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ASOCIACION REGIONAL DE EMPRESAS DE PETROLEO
Y GAS NATURAL EN LATINOAMERICA Y EL CARIBE

OIL SPILLS RISK ASSESSMENT AND MANAGEMENT

Canadian International
Development Agency

Environmental Services
Association of Alberta

ARPEL GUIDELINE

OIL SPILLS
RISK ASSESSMENT AND MANAGEMENT

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Introduction

This guideline presents a framework for conducting oil spill risk assessments using various but consistent approaches which allow for their comparison.

The framework for conducting a risk assessment generally follows six steps:

Step 1: Plan the Risk Assessment.

Step 2: Analyze Hazards: Identify and Describe Oil Spill Scenarios.

Step 3: Analyze the Probability of Spill Scenarios.

Step 4: Analyze the Consequences of Spill Scenarios.

Step 5: Characterize the Risks of Spill Scenarios.

Step 6: Manage the Risks.

Each section of this guideline outlines the importance of each step in the overall risk assessment process. Examples demonstrate the use of the various methods for accomplishing each step's objectives.

Figure 1 illustrates the guideline's key steps to conduct an environmental risk assessment. Although written to address oil spill risks, the techniques can also be applied to other types of environmental risk assessments.

What is Risk?

Risk can mean different things to different organizations or individuals.

It can be defined as the possibility of an event occurring and the likely adverse effects on people, animals, property, facilities, and the environment. In other words, risk is a function of the incident's probability and its consequences.

Risk = Probability + Consequences

To illustrate this definition of risk, the following examples are useful:

Examples

An oil industry spill study researched a tanker route and concluded that the risk of spills of >10,000 bbls is 1 for every 110,000 bbls transported . In this case, risk was defined as a function of probability of an oil spill incident occurring. An assessment of the consequences of the event was not conducted. In this example, risk was defined as:

Risk =
Probability of Spill Occurring

A different risk study identified the impact of potential major oil spill incidents (greater than 100,000 bbls) on surrounding geography such as sensitive habitats. In this case, the risk assessment was based on the consequences of oil spill incidents with little or no determination of the likelihood of an event actually occurring. In this example, risk was defined as:

Risk =
Consequences of Spilled Oil

What is a Risk Assessment?

A risk assessment is a systematic framework used to identify and describe the sources and causes of risk.

The purpose of a risk assessment is to provide information to decision-makers in a form that allows for the comparison of risk reduction alternatives.

A risk assessment helps to answer key questions:

- What can go wrong and why?
- How likely is the occurrence of certain incidents?
- What are the effects and how serious are they?
- What can we do about it?

A risk assessment does not eliminate risk.

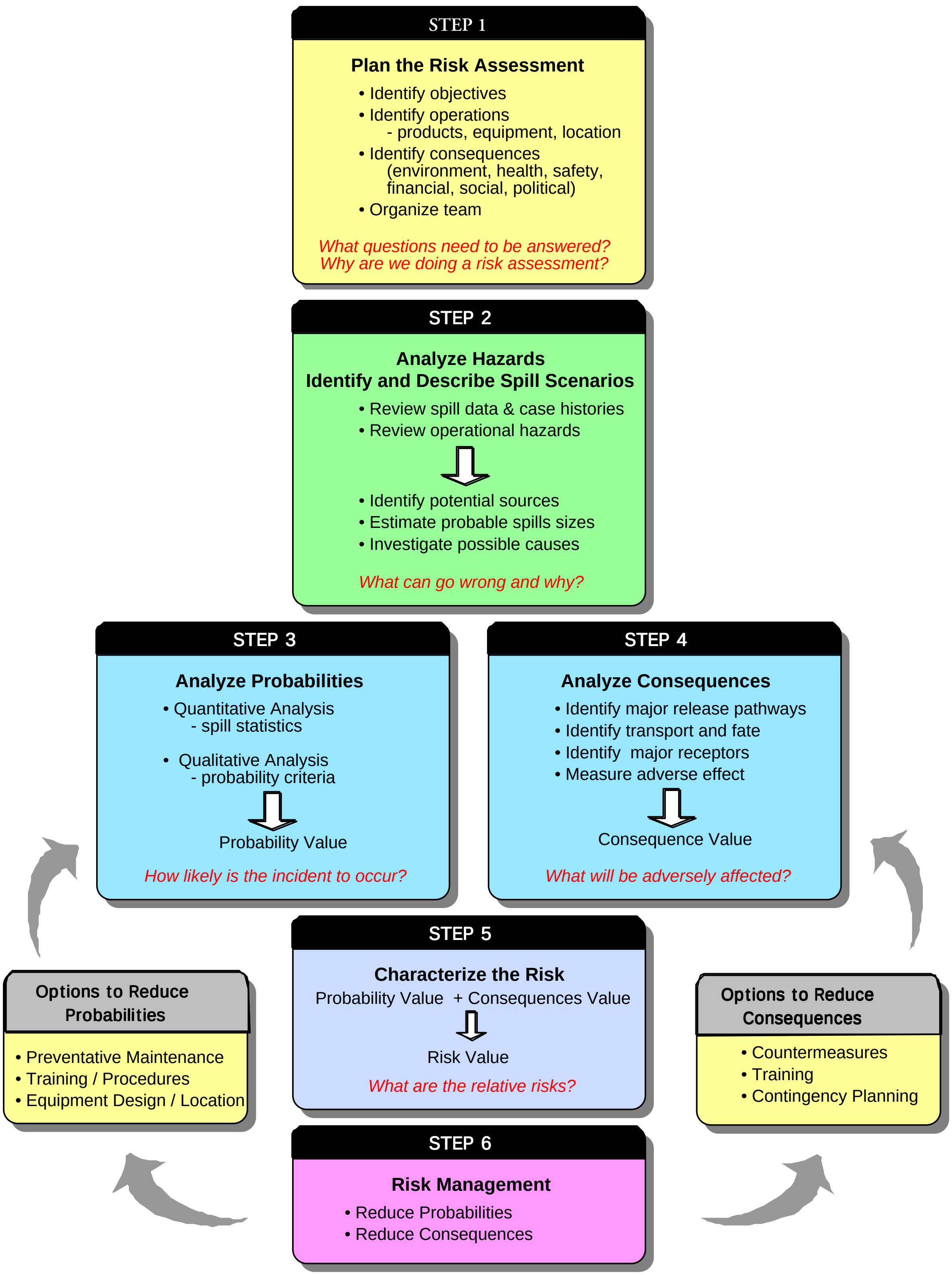
Risk Assessment and Oil Spill Preparedness

A risk assessment and management is an ongoing process decide to compliment the formation of contingency plans, design of facilities or reduction of incidents. Risk assessments can be completed before, during or prior to other oil spill management programs.

An improved understanding of the factors which increase the frequency of oil spills and the factors which increase the consequences of oil spills will lead to more effective allocation of resources for improved oil spill preparedness.

As a part of oil spill preparedness, risk assessments should be initiated to ensure that contingency plans are directed at the highest sources of risk. Training programs and countermeasures equipment can be organized with an understanding of the greatest consequences. Maintenance programs designed to reduce oil spill incidents can be directed at the greatest potential sources of spills.

Figure 1. Risk Assessment and Management Framework



Step 1 Plan the Risk Assessment

STEP 1

Plan The Risk Assessment

- Identify objectives
- Identify operations
  - products, equipment, location
- Identify consequences (environment, health, safety, financial, social, political)
- Organize team

What questions need to be answered?
Why are we doing a risk assessment?

The purpose of pre-assessment planning is to ensure that the risk assessment process is feasible and that it will satisfy the objectives of risk management.

Decisions made during the initial stages of the risk assessment will be the map that guides the size, direction and complexity of the study.

The following steps should be addressed in planning a risk assessment study.

Step 1A Identify Objectives

Risk assessments can be many things to many people. They can be aimed at evaluating diverse groups of risks or quantifying a single specific risk source. Assessments can utilize vast arrays of data, models, and expertise to quantify acceptable risk levels or they can simply be designed to characterize major sources of risk.

The first step is to establish the objectives of the assessment. Why is the risk assessment being initiated? Objectives of risk assessments may stem from corporate risk reduction strategies, business objectives, environmental management or safety policies, or operational goals. Some examples of why a risk assessment may be completed include:

- Improve future design of equipment
- Reduce potential incidents from existing equipment with additional design or training
- Describe the sources of risk so that they may be communicated to workers, public or senior management

The objectives must clearly identify the specific purpose of the study including what questions need to be answered and how the information will be used.

Examples

National Pipelines Company is building a new pipeline that will transport crude oil 30 km for processing. The risk manager wants to compare the risk to the public of each pipeline section. This will assist with locating release control mechanisms.

Objective

Identify key locations to install emergency shutdown valves.

An oil production company wants to evaluate the risks to the public, environment, and workers from its production, storage, and transportation operations. The results will be used to direct limited finances to operational areas.

Objective

Idenitfy High Risk Operational Areas.

