CONFIDENTIAL

    

Pipeline Risk Assessment and Environmental Consequence Analysis

March 2007

ENSR Corporation
March 2007
Document No.: 10623-004

ENSR | AECOM

Contents

List of Appendices

List of Tables

List of Figures

1.0 Project Overview

TransCanada Keystone Pipeline, L.P. (Keystone) proposes to construct and operate a crude oil pipeline and related facilities from Hardisty, Alberta, Canada, to Patoka, Illinois, in the United States (U.S.). The project, known as the Keystone Pipeline Project, initially will have the nominal capacity to deliver 435,000 barrels per day (bpd) of crude oil from an oil supply hub near Hardisty to existing terminals in Wood River and Patoka, Illinois. If market conditions warrant expansion in the future, additional pumping capacity could be added to increase the nominal average throughput to 591,000 bpd. Based on shipper interest, Keystone also is considering the construction of two pipeline extensions to take crude oil from terminals in Fort Saskatchewan, Alberta, and deliver to Cushing, Oklahoma.

In total, the Keystone Pipeline Project will consist of approximately 1,845 miles of pipeline, including about 767 miles in Canada and 1,078 miles within the U.S. **(Figure 1-1)**. These distances will increase if the potential pipeline extension to Cushing, Oklahoma, is constructed as discussed below.

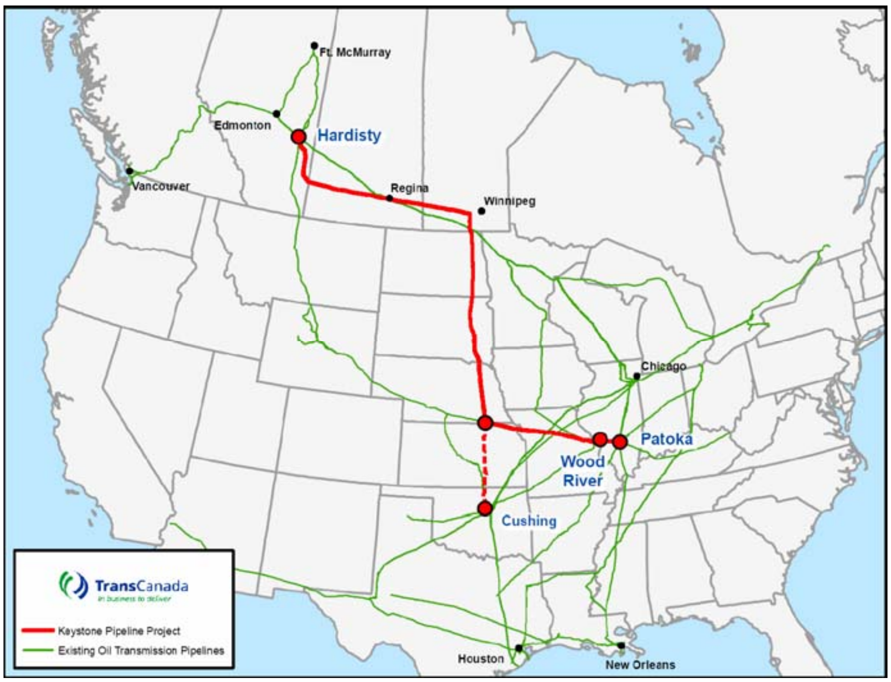

Figure 1-1 Overview Map of the Keystone Pipeline Project
(Potential Cushing Extension represented by the dotted line)

In the U.S., Keystone will construct and operate a new 1,078-mile pipeline (Keystone Mainline) that will transport crude oil from the Canadian border to existing terminals in the Midwest. The proposed pipeline will consist of 1,023 miles of 30-inch pipe between the Canadian border and Wood River, Illinois and a 55-mile segment of 24-inch pipeline between Wood River and Patoka, Illinois. Depending on the results of an additional binding Open Season held in early 2007, Keystone also may construct a 294-mile, 36-inch pipeline extension to Cushing, Oklahoma (Cushing Extension). Thus, there will be 1,372 total miles of new pipeline in the U.S. if the Cushing Extension is constructed. Unless specified, the remainder of this Risk Assessment describes and evaluates the U.S. portion of the Keystone Pipeline Project, including both the Keystone Mainline and Cushing Extension, and the additional facilities required to increase nominal capacity to 591,000 bpd.

The Keystone Pipeline Project will require the issuance of a Presidential Permit by the U.S. Department of State (DOS) to cross the U.S./Canadian border. Issuance of the Presidential Permit is considered a federal action and is subject to environmental review pursuant to the National Environmental Policy Act (NEPA) (42 United States Code § 4321 et seq.). In conjunction with the NEPA analysis, a preliminary evaluation of spill risk, including the likelihood of an inadvertent release, the probable size of a release, and the potential impacts of an accidental release was submitted to the DOS on July 1, 2006 and updated in this report. This document represents the final spill, risk, and consequence evaluation for the NEPA analysis, based on updated HCA information and new information on commodity composition.

2.0 Introduction

This document represents Keystone's final evaluation of the risk of a pipeline disruption and its potential environmental consequences for NEPA analysis. This section focuses on the potential for spills during operations and the subsequent potential effects on sensitive resources and humans associated with major spills. Additional effects on public health and safety that could occur during project construction are discussed under other resource sections (e.g., air quality, water resources, transportation, land use, and aesthetics) within the Keystone Pipeline Project's Environmental Report (ER), which was submitted to the DOS on April 19, 2006. An updated ER was submitted on November 17, 2006, and updated ER tables were submitted January 26, 2007.

This report builds upon the baseline information presented in the July 10, 2006 submission to the DOS. The report presents the results of a pipeline oil spill frequency and spill analysis based on Keystone's design and operations criteria and applies the resulting risk probabilities to an environmental consequence analysis that incorporates project-specific environmental data. Specifically, this report evaluates the risk of crude oil spills during pipeline operations, including contribution of natural hazards to spill risk, and the subsequent potential effects on humans and other sensitive resources, called high consequence areas (HCAs), that include populated areas, drinking water areas, and/or ecologically sensitive areas.

3.0 Spill Frequency-Volume Study

An updated project-specific oil spill frequency and volume study for the Keystone Pipeline Project was conducted by DNV Consulting and is provided in Appendix A. DNV Consulting assessed the U.S. portion of the Keystone Pipeline in terms of frequency and volume of potential spills to quantify the likelihood of realistic maximum spill volumes. The study estimated the frequency and volume of releases for each defined pipeline segment for three postulated hole sizes and six distinct and independent failure causes and developed a frequency-volume curve for the pipeline as a whole.

The study is a quantitative assessment of spill potential for the entire pipeline system and of individual segments of the pipeline utilizing publicly available historical spill data collected from incident reports (Appendix A). The Keystone Pipeline system was partitioned into 1,720 segments (1,356 segments on the Keystone Mainline and 364 segments on the Cushing Extension) based on design, operational, terrain, and other potential risk parameters. Spill frequency was estimated for each segment along with potential spill volumes, based on small holes (0.06-inch diameter), medium holes (2-inch diameter), and large holes (10-inch-diameter). The study evaluated two throughput scenarios; a nominal throughput of 435,000 bpd and a maximum nominal throughput of 591,000 bpd. The two product types that will be transported, synthetic crude and diluted bitumen, were assessed. The simulation assumed the Cushing Extension would operate under 591,000 bpd and carry diluted bitumen.

3.1 Spill Frequency

Spill frequencies were estimated from publicly available historical data and modified by project-specific factors for the Keystone Pipeline system. Based on the available information, the study produced frequencies for spills ranging from 0.9 spills per 10 years (at a throughput of 435,000 bpd of synthetic crude oil over the Keystone Mainline) to a maximum frequency for spills of 1.5 spills per 10 years (for a throughput of 591,000 bpd of diluted bitumen over the entire pipeline system). These rates are equivalent to one spill every 11 or 7 years, respectively. **Table 3-1** shows the number of spills that might occur along the Keystone Pipeline system during the 10 years of service.

Table 3-1 Spill Occurrence Interval Associated with the Proposed Keystone Project over 10 Years

	Projected Number of Spills per 10 years[1]			
	Diluted Bitumen (350 cSt Crude) 435 bpd	**Diluted Bitumen (350 cSt Crude) 591 bpd**	**Synthetic Crude 435 bpd**	**Synthetic Crude 591 bpd**
Keystone Mainline (1,078 miles)	0.94	1.18	0.90	0.93
Cushing Extension (294 miles)	NA[2]	0.32	NA[2]	NA[2]
Total Keystone Project (1,372 miles)	0.94	1.51	0.90	0.93

[1]See Appendix A.

While future events cannot be known with absolute certainty, spill frequencies can be used to estimate the number of events that might occur. Actual frequency may differ from the predicted values of this analysis. Notably, with the implementation of U.S. Department of Transportation's (USDOT) Integrity Management Rule, the number of spills is expected to decline from historical levels observed on other pipelines. Incident frequencies have been steadily decreasing and are five times lower in recent years compared with thirty years ago (EGIG 2005).

3.2 Spill Volume

Estimated spill volumes were based on leak rate and time to isolate for throughputs of 435,000 and 591,000 bpd along the Keystone Pipeline system. The study currently assumes draindown within the affected segment. Actual incident data from the *Hazardous Liquid Pipeline Risk Assessment* (California State Fire Marshal [CSFM] 1993) indicate that spill volumes are significantly less than the potential draindown volume. For example, in 50 percent of the cases, the actual spill volume represented less than 0.75 percent of the maximum potential draindown volume. In 75 percent of the cases, the actual spill volume represented less than 4.6 percent of the maximum draindown volume. Procedures to reduce spill volume, such as by reducing draindown and depressurizing are not estimated or included in the analysis. If these procedures were included, it may significantly reduce the predicted spill volumes estimated for the Keystone Pipeline, bringing the spill volume distribution more in line with USDOT historical data.

Of the postulated maximum of 1.5 spills along the Keystone Pipeline system during a 10-year period, the project-specific spill and volume study's findings suggest that approximately 0.3 spills would be 50 barrels[1] or less; 0.5 spills would consist of between 50 and 1,000 barrels; 0.5 spills would consist of between 1,000 and 10,000 barrels; and 0.2 spills would contain more than 10,000 barrels (Appendix A).

This Pipeline Risk Assessment and Environmental Consequence Analysis report utilizes publicly available historical spill data collected from incident reports over a number of decades. However, these data are unsuitable to support a comparable risk analysis associated with spills smaller than 50 barrels, since the historical threshold for reportable spills was 50 barrels. This threshold was only recently reduced from 50 barrels to 5 gallons, effective February 2002. The results of the study are incorporated into the environmental consequence analysis presented in Section 4.0.

The most extensive database of pipeline spills less than 50 barrels is maintained by the State of California (CSFM 1993). Based on these historical data, the estimated occurrence intervals for a spill of 50 barrels or less occurring anywhere along the entire pipeline system is once every 9 years, a spill between 50 and 1,000 barrels might occur once in 38 years; a spill of 1,000 and 10,000 barrels might occur once in 89 years; and a spill containing more than 10,000 barrels might occur once in 625 years. Applying these statistics to a 1-mile section, the chances of a large spill (greater than 10,000 barrels) would be less than once every 857,000 years per mile.

Historically, large spills of 10,000 barrels or more are uncommon. In California, approximately 1 percent of the spills occurring between 1981 and 1990 resulted in 10,000 barrels or more, with the largest spill consisting of 31,000 barrels (CSMF 1993). These statistics are similar to nationwide incident rates. For crude oil pipelines, there were a total of 26 spills of greater than 10,000 barrels between 1986 to present, representing 1.3 percent of all crude oil spills. **Table 3-2** provides a summary of crude oil spills greater than 10,000 barrels. Since 1986, the greatest volume of crude oil spilled in the U.S. was 49,000 barrels.

Keystone has estimated the maximum spill volumes along the pipeline. The highest projected spill volume for any single segment was 40,600 barrels, while the median maximum spill volume for all segments of the Keystone Pipeline was 16,500 barrels. Again, the probability of a very large spill (>30,000 barrels) is under 0.1 percent. Consequently, this report grouped the risk of very large spills together with spills of over 20,000 barrels.

---

[1] A barrel of oil equals 42 gallons.

Table 3-2 Summary of Historic Crude Oil Pipeline Spills of 10,000 Barrels or Greater

Year	Volume (barrels)
1986	10,020
1986	12,500
1986	14,000
1986	18,000
1988	20,554
1988	23,534
1988	10,000
1989	12,000
1989[1]	31,300
1990	20,027
1990	12,000
1991	40,500
1991	28,200
1995	30,000
1997	11,206
1998	12,884
1998	17,806
1998	32,903
1999	10,500
1999	15,007
1999	10,205
2000	11,644
2005	25,435
2005	23,614
2005	10,380
2006	49,000
2006	15,000
Total Number of Recorded Crude Oil Spills	*1935*
Spills >10,000 Barrels Crude Oil as Percent of Total Recorded Crude Oil Spills	*1.4*

[1]Represents the largest spill reported in the California State Fire Marshal study (1993).

Note: Data represents information from the USDOT OPS Hazardous Liquid Accident Data databases (1986 to January 2002 and January 2002 to Present) (USDOT 2007).

4.0 Consequences of a Spill

4.1 Human Consequences

The risk associated with the Keystone Pipeline system can be compared with the general risk to the population encountered in everyday life. Proposed actions that result in negligible additional risk from any cause are generally acceptable. The National Center for Health Statistics (CDC 2003) overall average annual death rate for the general population in the U.S. is approximately 830 per 100,000. The USDOT reports the historical average risk to the general population per year associated with all hazardous liquids transmission pipelines, such as Keystone, is 0.004 in100,000 (USDOT 2002). Therefore, the predicted risk of fatality to the public from incidents associated with the Keystone Pipeline over and above the normal U.S. death rate is negligible (<1 percent).

