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MANAGING OIL SPILL RISKS OF TRANSNATIONAL ONSHORE PIPELINES

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Abstract

The management of oil spill risks of large transnational onshore pipelines is a huge and demanding task but one that is not impossible as shown by the examples of the BTC and Trans-Alaskan pipelines. Their trans-boundary nature poses significant challenges in terms of positioning of the infrastructure, the supporting logistics and the deployment of resources to combat accidental oil spills. This paper looks at industry best practices and presents a methodology and framework for managing oil spill risks by distilling lessons from industry and using the experience of ***Oil Spill Response*** in responding to inland oil spills from pipelines.

Introduction

Oil transportation by pipelines is generally considered to be the safest way of moving oil in bulk. The management of oil spill risks of large transnational onshore pipelines is a huge and demanding task. Their trans-boundary nature poses significant challenges in terms of positioning of the infrastructure, the supporting logistics and the deployment of resources to combat accidental oil spills. A compounding factor in ensuring the reliability and safety of these large infrastructures is its geopolitical importance in terms of energy security and not just trade. The BTC (Baku-Tblisi-Ceyhan) pipeline, which straddles three countries namely Azerbaijan, Georgia and Turkey, is a good example. From the first oil received in Ceyhan in mid-2006 to 1st November 2009, it has supplied 100.8million tons of Azeri crude.

Oil remains a preferred energy source and increasing demand for this resource translates to an increasing demand to transport them where they are needed safely, speedily and at the cheapest cost. It costs approximately 50 cents per barrel to move oil by pipelines over 1000km (Goodland 2005). In this regard, pipelines remain a cost-effective choice especially for transporting at long distances on land. Consequently, construction of these mega pipeline infrastructure projects will have immediate significant impacts on the environment in the event of a large release of hydrocarbons. It is necessary then that these projects be carefully assessed and managed to mitigate the adverse impacts of an oil spill incident.

The term ‘transnational’ is loosely used throughout this paper to mean a pipeline that traverses borders whether local, national or regional. So while the whole of the Trans-Alaska Pipeline System (TAPS) is in the United States (Alaska), the physical infrastructure spans a number of cities and communities. The term ‘oil’ as used in this paper refers to crude oil.

This paper looks at best practices and presents a methodology and framework for managing oil spill risks by distilling lessons from industry focusing on large infrastructure pipeline projects such as BTC and TAPS.

The Impact of Oil Spills

It is obvious to state that an oil spill, no matter how small, will have an immediate impact on the natural environment. The very nature of transnational pipelines passing through sensitive remote areas poses a big threat not just in terms of a spill but also explosions and catasthropic ruptures. It is not only sensitive areas that are major concerns but communities as well as some of these pipelines cross populated areas. In June 10, 1999 a pipeline rupture in a Bellingham, Washington park led to the release of 277,200gallons of gasoline which ignited, causing an explosion that killed two children and one adult.

The Prudhoe Bay oil spill (2006 Alaska Oil Spill) at a pipeline owned by BP Exploration Alaska (BPXA) is a classic example of the massive impact of such an incident even to a major oil company. Corossion caused a 0.25inch (0.64cm) hole on the 34inch (86cm) pipeline which released a total of 212,252gallons (5,053.6bbl) in March 2008 leaving bare 2-acres of land. The impact to BP was significant as it had to shut down most of the pipeline when it was discovered that 10km was badly corroded leading to losses in the hundreds of millions of dollars. The spill's impact was so severe to BP's public image that its share price slumped by 2%.

Even new pipelines are not immune to spills. The TAPS experienced several serious leaks. Two occurred soon after commissioning, one at a pump station that released 16,000gallons (516.13bbl) due to operator error and one following an act of sabotage (bomb) that released 600,000gallons (19,354.84bbl).

These examples show the importance of maintaining the reliability and safety of oil pipelines. Although this comes at a cost, a large spill incident will cost even more. Alyeska officials have been quoted as estimating environmental protection costs of the TAPS as being $2.8billion – it is assumed (although not specifically stated) that this includes the costs of the above ground supports and at least some of the inflation costs due to the Environmental Impact Assessment (EIA) delays (Sakhalin Energy Investment Co. Ltd.).