Step 1B Identify Operations

Clearly define the type and extent of operations, equipment or products that will be included or excluded in the assessment. The assessment may be limited to a specific piece of equipment, a single facility or an entire company's operations.

A clearly defined assessment (i.e., scope) will assist with limiting the complexity of the study while still satisfying the objectives. The scope should define specific limits in key areas including (but not limited to):

- **Products**
  A single product (oil) or all products (oil, natural gas, chemicals, wastewater) may be included in the study.

- **Equipment**
  Many different types of equipment may be investigated (e.g., storage tanks, transport vessels, pipelines). A more focused assessment may study a specific piece of equipment (e.g., underground storage tanks).

- **Geographical or Operating Areas**
  An assessment may further define the scope to include only those areas within a specific geographical area. This area may be defined by political, operational, or logistical boundaries. For example, a study may focus on a single distribution terminal or an entire company's facilities along a coastal area. Risk from an entire facility may be investigated or simply the risk posed by a group of storage tanks at a single facility.

The objectives of the assessment should be revisited to ensure that the scope reflects those objectives.

Example

National Pipeline Company is establishing the scope of a risk assessment which will evaluate risks to the public from a proposed pipeline. The following limits have been set on the scope of the assessment:

- ***Products:*** *Crude oil containing hydrogen sulphide*
- ***Equipment:*** *58 mm internal diameter steel pipeline located in the Monteverde region*
- ***Geographical / Operations Areas:*** *5 km section of pipeline between San Carlos and the Las Brisas refinery*

Step 1C Identify Consequences

Identify the types of consequences to be included in the assessment. This should be based on the stated assessment's objectives and the ability of the available resources to measure those consequences. General consequence categories are:

- **Ecological or Environmental**
  Impacts to soil, water, air and living organisms within ecosystems.
- **Public Health**
  Transient and fixed locations of public and populations outside the facility boundaries.
- **Safety or Workplace**
  Risks to employee safety within facility or company boundaries.
- **Social and Public Perception**
  Effects of operations on the public's perception of the company.
- **Financial**
  Effects on corporate financial viability associated with issues such as lost product, reclamation costs, or non-compliance penalties.
- **Insurance**
  Potential of operations to generate liability claims due to damage to workers, public and the environment.

Example

National Pipeline Company is establishing the range of consequences to be included in a risk assessment which will evaluate the risk of a proposed pipeline to the public. The consequences to be investigated will be limited to public exposure to hydrogen sulphide gas (H_2S).

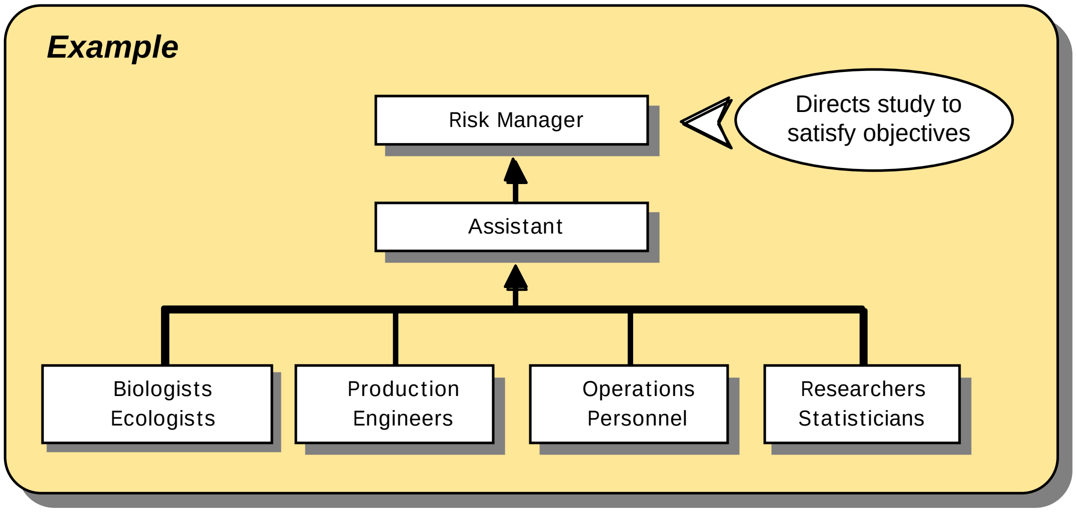
Step 1D Organize the Risk Assessment Team

After the assessment's objectives and scope have been identified, a team should be formed to conduct the assessment. A risk assessment team may be a single individual but is more likely to include individuals with the following expertise:

- current operations and spills history
- technical knowledge of areas to be investigated
- statistical methodologies
- risk assessment methodologies
- management objectives
- impacts on human health, safety, ecosystem

Use checklists or tables to summarize team requirements to ensure that there is sufficient expertise to meet the objectives and scope identified in the earlier planning steps.

The team members will report to a risk assessment manager. The risk assessment manager requires a general knowledge in each area as well as knowledge in risk assessment methodologies.



Step 1 Review

The objectives and scope of the risk assessment should be re-evaluated to ensure that available resources will enable the risk manager to satisfy the objectives. For example, delineating the detailed consequences of an oil spill such as long-term impacts on a fish population may not be feasible if toxicity information or financial resources are not available to conduct chronic toxicity tests over a period of several years.

At the end of Step 1, ensure that the following tasks are completed:

- ❐ Objectives of the study are clearly identified.
- ❐ The specific operations that will be included in the study are identified and listed.
- ❐ The types of consequences that will be studied are identified.
- ❐ The risk assessment team includes the necessary expertise to satisfy the objectives.

Step 2 Analyze Hazards: Identify and Describe Spill Scenarios

STEP 2

Analyze Hazards
Identify and Describe Spill Scenarios

- Review spill data & case histories
- Review operational hazards

⇩

- Identify potential sources
- Estimate probable spills sizes
- Investigate possible causes

What can go wrong and why?

The purpose of hazard analysis is to identify and describe spill scenarios which include potential sources of spills, probable product type and spill volume, and causes of incidents.

> *You cannot evaluate the risks if you do not know the sources and characteristics of the spills.*

Several methods can be used to identify the risk sources. The selected method will depend on the assessment's objectives, scope, and available resources.

This section shows how to use oil spill accident data and case histories to identify and describe sources, trends and causes of spills.

Appendix 3.0 presents alternative approaches for identifying oil spill scenarios:

- Event or Fault Trees
- What-if Scenarios
- Hazard and Operability Analysis (HAZOP)

Step 2A Review Oil Spill and Accident Data

Review available data and incident case histories to identify trends in spill causes, sources and sizes. Incident records may often be obtained from company or regulatory records. Other sources of data useful for identifying potential sources include publicly available databases (see Appendix 2.0) and oil industry journals.

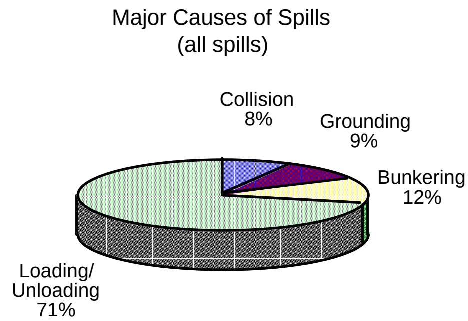
The following are examples of trends in offshore, coastal and inland spills that have been identified from historical data:

Figure 2A
Major Causes of Offshore Spills

The majority of small or intermediate spills in offshore waters are caused by loading and unloading operations.

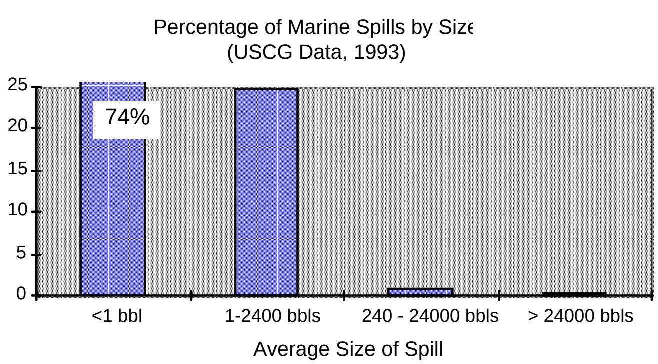
Statistics from ITOPF indicate that more than 70% of all spills occurred during loading and unloading operations.

Yet, the major causes of large spills are the result of collisions and groundings of vessels.



(ITOPF, provided to IPIECA, 1991)

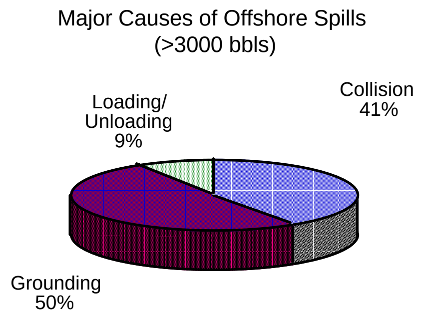
Figure 2B
Offshore Spills by Size



Large instantaneous releases of oil, such as the Exxon Valdez spill, are very uncommon.

U.S. Coast Guard (USCG) statistics suggest that more than 80% of spills are less than 1 bbl and that large (>24,000 bbls) spills account for less than 1% of spill events.