4.2 Environmental Consequences

The environmental risk posed by a crude oil pipeline is a function of 1) the probability of an accidental release, 2) the probability of a release reaching an environmental receptor (e.g., waterbody, fish), 3) the concentration of the contamination once it reaches the receptor, and 4) the hazard posed by that concentration of crude oil to the receptor. Based on spill probabilities and estimated spill volumes, this environmental assessment determines the probability of exposure to environmental receptors and the probable impacts based on a range of potential concentrations.

4.2.1 Environmental Fate of Crude Oil Spills

4.2.1.1 Crude Oil Composition

The composition of crude oil varies widely, depending on the source and processing. Crude oils are complex mixtures of hundreds of organic (and a few inorganic) compounds. These compounds differ in their solubility, toxicity, persistence, and other properties that profoundly affect their impact on the environment. The effects of a specific crude oil cannot be thoroughly understood without taking its composition into account.

Crude oil transported by the Keystone Pipeline Project is derived from the Alberta oil sands region. The oil extracted from the sands is called bitumen, which is highly viscous. In order for the bitumen to be transported by pipeline, it is either mixed with diluent and is transported as diluted bitumen or upgraded to synthetic crude oil. The precise composition of synthetic crude will vary by shipper and is considered proprietary information. For the purposes of this analysis, two product types of crude oil will be transported; synthetic crude and diluted bitumen. In general, the pipeline will contain batches of these two products and 10 percent of batches will be synthetic crude and 90 percent of batches will be diluted bitumen.

The primary classes of compounds found in crude oil are alkanes (hydrocarbon chains), cycloalkanes (hydrocarbons containing saturated carbon rings), and aromatics (hydrocarbons with unsaturated carbon rings). Most crude oils are more than 95 percent carbon and hydrogen, with small amounts of sulfur, nitrogen, oxygen, and traces of other elements. Crude oils contain lightweight straight-chained alkanes (e.g., hexane, heptane), cycloalkanes (e.g., cyclyohexane), aromatics (e.g., benzene, toluene), cycloalkanes, and heavy aromatic hydrocarbons (e.g., polycyclic aromatic hydrocarbons [PAHs], asphaltines). Straight-chained alkanes are more easily degraded in the environment than branched alkanes. Cycloalkanes are extremely resistant to biodegradation. Aromatics (i.e., benzene, toluene, ethylbenzene, xylenes [BTEX compounds]) pose the most potential for environmental concern. Because of their lower molecular weight they are more soluble in water than alkanes and cycloalkanes.

4.2.1.2 Environmental Fate and Transport

Accidental releases of crude oil can occur during transport by pipeline. Once released into the terrestrial environment, the crude oil will pool in low-lying areas. Some lighter volatile constituents of the crude oil will evaporate into air, while other constituents will bind or leach into soils, or dissolve into water. Hydrocarbons that volatilize into the atmosphere are broken down by sunlight into smaller compounds. This process, referred to as photodegradation, occurs rapidly in air and the rate of photodegradation increases as molecular weight increases. If released onto soil, a portion of the crude oil will penetrate the soil as a result of the effects of gravity and capillary action. The rate of penetration will depend on the nature of the soil. Since crude oil is more viscous than water, crude oils penetrate soils less quickly. When released into water, a portion of the crude oil will tend to float to the surface where it can evaporate, other fractions will dissolve, and some material may descend to the bottom as sedimentation.

The spread of crude oil across water increases with wind and current speed and increasing temperature. Most crude oils spread across surface waters at a rate of 100 to 300 meters per hour. Surface ice will greatly reduce the spreading rate of oil across a waterbody. Spreading reduces the bulk quantity of crude oil present in the vicinity of the spill but increases the spatial area within which adverse effects may occur. Thus crude oil in flowing, as opposed to contained, waterbodies will be less concentrated in any given location, but may cause impacts, albeit reduced in intensity, over a much larger area. Spreading and thinning of spilled crude oil also increases the surface area of the slick, thus enhancing surface dependent fate processes such as evaporation, degradation, and dissolution.

Dispersion of crude oil increases with increasing surface turbulence. The dispersion of crude oil into water may serve to increase the surface area of crude oil susceptible to dissolution and degradation processes and thereby limit the potential for physical impacts.

Evaporation will be the primary mechanism of loss for low molecular weight constituents and light oil products. As lighter components evaporate, remaining crude oil becomes denser and more viscous. Evaporation thus tends to reduce crude oil toxicity but enhances crude oil persistence. Bulk evaporation of Alberta crude oil accounted for an almost 50 percent reduction in volume over a 12-day period (Shiu et al. 1988). Evaporation increases with increased spreading of a slick, increased temperature, and increased wind and wave action.

Dissolution of crude oil in water is not a significant process controlling the crude oil's fate in the environment, since most components of oils are relatively insoluble (Neff and Anderson 1981). Moreover, overall solubility of crude oils tend to be less than their constituents since solubility is limited to the partitioning between oil and water interface and individual compounds are often more soluble in oil than in water, thus they tend to remain in the oil. Nevertheless, dissolution is one of the primary processes affecting the toxic effects of a spill, especially in confined waterbodies. Dissolution increases with decreasing molecular weight, increasing temperature, decreasing salinity, and increasing concentrations of dissolved organic matter. Greater photodegradation also tends to enhance the solubility of crude oil in water.

Heavy molecular weight hydrocarbons will bind to suspended particulates, and this process can be significant in highly turbid or eutrophic waters. Organic particles (e.g., biogenic material) tend to be more effective at sorbing oils than inorganic particles (e.g., clays). Sorption processes and sedimentation reduce the quantity of heavy hydrocarbons present in the water column and available to aquatic organisms. However, these processes also render hydrocarbons less susceptible to degradation. Sedimented oil tends to be highly persistent and can cause shoreline impacts.

Photodegradation of crude oil increases with greater solar intensity. It can be a significant factor controlling the disappearance of a slick, especially of lighter oil constituents; but it will be less important during cloudy days and winter months. Photodegraded crude oil constituents tend to be more soluble and more toxic than parent compounds. Extensive photodegradation, like dissolution, may thus increase the biological impacts of a spill event.

In the immediate aftermath of a crude oil spill, natural biodegradation of crude oil will not tend to be a significant process controlling the fate of spilled crude oil in waterbodies previously unexposed to oil. Microbial populations must become established before biodegradation can proceed at any appreciable rate. Also, prior to weathering (i.e., evaporation and dissolution of light-end constituents), oils may be toxic to the very organisms responsible for biodegradation and high molecular weight constituents tend to be resistant to biodegradation. Biodegradation is nutrient and oxygen demanding and may be precluded in nutrient-poor aquatic systems. It also may deplete oxygen reserves in closed waterbodies, causing adverse secondary effects to aquatic organisms.

With time, however, microorganisms capable of consuming crude oil generally increase in number and the biodegradation process naturally remediates the previously contaminated soil. The biodegradation process is enhanced as the surface area of spilled oil increases (e.g., by dispersion or spreading). Biodegradation has been shown to be an effective method of remediating soils and sediments contaminated by crude oil.

Overall, the environmental fate of released crude oil is controlled by many confounding factors and persistence is difficult to predict with great accuracy. Major factors affecting the environmental fate include spill volume, type of crude oil, dispersal rate of the crude oil, terrain, receiving media, and weather. Once released, the physical environment largely dictates the environmental persistence of the spilled material. Along the Keystone Pipeline route, the primary habitats of concern include low gradient streams, rivers, and small intermittent ponds. Wetlands also occur along the proposed pipeline route. Estimates of the length of time materials could persist at potentially acute concentrations vary depending on the size of spill and environmental conditions. In warm summer months, the acutely toxic volatile component of crude oil will evaporate quickly, and a relatively small release into a high gradient stream would be expected to rapidly dissipate. In contrast, crude oil released into a small stream in winter could become trapped under pockets of ice and, thus persist longer.

4.2.2 Environmental Impacts

An evaluation of the potential impacts resulting from the accidental release of crude oil into the environment is discussed by environmental resource below.

4.2.2.1 Soils

Because pipelines are buried, soil absorption of spilled crude oil could occur, thus impacting the soils. Subsurface releases to soil tend to disperse slowly and are generally located within a contiguous and discrete area. Effects to soils can be quite slow to develop, allowing time for emergency response and cleanup actions to mitigate effects to potential receptors.

In the event of a spill, a portion of the released materials would enter the surrounding soil and disperse both vertically and horizontally in the soil. The extent of dispersal would depend on a number of factors, including size and rate of release, topography of the release site, vegetative cover, soil moisture, bulk density and soil porosity. High rates of release from the buried pipeline would result in a greater likelihood that released materials would reach the ground surface.

The majority of crude oil from an underground pipeline spill would likely reside in the less consolidated soil (lower soil bulk density) within the pipeline trench. If a release were to occur in sandy soils found throughout the Keystone pipeline or badland areas, it is likely that the horizontal and vertical extent of the contamination would be greater than in areas containing more organic soils. Crude oil released into sandy or badland soils would likely become visible to aerial surveillance due to product on the soils surface or discoloration of vegetation. If present, soil moisture and moisture from precipitation would increase the dispersion and migration of crude oil.

The vast majority of the Keystone pipeline is located in relatively flat terrain. In these flat locations, the oil would disperse horizontally within the pipeline trench with a smaller portion of the spilled oil moving into the surrounding, more consolidated soil. If the spill were to occur on a steep slope, crude oil would likely pool primarily within the trench behind any trench breakers. If sufficient volume existed, the crude oil would breach the soil's surface as it extended over the top of the trench breaker. Once on the soil's surface, the release would be more apparent to leak surveillance patrols.

Both on the surface and in the subsurface, rapid attenuation of light, volatile constituents (due to volatilization) would quickly reduce the total volume of product, while heavier constituents would be more persistent. Except in cases of high rate and high total volume releases, and environmental settings characterized by steep topography or karst terrain, soil impacts would be confined to a relatively small, contiguous, and easily defined area. This would facilitate cleanup and remediation. Within a relatively short time, lateral migration would generally stabilize and downward vertical migration could begin to occur.

Keystone would be responsible for cleanup of contaminated soils. Once remedial cleanup levels were achieved in the soils, no adverse or long-term impacts would be expected.

The maximum volume of soil that would need to be removed was estimated for a conservative spill volume of 2,000 barrels (over 80 percent of historical spills from modern pipelines are smaller than this volume [OPS 2007]). The volume of soil requiring removal ranged from 2,100 to 2,000,000 cubic yards. Soil cleanup levels for benzene from petroleum releases vary by state (Nebraska: 3.63 parts per million [ppm]; Illinois: 1.6 ppm; South Dakota: 17 ppm; Kansas 9.8 ppm). The highest volume was calculated assuming uniform distribution of oil and removal to achieve the most stringent state recommended soil cleanup level (RCL) for benzene (1.6 ppm). The lowest volume estimated assumes the same 2,000 barrel release but calculates the volume of soil based on an estimated 30 percent soil porosity and a 10 percent soil moisture content. The actual remediation soil volume would likely be intermediate to these values, though closer to the lowest volume estimate.

These estimates are gross estimations. Release dynamics such as leak rate, leak duration, and effects of isolation controls would result in different surface spreading and infiltration rates, which in turn, affect the final volume of affected soil to be remediated.

4.2.2.2 Vegetation and Soil Ecosystems

Crude oil released to the soil's surface could potentially produce localized effects on plant populations. Terrestrial plants are much less sensitive to crude oil than aquatic species. The lowest toxicity threshold for terrestrial plants found in the USEPA ECOTOX database (USEPA 2001) was 18.2 ppm for benzene, higher than the 7.4 ppm threshold for aquatic species and the 0.005 ppm threshold for human drinking water. Similarly, available data from the USEPA database indicate that earthworms also are less sensitive than aquatic species (toxicity threshold was greater than 1,000 ppm). If concentrations were sufficiently high, crude oil in the root zone could harm individual plants and organisms.

Release of crude oil could result in the contamination of soils (see Soils, Section 4.2.2.1 above). Keystone would be responsible for cleanup of contaminated soils. Once remedial cleanup levels were achieved in the soils, no adverse or long-term impacts to vegetation would be expected.

4.2.2.3 Wildlife

Spilled crude oil can affect organisms directly and indirectly. Direct effects include physical processes, such as oiling of feathers and fur, and toxicological effects, which can cause sickness or death. Indirect effects are less conspicuous and include habitat impacts, nutrient cycling disruptions, and alterations in ecosystem relationships. The magnitude of effects varies with multiple factors, the most significant of which include the amount of material released, the size of the spill dispersal area, the type of crude oil spilled, the species assemblage present, climate, and the spill response tactics employed.

Wildlife, especially birds and shoreline mammals, are typically among the most visibly affected organisms in any crude oil spill. Effects of crude oil can be differentiated into physical (mechanical) and toxicological (chemical) effects. Physical effects result from the actual coating of animals with crude oil, causing reductions in thermal insulative capacity and buoyancy of plumage (feathers) and pelage (fur).

Crude oil released to the environment may cause adverse biological effects on birds and mammals via inhalation or ingestion exposure. Ingestion of crude oil may occur when animals consume oil-contaminated food, drink oil-contaminated water, or orally consume crude oil during preening and grooming behaviors.

Potential adverse effects could result from direct acute exposure. Acute toxic effects include drying of the skin, irritation of mucous membranes, diarrhea, narcotic effects, and possible death. While releases of crude oil may have an immediate and direct effect on wildlife populations, the potential for physical and toxicological effects attenuates with time as the volume of material diminishes, leaving behind more persistent, less volatile, and less water-soluble compounds. Although many of these remaining compounds are toxic and potentially carcinogenic, they do not readily disperse in the environment and their bioavailability is low, and therefore, the potential for impacts is low.

Unlike aquatic organisms that frequently cannot avoid spills in their habitats, the behavioral responses of terrestrial wildlife may help reduce potential adverse effects. Many birds and mammals are mobile and generally will avoid oil-impacted areas and contaminated food (Sharp 1990; Stubblefield et al. 1995). In a few cases, such as cave-dwelling species, organisms that are obligate users of contaminated habitat may be exposed. However, most terrestrial species have alternative, unimpacted habitat available, as will often be the case with localized spills (in contrast to large-scale oil spills in marine systems), therefore, mortality of these species would be limited (Stubblefield et al. 1995).