Key Elements of Oil Spill Prepareness and Response for Onshore Pipelines

In planning and determining the response strategies you'll be developing for onshore pipelines there are certain key elements that you need to prepare for. These are:

- **Risk Assessment** – a comprehensive risk assessment forms a solid scientific foundation for all aspects of your response plans. It gives an indication on where you can position your intervention measures and what equipment needs to be there to effectively manage a spill incident. An essential part of risk assessment is oil spill modeling and that means knowing the type of oil you are dealing.
- **Environmental Sensitivties –** these are the sensitivities in the area that may be potentially impacted in an oil spill. The risk assessment goes hand-in-hand with the environmental sensitivities to produce an environmental risk assessment (ERA). UNDP/ESMAP (2003) defines environmental risk a combination of the restitution time, defined as the time required for the natural resource environment to recover from the damage, and the probability that a rupture would occur in that environment.
- **Pipeline Response Strategy** – for very long pipelines that span a wide geographic area it is not possible or practical to place spill intervention measures for every kilometer or ten. Therefore it is essential that siting of response bases be optimized to respond in an efficient and timely manner.
- **Equipment types and Quantity** – the types and amount of equipment would depend on a number of factors, namely: oil type and how long it will take for additional resources to arrive on site after the initial response.
- **Stakeholder management –** this is an often overlooked critical element. A stakeholder is anyone who has an interest in the project and can influence or impact the success of a project. By understanding their motives and position, it becomes possible to influence, in a positive way, and to minimise or resolve issues which may have become a barrier to the success of the project.
- **Transboundary issues** – this is important to consider especially if a spill happens in close to international or local borders where there spill might impact the sensitive resources of neighboring countries or communities and where there might be differences in emergency response management practices. Mitigation involves a combination of liaison contacts, lines of reporting between regions or countries, estimates of the limits of transboundary contamination and the recognition of the need for rapid cooperation (Owens et al 2005).

Oil Spill Risk Management in Pipelines

The number of pipelines transporting oil worldwide is straggering and is set to increase. A joint study by UNDP (United Nations Development Programme) and the World Bank Energy Sector Management Assistance Program (ESMAP) states that in the near future, the world will need more cross-border oil and gas pipelines to bring remote reserves to market as reserves close to traditional markets are slowly being deplted. As such, it is critical to manage oil spill risks especially in major pipeline systems. In Western Europe alone the amount has grown from 12,800km carrying 310million m^3 in 1971 to 30,800km transporting 672million m^3 in 2000. Spill statistics collated for 30 years show that the frequency of spillages has improved from 1.2 per 1000km or pipeline per year to 0.25 per 1000km per pipeline per year (Concawe 2002).

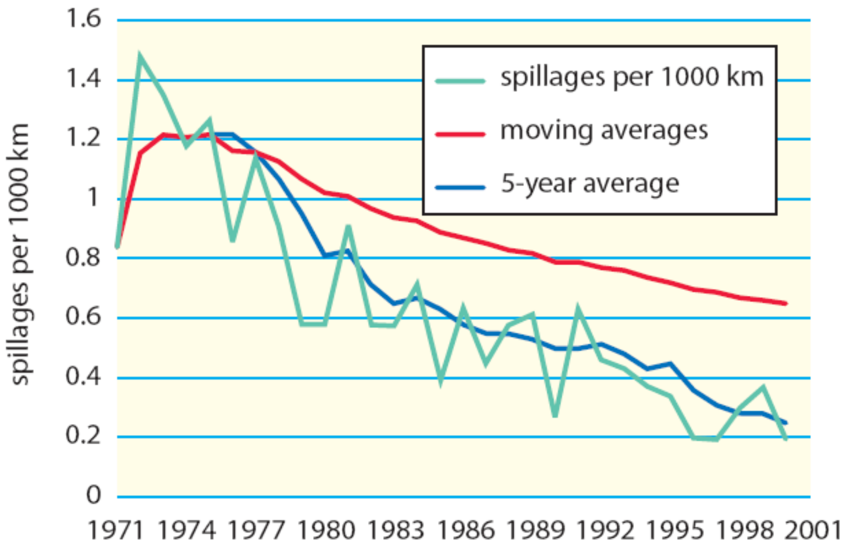


Figure 1 Pipeline Spillages from 1971-2001 (Concawe 2002)

