CONFIDENTIAL

Prepared for: Keystone Pipeline Project
TransCanada Keystone Pipeline, LP

Pipeline Risk Assessment and Environmental Consequence Analysis

ENSR Corporation
June 2006
Document No.: 10623-004

ENSR | AECOM

CONFIDENTIAL

Prepared for: Keystone Pipeline Project
TransCanada Keystone Pipeline, LP

Pipeline Risk Assessment and Environmental Consequence Analysis

Prepared By

Reviewed By

ENSR Corporation
June 2006
Document No.: 10623-004

ENSR | AECOM

Contents

List of Tables

List of Figures

1.0 Project Overview

TransCanada Keystone Pipeline, LP (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 or Keystone, initially will have the capacity to deliver 435,000 barrels per day (bpd) of crude oil from an oil supply hub near Hardisty to existing terminals in Salisbury, Missouri, and Wood River and Patoka, Illinois. If market conditions warrant expansion in the future, additional pumping capacity could be added to increase the 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 1,833 miles of pipeline, including about 760 miles in Canada and 1,073 miles within the U.S. (**Figure 1-1**). These distances will increase if either or both of two potential pipeline extensions to Fort Saskatchewan, Alberta, or Cushing, Oklahoma, are constructed as discussed below.

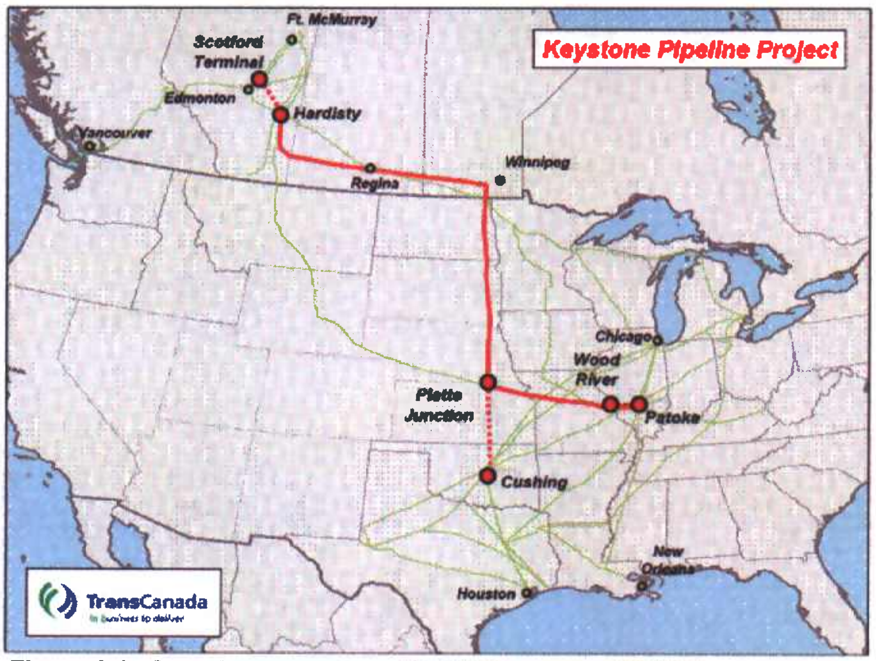

Figure 1-1 Overview Map of the Keystone Pipeline Project (Potential expansions represented by the dotted line)

In the U.S., Keystone will construct and operate a new 1,073-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 1,018 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 to be held later in 2006, Keystone also may construct a 291-mile 30-inch pipeline extension to Cushing, Oklahoma (Cushing Extension). Thus, there will be 1,365 total miles of new pipeline in the U.S. if the Cushing Extension is constructed. Unless specified, the remainder of this Supplemental Filing 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 capacity to 591,000 bpd.