Indirect environmental effects of spills can include reduction of suitable habitat or food supply. Primary producers (e.g., algae and plants) may experience an initial decrease in primary productivity due to physical effects and acute toxicity of the spill. However, these effects tend to be short-lived and a decreased food supply is not considered to be a major chronic stressor to herbivorous organisms after a spill. If mortality occurs to local invertebrate and wildlife populations, the ability of the population to recover will depend upon the size of the impact area and the ability of surrounding populations to repopulate the area.

4.2.2.4 Water Resources

Crude oil could be released to water resources if the pipeline is breached or leaks occur. As part of project planning and in recognition of the environmental sensitivity of waterbodies, the Keystone Pipeline routing process attempted to minimize the number waterbodies crossed, including groundwater aquifers. Furthermore, valves have been strategically located along the Keystone Pipeline to help reduce the amount of crude oil that could potentially spill into waterbodies, if such an event were to occur. The location of valves, spill containment measures, and implementing actions in the Keystone Emergency Response Plan would mitigate adverse effects to both surface and groundwater.

<u>Groundwater</u>

Multiple groundwater aquifers underlie the proposed Keystone Pipeline system. Vulnerability of these aquifers is a function of the depth to groundwater and the permeability of the overlying soils. While routine operation of the Keystone Pipeline would not affect groundwater, there is the possibility that a release could migrate through the overlying surface materials and enter a groundwater system.

In general, the potential for groundwater contamination following a spill would be more probable in locations where a release into or on the surface of soils has occurred:

- Where a relatively shallow water table is present (as opposed to locations where a deeper, confined aquifer system is present);
- Where relatively porous soil conditions are present throughout the unsaturated zone; and
- Where, in cooperation with federal and state agencies, the USDOT has identified groundwater resources that are particularly vulnerable to contamination. These resources are designated as HCAs (Section 4.3.2).

Depending on soil properties, the depth to groundwater, and the amount of crude oil in the unsaturated zone, groundwater contamination can result from the migration of dissolved constituents and free crude oil. Movement in the dissolved phase typically extends for greater distances than movement of pure crude oil in the subsurface. Crude oil is less dense than water and initially would tend to form a floating pool after reaching the groundwater surface. This pool would tend to migrate laterally in the direction of groundwater flow, and the oil flow velocity would be a function of the soil properties and groundwater flow rate. Those compounds in the crude oil that are soluble in water will form a larger, dissolved "plume." This plume also would tend to migrate laterally in the direction of groundwater flow. The flow velocity of dissolved constituents also would be a function of the groundwater flow rate and would tend to migrate at a faster rate than free crude oil itself.

The extent to which groundwater may be contaminated by a release of crude oil depends upon the rate of contaminant transport in the subsurface. The rate of contaminant movement depends, in turn, on the rate of groundwater movement and the attenuation mechanisms that act to retard contaminant movement. In shallow aquifer systems where impacts from released crude oil are most likely, the rate of groundwater movement depends upon the hydraulic gradient, aquifer permeability and porosity, and the geometry of the aquifer system. Groundwater flow rates typically move less than 1 foot per year, though there can be much more rapid movement in individual locations (Wilson 1986). Individual constituents tend to move faster than the groundwater itself; however, contamination often takes years to decades to disperse one mile from the point of origin (Wilson 1986).

If exposure to humans or other important resources would be possible from a release into groundwater, then regulatory standards, such as drinking water criteria (maximum contaminant levels [MCL]) would mandate the scope of remedial actions, timeframe for remediation activities, and cleanup levels. The promulgated drinking water standards for humans vary by several orders of magnitude for crude oil constituents. For human health protection, the national MCL is an enforceable standard established by the U.S. Environmental Protection Agency (USEPA) and is designed to protect long-term human health. Of the various crude oil constituents, benzene has the lowest national MCL at 0.005 ppm[2] and, therefore, it was used to evaluate impacts on drinking water supplies, whether from surface waters or groundwaters.

However, response and remediation efforts have the potential for appreciable adverse effects from construction/cleanup equipment. If no active remediation activities were undertaken, natural biodegradation and attenuation would ultimately allow a return to preexisting conditions in both soil and groundwater. Depending on the amount of crude oil reaching the groundwater and natural attenuation rates, this would likely require up to tens of years. Keystone will utilize the most appropriate cleanup procedure as determined in cooperation with the applicable federal and state agencies.

Attenuation mechanisms that retard the movement of contaminants include dispersion, sorption, volatilization, abiotic chemical degradation, and biological degradation. The extent to which any of these mechanisms would retard contaminant movement at a given location depends upon site-specific conditions. In general, crude oil in groundwater tends to biodegrade as described for soil releases. Even in the case of large released volumes and floating free crude oil, dispersive forces become balanced with biodegradation and attenuation

[2] All affected states along the Keystone Pipeline route use the national MCL value of 0.005 ppm.

mechanisms, establishing degradation equilibrium. The typical result is a relatively limited zone of impact, typically 200 meters or less downgradient (USGS 1998). Over time, these natural degradation mechanisms, along with other natural attenuation mechanisms, including dispersion, result in the removal and/or destruction of crude oil materials; both in groundwater, and in overlying impacted soils. Observed degradation rates indicate this process would typically occur in timeframes measured in tens of years, depending on the concentration of crude oil in the groundwater.

Flowing Surface Waters

The USDOT, in cooperation with federal and state agencies, has identified surface water resources that are particularly vulnerable to contamination. These surface water resources are designated as HCAs (Section 4.3.2). Broadly, this report evaluated impacts to downstream drinking water sources by comparing projected surface water benzene concentrations with the national MCL for benzene. Rather than evaluate the risk to each waterbody crossed by the Keystone Pipeline, this risk assessment evaluated categories of streams, based on the magnitude of streamflow and stream width. **Table 4-1** summarizes the stream categories used for the assessment and identifies several representative streams within these categories.

Table 4-1 Stream Categories

	Streamflow (cubic feet per second; cfs)	Stream Width (feet)	Representative Streams
Low Flow Stream	10 – 100	<50	Shell Creek, Mill Creek
Lower Moderate Flow Stream	100 – 1,000	50 – 500	Pembina Creek, James River, Sheyenne River, Cuivre River
Upper Moderate Flow Stream	1,000 – 10,000	500 – 1,000	Platte River, Chariton River, Missouri River
High Flow Stream	>10,000	1,000 – 2,500	Mississippi River

It was conservatively assumed that the entire volume of a spill was released directly into a waterbody and that complete, instantaneous mixing occurred. A 1-hour release period for the entire spill volume was assumed in order to maximize the product concentration in water. The estimated benzene concentrations were then compared with the human health drinking water MCL for benzene (**Tables 4-2** through **4-5)**. Results suggest that most spills that enter a waterbody could result in exceedence of the national MCL for benzene. Although the assumptions used are highly conservative and, thus, overestimate potential benzene water concentrations, the results emphasize the need for rapid notification of managers of municipal water intakes downstream of a spill so that any potentially affected drinking water intakes could be closed to bypass river water containing crude oil.

In addition to evaluating a spill to generic flowing water, the potential for impacts to any specific waterbody were also evaluated. To do this, the occurrence interval for a spill at any one representative stream within one of the four stream categories was calculated based on spill probabilities generated from the USDOT database. To be conservative, a 500-foot buffer on either side of the river was added to the crossing widths identified in **Table 4-1**. The occurrence intervals shown on **Tables 4-2** through **4-5** indicate the chance of a spill occurring at any specific waterbody is very low. Depending on throughput and transported material, occurrence intervals for a spill at any representative stream within any of the stream categories ranged from about 250,000 years for a large waterbody to over 6,800,000 years for a small waterbody (less likely to occur in any single small waterbody than any single large waterbody). If any release did occur, it is likely that the total

Table 4-2 Comparison of Estimated Benzene Concentrations from 435,000 bpd Throughput Diluted Bitumen (350cSt Crude Oil) Release with the Benzene MCL

Throughput 435,000 bpd	Benzene MCL (ppm)	Stream Flow Rate (cfs)	Product Released: Small spill: 50 barrels		Moderate spill: 1,000 barrels		Large spill: 10,000 barrels		Very Large spill: 20,000 barrels	
			Benzene Conc. (ppm)	Occurrence Interval (years)	Benzene Conc. (ppm)	Occurrence Interval (years)	Benzene Conc. (ppm)	Occurrence Interval (years)	Benzene Conc. (ppm)	Occurrence Interval (years)
Low Flow Stream	0.005	10	**11**	**5,905,509**	**217**	**1,344,412**	**2175**	**1,877,913**	**4349**	**5,218,915**
Lower Moderate Flow Stream	0.005	100	**1**	**4,133,856**	**22**	**941,089**	**217**	**1,314,539**	**435**	**3,653,240**
Upper Moderate Flow Stream	0.005	1,000	**0.1**	**3,100,392**	**2.2**	**705,816**	**22**	**985,904**	**43**	**2,739,930**
High Flow Stream	0.005	10,000	**0.01**	**1,771,623**	**0.2**	**403,324**	**2.2**	**563,374**	**4.3**	**1,565,674**

Notes:

-Historical data indicate that the most probable spill volume would be less than 50 barrels. However, this analysis is based on the spill frequencies and volumes calculated from complete draindown (Appendix A), which overestimates the proportion of larger spills. Consequently, the assessment is conservative in its evaluation on the magnitude of environmental consequences.

-The Keystone pipeline is estimated to transport diluted bitumen (350 cSt crude oil) 90% of the time for the purposes of this analysis.

-Estimated concentration is based on release of benzene into water over a 1-hour period with uniform mixing conditions.

-Concentrations are based on a 0.15 percent by weight benzene content of the transported material.

-Shading indicates estimated benzene concentrations that could exceed the benzene MCL of 0.005 ppm.

-Occurrence intervals are based on an overall predicted incident frequency of 0.094 spills/year for 435,000 bpd along the Keystone Pipeline Mainline (Appendix A), projected frequencies of each spill volume, and estimated stream widths. Widths of higher flow streams are greater than widths of lower flow streams, with more distance where an incident might occur. This results in a greater predicted frequency for high flow streams and a corresponding lower occurrence interval.

Table 4-3 Comparison of Estimated Benzene Concentrations from 435,000 bpd Throughput Synthetic Crude Release with the Benzene MCL

Throughput – 435,000 bpd	Benzene MCL (ppm)	Stream Flow Rate (cfs)	Product Released							
			Small spill: 50 barrels		Moderate spill: 1,000 barrels		Large spill: 10,000 barrels		Very Large spill: 20,000 barrels	
			Benzene Conc. (ppm)	Occurrence Interval (years)	Benzene Conc. (ppm)	Occurrence Interval (years)	Benzene Conc. (ppm)	Occurrence Interval (years)	Benzene Conc. (ppm)	Occurrence Interval (years)
Low Flow Stream	0.005	10	**1**	**6,842,909**	**27**	**1,403,496**	**269**	**2,089,507**	**538**	**6,648,130**
Lower Moderate Flow Stream	0.005	100	**0.1**	**4,790,037**	**2.7**	**982,447**	**27**	**1,462,655**	**54**	**4,653,691**
Upper Moderate Flow Stream	0.005	1,000	**0.01**	**3,592,527**	**0.3**	**736,835**	**3**	**1,096,991**	**5.4**	**3,490,268**
High Flow Stream	0.005	10,000	0.001	2,052,873	**0.03**	**421,049**	**0.3**	**626,852**	**0.5**	**1,994,439**

Notes:

-Historical data indicate that the most probable spill volume would be less than 50 barrels. However, this analysis is based on the spill frequencies and volumes calculated from complete draindown (Appendix A), which overestimates the proportion of larger spills. Consequently, the assessment is conservative in its evaluation on the magnitude of environmental consequences.

-The Keystone pipeline is estimated to transport synthetic crude oil 10% of the time for the purposes of this analysis.

-Estimated concentration is based on release of benzene into water over a 1-hour period with uniform mixing conditions.

-Concentrations are based on a 0.02 percent by weight benzene content of the transported material.

-Shading indicates estimated benzene concentrations that could exceed the MCL of 0.005 ppm.

-Occurrence intervals are based on an overall predicted incident frequency of 0.090 spills/year for 435,000 bpd along the Keystone Pipeline Mainline (Appendix A), projected frequencies of each spill volume, and estimated stream widths. Widths of higher flow streams are greater than widths of lower flow streams, with more distance where an incident might occur. This results in a greater predicted frequency for high flow streams and a corresponding lower occurrence interval.

Table 4-4 Comparison of Estimated Benzene Concentrations from 591,000 bpd Throughput Diluted Bitumen (350cSt Crude Oil) Release with the Benzene MCL

			Product Released							
			Small spill: 50 barrels		Moderate spill: 1,000 barrels		Large spill: 10,000 barrels		Very Large spill: 20,000 barrels	
Throughput – 591,000 bpd	Benzene MCL (ppm)	Stream Flow Rate (cfs)	Benzene Conc. (ppm)	Occurrence Interval (years)	Benzene Conc. (ppm)	Occurrence Interval (years)	Benzene Conc. (ppm)	Occurrence Interval (years)	Benzene Conc. (ppm)	Occurrence Interval (years)
Low Flow Stream	0.005	10	**11**	**1,494,147**	**217**	**857,465**	**2175**	**954,506**	**4349**	**2,402,322**
Lower Moderate Flow Stream	0.005	100	**1**	**1,045,903**	**22**	**600,226**	**217**	**668,154**	**435**	**1,681,625**
Upper Moderate Flow Stream	0.005	1,000	**0.1**	**784,427**	**2.2**	**450,169**	**22**	**501,116**	**43**	**1,261,217**
High Flow Stream	0.005	10,000	**0.01**	**448,244**	**0.2**	**257,240**	**2.2**	**286,352**	**4.3**	**720,697**

Notes:

-Historical data indicate that the most probable spill volume would be less than 50 barrels. However, this analysis is based on the spill frequencies and volumes calculated from complete draindown (Appendix A), which overestimates the proportion of larger spills. Consequently, the assessment is conservative in its evaluation on the magnitude of environmental consequences.