According to Concawe report (2002), two most important causes of spillages are third party incidents and mechanical failure, with corrosion well back in third place and operational and natural hazards making minor contributions. Third party incidents such as vandalism remain a top problem, in spite of strict security measures, for pipeline operators in the Niger Delta region. In 1999 rupture incidents, 27 were due to natural causes such as wear and tear from corrosion while 497 were due to vandalization (Adebayo and Dada 2008).

Egan (1999) prescribes the risk management techniques for pipeline spill prevention and response:

1. What might go wrong? (Sometimes called a risk scenario)
2. What are the most likely locations for events leading to spills?
3. How often will it happen? (The likelihood or frequency)
4. What are the consequences? (costs for repair, environmental cleanup and restoration, fines and penalties and intangible costs associated with public image of the company)

The main point about risk assessment to remember is that it does not attempt to predict how many failures will happen in a project and where these failures will happen. Only in extreme cases can this be known. Risk management has always been practiced by pipeline operators and everytime a decision is made to spend resources in a certain way, a risk management decision has been made.

Risk Assessment

The risk assessment provides a systematic approach for the identification, management and reduction of the risk. It is a critical step in risk management. If done correctly, it determines the minimum level of preparedness in order to respond effectively. The generic process for risk assessments is presented in Figure 1.

Figure 2 The general process of a comprehensive risk assessment

The generic process above is fairly straightforward. A crude oil pipeline assessment would analyze the frequency and size of potential releases of crude oil from other pipelines of the same nature. Frequency is based on an examination of leakage rates in similar pipeline systems and the potential scale of problems modelled using well-established computer models. Lastly, the study identifies measures to reduce the potential for leakage and the strategies used to mitigate the effects of a spill incident. Selecting the data and variables to determine the risk profile requires the use of good judgement.

Stewart and Leschine (1986) write that the process of risk assessment always has an element of judgement. Judgement is required to select relevant information from a vast, but incomplete, resource of data about the past and to process that information in order to make an inference about future risk. They identify three general approaches to oil spill risk assessment: the intutitive approach, the empirical approach and the simulation approach:

- **Intuitive** - relies on gathering relevant information which is used as a basis for a judgement of oil spill risks by an expert or decision-makers.
- **Empirical** - a typical approach is to develop a model based on a large sample of data. For example, using pipeline data from the United States to deternine pipeline risk probabilities for a specific pipeline project elsewhere.
- **Simulation –** based on data, theory, technical expertise, general expertise attempt to simulate the most important features of the system, for example, used to produce oil or deliver it to ports and in the processing or transshipment facilities.

Other methods combine any two approaches or even all three. Either way the authors are saying that judgement is a fundamental element in all these approaches. Oftentimes, with limited information available a preliminary risk assessment is developed so as to have an initial picture for the project. Table 1 gives an example of a very simple preliminary risk assessment matrix.

Table 1 Preliminary risk assessment for an onshore pipeline project with a marine terminal

HAZARD	LOCATION	EVENT	FATE OF SPILLED OIL
Pipeline	Along pipeline route or the spurlines	Catastrophic failure.	Permeable Soil.
Pipeline	Along pipeline route or the spurlines	Catastrophic failure.	Water course (e.g. stream, river, dam).

