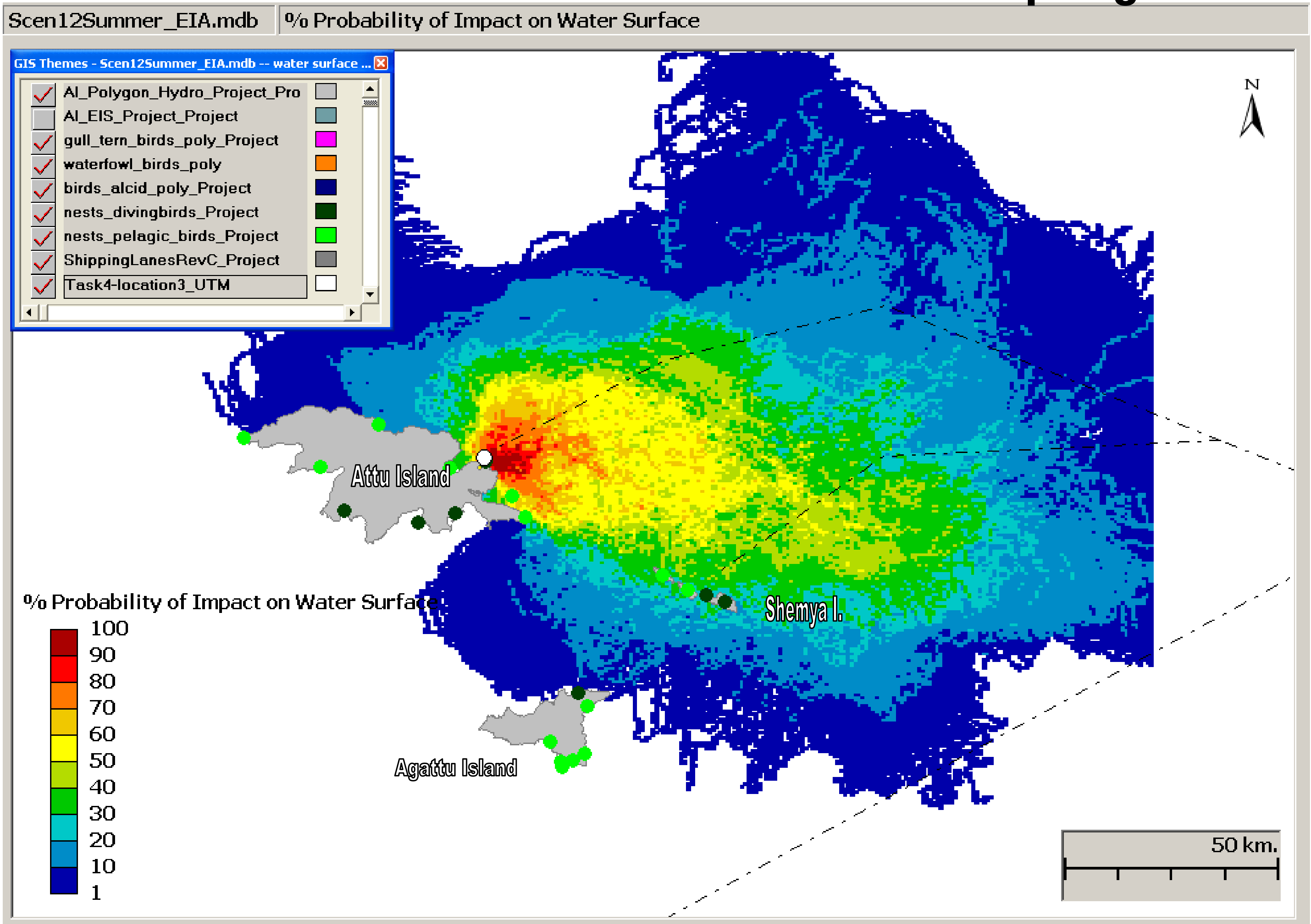
Scenario 10 - Winter - Birds



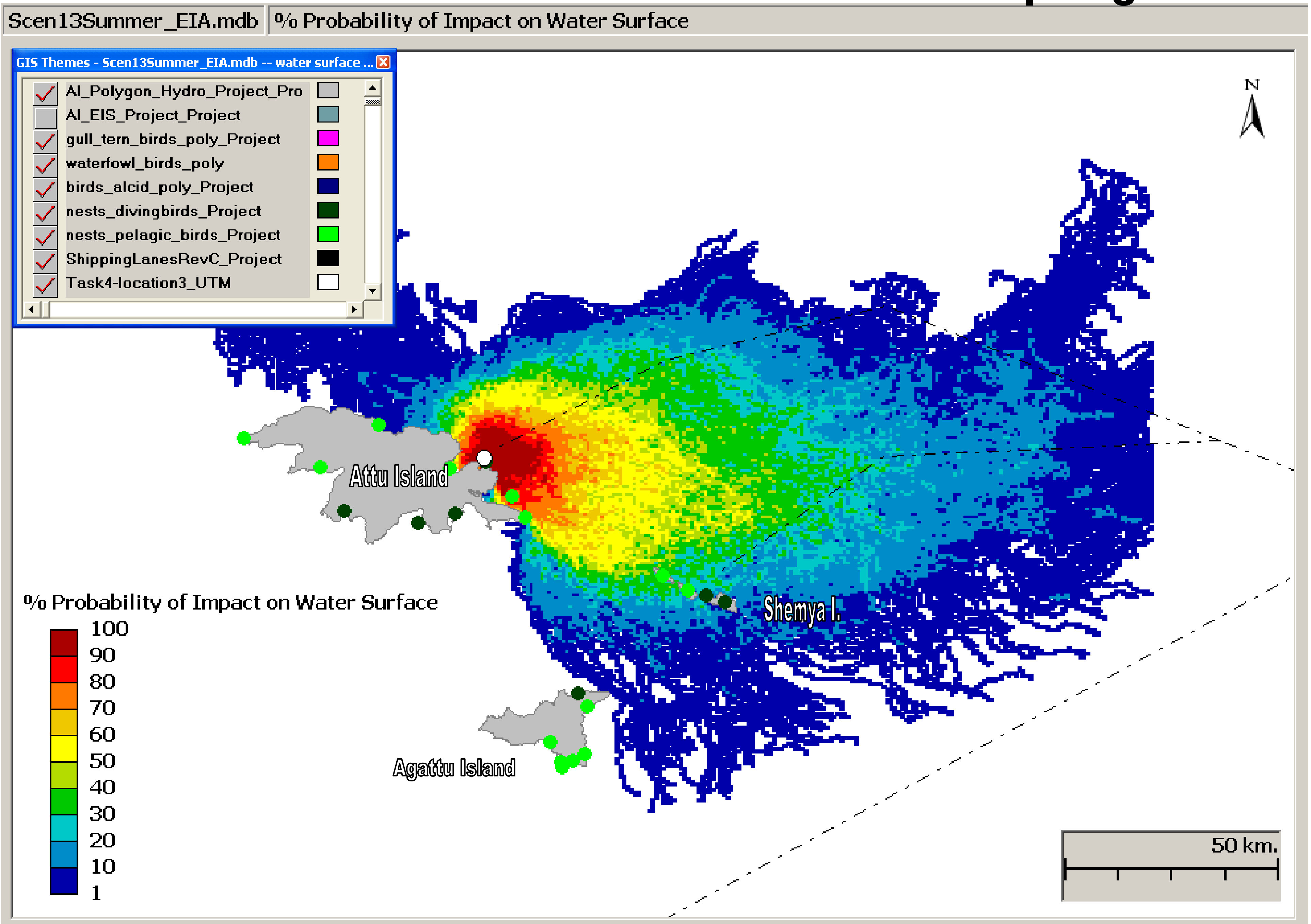
Scenario 11 - Summer - Birds



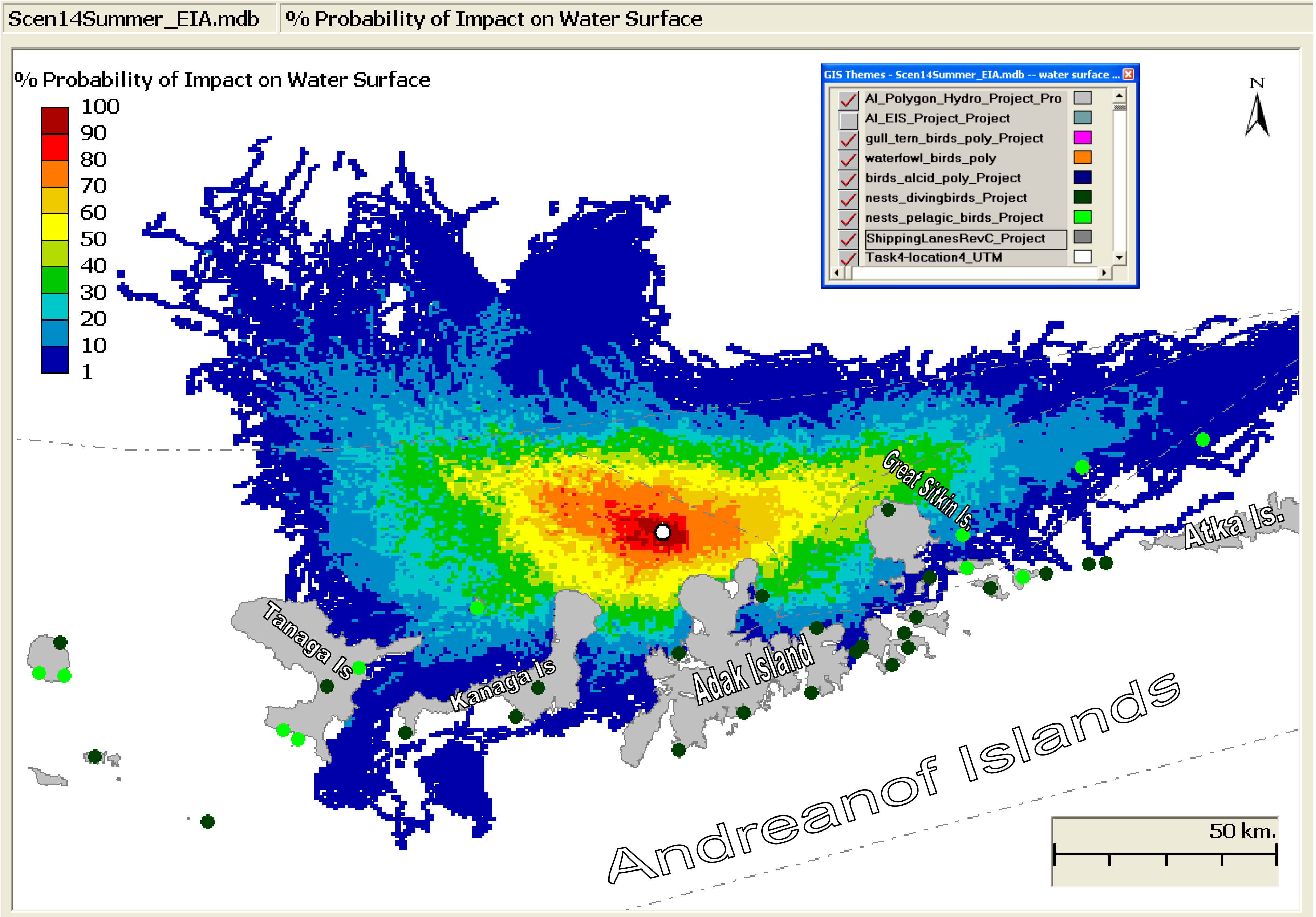
Scenario 12 - Spring - Birds



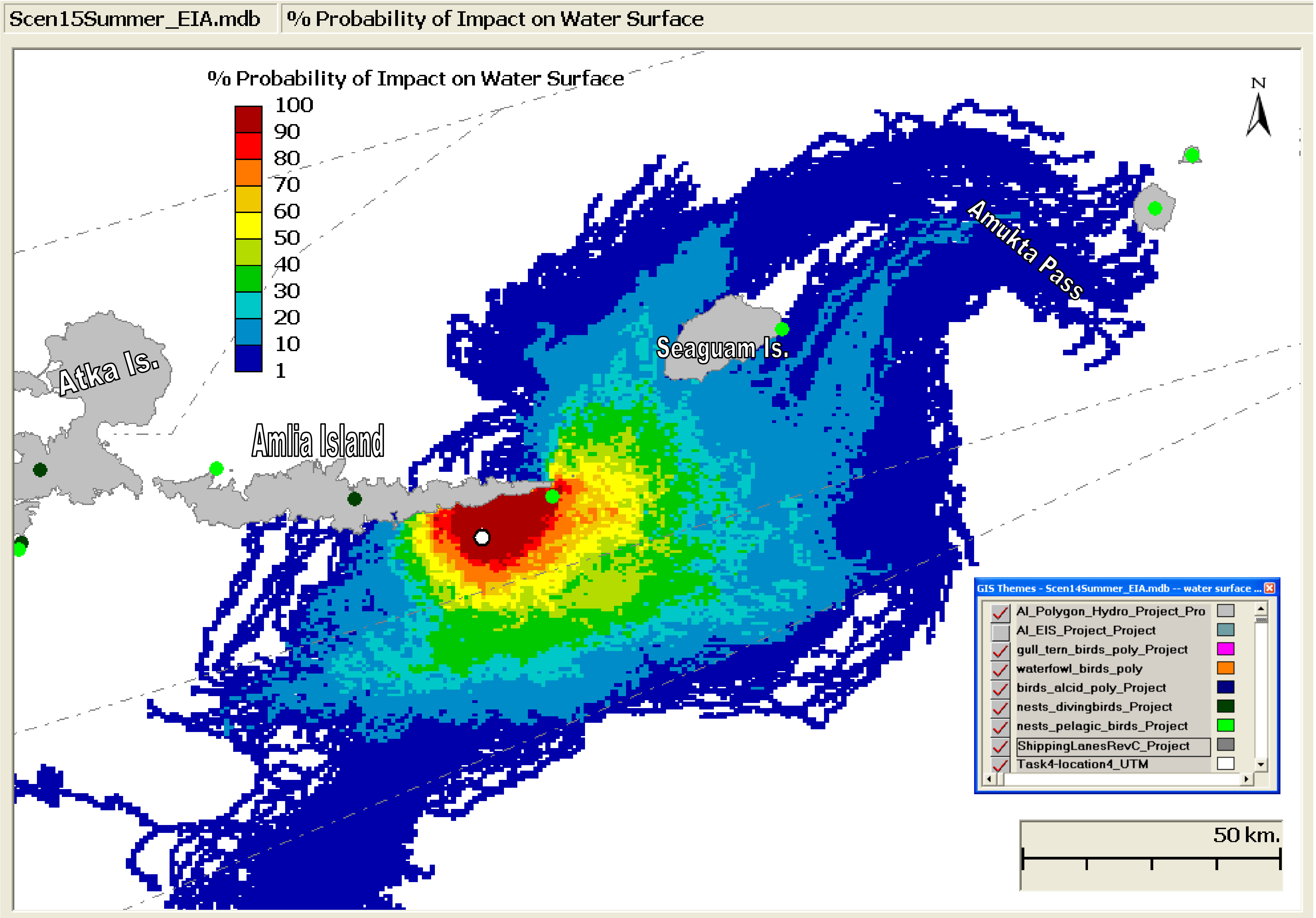
Scenario 13 - Spring - Birds



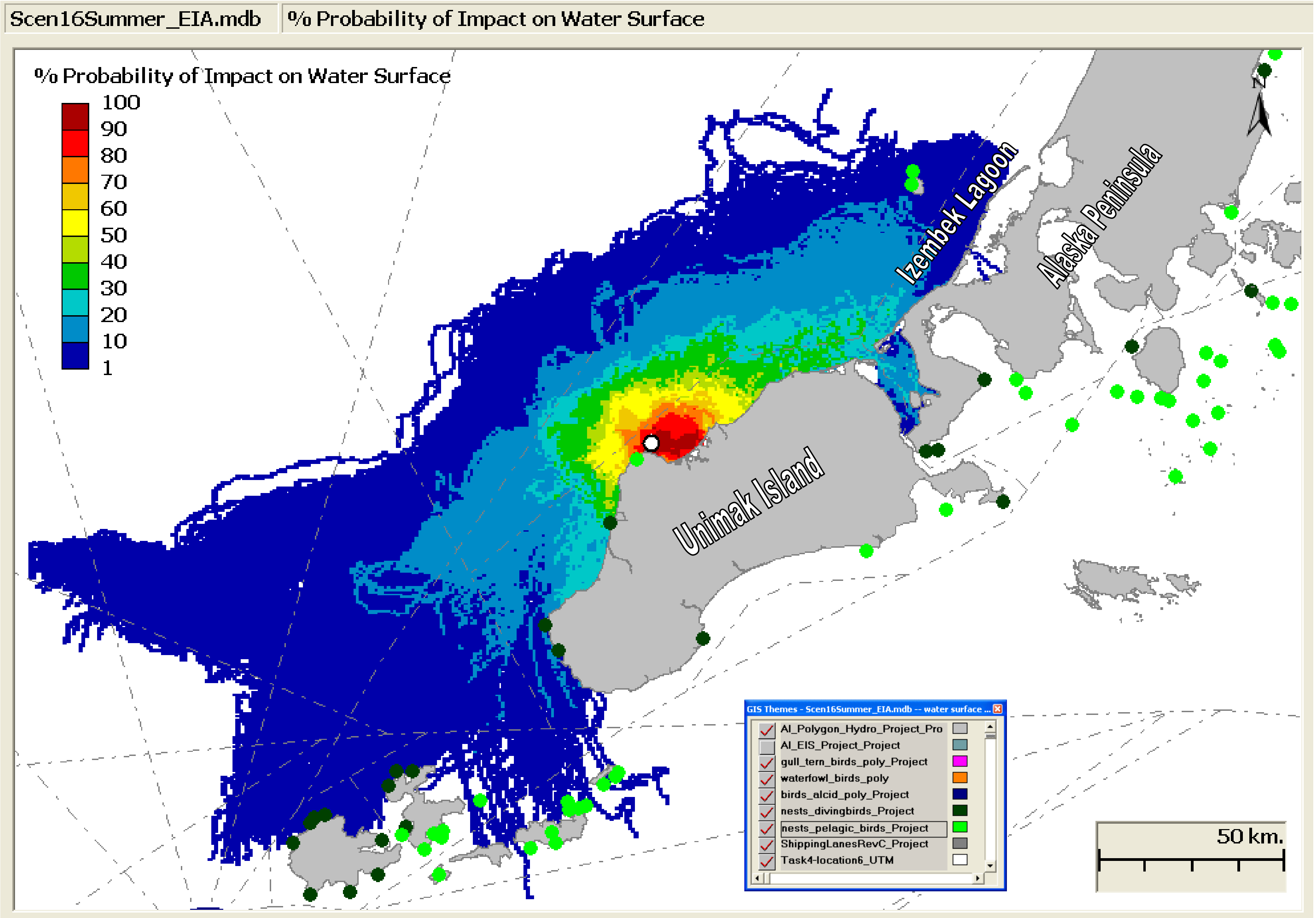
Scenario 14 - Summer - Birds