The Keystone Pipeline Project will require the issuance of a Presidential Permit by the U.S. Department of State 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.). Keystone filed a Presidential Permit Application and Environmental Report (ER) on April 19, 2006. The ER was intended to provide the Department of State and other involved agencies with adequate information to commence review of the Keystone Pipeline Project under NEPA. The ER includes an objective disclosure of beneficial and adverse environmental impacts resulting from the Keystone Pipeline Project, as well as a set of reasonable alternatives. Keystone has stated that it will supplement the environmental information provided in the ER with the results of its field studies and pipeline risk assessment as they are completed.

2.0 Introduction

This portion of the supplemental filing represents Keystone's initial evaluation of the risk of a pipeline disruption and its potential environmental consequences. 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 ER, which was submitted to the Department of State on April 19, 2006.

General information on pipeline safety and historical spills as documented in the U.S. Department of Transportation (USDOT) incident database were previously presented in Section 3.12 of the ER. Section 3.12 of the ER also summarized the location and extent of natural hazards and sensitive natural and human resources near the Keystone Pipeline Project.

This report builds upon the baseline information presented in the ER. The report presents the results of a pipeline oil spill frequency and spill analysis based on Keystone's current project-specific 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.

As Keystone collects additional information to support the risk assessment through ongoing design work and environmental field surveys, this risk assessment and its supporting reference documents will continue to evolve. The risk assessment process is an iterative procedure in which information is continually updated and refined in an effort to improve the specificity of the assessment. Keystone anticipates submitting an updated consequence analysis in November 2006 that incorporates the additional design and environmental data into the assessment.

3.0 Spill Frequency-Volume Study

A 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. The Keystone Pipeline system was partitioned into 1,317 segments based on similar design, operational, terrain, and other potential risk parameters, each with a virtually consistent risk profile. Spill frequency was estimated for each segment along with potential spill volumes, based on small holes (<0.1-inch diameter), medium holes (1-inch diameter), and large holes (>10-inch diameter).

Two throughput scenarios were evaluated, a 435,000 bpd and a 591,000 bpd throughput case (nominal and maximum throughput). For the assessment, a leak detection capability of 1.5 percent in 138 minutes and a 15 percent leak detected within 18 minutes was assumed. Because Keystone is currently engineering the pipeline system, a detailed hydraulic profile and leak detection systems are not currently available. As the engineering and design progresses, the information will be integrated into the study and revised spill frequency and spill volumes will be estimated.

3.1 Spill Frequency

Spill frequencies were estimated from historical data and modified by project-specific factors to estimate spill frequencies for the Keystone Pipeline system. Based on the available information, the study produced an overall frequency for spills or leaks greater than 50 barrels of 0.14 spills per year for a throughput of 435,000 bpd over the entire pipeline system, equivalent to one spill every 7 years. **Table 3-1** shows the number of spills that might occur along the Keystone Pipeline system during the next 10 years.

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

	Spills[1]
Keystone Mainline (1,073 miles)	1.1
Cushing Extension (291 miles)	0.3
Total Keystone Project (1,365 miles)	1.4

[1]Calculated based on project-specific analysis of spill probabilities for 435,000 bpd (**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 USDOT's 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 complete drain down within the affected segment, recognizing that actual spill volumes are expected to be significantly less. Actual incident data from the *Hazardous Liquid Pipeline Risk Assessment* (California State Fire Marshal 1993) indicate that spill volumes are significantly less than the potential drain down volume. For example, in 50 percent of the cases, the actual spill volume represented less than 0.75 percent of the maximum potential drain down volume. In 75 percent of the cases, the actual spill volume represented less than 4.6 percent of the maximum drain down volume. Procedures to reduce spill volume, such as depressurization and drain down, may significantly reduce the predicted spill volumes estimated for the Keystone Pipeline, bringing the spill volume distribution more in line with USDOT historical data. Spill volume estimates, revised to account for drain down and depressurization, will be included in Keystone's November 2006 Supplemental filing.