-The Keystone pipeline is estimated to transport diluted bitumen (350 cSt crude oil) 90% of the time for the purposes of this analysis.

-Estimated concentration is based on release of benzene into water over a 1-hour period with uniform mixing conditions.

-Concentrations are based on a 0.15 percent by weight benzene content of the transported material.

-Shading indicates estimated benzene concentrations that could exceed the MCL of 0.005 ppm.

-Occurrence intervals are based on an overall predicted incident frequency of 0.151 spills/year for 591,000 bpd along the entire Keystone Pipeline (Appendix A), projected frequencies of each spill volume, and estimated stream widths. Widths of higher flow streams are greater than widths of lower flow streams, with more distance where an incident might occur. This results in a greater predicted frequency for high flow streams and a corresponding lower occurrence interval.

Table 4-5 Comparison of Estimated Benzene Concentrations from 591,000 bpd Throughput Synthetic Crude Release with the Benzene MCL (the Occurrence Interval

Throughput – 591,000 bpd	Benzene MCL (ppm)	Stream Flow Rate (cfs)	Product Released							
			Small spill: 50 barrels		Moderate spill: 1,000 barrels		Large spill: 10,000 barrels		Very Large spill: 20,000 barrels	
			Benzene Conc. (ppm)	Occurrence Interval (years)	Benzene Conc. (ppm)	Occurrence Interval (years)	Benzene Conc. (ppm)	Occurrence Interval (years)	Benzene Conc. (ppm)	Occurrence Interval (years)
Low Flow Stream	0.005	10	**1**	**6,094,152**	**27**	**1,358,541**	**269**	**1,927,825**	**538**	**5,442,000**
Lower Moderate Flow Stream	0.005	100	**0.1**	**4,265,906**	**2.7**	**950,979**	**27**	**1,349,478**	**54**	**3,809,400**
Upper Moderate Flow Stream	0.005	1,000	**0.01**	**3,199,430**	**0.3**	**713,234**	**2.7**	**1,012,108**	**5**	**2,857,050**
High Flow Stream	0.005	10,000	0.001	1,828,246	**0.03**	**417,562**	**0.3**	**578,348**	**0.5**	**1,632,600**

Notes:

-Historical data indicate that the most probable spill volume would be less than 50 barrels. However, this analysis is based on the spill frequencies and volumes calculated from complete draindown (Appendix A), which overestimates the proportion of larger spills. Consequently, the assessment is conservative in its evaluation on the magnitude of environmental consequences.

-The Keystone pipeline is estimated to transport synthetic crude oil 10% of the time for the purposes of this analysis.

-Estimated concentration is based on release of benzene into water over a 1-hour period with uniform mixing conditions.

-Concentrations are based on a 0.02 percent by weight benzene content of the transported material.

-Shading indicates estimated benzene concentrations that could exceed the MCL of 0.005 ppm.

-Occurrence intervals are based on an overall predicted incident frequency of 0.093 spills/year for 591,000 bpd along the Keystone Pipeline Mainline (Appendix A), projected frequencies of each spill volume, and estimated stream widths. Widths of higher flow streams are greater than widths of lower flow streams, with more distance where an incident might occur. This results in a greater predicted frequency for high flow streams and a corresponding lower occurrence interval.

release volume of a spill likely would be 50 barrels or less based on historical spill volumes, or less than 10,000 barrels based on the spill volume study (Appendix A).

In summary, while a release of crude oil directly into any given waterbody would likely cause an exceedance of drinking water standards, the frequency of such an event would be low. Nevertheless, streams and rivers with downstream drinking water intakes represent sensitive environmental resources and could be temporarily impacted by a crude oil release. The Emergency Response Plan contains provisions for protecting and mitigating potential impacts to drinking water.

Aquatic Organisms

The concentration of crude oil constituents in an actual spill would vary both temporally and spatially in surface water, however, localized toxicity could occur from virtually any size of crude oil spill. **Table 4-6** summarizes the acute toxicity values (USEPA AQUIRE database 2000) of various crude oil hydrocarbons to a broad range of freshwater species. Acute toxicity refers to the death or complete immobility of an organism within a short period of exposure. The LC_{50} is the concentration of a compound necessary to cause 50 percent mortality in laboratory test organisms. For aquatic biota, most acute LC_{50}s for monoaromatics range between 10 and 100 ppm. LC_{50}s for the polyaromatic naphthalene were generally between 1 and 10 ppm, while LC_{50} values for anthracene were generally less than 1 ppm.

Table 4-6 shows fish are among the most sensitive aquatic biota, while aquatic invertebrates generally have intermediate sensitivities, and algae and bacteria tend to be the least sensitive. Nevertheless, even when major fish kills have occurred as a result of oil spills, population recovery has been observed, and long-term changes in fish abundance have not been reported. Benthic (bottom-dwelling) aquatic invertebrates tend to be more sensitive than algae, but are equally or less sensitive than fish. Planktonic (floating) species tend to be more sensitive than most benthic insects, crustaceans, and molluscs.

In aquatic environments, toxicity is a function of the concentration of a compound necessary to cause toxic effects combined with the compound's water solubility. For example, a compound may be highly toxic, but if it is not very soluble in water then its toxicity to aquatic biota is relatively low. The toxicity of crude oil is dependent of the toxicity of its constituents. As an example, **Table 4-7** summarizes the toxicity of various crude oil hydrocarbons to the zooplankton, *Daphnia magna*. The relative toxicity of decane is much lower than for benzene or ethylbenzene because of the comparatively low solubility of decane. Most investigators have concluded that the acute toxicity of crude oil is related to the concentrations of relatively lightweight aromatic constituents, particularly benzene.

While lightweight aromatics such as benzene tend to be water soluble and relatively toxic, they also are highly volatile. Thus, most or all of the lightweight hydrocarbons accidentally released into the environment evaporate, and the environmental persistence of crude oil tends to be low. High molecular weight aromatic compounds, including PAHs, are not very water-soluble and have a high affinity for organic material. Consequently, these compounds, if present, have limited bioavailability, which render them substantially less toxic than more water-soluble compounds (Neff 1979). Additionally, these compounds generally do not accumulate to any great extent because these compounds are rapidly metabolized (Lawrence and Weber 1984; West et al.1984). There are some indications, however, that prolonged exposure to elevated concentrations of these compounds may result in a higher incidence of growth abnormalities and hyperplastic diseases in aquatic organisms (Couch and Harshbarger 1985).

Significantly, some constituents in crude oil may have greater environmental persistence than lightweight compounds (e.g., benzene), but their limited bioavailability renders them substantially less toxic than other more soluble compounds. For example, aromatics with four or more rings are not acutely toxic at their limits of solubility (Muller 1987). Based on the combination of toxicity, solubility, and bioavailability, benzene was determined to drive toxicity associated with potential crude oil spills.

Table 4-6 Acute Toxicity of Aromatic Hydrocarbons to Freshwater Organisms

Species	Toxicity Values (ppm)				
	Benzene	Toluene	Xylene	Naphthalene	Anthracene
Carp (*Cyprinus carpio*)	40.4	---	780	---	---
Channel catfish (*Kctalurus*)	---[1]	240	---	---	---
Clarias catfish (*Clarias* sp.)	425	26	---	---	---
Coho salmon (*Oncorhyncus kisutch*)	100	---	---	2.6	---
Fathead minnow *(Pimephales)*	---	36	25	4.9	25
Goldfish (*Carassius auratus*)	34.4	23	24	---	---
Guppy (*Poecilia reticulate*)	56.8	41	---	---	---
Largemouth bass (*Micropterus*)	---	---	---	0.59	---
Medaka (*Oryzias* sp.)	82.3	54	---	---	---
Mosquitofish (*Gambusia affinis*)	---	1,200	---	150	---
Rainbow trout (*Oncorhyncus mykis)*	7.4	8.9	8.2	3.4	---
Zebrafish (*Therapon iarbua*)	---	25	20	---	---
Rotifer *(Brachionus calyciflorus)*	>1,000	110	250	---	---
Midge *(Chironomus attenuatus)*	---	---	---	15	---
Midge *(Chironomus tentans)*	---	---	---	2.8	---
Zooplankton *(Daphnia magna)*	30	41	---	6.3	0.43
Zooplankton *(Daphnia pulex)*	111	---	---	9.2	---
Zooplanton *(Diaptomus forbesi)*	---	450	100	68	---
Amphipod *(Gammarus lacustris)*	---	---	0.35	---	---
Amphipod *(Gammarus minus)*	---	---	---	3.9	---
Snail *(Physa gyrina)*	---	---	---	5.0	---
Insect *(Somatochloa cingulata)*	---	---	---	1.0	---
Chlorella vulgaris	---	230	---	25	---
Microcystis aeruginosa	---	---	---	0.85	---
Nitzschia palea	---	---	---	2.8	---
Scenedesmus subspicatus	---	130	---	---	---
Selenastrum capricornutum	70	25	72	7.5	---

[1]Indicates no value was available in the database.

Note: Data summarize conventional acute toxicity endpoints from USEPA's ECOTOX database. When several results were available for a given species, the geometric mean of the reported LC50 values was calculated.

Table 4-7 Acute Toxicity of Crude Oil Hydrocarbons to *Daphnia magna*

Compound	48-hr LC_{50} (ppm)	Optimum Solubility (ppm)	Relative Toxicity
Hexane	3.9	9.5	2.4
Octane	0.37	0.66	1.8
Decane	0.028	0.052	1.9
Cyclohexane	3.8	55	14.5
methyl cyclohexane	1.5	14	9.3
Benzene	9.2	1,800	195.6
Toluene	11.5	515	44.8
Ethylbenzene	2.1	152	72.4
p-xylene	8.5	185	21.8
m-xylene	9.6	162	16.9
o-xylene	3.2	175	54.7
1,2,4-trimethylbenzene	3.6	57	15.8
1,3,5-trimethylbenzene	6	97	16.2
Cumene	0.6	50	83.3
1,2,4,5-tetramethylbenzene	0.47	3.5	7.4
1-methylnaphthalene	1.4	28	20.0
2-methylnaphthalene	1.8	32	17.8
Biphenyl	3.1	21	6.8
Phenanthrene	1.2	6.6	5.5
Anthracene	3	5.9	2.0
9-methylanthracene	0.44	0.88	2.0
Pyrene	1.8	2.8	1.6

Note: The LC_{50} is the concentration of a compound necessary to cause 50 percent mortality in laboratory test organisms within a predetermined time period (e.g., 48 hours) (USEPA 2000).

Relative toxicity = optimum solubility/LC_{50}.

Table 4-8 summarizes chronic toxicity values (most frequently measured as reduced reproduction, growth, or weight) of benzene to freshwater biota. Chronic toxicity from other oil constituents may occur, however, if sufficient quantities of crude oil are continually released into the water to maintain elevated concentrations.

Table 4-8 Chronic Toxicity of Benzene to Freshwater Biota

Taxa	Test species	Chronic Value (ppm)
Fish	Fathead minnow (*Pimephales promelas*)	17.2 *
	Guppy (*Poecilia reticulata*)	63
	Coho salmon (*Oncorhynchus kitsutch*)	1.4
Amphibian	Leopard frog (*Rana pipens*)	3.7
Invertebrate	Zooplankton (*Daphnia* spp.)	>98
Algae	Green algae (*Selenastrum capricornutum*)	4.8 *

Note: Test endpoint was mortality unless denoted with an asterisk (*). The test endpoint for these studies was growth.

The potential impacts to aquatic organisms of various-sized spills to waterbodies were modeled assuming the benzene content within each type of crude oil completely dissolved in the water. The benzene concentration was predicted based on amount of crude oil spilled and streamflow. The estimated benzene concentrations were compared to conservative acute and chronic toxicity values for protection of aquatic organisms. For aquatic biota, the lowest acute and chronic toxicity thresholds for benzene are 7.4 ppm and 1.4 ppm, respectively, based on standardized trout toxicity tests (USEPA 2000). These toxicity threshold values are considered protective of acute and chronic effects to aquatic biota. Although trout are not found in many of the habitats crossed by the project, trout are among the most sensitive aquatic species and reliable acute and chronic trout toxicity data are available.

Tables 4-9 to **4-16** summarize the predicted acute and chronic toxicity to aquatic resources. Broadly, acute toxicity could potentially occur if substantial amounts of crude oil were to enter most rivers and streams, as demonstrated by the Moderate and Large Spill Scenarios. If such an event were to occur within a small stream, aquatic species in the immediate vicinity and downstream of the rupture could be killed or injured. Chronic toxicity also could potentially occur in small and moderate sized streams and rivers. However, emergency response, containment, and cleanup efforts would help reduce the concentrations and minimize the potential for chronic toxicity. In comparison, relatively small spills (less than 50 barrels) into moderate and large rivers would not pose a major toxicological threat. In small to moderate sized streams and rivers, some toxicity might occur in localized areas, such as backwaters where concentrations would likely be higher than in the mainstream of the river.

The likelihood of a release into any single waterbody is low, with an occurrence interval of once every 250,000 to 6,800,000 years (**Tables 4-9** to **4-16**). If any release did occur, it is likely that the total release volume of a spill likely would be 50 barrels or less based on historical spill volumes, or less than 10,000 barrels based on the spill volume study (Appendix A). Maximum spill volumes for these rivers would be approximately 20,000 barrels.

Table 4-17 shows the likelihood of spills in selected river systems, as well as average flow of water available to dilute any potentially spilled material. Higher stream volumes correlate with more rapid dilution of any potentially spilled material and therefore lower toxicity.