HAZARD	LOCATION	EVENT	FATE OF SPILLED OIL
Pipeline	Along pipeline route or the spurlines	Small chronic leak.	Permeable Soil.
Pipeline	Along pipeline route or the spurlines	Small chronic leak.	Water course (e.g. stream, river).
Storage Tanks	Terminal	Catastrophic failure.	Bunded area
Storage Tanks	Terminal	Leak/hole/puncture	Bunded area
Subsea Pipeline	Marine Terminal/SPM	Catastrophic failure.	At sea (underwater)
Subsea Pipeline	Marine Terminal/SPM	Small chronic leak.	At sea (underwater)
Flexible risers	Marine Terminal/SPM	Catastrophic failure.	As sea (surface)
Flexible risers	Marine Terminal/SPM	Leak/puncture/tear	As sea (surface)
Road Tanker.	Road	Catastrophic failure.	Permeable Soil.
Road Tanker.	Road	Catastrophic failure.	Water course (e.g. stream, river).

If you notice, Table 1 does not have yet the rankings or probabilities for the risk scenarios. This is one of the characteristics of preliminary risk assessments. They are explorative in nature and is meant to be a general reference for the comprehensive risk assessment or a Qualitative Risk Assessment (QRA), whichever the organization decides to adopt, that will be done before the start of the actual project. For this specific project, these four headings (Hazard, Location, Event and Fate of Spilled Oil) were identified as the most important.

Why is the discussion on risk assessment so important?

Mainly because this forms a solid foundation for the mitigation measures and the oil spill response strategies that you will develop to effectively manage a spill incident anywhere on the length of the entire pipeline.

Environmental Sensitivities

The identification of environmental sensitivities along the route of the pipeline is an important element in planning for a response. Environmental sensitivity maps convey environmental and socio-economic data in a cartographic format so that information is represented in its respective geographic location. The area represented by sensitivity maps can range from an entire country's coastline to a small local area in the vicinity of an oil operation. Sensitivity maps are not confined to the coastal environment, but they can also cover inland sensitivities along a pipeline route or inland waterway. Sensitivity information can be displayed in two formats; hard paper copies as a single map or a series of maps, or electronically using Geographical Information Systems (GIS) as a tool.

Figure 3 Environmental sensitivities like mangroves and river crossing need to be identified

The identification of environmental sensitivities has been ongoing since the late 19070s and early 1980s after being developed by NOAA and often focusing on coastal areas (Underwood). The use of GIS as a tool for sensitivity mapping has greatly enhanced it as a planning tool. These maps provide the basis for decision-making during a spill response. GIS is now widely used for spill planning and response because they support integration and preparation of geospatial information on the location, nature and sensitivities of different resources with rapid access (Ivanov and Zatyagalova).

Simple and functional environmental sensitivity maps can also be made without the use of sophisticated tools such as GIS. Some operators have surveyed the entire length of the pipeline and identified sensitive resources using digital photography and a GPS (Global Positioning System). Small and simple GPS units can give the necessary accuracy for ESI mapping needs. The availability of instant geographic information on Google Earth facilitates the process even further.

Figure 4 Basic handheld GPS for mapping

Figure 5 A simple sensitivity map using Google Earth

Pipeline Response Strategy

Pipeline response strategy is inevitabley tied to the risk assessment and the environmental sensitivities along the pipeline route. So if these two elements are not developed properly then the whole oil spill response program will not be able to meet the requirements. Intimate knowledge of the oil and its fate and weathering when spilled are basic but critical information for the oil spill response planner. Because sometimes the oil type more than anything else dictates the response strategies to be developed. The Mangala pipeline from the Rajasthan onshore field is a good example.

Mangala crude is a highly viscous, waxy crude and is expected to form a solid gel at room temperature because of its high pour point. The key properties of the oil are listed in Table 2.

Table 2 Physical properties of Mangala crude

Appearance	Black/viscous
Density @ 60°F	0.8792g/ml
Specific Gravity @ 60°F	0.8801
API Gravity 60°F	29.28
Pour point	39 – 45°C
Flash Point	53°C
Wax Content	35.1% (Wt)
Asphaltenes	<0.50% (Wt)
Resin Content	20-30% (Wt)
Sulphur Content	0.081% (Wt)
Viscosity* @ 60°C	32.74cSt
Wax Appearance Temperature	65 °C

From the properties above, the oil is classified as belonging to Group 4[1] by virtue of its high pour point. Group 4 oils are very persistent due to their lack of volatile material and high viscosity, which inhibits both evaporation and dispersion (*ITOPF Handbook, 2008*). The oil contains low asphaltenes. The high resin content (typical oils less than 5%) stabilizes the asphaltenes but also aids the formation of stable emulsions. The WAT (Wax Appearance Temperature) or cloud point of 65 °C means that the oil needs to be constantly heated at 65 °C to prevent wax formation and clogging of the pipeline.