Figure 2C
Causes of Large Offshore Spills



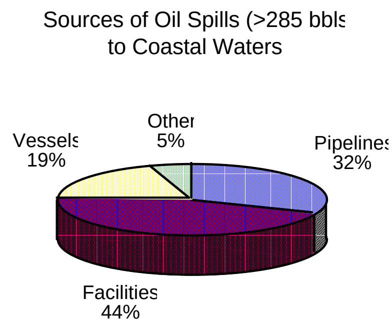
(ITOPF, provided to IPIECA, 1991)

Major causes of large offshore spills have been found to be groundings and collisions.

Figure 2D
Sources of Coastal Spills

The U.S. Environmental Protection Agency reported that the majority of coastal spills occur from facilities and pipeline operations.

Many reports suggest that spills from facilities (refineries, storage tanks, drilling platforms, land transportation, pipelines) outnumber spills from vessel (tankers, barges, freighters) on an annual basis.

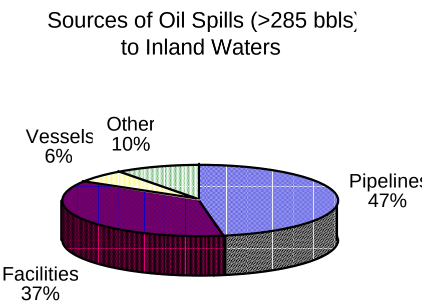


(EPA, 1997)

Figure 2E
Inland Spill Sources

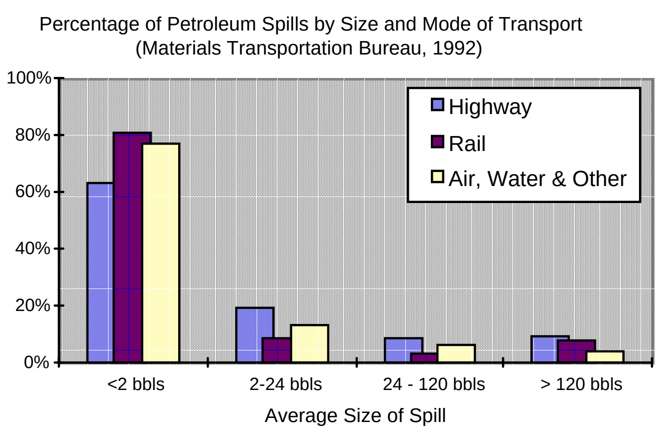
The American Petroleum Institute reports that 42% of spills occur into inland water bodies while only 30% of spills occur into coastal waters within 12 miles of U.S. shores.

The U.S. Environmental Protection Agency (EPA) also reports that the majority of spills into inland waters are associated with activities at facilities and pipelines.



(EPA, 1997)

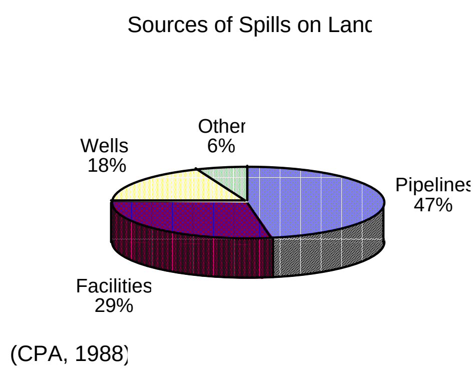
Figure 2F
Coastal Spills by Size



Similar to coastal water spill statistics, the majority of spills on land are small, minor events and not large catastrophic incidents.

Figure 2F illustrates that during petroleum product transport by rail, road, air or water it is still the minor spills that are most common.

Figure 2G
Spill Sources on Land

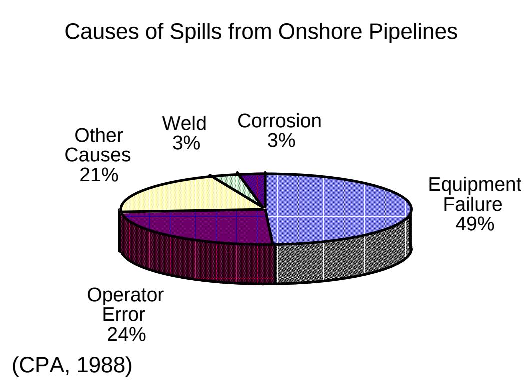


The greatest source of spills on land is from facilities and pipelines.

The Canadian Petroleum Association (CPA) found than spills on land are usually caused by internal and external corrosion, equipment failure, tank overflows and leaks, and operator error.

Figure 2H
Onshore Pipeline Spill Causes

When examining spills from onshore pipelines, the CPA found that operator error and equipment failure account for more than half the incidents.



Step 2B Group Spill Incidents

Whether or not a risk assessment uses historical accident data and/or brainstorming sessions to analyse potential spill scenarios, it is essential that spill scenarios are identified. This will provide a starting point for the assessment of the probability of an incident occurring and its consequences.

Based on the objectives, scope, and range of oil spills types identified, group spill scenarios according to the following factors:

- spill volume
- equipment source
- facility type
- spill cause

Example

Following an analysis of the possible hazards at an onshore oil facility, the following list of oil spill scenarios was generated.

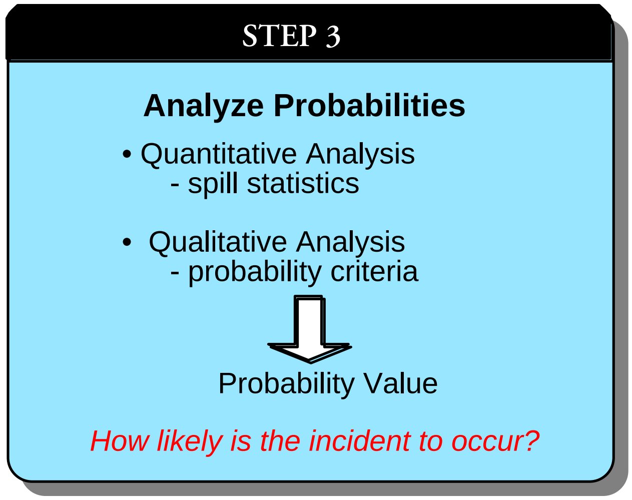
Potential Spill Volume (bbls)	Spill Sources (Scenarios)	Probabilities	Consequences
1-49	Chronic Valve Leaks Sampling Spills Truck Loading/Unloading Stuffing Box Leaks		
50-999	Pipeline leak Sampling spills Truck Accident Valve Leaks Flange Leaks		
1,000-5,000	Pipeline Rupture Lightning Strike Well blowout Vandalism/Terrorism Production Tank Rupture		
>5,000	No foreseeable circumstances		
STEP 2		**STEP 3**	**STEP 4**

Step 2 Review

At the end of Step 2 ensure that the following tasks are completed:

- ❒ Common sources of oil spills are identified.
- ❒ Common causes of oil spills are identified.
- ❒ Expected spill volumes of incidents are estimated.
- ❒ Spill incidents are grouped into categories based on source, size and / or cause.

Step 3 Analyze Probabilities



Risk is a function of the probability of an incident occurring and the consequences of the incident.

After establishing assessment objectives and scope and after the identifying risk scenarios, the assessment must attempt to determine the probability of the identified risk scenarios occurring.

In general, probability analysis can be described using two methods:

- **Quantitative** methods are often used in situations where appropriate historical accident and spill data are available.

- **Qualitative** methods are often employed when statistical data are not available to the risk assessors. Instead, qualitative judgements are made based on factors which may increase or decrease the likelihood (probability) of a spill incident occurring.

Step 3A Quantitatively Estimate Incident Probabilities

Historical data may be reviewed and a probable event frequency (or probability) can be determined. Event frequency would be based on the total number of applicable accidents and the total population of equipment or facilities.

Most often, frequency data are used which has been previously determined for similar operating conditions. A historical incident frequency rate can be obtained by dividing the total number of incidents by the study population.

$$Frequency = \frac{Total\ Number\ of\ Applicable\ Accidents}{Total\ Number\ of\ Spill\ Sources}$$

The frequency estimate can be presented in terms of units of oil produced, processed, or transported (e.g., billion barrels of oil produced). This frequency estimate value can then be compared to the actual quantity of oil produced or transported by a company. This will determine the estimated number of spills or probability of spills from a specific mode of transportation or operation.

The following table illustrates how frequency data may be applied to a company's operations to develop the oil spill probability.

Spill Category	Frequency Data	Company Volumes	Expected Frequency of Spills for Company	Probability
Tanker Spills >150,000 bbls	0.1 spills / billion bbls transported (USCG)	130 million bbls transported per year	0.013 spills / yr	one spill in 77 yrs

Note: Caution should be used when using statistical methods for estimating probabilities. The user should be aware of how closely the circumstances of the study correspond to the circumstances from which the statistics were generated. Different statistical criteria can generate different statistics which can lead to inapplicable conclusions.