Table 4-9 Comparison of Estimated Diluted Bitumen (350cSt Crude Oil) Concentrations Following a Spill to the Acute Toxicity Thresholds for Aquatic Life (7.4 ppm) for Streams Crossed by the Proposed Action (435,000 bpd Throughput – Diluted Bitumen)

Throughput 435,000 bpd	Stream Flow Rate (cfs)	Acute Toxicity Threshold (ppm)	Product Released: Small spill: 50 barrels – Benzene Conc. (ppm)	Small spill: 50 barrels – Occurrence Interval (years)	Moderate spill: 1,000 barrels – Benzene Conc. (ppm)	Moderate spill: 1,000 barrels – Occurrence Interval (years)	Large spill: 10,000 barrels – Benzene Conc. (ppm)	Large spill: 10,000 barrels – Occurrence Interval (years)	Very Large spill: 20,000 barrels – Benzene Conc. (ppm)	Very Large spill: 20,000 barrels – Occurrence Interval (years)
Low Flow Stream	10	7.4	**11**	**5,905,509**	**217**	**1,344,412**	**2175**	**1,877,913**	**4349**	**5,218,915**
Lower Moderate Flow Stream	100	7.4	1	4,133,856	**22**	**941,089**	**217**	**1,314,539**	**435**	**3,653,240**
Upper Moderate Flow Stream	1,000	7.4	0.1	3,100,392	2.2	705,816	**22**	**985,904**	**43**	**2,739,930**
High Flow Stream	10,000	7.4	0.01	1,771,623	0.2	403,324	2.2	563,374	4.3	1,565,674

Notes:

-Historical data indicate that the most probable spill volume would be less than 50 barrels. However, this analysis is based on the spill frequencies and volumes calculated from complete draindown (Appendix A), which overestimates the proportion of larger spills. Consequently, the assessment is conservative in its evaluation on the magnitude of environmental consequences.

-The Keystone pipeline is estimated to transport diluted bitumen (350 cSt crude oil) 90% of the time for the purposes of this analysis.

-Estimated proportion of benzene in the transported material is 0.15 percent, and is assumed to be entirely water solubilized in the event of a spill. The resulting concentration was calculated by multiplying 0.15 percent of the total amount of material released divided by 1 hour of stream flow volume. The model assumes uniform mixing conditions.

-Benzene concentrations are compared against the acute toxicity threshold for benzene.

-Shading indicates concentrations that could potentially cause acute toxicity to aquatic species. The darkest shading represents high probability of acute toxicity (>10 times the toxicity threshold); lighter shading represents moderate probability of acute toxicity (1 to 10 times the toxicity threshold); and unshaded areas represent low probability of acute toxicity (<toxicity threshold).

-Occurrence intervals are based on an overall predicted incident frequency of 0.094 spills/year along the Keystone Pipeline Mainline (Appendix A), projected frequencies of each spill volume, and estimated stream widths. Widths of higher flow streams are greater than widths of lower flow streams, with more distance where an incident might occur. This results in a greater predicted frequency for high flow streams and a corresponding lower occurrence interval.

Table 4-10 Comparison of Estimated Synthetic Crude Oil Concentrations Following a Spill to the Acute Toxicity Thresholds for Aquatic Life (7.4 ppm) for Streams Crossed by the Proposed Action (435,000 bpd Throughput – Synthetic Crude)

			Product Released							
			Small spill: 50 barrels		Moderate spill: 1,000 barrels		Large spill: 10,000 barrels		Very Large spill: 20,000 barrels	
Throughput 435,000 bpd	Stream Flow Rate (cfs)	Acute Toxicity Threshold (ppm)	Benzene Conc. (ppm)	Occurrence Interval (years)	Benzene Conc. (ppm)	Occurrence Interval (years)	Benzene Conc. (ppm)	Occurrence Interval (years)	Benzene Conc. (ppm)	Occurrence Interval (years)
Low Flow Stream	10	7.4	1	6,842,909	**27**	**1,403,496**	**269**	**2,089,507**	**538**	**6,648,130**
Lower Moderate Flow Stream	100	7.4	0.1	4,790,037	2.7	982,447	**27**	**1,462,655**	**54**	**4,653,691**
Upper Moderate Flow Stream	1,000	7.4	0.01	3,592,527	0.3	736,835	3	1,096,991	5.4	3,490,268
High Flow Stream	10,000	7.4	0.001	2,052,873	0.03	421,049	0.3	626,852	0.5	1,994,439

Notes:

-Historical data indicate that the most probable spill volume would be less than 50 barrels. However, this analysis is based on the spill frequencies and volumes calculated from complete draindown (Appendix A), which overestimates the proportion of larger spills. Consequently, the assessment is conservative in its evaluation on the magnitude of environmental consequences.

-The Keystone pipeline is estimated to transport synthetic crude oil 10% of the time for the purposes of this analysis.

-Estimated proportion of benzene in the transported material is 0.02 percent, and is assumed to be entirely water solubilized in the event of a spill. The resulting concentration was calculated by multiplying 0.02 percent of the total amount of material released divided by 1 hour of stream flow volume. The model assumes uniform mixing conditions.

-Benzene concentrations are compared against the acute toxicity threshold for benzene.

-Shading indicates concentrations that could potentially cause acute toxicity to aquatic species. The darkest shading represents high probability of acute toxicity (>10 times the toxicity threshold); lighter shading represents moderate probability of acute toxicity (1 to 10 times the toxicity threshold); and unshaded areas represent low probability of acute toxicity (<toxicity threshold).

-Occurrence intervals are based on an overall predicted incident frequency of 0.090 spills/year along the Keystone Pipeline Mainline (Appendix A), projected frequencies of each spill volume, and estimated stream widths. Widths of higher flow streams are greater than widths of lower flow streams, with more distance where an incident might occur. This results in a greater predicted frequency for high flow streams and a corresponding lower occurrence interval.

Table 4-11 Comparison of Estimated Diluted Bitumen (350 cSt Crude Oil) Concentrations Following a Spill to the Acute Toxicity Thresholds for Aquatic Life for Streams Crossed by the Proposed Action (591,000 bpd Throughput – Diluted Bitumen)

Throughput 591,000 bpd	Stream Flow Rate (cfs)	Acute Toxicity Threshold (ppm)	Product Released							
			Small spill: 50 barrels		Moderate spill: 1,000 barrels		Large spill: 10,000 barrels		Very Large spill: 20,000 barrels	
			Benzene Conc. (ppm)	Occurrence Interval (years)	Benzene Conc. (ppm)	Occurrence Interval (years)	Benzene Conc. (ppm)	Occurrence Interval (years)	Benzene Conc. (ppm)	Occurrence Interval (years)
Low Flow Stream	10	7.4	**11**	**1,494,147**	**217**	**857,465**	**2175**	**954,506**	**4349**	**2,402,322**
Lower Moderate Flow Stream	100	7.4	1	1,045,903	**22**	**600,226**	**217**	**668,154**	**435**	**1,681,625**
Upper Moderate Flow Stream	1,000	7.4	0.1	784,427	2.2	450,169	**22**	**501,116**	**43**	**1,261,217**
High Flow Stream	10,000	7.4	0.01	448,244	0.2	257,240	2.2	286,352	4.3	720,697

Notes:

-Historical data indicate that the most probable spill volume would be less than 50 barrels. However, this analysis is based on the spill frequencies and volumes calculated from complete draindown (Appendix A), which overestimates the proportion of larger spills. Consequently, the assessment is conservative in its evaluation on the magnitude of environmental consequences.

-The Keystone pipeline is estimated to transport diluted bitumen (350 cSt crude oil) 90% of the time for the purposes of this analysis.

-Estimated proportion of benzene in the transported material is 0.15 percent, and is assumed to be entirely water solubilized in the event of a spill. The resulting concentration was calculated by multiplying 0.15 percent of the total amount of material released divided by 1 hour of stream flow volume. The model assumes uniform mixing conditions.

-Shading indicates concentrations that could potentially cause acute toxicity to aquatic species. The darkest shading represents high probability of acute toxicity (>10 times the toxicity threshold); lighter shading represents moderate probability of acute toxicity (1 to 10 times the toxicity threshold); and unshaded areas represent low probability of acute toxicity (<toxicity threshold).

-Occurrence intervals are based on an overall predicted incident frequency of 0.151 spills/year along the entire Keystone Pipeline (Appendix A), projected frequencies of each spill volume, and estimated stream widths. Widths of higher flow streams are greater than widths of lower flow streams, with more distance where an incident might occur. This results in a greater predicted frequency for high flow streams and a corresponding lower occurrence interval.

Table 4-12 Comparison of Estimated Synthetic Crude Oil Concentrations Following a Spill to the Acute Toxicity Thresholds for Aquatic Life for Streams Crossed by the Proposed Action (591,000 bpd Throughput – Synthetic Crude)

Throughput 591,000 bpd	Stream Flow Rate (cfs)	Acute Toxicity Threshold (ppm)	Product Released: Small spill: 50 barrels		Moderate spill: 1,000 barrels		Large spill: 10,000 barrels		Very Large spill: 20,000 barrels	
			Benzene Conc. (ppm))	Occurrence Interval (years)	Benzene Conc. (ppm)	Occurrence Interval (years)	Benzene Conc. (ppm)	Occurrence Interval (years)	Benzene Conc. (ppm)	Occurrence Interval (years)
Low Flow Stream	10	7.4	1	6,094,152	**27**	**1,358,541**	**269**	**1,927,825**	**538**	**5,442,000**
Lower Moderate Flow Stream	100	7.4	0.1	4,265,906	2.7	950,979	**27**	**1,349,478**	**54**	**3,809,400**
Upper Moderate Flow Stream	1,000	7.4	0.01	3,199,430	0.3	713,234	2.7	1,012,108	5	2,857,050
High Flow Stream	10,000	7.4	0.001	1,828,246	0.03	417,562	0.3	578,348	0.5	1,632,600

Notes:

-Historical data indicate that the most probable spill volume would be less than 50 barrels. However, this analysis is based on the spill frequencies and volumes calculated from complete draindown (Appendix A), which overestimates the proportion of larger spills. Consequently, the assessment is conservative in its evaluation on the magnitude of environmental consequences.

-The Keystone pipeline is estimated to transport synthetic crude oil 10% of the time for the purposes of this analysis.

-Estimated proportion of benzene in the transported material is 0.02 percent, and is assumed to be entirely water solubilized in the event of a spill. The resulting concentration was calculated by multiplying 0.02 percent of the total amount of material released divided by 1 hour of stream flow volume. The model assumes uniform mixing conditions.

-Benzene concentrations are compared against the acute toxicity threshold for benzene.

-Shading indicates concentrations that could potentially cause acute toxicity to aquatic species. The darkest shading represents high probability of acute toxicity (>10 times the toxicity threshold); lighter shading represents moderate probability of acute toxicity (1 to 10 times the toxicity threshold); and unshaded areas represent low probability of acute toxicity (<toxicity threshold).

-Occurrence intervals are based on an overall predicted incident frequency of 0.093 spills/year along the Keystone Pipeline Mainline (Appendix A), projected frequencies of each spill volume, and estimated stream widths. Widths of higher flow streams are greater than widths of lower flow streams, with more distance where an incident might occur. This results in a greater predicted frequency for high flow streams and a corresponding lower occurrence interval.

Table 4-13 Comparison of Estimated Diluted Bitumen (350 cSt Crude Oil) Concentrations Following a Spill to the Chronic Toxicity Thresholds for Aquatic Life for Streams Crossed by the Proposed Action (435,000 bpd Throughput – Diluted Bitumen)

Throughput 435,000 bpd	Stream Flow Rate (cfs)	Chronic Toxicity Threshold (ppm)	Product Released							
			Small spill: 50 barrels		Moderate spill: 1,000 barrels		Large spill: 10,000 barrels		Very Large spill: 20,000 barrels	
			Benzene Conc. (ppm)	Occurrence Interval (years)	Benzene Conc. (ppm)	Occurrence Interval (years)	Benzene Conc. (ppm)	Occurrence Interval (years)	Benzene Conc. (ppm)	Occurrence Interval (years)
Low Flow Stream	10	1.4	0.1	5,905,509	1.3	1,344,412	**13**	**1,877,913**	**26**	**5,218,915**
Lower Moderate Flow Stream	100	1.4	0.01	4,133,856	0.1	941,089	1.3	1,314,539	**2.6**	**3,653,240**
Upper Moderate Flow Stream	1,000	1.4	0.001	3,100,392	0.01	705,816	0.1	985,904	0.3	2,739,930
High Flow Stream	10,000	1.4	0.0001	1,771,623	0.001	403,324	0.01	563,374	0.03	1,565,674

Notes:

-Historical data indicate that the most probable spill volume would be less than 50 barrels. However, this analysis is based on the spill frequencies and volumes calculated from complete draindown (Appendix A), which overestimates the proportion of larger spills. Consequently, the assessment is conservative in its evaluation on the magnitude of environmental consequences.

-The Keystone pipeline is estimated to transport diluted bitumen (350 cSt crude oil) 90% of the time for the purposes of this analysis.

-Estimated proportion of benzene in the transported material is 0.15 percent, and is assumed to be entirely water solubilized in the event of a spill. The resulting concentration was calculated by multiplying 0.15 percent of the total amount of material released divided by 7 days of stream flow volume. The model assumes uniform mixing conditions.

-The chronic toxicity value for benzene is based on a 7-day toxicity value of 1.4 ppm for trout.

-Exposure concentrations were estimated over a 7-day period since the chronic toxicity value was based on a 7-day exposure.

-Shading indicates concentrations that could potentially cause chronic toxicity to aquatic species. The darkest shading represents high probability of chronic toxicity (>10 times the toxicity threshold); lighter shading represents moderate probability of chronic toxicity (1 to 10 times the toxicity threshold); and unshaded areas represent low probability of chronic toxicity (<toxicity threshold).

-Occurrence intervals are based on an overall predicted incident frequency of 0.094 spills/year along the Keystone Pipeline Mainline (Appendix A), projected frequencies of each spill volume, and estimated stream widths. Widths of higher flow streams are greater than widths of lower flow streams, with more distance where an incident might occur. This results in a greater predicted frequency for high flow streams and a corresponding lower occurrence interval.