Since the oil is very waxy and has a high pour point, it will solidify in a matter of minutes once it is spilled on land – which means it will flow but within a limited range before it solidifies completely. Therefore, manual (for small operational spills) and mechanical recovery (for large spills) of the oil would be the main response. In a similar arrangement to the BTC response plan, the Mangala pipeline needs to pre-identify containment sites.

The Mangala pipeline crosses 22 major canals, 26 rivers and 26 drain channels and nala. To respond to an oil spill incident in any of these, containment sites along the pipeline route are pre-selected. In the event of an accidental discharge, response teams will be mobilised to different containment sites in order to protect key environmental areas and to minimise the distance that oil travels downstream. These are selected according to the following criteria:

- Access
  - Safety
  - In different weather conditions or seasons
- Stream flow
  - Speed
  - Likely movement of oil
- Lay down area
- Suitability for equipment deployment
- Travel times
  - Of leaked oil to site
  - Of response crew to site

For the BTC pipeline project, a significant amount of spill response planning was undertaken during the environmental impact analysis before construction, and continued throughout the construction phase (Gundlach et al 2005). Gundlach et al (2005) further expounds on the response strategy:

- A pre-construction kilometer-by-kilometer risk assessment of spill size and potential impacts taking into account ecological, cultural (archeological), groundwater and surface water resources along the pipeline
- Special Response Areas (SRAs), each having a detailed response plan due to the presence of ecological and/or groundwater resources and earthquake faults
- Sensitive resources along and downstream of the pipeline
- Identification of probable drainage slope (0.01 basis from topographic maps) for spilled oil from the pipeline, with each drainage area minimally having two pre-designated containment sites for oil spill control and recovery
- Development of a Containment Site Manual using a database format that identifies over 300 Containment Sites, road directions, environmental conditions, seasonal river/stream width, response equipment, downstream receptors, site photographs and location map

[1] Based on ITOPF (International Tanker Owners Pollution Federation) classification of oil according to their specific gravity. High pour point oils are treated as Group 4 and would only behave as Group 3 at high ambient temperatures well above their pour points (*ITOPF Handbook 2008).*

- 1:30,000 scale topographic maps indicating drainage flow from pipeline, Containment sites, environmental areas, SRAs, pipeline sensitivity, water bodies, Ecologically important areas (for plants), major river crossings and roads to each Containment site

The BTC pipeline response strategy is quite comprehensive and covers the whole length of the pipeline.

