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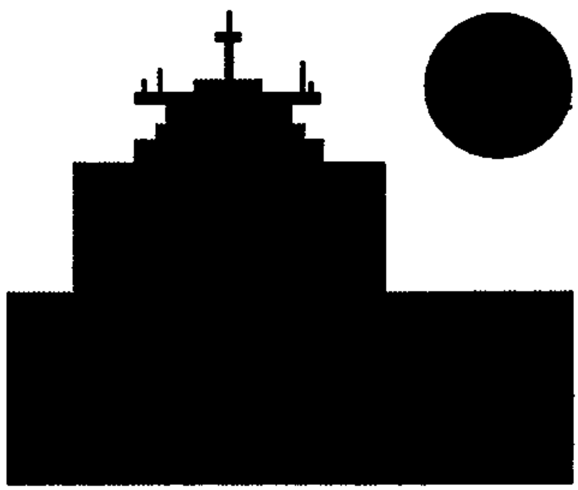
Human and Organizational Errors in Loading and Discharge Operations at Marine Terminals

SEA GRANT PROJECT R / OE 28



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1.0 INTRODUCTION

Human error in the marine industry has been an ongoing research activity at the University of California at Berkeley since 1990. Begun by Professor Robert G. Bea and then doctoral graduate student William Moore, the research looked at human error across the spectrum of the marine industry using examples from tanker operations to operations on offshore platforms. Accident data were gathered from sources world-wide, from which it was verified that human and organizational errors were the cause of roughly 64% of all accidents due to operations (Figure 1.1).

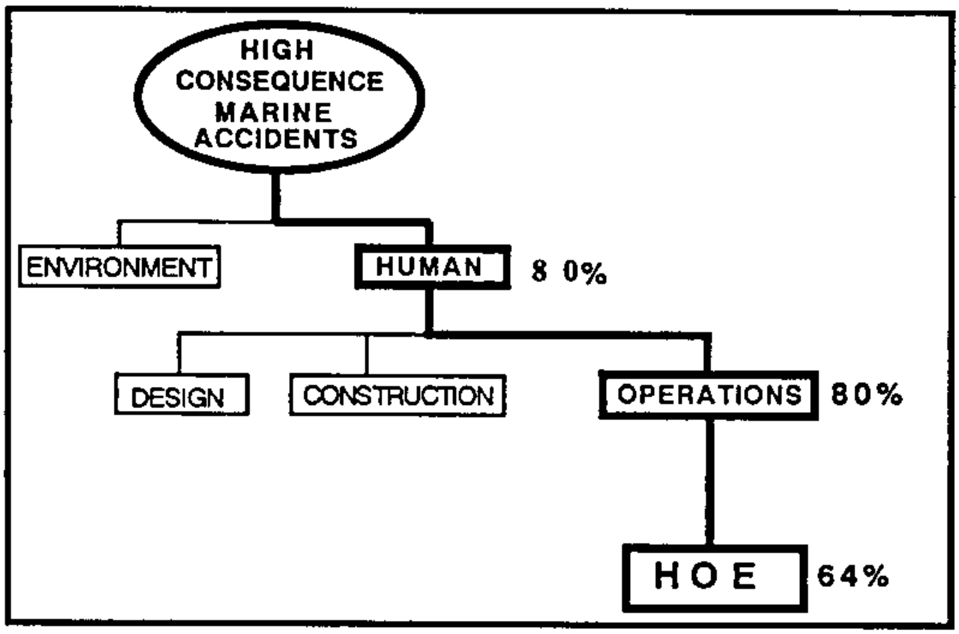

Figure 1.1: HOE in marine accidents.

The purpose of this project is to study the occurrence and then be able to minimize the likelihood of human error in one specific area of the marine industry: spills in California waters during tanker loading and discharging operations of petrochemicals at marine terminals. The paper describes tanker loading and discharge operations in general and the individual, system, environmental, organizational and procedural factors that go into increasing the probability of spill incidents.

The overall project involves developing qualitative and quantitative models that provide insights into spill accidents and allows one to evaluate improvements in various aspects of loading and discharge operations.

The need for this project arose through the Oil Pollution Act of 1990 (OPA 90) which suggested improvements in a variety of areas in the oil industry in the wake of the Exxon Valdez accident. Through a consortium of sponsors which included the U.S. Coast Guard, the California State Lands Commission, and Chevron Oil Company, the project proceeded into a study of wharf based loading and discharge operations (LDO) at Richmond, CA. Future studies will involve an investigation of a deep water terminal off El Segundo, CA, and how human and organizational errors enter the spill accident picture there.

Concurrent with the present study of the wharf based loading and discharge operation is the development of a database that will provide identification, archiving, analysis, and reporting of human and organizational errors of LDO for both the deep water and wharf based locations.

Crucial to the study of petrochemical transfer operations was the assistance of the California State Lands Commission through its Marine Facilities Inspection and Management Division. They enthusiastically provided important documentation as to terminal deficiency data, as well as rules and regulations concerning legal requirements for transfer operations. These rules and regulations were developed mostly as a result of the Exxon Valdez spill of 1989. These regulations, as well as ship and terminal procedures for safe and efficient transfer operations form the basis for the human error study since they represent the activities that must be adhered to in order to minimize the potential of a spill.

Terminal site visits provided invaluable information and insight into loading and discharge operations. Major sites visited were Chevron Richmond, CA, Shell Martinez, CA, ARCO Long Beach, CA, and MOBIL Long Beach, CA. Without these site visits, a clear understanding of transfer operations would not have been possible.

ACKNOWLEDGMENT

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2.0 THE ROLE OF HOE IN LDO OIL SPILLS

Because human and organizational error data has not historically been clearly defined and archived by the marine industry, a discussion on the role of these factors on oil spills during LDO can only be general at the present time. Currently under study, a proposed database management system will be completed in the near future as part of this project which will enable one to archive as well as manage this information in a useful manner for operators and regulators alike. Part of the current difficulty in HOE spill data involves the lack of clarity, thoroughness and consistency in describing specific spill incidents. A comprehensive evaluation of the current state of affairs with respect to the various methods of data archiving by different organizations, entitled *Marine Human and Organizational Error: A Database Evaluation* , has been completed and is an associated part of this project update. As a result of this evaluation, some specific insights can be gained in the role of HOE in oil spills at marine terminals in California.

For example, a Genwest Systems Inc. (Edmonds, WA) study conducted for Washington State of oil facilities and pipelines revealed that 43% of storage tank spill incidents were caused as a result of overfilling [Genwest, 1993]. Tank overfilling also happens to be a frequent contributor to spills during LDO at California marine terminals according to the California State Lands Commission and marine terminal operators. Though not specifically stated, we can assume that many of the spills due to overfilling in the Genwest study can be attributed to human and organizational error.

The U.S. government's Environmental Protection Agency, through it's Emergency Response Notification System (ERNS) fact sheet, has reported that "operator error" makes up 15% of all the causes of petroleum releases reported in California waters for the years 1987-1994 [EPA, 1994]. Equipment failure accounted for 27%. However, if equipment failure is the result of inadequate maintenance, for example, this cause could be classified as human and organizational error. Other causes mentioned are "unknown" and "transportation accident", both of which, if investigated thoroughly, may point toward human and organizational errors as well. Thus, if viewed appropriately, human and organizational errors would make up a much greater number of the total causes of spills in this ERNS fact sheet.

With respect to the total amount of oil products spilled in California waters due to LDO and HOE, a relatively clear picture can be drawn. For instance, a spill incident summary conducted by the U.S. Coast Guard shows transfer related pollution incidents to be about 19% of all the number of spill incidents recorded in the year 1989 (Table 2.1). California has seen almost one million gallons of oil products spill into her waters in the past six years (California State Lands Commission), LDO contributing not insignificantly to this total. On a world wide basis, Lloyd's [Gray, 1994] estimates the total tonnage of oil entering the sea due to terminal operations at 0.03 million for 1990, making the study of human and organizational errors in loading and discharge operations of significant importance.

Incident Type	% of Total
Transfer Discharge	19
Bilge Water Discharge	17
Vessel Sinking	12
Facility Discharge	17
Marina Discharges	7
Vessel Discharges	15
Crane Barge Discharges	7
Transportation Discharges	4
Other	2

Table 2.1: Discharge Violation Types.

3.0 DESCRIPTION OF HUMAN AND ORGANIZATIONAL ERRORS (HOE)

There are five major players involved in the cause of spills during transfer operations (Figure 3.1).

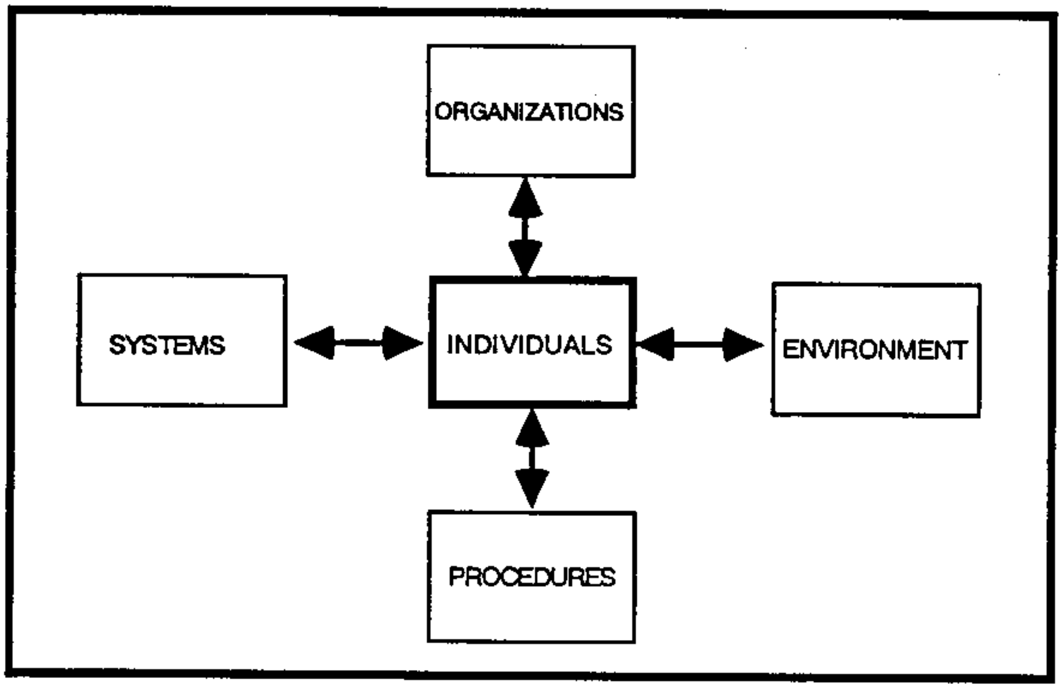

Figure 3.1: The major players in HOE.

At the core of the spill problem is the individual or teams of individuals, the front line operators of an engineered enterprise. These people in turn are related directly to the four other constituents that make up the human error problem: organizations (groups of individuals), systems (pipelines, valves, hoses, etc.), procedures, (the software or instructions on how responsibilities should be carried out), and physical environments (layout of work area, lighting conditions, extreme temperatures, rain, lightning, etc.). How and to what extent the individual relates to the four constituents is the issue behind the study of causes of human errors.

Individuals are the most complex to study because conditions of error proneness can arise as a result of a wide variety of human attributes and states [Reason, 1990]. The mental and physical state of an individual is considered an excellent indicator as to whether he or she will or will not commit even simple errors. These states are numerous, but the important ones we focus on in the operation of complex and high consequence activities include ignorance, drug abuse, laziness, wishful thinking, greed, folly, carelessness, boredom, bad judgment, poor training and fatigue [Moore, Bea, 1993; Reason,1990].

Table 3.1 shows an error taxonomy that identifies principal individual failures that can lead to LDO spills. Any of these conditions present in front line operators, solely or combined, serve to increase the chances of accidents in these operations.

TABLE 3.1: INDIVIDUAL ERROR CLASSIFICATION

Communication	*Ignorance*	*Slips*
Violations	*Planning*	*Mistakes*
Limitations		*Training*

External error prone conditions and states from organizations, procedures, systems and environments will inevitably make this undesirable condition worse.

As with individuals, a taxonomy has also been developed for the identification and study of error prone conditions in organizations, systems, environments and procedures [Moore, Bea, 1993; Reason, 1990] and these are shown below in Tables 3.2, 3.3, 3.4, and 3.5.

TABLE 3.2: ORGANIZATIONAL ERROR CLASSIFICATION

Communications	*Planning*	*Culture*
Structure	*Violations*	*Monitoring*
Ignorance		*Mistakes*

TABLE 3.3: SYSTEM ERROR CLASSIFICATION

Serviceability	*Durability*	*Compatibility*
Capacity		

TABLE 3.4: ENVIRONMENT ERROR CLASSIFICATION

Internal	*External*

TABLE 3.5: PROCEDURES ERROR CLASSIFICATION

Incorrect	*Incomplete*	*Inaccurate*
Complex	*Organization*	*Documentation*

For example, the corporate culture of an organization can instill an atmosphere of greed within the ranks through overtime pay incentives without consideration to the effects of operator fatigue due to unusually long work shifts. Corporate profit mindedness can also cause operators to work at rates that are above the norm, thereby increasing the likelihood of potential accidents. Aggressive management style, further, can cause an atmosphere of fear within the ranks, with the end result being employee resentment or disillusionment causing little company loyalty. For loading and discharge operations at marine terminals, all of these organizational conditions merely serve to increase the probability of the occurrence of spills.

Similarly, procedures that are supposed to get tasks done could be overly complex, incomplete, or worse, missing. Procedures are accomplished using skill-based, rule-based or knowledge-based frameworks [Rasmussen, 1986], and all three must be available to a certain degree to get a task done successfully. During a pumping procedure in a marine transfer operation for example, it does no good if the pump machinery instructions (rule-based) do not exist, the pump operator (skill-based) is out sick, and the terminal supervisor (knowledge-based) is at a safety meeting. Confusing rules, excessive skill demands, and limited knowledge of operations all increase the probability of spills.

Systems may suffer from a lack of redundancy, operability and ergonomics, and monitoring. Thankfully, many major marine terminals do operate under state-of-the-art computerized conditions which include back-up systems and early warning alarms, but many, especially the smaller operations, don't. Often systems suffer from close coupling where a problem in one area will inevitably cause a problem in another area. These conditions, along with severe demands, close tolerances, latent flaws and false alarms, characterize error prone marine systems which cause spills.

The physical environment of the transfer area can also invite accidents. Error inducing environments include poor lighting and ventilation, areas of extreme temperatures and a lack of shelter from wind or rain.

All of the conditions above serve to increase the probability of spills in loading and discharge operations. How to measure their impact is the subject of a later chapter.

4.0 DESCRIPTION OF LOADING AND DISCHARGE OPERATIONS (LDO)

A transfer operation at a marine terminal can be described as a seven step process (Figure 4.1). This process is described below.

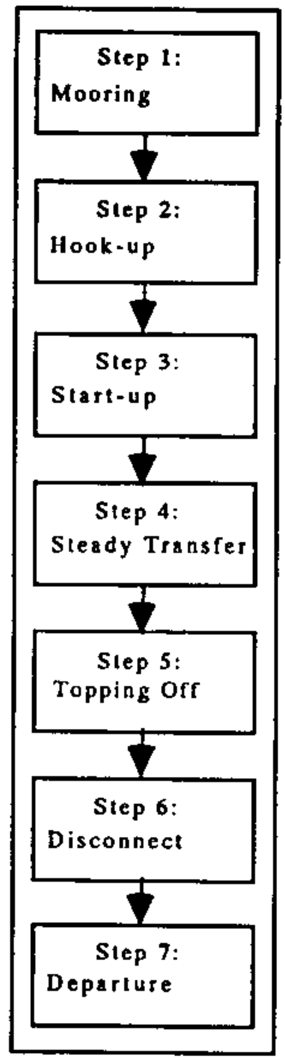

Figure 4.1: The 7 steps of LDO.