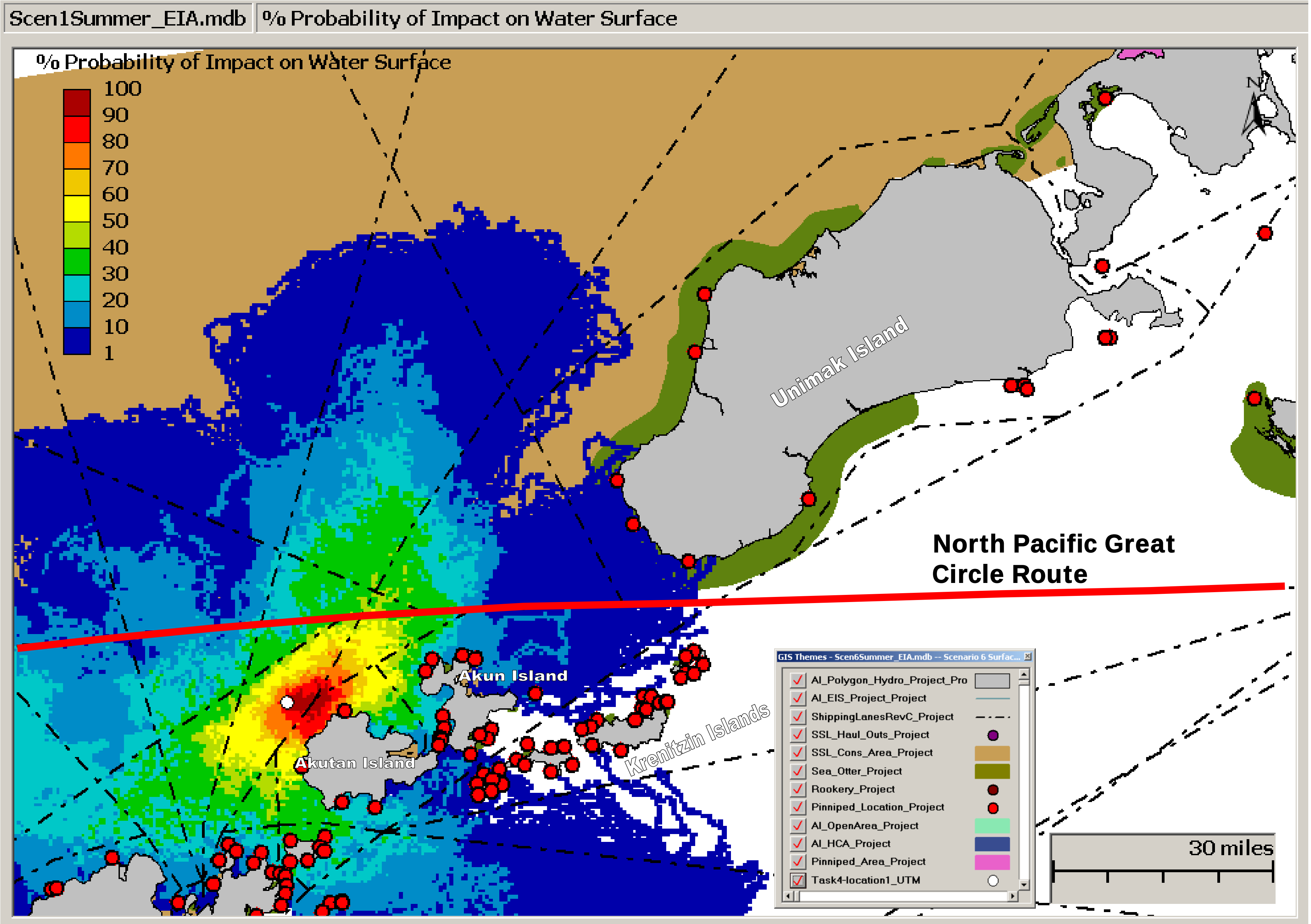
Scenario 15 - Summer - Birds



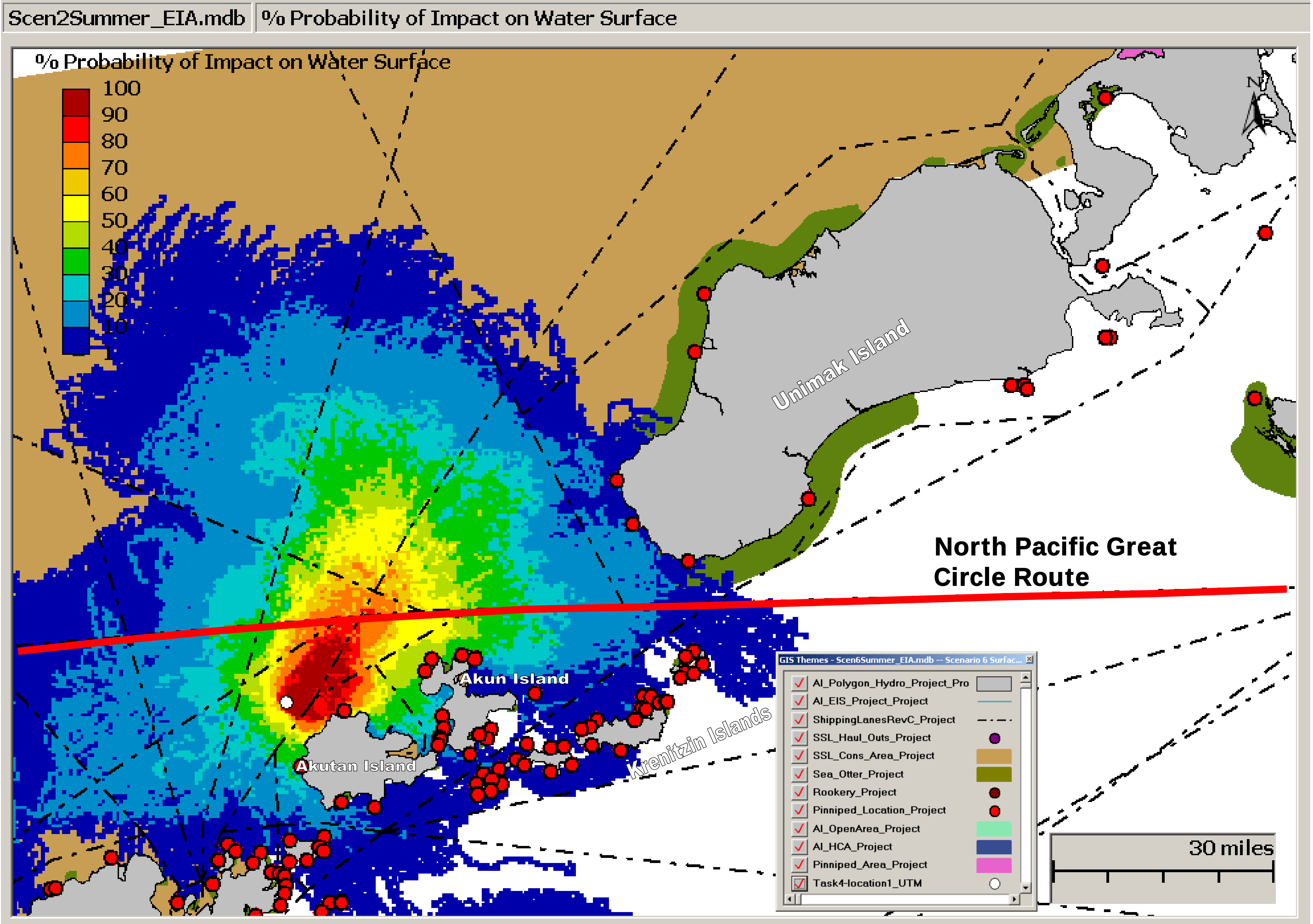
Scenario 16 - Spring - Birds



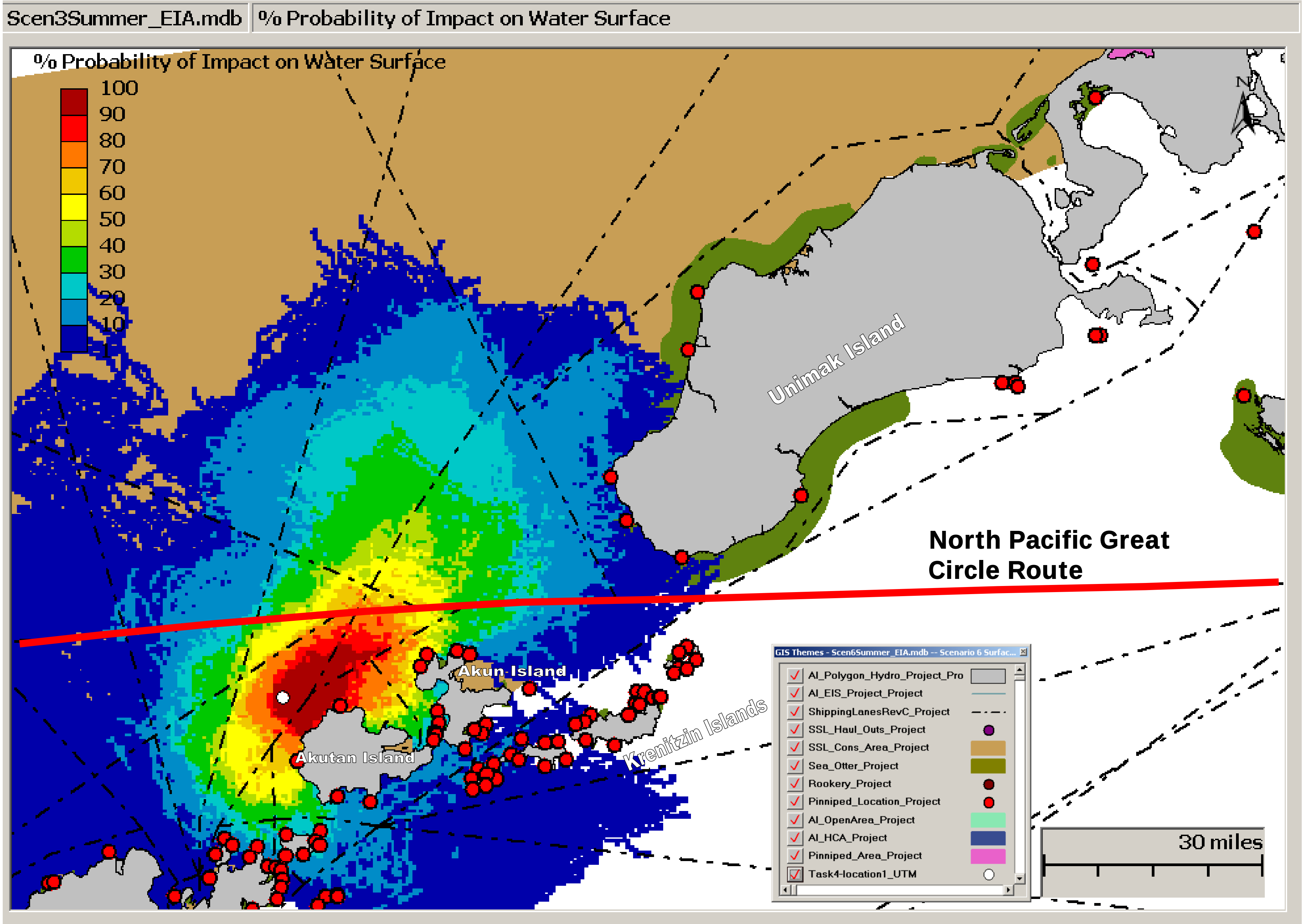
Scenario 1 – Summer Marine Mammals



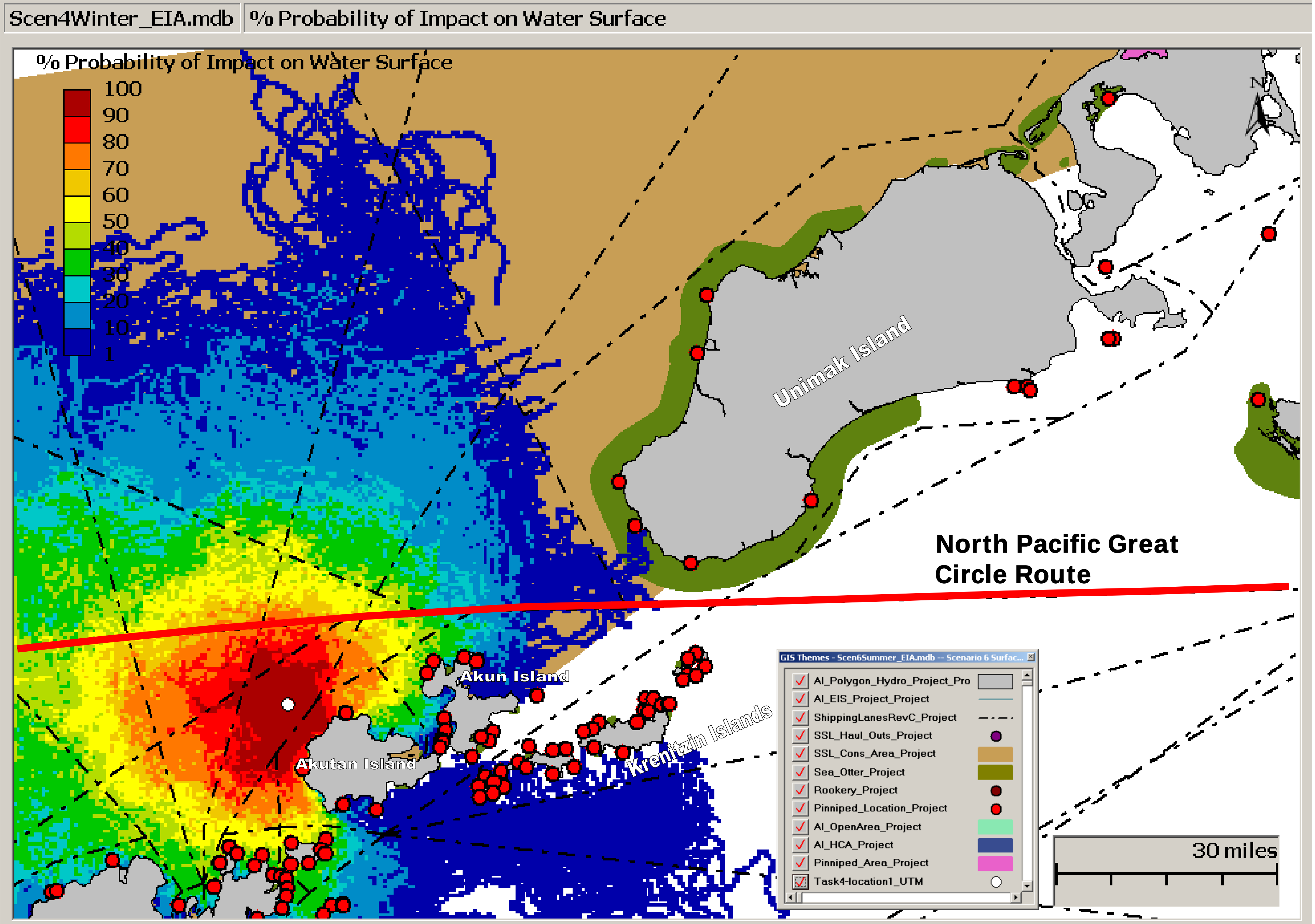
Scenario 2 – Summer Marine Mammals



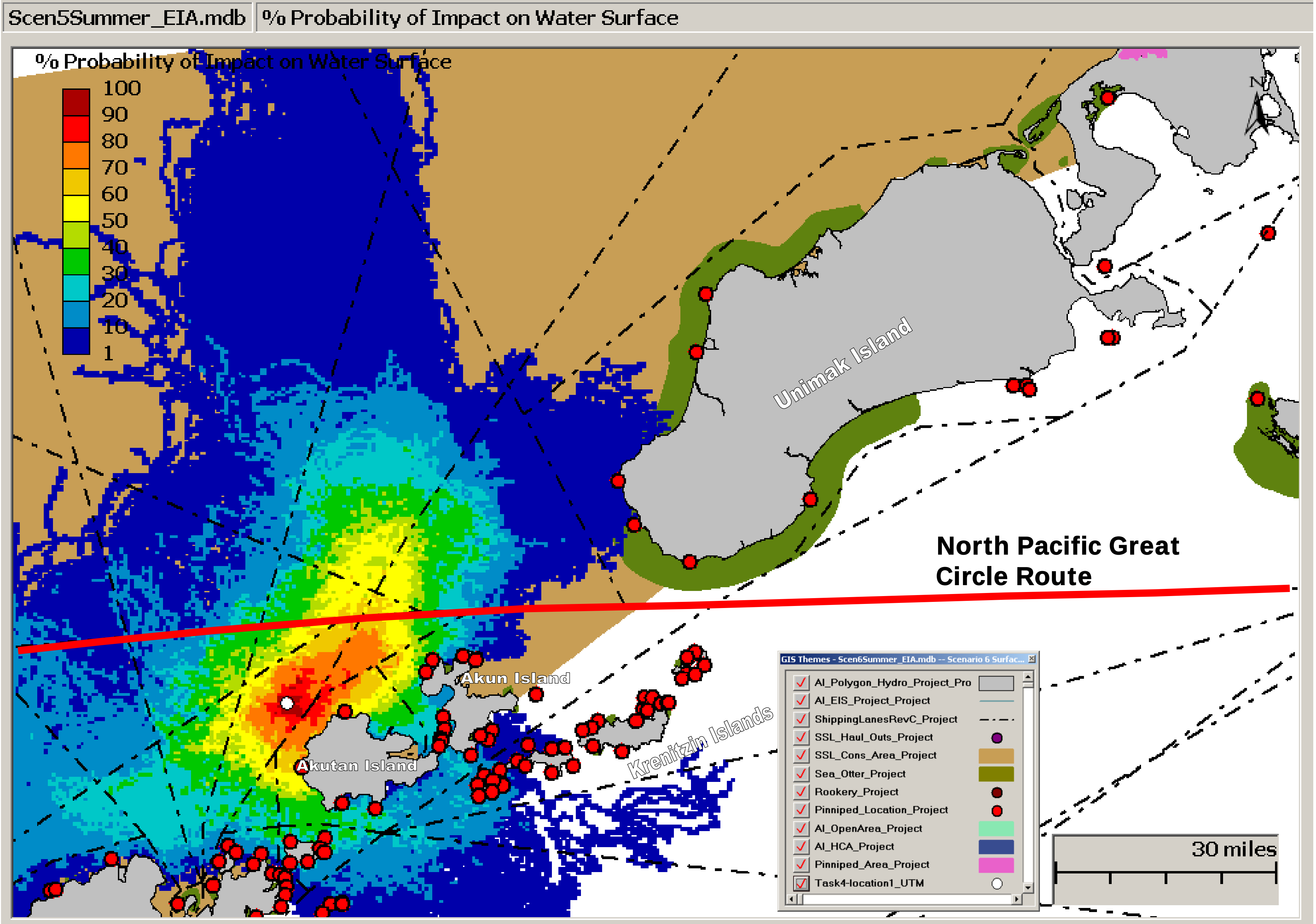
Scenario 3 – Summer Marine Mammals