Of the postulated 1.4 spills along the Keystone Pipeline system during a 10-year period, the study's findings suggest that approximately 0.2 would be 50 barrels or less; 0.8 would consist of between 50 and 1,000 barrels; 0.3 would consist of between 1,000 and 10,000 barrels; and 0.2 would contain more than 10,000 barrels[1] (**Appendix A**). The spill volume frequency distribution likely underestimates the proportion of spill volumes under 50 barrels due to reliance upon the greater than 50 barrel reporting criteria within the USDOT incident database. The current analysis tends to overemphasize larger spills and underreport the small spills, making the assessment conservative.

Based on probabilities generated from the study, the estimated occurrence intervals for a spill of 50 barrels or less occurring anywhere along the entire pipeline system is once every 65 years, a spill between 50 and 1,000 barrels might occur once in 12 years; a spill of 1,000 and 10,000 barrels might occur once in 39 years; and a spill containing more than 10,000 barrels might occur once in 50 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 67,000 years. The results of the study are incorporated into the environmental consequence analysis presented in Section 4.0 below.

3.3 Contribution of Natural Hazards to Spill Potential

As part of its National Pipeline Mapping System (NPMS) program, the USDOT has compiled data from a variety of sources to identify areas of high geologic hazard potential for pipelines (USDOT-NPMS 2005). The Integrity Management Rule (2002) states that segments of pipeline with a high geologic risk and the potential to impact HCAs must implement protective measures. HCAs are specific locales and areas where a release could have the most significant adverse consequences. Examples of protective measures may include: enhanced damage prevention programs, reduced inspection intervals, corrosion control program improvements, leak detection system enhancements, installation of Emergency Flow Restricting Devices (EFRDs), and emergency preparedness improvements. **Table 3-2** provides a summary of the geologic hazards and pipeline miles identified with HCAs.

---

[1] Total does not sum to 1.4 spills due to rounding.

Table 3-2 Summary of Geological Hazard HCAs Identified Along the Keystone Pipeline Project

	Potential Geological Hazards (miles of pipeline)		
	Earthquake	**Flood**	**Landslide**
Keystone Mainline			
North Dakota	0.0	3.0	0.0
South Dakota	0.0	21.9	7.7
Nebraska	0.0	21.9	13.1
Kansas	0.0	10.9	0.0
Missouri	0.0	99.5	30.1
Illinois	0.0	12.8	6.9
Keystone Mainline subtotal	*0.0*	*170.1*	*57.8*
Cushing Extension			
Nebraska	0.0	2.5	2.5
Kansas	0.0	107.2	7.0
Oklahoma	0.0	27.8	0.0
Cushing Extension Subtotal	*0.0*	*137.4*	*9.5*
Project Total	**0.0**	**307.5**	**67.3**

Seismicity and Faults. Seismic damage to buried pipelines is due to the combination of seismic wave propagation and permanent ground displacement. Strong ground shaking also can cause water-saturated soils to become liquified (liquifaction). Earthquakes tend to cause more damage to segmented pipelines than to continuous pipelines that have joints consisting of full penetration welded steel. The Keystone Pipeline will be a continuous pipeline. Buckling and pinhole leaks (typically at previously weakened areas of corrosion) are the most common types of pipeline damage caused by seismic events.

Nationwide, earthquakes (and other natural hazards) are responsible for less than 3 percent of all pipeline incidents each year. Moreover, O'Rourke and Palmer (1996) studied earthquake performance data for steel transmission and distribution pipelines over a 61-year period. Their review of the data found that post-1945 electric arc-welded transmission pipelines in good repair have performed very well in earthquakes.

Keystone will construct all new facilities to current Uniform Building Code standards. Additional engineering measures to account for seismic activity are not expected to be required due to relatively low seismic activity in the region crossed by the Keystone Pipeline Project.

Federal regulations (49 CFR 195) require Keystone to conduct an internal inspection if an earthquake, landslide, or soil liquefaction is suspected of having caused abnormal movement of the pipeline. Consequently, damage to the pipeline would be detected quickly and spills would be averted or minimized. The likelihood of earthquake damage to the Keystone Pipeline is low, as the entire Keystone Pipeline Project falls outside of the USDOT-defined high earthquake hazard areas.