4.1 Step 1: Docking

Docking is the process of approaching and securing a ship to a terminal in a safe fashion. Tankers at shallow draft terminals displace 200,000 tons on the average and are assisted by tugs during the final stages of maneuvering near the terminal. Care must be taken to ensure a proper approach speed for these ships when pushed to the terminal by tugs since major damage can occur to either ship or terminal if it is moving too fast and a collision with a pier or wharf occurs. The orientation of the ship as it strikes the wharf is also critical. The ship should touch the wharf with its sides perfectly parallel to the face of the wharf in order to distribute the considerable contact forces.

Communications between the ship and tug captain is also very important. Usually the assisting tug is located seaward of the ship and thus has little or no visibility of the wharf/ship contact area. Therefore, he must rely on information relayed from the ship or the shore to adjust his push or pull on the ship so it's velocity does not exceed the docking maximum. Responses from the tug captain must be sure and immediate. Often the tug captain is slow to respond to ship/shore instructions. The tug captain must further know immediately when contact is made in order to back off since continuation at maximum thrust from the tug could rupture the side shell of the ship causing a spill.

Often the terminal is located in areas of high currents and this can make the process of moving such large vessels difficult and dangerous. Ship and tug captains must be able to anticipate the effects that currents may have on ship movement. Underestimating its magnitude or worse, overlooking its existence could cause the ship to strike the wharf unexpectedly, possibly damaging the wharf or puncturing the ship's side plating, again easily causing a major spill.

Once the ship is snugly against the wharf it must be secured. This is done by attaching steel or synthetic cable between the ship's bollards and the shore's bollards. Care during this process must be taken due to various reasons. First the tension must not be too tight or too loose since either can lead to damage to the ship or wharf during the course of the transfer. The tension on the cables must be continuously monitored because of the changes in draft as a result of the transfer and tide. Also, since docking cables are usually paired, mixed mooring cables (one steel, the other synthetic) to a single bollard should not be allowed because of the difference in elastic properties. Head, breast, and stern lines must all be employed to assure a secure docking. Experts at marine terminals have indicated that docking is considered to have a low probability of spill likelihood.

The individuals involved in a typical docking operation are:

- Ship Master
- Pilot
- First Mate
- Engine Room crew
- Ship line tenders
- Tug Captain(s)
- Tug Mates
- Wharf line tenders
- Wharf Master

In summary, the major spill-prone concerns during docking are:

1) Proper vessel approach speed.
2) Proper ship orientation when docking.
3) Excellent communications between ship/shore/tug.
4) Knowledge of environmental factors (current, wind).
5) No mixed docking cables (steel and synthetic together).
6) Monitoring of docking cables for proper tension.

4.2 Step 2: Hose Hook-up

Once the ship is safely docked, attention is turned to the commencement of the transfer operation. However, nothing is done before what is known as a Pre-Transfer Conference between authorized representatives of the ship and terminal is conducted. Appendix 5 describes the topics covered in the conference in detail. Essentially, the conference is a means of arriving at an understanding between the ship and shore representatives relative to the ensuing transfer operation. Cargo type, flow rates, communication signals, stoppages, emergency procedures and the like are topics covered.

Adherence to each of the topics enumerated is crucial to a successful and error-proof transfer operation. Once the understanding is reached and the accompanying Declaration of Inspection (DOI, Appendix 6) is signed, the transfer may begin, with the hook-up of hoses being the first step.

Hose hook-up can be defined as the act of mating the shore hoses with the ship intake/out-take manifolds. Two types of connections are made. The first is for the vapor recovery system and the second is for the cargo. The vapor recovery system (VRS) is crucial to safe transfer operations since cargo fumes accumulated in the ship tanks can explode given the presence of oxygen and an ignition source. Essentially the VRS completely dilutes or enriches the fumes beyond a flammable range thus creating a safe vapor environment in the tank. Vapor recovery systems can be either on the ship or on land.

Compromised hoses should never be used. Hoses (cargo and VRS) must be in good shape, have no kinks or holes, and not be frayed. The connection must be made with a bolt in every hole of the manifold and tightened to a specific torque. Gaskets that prevent leaks between the connections must also be in good condition, with no visible kinks or signs of deterioration.

Important to the prevention of spills during the hook-up phase is ensuring that spill catch basins are in place under the connections and that the cargo hoses have been properly drained after the previous transfer. If hoses have not been drained properly spills could easily occur when the end caps of these hoses are disconnected prior to attachment to the ship manifolds. The spill can go directly into the water if the catch basin is not immediately beneath the hose or is of an insufficient size to hold the spill volume.

Operator fatigue is also an important consideration during hook-up vis-a-vis the prevention of spills. This is so because the ship personnel are usually tired due to the constant vigilance of navigation and the extensive ship preparations that are conducted before entering port, as well as simply having been at sea for an extended period of time. Time is money and no time is wasted between entering port, docking, and hooking-up. The hooking-up procedure, crucial to the success of the initial stages of transfer, must therefore be done with extra vigilance.

Complacency in completing the Declaration of Inspection (DOI) checklist, part of the pre-transfer conference is cited as a source of errors, and this too can probably be traced back to personnel fatigue.

Marine terminal experts indicate that hook-up is also considered to have a low probability of spill likelihood. However, care must be exercised when removing the hose cap if there is any cargo residue present in the hose from the previous transfer.

The individuals involved in a typical hook-up operation are:

- Wharf hose handlers
- Wharf chickstand operator
- Ship hose handlers

In summary, the major spill-prone concerns during hook-up are:

1) Ensure that Pre Transfer Conference and DOI are conducted.
2) Vapor Recovery System hose is properly connected.
3) Vapor Recovery System checked and operating properly.
4) Cargo hose is not compromised.
5) Hose gaskets not compromised.
6) Cargo hose/manifold bolts placed in every hole.
7) Proper torque is applied to each bolt.
8) Catch basin in place under each connection.
9) Awareness of operator fatigue.
10) Good communications between ship/shore.

4.3 Step 3: Flow Start-Up

This step in the transfer process concerns itself with the initial stages of fluid pumping. Communication between ship and shore is crucial during this step since a premature start could send flow through the wrong pipe, into the wrong tank, or directly into the water. Initial flow rates should always be low, and this rate will have been discussed during the pre-transfer conference.

All valves in a dedicated pipeline must be opened during pumping or allowable pipe pressures could be exceeded, perhaps causing them to burst. The valve closest to the source tank is the last one opened. During discharge, this valve is on the ship, and during loading, this valve is next to the shore tank.

When the go-ahead is given, the last valve is opened, the pumps turned on, and the flow rate is set to a minimum. At this point checks are conducted to ensure that the flow is indeed going to the correct place and that no leaks are occurring in any of the pipes or at any connections, such as at the ship manifold connection. Once the integrity of the flow has been verified and no leaks discovered, orders are given to increase the flow to the maximum agreed upon.

During start up, it is usually necessary to also check the chick stand hose support, especially when the flow rate is at its maximum. This is because the cyclic motion of the pumps can be transferred to the hose at this point causing it to move in a swinging motion. This motion must be restrained so that a tear in the hose would not be possible.

Marine experts indicate that start-up is considered to have a moderate probability of spill likelihood. This is so because this is the first step where a considerable volume of cargo is actually beginning to move. It is also considered moderate because since the initial flow is at a minimum, an immediate and safe flow shut-down is possible if any problems are noticed. No complacency during this step is tolerable.

The individuals involved in a typical flow start-up operation are:

- Shore pump man (loading)
- Ship pump man (discharge)
- Deck officer
- Deck hands
- Ship mates

- Wharf personnel

In summary, the major spill-prone concerns during flow start-up are:

1) Excellent communications between ship/shore.
2) Hose properly supported.
3) Proper valve opening sequence.
4) Slow initial flow rate.
5) Potential leak sites checked.
6) Flow route verified.
7) Pipeline pressures monitored.

4.4 Step 4: Steady Transfer

Once start-up has commenced, and it has been verified that no leaks are present and that the cargo is going where it is supposed to, orders can be given to slowly increase the flow rate to the maximum. Barring any unexpected mishaps, the maximum flow rate is continued for the duration of the transfer. This step, steady transfer, takes the longest time of all steps in the transfer process and involves the hourly checking of leaks, tank soundings, flow volume calculations, and the general proper operation of the entire system. Duration of this process is on the order of tens of hours.

Anticipation is a key attribute of the operators during this step since they are constantly vigilant for any signs of change in their monitoring instruments. Also, since the flow rate is so high (400 bbl/min.) operators must anticipate slow-downs and stoppages. Slow-downs and stoppages can arise as a result of the sudden occurrence of bad weather (lightning in the vicinity), system breakdowns, or simply arriving near the end of the transfer process. Stoppages must not be so sudden and immediate that the back pressure caused by shutting valves under high velocity flow would cause them or the pipes to fail.

Throughout the steady transfer process, operators must also be vigilant as to vessel movements. Environmental factors such as winds and waves could so violently move a ship that the shore hose connections would part. Since the flow is at its maximum during this step, a significant spill would result. Movements due to changes of draft as a result of the transfer must also be taken into account during this stage. This means the mooring lines must be adjusted accordingly.

Since the start-up stage should have verified that the flow can proceed without mishap, and since violent ship motions due to environmental conditions are rare, steady-state transfer is considered to have a low probability of spill likelihood, according to terminal experts.

The individuals involved in a typical steady transfer operation are:

- Shore pump man (loading)
- Ship pump man (discharge)
- Deck hands
- Watch officers
- Wharf personnel

In summary, the major spill-prone concerns during steady transfer are:

1) Hourly checks for leaks, tank soundings.
2) Anticipation for flow slow-downs, stoppages.
3) Vessel movement awareness.
4) Excellent communication between ship/shore.
5) Vigilance maintained throughout process.

4.5 Step 5: Topping Off

With the flow rate and tank sizes known, one can anticipate when the tanks will become full. When this time arrives, the flow rate is reduced to a predetermined amount and the process of topping off of the tanks is begun. Topping off occurs usually in the last 1.5 hours of the transfer and the operation is similar to that of start-up, except opposite. Since there are multiple tanks on a ship or on shore, the tanks are filled in a staggered manner.

When topping off, allowance should be made for cargo expansion resulting from an increase in temperature. The temperature of the cargo will closely approximate the sea temperature encountered. In general, oil and ballast tanks must be topped off so that the liquid level is at least 2 feet below the deck level at the expansion trunk, though different vessels have different requirements. Vessels should not fill individual cargo or bunker tanks to over 98% capacity.

Visual inspections of tanks or gauges is necessary in order to see the level of cargo in each tank. The pump man must rely on the person viewing the tank or gauges in order to know when to completely shut off the pumps. This third-party reliance at such a critical stage often leads to spills.

In topping-off tanks, the vessel officer-in-charge must take every precaution to prevent an overflow, reducing the flow rate or number of tanks being loaded as necessary. Close communication must be maintained with terminal personnel. Shore personnel must be given sufficient notice to ensure proper control of terminal valves and pumps. During topping-off, the officer-in-charge must personally supervise the operation.

Topping off is considered to be the process with the highest risk in terms of spill potential. This is so because of the small margin of safety due to the ever decreasing reservoir. If the flow rate is even moderate, and the tank volume filled to capacity, overflow is the result. Inadvertent closing or opening of wrong valves during fill-up of staggered tanks may also lead to spills.

The individuals involved in a typical topping off operation are:

- Shore pump man (loading)
- Ship pump man (discharge)
- Deck hands
- Watch officers
- Wharf personnel

In summary, the major spill-prone concerns during topping off are:

1) Topping off initiation time must be well anticipated.
2) Visual inspection of tanks/gauges must be conducted.
3) Vigilance throughout process maintained.
4) Proper valve closing sequence. If loading, shore must shut their valve first. If discharging, ship must shut their valve first.
5) Excellent communication between ship/shore maintained.
6) Vessel movement awareness maintained.
7) Butterworth plates, tank tops, manifold blanks and ullage plugs should be secured and the gaskets fitted as required for protection against entry of sea.

4.6 Step 6: Disconnect

This process involves removing the bolts connecting the shore hoses and the ship manifolds, purging the hoses with air or inert gas to clear it of excess product, and capping both the hoses and the manifolds.

The first step is to slowly untighten the bottom bolts connecting the hose to the manifold. Slow loosening of the bolts is important. This is done to allow any residue remaining in the hose to slowly ooze out and drip in the catch basin if it must. Once this is done all other bolts can then be removed. The slow removal of the bolts will also tell the operator if undue pressure still exists in the hose or if the pumps are still operating. If so, and product is leaking badly, he can tighten the bolts and investigate the problem. Compared to the previous steps, the operator sees directly if product is spilling or not and thus has complete control over its occurrence.

Once all bolts are removed, the hose must be cleared of product for use in the next transfer. This step also allows for error since if the u-shaped hose becomes inverted, product will readily spill. Once safe disconnection is complete, and the hose cleared of any remaining residue, the chickstand (loading arm) operator can swing the hose away from the ship.

The disconnection step is seen as moderate in terms of spill probability due to the residue that may remain in the hose. The risk magnitude is similar to the hook-up stage.

The individuals involved in a disconnect operation are:

- Shore pump man (loading)
- Ship pump man (discharge)
- Deck hands
- Wharf chickstand operator

In summary, the major spill-prone concerns during disconnection are:

1) Proper bolt untighteting sequence.
2) Residual hose product must be purged properly.

4.7 Step 7: Departure

Once the transfer is terminated and all aspects of the ship's business are complete, it's time for the ship to leave the terminal. Environmental conditions similar to the ones encountered during docking must be made aware of. Wind, waves and currents are the major factors here. Generally, it is easiest to depart if the bow is pointing in the right direction for voyaging. The assistance of tugs is always utilized, as in docking.

The draft of the vessel must be known, as well as the depth of the water. During the course of the transfer, the depth of water certainly will have changed due to the tides, and there must always be at least a two foot clearance between the bottom plating of the ship and the bottom surface.

Like docking, departure poses a minimum spill risk since it involves so many well-trained and licensed personnel such as the ship and tug captains, though care must still be exercised that a full ship is not pushed inadvertently against the wharf and holed.

Departure is considered to have a low probability of spill likelihood.

The individuals involved in a typical departure operation are:

- Ship Master
- Pilot
- First Mate
- Engine Room crew
- Ship line tenders
- Tug Captain(s)
- Tug Mates
- Wharf line tenders
- Wharf Master

In summary, the major spill-prone concerns during departure are:

1) Proper vessel departure speed.
2) Proper ship orientation when departing.
3) Excellent communications between ship/shore/tug.
4) Awareness of environmental factors (current, wind, waves).

4.8 Summary of principal hazards that can lead to spills during LDO:

Docking:

1) Proper vessel approach speed.
2) Proper ship orientation when docking.
3) Excellent communications between ship/shore/tug.
4) Knowledge of environmental factors (current, wind, waves).
5) No mixed docking cables (steel and synthetic together).
6) Monitoring of docking cables for proper tension.

Hook-up:

1) Ensure that Pre Transfer Conference and DOI are conducted.
2) Vapor Recovery System hose is properly connected.
3) Vapor Recovery System checked and operating properly.
4) Cargo hose is not compromised.
5) Hose gaskets not compromised.
6) Cargo hose/manifold bolts placed in every hole.
7) Proper torque is applied to each bolt.
8) Catch basin in place under each connection.
9) Awareness of operator fatigue.
10) Good communications between ship/shore.

Start-up:

1) Excellent communications between ship/shore.
2) Hose properly supported.
3) Proper valve opening sequence.
4) Slow initial flow rate.
5) Potential leak sites checked.
6) Flow route verified.
7) Pipeline pressures monitored.

Steady transfer:

1) Hourly checks for leaks, tank soundings.
2) Anticipation of flow slow-downs, stoppages.
3) Vessel movement awareness.
4) Excellent communication between ship/shore.
5) Vigilance maintained throughout process.