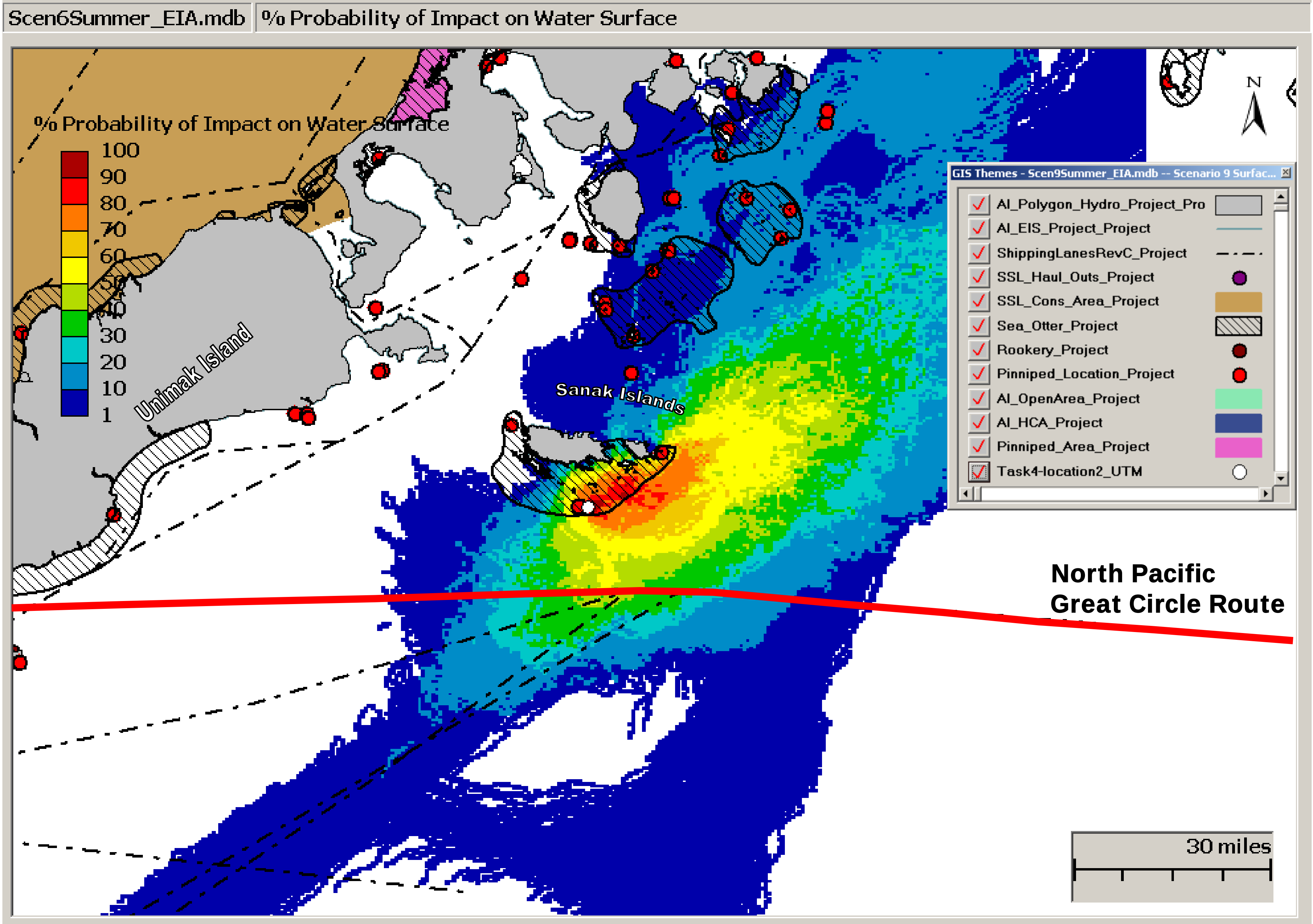
Scenario 4 – Winter Marine Mammals



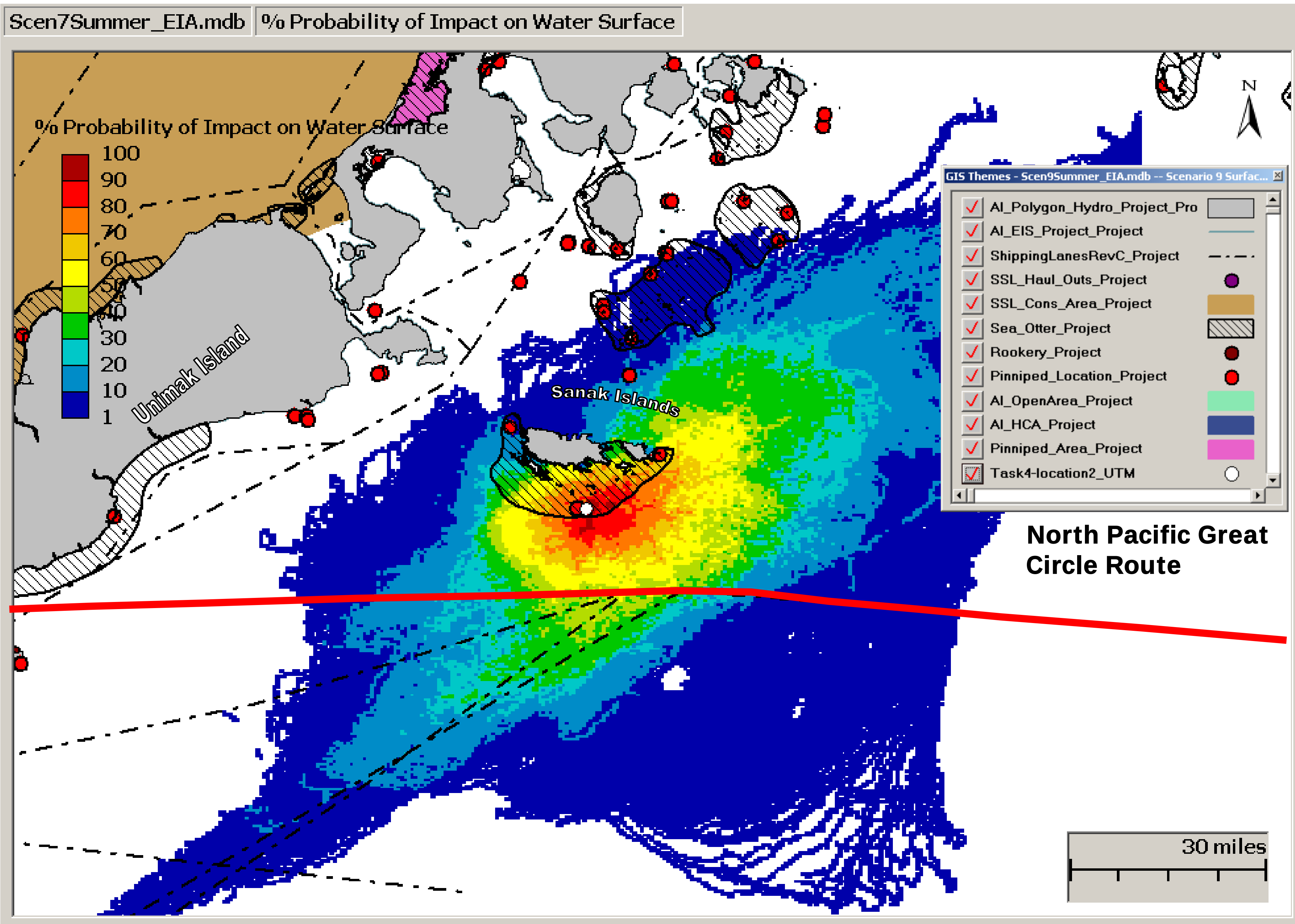
Scenario 5 – Summer Marine Mammals



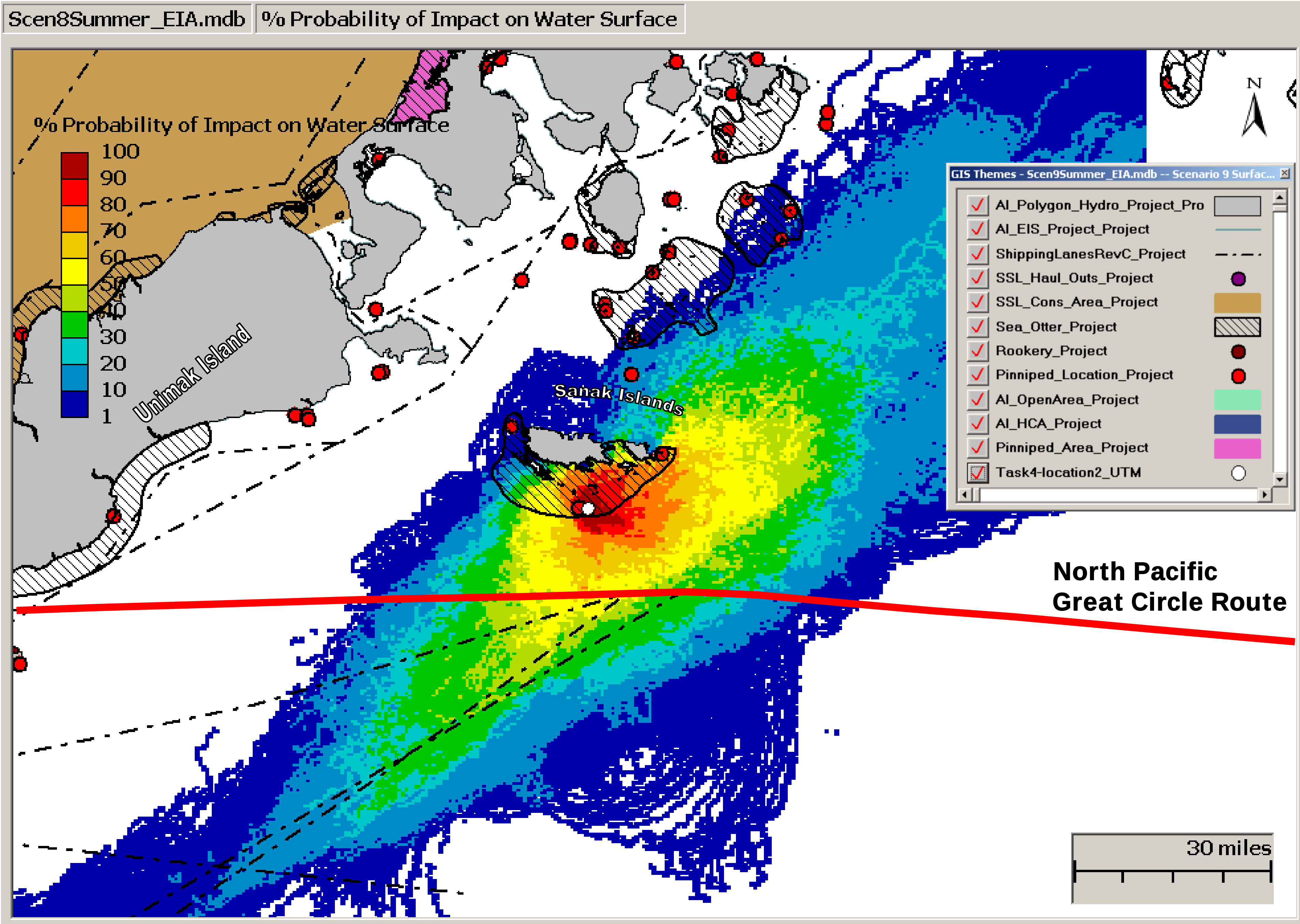
Scenario 6 – Summer Marine Mammals



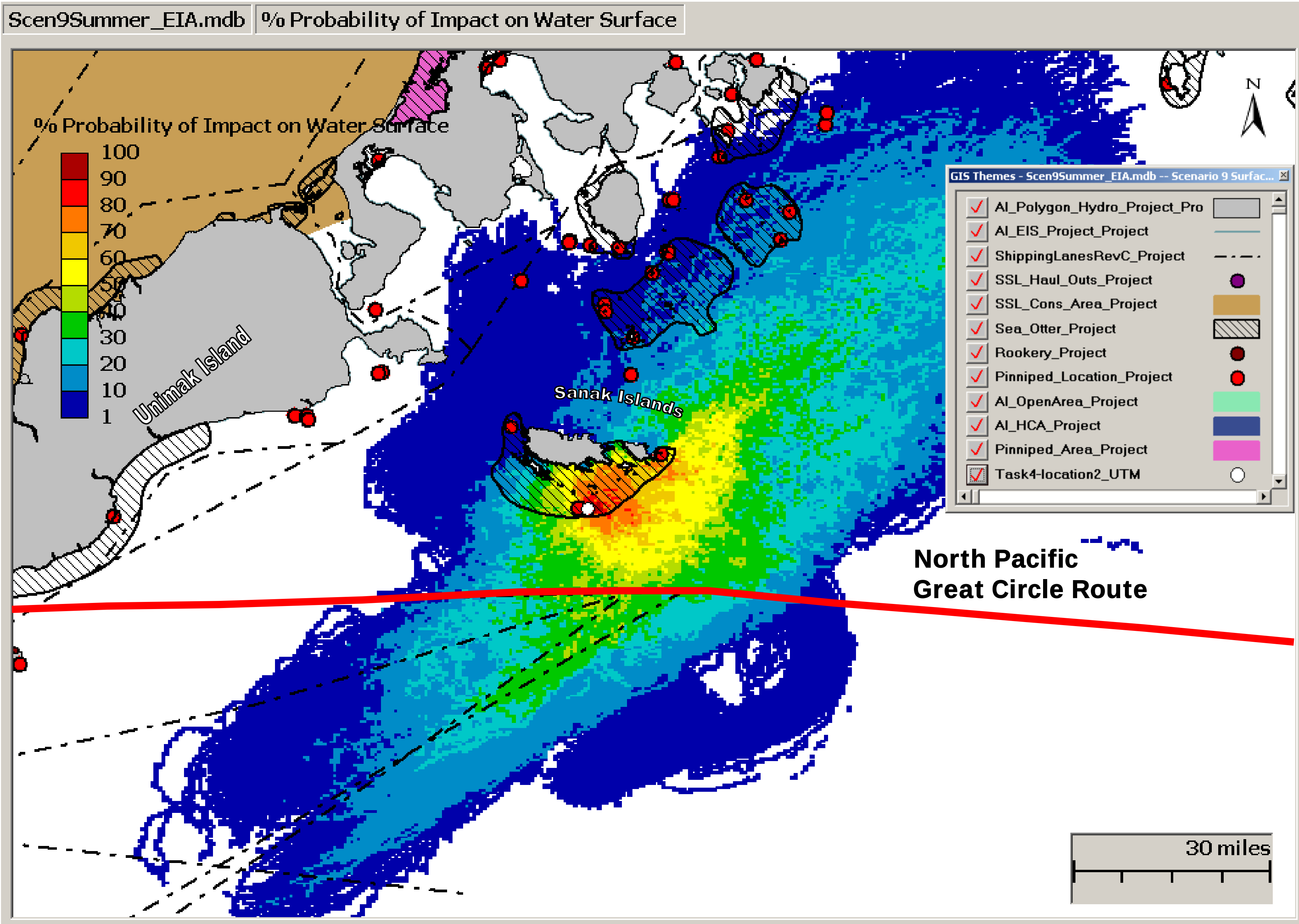
Scenario 7 – Summer Marine Mammals



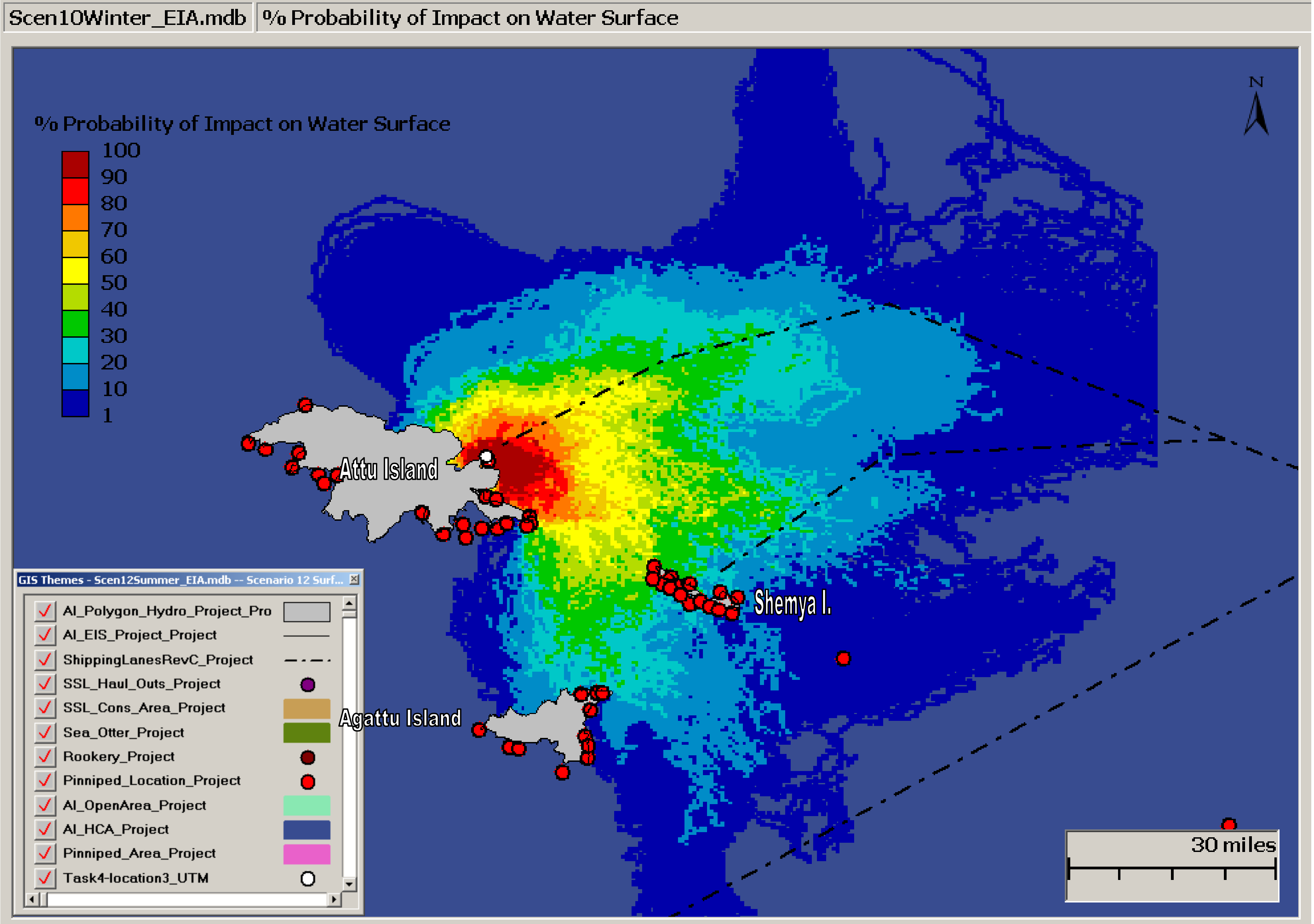