Landslides. Three segments of the Keystone Pipeline Project cross areas identified by the NPMS as having high landslide potential (**Table 3-2**). These areas are located at 1) the Missouri River crossing near Yankton, South Dakota; 2) the Nebraska-Kansas border at Silver Hills; and 3) the Missouri and Mississippi River crossings. These areas will be field verified and evaluated for recent landslide activity and determination of whether HCAs could be impacted. Overall, landslides are considered a low hazard to the Keystone Pipeline system.

Subsidence. Subsidence of the ground surface can result in damage due to loss of support and the transfer of stresses in the ground to structures and facilities. Subsidence can be caused by several factors, but the cause of subsidence considered here is the dissolution of subsurface strata. Limestone, dolomite, gypsum or other susceptible rock is susceptible to water solution. The dissolution may cause surface effects such as sinkholes or depressions of the ground surface, caves, sinking streams, springs and seeps, and valleys with closed drainage (Kastning and Kastning 1999). The surface effects of dissolution are referred to as karst terrain.

Several areas of potential karst hazards were identified along the proposed route based on the map produced by Davies et al. (1984). In South Dakota and Nebraska, Upper Cretaceous Niobrara Formation and equivalents are identified as strata that could be involved in the formation of karst. Areas in northeast Kansas and Missouri are underlain by limestones in Pennsylvanian and Permian-age strata. The solution features are characterized as irregularly spaced (1,000 feet or more) small fissures (less than 1,000 feet long and 50 feet deep) with 50 feet or more overburden. Overall, subsidence is a low hazard to the Keystone Pipeline System.

Flooding. Scattered portions of the Keystone Pipeline Project cross areas that are ranked as high flood hazard areas by the NPMS (**Table 3-2**). These areas are more prevalent along the southern portion of the route and are generally collocated with major river systems, such as the Missouri, Platte, Kansas, Arkansas, and Mississippi Rivers. These areas will be field verified and cross-checked with Federal Emergency Management Agency flood maps. If the area is highly susceptible to flooding, then the portion of pipeline within the affected area will be cross-referenced for presence of HCAs and, if present, protective measures will be taken, as per 49 CFR Part 195. Additionally, if aboveground facilities are located within potential floodplains, Keystone will evaluate the potential for relocating these facilities and/or measures to reduce damage to aboveground facilities should flooding occur.

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 are generally acceptable. The National Center for Health Statistics (CDC 2003) age-adjusted average annual death rate 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 hazardous liquids transmission pipelines, such as Keystone, is 1 in 27,708,096 (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, a black and thick oil. In order for the bitumen to be transported by pipeline, an upgrading technology is applied to convert the bitumen to synthetic crude oil. The precise composition of synthetic crude will vary by shipper and is considered proprietary information.

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 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.

Spreading of crude oil 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 are frequently located 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

Soils could be impacted because pipelines are buried and soil absorption of spilled crude oil would occur. In contrast with crude oil releases to surface waters where the oil would disperse downstream, subsurface releases to soil tend to disperse more 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.

Depending 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), a portion of the released materials would enter the surrounding soil and disperse both vertically and horizontally in the soil. High rates of release from the buried pipeline would result in a greater likelihood that released materials would reach the ground surface, while low rates of release would be more likely to primarily remain within the less compacted pipe trench backfill with a smaller portion dispersing within surrounding, consolidated subsurface materials. The sandy soils found throughout most of the pipeline route would likely facilitate horizontal and vertical dispersion. If present, soil moisture and moisture from precipitation would increase the dispersion and migration of crude oil.

Crude oil released to the soil's surface could potentially produce localized effects on plant populations (see Vegetation, Section 3.2.3 below). Within areas of active agriculture, the release of crude oil could result in the contamination of soils. 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 agricultural lands would be expected.