Topping off:

1) Topping off initiation time must be well anticipated.
2) Visual inspection of tanks/gauges must be conducted.
3) Vigilance throughout process maintained.
4) Proper valve closing sequence. If loading, shore must shut their valve first. If discharging, ship must shut their valve first.
5) Excellent communication between ship/shore maintained.

6) Vessel movement awareness maintained.

7) Butterworth plates, tank tops, manifold blanks and ullage plugs should be secured and the gaskets fitted as required for protection against entry of sea.

Disconnect:

1) Proper bolt untighteting sequence.

2) Residual hose product must be purged properly.

Departure:

1) Proper vessel departure speed.

2) Proper ship orientation when departing.

3) Excellent communications between ship/shore/tug.

4) Knowledge of environmental factors (current, wind, waves).

5.0 MODEL DEVELOPMENT TO CHARACTERIZE OPERATIONAL SPILL PROBABILITY.

Developing a model to measure operational spill probability can be accomplished by following the steps outlined below. The outline combines features of Probability Risk Analysis (PRA) [Reason, 1990] and Human Reliability Analysis (HRA) [Swain & Guttman, 1983] techniques. The steps involved are:

1. Create a system and process analysis of the operation.

2. Identify potential hazards of interest to study or minimize. (In the case of LDO, the hazard we are looking at is an oil spill.).

3. Identify contributing, initial, and compounding events that could lead to this hazard.

4. Establish the possible sequences that could give rise to these events incorporating HOE using event trees and influence diagrams.

5. Use expert judgment to quantify each event sequence from the event trees and influence diagrams.

6. Determine the overall spill risk by aggregating over all possible spill sequences.

The statistical technique used borrows from the development of THERP (Technique for Human Error Rate Prediction) [Swain & Guttmann, 1983]. The basic assumption behind this development is that human actions and error proneness can be evaluated as easily as machine parts. The objective of this model is to

> "predict human error probabilities and to evaluate the degradation of a man-machine system likely to be caused by human errors in

connection with equipment functioning, operational procedures and practices, or other system and human characteristics that influence system behavior."

5.1 QUALITATIVE METHODOLOGY

The qualitative evaluation of HOE in LDO involves the completion of the first four steps outlined above. Underlying the entire process is a reasonably detailed and realistic understanding of a loading and discharge operation. The first step in achieving this understanding is a system and process analysis of the loading and discharge operation.

5.1.1 SYSTEM ANALYSIS:

A system analysis is simply an accounting of all of the major systems and elements of a particular operation. A system analysis identifies not only all the major hardware that goes onto LDO, but also those components which contribute directly to spills, such as the importance of proper gaskets or connecting the transfer hoses with a bolt in every hole. The system analysis was thus compiled for the major hardware elements involved in a transfer operation and a reasonable detailed list appears below. A layout of a typical wharf indicating the major systems and elements is shown in Figures 5.1 and 5.2. Table 5.1 lists the primary components that comprise an LDO system.

To become familiar with the various systems involved with a transfer operation, visits to various marine terminals and interviews with personnel were arranged. Appendix 1 lists the terminals visited and the personnel interviewed. These visits and interviews provided first hand insights into transfer operations as well as with collateral material such as inspection checklists, operation guidelines, and other reports applicable to transfer operations. Appendix 4, for example, details a terminal Declaration of Inspection (DOI) checklist which is filled out after ship arrival and prior to any product flow from which much information can be extracted regarding a safe loading and discharge operation.

TYPICAL LDO SYSTEM LAYOUT

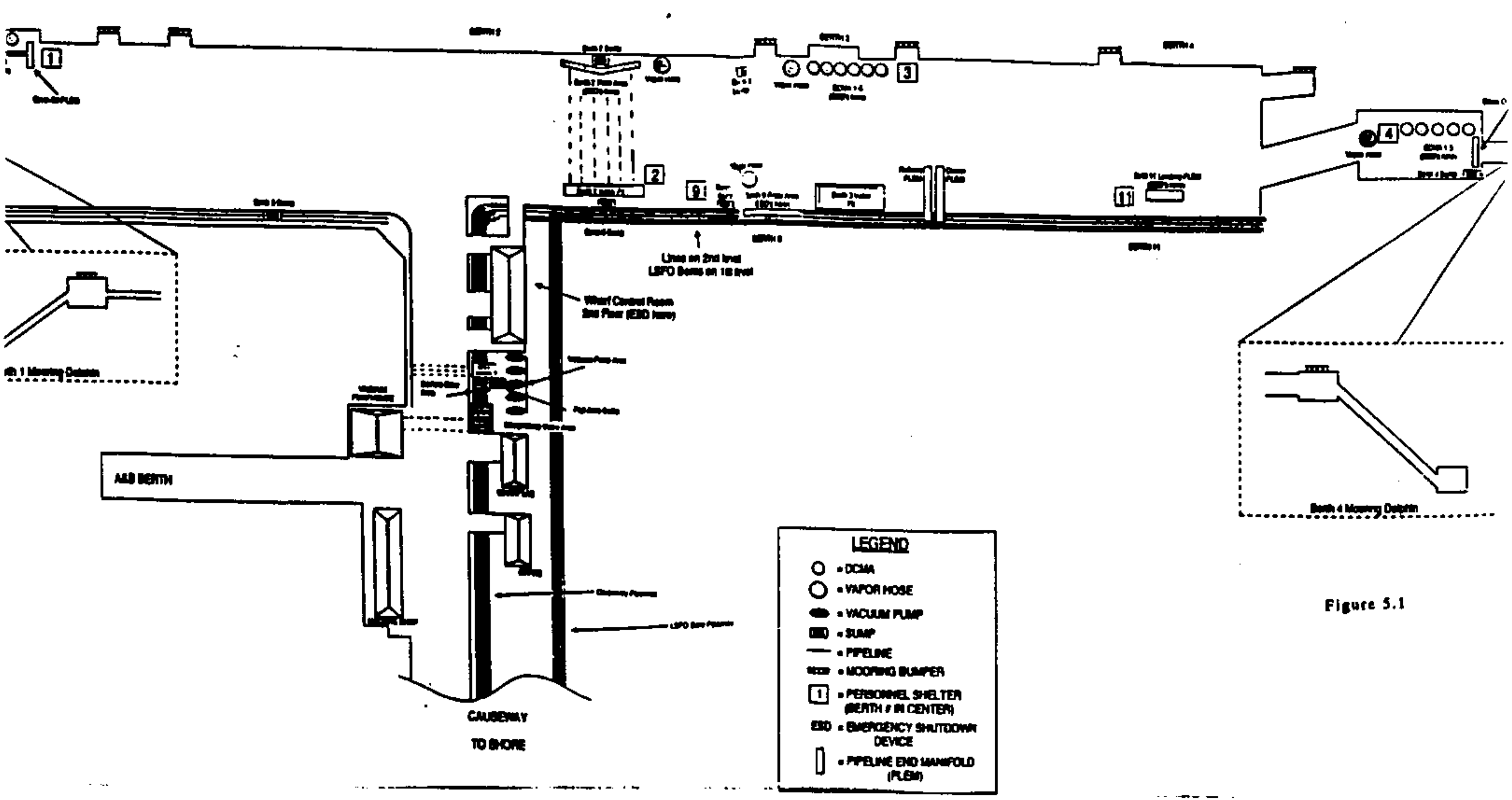

Figure 5.1

TYPICAL LDO WHARF BERTHING LAYOUT

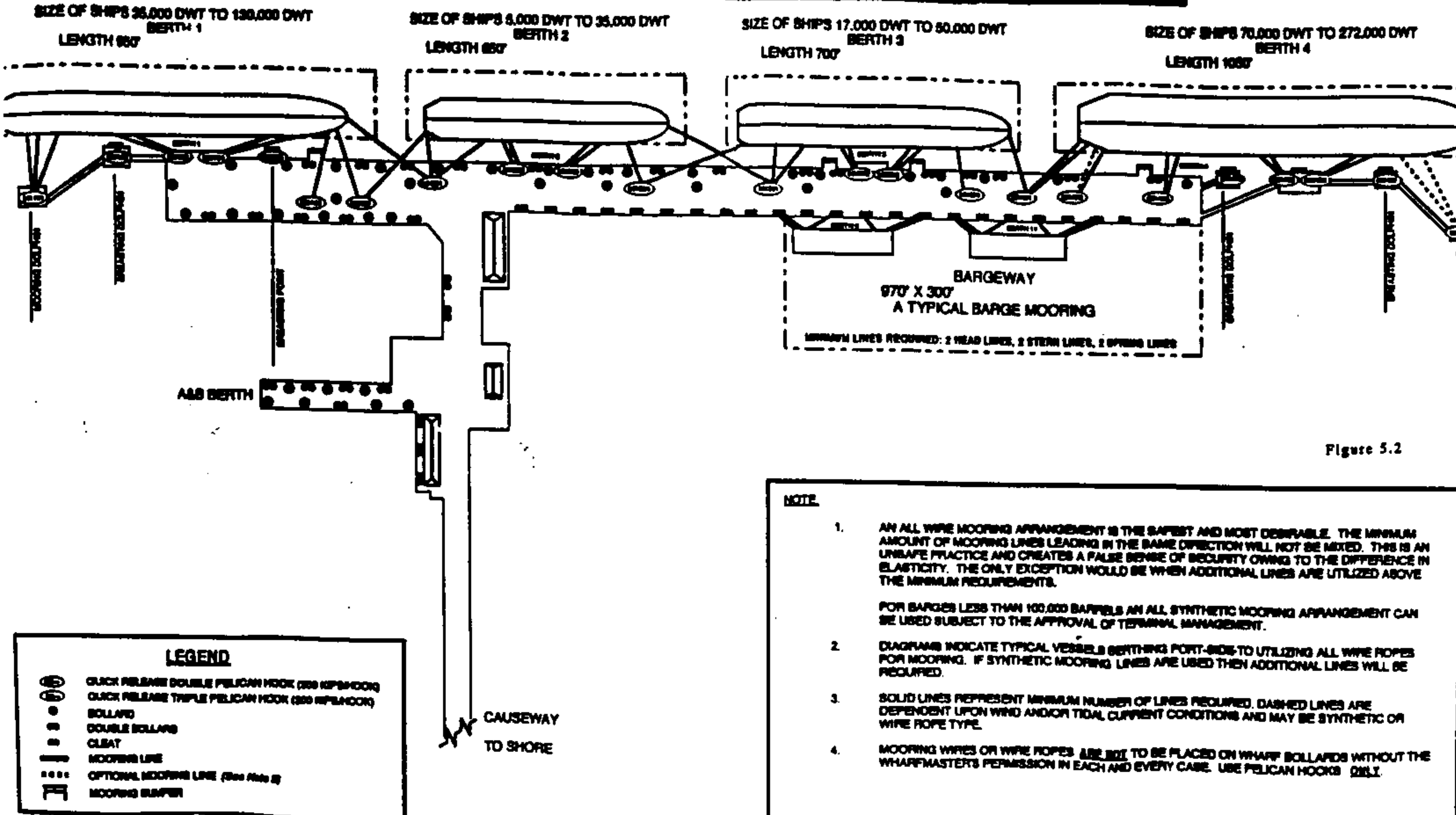

Figure 5.2

NOTE:

1. AN ALL WIRE MOORING ARRANGEMENT IS THE SAFEST AND MOST DESIRABLE. THE MINIMUM AMOUNT OF MOORING LINES LEADING IN THE SAME DIRECTION WILL NOT BE MIXED. THIS IS AN UNSAFE PRACTICE AND CREATES A FALSE SENSE OF SECURITY OWING TO THE DIFFERENCE IN ELASTICITY. THE ONLY EXCEPTION WOULD BE WHEN ADDITIONAL LINES ARE UTILIZED ABOVE THE MINIMUM REQUIREMENTS.

   FOR BARGES LESS THAN 100,000 BARRELS AN ALL SYNTHETIC MOORING ARRANGEMENT CAN BE USED SUBJECT TO THE APPROVAL OF TERMINAL MANAGEMENT.

2. DIAGRAMS INDICATE TYPICAL VESSELS BERTHING PORT-SIDE-TO UTILIZING ALL WIRE ROPES FOR MOORING. IF SYNTHETIC MOORING LINES ARE USED THEN ADDITIONAL LINES WILL BE REQUIRED.

3. SOLID LINES REPRESENT MINIMUM NUMBER OF LINES REQUIRED. DASHED LINES ARE DEPENDENT UPON WIND AND/OR TIDAL CURRENT CONDITIONS AND MAY BE SYNTHETIC OR WIRE ROPE TYPE.

4. MOORING WIRES OR WIRE ROPES <u>ARE NOT</u> TO BE PLACED ON WHARF BOLLARDS WITHOUT THE WHARFMASTER'S PERMISSION IN EACH AND EVERY CASE. USE PELICAN HOOKS <u>ONLY</u>.

Similarly, Appendix 3 shows a typical vessel Pre-Transfer Agreement, detailing other factors involved in performing safe loading or discharge procedures.

TABLE 5.1: SYSTEM COMPONENTS FOR LDO:

Mooring System:

- Quick release double pelican hooks
- Quick release triple pelican hooks
- Bollards
- Double bollards
- Cleats
- Spring lines
- Breast lines
- Mooring bumpers
- Tug support
- Emergency tow wires
- Mooring dolphins
- Breasting dolphins

Hose/Pipeline System:

- Causeway pipelines
- Hose risers/chickstands
- Straightaway valves
- Hose gaskets
- Sumps
- Connection manifolds
- Pipeline end manifolds
- Manifold bolts and tightening devices
- Valve pits
- Drains and scuppers
- Containment wells
- Emergency shut down devices

Pump System:

- Vacuum Pumps
- Sumps
- Backflow valves
- Pressure gauges

Containment System:

- Ship boom
- Riser containment wells
- Manifold containment wells
- Valve pit containment wells

Communication Systems:

- Ship/shore main communications
- Ship/shore alternate communications
- Ship/shore portable communications

Safety System:

- Flame arresters/fire fighting gear
- Emergency escape signs and routes
- No Smoking signs
- Gangways and nets
- Emergency shutdown devices

Wharf operations system:

- Wharf control room
- Wharf labs
- Wharf offices
- Wharf pump house
- Wharf personnel shelters

Monitoring System:

Wharf control room
Computer terminals
Reporting files
Checklists

5.1.2 PROCESS ANALYSIS

To study the human component of LDO and how a transfer operation is accomplished, a process analysis is then done. A process analysis involves writing down, without any major exclusions, the steps involved in an operation. The process analysis enables one to have a clear idea of the sequence and relationships between steps in a loading and discharge operation and gives an idea of the task complexity.

The purpose of a process study in this case is to allow one to fully understand the activities involved in loading and discharge operations. Consultation with operation manuals and operators in the field enabled us to compile a list detailing the process involved. A process analysis for a typical transfer operation is summarized in Table 5.2, where the bold entries indicate processes with a relatively high spill risk potential.

Table 5.2 PROCESS ANALYSIS FOR LDO:

Step 1: Docking

Maintain constant ship/tug/shore communication.
Approach vessel to terminal using tug assist.
Orient ship properly.
Tie up ship with mooring lines to quick release bollards using proper tension.
Attach gangway and net.
Attach emergency tow wires to ship.
Connect ship fire hose to shore main.
Conduct Pre-Transfer Conference and DOI

Step 2: Hook-up

Hook up of cargo hose:

Blank off all components not used.

Shut overboard discharge, sea suction valves.

Close containment drains.

Check condition of hose.

Check condition of hose gasket.

Check that hose is long enough for ship movement.

Remove hose cap.

Remove manifold cap.

Lift hose using chick stand mechanism.

Place product hose end over small discharge containment area.

Connect hose to ship manifold flange using a bolt in every hole and proper torque.

Check operation of valves.

Check hose support.