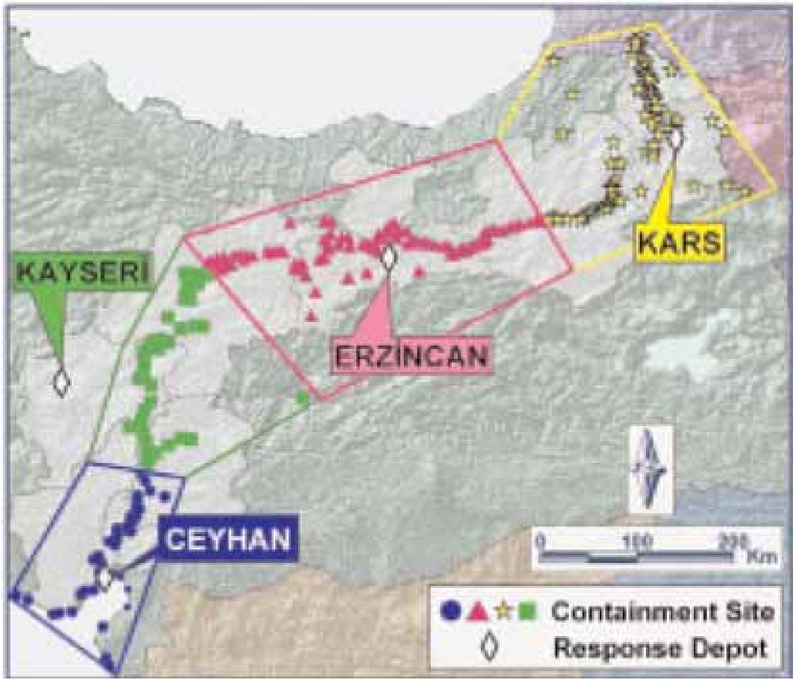


Figure 6 BTC pipeline's containment sites and response depots (Gundlach 2005)

Response Base and Oil Spill Equipment Guidelines

The guideline for equipment needs in an onshore pipeline is largely dependent on the pipeline response strategy. This is usually in the last part of an oil spill response program as all the risk assessments have been done and sensitivities mapped. The two main drivers of equipment selection are:

- **Oil type and operating environment** – the equipment must be suited to handle all type(s) of oil that will be handled by the pipeline and at the same time appropriate for the specific operating environments that may be encountered; and
- **Risk profile and Tier 1 requirement** – the risk profile would dictate the quantity of equipment stockpile needed for an effective Tier 1 response. This must be in conjunction with national legislation or standards for Tier 1 equipment. It is also important to note that National Oil Spill Plans or the specific country regulations may require specific types and number of equipment for particular type of operations. When Tier 2 and Tier 3 assistance is deemed not very accessible, then a larger Tier 1 stockpile may be required to maintain the initial response operations until Tier 2/3 resources arrive on site.

For Mangala crude, it is already known that the response strategy will be manual (for small operational spills) and mechanical recovery (for large spills). The recommended equipment for recovery of Mangala Crude spilled inland includes:

- Shovels and rakes
- Front-end loaders/backhoe
- Tipper/dump trucks
- Plastic pit liners
- 4x4 vehicles to access remote areas
- PPE (personnel protective equipment)

The bases can also be located close to or at the Terminal facilities (i.e. Radhanpur, Viramgam) or at the offtakes for these Terminals (i.e. Radhanpur Terminal, Salaya). The bases are will provide the primary response for Tier 1 spills and the initial response to Tier 2/3 response until further resources arrive to augment Tier 1 resources. The main advantage of locating these response bases here is that there is already an infrastructure available to be used as an equipment depot or staging point as well as personnel to operate and maintain the equipment.

The BTC pipeline response strategy operates much in the same way as four response depots are established along the pipeline route (see Figure 6) which contains the Tier 1 kits. An interesting feature on siting of these bases was that it was based primarily on guidelines of time, spill volume recovery and storage (Gundlach 2005):

- Less than 12hrs to deploy first response resources sufficient to remove 520 tons in 36hrs at each containment site
- Less the 24hrs for the full deployment of Tier 2 resources of 2986tons
- First response of <12hrs with a containment capability of 356tons
- Tier 2 response of <24hrs with a containment capability of 1450tons

Stakeholder Management

A stakeholder is anyone who has an interest in the project and can influence or impact the success of a project. By understanding their motives and position, it becomes possible to influence, in a positive way, and to minimise or resolve issues which may have become a barrier to the success of the project. Figure 4 depicts a simple stakeholder chart for a pipeline project. The different sizes of the boxes show the relative influence of the stakeholder to the overall oil spill planning and preparedness for the project.