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.

If a spill were to occur, the majority of the crude oil would likely reside in the less consolidated soil (lower soil bulk density) within the pipeline trench. The vast majority of the 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 the 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. Soil types and the presence of clay lenses, layers of bedrock, or karst terrain would significantly influence the dispersal pattern of spilled materials.

Crude oil released to the environment would tend to have greater dispersion in sandy and badland soils than in more consolidated soils. If a release were to occur in sandy soils or badland areas, it is likely that the spatial extent of the contamination would be greater than in areas containing more organic soils. Consequently, the amount of soil that would need to be cleaned up would be less than or equal to the maximum amount. 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.

The removal and disposal of contaminated soil likely represents the remedial action that would cause the greatest amount of surface disturbance. Based on a spill volume of 2,000 barrels (over 80 percent of spills are smaller than this volume), the maximum amount of soil that would need to be removed was calculated. Soil cleanup levels for benzene in soil 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 volume of soil remediation is based upon two different calculations to aid in identifying worst-case (2,001,277 cubic yards) and best-case (2,059 cubic yards) volume estimates. The worst-case estimate assumes a 2,000-barrel release, an estimated concentration of benzene in the oil, and a uniform distribution of oil to achieve the most stringent state recommended soil cleanup level (RCL) for benzene (1.6 ppm). The approach assumes that all the oil is evenly spread to a mass of oil such that the resulting oil benzene concentration is 1.6 milligrams per kilograms. Because the RCL is used as a target, the resulting volume of soil is actually the volume of soil at which no removal action would be needed. The best case estimate assumes the same 2000 barrel release but calculates the volume of soil that could fill with the volume of the release based on an estimated 30 percent soil porosity and a 10 percent soil moisture content and would likely be the minimum volume of soil to be removed. The actual remediation soil volume would likely be closer to the best-case estimate although higher than this 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 Water Resources

While normal operations would not adversely affect water resources, abnormal operations could result in released crude oil entering water resources. As part of project planning and in recognition of the environmental sensitivity of waterbodies, the Keystone Pipeline routing process attempted to minimize the waterbodies crossed. 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 the Keystone Emergency Response Plan would mitigate adverse effects to both surface and groundwater.

Flowing Surface Waters

To evaluate the likelihood of adverse effects to surface water resources, measurement endpoints were developed to correspond with the most sensitive resource potentially affected (surface water that provides drinking water and supports aquatic life) and to address the primary regulatory thresholds that trigger emergency response and remediation. These measurement endpoints (toxicity thresholds and drinking water standards) were compared to the maximum possible concentration of benzene. Benzene values were selected for comparison because they were the most likely to show adverse impacts to aquatic biota and drinking water.

These measurement endpoints were compared to estimated concentrations of crude oil in the surface water. Rather than evaluate the risk to each waterbody crossed by the Keystone Pipeline, this risk assessment evaluated streams categories, broadly classified by 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

Although the concentration of crude oil constituents in an actual spill would vary both temporally and spatially and localized toxicity could occur from virtually any size of crude oil spill, for this analysis it was conservatively assumed that the entire volume of the spill was released directly into a waterbody and that complete, instantaneous mixing occurred. These assumptions are highly conservative and, thus, overestimate potential toxic effects. These estimated benzene concentrations within the surface waterbodies were then compared with acute and chronic toxicity thresholds for human health drinking water thresholds and for aquatic biota.

The promulgated drinking water standards for humans vary by several orders of magnitude for crude oil constituents. For human health protection, the national Maximum Contaminant Level (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 or groundwaters.

An evaluation of water quality was conducted to assess potential risk to drinking water supplies. The estimated concentrations of benzene within representative streamflows are summarized in **Tables 4-2** and **4-3**. A 1-hour release period for the entire spill volume was assumed in order to maximize the product concentration in water. Results suggest that most spills that enter a waterbody could result in exceedence of the national MCL for benzene. These findings indicate that rapid notification of managers of municipal water intakes downstream

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

of a spill would be essential so that any drinking water intakes could be closed to bypass river water containing crude oil.