Pressure check hose in place.

Check operation of pressure gauges.

Hook up inert gas hose.

Connect IG hose to proper manifold using a bolt in every hole and proper torque.

Close tightly tank hatches, butterworth plates, ullage plugs.

Electrically insulate ship/shore.

Test alarms.

Maintain oxygen content at less than 8%.

Step 3: Flow start-up

(Loading):

Maintain excellent ship/shore communications.

Turn IG system on.

Open ship-side valves.

Open shore-side valves.

Turn shore pump on to minimum flow rate.
Check for leaks along system and in water.
Check hose support for excessive cyclic movement.
Slowly increase flow to agreed upon maximum.
Monitor system.

(Discharge):

Maintain excellent ship/shore communications.
Turn IG system on.
Open shore-side valves.
Open ship-side valves.
Turn ship pump on to minimum flow rate.
Check for leaks along system and in water.
Check hose support for excessive cyclic movement due to flow pumping action.
Slowly increase flow to agreed upon maximum.
Monitor system.

Step 4: Steady transfer

Maintain hourly communication between VPIC/TPIC.
Monitor line pressures.
Monitor tanks.
Check for leaks along system and in water.
Check vessel draft.
Monitor mooring lines tension due to draft changes.
Periodically calculate volumes.
Anticipate slow downs and stoppages.
Anticipate end of transfer.

Step 5: Topping Off

Maintain constant communications with ship/shore.
Decrease flow rate of product.
Monitor tank levels closely.
Fill tanks to within 98% of tank volume using a staggered process.

When tanks are at 98% capacity (full):

(Loading):

Close ship-side valves.
Close shore-side valves.
Turn shore pump off.

(Discharging):

Close shore-side valves.
Close ship-side valves.
Turn ship pump off.

Step 6: Disconnect

Disconnect bottom bolts attaching hose to manifold.
Make sure there is no excessive line pressure.
Disconnect remaining bolts.
Move hose away from ship using chick stand.
Clear hose of residual product by purging.

Step 7: Departure

Maintain constant ship/tug/shore communication.
Ensure vessel has minimum 2 foot bottom clearance.
Disconnect mooring lines.
Move vessel away from terminal using tugs.
Depart terminal area.

5.1.3 IDENTIFYING HAZARDS

Once a system and process analysis is complete, the various potential hazards in a loading and discharge operation can be identified by screening through these lists. Many hazards exist, such as explosions and fires, however, because of the scope of this study, only one hazard is considered: oil spills due to typical loading and discharge operations.

5.1.4 SCREENING/IDENTIFYING EVENTS

The system and process analysis is again scrutinized in the next step of the model development to identify all the possible initiating events that lead directly to typical operational spill incidents.

For example, an initiating event could be that a gasket ruptures and causes oil to spill. Or, perhaps a hose ruptures causing oil to spill. Table 5.3 lists typical operational initiating events (and their underlying contributors) that could initiate spills during the various steps of the transfer operation and their relative probability of occurrence, according to information gathered from interviews with terminal experts. Of course, other non-typical initiating events are possible also, such as a collision during docking and the subsequent puncture of the ship tanks, but these unusual events are not considered in the model example, though their inclusion would be straightforward.

For the purposes of the model, the typical initiating events must be exhaustive, and including the unusual initiating events merely adds complexity. Underlying or contributing events under typical operations is simply the loading and discharge of cargo. Also, under typical spill scenarios, compounding events that worsen the initial spill event rarely occur. Nevertheless, for the purpose of completeness and illustration, possible unusual contributing, initiating, and compounding events are shown in Appendix 2. Contributing events can occur due to time pressures, economic pressures, or any other influences that might disturb typical operations.

TABLE 5.3

TYPICAL CONTRIBUTING, INITIATING AND COMPOUNDING EVENTS LEADING TO SPILLS:

CONTRIBUTING EVENT	*INITIATING EVENT*	*COMPOUNDING EVENT*
DOCKING:		
None	None	
HOOK-UP:		
LDO	Hose not purged	
START-UP:		
LDO	Pipe/Hose not attached	
LDO	Pipe/Hose not connected properly	
LDO	Pipe/Hose Ruptures	
LDO	Valves aligned improperly	
LDO	Valves fail	
LDO	Gasket omitted	
LDO	Gasket Ruptures	
TOPPING-OFF:		
LDO	Overfilling	
LDO	Hose Ruptures	
LDO	Valves aligned improperly	
LDO	Valves fail	
LDO	Gasket Ruptures	
DISCONNECT:		
LDO	Hose not purged	
LDO	Hose disconnected improperly	
DEPARTURE		
None	None	

Usually, there are no compounding effects during operational spills that cause these spills to magnify since spills are generally small and manageable. Based on results from interviews with various marine terminal experts, Table 5.4 shows likely initiating events and their relative spill probabilities.

TABLE 5.4
INITIATING EVENT PROBABILITIES OF OCCURRENCE

EVENT	PROBABILITY OF SPILL OCCURRENCE
HOOK-UP:	
Hose not purged, hose lifted	Medium
START-UP:	
Hose not attached	Low
Hose not connected properly	High
Hose Ruptures	Low
Valves not set properly	Low
Valves fail	Low
Gasket omitted	Low
Gasket Ruptures	Low
TOPPING-OFF:	
Overfilling	High
Hose Ruptures	Low
Valves not set properly	Low
Valves fail	Low
Gasket Ruptures	Low
DISCONNECT:	
Hose not purged	High
Hose disconnected improperly	Low

5.1.5 EVENT TREES

Next, the sequence leading to accident events and the influence of decisions and actions by humans and organizations must be established to further the model development. Event trees and influence diagrams have historically been the best method of doing this [Phillips, 1990; Moore, 1993].

Tree diagrams show clearly the sequence of events leading to oil spills. An event tree showing how spills occur during loading and discharge operations is shown in Figure 5.3. It shows how the loading and discharge operation in general leads to spills.

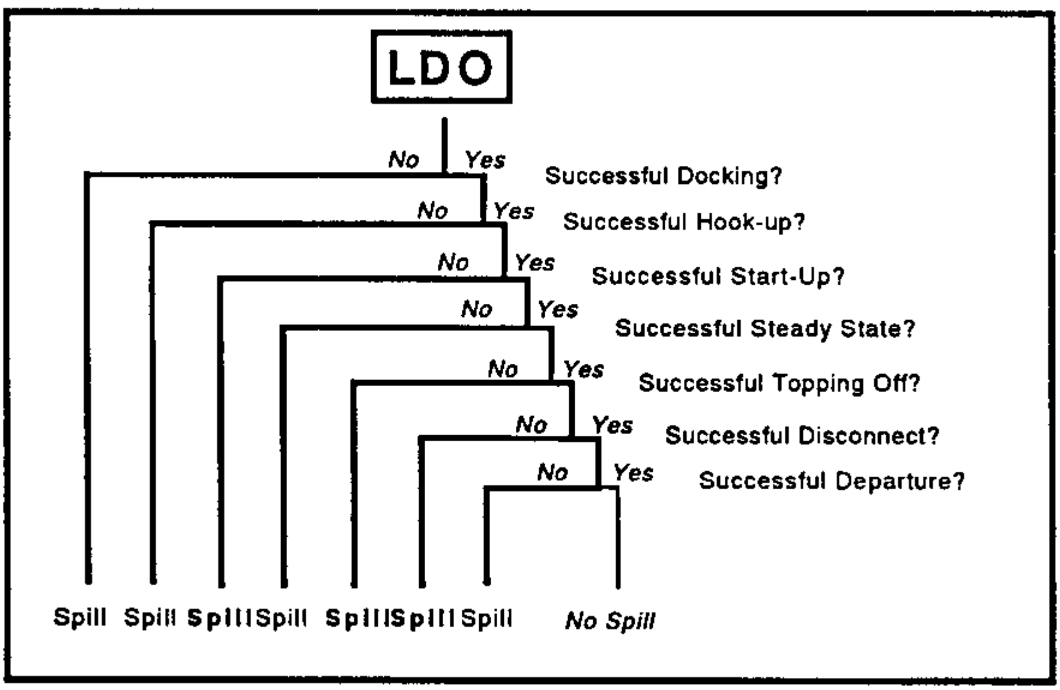

Figure 5.3: Basic spill event tree for LDO. Start-up, topping-off, and disconnect have higher spill probabilities than other LDO stages.

From interviews with marine terminal experts, and verified by the preliminary questionnaire described in Appendix 5, it has been determined that the highest risk probabilities occur during only three of the seven LDO stages: start-up, topping-off, and disconnect. Basic event trees for these scenarios are shown in Figures 5.4 through 5.6. Influence diagrams for these three steps will be presented and explained later. This will give additional insight into the relationships between HOE and these operations.

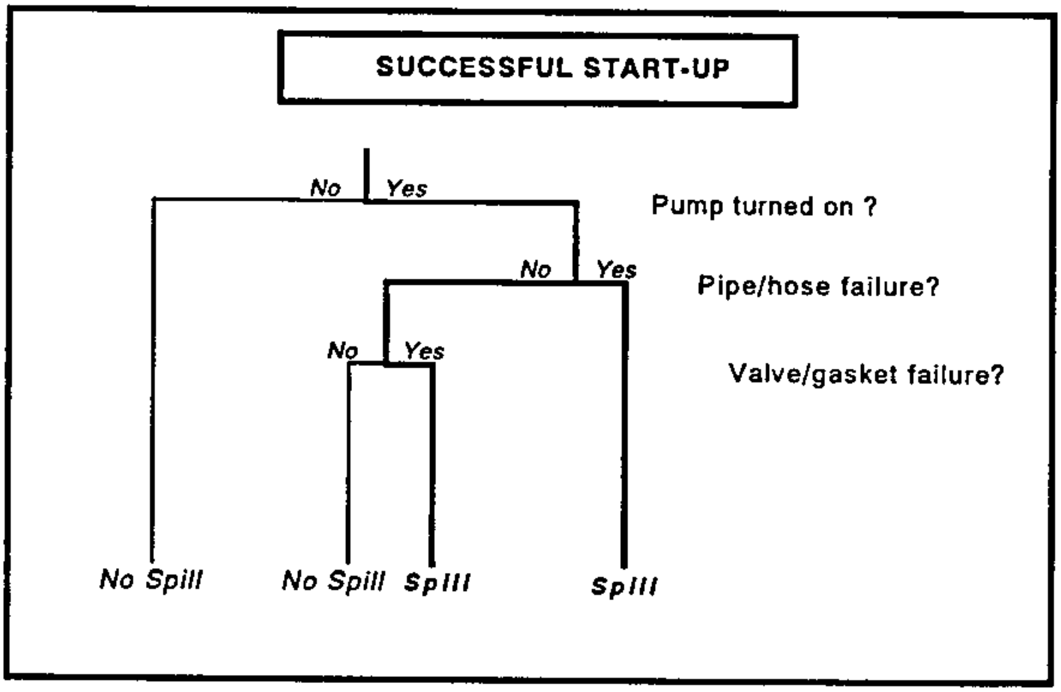

Figure 5.4: Basic spill event tree for start-up process.

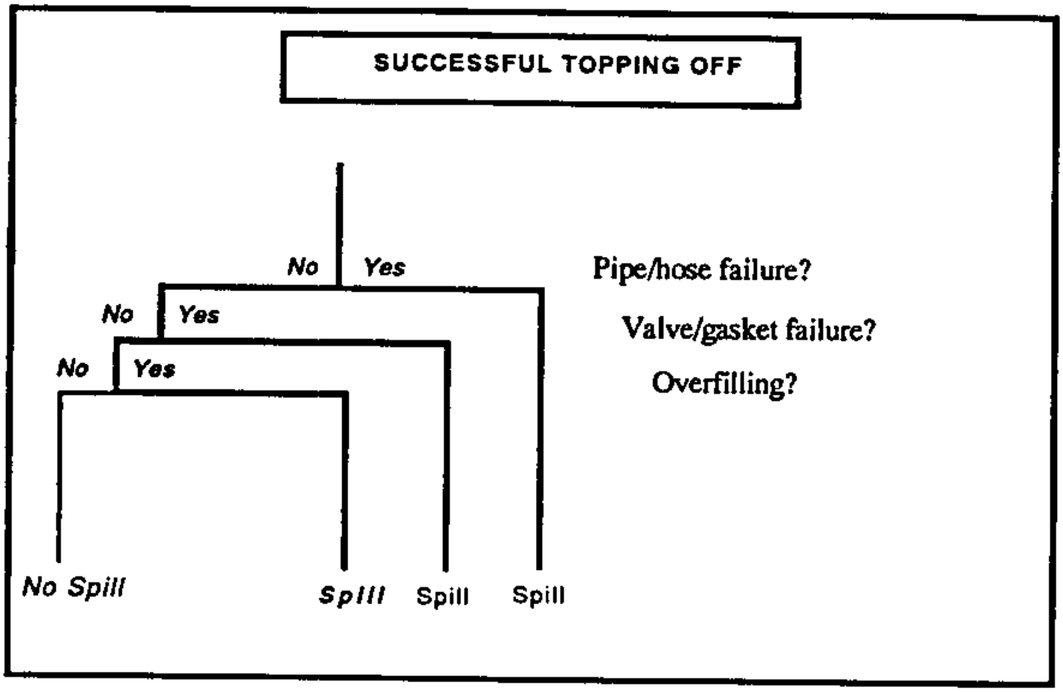

Figure 5.5: Basic spill event tree for topping off process.

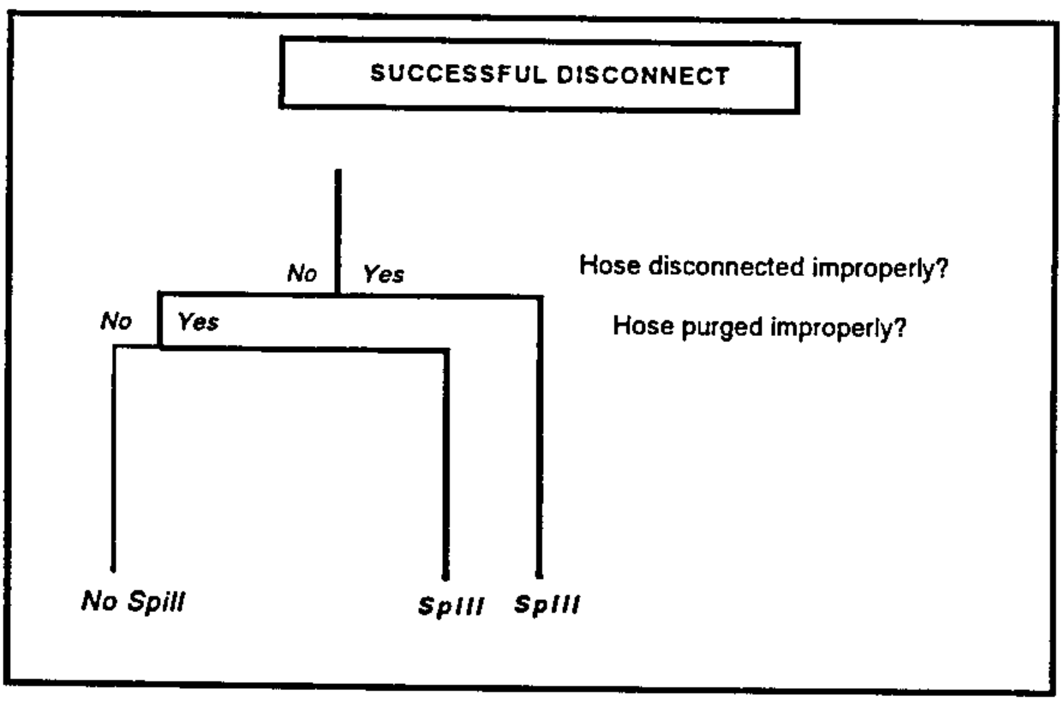

Figure 5.6: Basic spill event tree for disconnect process.