Scenario 8 – Summer Marine Mammals



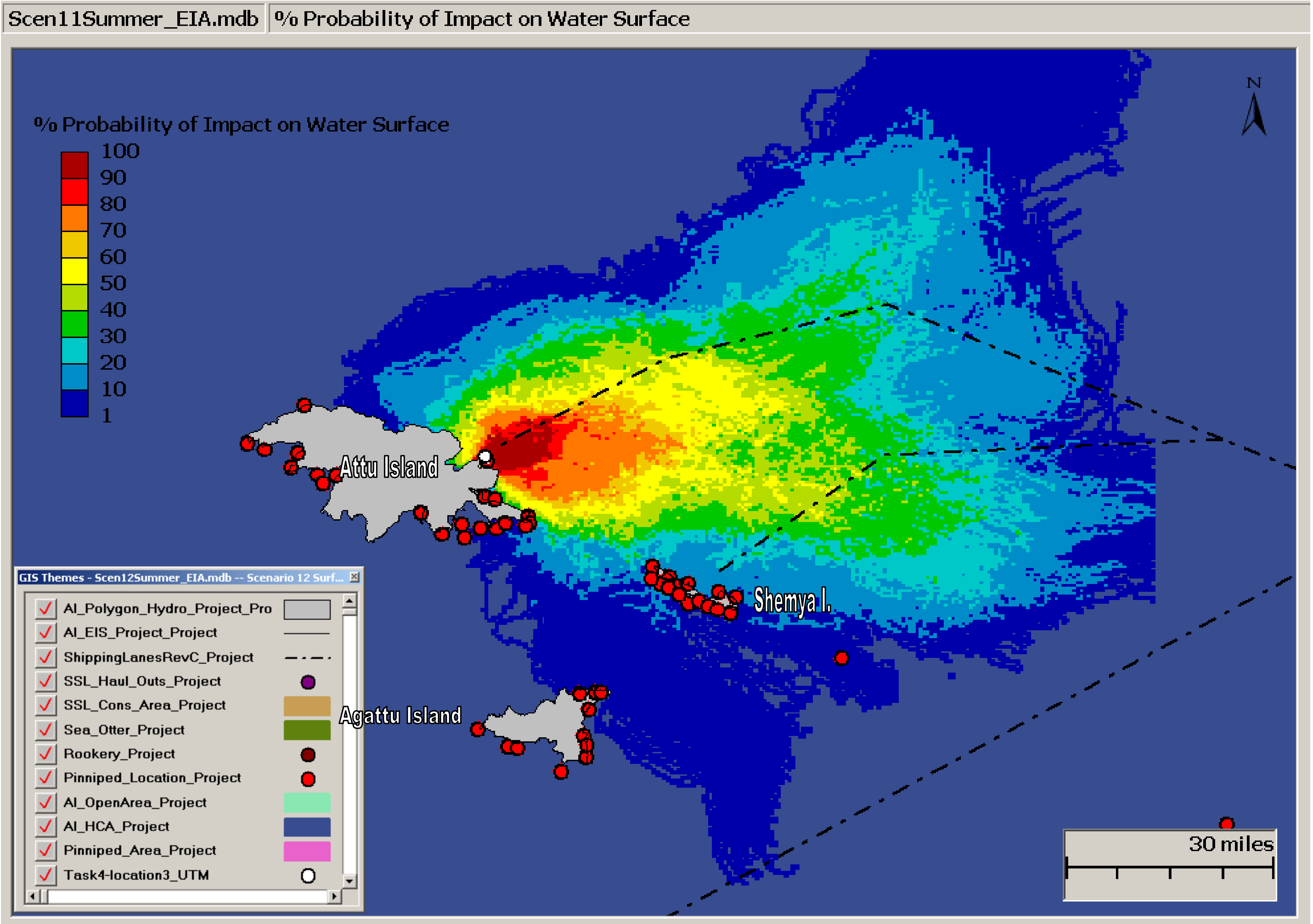
Scenario 9 – Summer Marine Mammals



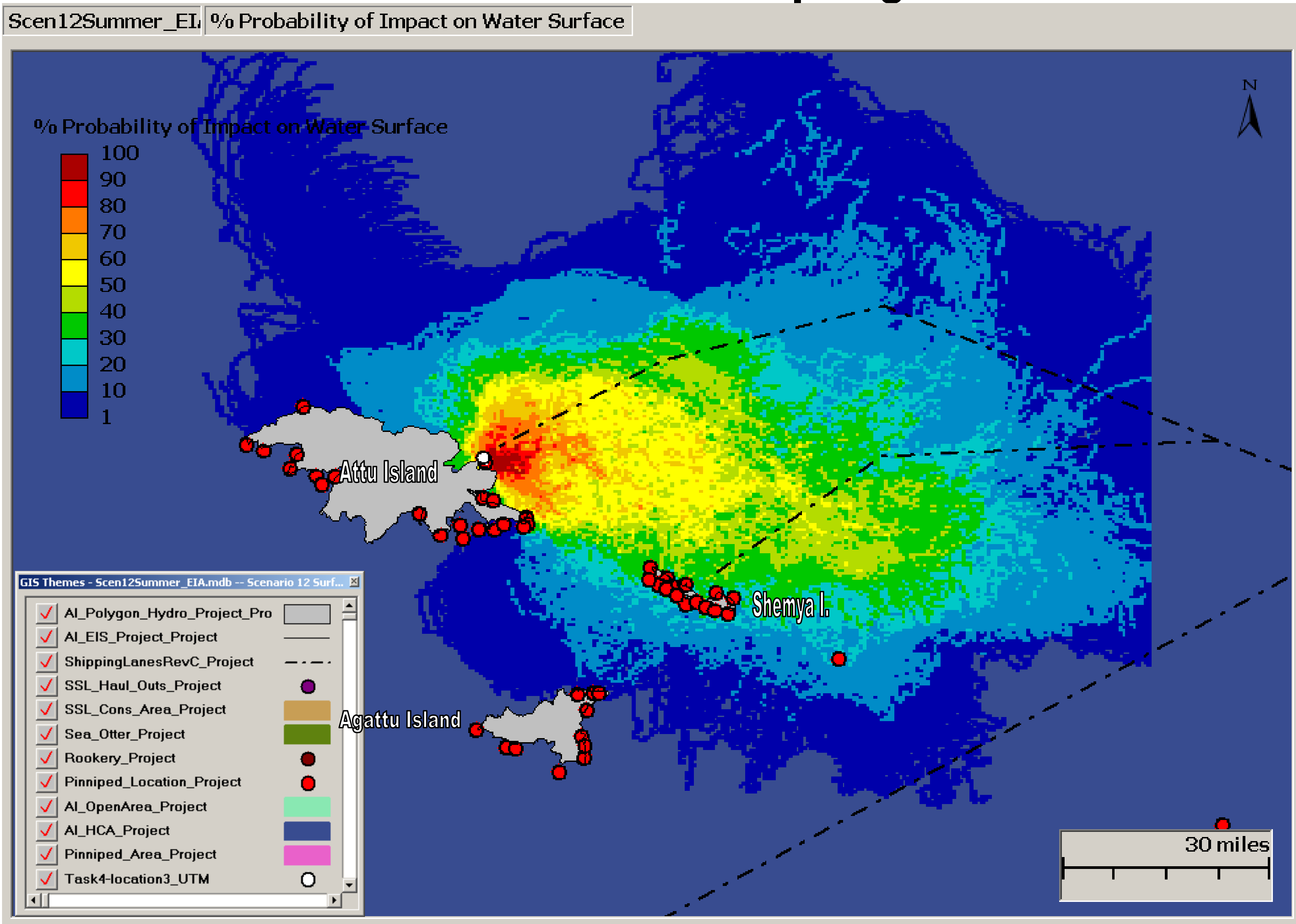
Scenario 10 – Winter Marine Mammals



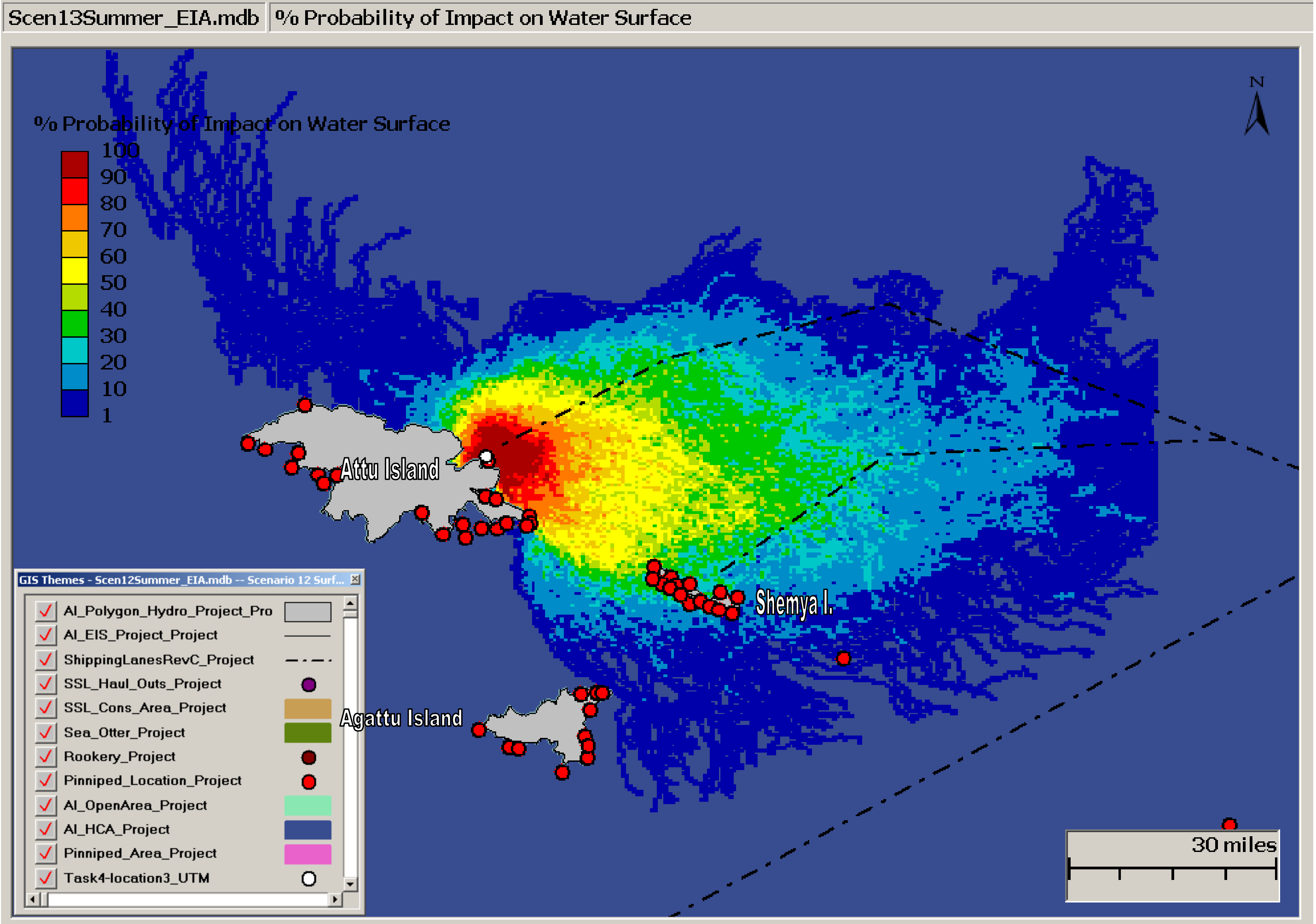
Scenario 11 – Summer Marine Mammals



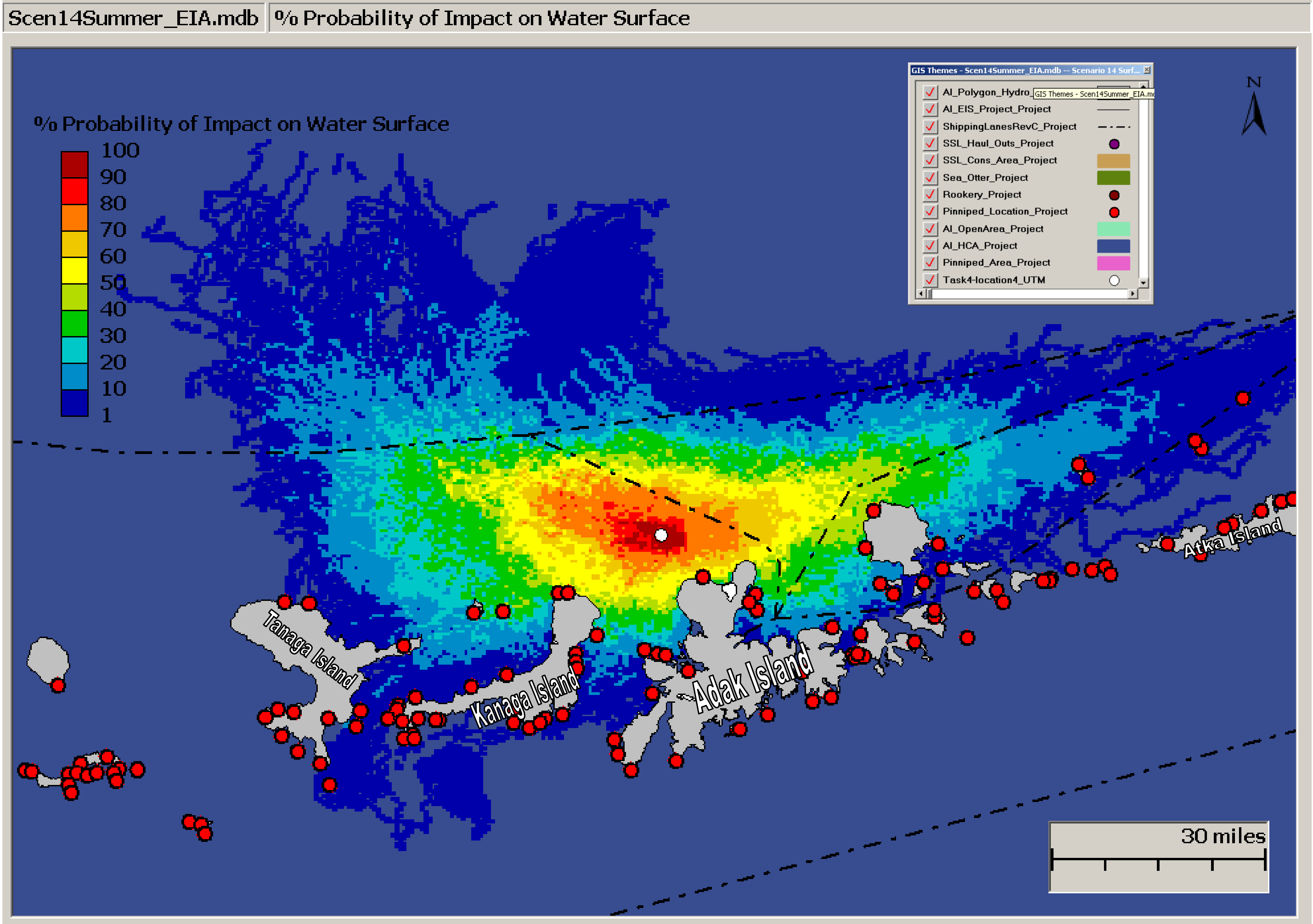
Scenario 12 – Spring Marine Mammals