Example

A petroleum company transports 50,000 bbls a day (18 million bbls per year) of oil via an offshore pipeline. Data obtained from the Marine Industry Group (MIRG) (1991) for spills in the Gulf of Mexico indicates that the frequency of a spill (>10,000 bbls of oil) is 0.4 spills per billion bbls transported. Using these data, the probability of the company experiencing a spill is one in 139 years.

However, data obtained from studies of crude oil spills in Canada's Atlantic Region by the Canadian Petroleum Products Institute (1991) indicate that the chance of a spill (>10,000 bbls of oil) is 0.67 per billion of bbls transported. Using these data, the probability of the company experiencing a spill is one in 83 years.

Spill Category	Frequency Data	Company Volumes	Expected Frequency of Spills	Probability
Crude Oil Tanker Spills >10,000 bbls	0.40 spills / billion bbls transported (MIRG)	18 million bbls transported / year	0.0072 spills / year	one in 139 years
	0.67 spills / billion bbls transported (CPPI)	18 million bbls transported / year	0.0121 spills / year	one in 83 years

The different frequency data may be due to a number of factors including:

- different geographical areas
- different reporting requirements for spills
- different levels of control or vessel management
- different data management

Probability equations can be developed to include various site-specific considerations and may include constant values, site specific statistics, and weighting factors. However, these equations may demand increasing specific statistical information and may introduce increasing sources of error as more specific data are included.

The variance of data in the following table illustrates the need to be familiar with the parameters of each data source.

Table 1. Selected Frequency Estimates for Oil Spills.

Spill Category	Data Source	Frequency Data
Tanker Spills		
> 150,000 bbls	United States Coast Guard	0.1 spills / billion bbls transported
> 150,000 bbls	Marine Industry Group (MIRG) (1991)	0.05 spills / billion bbls transported
> 100,000 bbls	S. L. Ross Environmental Research	0.07 spills / billion bbls transported
> 10,000 bbls	Marine Industry Group (MIRG) (1991)	0.41 spills / billion bbls transported
> 10,000 bbls	S. L. Ross Environmental Research	0.19 spills / billion bbls transported
> 1,000 - 10,000 bbls	Marine Industry Group (MIRG) (1991)	0.28 spills / billion bbls transported
> 1,000 bbls	S. L. Ross Environmental Research	0.47 spills / billion bbls transported
> 1,000 bbls	Marine Industry Group (MIRG) (1991)	0.68 spills / billion bbls transported
> 1,000 bbls	United States Coast Guard	1.3 spills / billion bbls transported
1-999 bbls	United States Coast Guard	28 spills / billion bbls transported
50-999 bbls	S. L. Ross Environmental Research	3.2 spills / billion bbls transported
1-49 bbls	S. L. Ross Environmental Research	21 spills / billion bbls transported
Tanker at Sea		
> 1,000 bbls	Lanfear and Amutz (1983)	0.9 spills / billion bbls transported
> 10,000 bbls	Lanfear and Amutz (1983)	0.5 spills / billion bbls transported
Tanker in Port		
> 10,000 bbls	Lanfear and Amutz (1983)	0.15 spills / billion bbls transported
> 1,000 bbls	Lanfear and Amutz (1983)	0.4 spills / billion bbls transported
SPM Loading Spills		
> 1,000 bbls	S. L. Ross Environmental Research	2.3 spills / billion bbls transported
1-999 bbls	S. L. Ross Environmental Research	37 spills / billion bbls transported
Platform Spills		
> 10,000 bbls	Lanfear and Amutz (1983)	0.44 spills / billion bbls transported
> 1,000 bbls	Lanfear and Amutz (1983)	1.0 spills / billion bbls transported
> 1,000 bbls	United States Coast Guard	0.60 spills / billion bbls produced
50-999 bbls	United States Coast Guard	14 spills / billion bbls produced
1-49 bbls	United States Coast Guard	381 spills / billion bbls produced
Offshore Production Wells		
> 150,000 bbls	Canadian Petroleum Institute (1989)	0.063 / billion bbls produced
> 150,000 bbls	S. L. Ross Environmental Research	$2.5 * 10^{-5}$ spills / wells / yr
> 10,000	S. L. Ross Environmental Research	$1.0 * 10^{-5}$ spills / wells / yr
Offshore Drilling Blowouts		
> 150,000 bbls	S. L. Ross Environmental Research	$4.23 * 10^{-5}$ spills / wells drilled
> 10,000 bbls	S. L. Ross Environmental Research	$9.86 * 10^{-5}$ spills / wells drilled
>10,000 bbls	Lanfear and Amutz (1983)	0.67 spills / billion bbls transported
> 1,000 bbls	Lanfear and Amutz (1983)	1.6 spills / billion bbls transported
> 1,000 bbls	S. L. Ross Environmental Research	0.67 spills / billion bbls transported
Storage Tank Spills		
> 1,000 bbls	S. L. Ross Environmental Research	$1.11 * 10^{-2}$ spills / yr / million bbls
Offshore Pipeline Spills		
> 1,000 bbls	United States Coast Guard	0.67 spills / billion bbls transported
> 1,000 bbls	United States Coast Guard	$0.17 * 10^{-3}$ spill / mile / year

Statistical-based methods suffer from several disadvantages including:

- They may not be appropriate for risk assessment studies with limited resources or data availability.
- There is often a rarity of major oil spill events and lack of data for minor chronic spills.
- The data may be incomplete or of poor quality with respect to the sample size, data source, and data age.
- The risk assessment team may not have the resources to properly obtain and analyze the available data.
- Historical data may be derived from data sources or operations which are not typical of a company's operations. Some data may be extremely specific to a certain type of equipment.
- Unique external factors (e.g. wind, sea conditions, water depth) may play a role in increasing or decreasing the frequency of oil spills incidents.
- The role that human error plays in causing spills. Some studies have indicated that as much as 80% of accidents are due to human error.
- Estimates based on historical data may not include site-specific risk reduction factors including safety management and containment systems.

Step 3B Qualitatively Estimate Probability

An alternative to calculating probabilities based on historical frequency or statistical data is to identify those factors which increase or decrease the chance of a spill incident occurring and evaluate the specific circumstance for evidence of those factors.

Factors can be derived from numerous sources including:

- case histories
- spill and accident data
- expert opinion

Identified factors can be weighted, arranged in a matrix, used as a scoring or ranking system, or graphically displayed.

Checklists can identify operations and include factors that pose increased probabilities of incident occurrence. They may be developed for general operations, for specific equipment or for operation areas such as the following:

- onshore and offshore pipelines
- marine terminals
- single point moorings
- transportation pipelines
- transportation tankers
- onshore refineries
- onshore pipelines
- transport trucks
- wellhead
- bulk storage facilities
- underground tanks

Example

After a review of historical case studies, a number of leading causes of pipeline failures was found to include various pipeline construction, product handling, and operating conditions. Generally, the available data may not be suitable for calculating probabilities but it may be suitable for comparing two pipelines within a company's operations or for identifying segments in the greatest need of upgrading.

The probability value is a valuable tool that allows for comparison of different operations and also allows for the examination of the sources of risk.

Probability Criteria	**Pipeline Segment #1**	**Pipeline Segment #2**
Pipeline age <20 yrs	☑	❑
Pipeline diameter <6"	☑	☑
Corrosion protection	☑	❑
Cathodic protection	☑	❑
Internal coating	❑	❑
External coating	❑	❑
Smart pig tests	☑	☑
Periodic right-of-way inspection	❑	❑
Periodic ultrasound tests	❑	❑
No leaks in past 3 years	☑	☑
Probability of Spill	**Low**	**High**

A useful tool in developing checklists or probability criteria are auditing guidelines. Auditing protocols are typically focused toward identifying those operational conditions that minimize leaks or releases to the environment.

Therefore, auditing guidelines can also provide a starting point to develop criteria which increase or decrease to probability of an oil spill.

Guideline

Refer to the "ARPEL Guidelines for Conducting Environmental Audits for Onshore Petroleum Operations" (Guideline #9) and "ARPEL Guidelines for Conducting Environmental Audits in the Petroleum Industry Operations" (Guideline #14).

Step 3C Assign a Probability Value

Whether the risk assessment uses **quantitative** or **qualitative** methods for analyzing spill probabilities, the objective of Step 3 is to develop a probability value. The probability value is determined by comparing the outcome of all possible spill probability outcomes.

The probability value is the common denominator that allows comparison of probability and consequences.

For example, a range of potential probability values for the results of an oil spill from a production facility might be:

Range of Possible Spill Probabilities	Example of Range Spill Incidents	Probability Value
Frequent (1 incident per year)	Chronic leaking from valves	10
		9
		8
		7
	Rupture of 500 bbl storage tank	6
		5
		4
		3
Remote (1 incident in life of operation)		2
	Spill of >100,000 barrels at small oil facility	1

Step 3 Review

Quantitative methods for estimating probabilities are most applicable under the following circumstances:

- When reliable spill data are available and compare directly with the proposed risk assessment study.
- When multiple risk assessment studies (possibly from different sources) identify standard spill statistics that will be consistently used.