5.1.6 INFLUENCES

Influence diagrams show sources of influence between events. A detailed explanation of influence diagramming can be found in Howard & Matheson[1981] or Moore [1993]. Essentially, two connected nodes in an influence diagram can describe quantitatively the relationship between them.

Figure 5.7 shows in a general form the global influences or dependencies between external environmental operating conditions, HOE, and events, decisions and actions during LDO and how they lead to spills.

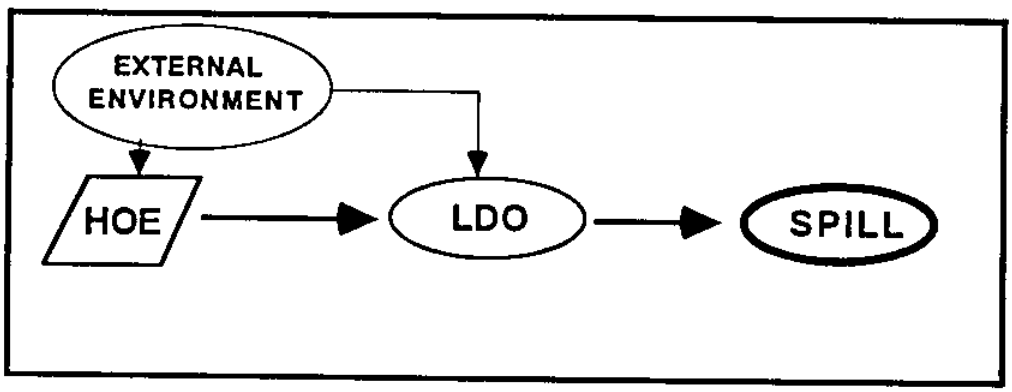

Figure 5.7: Global spill influences during LDO

This diagram is expanded to describe how spills can occur through any of the seven steps involved in an LDO operation as shown in figure 5.8. We can assume that spills occur only during one of the steps since for a given LDO, a spill during each step is indeed rare. The arrow through the start-up process is bold to illustrate an example to follow.

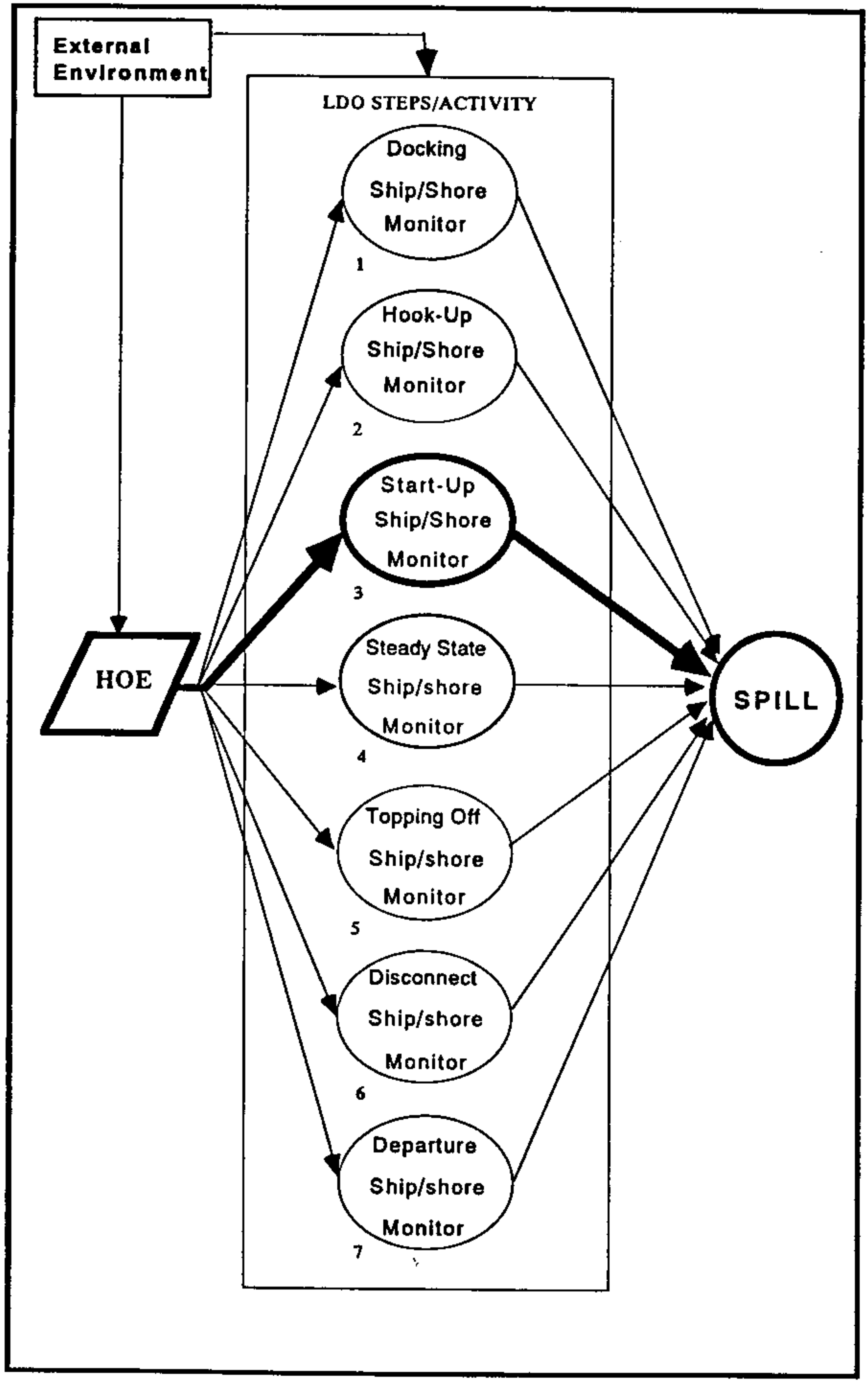
External Environment
LDO STEPS/ACTIVITY
Docking Ship/Shore Monitor
1
Hook-Up Ship/Shore Monitor
2
Start-Up Ship/Shore Monitor
3
Steady State Ship/shore Monitor
4
Topping Off Ship/shore Monitor
5
Disconnect Ship/shore Monitor
6
Departure Ship/shore Monitor
7
HOE
SPILL

Figure 5.8: (Previous page) Spills due to HOE occur through any of the 7 LDO steps. Bold line indicates example in text.

Using the start-up step of LDO indicated in bold above as a specific example, Figure 5.8 can be further expanded to include the factors specific to HOE, showing how it can affect contributing, initiating, and compounding events during the start up process, thus leading to spills. This expansion is shown in Figure 5.9. For the model to be useful, possible contributing, initiating, and compounding events, decisions and actions should be exhaustive. Similar diagrams may be drawn for each of the other steps involved in LDO.

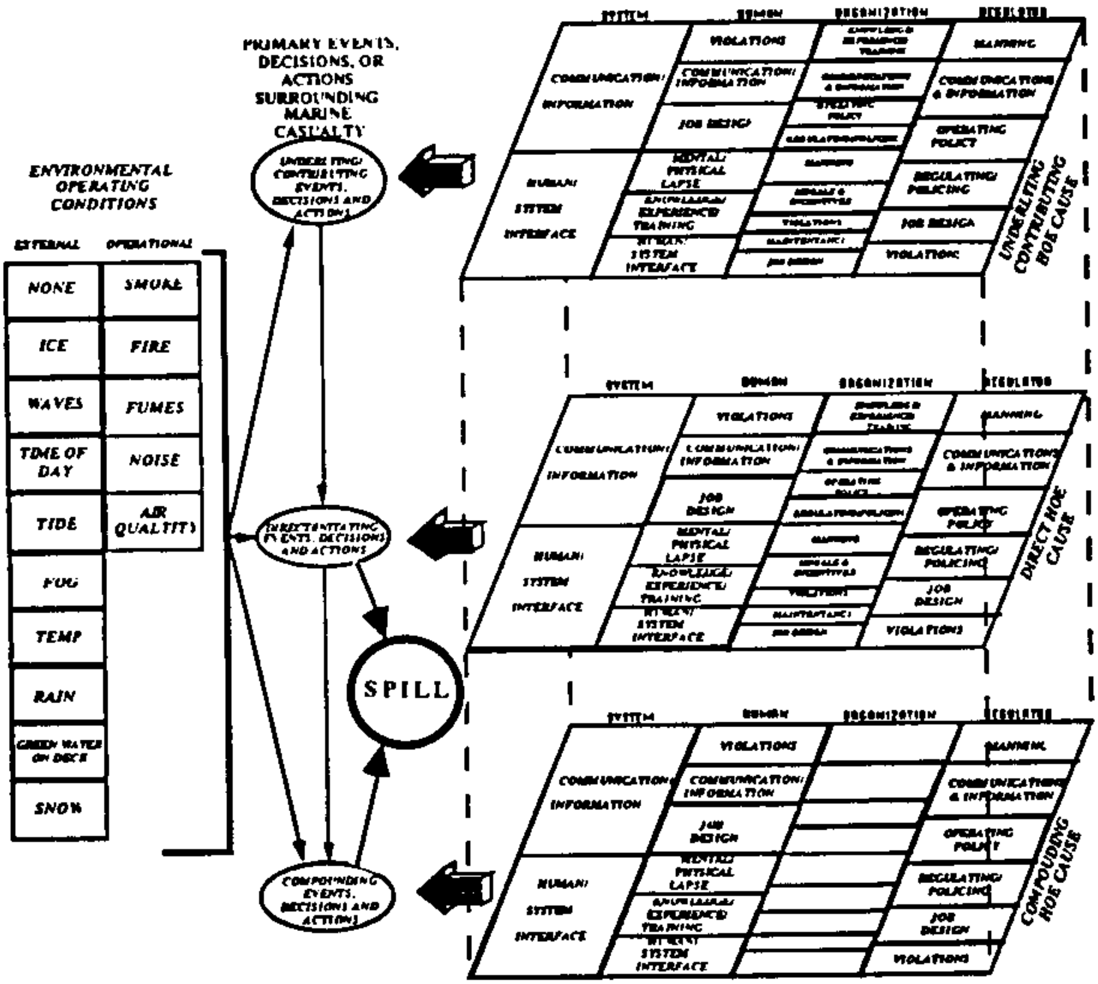

Figure 5.9: Influence of HOE and operating environment on marine casualty events, decisions, and actions leading to spills.

5.1.7 EXPERT JUDGEMENT

The next step in the model development is to quantify each event sequence. As noted in previous studies, [Moore,1993], minimal human and organizational factors have been incorporated into the literature and databases of marine accidents. To be able to understand the occurrence and frequency of HOE in loading and discharge accident sequences, expert judgment is necessary. The figure below shows graphically the current state of affairs with respect to HOE data on LDO. Presently, there is no consistent and thorough reporting methodology of HOE in LDO. Development of an HOE data archiving system is an associated part of this current project and will be presented in other reports on this project.

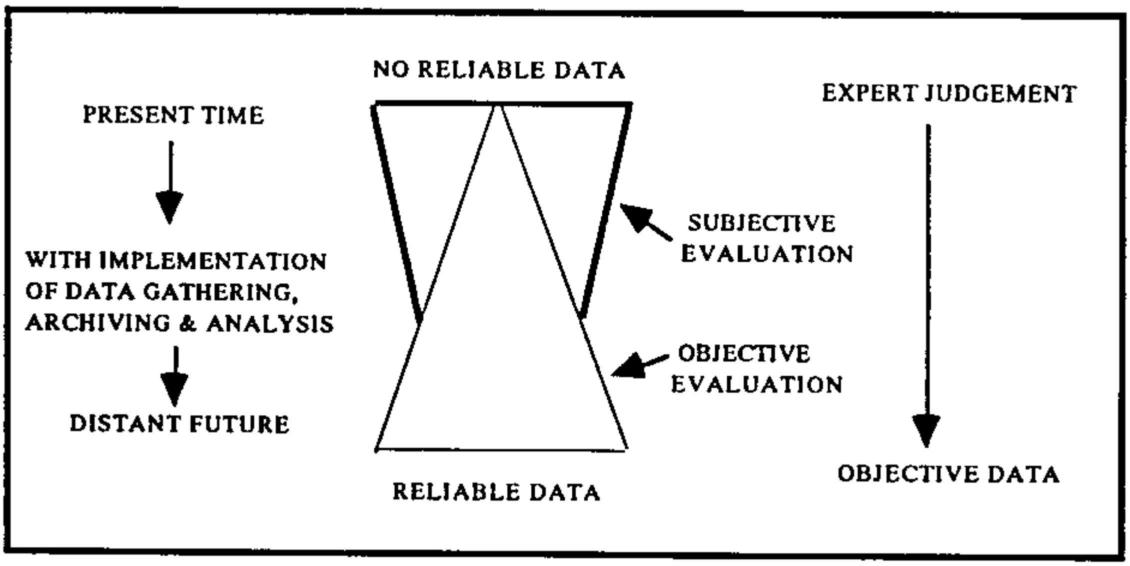

Figure 5.10: Expert judgement is currently needed in HOE evaluations.

Interviews and questionnaires were two methods that were used during this project to solicit information. Interviews involved a wide variety of marine experts, and these individuals are listed in Appendix 1. A questionnaire was distributed to dock workers at marine terminals because they are the front line operators of the loading and discharge systems and are in the best position to respond to the questions asked. The questionnaire primarily asks questions regarding the extent to which they believe human and organizational errors enter accident scenarios as well as questions regarding how and to what extent they personally interact with other external organizations such as regulatory agencies during loading and discharge operations. The questionnaire is a work in progress, some refinements still being necessary. However, this version is detailed in Appendix 5 and includes some results

.

The results of the questionnaire clearly show start-up, topping off and disconnect as being the three LDO steps with the highest spill risk potential during loading or discharge. These three steps thus become the focus of inquiry with respect to human, organizational, environmental, procedural and system factors that may influence oil spill probabilities.

The questionnaire continues by asking questions as to which specific human, organizational, environmental, procedural and system factors most likely contribute to spills under two scenarios: overfilling tanks and hose failure. With regards to tank overfilling, human error due to mistakes and system errors due to serviceability of the system are the two factors most cited, in this order. With regards to a hose failure, system errors due to serviceability and human error due to mistakes are the factors most cited, in this order. Thus, human mistakes and system serviceability are felt to be the highest contributors to the increase of oil spill risk. Other factors such as human ignorance or organizational violations seem to affect spill risk very little with regards to overfilling and hose failure.

As stated previously, this questionnaire is a work in progress and further refinements and additions still need to be made for the results to be accurate and meaningful.

Lastly, the information and data gathered is quantified numerically, and this is the subject of the next section.

5.2 QUANTITATIVE MODELLING OF HOE IN LDO

5.2.1 QUANTIFYING TASK RELIABILITY

Primarily developed for the evaluation of human error in nuclear power plants, Williams (1988), Swain & Guttman (1981), and Edmondson (1993) have developed useful quantification procedures for these errors. Based on experiments and simulations of nuclear power plant operations, the information categorizes human task reliability.

Figure 5.11 shows the results of the experiments performed by Swain & Guttman. Generic error rates are given to typical tasks performed under general types of impediments and influences. The range of error rates mirrors the range of impediment and influences. If the influence level is high, then the error probability will also be high.