Table 4-14 Comparison of Estimated Synthetic Crude Oil Concentrations Following a Spill to the Chronic Toxicity Thresholds for Aquatic Life for Streams Crossed by the Proposed Action (435,000 bpd Throughput – Synthetic Crude)

Throughput 435,000 bpd	Stream Flow Rate (cfs)	Chronic Toxicity Threshold (ppm)	Product Released							
			Small spill: 50 barrels		Moderate spill: 1,000 barrels		Large spill: 10,000 barrels		Very Large spill: 20,000 barrels	
			Benzene Conc. (ppm)	Occurrence Interval (years)	Benzene Conc. (ppm)	Occurrence Interval (years)	Benzene Conc. (ppm)	Occurrence Interval (years)	Benzene Conc. (ppm)	Occurrence Interval (years)
Low Flow Stream	10	1.4	0.01	6,842,909	0.2	1,403,496	**1.6**	**2,089,507**	**3.2**	**6,648,130**
Lower Moderate Flow Stream	100	1.4	0.001	4,790,037	0.02	982,447	0.2	1,462,655	0.3	4,653,691
Upper Moderate Flow Stream	1,000	1.4	0.0001	3,592,527	0.002	736,835	0.02	1,096,991	0.03	3,490,268
High Flow Stream	10,000	1.4	0.00001	2,052,873	0.0002	421,049	0.002	626,852	0.003	1,994,439

Notes:

-Historical data indicate that the most probable spill volume would be less than 50 barrels. However, this analysis is based on the spill frequencies and volumes calculated from complete draindown (Appendix A), which overestimates the proportion of larger spills. Consequently, the assessment is conservative in its evaluation on the magnitude of environmental consequences.

-The Keystone pipeline is estimated to transport synthetic crude oil 10% of the time for the purposes of this analysis.

-Estimated proportion of benzene in the transported material is 0.02 percent, and is assumed to be entirely water solubilized in the event of a spill. The resulting concentration was calculated by multiplying 0.02 percent of the total amount of material released divided by 7 days of stream flow volume. The model assumes uniform mixing conditions.

-The chronic toxicity value for benzene is based on a 7-day toxicity value of 1.4 ppm for trout.

-Exposure concentrations were estimated over a 7-day period since the chronic toxicity value was based on a 7-day exposure.

-Shading indicates concentrations that could potentially cause chronic toxicity to aquatic species. The darkest shading represents high probability of chronic toxicity (>10 times the toxicity threshold); lighter shading represents moderate probability of chronic toxicity (1 to 10 times the toxicity threshold); and unshaded areas represent low probability of chronic toxicity (<toxicity threshold).

-Occurrence intervals are based on an overall predicted incident frequency of 0.090 spills/year along the Keystone Pipeline Mainline (Appendix A), projected frequencies of each spill volume, and estimated stream widths. Widths of higher flow streams are greater than widths of lower flow streams, with more distance where an incident might occur. This results in a greater predicted frequency for high flow streams and a corresponding lower occurrence interval.

CONFIDENTIAL

ENSR | AECOM

Table 4-15 Estimated Diluted Bitumen (350cSt Crude Oil) Concentrations Compared to the Chronic Toxicity Threshold for Aquatic Life for Streams Crossed by the Proposed Action (591,000 bpd Throughput – Diluted Bitumen)

Throughput 591,000 bpd	Stream Flow Rate (cfs)	Chronic Toxicity Threshold (ppm)	Product Released							
			Small spill: 50 barrels		Moderate spill: 1,000 barrels		Large spill: 10,000 barrels		Very Large spill: 20,000 barrels	
			Benzene Conc. (ppm)	Occurrence Interval (years)	Benzene Conc. (ppm)	Occurrence Interval (years)	Benzene Conc. (ppm)	Occurrence Interval (years)	Benzene Conc. (ppm)	Occurrence Interval (years)
Low Flow Stream	10	1.4	0.1	1,494,147	1.3	857,465	**13**	**954,506**	**26**	**2,402,322**
Lower Moderate Flow Stream	100	1.4	0.01	1,045,903	0.1	600,226	1.3	668,154	**2.6**	**1,681,625**
Upper Moderate Flow Stream	1,000	1.4	0.001	784,427	0.01	450,169	0.1	501,116	0.3	1,261,217
High Flow Stream	10,000	1.4	0.0001	448,244	0.001	257,240	0.01	286,352	0.03	720,697

Notes:

-Historical data indicate that the most probable spill volume would be less than 50 barrels. However, this analysis is based on the spill frequencies and volumes calculated from complete draindown (Appendix A), which overestimates the proportion of larger spills. Consequently, the assessment is conservative in its evaluation on the magnitude of environmental consequences.

-The Keystone pipeline is estimated to transport diluted bitumen (350 cSt crude oil) 90% of the time for the purposes of this analysis.

-Estimated proportion of benzene in the transported material is 0.15 percent, and is assumed to be entirely water solubilized in the event of a spill. The resulting concentration was calculated by multiplying 0.15 percent of the total amount of material released divided by 7 days of stream flow volume. The model assumes uniform mixing conditions.

-The chronic toxicity value for benzene is based on a 7-day toxicity value of 1.4 ppm for trout.

-Exposure concentrations were estimated over a 7-day period since the chronic toxicity value was based on a 7-day exposure.

-Shading indicates concentrations that could potentially cause chronic toxicity to aquatic species. The darkest shading represents high probability of chronic toxicity (>10 times the toxicity threshold); lighter shading represents moderate probability of chronic toxicity (1 to 10 times the toxicity threshold); and unshaded areas represent low probability of chronic toxicity (<toxicity threshold).

-Occurrence intervals are based on an overall predicted incident frequency of 0.151 spills/year along the entire Keystone Pipeline (Appendix A), projected frequencies of each spill volume, and estimated stream widths. Widths of higher flow streams are greater than widths of lower flow streams, with more distance where an incident might occur. This results in a greater predicted frequency for high flow streams and a corresponding lower occurrence interval.

Table 4-16 Estimated Synthetic Crude Oil Concentrations Compared to the Chronic Toxicity Threshold for Aquatic Life for Streams Crossed by the Proposed Action (591,000 bpd Throughput – Synthetic Crude)

Throughput 591,000 bpd	Stream Flow Rate (cfs)	Chronic Toxicity Threshold (ppm)	Product Released							
			Small spill: 50 barrels		Moderate spill: 1,000 barrels		Large spill: 10,000 barrels		Very Large spill: 20,000 barrels	
			Benzene Conc. (ppm)	Occurrence Interval (years)	Benzene Conc. (ppm)	Occurrence Interval (years)	Benzene Conc. (ppm)	Occurrence Interval (years)	Benzene Conc. (ppm)	Occurrence Interval (years)
Low Flow Stream	10	1.4	0.01	6,094,152	0.2	1,358,541	**1.6**	**1,927,825**	**3.2**	**5,442,000**
Lower Moderate Flow Stream	100	1.4	0.001	4,265,906	0.02	950,979	0.2	1,349,478	0.3	3,809,400
Upper Moderate Flow Stream	1,000	1.4	0.0001	3,199,430	0.002	713,234	0.02	1,012,108	0.03	2,857,050
High Flow Stream	10,000	1.4	0.0001	1,828,246	0.0002	417,562	0.002	578,348	0.003	1,632,600

Notes:

-Historical data indicate that the most probable spill volume would be less than 50 barrels. However, this analysis is based on the spill frequencies and volumes calculated from complete draindown (Appendix A), which overestimates the proportion of larger spills. Consequently, the assessment is conservative in its evaluation on the magnitude of environmental consequences.

-The Keystone pipeline is estimated to transport synthetic crude oil 10% of the time for the purposes of this analysis.

-Estimated proportion of benzene in the transported material is 0.02 percent, and is assumed to be entirely water solubilized in the event of a spill. The resulting concentration was calculated by multiplying 0.02 percent of the total amount of material released divided by 7 days of stream flow volume. The model assumes uniform mixing conditions.

-The chronic toxicity value for benzene is based on a 7-day toxicity value of 1.4 ppm for trout.

-Exposure concentrations were estimated over a 7-day period since the chronic toxicity value was based on a 7-day exposure.

-Shading indicates concentrations that could potentially cause chronic toxicity to aquatic species. The darkest shading represents high probability of chronic toxicity (>10 times the toxicity threshold); lighter shading represents moderate probability of chronic toxicity (1 to 10 times the toxicity threshold); and unshaded areas represent low probability of chronic toxicity (<toxicity threshold).

-Occurrence intervals are based on an overall predicted incident frequency of 0.093 spills/year along the Keystone Pipeline Mainline (Appendix A), projected frequencies of each spill volume, and estimated stream widths. Widths of higher flow streams are greater than widths of lower flow streams, with more distance where an incident might occur. This results in a greater predicted frequency for high flow streams and a corresponding lower occurrence interval.

Table 4-17 Large River Systems Crossed by the Proposed Keystone Pipeline[1]

Major River/Major Lake	Annual Failure Frequency	Median Stream Flow (cfs)[2]
Missouri River (SD/NE Border)	5.83×10^{-5}	20,100
Platte River	2.33×10^{-5}	18,00
Missouri River (KS/MO Border)	5.02×10^{-5}	45,700
Mississippi River	7.24×10^{-5}	146,200
Kaskaskia River/Carlyle Lake	1.60×10^{-5}	1,900

[1]Due to Homeland Security issues, the precise maximum spill volume for specific location is considered highly sensitive and confidential, and is therefore not provided in this document.

[2]USGS 2007 average stream flow 1990-1995.

While a release of crude oil into any given waterbody might cause immediate localized toxicity to aquatic biota, particularly in smaller streams and rivers, the frequency of such an event would be low. Nevertheless, streams and rivers with aquatic biota represent the sensitive environmental resources that could be temporarily impacted by a crude oil release.

Wetlands/Prairie Potholes/Playa Lakes

Although planning and routing efforts have reduced the overall number of wetlands (including prairie potholes and playa lake environments) and static waterbody environments crossed by the Keystone Pipeline, wetlands and waterbodies with persistently saturated soils are present along and adjacent to the Keystone Pipeline route. The effects of crude oil released into a wetland environment will depend not only upon the quantity of oil released, but also on the physical conditions of the wetland at the time of the release. Wetlands include a wide range of environmental conditions. Wetlands can consist of many acres of standing water dissected with ponds and channels, or they may simply be areas of saturated soil with no open water. A single wetland can even vary between these two extremes as seasonal precipitation varies. Wetland surfaces are generally low gradient with very slow unidirectional flow or no discernable flow. The presence of vegetation or narrow spits of dry land protruding into wetlands also may isolate parts of the wetland. Given these conditions, spilled materials may remain in restricted areas for longer periods than in river environments.

Crude oil released from a subsurface pipe within a wetland could reach the soil surface. If the water table reaches the surface, the release would manifest as floating crude oil. The general lack of surface flow within a wetland would restrict crude oil movement. Where surface water is present within a wetland, the spill would spread laterally across the water's surface and be readily visible during routine right-of-way (ROW) surveillance. The depth of soil impacts likely would be minimal, due to shallow (or emergent) groundwater conditions. Conversely, groundwater impacts within the wetland are likely to be confined to the near-surface, enhancing the potential for biodegradation. If humans or other important resource exposures were to occur in proximity to the wetland, then regulatory drivers would mandate the scope of remedial actions, timeframe for remediation activities, and cleanup levels. However, response and remediation efforts in a wetland have the potential for appreciable adverse effects from construction/cleanup equipment. If no active remediation activities were undertaken, natural biodegradation and attenuation would ultimately allow a return to preexisting conditions in both soil and groundwater. This would likely require a timeframe on the order of tens of years. Keystone will utilize the most appropriate cleanup procedures as determined in coordination with the applicable federal and state agencies.

The chance of a spill occurring at any specific wetland along the pipeline is very low. Based on survey data and aerial interpretation, wetlands comprise 69.4 miles of the entire Keystone Pipeline system (Table 3.5-8 of the revised Keystone Environmental Report tables filed January 2007). Of the estimated maximum of 1.5 spills postulated to occur during a 10-year period within the entire pipeline system, about 0.08 spills would be expected to occur within wetland areas (equivalent to one spill every 130 years). If any release did occur, it is likely that the total release volume of a spill likely would be 50 barrels or less based on historical spill volumes, or less than 10,000 barrels based on the spill volume study (Appendix A).

The predicted effects of a spill reaching standing water (e.g., reservoirs, prairie potholes) would depend largely upon the volume of crude oil entering the waterbody and the volume of water within the waterbody.

Table 4-18 summarizes the amount of water necessary to dilute spill volumes below aquatic toxicity and drinking water thresholds. While this preliminary approach does not account for fate and transport mechanisms, mixing zones, environmental factors, and emergency response capabilities, it does provide an initial benchmark for identifying areas of potential concern.

Table 4-18 Amount of Water Required to Dilute Crude Oil Spills Below Threshold Values

Barrels of Crude Oil	Volume of Water Required to Dilute Crude Oil Below Threshold (acre-feet)[1]		
	Acute Toxicity Threshold (7.4 milligrams per liter [mg/L])	Chronic Toxicity Threshold (1.4 mg/L)	Drinking Water MCL (0.005 mg/L)
Diluted Bitumen (350 cSt Crude)			
50	4.6	24.3	6,807
150	13.8	72.9	20,420
1,000	92.0	486	136,136
10,000	920	4,862	1,361,358
Synthetic Crude Oil			
50	0.57	3.0	841
150	1.7	9.3	2,524
1,000	11.4	60.1	16,826
10,000	114	601	168,258

[1]Thresholds based on aquatic toxicity and drinking water thresholds established for benzene. The estimated benzene content of the diluted bitumen (350 cSt crude oil) is 0.15 percent by weight. The synthetic crude oil is estimated to have a benzene content of 0.02 percent by weight.

Based on a review of publicly available toxicity literature for wetland plant groups (i.e., algae, annual macrophytes, and perennial macrophytes), crude oil is toxic to aquatic plants but at higher concentrations than observed for fish and invertebrates. Therefore, spill concentrations that are less than toxic effect levels for fish and invertebrates (see Aquatic Organisms, above) also would be protective for wetland plant species.