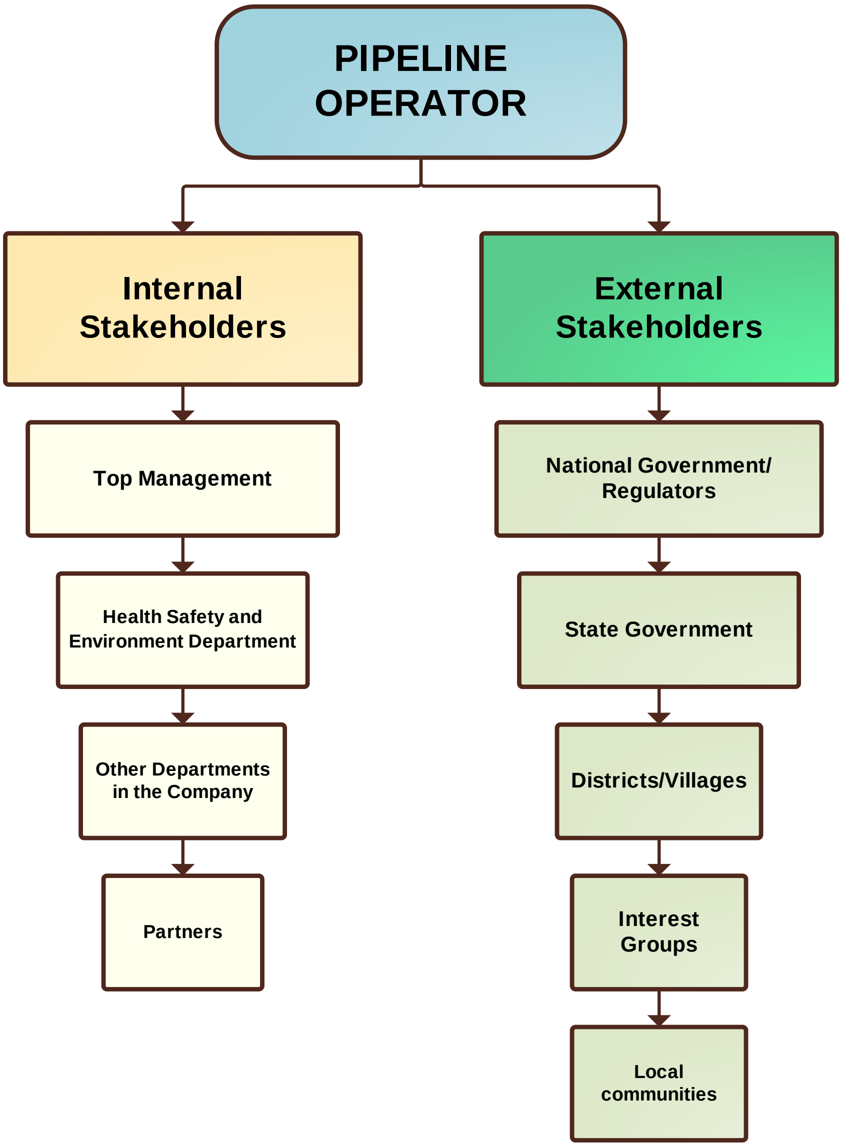
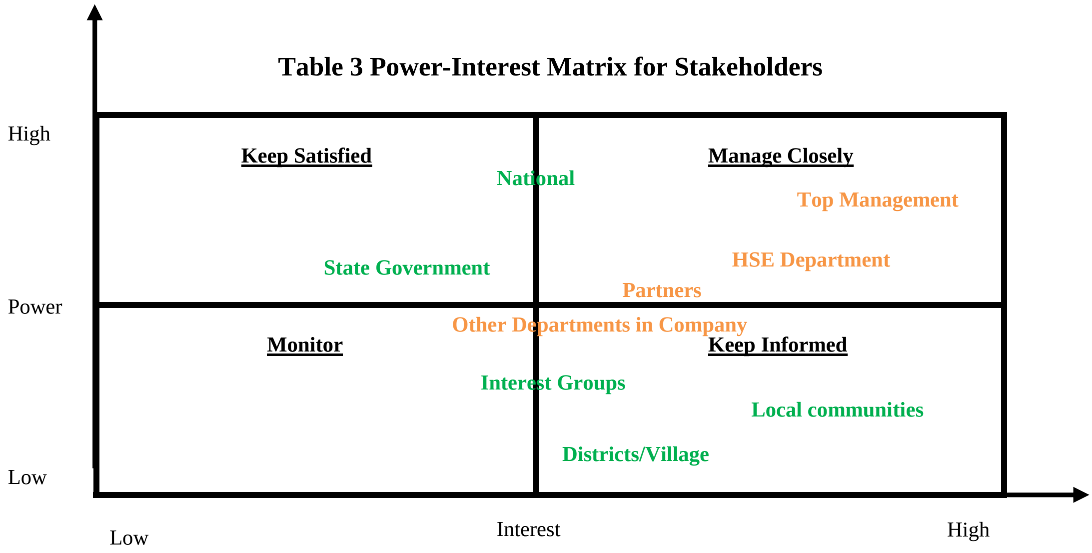