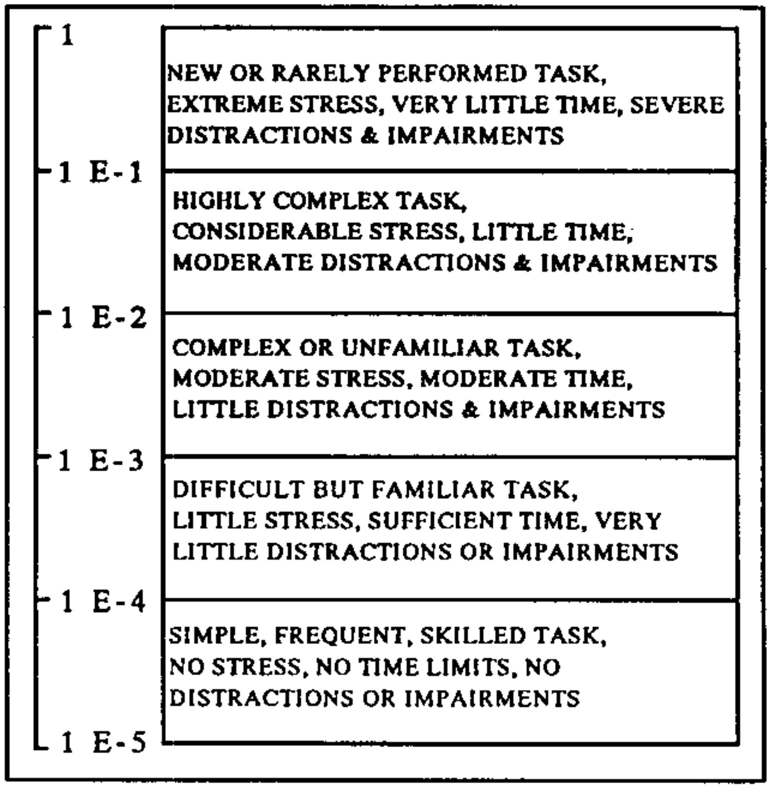

Figure 5.11: Generic human task error rates. Y axis represents mean probability of human error or failure per task.

These ranges show the mean probability of a human error per task performed. Williams (1988) published the one standard deviation ranges associated with the means of human errors. These results are shown in Figure 5.12.

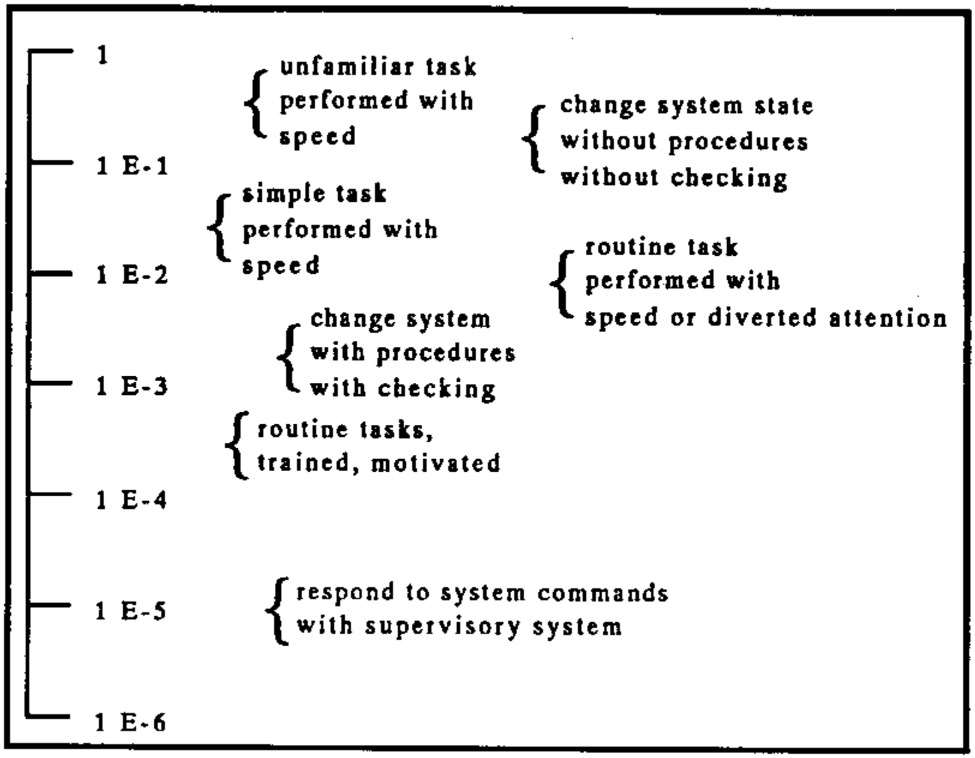

Figure 5.12: Nominal human task performance unreliability (mean and one standard deviation shown).

Performance shaping factors (influences that can result in an increase in the mean rates of human errors) have also been developed [Williams (1988); Swain and Guttman (1983)]. These were also attained from experiments and simulations of nuclear power plant operations but can be used just as effectively in LDO. These are shown in figure 5.13.

ERROR PRODUCING CONDITION	*MULTIPLIER*
Unfamiliarity	17
Time shortage	11
Low signal to noise ratio	10
Features over-ride allowed	9
Spatial/Funct. incompatibility	8
Design model mismatch	8
Irreversible action	8
Information overload	6
Technique unlearning	6
Knowledge transfer	5.5
Performance ambiguity	5
Misperception of risk	4
Poor feedback	4
Inexperience	3
Communication filtering	3
Inadequate checking	3
Objectives conflicts	3
Limited diversity	2.5
Educational mismatch	2
Dangerous incentives	2
Lack of exercise	1.8
Unreliable instruments	1.6
Absolute judgements required	1.6
Unclear allocation of functions	1.6
Lack of progress tracking	1.4
Limited physical capabilities	1.4
Emotional stress	1.3
Sleep cycle disruption	1.2

Figure 5.13 Performance shaping factors.

These performance shaping factors are useful in developing quantification of the potential effects of changes in systems, organizations, environments and procedures.

5.2.2 PROBABILITIES

Once an exhaustive set of initiating accident events and the final state of the system has been established, the probability of an operational oil spill during LDO can be represented by [Moore, Bea 1993]:

$$p(loss_k) = \sum_i \sum_m p(in_i)p(fist_m | in_i)p(loss_k | fist_m) \qquad (1)$$

This equation is expanded to include relevant decisions and actions constituting another exhaustive set at different stages during the loading and discharge operation. These decisions and actions can be examined from the front-line operating crew level to top management level. Equation 1 thus becomes:

$$p(loss_k) = \sum_i \sum_m \sum_n p(A_n)p(in_i | A_n)p(fist_m | in_i, A_n)p(loss_k | fist_m, A_n) \qquad (2)$$

The effects of organizational procedures and policies on the risk are determined through examining the probabilities of the actions and decisions conditional on relevant organizational factors (O_h). The probabilities of various degrees of loss can be examined conditioned upon different contributing organizational factors using, finally:

$$p(loss_k | O_h) = \sum_i \sum_m \sum_n p(A_n | O_h)p(in_i | A_n)p(fist_m | in_i, A_n)p(loss_k | fist_m, A_n) \qquad (3)$$

where:

$loss_k$ - loss i.e.: spill

A_n - action taken i.e.: turn pump on

O_b - HOE factor i.e.: procedures not known

in_i - initiating event i.e.: valves not aligned correctly

$fist_m$ - final state of system i.e. leak occurs

In influence diagram form, this equation and the variables can be represented for the start-up step in LDO as shown in figure 5.14, with the bold line indicating the particular variables used above.

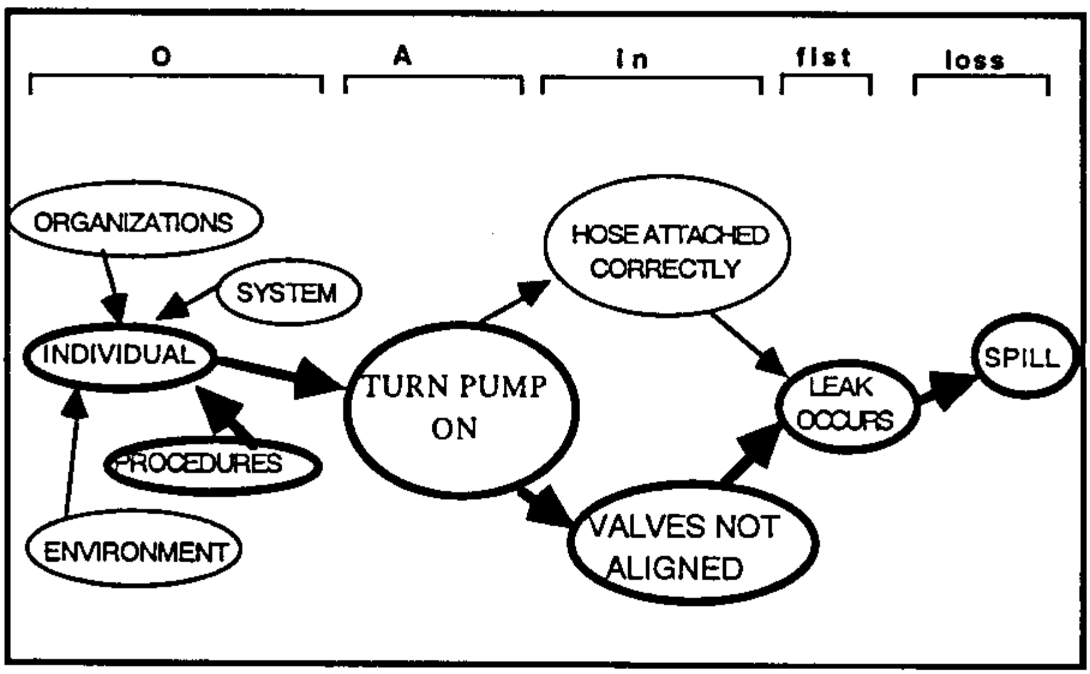

Figure 5.14: Influences on spill during start-up process, showing equation variables.

Similar influence diagrams can be constructed for the other two steps in LDO with relatively high likelihoods of spills. The influence diagrams for the topping-off step and the disconnect step are shown in Figures 5.15 and 5.16.

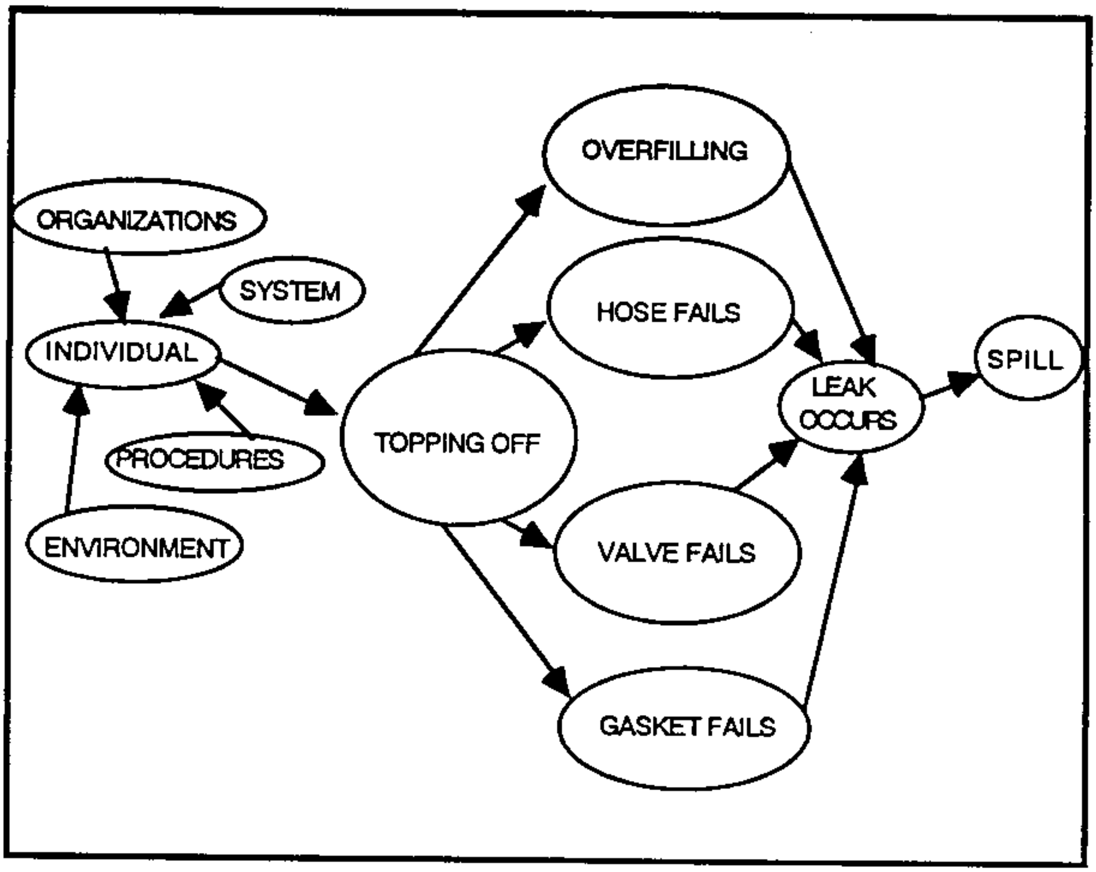

Figure 5.15: Influences on spill during the topping off process.

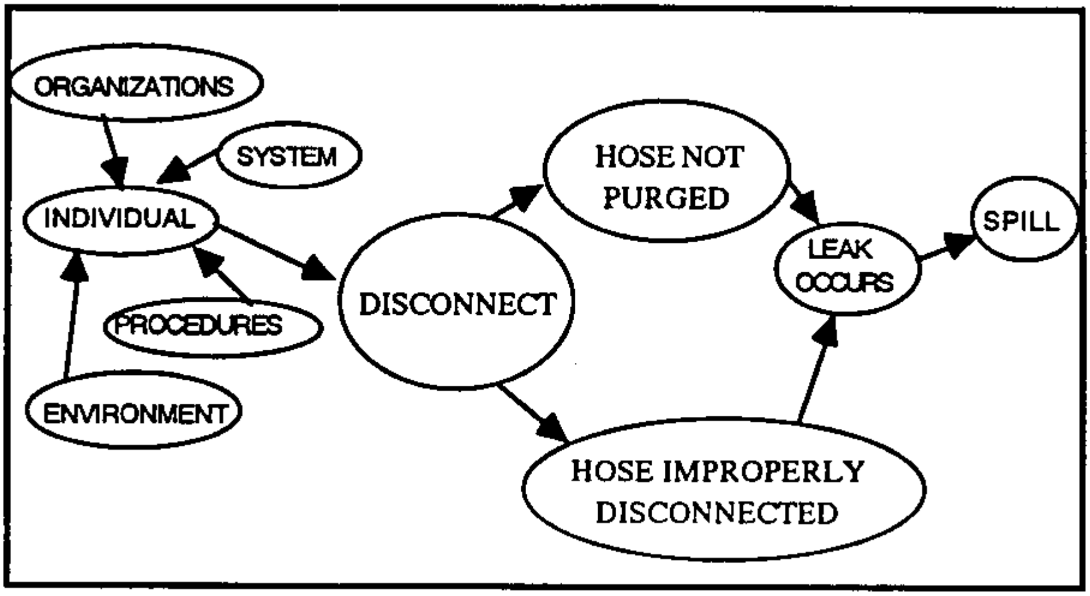

Figure 5.16 Influences on spill during the disconnect process.

An example of the application of this quantitative model for the purposes of calculating spill probability during the start up stage of LDO is shown below for a single series of conditions indicated by the bold arrow in figure 5.14. Similar computations must be made for all possible combinations.

p[turn pump on|procedure not known] =.01

p[valves not aligned correctly|turn pump on] =.01

p[leak occurs|valves not aligned correctly, turn pump on] =.90

p[spill|leak occurs, turn pump on] =.90

p[spill|procedure not known]= **(.01)(.01)(.90)(.90) = .000081**

A flowchart approach to identifying specific HOE from accidents can be modeled using the diagram in Figure 5.17. It shows the root causes of HOE for any accident or error incident. Using this flowchart in interviews with terminal experts, it can provide quantitative measurements of accident causes and provide insights to possible remedial fixes.