In summary, while a release of crude oil into wetland and static waterbodies has the potential to cause temporary environmental impacts, the frequency of such an event would be low. Nevertheless, wetlands and static waterbodies represent sensitive environmental resources.

4.3 Risk to Populated and High Consequence Areas (HCAs)

Consequences of inadvertent releases from pipelines can vary greatly, depending on where the release occurs. Pipeline safety regulations use the concept of HCAs to identify specific locales and areas where a release could have the most significant adverse consequences. HCAs include populated areas, drinking water, and unusually sensitive ecologically resource areas (USAs) that could be damaged by a hazardous liquid pipeline release. **Table 4-19** identifies the types and lengths of HCAs crossed by the Keystone Pipeline Project. HCAs are subject to higher levels of inspection, per 49 CFR Part 195. These data are compiled from a variety of data sources, including federal and state agencies (e.g., state drinking water agencies, the Environmental Protection Agency). The USDOT acknowledges that spills within a sensitive area might not actually impact the sensitive resource and encourages operators to conduct detailed analysis, as needed. Keystone has conducted a preliminary evaluation of HCAs crossed or located downstream of the pipeline (Appendix B). These HCAs will be subject to higher levels of inspection, as per 49 CFR Part 195. Furthermore, Keystone has subsequently evaluated the location of valves as a measure to reduce potential risk to HCAs. As a result of the preliminary HCA evaluation, some proposed valve locations were moved and additional valves were added to protect HCAs (see Keystone's March 2007 filing with the DOS).

Assuming that 1.5 spills occurred along the Keystone Pipeline system in a 10-year period, it is estimated that approximately 0.25 of these spills would occur in HCAs (**Table 4-19**). Although the number of predicted spills in HCAs is relatively small, the potential impacts of these individual spills are expected to be greater than in other areas due to the environmental sensitivity within these areas. **Table 4-20** also shows the number of spills and their predicted sizes.

4.3.1 Populated Areas

OPS-defined high population areas occur along 3.9 miles of the Keystone Pipeline system. These high population areas have been identified as HCAs by the USDOT based on U.S. Census data (**Table 4-19**). More than 99 percent of these miles are near St. Louis, Illinois. Keystone has reviewed and identified approximately 39 miles of other populated areas as HCAs in accordance with USDOT.

4.3.2 Drinking Water

USDOT defines identifies both surface water and groundwater as for drinking water USAs as defined in 49 CFR Part 195. Surface water USAs include intakes for community water systems and non-transient non-community water systems that do not have an adequate alternative drinking water source. Groundwater USAs include the source water protection area for community water systems and non-transient non-community water systems that obtain their water supply from a Class I or Class IIA aquifer and do not have an adequate alternative drinking water source. If the source water protection area is not available, the wellhead protection area (WHPA) becomes the USA.

Surface water USAs identified for their potential as a drinking water resource have a 5-mile buffer placed around their intake location. The groundwater USAs have buffers that vary in size. These buffers are designated by the state's source water protection program or their wellhead protection program and the buffer sizes vary from state to state.

Isolated segments of the Keystone Pipeline Project cross areas that are considered HCAs by the USDOT due to potential risks to sensitive drinking water resources (**Table 4-19**). These areas are scattered throughout both the Keystone Mainline and Cushing Extension Pipeline routes. Keystone has conducted a more thorough evaluation to identify HCAs associated with sensitive drinking water resources (Appendix B). Segments of the pipeline that could potentially affect HCAs will be subject to higher levels of inspection, as per 49 CFR Part 195. Based on Keystone's preliminary assessment, some valve locations have been moved and additional valves have been added to protect drinking water USAs. These updated locations have been submitted to the DOS in the March 2007 filing.

Table 4-19 Mileage Summary of USDOT-Defined HCAs Identified Along the Keystone Pipeline Project, Based on Centerline Filed December 2006

	Miles of Pipeline				**Projected Number of Spills in 10 years *(occurrence interval)***			
	Populated Areas	**Drinking Water**	**Ecologically Sensitive Area**	**Total in HCAs[1]**	**Populated Areas**	**Drinking Water**	**Ecologically Sensitive Area**	**Total HCAs[1]**
North Dakota	0.0	2.1	2.0	4.1	NA	0.002 (4,300 yrs)	0.002 (4,550 yrs)	0.005
South Dakota	1.0	9.2	22.4	29.2	0.001 (9,100 yrs)	0.010 (990 yrs)	0.025 (405 yrs)	0.03
Nebraska	0.0	0.0	10.5	6.5	NA	NA	0.011 (865 yrs)	0.007
Kansas	0.0	8.9	18.6	27.5	NA	0.010 (1,020 yrs)	0.020 (490 yrs)	0.03
Missouri	2.1	3.8	59.4	69.5	0.002 (4,300 yrs)	0.004 (2,300 yrs)	0.065 (155 yrs)	0.08
Illinois	4.7	12.0	7.5	21.9	0.005 (1,900 yrs)	0.013 (760 yrs)	0.008 (1,200 yrs)	0.02
Keystone Mainline subtotal	*7.8*	*36.1*	*120.4*	*158.8*	*0.008 (1,200 yrs)*	*0.040 (250 yrs)*	*0.13 (75 yrs)*	*0.17*
Nebraska	0.0	0.0	0.0	0.0	NA	0.0	0.0	0.00
Kansas	0.0	35.9	47.8	67.0	NA	0.039 (250 yrs)	0.053 (190 yrs)	0.07
Oklahoma	0.8	11.4	7.5	16.1	0.001 (11,400 yrs)	0.012 (800 yrs)	0.008 (1,200 yrs)	0.02
Cushing Extension Subtotal	*0.8*	*47.8*	*55.3*	*83.1*	*0.001 (11,400 yrs)*	*0.053 (190 yrs)*	*0.061 (165 yrs)*	*0.09*
Project Total	**8.6**	**83.5**	**175.7**	**241.9**	**0.009 (1,100 yrs)**	**0.092 (110 yrs)**	**0.19 (52 yrs)**	**0.27 (37 yrs)**

[1]Numbers are not additive because some miles overlap in the different types of HCAs.

Note: NA indicates no USDOT-defined populated area within the segment.

Projected number of spills in 10 years and occurrence interval were conservatively estimated based on the maximum probability of spills (1.5 spills in 10 years during operation at 591,000 bpd and transporting diluted bitumen). This estimates the maximum possible risk, and assumes risk is evenly disturbed along the entire proposed pipeline and Cushing Extension.

Table 4-20 Release and Spill Volume Occurrence Interval Associated with the Keystone Pipeline Project

	Miles of Pipe[1]	Total Number of Predicted Spills	<50 barrels (bbls)	50 to 1,000 bbls	1,000 to >10,000 bbls	>10,000 bbls
KEYSTONE MAINLINE						
Populated Areas	7.8	0.008 (1,200 years)	0.002 (5,750 years)	0.003 (3,300 years)	0.003 (3,650 years)	0.001 (9,250 years)
Drinking Water Areas	36.1	0.040 (250 years)	0.008 (1,250 years)	0.014 (710 years)	0.012 (190 years)	0.005 (2,000 years)
Ecologically Sensitive Areas	120.4	0.13 (75 years)	0.027 (370 years)	0.046 (210 years)	0.042 (240 years)	0.017 (600 years)
CUSHING EXTENSION						
Populated Areas[2]	0.8	0.001 (11,400 yrs)	0.0002 (60,000 yrs)	0.0003 (32,100 yrs)	0.0003 (35,800 yrs)	0.0001 (90,000 yrs)
Drinking Water Areas	47.8	0.053 (190 years)	0.011 (940 years)	0.019 (540 years)	0.017 (600 years)	0.007 (1,500 years)
Ecologically Sensitive Areas	55.3	0.061 (165 years)	0.012 (810 years)	0.022 (460 years)	0.019 (520 years)	0.007 (1,300 years)

[1]The amount of pipe located within HCAs was quantified by geographical information system (GIS) and was based on the intersection of a 1,000-foot-wide corridor (centered on the pipeline route) and USDOT-defined HCAs. Probability of a spill was based on the highest projected spill frequency rate on the Keystone pipeline of 0.151 spills per year (Appendix A).

4.3.3 Ecologically Sensitive Areas

Portions of the Keystone Pipeline Project cross areas that are considered HCAs by the USDOT due to potential risks to ecologically sensitive resources (**Table 4-19**). These areas focus on the characteristics of rarity, imperilment, or the potential for loss of large segments of an abundant population during periods of migratory concentration. These include;

- Critically imperiled and imperiled species and/or ecological communities,
- Threatened and endangered (T&E) species (or multi-species assemblages where three or more different candidate resources co-occur),
- Migratory waterbird concentrations.
- Areas containing candidate species or ecological communities identified as excellent or good quality, and
- Areas containing aquatic or terrestrial candidate species and ecological communities that are limited in range.

Portions of the Keystone Pipeline Project cross areas that are considered HCAs by the USDOT due to potential risks to ecologically sensitive areas (**Table 4-19**). These ecologically sensitive areas are frequently associated with major river systems (e.g., Missouri, Platte, and Mississippi Rivers). As with other HCAs, these locations will be subject to higher levels of inspection, as per 49 CFR Part 195, in order to reduce the probability of pipeline incident.

4.3.4 Distribution of Risk Among HCAs

Up to this point in this document, risk was assumed to be uniformly distributed along the Keystone Pipeline system. This provides a broad overview of risk along the entire system. However, in reality risk is unevenly distributed along the pipeline. Due to Homeland Security reasons, the precise risk for specific locations is highly confidential. Nevertheless, Keystone is providing a preliminary evaluation of risk to HCAs that incorporates site-specific risk factors. Per federal regulations (Integrity Management Rule, 49 CFR Part 195), the site-specific evaluation of risk is an ongoing process and is regulated by the USDOT.

If risk was evenly distributed along the entire length of pipeline, then the sum of the maximum spill volumes from 430 of the 1,720 segments would account for 25 percent of the total maximum spill volume for the entire Keystone Pipeline system. However, risk is not distributed evenly across the system. By summing the higher maximum spill volumes, the number of segments accounting for 25 percent of the total maximum spill volume varies between 39 and 66 segments, depending on the type of product transported and the amount of throughput. **Table 4-21** quantifies the number of segments along the entire length of the Keystone Pipeline system that contribute the greatest amount to risk, defined as the number of segments that contribute 25 percent of the total maximum spill volume for the entire Keystone Pipeline system.

Table 4-21 Segments Accounting for 25 Percent of Total Maximum Spill Volume

	Diluted Bitumen		**Synthetic Crude**	
	435,000 bpd throughput	**591,000 bpd throughput**	**435,000 bpd throughput**	**591,000 bpd throughput**
Number of segments that contribute 25 percent of total maximum spill volume	66	39	62	66
Length of pipe that contributes to 25 percent of the total maximum spill volume (miles)	21	9	19	20

Many of these higher risk segments are not located within HCAs. **Table 4-22** identifies the miles of HCAs crossed by these higher risk segments. None of the higher risk segments are located within populated area HCAs. There are some ecologically sensitive areas and drinking water USAs that will be crossed by the higher risk segments. Appendix B incorporates the risk associated with each pipeline segment into Keystone's preliminary evaluation of risk to HCAs.

Table 4-22 Length of Higher Risk Segments Within HCAs (miles)

	Diluted Bitumen		**Synthetic Crude**	
Type of HCA	**435,000 bpd throughput**	**591,000 bpd throughput**	**435,000 bpd throughput**	**591,000 bpd throughput**
Populated Areas	0.0	0.0	0.0	0.0
Ecologically Sensitive Areas	8.0	6.6	11.0	11.2
Drinking Water	5.3	0.0	5.3	6.2

To protect these sensitive resources, HCAs would be subject to a higher level of inspection per USDOT regulations. Federal regulations require periodic assessment of the pipe condition and correction of identified anomalies within HCAs. Keystone will develop management and analysis processes that integrate available integrity-related data and information and assess the risks associated with segments that can affect HCAs.

Based on Keystone's preliminary assessment of HCAs (Appendix B), some valve locations have been moved and additional valves have been added to protect HCAs. These updated locations have been submitted to the DOS in the March 2007 filing. In addition, Keystone will develop and implement a risk-based integrity management program (IMP). The IMP will use state-of-practice technologies applied within a comprehensive risk-based methodology to assess and mitigate risk associated with all pipeline segments including HCAs.

5.0 Keystone's Pipeline Safety Program

Pipelines are one of the safest forms of crude oil transportation and provide a cost effective and safe mode of transportation for oil on land. Overland transportation of oil by truck or rail produces higher risk of injury to the general public than the proposed pipeline (USDOT 2002). The Keystone Pipeline system will be designed, constructed and maintained in a manner that meets or exceeds industry standards.

Historically, the most significant risk associated with operating a crude oil pipeline is the potential for third-party excavation damage. The pipelines will be built within an approved right-of-way (ROW) and visible signs will be installed at all road, railway, and water crossings. Keystone also will mitigate third-party excavation risk by implementing a comprehensive Integrated Public Awareness program focused on education and awareness in accordance with 49 CFR 195.440 and API RP1162. Further, Keystone's operating staff will complete regular visual inspections of the ROW (at least once every 3 weeks and a minimum of 26 times per year) as per 49 CFR 195.412 and monitor activity in the area to prevent unauthorized trespass or access.

Keystone will have a maintenance, inspection, and repair program that ensures the integrity of its pipeline. Keystone's annual Pipeline Maintenance Program (PMP) will be designed to maintain the safe operation of the pipeline system. The PMP will include routine aerial patrol of the ROW, periodic inline inspections and cathodic protection readings underpinned by a company wide goal to ensure facilities are reliable and in service. Data collected in each year of the program will be fed back into the decision making process for the development of the following year's program. In addition, the pipeline system will be monitored 24 hours a day, 365 days a year from the oil control center using leak detection systems and supervisory control and data acquisition (SCADA). During operations, Keystone will have an Emergency Response Program in place to manage a variety of events.