To evaluate the potential for drinking water impacts to occur in any specific waterbody, the occurrence interval for a spill at the river crossing was calculated based on 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**.

Results indicate that the chance of a spill occurring at any specific waterbody is very low. Depending on throughput, occurrence intervals ranged from about 16,000 years for a large waterbody to over 450,000 years for a small waterbody. 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 1,000 barrels based on the spill volume study (**Appendix A**).

In summary, while a release of crude oil 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 the sensitive environmental resources and could be temporarily impacted by a crude oil release.

Wetlands/Prairie Potholes/Playa Lakes

Although planning and routing efforts attempted to reduce the overall number of wetlands (including prairie potholes and playa lake environments) and static waterbodies environment crossed by the Keystone Pipeline, wetlands and waterbodies with persistently saturated soils commonly occur 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 baseline conditions in both soil and groundwater. This would likely require a timeframe on the order of tens of years.

The evaluation of spill effects on fish and aquatic invertebrates also is applicable to wetland environments and plants. Based on a review of 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, assumptions and calculations based on aquatic life standards are conservative (i.e., more likely to show an adverse effect than if the limited amount of wetland toxicity data were used). Therefore, spill concentrations that are less than toxic effect levels for fish and invertebrates also would be protective for wetland plant species.

Table 4-2 Estimated Benzene Concentrations from Crude Oil Release Compared with Human Drinking Water for Streams Crossed by the Proposed Action

Throughput – 435,000 bpd	Benzene MCL (ppm)	Stream Flow Rate (cfs)	Product Released: Small spill: 50 barrels		Product Released: Moderate spill: 1,000 barrels		Product Released: Large spill: 10,000 barrels	
			Concentration (ppm)	Occurrence Interval (years)	Concentration (ppm)	Occurrence Interval (years)	Concentration (ppm)	Occurrence Interval (years)
Low Flow Stream	0.005	10	**11**	**457,042**	**220**	**63,562**	**2,201**	**342,782**
Lower Moderate Flow Stream	0.005	100	**1.1**	**319,930**	**22**	**44,494**	**220**	**239,947**
Upper Moderate Flow Stream	0.005	1,000	**0.11**	**239,947**	**2.2**	**33,370**	**22**	**179,690**
High Flow Stream	0.005	10,000	**0.01**	**137,113**	**0.2**	**19,069**	**2.2**	**102,835**

Notes:

-Predicted rates apply for each stream crossing.

-Estimated concentration is based on release of benzene into water over a 24-hour period with uniform mixing conditions.

-Concentrations are based on a 0.15 percent by weight benzene content of the crude oil.

-Benzene concentrations compared to benzene's MCL of 0.005 ppm.

-Shading indicates concentrations that could exceed the MCL.

-Occurrence intervals are based on a predicted incident frequency of 0.14 spills/year for 435,000 bpd along the entire Keystone Pipeline (**Appendix A**) 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 Estimated Benzene Concentrations from Crude Oil Release Compared with Human Drinking Water Standard for Streams Crossed by the Proposed Action

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	
			Concentration (ppm)	Occurrence Interval (years)	Concentration (ppm)	Occurrence Interval (years)	Concentration (ppm)	Occurrence Interval (years)
Low Flow Stream	0.005	10	11	281,692	220	52,783	2,201	217,030
Lower Moderate Flow Stream	0.005	100	1.1	197,149	22	36,948	220	151,921
Upper Moderate Flow Stream	0.005	1,000	0.11	147,862	2.2	27,711	22	113,941
High Flow Stream	0.005	10,000	0.01	84,493	0.2	15,835	2.2	65,109

Notes:

-Predicted rates apply for each stream crossing.

-Estimated concentration is based on release of benzene into water over a 24-hour period with uniform mixing conditions.