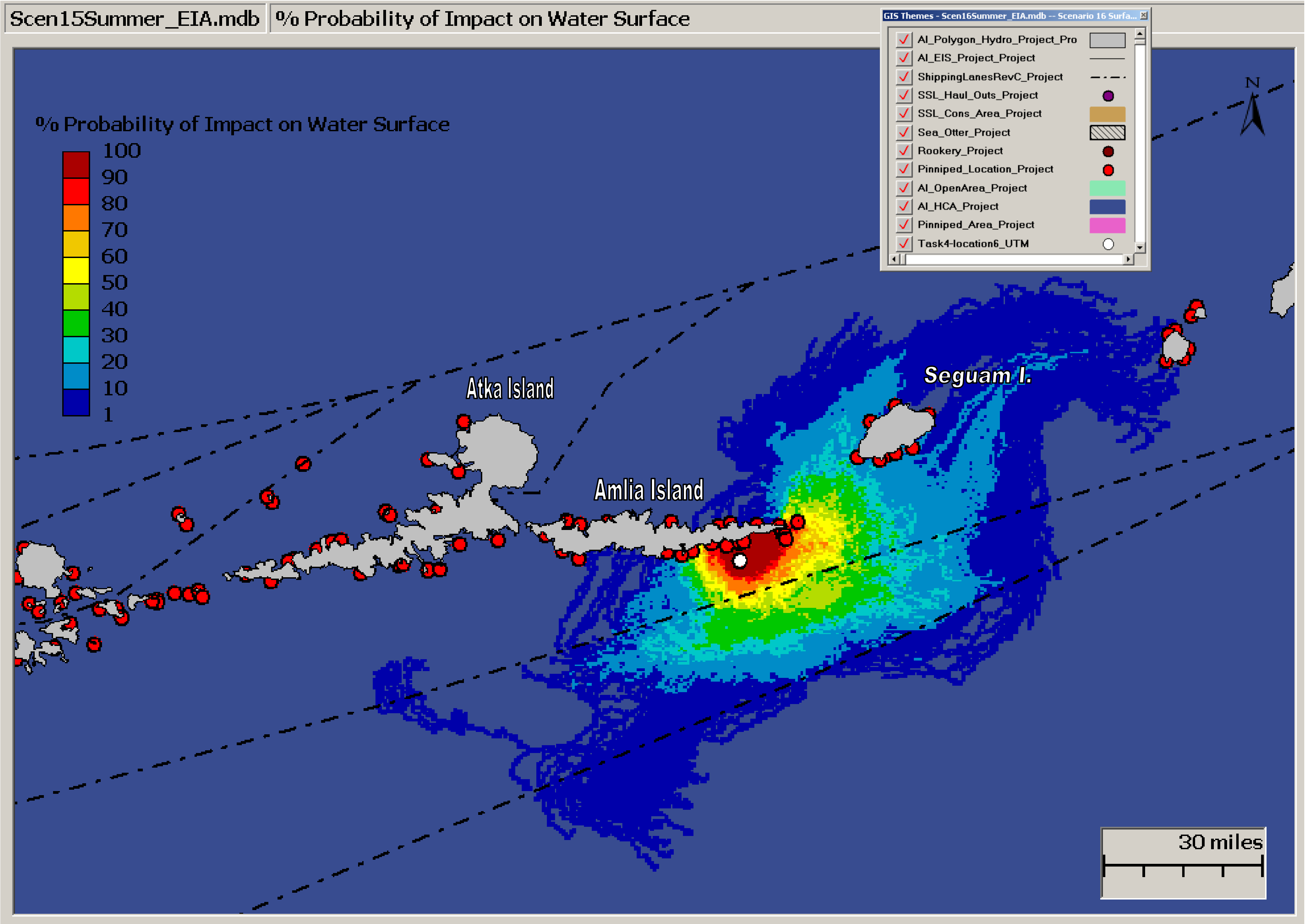
Scenario 13 – Spring Marine Mammals



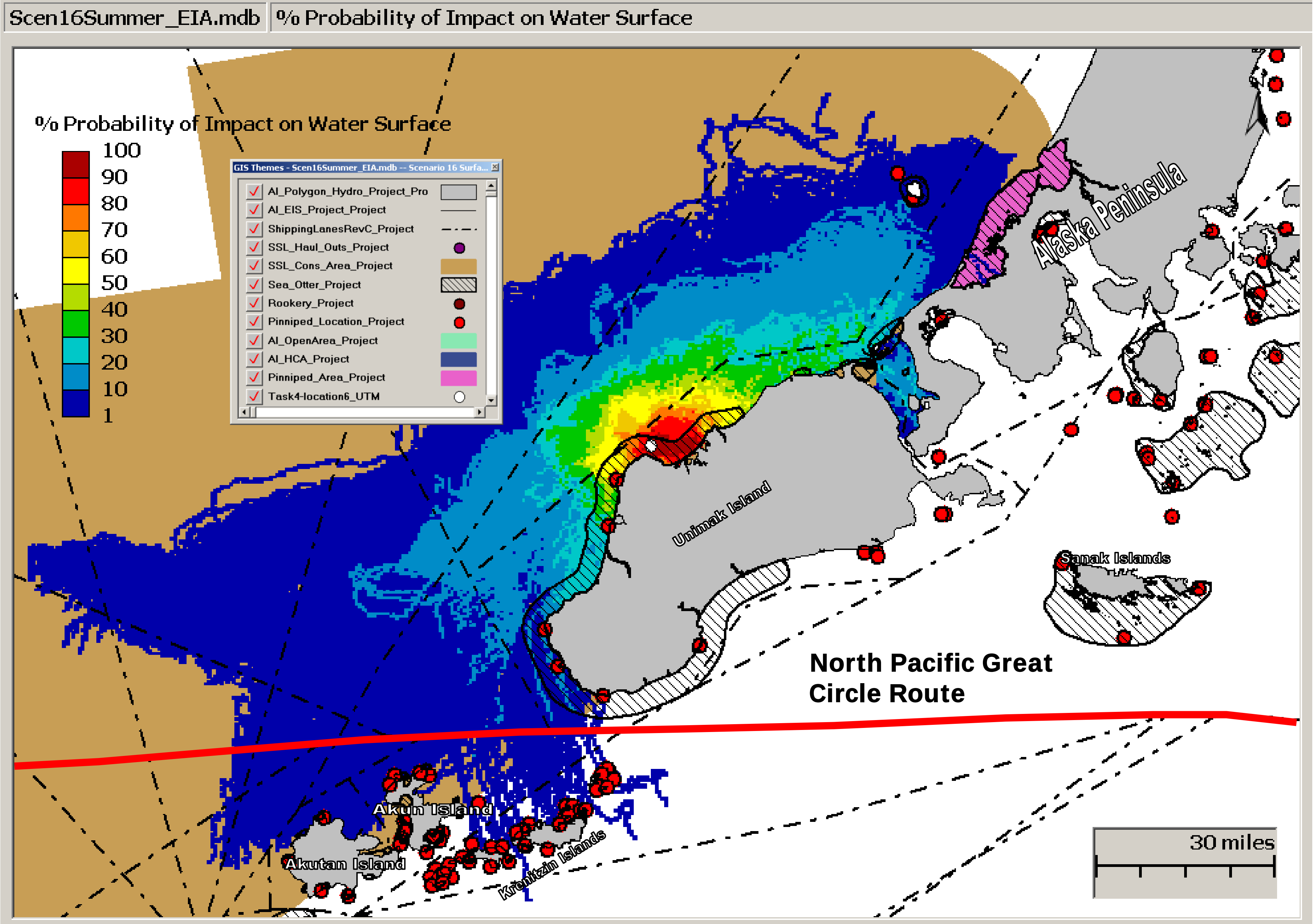
Scenario 14 – Summer Marine Mammals



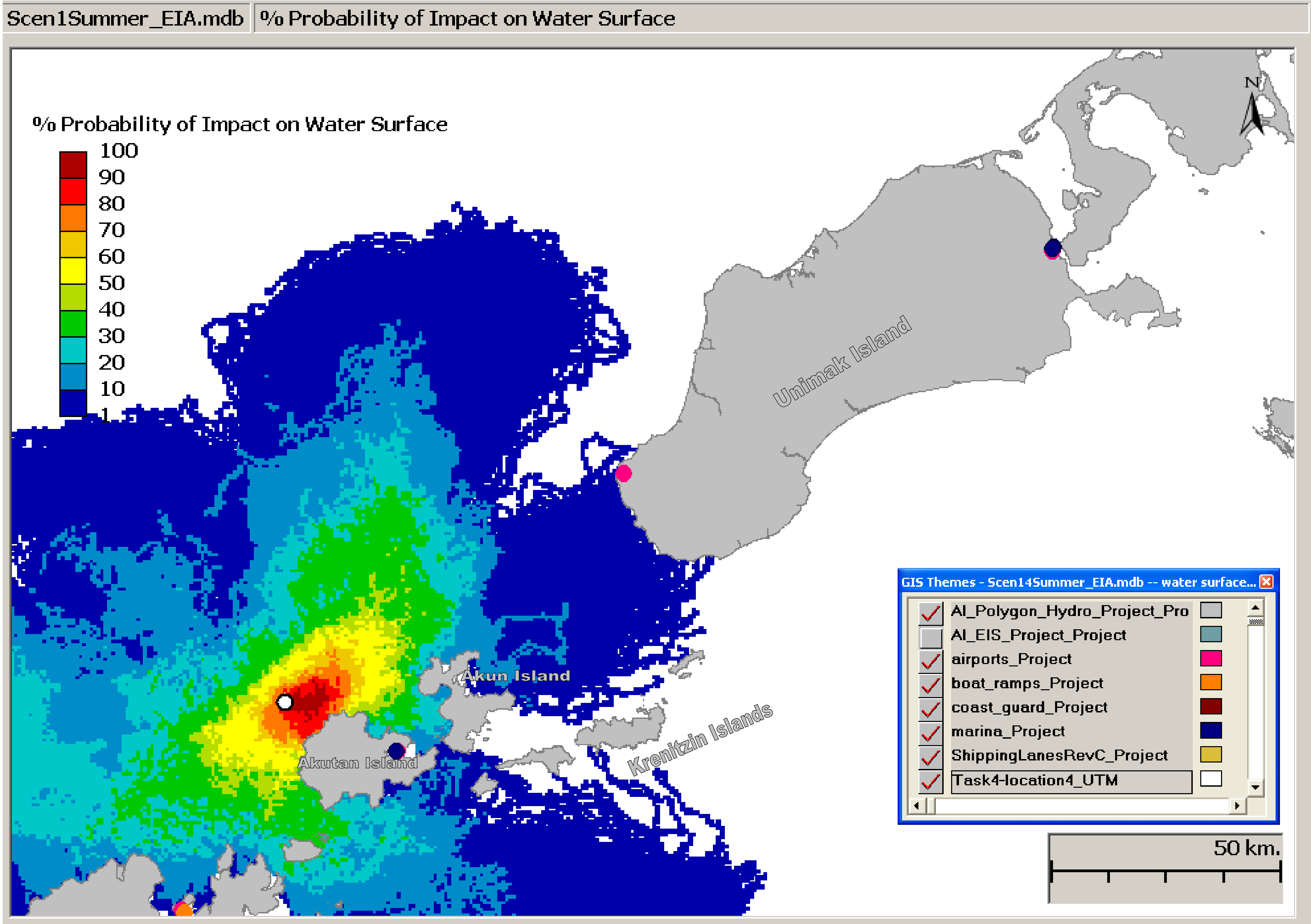
Scenario 15 – Summer Marine Mammals



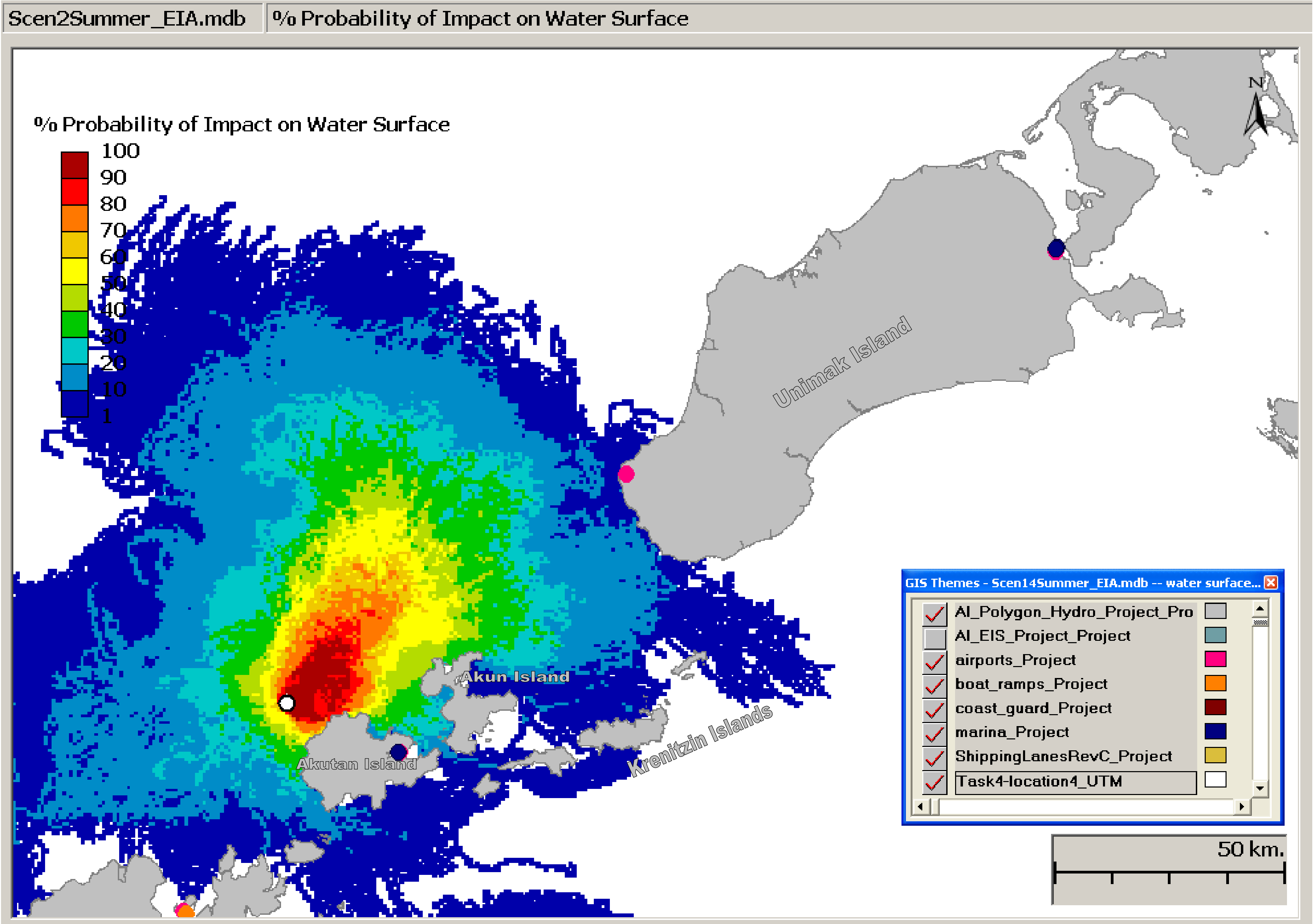
Scenario 16 – Spring Marine Mammals



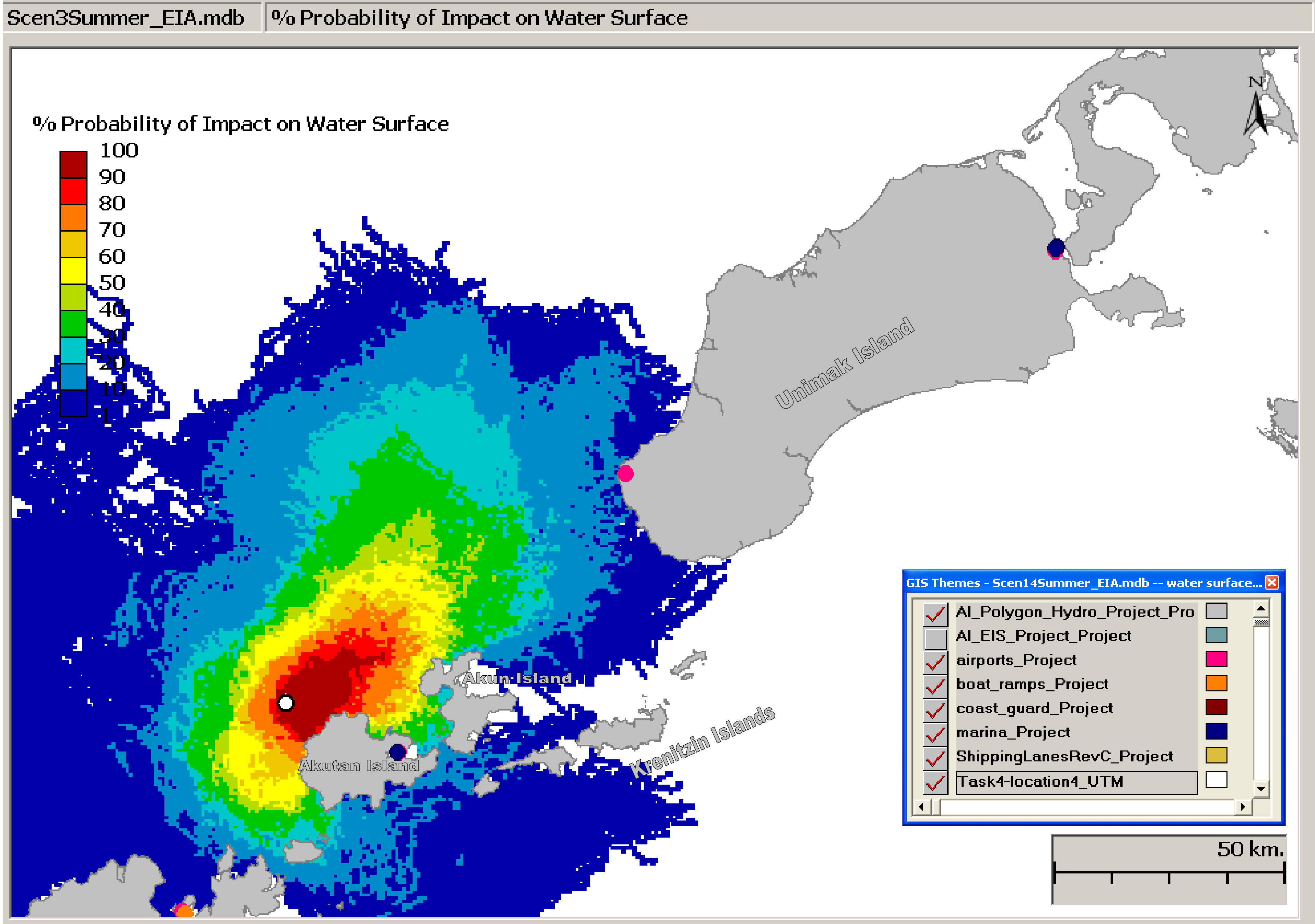
Scenario 1 - Summer - Socioeconomics