6.0 Conclusion

In summary, this conservative analysis of the proposed Keystone Pipeline system shows that the predicted frequency of incidents is low, the probability of a large spill occurring is low, and, consequently, risk of environmental impacts is minimal. Compliance with regulations, application of Keystone's IMPs and its ERP, as well as adherence to safety procedures will help to ensure long-term environmentally sound and safe operation of the pipeline.

7.0 REFERENCES

California State Fire Marshal. 1993. Hazardous Liquid Pipeline Risk Assessment. Office of the State Fire Marshal, Pipeline Safety Division, Sacramento, California. 187 pp.

Center for Disease Control – National Center for Health Statistics for 2003. Online data summary. URL:http://www.cdc.gov/nchs.

Couch, J. A. and J. C. Harshbarger. 1985. Effects of carcinogenic agents on aquatic animals: an environmental and experimental overview. J. Environ. Sci. Health, Part C, Environ. Carcin. Rev. 3:63-105.

Davies, W. E., J. H. Simpson, G. C. Ohlmacher, W. S. Kirk, and E. G. Newton. 1984. Engineering Aspects of Karst. U.S. Geological Survey, National Atlas, scale 1:75,000.

European Gas Pipeline Incident Data Group (EGIG). 2005. Gas Pipeline Incidents, 6th EGIG-report 1970-2004. Doc Number EGIG 05.R.0002, December 2005.

Illinois State Geological Survey (ISGS). 2004. Online Coal maps, publications, and coal resource data. URL: http://www.isgs.uiuc.edu/isgshome/coal.htm. website updated September 16, 2004. Site reviewed February 3, 2006.

Kastning, E. H. and K. M. Kastning. 1999. Misconceptions about Cave and Karst: Common Problems and Educational Solutions, National Cave and Karst Management Symposium, P. 99-106.

Lawrence, J.F. and D.F. Weber. 1984. Determination of polycyclic aromatic hydrocarbons in some Canadian commercial fish, shellfish, and meat products by liquid chromatography with confirmation by capillary gas chromatography with fluorescence detection. J. Agric. Food Chem. 32:794-797.

Muller, H. 1987. Hydrocarbons in the freshwater environment. A Literature Reivew. Arch. Hydrobiol. Beih. Ergebn. Limnol 24:1-69.

Neff, J. M. 1979. Polycyclic aromatic hydrocarbons in the aquatic environment. Applied Science publ. Ltd., London. 262 pp.

Neff, J.M. and J.W. Anderson. 1981. Response of Marine Animals to Petroleum and Specific Hydrocarbons. Applied Science Publishers, London. 177 pp.

O'Rourke, M.J. and Palmer. 1996. Earthquake Performance for Gas Transmission Pipelines. Earthquake Spectra 12(3):493.

Sharp, B. 1990. Black oystercatchers in Prince William Sound: oil spill effects on reproduction and behavior in 1989. *Exxon Valdez Trustees' Study-Bird Study Number 12*. U.S. Fish and Wildlife Service, Portland, Oregon.

Shiu, W.Y. A. Maijanen, A.L.Y. Ng and D. Mackay. 1988. Preparation of aquesous solutions of sparingly soluble organic substances: II. Multicomponent systems – hydrocarbon mixtures and petroleum products. Environ. Toxicol. Chem. 7:125-137.

Stubblefield, W. A., G. A. Hancock, W. H. Ford, H. H. Prince, and R. K. Ringer. 1995. Evaluation of toxic properties of naturally weathered Exxon Valdez crude oil to surrogate wildlife species. Pp. 665-692. In: P.

G. Wells, H. N. Butler, and J. S. Hughes 9eds)., *Exxon Valdex Oil Spill: Fate and Effects in Alaskan Waters, ASTM STP 1219*. American Society for Testing and Materials, Philadelphia, Pennsylvania.

U.S. Environmental Protection Agency (USEPA). 2001. ECOTOX database. Internet database for aquatic and terrestrial toxicity data. http://www.epa.gov/ecotox/.

USEPA. 2000. AQUIRE ECOTOX database. Internet database for aquatic toxicity data. http://www.epa.gov/ecotox/.

U.S. Geological Service (USGS). 1998. Groundwater Contamination by Crude Oil near Bemidji, Minnesota. U.S. Geological Survey Fact Sheet 084-98, September 1998.

U.S. Geological Service (USGS). 2007. website. http://waterdata.usgs.gov\nws\rt.

U.S. Department of Transportation. 2002. Office of Pipeline Safety Pipeline Statistics. Website: http://ops.dot.gov/stats/ stats.htm

U.S. Department of Transportation – National Pipeline Mapping System (USDOT-NPMS). 2005. Confidential data from the NPMS database.

U.S. Department of Transportation. 2007. Office of Pipeline Safety Pipeline Statistics. Website: http://ops.dot.gov/stats/IA98.htm

West, W. R., P.A. Smith, P. W. Stoker, G. M. Booth, T. Smith-Oliver, B. E. Butterworth, and M. L. Lee. 1984. Analysis and genotoxicity of a PAC-polluted river sediment. Pages 1395-1411 In: M. Cooke and A. J. Dennis (eds.). Polynuclear aromatic hydrocarbons: mechanisms, methods, and metabolism. Battelle Press, Columbus, Ohio.

Wilson, L. 1986. Vulnerable aquifers. Pp. 60-61 in J.L. Williams, ed. New Mexico in Maps, New Mexico Press, Albuquerque, New Mexico.

8.0 Glossary

Accidental Release

An accidental release is an unplanned occurrence that results in a release of oil or natural gas from the pipeline.

Acute exposure

Exposure to a chemical or situation for a short period of time.

Acute toxicity

The ability of a substance to cause severe biological harm or death soon after a single exposure or dose.

Adverse effect

Any effect that causes harm to the normal functioning of plants or animals due to exposure to a substance (i.e., a chemical contaminant).

Algae

Chiefly aquatic, eucaryotic one-celled or multicellular plants without true stems, roots and leaves that are typically autotrophic, photosynthetic, and contain chlorophyll. They are food for fish and small aquatic animals.

Aquifer

An underground layer of water-bearing permeable rock, or unconsolidated materials (gravel, sand, silt or clay) from which groundwater can be usefully extracted using a water well.

Barrel

A barrel is a standard measure of a volume of oil and is equal to 42 gallons.

Benthic invertebrates

Those animals without backbones that live on or in the sediments of a lake, pond, river, etc.

Bioavailability

How easily a plant or animal can take up a particular contaminant from the environment.

Biodegradation

Biodegradation is the breakdown of organic contaminants by microbial organisms into smaller compounds. The microbial organisms transform the contaminants through metabolic or enzymatic processes. Biodegradation processes vary greatly, but frequently the final product of the degradation is carbon dioxide or methane.

BPD

Abbreviation for barrels per day

Cathodic Protection System

A technique to provide corrosion protection to a metal surface by making the surface of the metal object the cathode of an electrochemical cell. In the pipeline industry that is done using impressed current. Impressed current Cathodic Protection (ICCP) systems use an anode connected to a DC power source (a cathodic protection rectifier).

Chronic toxicity

The capacity of a substance to cause long-term poisonous health effects in humans, animals, fish, and other organisms. Biological tests that use sublethal effects such as abnormal development, growth, and reproduction, rather than solely lethality, as endpoints.

Contaminant

Any physical, chemical, biological, or radiological substance found in air, water, soil or biological matter that has a harmful effect on plants or animals; harmful or hazardous matter introduced into the environment.

Ecosystem

The sum of all the living plants and animals, their interactions, and the physical components in a particular area.

Emergency Flow Restricting Device (EFRD)

An emergency flow-restricting device is a device used to restrict or limit the amount of oil or gas that can release out of a leak or break in a pipeline. Check valves and remote control valves are types of EFRDs.

Exposure

How a biological system (i.e., ecosystem), plant, or animal comes in contact with a chemical.

Event

An event is a significant occurrence or happening. As applicable to pipeline safety, an event could be an accident, abnormal condition, incident, equipment failure, human failure, or release.

Facility

Any structure, underground or above used to transmit a product.

Failure Frequency

Failure frequency is the rate at which failures are observed or are predicted to occur, expressed as events per given timeframe.

Failure Probability

Failure probability is the probability that a structure, device, equipment, system, etc. will fail on demand or will fail in a given time interval, expressed as a value from 0 to 1.

Failure Rate

Failure rate is the rate at which failures occur. It is the number of failure events that occur divided by the total elapsed operating time during which those events occur or by the total number of demands, as applicable.

Geographical Information System (GIS)

A computer data system for creating and managing spatial data and associated attributes.

Habitat

The place where a population of plants or animals and its surroundings are located, including both living and non-living components.

High Consequence Area (HCA)

A high consequence area is a location that is specially defined in USDOT pipeline safety regulations as an area where pipeline releases could have greater consequences to health and safety or the environment. For oil pipelines, HCAs include high population areas, other population areas, commercially navigable waterways and areas unusually sensitive to environmental damage, including ecologically sensitive areas and drinking water resources. Regulations require a pipeline operator to take specific steps to ensure the integrity of a pipeline for which a release could affect an HCA and, thereby, provide protection of the HCA.

High Population Area

A high population area is an urbanized area, as defined and delineated by the U.S. Census Bureau, which contains 50,000 or more people and has a population density of at least 1,000 people per square mile. High population areas are considered HCAs.

Incident

As used in pipeline safety regulations, an incident is an event occurring on a pipeline for which the operator must make a report to the Office of Pipeline Safety. There are specific reporting criteria that define an incident that include the volume of the material released, monetary property damage, injuries, and fatalities (Reference 49 CFR 191.3, 49CFR 195.50).

Integrity Management Program

An IMP is a documented set of policies, processes, and procedures that are implemented to ensure the integrity of a pipeline. An oil pipeline operator's IMP must comply with the federal regulations (i.e., the Integrity Management Rule, 49 CFR 195).

Integrity Management Rule

The Integrity Management Rule specifies regulations to assess, evaluate, repair, and validate the integrity of hazardous liquid pipelines that, in the event of a leak or failure, could affect HCAs.

Invertebrates

Animals without backbones: e.g., insects, spiders, crayfish, worms, snails, mussels, clams, etc.

LC_{50}

A concentration expected to be lethal to 50 percent of a group of test organisms.

Leak

A leak is a small opening, crack, or hole in a pipeline allowing a release of oil or gas.

Likelihood

Likelihood refers to the probability that something possible may occur. The likelihood may be expressed as a frequency (e.g., events per year), a probability of occurrence during a time interval (e.g., annual probability), or a conditional probability (e.g., probability of occurrence, given that a precursor event has occurred).

Maximum Contaminant Level (MCL)

The maximum level of a contaminant allowed in drinking water by federal or state law. Based on health effects and currently available treatment methods.

National Pipeline Mapping System (NPMS)

The National Pipeline Mapping System is a GIS database that contains the locations and selected attributes of natural gas transmission lines, hazardous liquid trunklines, and liquefied natural gas (LNG) facilities operating in onshore and offshore territories of the United States.

One-Call System

A one-call system is a system that allows excavators (individuals, professional contractors, and governmental organizations) to make one telephone call to underground facility operators to provide notification of their intent to dig. The facility operators or, in some cases, the one-call center can then locate the facilities before the excavation begins so that extra care can be taken to avoid damaging the facilities. All 50 states within the U.S. are covered by one-call systems. Most states have laws requiring the use of the one-call system at least 48 hours before beginning an excavation.

Other Populated Areas

An ‘other populated area’ is a census designated place, defined and delineated by the U.S Census Bureau as settled concentrations of population that are identifiable by name but are not legally incorporated under the laws of the state in which they are located.

Operator

An operator is a person who engages in the transportation of gas (Reference 49 CFR 192.3) or a person who owns or operates pipeline facilities (Reference 49 CFR 195.2).

Polycyclic Aromatic Hydrocarbons (PAHs)

Group of organic chemicals.

Pipeline

Used broadly, pipeline includes all parts of those physical facilities through which gas, hazardous liquid, or carbon dioxide moves in transportation. Pipeline includes but is not limited to: line pipe, valves and other appurtenances attached to the pipe, pumping/compressor units and associated fabricated units, metering, regulating, and delivery stations, and holders and fabricated assemblies located therein, and breakout tanks.

Playa Lake

A rain-filled small, round depression in the surface of the ground.

Prairie Pothole

Water-holding depressions of glacial origin in the prairies of northern United States and southern Canada. Water is supplied by rainfall, basin runoff and seepage inflow of groundwater.

Receptor

The species, population, community, habitat, etc. that may be exposed to contaminants.

Risk

Risk is a measure of both the likelihood that an adverse event could occur and the magnitude of the expected consequences should it occur.

Sediment

The material of the bottom of a body of water (i.e., pond, river, stream, etc.).

Stressor

Any factor that may harm plants or animals; includes chemical (e.g. metals or organic compounds), physical (e.g. extreme temperatures, fire, storms, flooding, and construction/development) and biological (e.g. disease, parasites, depredation, and competition).

Supervisory Control and Data Acquisition System (SCADA)

A SCADA is a pipeline control system designed to gather information such as pipeline pressures and flow rates from remote locations and regularly transmit this information to a central control facility where the data can be monitored and analyzed.

Throughput

Amount of oil through a pipeline during a specified time.

Toxicity Testing

A type of test that studies the harmful effects of chemicals on particular plants or animals.

Toxicity Threshold

Numerical values that represent concentrations of contaminants in abiotic media (sediments, water, soil) or tissues of plants and animals above which those contaminants are expected to cause harm.

Unusually Sensitive Areas (USAs)

A USA is a drinking water or ecological resource area that is unusually sensitive to environmental damage from a hazardous liquid pipeline release, as defined in 49 CFR 195.6.

Zooplankton

Small, usually microscopic animals (such as protozoans) found in lakes and reservoirs.

Appendix A

Frequency – Volume Study of Keystone Pipeline

Appendix B

Preliminary HCA Evaluation
(to be filed April 2007)