-Concentrations are based on a 0.15 percent by weight benzene content of the crude oil.

-Benzene concentrations compared to benzene's MCL of 0.005 ppm.

-Shading indicates concentrations that could exceed the MCL.

-Occurrence intervals are based on a predicted incident frequency of 0.19 spills/year for 591,000 bpd along the entire Keystone Pipeline (**Appendix A**) 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.

Results indicate that the chance of a spill occurring at any specific wetland is very low. Based on National Wetlands Inventory mapping, wetlands comprise 46.4 miles of the entire Keystone Pipeline system (Table 3.5-8 of the Keystone Environmental Report). Of the estimated 1.4 spills postulated to occur during a 10-year period within the entire pipeline system, about 0.05 spills would be expected to occur within wetland areas (equivalent to one spill every 200 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 1,000 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 4-4** 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. An evaluation of standing water resources that could be impacted by a crude oil spill will be evaluated more completely in Keystone's November 2006 supplemental filing.

Table 4-4 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)
50	4.6	25	6,890
150	14	74	20,669
1,000	93	492	137,790
10,000	931	4,921	1,377,904

[1]Thresholds based on aquatic toxicity and drinking water thresholds established for benzene. For the Keystone crude oil, the benzene content is estimated to be 0.15 percent by weight.

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 the sensitive environmental resources and further evaluation of potential impacts is warranted.

Groundwater

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); and
- Where relatively porous soil conditions are present throughout the unsaturated zone.

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 potential groundwater receptors 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 relative to groundwater 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 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 drivers would mandate the scope of remedial actions, timeframe for remediation activities, and cleanup levels. 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 baseline conditions in both soil and groundwater. Depending on the amount of crude oil reaching the groundwater and natural attenuation rates, this would likely require a timeframe up to the range of tens of years.

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 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.

4.2.2.3 Vegetation

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 3.2.1 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.

4.2.2.4 Wildlife and Aquatic Resources

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.

The toxicity of crude oil is dependent upon its composition and that of its water-soluble fraction (WSF), especially of its aromatic content. The WSF of crude oil is dominated by one- and two-ringed aromatics (e.g., benzene and naphthalene) along with some short-chained alkanes. Long-chained alkanes (e.g., decane) and aromatic compounds with many rings (e.g., PAHs) tend to be less soluble in water. As an example, **Table 4-5** 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 (BETX and naphthalenes), particularly benzene.

Because of competing effects of solubility and toxicity, the higher the concentration of these aromatics in a particular crude oil, the more toxic it will be. Studies have shown that lighter, more volatile compounds (e.g., benzene) are more acutely toxic than heavier, more viscous compounds. While lightweight aromatics 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 (Couch and Harshbarger 1985).

The sensitivity of organisms to crude oil is extremely varied. **Table 4-6** summarizes acute toxicity data for a broad range of species based on USEPA's AQUIRE database (USEPA 2000). 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. 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.

Fewer data are available to evaluate the toxicity of crude oil hydrocarbons on terrestrial organisms. **Table 4-7** summarizes toxicity data from the EPA's ECOTOX database (2001) for earthworms and terrestrial plants. Comparison of LC_{50} values for benzene suggests that aquatic species are more sensitive to crude oil than terrestrial organisms. Insufficient information was available to evaluate other constituents of concern.

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).

Table 4-5 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 4-6 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 LC_{50} values was calculated.

Table 4-7 Comparison of Benzene Toxicity Concentrations for Various Organisms

	Benzene
Aquatic species	7.4 ppm
Terrestrial plant	18.2 ppm
Earthworm	>1,000 ppm

Table 4-8 summarizes chronic toxicity (most frequently measured as reduced reproduction, growth, or weight) of benzene to freshwater biota. Benzene was selected as the most conservative measure of chronic toxicity due to its combined water solubility and chronic toxicity value. 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*)	41 4.8 *

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

Wildlife Impacts

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.