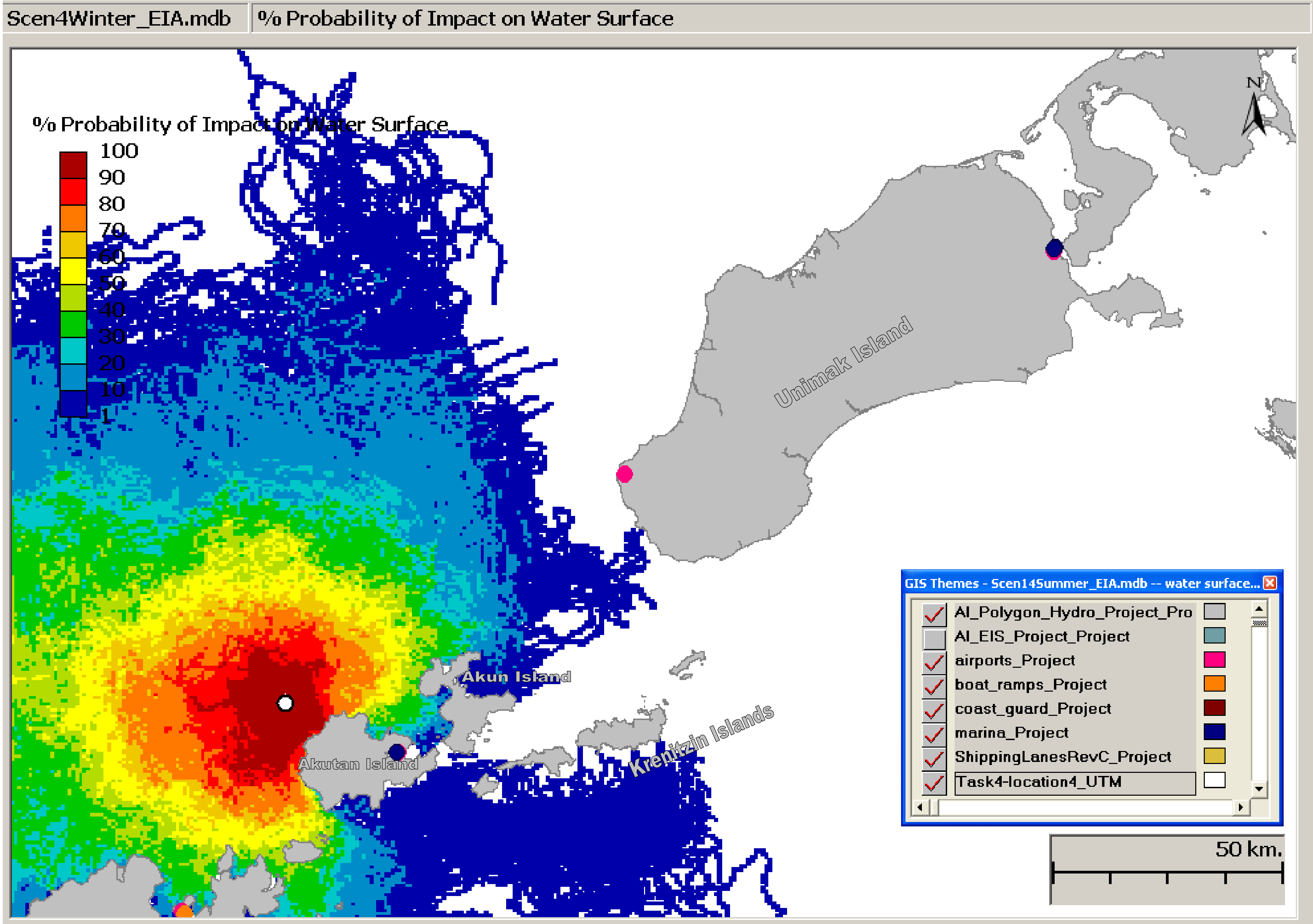
Scenario 2 - Summer - Socioeconomics



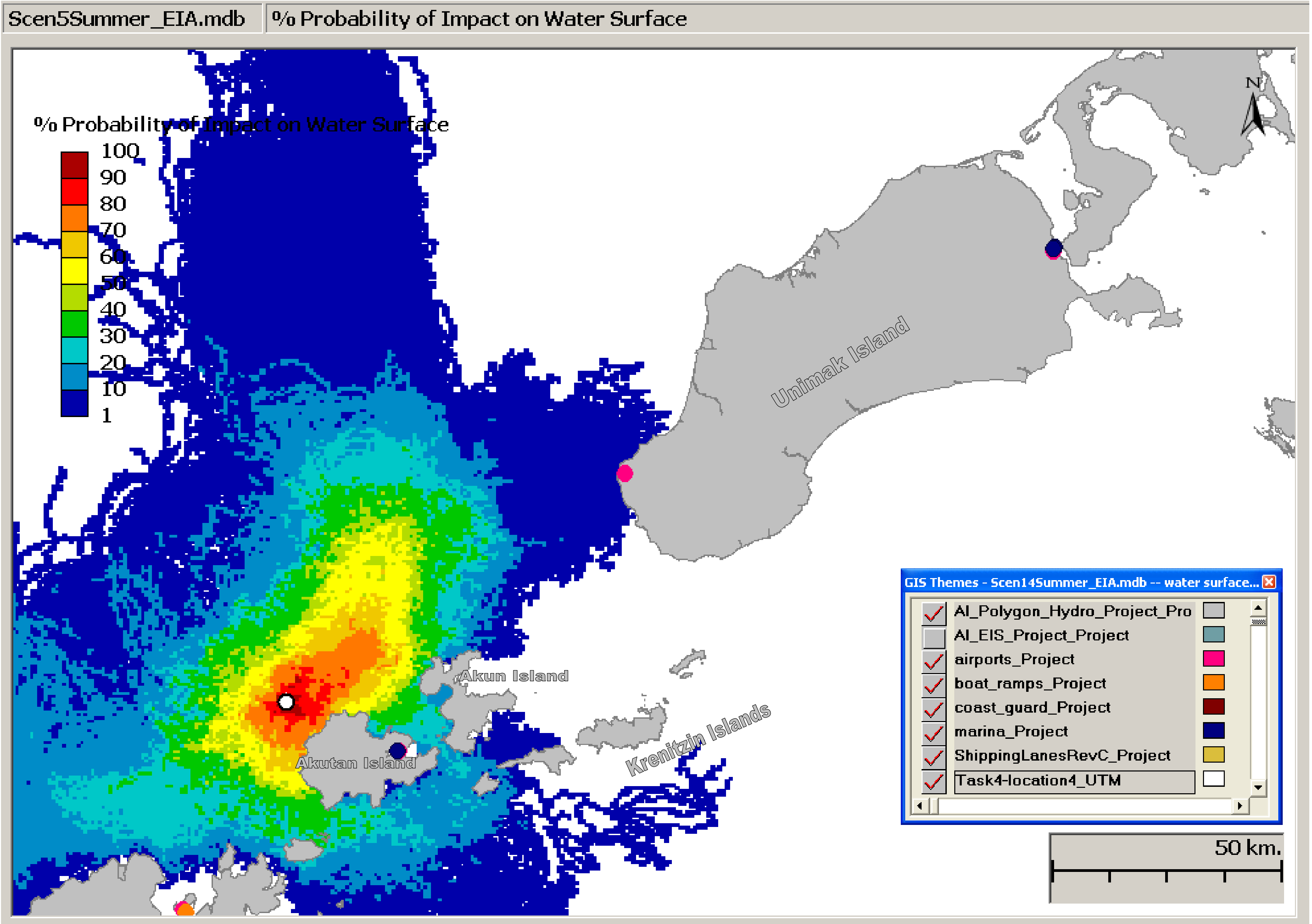
Scenario 3 - Summer - Socioeconomics



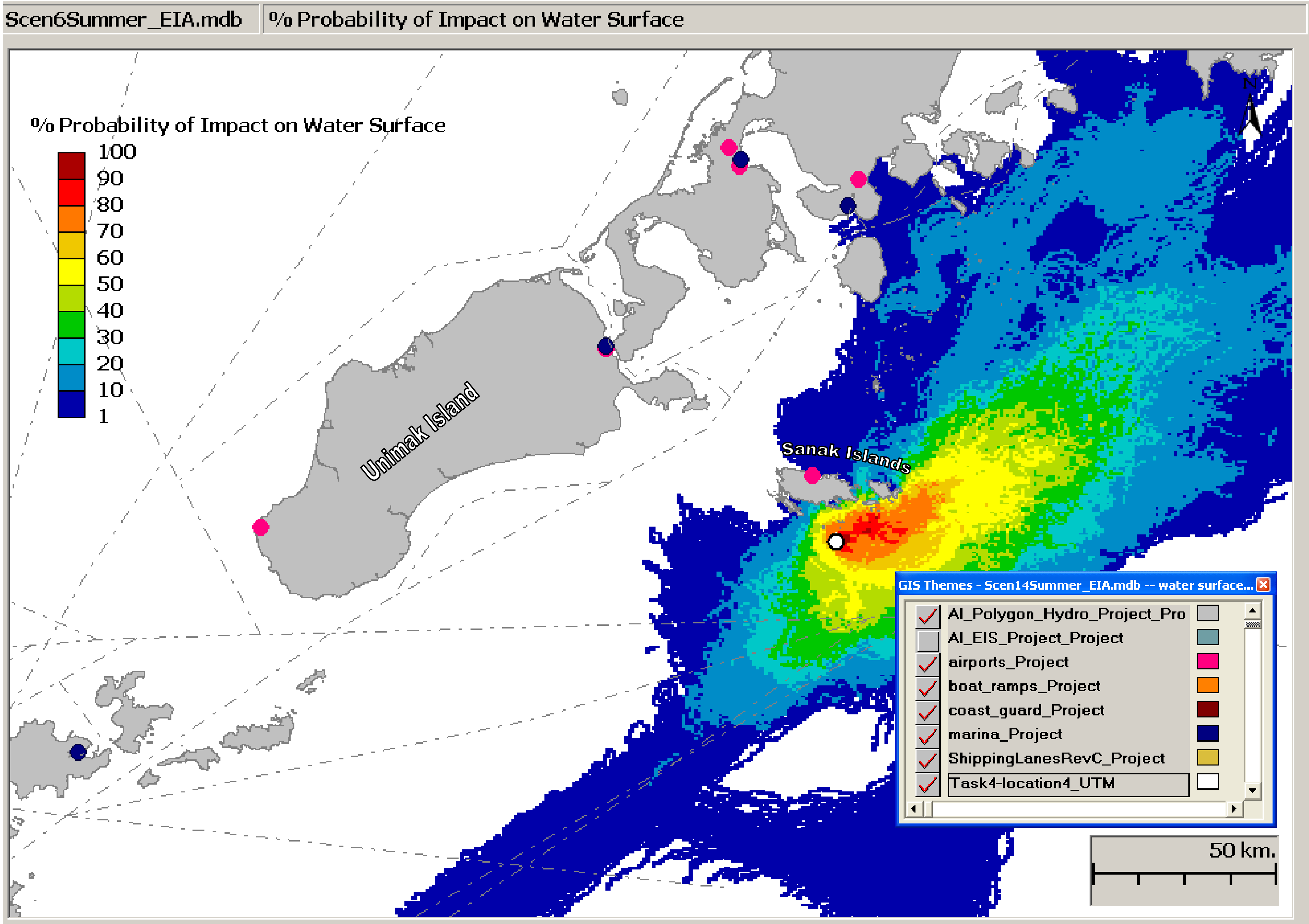
Scenario 4 - Winter - Socioeconomics



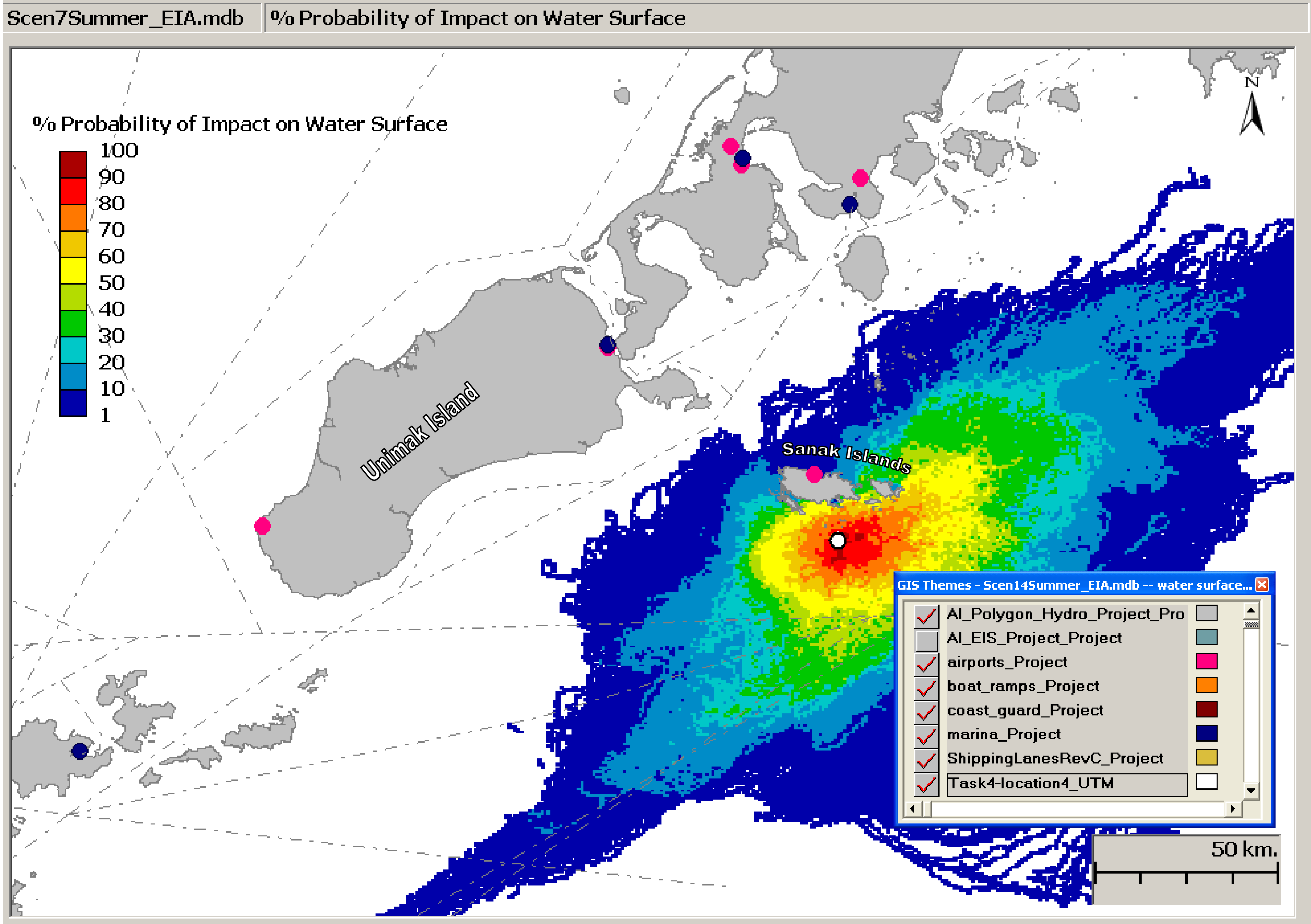
Scenario 5 - Summer - Socioeconomics



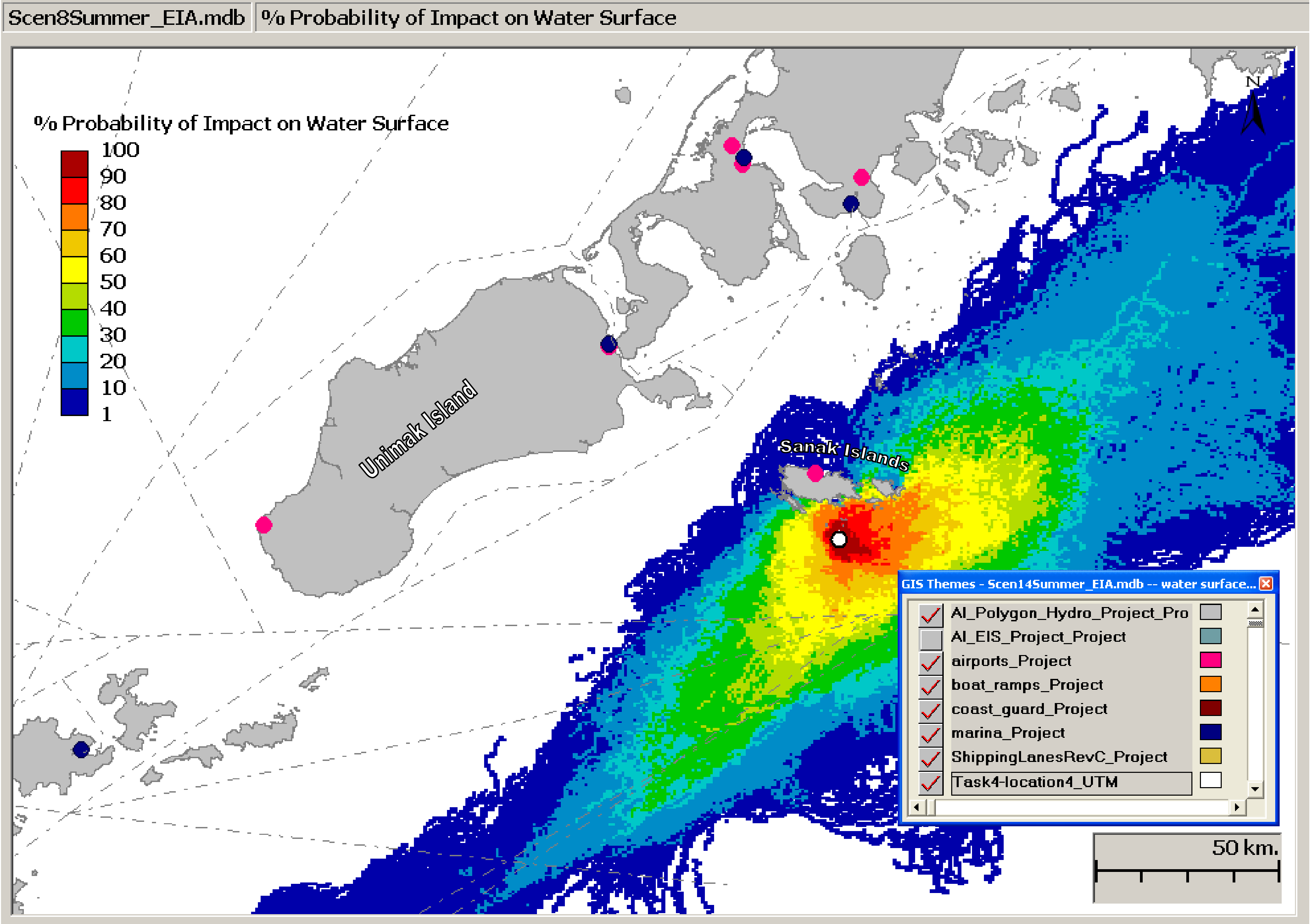