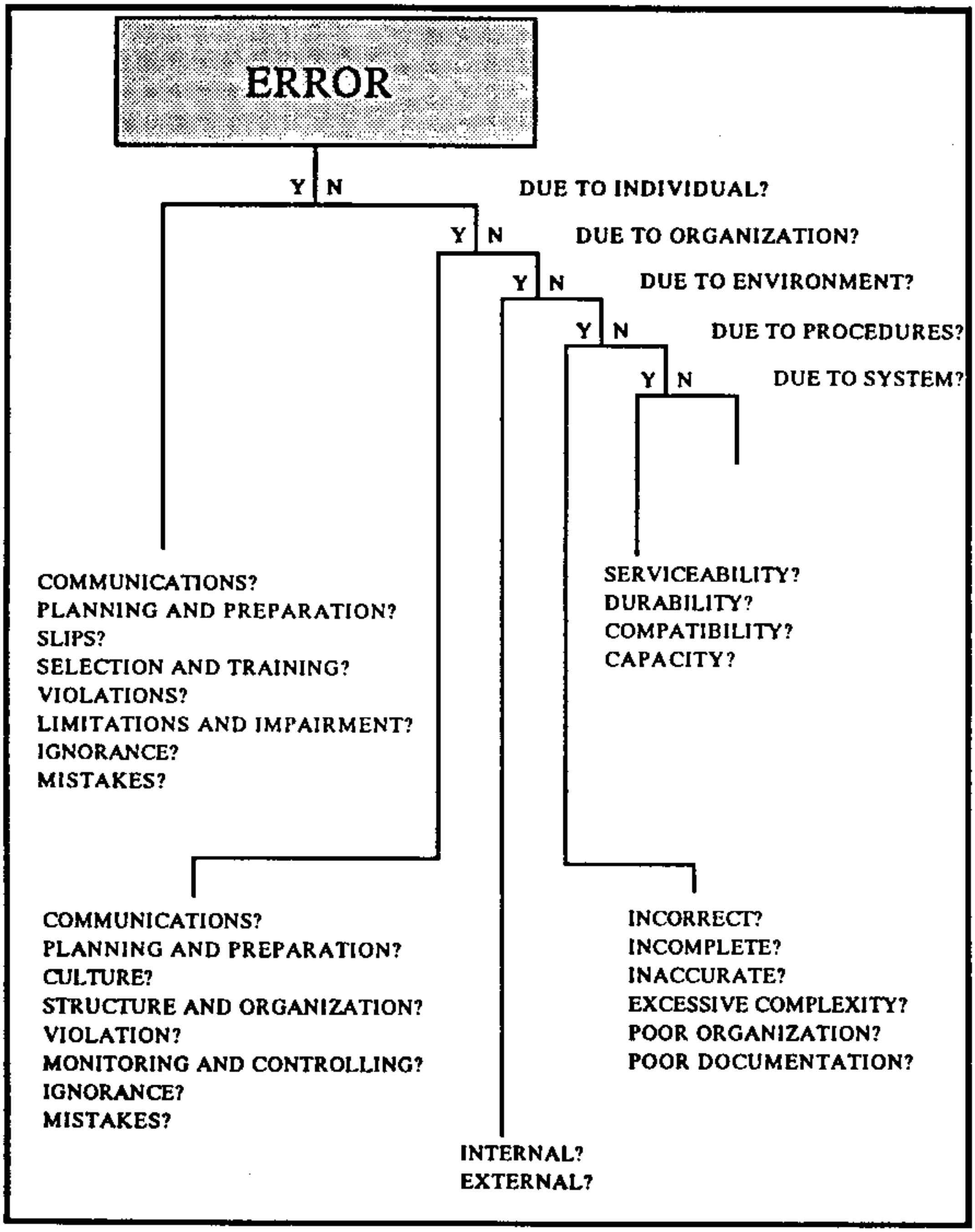

Figure 5.17: Error flowchart model for HOE root causes.

5.2.3 MODEL EVALUATION

Using the start-up process influence diagram of figure 5.14 and the HOE classification flow chart of figure 5.17 as an example in the model evaluation, one can assess the base rates of loading and discharge spills during the start-up process. The steps involve identifying the outcomes for each of the nodes in the influence diagrams and then quantifying their probabilities. Computerized data quantification management and archiving methods will be the subject of future reports.

As stated earlier, there is currently no specific data available on HOE in LDO. Thus, quantification at the present time is accomplished through the use of expert opinion and the use of the general task performance error likelihoods [Swain, Guttman, 1983]. Additions and modifications to the current questionnaire reflecting the use of these tools still need to be made.

What follows is a model evaluation for the assessment of spill rates for the start up process only using figure 5.14. Two numbers are given here: spill probability under the present system and spill probability resulting from an improvement in LDO due to closer monitoring, for example.

Because actual data is not yet available, the numbers that follow are to be used as guidelines only. Actual data from future site visits and questionnaires will provide real measurements of the impact of HOE factors in LDO. In this example, one must aggregate over all spill probabilities in order to calculate the total probability of a spill during the start-up process. For this example, the pump is assumed to be turned on and that the initiating spill event is due to valve or hose failure, but not both. It is also assumed that better monitoring results in a decrease in human and organizational errors as well as a decrease in hose and valve malfunctions thus decreasing a spill probability.

Similar evaluations can be performed for the other steps involved in LDO, particularly topping-off and disconnect, steps which also have high spill probabilities.

OUTCOMES WITHIN EACH NODE OF THE LDO START-UP PROCESS:

Organizations errors	**System errors**	**Proc. error**
communication	*serviceability*	*incorrect*
planning & Prep.	*durability*	*incomplete*
culture	*compatibility*	*inaccurate*
structure	*capacity*	*complex*
violation	*none*	*poor organization*
monitoring		*poor doc.*
ignorance	**Individual Error**	*none*
mistakes	*communications*	
none	*planning and prep.*	**Env. Error**
	mistakes	*internal*
Pump	*slips*	*external*
on	*selection and training*	*none*
off	*violations*	
	limitations	**Valves**
Hose	*ignorance*	*aligned*
attached ok	*none*	*not aligned*
not attached ok		
Leak		
occurs		
not occurs		

QUANTIFICATION OF SPILL PROBABILITIES FOR THE START-UP PROCESS USING THE INFLUENCE DIAGRAM OF FIGURE 5.14:

Organization	Individual	Hose	Valves	P[spill] present system	P[spill] better monitoring
communications	comm.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0002	.0002
"	plan.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0007	.0002
"	slips	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
"	sel.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	viol.	not ok	ok	.0003	.0002
"	"	ok	not ok	.0004	.0003
"	lim.	not ok	ok	.0003	.0002
"	"	ok	not ok	.0004	.0003
"	igno.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	mstk	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
planning	comm.	not ok	ok	.0005	.0003
"	"	ok	not ok	.0002	.0001
"	plan.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0003
"	slips	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
"	sel.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	viol.	not ok	ok	.0004	.0002
"	"	ok	not ok	.0004	.0003
"	lim.	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
"	igno.	not ok	ok	.0004	.0003

"	"	ok	not ok	.0006	.0002
"	mstk	not ok	ok	.0005	.0002
"	"	ok	not ok	.0004	.0003
culture	comm.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0002	.0002
"	plan.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	slips	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
"	sel.	not ok	ok	.0004	.0001
"	"	ok	not ok	.0006	.0002
"	viol.	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
"	lim.	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
"	igno.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0005
"	mstk	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
structure	comm.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0002	.0002
"	plan.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	slips	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
"	sel.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0005	.0002
"	viol.	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
"	lim.	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
"	igno.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	mstk	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
violations	comm.	not ok	ok	.0004	.0003

"	"	ok	not ok	.0002	.0002
"	plan.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	slips	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
"	sel.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	viol.	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
"	lim.	not ok	ok	.0004	.0002
"	"	ok	not ok	.0004	.0003
"	igno.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	mstk	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
monitor	comm.	not ok	ok	.0004	.0001
"	"	ok	not ok	.0002	.0001
"	plan.	not ok	ok	.0004	.0001
"	"	ok	not ok	.0006	.0001
"	slips	not ok	ok	.0002	.0001
"	"	ok	not ok	.0004	.0002
"	sel.	not ok	ok	.0004	.0002
"	"	ok	not ok	.0006	.0001
"	viol.	not ok	ok	.0002	.0001
"	"	ok	not ok	.0004	.0002
"	lim.	not ok	ok	.0002	.0001
"	"	ok	not ok	.0004	.0002
"	igno.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	mstk	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
ignorance	comm.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0002	.0002
"	plan.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	slips	not ok	ok	.0002	.0002

"	"	ok	not ok	.0004	.0003
"	sel.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	viol.	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
"	lim.	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
"	igno.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	mstk	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
mistakes	comm.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0002	.0002
"	plan.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	slips	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
"	sel.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	viol.	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
"	lim.	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
"	igno.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	mstk	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003

System	Individual	Hose	Valves	P[spill] present system	P[spill] better monitoring
serviceability	comm.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0002	.0002
"	plan.	not ok	ok	.0004	.0003

"	"	ok	not ok	.0006	.0002
"	slips	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
"	sel.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	viol.	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
"	lim.	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
"	igno.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	mstk	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
durability	comm.	not ok	ok	.0005	.0003
"	"	ok	not ok	.0002	.0002
"	plan.	not ok	ok	.0004	.0002
"	"	ok	not ok	.0006	.0002
"	slips	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
"	sel.	not ok	ok	.0004	.0002
"	"	ok	not ok	.0006	.0002
"	viol.	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
"	lim.	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
"	igno.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	mstk	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
compat.	comm.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0002	.0002
"	plan.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	slips	not ok	ok	.0002	.0001
"	"	ok	not ok	.0004	.0003
"	sel.	not ok	ok	.0004	.0003

"	"	ok	not ok	.0006	.0002
"	viol.	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
"	lim.	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
"	igno.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	mstk	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
capacity	comm.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0002	.0002
"	plan.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	slips	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
"	sel.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	viol.	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
"	lim.	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
"	igno.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	mstk	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003

Procedures	Individual	Hose	Valves	P[spill] present system	P[spill] better monitoring
incorrect	comm.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0002	.0002
"	plan.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	slips	not ok	ok	.0002	.0002

"	"	ok	not ok	.0004	.0003
"	sel.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	viol.	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
"	lim.	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
"	igno.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	mstk	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
incomplete	comm.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0002	.0002
"	plan.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	slips	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
"	sel.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	viol.	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
"	lim.	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
"	igno.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	mstk	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
inaccurate	comm.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0002	.0002
"	plan.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	slips	not ok	ok	.0005	.0002
"	"	ok	not ok	.0004	.0003
"	sel.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	viol.	not ok	ok	.0005	.0002

"	"	ok	not ok	.0004	.0003
"	lim.	not ok	ok	.0003	.0002
"	"	ok	not ok	.0004	.0003
"	igno.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	mstk	not ok	ok	.0003	.0002
"	"	ok	not ok	.0004	.0003
too complex	comm.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0004	.0002
"	plan.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	slips	not ok	ok	.0004	.0002
"	"	ok	not ok	.0004	.0003
"	sel.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	viol.	not ok	ok	.0005	.0002
"	"	ok	not ok	.0004	.0003
"	lim.	not ok	ok	.0003	.0002
"	"	ok	not ok	.0004	.0003
"	igno.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	mstk	not ok	ok	.0005	.0002
"	"	ok	not ok	.0004	.0003
poor org.	comm.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0004	.0002
"	plan.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	slips	not ok	ok	.0003	.0001
"	"	ok	not ok	.0004	.0003
"	sel.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	viol.	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0002
"	lim.	not ok	ok	.0003	.0002
"	"	ok	not ok	.0004	.0003
"	igno.	not ok	ok	.0004	.0003

"	"	ok	not ok	.0006	.0002
"	mstk	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
poor docum.	comm.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0003	.0002
"	plan.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	slips	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
"	sel.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	viol.	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
"	lim.	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003
"	igno.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	mstk	not ok	ok	.0002	.0002
"	"	ok	not ok	.0004	.0003

Environment	Individual	Hose	Valves	P[spill] present system	P[spill] better monitoring
internal	comm.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0003	.0002
"	plan.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	slips	not ok	ok	.0003	.0002
"	"	ok	not ok	.0004	.0003
"	sel.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	viol.	not ok	ok	.0003	.0002
"	"	ok	not ok	.0004	.0003
"	lim.	not ok	ok	.0003	.0002

"	"	ok	not ok	.0004	.0003
"	igno.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	mstk	not ok	ok	.0002	.0001
"	"	ok	not ok	.0004	.0003
external	comm.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0002	.0001
"	plan.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	slips	not ok	ok	.0002	.0001
"	"	ok	not ok	.0004	.0003
"	sel.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	viol.	not ok	ok	.0002	.0001
"	"	ok	not ok	.0004	.0003
"	lim.	not ok	ok	.0002	.0001
"	"	ok	not ok	.0004	.0003
"	igno.	not ok	ok	.0004	.0003
"	"	ok	not ok	.0006	.0002
"	mstk	not ok	ok	.0002	.0001
"	"	ok	not ok	.0004	.0003

5.2.4 MODEL RESULTS

The model above calculates the spill probabilities for the start-up process. However, since statistical data regarding individuals, organizations, systems, procedures and internal and external environments is not complete, the results above should be used as guidelines only. Data collection methodologies are currently being developed, and once completed, the model results should reflect spill probabilities more accurately. The example shows spill probabilities decreasing as a result of improved monitoring of LDO, which translates into a decrease of HOE during the start-up process.

The model investigated spill influences and calculated spill probabilities for the start-up process only, though similar scenarios can be established for the other steps involved in LDO.

6.0 SUMMARY AND CONCLUSIONS

Loading and discharge operations at marine terminals can be described in a seven stage process. Each stage involves a series of events that must be executed correctly in order that no spill possibility can occur. Human and organizational considerations enter each activity in LDO directly, or in a contributing or compounding fashion. Qualitative and quantitative analyses using expert judgement through questionnaires, as well as event tree formulations and influence diagrams can be effective tools that allow one to estimate spill probabilities under varying conditions. This research has provided useful methodology to ascertain spill probabilities during loading and discharge operations. More comprehensive data on loading and discharge operations and spill reduction techniques will be the subject of future reports. These data and techniques will provide even a clearer picture of how and to what effect HOE influences spills during LDO.

APPENDIX 1

EXPERTS INTERVIEWED:

Chevron Shipping Company:

Dennis Arnette,	Port Superintendent, N.W. Region
Paul Jacobsen,	Terminal Supervisor, Richmond, CA
John D. Vitkauskas	Safety Group, San Francisco, CA

Chevron U.S.A. Inc.:

M.J. (Mike) Hughes	W.P.I Coordinator. Blending & Shipping Division, Richmond, CA
William Sallade	Wharf Trainer. Blending & Shipping Division, Richmond, CA
N. B. (Neale) Whitehurst	Wharf Master, Blending & Shipping Richmond, CA

California State Lands Commission,
Marine Facilities Inspection and Management Division:

Kevin G. Mercier	Assistant Division Chief, Long Beach, CA
Pete Johnson	Chief Engineer, Long Beach, CA
Capt. Livin D. Prabhu	Rules & Regulations, Long Beach, CA
Don Hermanson	Marine Terminal Safety Specialist Rules & Regulations Long Beach, CA
W. Robert Shilland	Marine Terminal Safety Specialist, Long Beach, CA
Robert C. Chatman	Marine Terminal Safety Inspector,

	Long Beach, CA
Capt. Scott D. Schaefer	Operations Supervisor, Vallejo, CA
Jay G. Phelps	Marine Terminal Safety Specialist, Vallejo, CA
James Hughes	Marine Terminal Safety Specialist, Vallejo, CA

APPENDIX 2

UNUSUAL
CONTRIBUTING, INITIATING, AND COMPOUNDING
EVENTS
LEADING TO SPILLS

CONTRIBUTING EVENT	*INITIATING EVENT*	*COMPOUNDING EVENT*
High docking speed	Collision w/ terminal	Spill in water/ floundering
Communications breakdown when docking	Collision w/ terminal	Spill in water/ floundering
Environmental factors when docking	Collision w/ terminal	Spill in water/ floundering
Environmental factors when docking	Collision w/ tug	Spill in water/ floundering
Tug problem	Collision w/ tug	Spill in water/ floundering
Excessive draft	Grounding	Spill in water
Port docking navigation	Grounding	Spill in water
Forget to hook up fire hose	Fire	Spill in area
No IG insulation	Explosion	Fire/Spill in area
Oxygen not less than 8%	Explosion	Fire/Spill in area
IG hose not checked	Explosion	Fire/Spill in area

APPENDIX 3

PRE-TRANSFER CONFERENCE

This conference is required before any oil (cargo, fuel, ballast, chemicals, etc.) is moved on or off the vessel or before any internal transfer.