Qualitative methods for estimating probabilities are most applicable when reliable statistics are not available and the objective of the study is to evaluate and compare sources and causes of risk. Qualitative methods are also a valuable tool for supporting statistically based methods.

Regardless of whether quantitative or qualitative methods are used, the objective is to generate a non-unit probability value. This value will be combined with analysis of consequences (Step 4) to generate an overall risk value (Step 5).

At the end of Step 3 ensure that the following tasks are completed:

❒ Statistics have been gathered to estimate the probability of spill incidents for each category identified in Step 2.

or

❒ Checklists have been developed to identify those operations with characteristics likely to increase the probability of spill incidents occurring.

❒ A probability index has been developed based on the range of possible probabilities, scores, or rankings.

❒ A relative non-unit probability value has been determined that can be combined with the analysis of consequences to generate an overall risk value.

Step 4 Analyze Consequences

STEP 4

Analyze Consequences

- Identify major release pathways
- Identify fate and effect
- Identify major receptors
- Measure adverse effect

⇩

Consequence Value

What will be adversely affected?

In the event of an oil spill, it is important to consider a number of potential factors that may affect the consequence of the spill including:

- risk of fire and explosion (especially when dealing with spills of gasoline and other volatile products)
- impact on biological resources (e.g. lethal and sublethal effects on fish)
- impact on population centres or adjacent properties (e.g., marinas, beaches, conservation areas, harbours and parks)
- impact on other freshwater or marine uses (e.g., mariculture, tourism, navigation, recreation, freshwater intakes)
- persistence of oil in soils and groundwater resources
- poor public perception (e.g., media coverage of a spill event)
- other site considerations (e.g., historical, archaeological, cultural)

There are many ways to analyze spill consequences from the simple to the very complex. The key is to analyze the consequence in a manner that provides enough information to assess the risks and satisfies the objectives of the study. Consequence analysis can be described by the following key components:

- identify the major pathways
- analyze the fate and transport
- identify major receptors
- measure exposure of receptors

Step 4A Identify Major Pathways

Identification of the primary transport mechanisms (major pathways) by which spilled oil is released into the environment will determine the environmental resources and human activities that may be at risk. Major pathways of spilled oil can involve:

- surface water
- groundwater
- soil
- sediment
- biota
- air

By identifying major pathways of spilled oil, the risk assessment can gain an initial understanding of the relationships of the properties of oil, its transport through the various media, and the adverse effects.

Step 4B Analyze Transport and Fate

The transport and fate of spilled oil within each pathway will play a major role in the degree of the adverse effects. Important considerations in evaluating the transport and fate of spilled oil include:

- spreading or movement on surface water and in the water column
- leaching into groundwater and subsurface soils
- movement via groundwater and porous soils
- absorption into soil and vegetation
- weathering, dispersion, evaporation and emulsification on soil and water surfaces
- interaction with debris
- transport by animals and human activities

Some crude oils may weather quickly while other may persist in water or soils. Light crudes may spread quickly while heavy crudes may spread slowly. Heavy crudes spilled on land may contaminate only the surface soil horizons whereas refined oils and lighter fuels may penetrate subsurface layers. The difference in product characteristics must be considered in identifying their transport and fate during a spill.

A key tool in identifying transport of spilled oil on water is the use of oil spill trajectory modelling. Computer models can be applied to project the movement of spilled oil and identify areas, amenities and biological resources having a high probability of impacts from spills.

Report

Refer to the "ARPEL Oil Spill Trajectory Modelling" (Report #4).

Numerous models are available for determining the transport of spilled oil including oil movement on water, in soil, and groundwater aquifers.

Other models, such as ADIOS II (provided by NOAA), also focus on the fate of spilled oil under different environmental conditions.

Step 4C Identify Major Receptors

An understanding of the major pathways and the likely fate of spilled oil will assist in identifying the major receptors at risk from an oil spill.

When evaluating risk receptors consider adverse effects of spilled oil which include:

- Physical contamination and smothering of living resources which causes a disruption of living functions such as feeding, respiration, and movement. Receptors at risk of physical contamination include aquatic life, marine mammals, reptiles, birds that feed by diving, and animals and plants in aquaculture facilities.
- Population density and recreational activities including beaches, boating, and diving. Spilled oil can cause serious levels of public concern and result in significant economic loss relating to tourism.
- Industrial facilities, such as shipyards or harbour operations, which rely on seawater or freshwater for operations.
- The toxicity of spilled oil as a function of the concentration of spilled oil (in water or soil) and the time required to cause an adverse toxic effect. As the toxicity differs for each type of hydrocarbon it is important to consider the various toxicities of aviation fuels, gasolines, and diesel fuels.
- Bioaccumulation by organisms of levels of hydrocarbon at very low concentrations. Mussels, oysters, and clams filter large volumes of seawater to extract food. Bioaccumulation in these organisms may result in adverse affects on their populations as well as health risk to other animals that consume these organisms.
- Oiling of terrestrial plants which can seriously disrupt the normal respiratory functions and result in poor growth or mortality. For larger vegetation species, spilled oil can still be detrimental if concentrations exceed specific levels in root bearing soil zones.

A key tool in identifying major oil spill receptors is the use of previously prepared sensitivity maps. Sensitivity maps can allow for the rapid identification of sensitive habitats, human use areas and valuable resources which may be included in the evaluation of consequences.

Guideline

Refer to the ARPEL Guideline #16, "The Development of Environmental Sensitivity Maps for Oil Spill Planning and Response."

Step 4D Measure or Estimate Adverse Effects

In evaluating the consequences of spilled oil, methods can range from simply identifying the key receptors which have a potential to be adversely affected by spilled oil to attempting to quantify the effects on certain indicator species.

The selection of the indicator of adverse effects must be based on a number of key factors including:

- Identified scope and objectives of the study.
  For example, if the objective were to evaluate the risk to human health in populations adjacent to the oil spill source, then benzene levels in drinking water supplies may be a suitable indicator of potential adverse effect.

- The ability of the risk assessment team to measure the indicator.
  For example, limited analytical resources may require an indicator which can be measured visually such as kilometres of oiled shoreline.

- The likelihood that the indicator relates directly to an adverse effect or a potential adverse effect.
  For example, benzene is a known carcinogen and therefore a good indicator of potential cancer risk if found in drinking water supplies.

Step 4E Determine a Consequence Value

After the spill consequences have been analyzed a consequence value should be developed.

Many indices have been developed that attempt to factor the adverse consequences of incidents based on the vulnerability of certain receptor types to spilled oil.

Available indices can be used to determine a range of consequences and a consequence value.

For example, a range of potential consequence values for the results of an oil spill from a production facility on shorelines might be:

Range of Possible Spill Consequences	Example of Range of Consequences	Consequence Value
Catastrophic	• Marshes, Swamps and Mangroves, Oxbow Lakes	10
		9
		8
		7
	• Sand Bars and Low-Slope Banks	6
		5
		4
		3
No adverse effect	• Exposed Vertical Cliffs/Walls or Vertical Banks	2
		1

Refer to Appendix 7.0 for an example of a Vulnerability Index. For a greater range of potential receptors affected by spilled oil refer to:

Guideline

ARPEL Guideline #16, "The Development of Environmental Sensitivity Maps for Oil Spill Planning and Response."

Step 4 Review

Upon completion of Step 4 ensure that the following tasks have been completed:

- ❒ The consequences of spill incidents identified in Step 2 have been identified and described.
- ❒ A consequence index or value scale has been developed or modified for the study.
- ❒ Checklists have been developed to identify those operations with characteristics likely to increase the probability of spill incidents occurring.
- ❒ A relative non-unit consequence value has been determined for oil spill scenarios that can be combined with the analysis of probabilities to generate an overall risk value.

Step 5 Characterize the Risk

STEP 5

Characterize the Risk

Probability Value + Consequences Value

⇩

Risk Value

What are the relative risks?

A common method for characterizing risk is to develop probability and consequence indices as described in the previous steps. The indices, developed from the range of possible outcomes, generate non-unit probability and consequence values. The non-unit values provide a common denominator that allows for the comparison of spill probabilities and spill consequences within the framework of the risk assessment.

Risk = Probability + Consequences

Since risk is a function of the probability and consequence of oil spills, those incidents that have high probabilities of occurring and serious consequences will pose the greatest risk. Conversely, those incidents with low probabilities and minor consequences may pose little or no risk.

The above can be displayed by the following example of a risk matrix:

Risk Value					
		Consequences			
		Low	Medium	High	Very High
Probability	Very High	**Possible Target for Risk Reduction**			
	High		**Strategies**		
	Medium				
	Low				

The probability and consequence values are combined to develop a risk value as illustrated below.

Oil Spill Incident	Probability Analysis	Consequences Analysis	Risk Level
1 bbl from a chronic leaking valve at production facility	Daily	Resources nearby: - mangrove forest - drinking water supply - agricultural area	
Value	10	8	18
20,000 bbls spilled during tanker collision	One incident in 25 years	Resources nearby include rocky shores and man-made seawalls	
Value	2	2	4

It important to note that the risk value identified is relative. The value is useful only for comparing different risk sources. The risk value cannot be compared against other values or indices from other studies which have used different methods in determining those values.