Figure 7 A simple stakeholder map of a pipeline operator

The stakeholders then need to be mapped in a power-interest grid (See Table 3) in order to develop a plan on how to deal or manage them. Stakeholder analysis is an important part of project management, especially for large undertakings where a lot of sectors might be involved.

Table 3 Power-Interest Matrix for Stakeholders



How to interpret the matrix:

- **High power, interested:** these are stakeholders you must fully engage with and make the greatest efforts to satisfy
- **High power, less interested:** put enough work to keep them satisfied
- **Low power, interested:** keep them adequately informed and communicate with them to ensure that no issues are arising
- **Low power, less interested:** monitor them

An important issue to manage is the perception of oil spill risk by the various stakeholders. There is an inclination for some to focus on large spills which in reality are rare. This results in an irrational fear and subsequently an unrealistic expectation that the company must have a large response capability at many locations. If not properly addressed, this can create friction or some resistance to the project.

Another possible issue is with regard to priority rankings of environmental resources in terms of oil spill response. Interest groups (i.e. environmental organisations) might view things differently.

Transboundary Issues

By its very nature, large transnational pipelines cross borders and with it bring transboundary issues especially if it straddles different countries like the BTC pipeline. One of the most important is the coordination of response when a spill is likely to cross international boundaries. As such, communications and emergency protocols need to be established and agreed between the two countries so there is a seamless transition from one response area in Country A to another in Country B. The oil spill response plans of all areas covered by the pipeline must be linked to each other with clear notification and reporting lines in the event of a transboundary spill.

Another critical issue is that of the importation of equipment from one country to another. Although in major emergencies, government agencies such as customs and immigration give special dispensation to emergency response equipment such as those used for oil spills. Nevertheless, a clear protocol on customs and immigration need to be included in the response plans to facilitate their entry into the country where the incident has occurred.

Tier 2 and Tier 3 arrangements need to be made in case of large incidents where the combined Tier 1 resources of the whole pipeline are overwhelmed. This facilitates easier access to personnel, equipment and logistics needed to sustain a prolonged cleanup campaign and also gives additional security to the pipeline operators and other stakeholders.

Figure 8 The BTC pipeline (blue) spans three countries – Azerbaijan, Georgia and Turkey (BIL)

Conclusion

It is clear that mitigating oil spill risks of transnational onshore pipelines is in the best interest of the public, the government authorities and the organization(s) operating the pipeline. The elements described here are the key elements and does not encompass all that maybe needed to fully mitigate against spill risks (i.e. Pipeline Integrity Management Systems including detection systems for spills). In summary, these are:

- **Risk Assessment** – a comprehensive risk assessment forms a solid scientific foundation for all aspects of your response plans.
- **Environmental Sensitivties** – these are the sensitivities in the area that may be potentially impacted in an oil spill. The risk assessment goes hand-in-hand with the environmental sensitivities to produce an environmental risk assessment (ERA).
- **Pipeline Response Strategy –** for very long pipelines that span a wide geographic area it is not possible or practical to place spill intervention measures for every kilometer or ten. Therefore it is essential that siting of response bases be optimized to respond in an efficient and timely manner.
- **Equipment types and Quantity –** the types and amount of equipment would depend on a number of factors, namely: oil type and how long it will take for additional resources to arrive on site after the initial response.
- **Stakeholder management –**By understanding their motives and position, it becomes possible to influence, in a positive way, and to minimise or resolve issues which may have become a barrier to the success of the project.
- **Transboundary issues** – this is important to consider especially if a spill happens in close to international or local borders where there spill might impact the sensitive resources of neighboring countries or communities and where there might be differences in emergency response management practices.

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