Scenario 6 - Summer - Socioeconomics



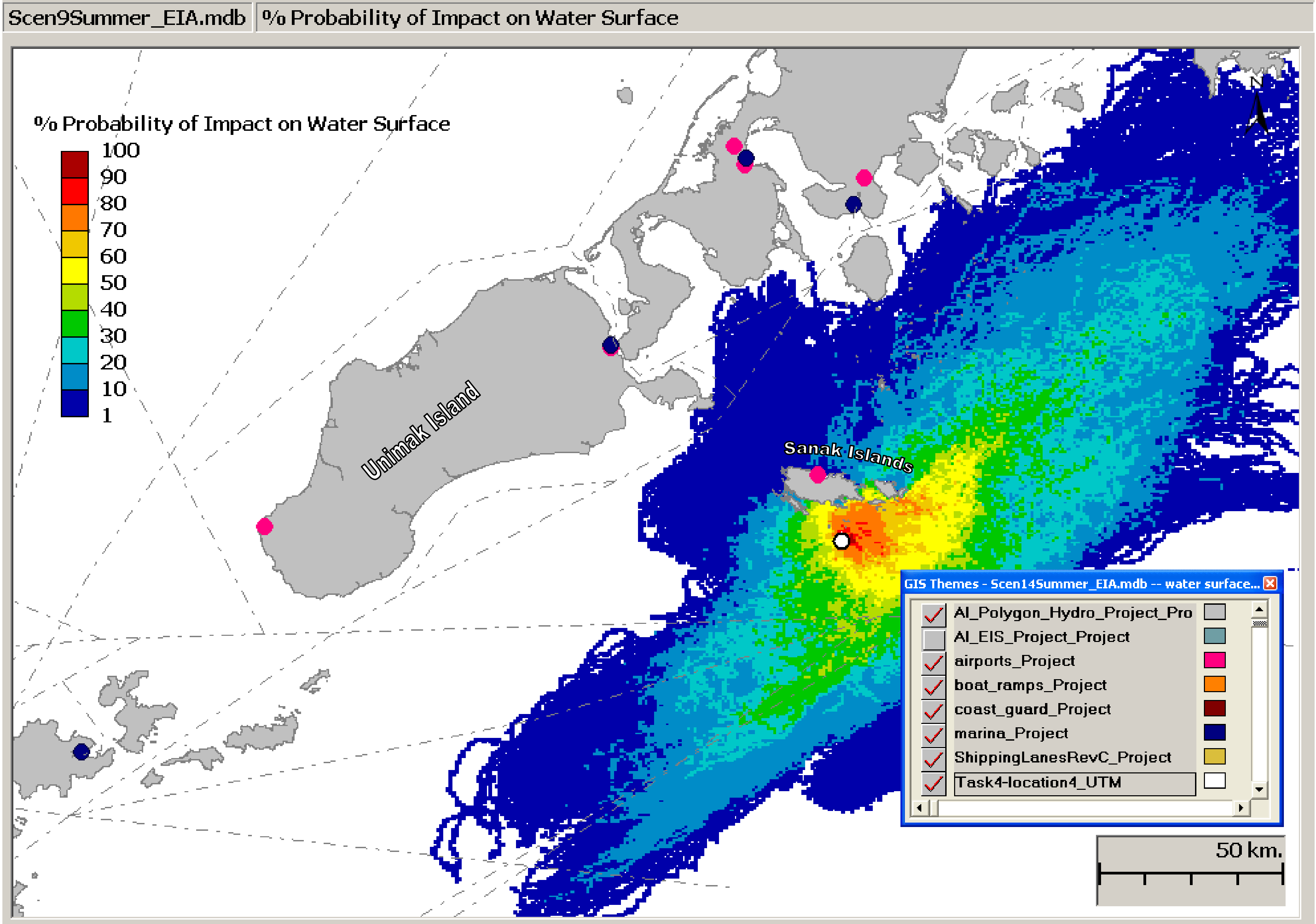
Scenario 7 - Summer - Socioeconomics



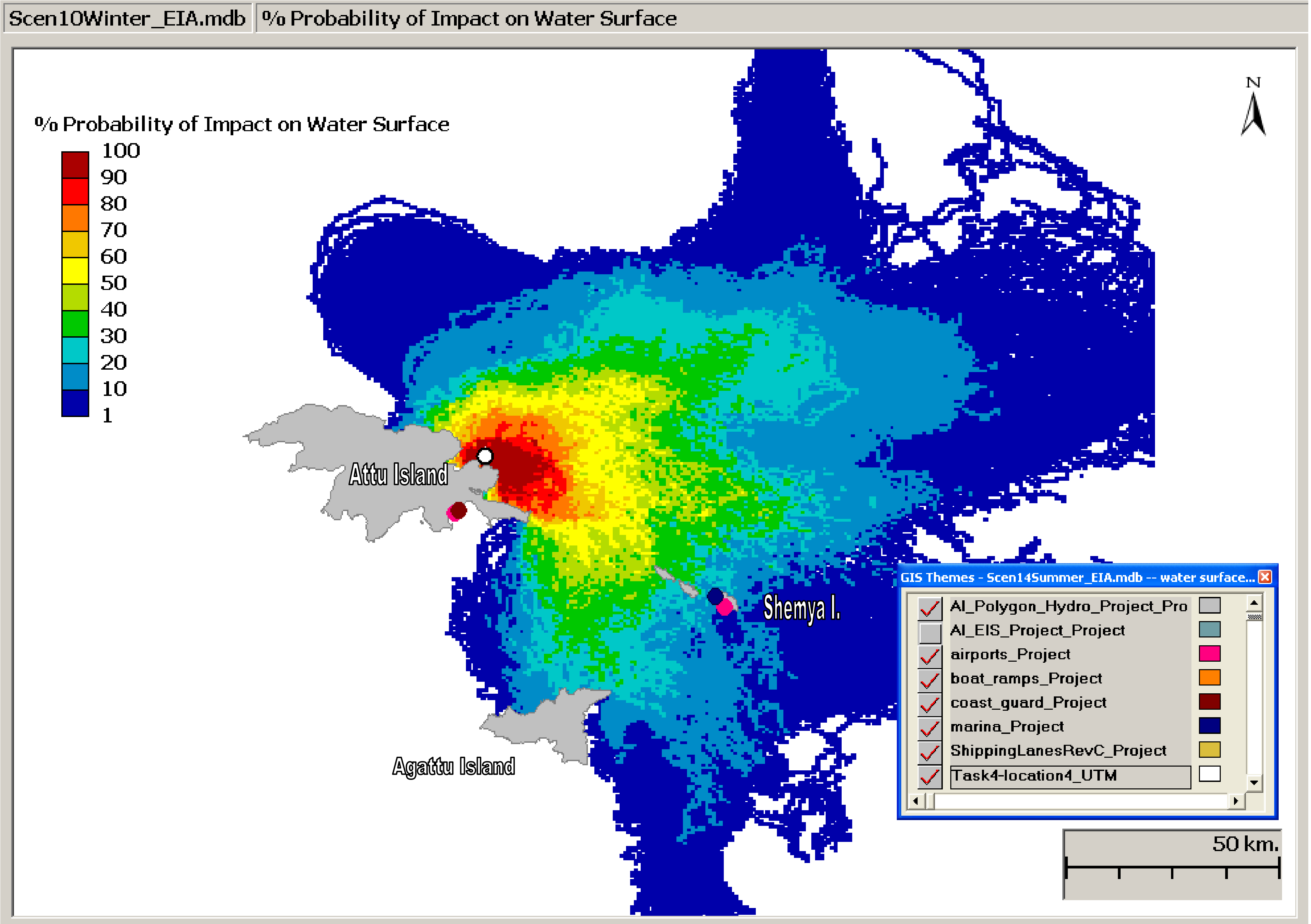
Scenario 8 - Summer - Socioeconomics



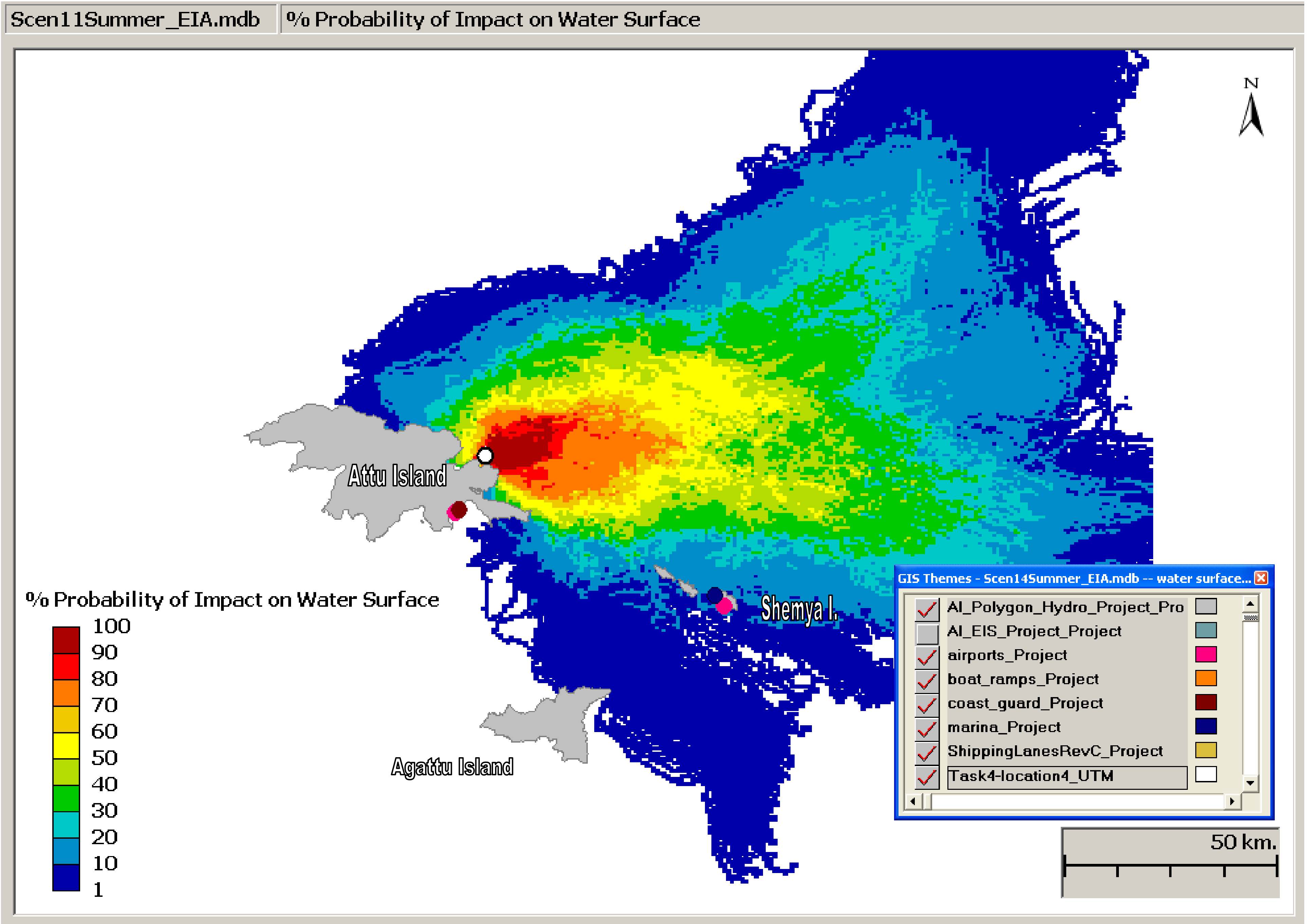
Scenario 9 - Summer - Socioeconomics



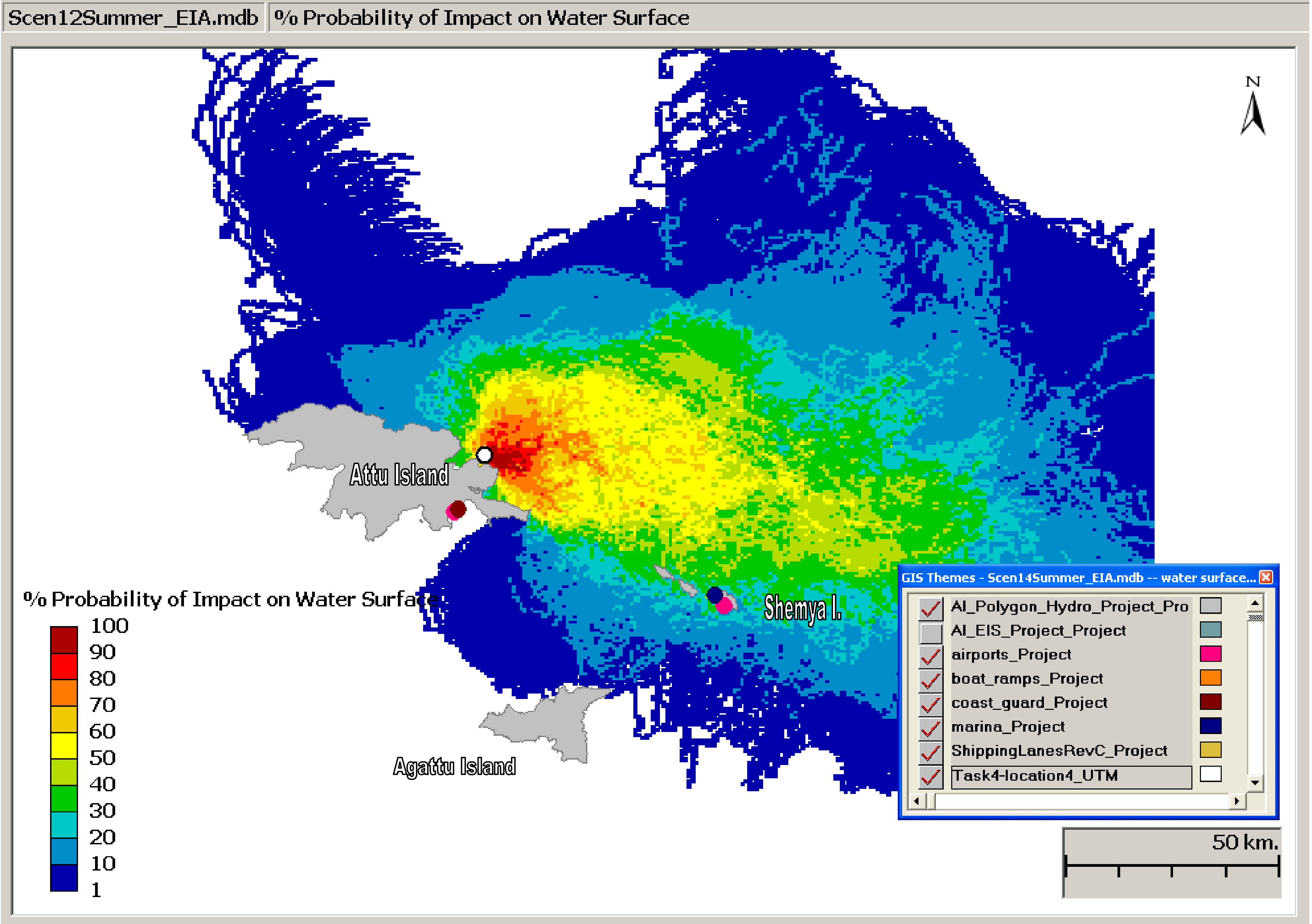
Scenario 10 - Winter- Socioeconomics