Step 5 Review

Upon completion of this step, the assessor should ensure that the following tasks are satisfied:

- ❒ A risk value for each spill incident has been determined and is based on non-unit probability and consequence values.
- ❒ Acceptable risk levels are identified.
- ❒ Major factors contributing to high probabilities and serious consequences are identified and described.

Step 6 Manage the Risk

STEP 6

Risk Management

- Reduce Probabilities
- Reduce Consequences

Risk levels are relative only within the subjective criteria of the assessment study. Risk values are most useful in evaluating risk reduction alternatives and comparing risk levels for different circumstances or to acceptable corporate benchmarks.

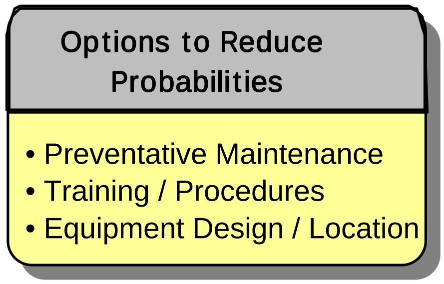
Risk management is the evaluation and implementation of the options for reducing the probability and consequences of spills.

Risk managers must determine what level of risk is acceptable. A company may target those incidents that pose only the greatest risk, or certain incidents may be targeted that pose a relative risk above an acceptable level. This acceptable level would be determined following a review of the incidents and evaluating the range of risk levels.

Risk reduction strategies must address one of two areas:

- options to reduce incident probability
- options to reduce the consequence of incidents

Step 6A Reduce Incident Probability



Incident probability may be affected by factors which are beyond the control of risk management programs.

Numerous risk management options can be designed to address abnormally high incident situations. These options may include:

- preventative maintenance and inspection programs
- anti-terrorist or improved security measures
- siting facilities to reduce incident probability
- improved vessel and equipment quality
- spill control and equipment protection measures

Appendix 5.0 includes several examples of preventative maintenance checklists which may be useful to identify those operations that pose the greatest spill risk.

Step 6B Reduce Incident Consequences

Options to Reduce Consequences

- Countermeasures
- Training
- Contingency Planning

A major factor affecting the consequences of an oil spill is a company's ability to respond to it.

Response abilities depend on a number of factors including:

- effective contingency plans in place
- availability of appropriate cleanup equipment and materials
- oil spill response organization and policies

The ability of organizations to respond effectively to an oil spill and minimize adverse environmental effects depends extensively on the organization and policies in place.

Guideline

Refer to "ARPEL Oil Spill Management and Contingency Planning Guidelines" (Guideline #17).

To identify the level of available spill countermeasures and management systems, a risk management should consider some or all of the following considerations.

- national or regional contingency plans
- corporate and site-specific contingency plans
- periodic testing of plans, personnel training and simulation exercises
- formal agreements with response organizations or industry associations
- employee training specifically in the operation of specialized equipment or supervision of field operations
- up-to-date and well maintained equipment

Appendix 4.0 includes an example index to evaluate countermeasures capabilities.

In addition, options for risk management may focus increased insurance for certain incident or maintenance of an emergency response fund. These risk management options may ensure that financial resources are in-place to respond to oil spill incidents adequately and, also, that incidents do not have catastrophic financial consequences to a company.

Database

Refer to the ARPEL Spill Expert and Oil Spill Equipment Inventory Database Applications (Version 2.0).

Step 6 Review

Upon completion of Step 6 ensure that:

- ❒ Risk reduction strategies that will reduce the probability of incidents occurring have been identified.
- ❒ Risk reduction strategies that will reduce the consequences of incidents have been identified.
- ❒ Other company and industry programs (e.g., contingency planning) have been identified that affect risk levels.
- ❒ Future risk reduction strategies have been identified.

Case Study

This case study represents a preliminary risk assessment using the “Step” approach. Note that the assessment results are specific to this particular example.

Problem:

Evaluate the risks to the public from a low vapour pressure pipeline transporting oil containing hydrogen sulphide gas.

Analyze Hazards:

Identified serious hazards from a this pipeline included explosion, oil spills, and hydrogen sulphide gas release. The most serious hazard to the public was determined, by means of expert review, was exposure to toxic H_2S gas.

The main causes of a pipeline release were also determined from records to be corrosion, weld failures, and external forces. [This case study focuses the major hazard. Other analysis on the effects of spilled oil on the public or environment could also be conducted].

Analyze Probabilities:

The probability of a major and partial rupture (leak) to this line were determined from historical spill records. The probability of a major rupture was determined to be $9.7 * 10^{-5}$ per km year. The probability of a partial rupture was determined to be $2.9 * 10^{-4}$ per km year.

Analyze Consequences:

Consequence of the gas release were defined as the number of individuals expected to be exposed to levels of H_2S gas for a period of time that would result in serious health effects or death.

Data including meteorological conditions, time, H_2S concentrations, and pipeline operating conditions were modelled using a plume dispersion model to determine expected concentrations of toxic H_2S gas at distances from the pipeline versus time. This information was compared against available landuse and population maps to determine quantities of populations expected to be adversely affected by the gas component of the product release.

Analyze Risks:

The probabilities of an pipeline rupture occurring and the consequences of the subsequent gas release were combined to arrive at a risk value for each section of the pipeline. The risk value was expressed as risk to an individual of adverse health effects (or death). Risk was calculated as the number of chances in a million. The results were compared to the acceptable corporate levels and industry standards for determine if the risk level was acceptable.

Risks were reduced by:

- focusing on those causes of incidents that were most common (e.g. pipeline corrosion); and
- reducing potential consequences of a release by:
  - modifying certain pipeline operating conditions,
  - increasing the number and intensity of pipeline inspections,
  - increasing H_2S sensing technology along the pipeline,
  - upgrading emergency response.

A key component of any risk assessment is to document the information in a manner which is useful to risk managers. A sample Table of Contents for a risk assessment report follows:

Table of Contents

Introduction
- Objectives and Scope
- Limitations

Oil Spill Incidents
- Sources
- Sizes
- Causes

Probability Estimation
- Spill Frequencies
- Data Sources

Consequence of Oil Spills

Risk Levels of Oil Spill Incidents

Conclusions

Recommendations

Uncertainty

Data Sources

Appendix 1.0 Example of Risk Assessment Team Checklist

Examples of Objective	Possible Areas of Expertise	Examples of Team Members
Identify spill sources from normal operations	Operations Industrial spill tendencies Site-specific spill histories	Operations Foreman Production Engineer Spill Researcher
Identify spill sources from new equipment	Design specifications Regulations	Designer / draftsperson
Identify probabilities of spill incidents	Statistics Mathematics Data management	Statistician Mathematician Data manager
Evaluate effects of spilled oil on biological resources	Effects of oil on flora and fauna	Biologist Ecologist Botanist Toxicologist
Evaluate effects of incidents on public perception of company	Corporate policy Public reaction Cultural resources	Public spokesperson Political scientist Sociologist Archaeologist
Effects of incidents on viability of company's operations	Financial losses Administrative fines and penalties Investor relations	Senior managers Accountants Policy administrators Financial officers
Effects of incidents on worker safety	Daily operations Explosions and Fires Plume dispersion	Occupational health and safety personnel Plume modeling scientist Labour member

Appendix 2.0 Selected Publicly Available Databases

Source	Applicability
International Tanker Owners Pollution Federation Limited (ITOPF) oil spill database.	To date information on accidental spills of crude oil and products including fuel oils, from tankers, combined carriers, barges, etc.
Failure and Accidents Technical Information Systems (FACTS) Database.	To date information on major accident hazards database.
World Offshore Accident Databank (WOAD).	Information on more than 2600 offshore accidents.
The National Oceanic and Atmospheric Administration (NOAA) Oil Spill Case Histories, U.S. and International, 1967-1991.	Database of case histories for international spills >100,000 bbls and in U.S. <10,000 bbls.
International Oil Spill Statistics (IOSS) Spill Database.	List of every major spill around the world since 1960.
U.S. Coast Guard Pollutant Incident Reporting System PIRS database	To date data on oil and other pollutants discharged into the navigable waters in the United States from 1971.
U.S. Materials Transportation Bureau Liquid database	Over 4000 reports of petroleum spilled from pipelines since 1960.
U.S. Minerals Management Service (MMS) Database on tanker spills	To date information on tanker spills over 42,000 gallons from 1974-1992.
U.S. Minerals Management Service (MMS) MMS Pipeline Leaks and Repairs Database	To date information on date, size, cause and corrective actions of pipeline leaks.
The Institute Francais du Petrole TANKER Database	Contains data on accidents since 1955 involving non-military vessels.
The Institute Francais du Petrole PLATFORM Database	Contains data on accidents since 1955 involving drilling, production, and accommodations platforms.