* product identity, quantity and type is known
* sequence of transfer operations is decided upon
* amount of notice needed before stopping or changing the rate
* arrangement of the transfer systems and peculiarities of the systems are noted
* special precautions which will be taken at critical stages are noted
* initial, maximum and topping off rates are discussed
* all persons involved in operation are named and present
* federal and state regulations are reviewed and applied in transfer operation
* signals for stand-by, slowdown and stop transfer are decided upon
* emergency procedures are discussed
* spill reporting procedures are acknowledged
* watch and shift arrangements are discussed
* shutdown procedures are discussed
* anticipated cargo stoppages and delays noted
* approved Declaration of Inspection filled out and signed by VPIC & TPIC

APPENDIX 4

TYPICAL DECLARATION OF INSPECTION/SAFETY CHECKLIST PRIOR TO TRANSFER

The following checklist is typical of checklists performed during the pre transfer conference between authorized representatives of the terminal and the vessel, the VPIC (Vessel Person In Charge) and the TPIC (Terminal Person in Charge). Most of the topics here are extracted from the Code of Federal Regulations which govern the transfer of bulk cargoes at marine oil terminals. To further increase safety, some terminals add to the requirements stated in the code.

Asked of the VPIC:

1. Are warning lines displayed?
2. Is there any repair work in way of cargo spaces being carried on for which permission was not given?
3. Have connections been made and valves set?
4. Are all connections made to internal pipelines and not to hoses through a hatch?
5. Are there any open flames on deck?
6. Has the shore reported itself for transfer readiness?
7. Are sea valves connected to the cargo piping system closed?
8. If grades A, B, or C are to be loaded and boiler fires are lighted, has an inspection been made to determine whether these fires may be maintained with reasonable safety?
9. If grades A, B, or C cargoes are to be loaded and galley fires are lighted, has an inspection been made to determine whether the galley fires may be maintained with reasonable safety?
10. If grades A, B, or C cargoes are to be loaded and galley fires are lighted, has an inspection been made whether smoking is to be permitted in areas not on the weather deck?
11. If smoking is to be permitted in areas not on the weather decks, have those areas been designated?
12. Is the inert gas system being operated as necessary to maintain an inert atmosphere in the cargo tanks in compliance with the CFR?

Verified by the TPIC and VPIC:

1. Vessel moored properly.
2. Cargo hoses/arms are long enough and well supported.
3. Transfer system is aligned to allow the flow of oil.
4. Unused transfer system blanked/shut off.
5. Transfer system is attached to fixed piping connection.
6. Overboard discharges/sea suction valves are closed and sealed.
7. Cargo hoses/arms in good condition, annual tested and meet ANSI standard.
8. Cargo hoses/arms connections, transfer system connections are leak free.
9. Proper operation of monitoring devices, if any.
10. Discharge containment equipment is in place and accessible.
11. Scuppers and drains are closed.
12. Communication system is operable/language fluency by both persons in charge.
13. Emergency shutdown system is in position and operable.
14. Designated PIC at site has a copy of and conduct transfer operation in accordance with the operations manual/oil transfer procedures.
15. Sufficient personnel are on duty and conduct the transfer in accordance with the operations manual/oil transfer procedures.
16. Transfer conference has been held.
17. Lighting is provided between sunset and sunrise.
18. Fire fighting equipment laid out and ready for use.
19. Spill containment provisions are complied with.
20. Ability to move vessel in 30 minutes, under its own power, or with tug assistance.
21. Emergency towing wires rigged.
22. Doors/windows/ports closed. Ventilators trimmed.
23. Flame screens properly fitted where required/tank openings closed when possible.
24. Precautions regarding unauthorized craft along side.
25. Precautions regarding pump room entry, ventilation and bilges.
26. Anchors are up.
27. Safe access between vessel and terminal.
28. Noise abatement procedures discussed and understood.
29. Alcohol policy discussed and understood.

Verified by the TPIC and VPIC if Vapor Recovery System is used:

1. Vapor collection system is aligned to allow vapor to flow.

2. Vapor hose connected properly.
3. Electrical insulating device is fitted between connections.
4. Initial and maximum transfer rates are determined.
5. Maximum/minimum vapor connection pressure determined.
6. Tank barge overfill system connect to facility (if applicable).
7. Alarm/automatic shutdown tested/analyzer calibration.
8. Vapor hose is in good condition.
9. Inerted cargo tank oxygen content at or below 8%.

APPENDIX 5

NOTE: The following questionnaire includes the average responses for each of the scaled questions. 17 of 50 individuals responded to this questionnaire.

HOE PRELIMINARY QUESTIONNAIRE

Thank you for taking the time to complete this questionnaire. All responses are completely confidential and will be used as part of an ongoing project at U.C. Berkeley, whose goal is to help reduce the risk of oil pollution accidents at marine terminals.

Please answer all questions as honestly as possible. Feel free to comment or elaborate on back pages, or additional paper, if necessary. Please answer all questions independently, without consulting co-workers. Thank you again for your participation.

Organization:

Your Job Title/Position:

Your Crew # :

Day/Date Completed:

1. For each of the steps in a typical **LOADING** procedure, assess the level of risk in terms of the potential of a pollution accident:

	(circle a number)	(Avg.)
vessel arrival?	Low 1 2 3 4 5 6 7 High	1.9
hookup?	Low 1 2 3 4 5 6 7 High	2.8
startup?	Low 1 2 3 4 5 6 7 High	3.8
steady-rate?	Low 1 2 3 4 5 6 7 High	2.0
topping off?	Low 1 2 3 4 5 6 7 High	5.4
disconnect?	Low 1 2 3 4 5 6 7 High	4.0
departure?	Low 1 2 3 4 5 6 7 High	1.8

2. For each of the steps in a typical **DISCHARGE** procedure, assess the level of risk in terms of the potential of a pollution accident:

	(circle a number)	(Avg.)
vessel arrival?	Low 1 2 3 4 5 6 7 High	2.2
hookup?	Low 1 2 3 4 5 6 7 High	2.8
startup?	Low 1 2 3 4 5 6 7 High	3.7
steady-rate?	Low 1 2 3 4 5 6 7 High	2.0
topping off?	Low 1 2 3 4 5 6 7 High	3.5
disconnect?	Low 1 2 3 4 5 6 7 High	3.4
departure?	Low 1 2 3 4 5 6 7 High	1.9

3. What are the critical ways in which **you** personally attempt to prevent petroleum products from entering state waters?

4. How much latitude do you have in deciding what you will do during each of the steps in a typical loading and discharge operation?

	(circle a number)	(Avg.)
vessel arrival?	Low 1 2 3 4 5 6 7 High	2.7
hookup?	Low 1 2 3 4 5 6 7 High	4.0
startup?	Low 1 2 3 4 5 6 7 High	3.8
steady-rate?	Low 1 2 3 4 5 6 7 High	3.5
topping off?	Low 1 2 3 4 5 6 7 High	3.4
disconnect?	Low 1 2 3 4 5 6 7 High	4.0

departure? Low 1 2 3 4 5 6 7 High 2.2

5. What specific skills are required to do your job?

6. What training have you had that has been relevant to your job, both prior to your hiring, and while on the job?

7. What, if any, procedural changes would you suggest to decrease the chance of a pollution accident?

8. List all personnel you typically interact with (by position, not name) during typical loading and discharge operations (both on ship and on shore). Describe the nature of the interaction. (List as many as are applicable-write on back if necessary).

   a.
   b.
   c.
   d.
   e.

9. List all individuals from **outside agencies** you potentially interact with during a typical loading or discharge operation (i.e., individuals who are **not** employees of the terminal **or** the vessel). List by position or title and organizational affiliation. Do not list by specific name. (Please list as many as are applicable)

   Describe the nature of your relationship with these outside organizations and their representatives.

   a. Individual's Position or Title:
      Organization:
      How often do you interact with this individual/organization?
      Is this relationship helpful to you in preventing oil pollution accidents?
      In what ways?
      Is this relationship a hindrance to your ability to do your job in any way? Explain.

   b. Individual's Position or Title:
      Organization:

How often do you interact with this individual/organization?
Is this relationship helpful to you in preventing oil pollution accidents?
In what ways?
Is this relationship a hindrance to your ability to do your job in any way? Explain.

c. Individual's Position or Title:
Organization:
How often do you interact with this individual/organization?
Is this relationship helpful to you in preventing oil pollution accidents?
In what ways?
Is this relationship a hindrance to your ability to do your job in any way? Explain.

10. Given that a ship's or barge's tank overfilled and caused a spill, in your opinion, what is the probability that this failure can be attributed to the following factors:

	(Circle a number)	(Avg.)
human error?	Low 1 2 3 4 5 6 7 High	6.0
organizational factors (company)?	Low 1 2 3 4 5 6 7 High	2.4
environmental factors?	Low 1 2 3 4 5 6 7 High	2.0
system deficiencies (hardware)?	Low 1 2 3 4 5 6 7 High	5.0
operational procedures?	Low 1 2 3 4 5 6 7 High	2.4

10a. When due to **human factors**, what is the probability that it was due to:

		(Avg.)
ignorance?	Low 1 2 3 4 5 6 7 High	2.2
poor communications?	Low 1 2 3 4 5 6 7 High	4.5
preparation?	Low 1 2 3 4 5 6 7 High	3.5
slips/errors of judgment?	Low 1 2 3 4 5 6 7 High	4.8
poor selection and training?	Low 1 2 3 4 5 6 7 High	3.1
violations?	Low 1 2 3 4 5 6 7 High	2.2
limitations and impairments?	Low 1 2 3 4 5 6 7 High	2.4

mistakes?	Low 1 2 3 4 5 6 7 High	5.8

10b. When due to **organizational (company) factors**, what is the probability that it was due to:

		(Avg.)
organizational culture?	Low 1 2 3 4 5 6 7 High	2.2
organizational planning?	Low 1 2 3 4 5 6 7 High	3.0
organizational communications?	Low 1 2 3 4 5 6 7 High	3.5
organizational ignorance?	Low 1 2 3 4 5 6 7 High	2.5
organizational mistakes?	Low 1 2 3 4 5 6 7 High	2.8
lack of organizational monitoring?	Low 1 2 3 4 5 6 7 High	2.8
organizational structure?	Low 1 2 3 4 5 6 7 High	2.4
organizational violations?	Low 1 2 3 4 5 6 7 High	-

10c. When due to **environmental factors**, what is the probability that it was due to:

		(Avg.)
extreme temperatures?	Low 1 2 3 4 5 6 7 High	1.8
inadequate lighting?	Low 1 2 3 4 5 6 7 High	2.6
inclement weather (rain, wind,..)?	Low 1 2 3 4 5 6 7 High	3.2
strong currents?	Low 1 2 3 4 5 6 7 High	2.6

10d. When due to **system factors**, what is the probability that it was due to:

		(Avg.)
serviceability of the system?	Low 1 2 3 4 5 6 7 High	4.7
compatibility of the system?	Low 1 2 3 4 5 6 7 High	3.0
durability of the system?	Low 1 2 3 4 5 6 7 High	3.6
capacity of the system?	Low 1 2 3 4 5 6 7 High	2.9

10e. When due to **operational, procedural factors**, what is the probability that it was due to:

		(Avg.)
incorrect procedures?	Low 1 2 3 4 5 6 7 High	2.8
inaccurate procedures?	Low 1 2 3 4 5 6 7 High	2.9

poorly organized procedures?	Low 1 2 3 4 5 6 7 High	2.6
incomplete procedures?	Low 1 2 3 4 5 6 7 High	3.1
complex procedures?	Low 1 2 3 4 5 6 7 High	2.5
poorly documented procedures?	Low 1 2 3 4 5 6 7 High	2.9

11. Given that the vessel-to-shore chick stand connection failed, in your opinion, what is the probability that this failure can be attributed to the following factors:

		(Avg.)
human error?	Low 1 2 3 4 5 6 7 High	3.9
organizational factors (company)?	Low 1 2 3 4 5 6 7 High	2.8
environmental factors?	Low 1 2 3 4 5 6 7 High	2.1
system deficiencies (hardware)?	Low 1 2 3 4 5 6 7 High	4.9
operational procedures?	Low 1 2 3 4 5 6 7 High	2.5

11a. When due to **human factors**, what is the probability that it was due to:

		(Avg.)
ignorance?	Low 1 2 3 4 5 6 7 High	1.9
poor communications?	Low 1 2 3 4 5 6 7 High	3.1
preparation?	Low 1 2 3 4 5 6 7 High	2.9
slips/errors of judgment?	Low 1 2 3 4 5 6 7 High	3.5
poor selection and training?	Low 1 2 3 4 5 6 7 High	2.5.
violations?	Low 1 2 3 4 5 6 7 High	1.8
limitations and impairments?	Low 1 2 3 4 5 6 7 High	2.3
mistakes?	Low 1 2 3 4 5 6 7 High	4.1

11b. When due to **organizational (company) factors**, what is the probability that it was due to:

		(Avg.)
organizational culture?	Low 1 2 3 4 5 6 7 High	2.2
organizational planning?	Low 1 2 3 4 5 6 7 High	2.7
organizational communications?	Low 1 2 3 4 5 6 7 High	2.7
organizational ignorance?	Low 1 2 3 4 5 6 7 High	1.9
organizational mistakes?	Low 1 2 3 4 5 6 7 High	2.9
lack of organizational monitoring?	Low 1 2 3 4 5 6 7 High	2.5
organizational structure?	Low 1 2 3 4 5 6 7 High	2.2

organizational violations?	Low 1 2 3 4 5 6 7 High	1.9

11c. When due to **environmental factors**, what is the probability that it was due to:

		(Avg.)
extreme temperatures?	Low 1 2 3 4 5 6 7 High	1.9
inadequate lighting?	Low 1 2 3 4 5 6 7 High	2.6
inclement weather (rain, wind,..)?	Low 1 2 3 4 5 6 7 High	3.2
strong currents?	Low 1 2 3 4 5 6 7 High	3.1

11d. When due to **system factors**, what is the probability that it was due to:

		(Avg.)
serviceability of the system?	Low 1 2 3 4 5 6 7 High	4.3
compatibility of the system?	Low 1 2 3 4 5 6 7 High	3.2
durability of the system?	Low 1 2 3 4 5 6 7 High	4.0
capacity of the system?	Low 1 2 3 4 5 6 7 High	2.7

11e. When due to **operational, procedural factors**, what is the probability that it was due to:

		(Avg.)
incorrect procedures?	Low 1 2 3 4 5 6 7 High	2.5
inaccurate procedures?	Low 1 2 3 4 5 6 7 High	2.4
poorly organized procedures?	Low 1 2 3 4 5 6 7 High	2.5
incomplete procedures?	Low 1 2 3 4 5 6 7 High	2.6
complex procedures?	Low 1 2 3 4 5 6 7 High	2.1
poorly documented procedures?	Low 1 2 3 4 5 6 7 High	2.4

12. What, if any, system changes would you suggest to decrease the chance of a pollution accident?

13. What, if any, organizational changes would you suggest to decrease the chance of a pollution accident?

14. What, if any, changes would you suggest to decrease the chance of human error causing a pollution accident?

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