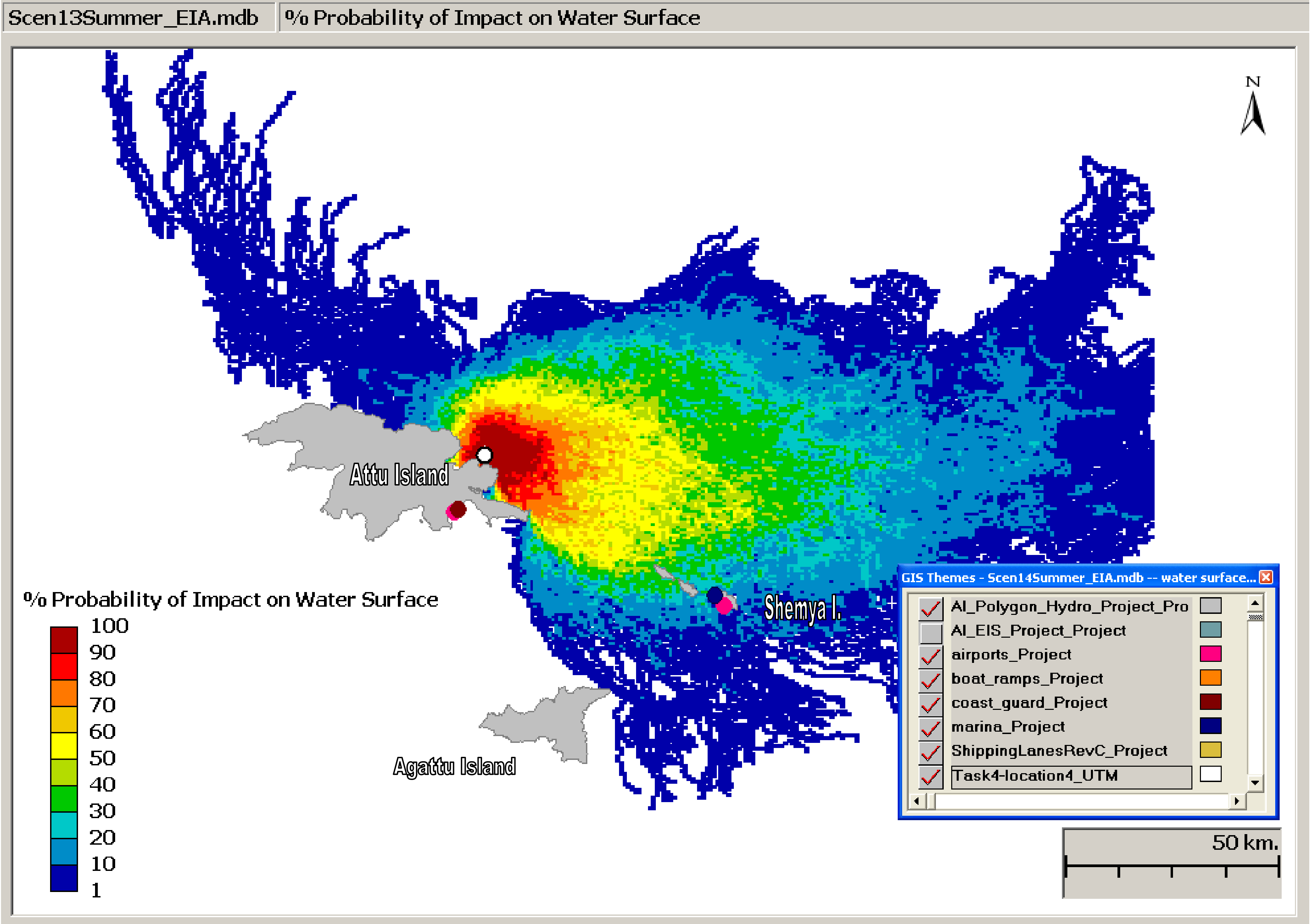
Scenario 11 - Summer - Socioeconomics



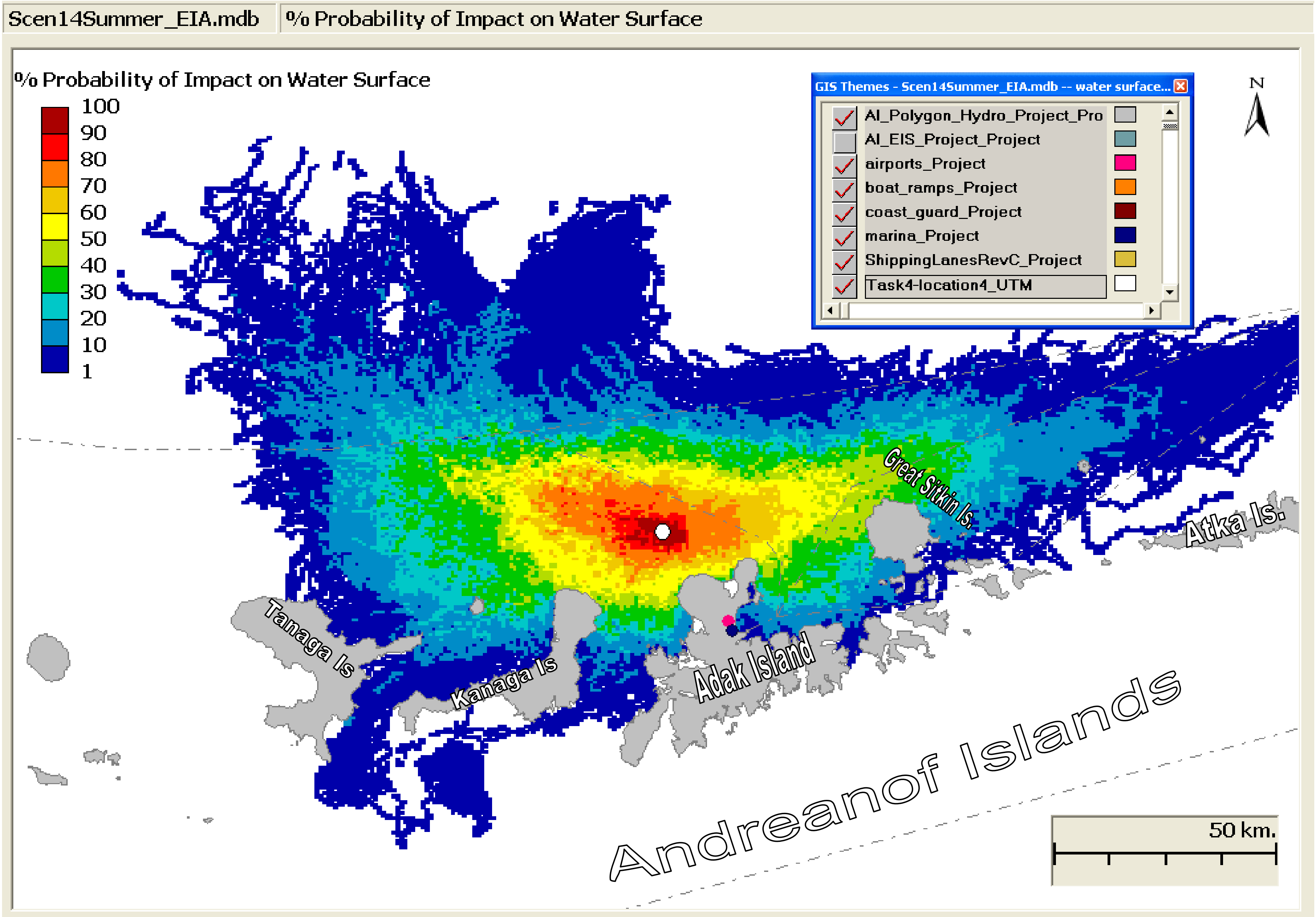
Scenario 12 - Spring - Socioeconomics



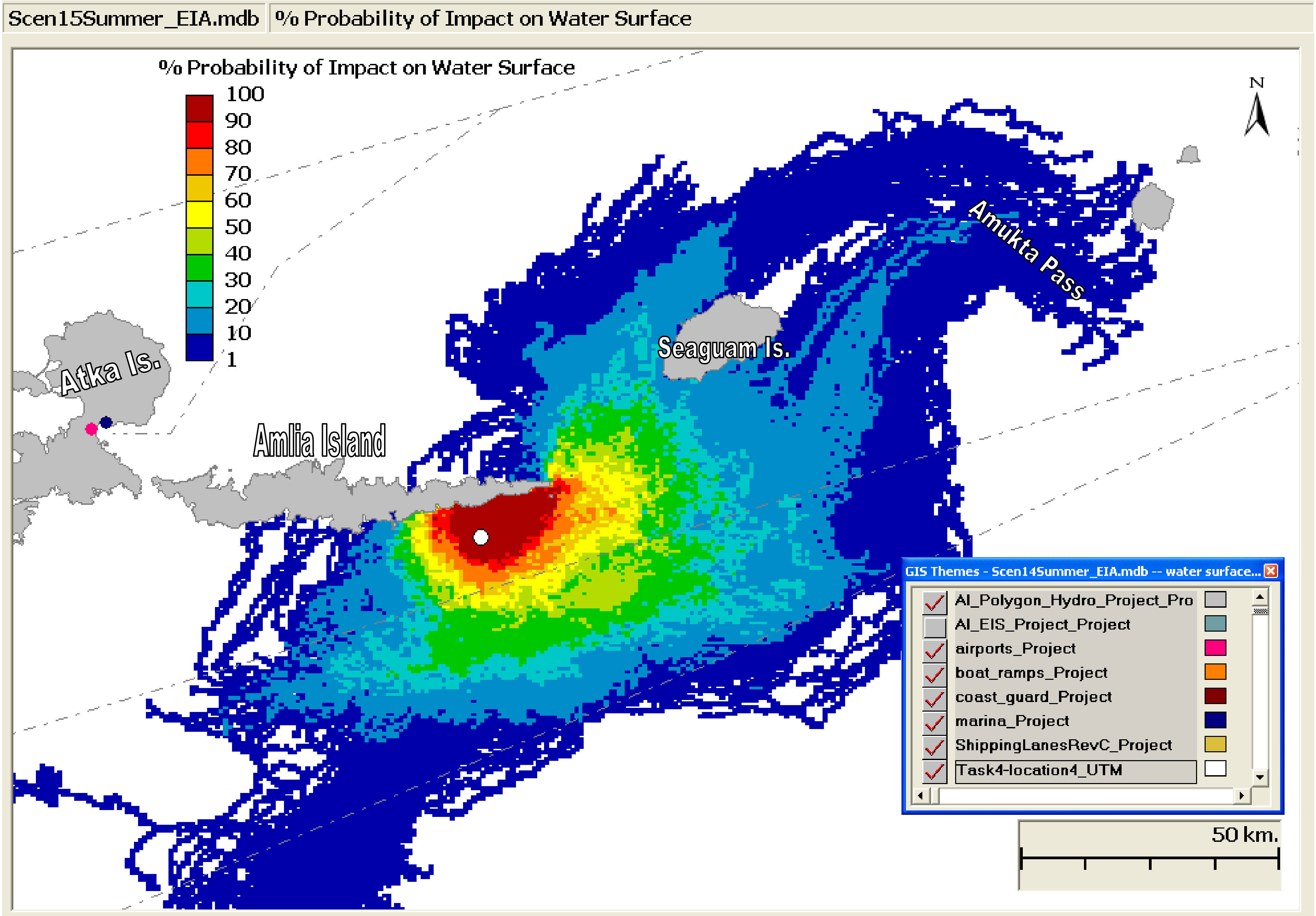
Scenario 13 - Spring - Socioeconomics



Scenario 14 - Summer - Socioeconomics



Scenario 15 - Summer - Socioeconomics



Scenario 16 - Spring - Socioeconomics