Appendix 3.0 Alternative Methods of Hazard Analysis

What-if Scenarios

What-if scenarios typically use a set of guide words to systematically investigate non-normal operating conditions and failure situations. In the context of a brainstorming session, experts (risk team) apply guide words such as "low" and "pressure" to process and flow diagrams, operating procedures, and control mechanisms. For example, the guide word 'High" and "Pressure" would direct the team to investigate High Pressure in process equipment and how that condition may lead to an oil spill:

"What if high pressure were exerted on the tank vent?"

Prior to the brainstorming session, risk teams should develop a list of guide words to include circumstances that are specific to the types of equipment, objectives and scope of the oil spill risk assessment. The objective of this session is to generate risk scenarios and identify oil spills that would be generated under non-normal operating conditions.

The brainstorming session should be facilitated by the risk manager with input from all members of the risk assessment team. In addition the following two additional individuals should be present at the brainstorming session:

- A person should be present to record all relevant discussion topics and pertinent team comments.
- A data recorder should be present to capture the team's responses to guide words. Responses may be recorded in note form, tables or spreadsheet formats.

The following are examples of guide words that may be used to direct brainstorming sessions:

Parameters	High	Low	None	Reverse
Flow	High Flow	Low Flow	No Flow	Reverse Flow
Pressure	High Pressure	Low Pressure	No Pressure	Vacuum
Temperature	High Temp	Low Temp	No Reading	Faulty Reading
Level	High Level	Low Level	No Level	Overflow
Ignition	Excessive Spark	Low Ignition	No Ignition	
Instrumentation	High Readings	Low Readings	No Readings	
Static	High Static	Low Static		
Depth		Low Depth	Grounding	

Hazard Operability Analysis

A Hazard Operability Analysis (HAZOP) is a formal systematic procedure conducted by a team of knowledgeable individuals to review the design and operations of a potentially hazardous system. Hazards are identified by examining and identifying possible deviations from normal safe operation and determining the possible consequences of those deviations. The HAZOP analysis also defines actions that may be necessary to mitigate risk. HAZOP studies are very time consuming but are generally very rigorous in identifying hazards and devising possible mitigation strategies. The records of a HAZOP study are usually represented in the form of a table that includes columns describing the following:

- Design Deviation
  - deviation from the design intent or operating conditions
- Consequences
  - the consequences of the deviation
- Possible Causes
  - the cause of the deviation
- Recommended Action
  - if necessary, actions that could mitigate possible hazards
- Action Complete
  - whether the recommended action has been completed or not

Design Deviation	Consequences	Possible Causes	Recommended Action	Action Complete

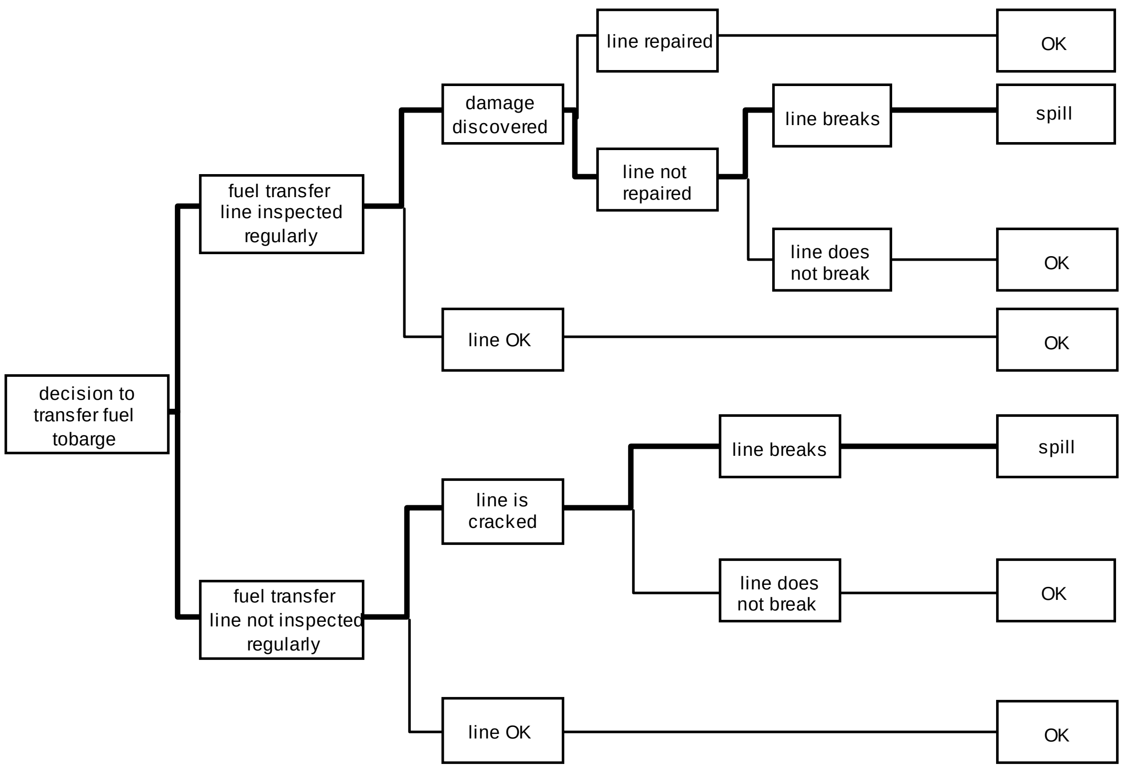
Event Tree / Fault Tree Analysis

An *Event Tree Analysis (ETA)* or *Fault Tree Analysis (FTA)* can be used to show all possible outcomes of a non-normal incident (e.g., oil spill), beginning with an initiating event (e.g., pipeline rupture) and proceeding through a series of protective features that succeed or fail as the accident continues. Alternatively, an event tree can identify a non-normal incident and work backward to identify all those scenarios which gave rise to the incident.

An event tree/fault tree analysis is useful in describing sequences of events that can lead to a spill and graphically displaying the relationship among events involved in the failure pathway.

An event tree is most suitable in dealing with single initiating events. For risk assessments an event tree may be most applicable to a single event with a single piece of equipment or with numerous pieces of similarly designed equipment (e.g., multiple underground tanks).

The following figure is a simplified example of an event tree for potential spills during a fuel transfer to a barge. The chain of events connected by the bold line lead to the occurrence of a spill.



Event Tree for a Fuel Transfer to a Barge

Failure Mode and Effect Analysis

A Failure Mode and Effect Analysis (FMEA) is similar to a HAZOP study but considers only potential equipment failures in process sequence or instrumentation loop. Worker interaction with equipment is not directly evaluated. FMEA documents all potential flaws in a system and allows evaluation of the risk associated with each flaw in order to help prevent the occurrence of high risks. The records for an FMEA can be represented in a table with columns describing the following:

- Subsystem
  - the component being examined
- Failure Mode
  - the manner and conditions in which the component fails
- Failure Effect
  - the effect of the failure
- Risk Rating
  - the frequency of occurrence and consequences
- Notes
  - possible corrective actions

Sub-system	Failure Mode	Failure Effect	Consequence Index		Notes
			Freq.	Cons.	

Appendix 4.0 Example of an Index to Evaluate Countermeasures

Range of Counter-measure Preparedness	Example of Range of Possible Equipment Packages	Value
Good Countermeasure Preparation	• Contains all types of cleanup equipment and supplies including containment and recovery devices, hand tools, communication equipment, land and water transport vehicles, lighting plants, safety gear, pumps and hoses, beach cleaning equipment, and auxiliary equipment. • Equipment is readily available. • Equipment is well maintained and kept in clean, operable condition. • Ample supply of trained personnel familiar with equipment and operations. • Site-specific contingency plans are in place and regularly tested.	5
	• Contains most types of cleanup equipment and supplies. • Equipment is well maintained and kept in clean, operable condition. • Equipment must be transported for 30 minutes to spill site. • Ample supply of trained personnel familiar with equipment and operations. • Site-specific contingency plans are in place and regularly tested.	4
	• Provide response capability to minor spills. • Transport and manpower available within several hours. • Only general corporate contingency plans are in place. No site-specific plans are developed.	3
	• Provide response capability to minor spills. • Transport and manpower available within several hours. • Only general corporate contingency plans are in place. No site-specific plans are developed.	2
Poor Countermeasure Preparation	• Provide equipment for very small spills by manual means. • No contingency plans have been developed or tested.	1

Appendix 5.0 Examples of Checklists of Factors Affecting Probability of Oil Spills

Onshore Pipelines

Factors that Reduce the Probability of Spill	Yes =0 No =1
❑ Pipeline age <20 years old	
❑ Pipeline diameter <6 inches	
❑ Corrosion protection	
❑ Cathodic protection	
❑ Internal coating	
❑ External coating	
❑ Smart pig tests	
❑ Periodic right-of-way inspection	
❑ Periodic ultrasound tests	
❑ Low pressure	
❑ Stable surface geology	
❑ No leaks in past 3 years	
Probability Value	

Underground Tanks

Factors that Reduce the Probability of Spill	Yes =0 No =1
❑ Steel Tank <20 years old	
❑ Double-walled construction	
❑ Corrosion protection	
❑ Cathodic protection	
❑ Internal coating	
❑ External coating	
❑ Integrity tests	
❑ Volume balances	
❑ Warning signs in place at road crossings	
❑ Aboveground structures protected from vandalism and vehicle collision	
❑ No evidence of leaks	
❑ Not acidic product	
❑ Not constructed in acidic soil region	
Probability Value	

Onshore Pumping Wells

Factors that Reduce the Probability of Spill	Yes =0 No =1
❑ Adequate lubrication of stuffing box	
❑ Pressure switches not required	
❑ Regular inspection and replacement of the rattigan rubber	
❑ Vibration switches	
❑ Safety bolts	
❑ Bridle cables in place on the horse’s head (pumpjack wells)	
❑ Regular inspection of bridle cables for fraying	
❑ Built-in BOP capability (if necessary) on wellhead stuffing box	
❑ Open surface casing vents	
Probability Value	

Production Facilities

Factors that Reduce Probability of Spill	Yes =0 No =1
❑ Dikes of adequate size to contain volume of fluids within production tanks	
❑ Overflow tanks of adequate size and kept empty at all times	
❑ Integrity of the dike adequately maintained	
❑ Minimal volumes of chemicals on-site	
❑ Chemical pumps checked daily	
❑ "No-flow" controls on recycle pumps	
❑ Bull plugs or blank flanges on all open-ended pipes or dead-end valves	
❑ Facility transfer and production lines indicate flow direction	
❑ Packing drip leaks from recycle pumps are contained	
Probability Value	

Appendix 6.0 Example of a Checklist Used by Financial and Insurance Organizations

Factors that Increase Environmental Liabilities (Risk)	**Yes =0 No =1**
❑ Previous activities on company property limited to non-industrial activities	
❑ No evidence of landfills, dump pits, or sumps contained on-site	
❑ No use of hazardous chemicals present and used on-site	
❑ No use or equipment containing asbestos, PCBs, or radioactive substances	
❑ On-site inventory of hazardous substances	
❑ Periodic maintenance inspections, environmental audits, or environmental training programs performed	
❑ In place environmental policies and programs to eliminate or mitigate potential environmental impacts which might result from oil spill incidents	
❑ Underground tanks regularly tested	
❑ Operations prevent discharge of effluent to municipal systems or private drainage channels	
❑ Operations prevent discharge of effluent directly to streams, creeks, or rivers	
❑ No evidence of pits, ponds, lagoons, landfills or hazardous materials on adjacent properties	
❑ Company operations are free of previous violations or contravention notices of existing environmental or safety regulations?	
Risk Value	

Appendix 7.0 Example of a Vulnerability / Sensitivity Index

Shoreline / Bank Types (Comparable)

ESI	Coastal (Estuarine)	Lake (Lacustrine)	River (Riverine)
1	Exposed Vertical Cliffs/Walls	Exposed Vertical Cliffs/Walls	Exposed Vertical Banks/Walls
2	Exposed Wave-Cut Platforms	Shelving Bedrock Shores	Bedrock Ledges
3	Fine/Medium-Grained Sand Beaches	Unconsolidated Sediment Bluffs	Unconsolidated Sediment Banks
4	Coarse -Grained Sand Beaches	Sand Beaches	Sand Bars and Low-Slope Banks
5	Mixed Sand and Gravel Beaches	Mixed Sand and Gravel Beaches	Mixed Sand and Gravel Bars and Low Banks
6	Gravel Beaches and Riprap	Gravel Beaches and Riprap	Gravel Bars and Riprap
7	Exposed Tidal Flats	Exposed Flats	*No Riverine Equivalent*
8	Sheltered Rocky Shores and Seawalls	Sheltered Rocky Shores and Seawalls	Sheltered Steeply Sloping Bluffs
9	Sheltered Tidal Flats	Sheltered Vegetated Low Banks and Mud/Sand Flats	Vegetated Low Banks
10	Marshes, Swamps and Mangroves	Marshes, Swamps, Bogs, Fens	Marshes, Swamps, Oxbow Lakes

(From USEPA and NOAA 1994)

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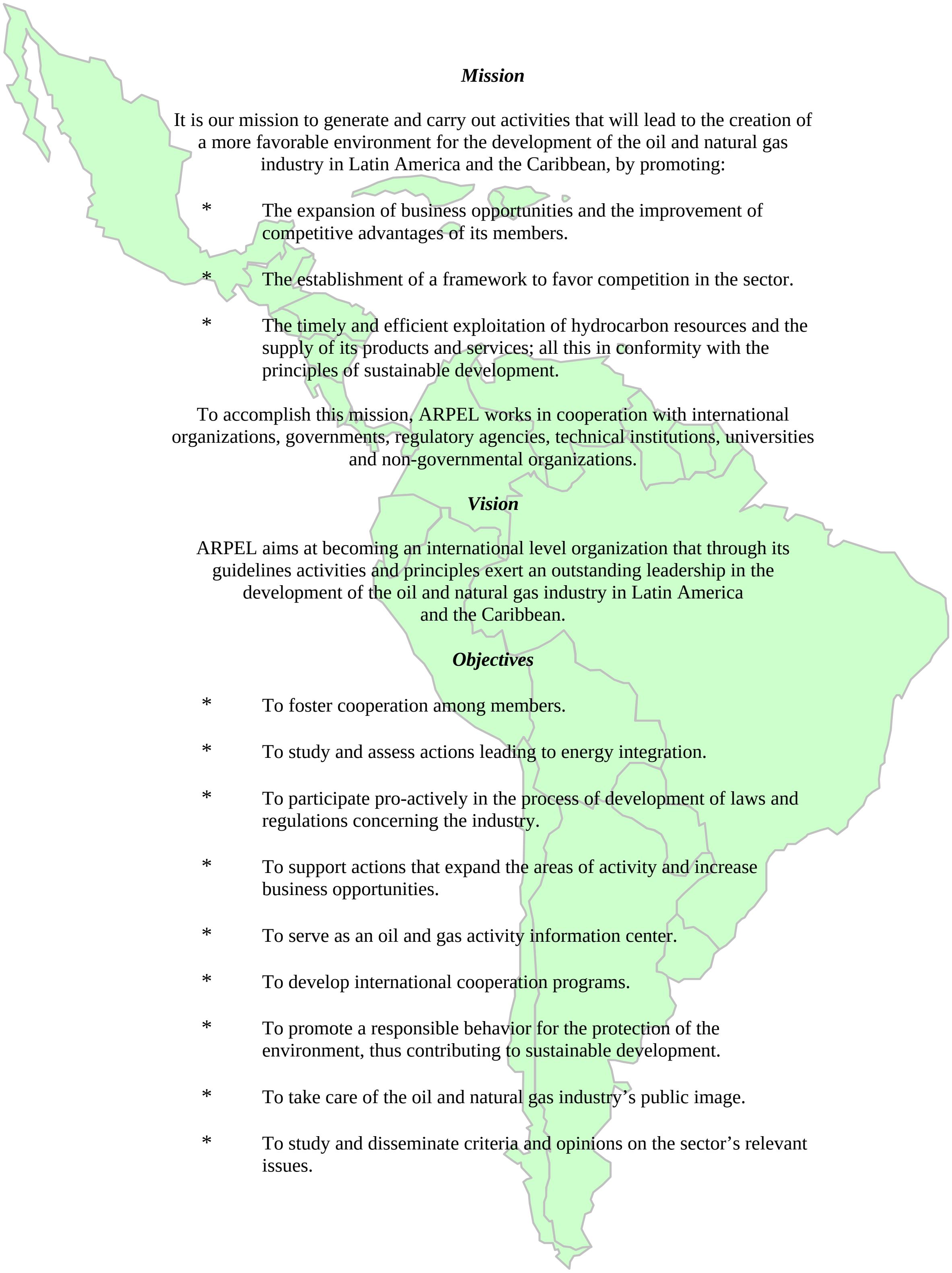

Mission

It is our mission to generate and carry out activities that will lead to the creation of a more favorable environment for the development of the oil and natural gas industry in Latin America and the Caribbean, by promoting:

* The expansion of business opportunities and the improvement of competitive advantages of its members.
* The establishment of a framework to favor competition in the sector.
* The timely and efficient exploitation of hydrocarbon resources and the supply of its products and services; all this in conformity with the principles of sustainable development.

To accomplish this mission, ARPEL works in cooperation with international organizations, governments, regulatory agencies, technical institutions, universities and non-governmental organizations.

Vision

ARPEL aims at becoming an international level organization that through its guidelines activities and principles exert an outstanding leadership in the development of the oil and natural gas industry in Latin America and the Caribbean.

Objectives

* To foster cooperation among members.
* To study and assess actions leading to energy integration.
* To participate pro-actively in the process of development of laws and regulations concerning the industry.
* To support actions that expand the areas of activity and increase business opportunities.
* To serve as an oil and gas activity information center.
* To develop international cooperation programs.
* To promote a responsible behavior for the protection of the environment, thus contributing to sustainable development.
* To take care of the oil and natural gas industry's public image.
* To study and disseminate criteria and opinions on the sector's relevant issues.

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