Aquatic Toxicity

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 were not very soluble in water then its toxicity to aquatic biota would be relatively low. The toxicity of crude oil is dependent of the toxicity of its constituents. Among these, benzene is generally considered the most toxic constituent due to the low concentrations at which toxic effects are observed and its high water solubility. Other compounds in crude oil are considered much less toxic. For this assessment, the benzene content within the crude oil hypothetically entering the waterbody was assumed to be completely dissolved in the water. This assumption overestimates the actual amount of benzene that likely would become solubilized in the water. Concentrations of benzene were compared to benzene toxicity thresholds to assess whether toxic effects might be anticipated.

For aquatic biota, the 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 other aquatic biota, since other major constituents of crude oil are less toxic. Although trout are not found in many of the habitats crossed by the project, trout studies were selected because trout are among the most sensitive aquatic species and reliable acute and chronic trout toxicity data are available.

Tables 4-9 to **4-12** summarize the predicted acute and chronic toxicity to aquatic resources, based on the amount of crude oil released and the streamflow. 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, toxicity could potentially kill or injure aquatic species in the immediate vicinity and downstream of the rupture. Under these two scenarios, 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 particular waterbody is low, with an occurrence interval of once every 16,000 to 500,000 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 1,000 barrels based on the spill volume study (**Appendix A**).

In summary, 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.

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 environmentally damaged from a hazardous liquid pipeline release (**Table 4-13**). 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 and the Environmental Protection Agency). These USDOT-designated HCAs are continually refined and updated. 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. TransCanada will conduct a thorough analysis of potential impacts to HCAs as part of its compliance with federal regulations.

Assuming that 1.4 spills occurred along the Keystone Pipeline system in a 10-year period, it is estimated that approximately 0.18 of these spills would occur in HCAs (**Table 4-13**). 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 4-14** also shows the number of spills and their predicted sizes.

4.3.1 Populated Areas

Highly populated HCAs occur along 4.0 miles of the Keystone Pipeline system. These highly populated areas have been identified as HCAs by the USDOT based on U.S. Census data (**Table 4-14**). More than 99 percent of these miles are near St. Louis, Illinois. Because of the recent population growth in some areas, Keystone also will review other populated areas, including those around Troy (Missouri), Edwardsville (Missouri) and the St. Louis area (Missouri and Illinois), to determine if these areas qualify as HCAs.

Table 4-9 Comparison of Estimated Crude Oil Concentrations Following a Spill to the Acute Toxicity Thresholds for Aquatic Life (7.4 ppm) for Streams Crossed by the Proposed Action

Throughput – 435,000 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	
			Concentration (ppm)	Occurrence Interval (years)	Concentration (ppm)	Occurrence Interval (years)	Concentration (ppm)	Occurrence Interval (years)
Low Flow Stream	10	7.4	**11**	**457,042**	**220**	**63,562**	**2,201**	**342,782**
Lower Moderate Flow Stream	100	7.4	1.1	319,930	**22**	**44,494**	**220**	**239,947**
Upper Moderate Flow Stream	1,000	7.4	0.11	239,947	2.2	33,370	**22**	**179,690**
High Flow Stream	10,000	7.4	2.2	102,835	0.2	19,069	0.01	137,113

Notes:

-Predicted rates apply for each stream crossing.

-Estimated proportion of benzene in the crude oil 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 crude oil released divided by 96 hours 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 a predicted incident frequency of 0.14 spills/year along the entire Keystone Pipeline (**Appendix A**) 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 Crude Oil Concentrations Following a Spill to the Acute Toxicity Thresholds for Aquatic Life for Streams Crossed by the Proposed Action

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	
			Concentration (ppm)	Occurrence Interval (years)	Concentration (ppm)	Occurrence Interval (years)	Concentration (ppm)	Occurrence Interval (years)
Low Flow Stream	10	7.4	**11**	**281,692**	**220**	**52,783**	**2,201**	**217,030**
Lower Moderate Flow Stream	100	7.4	1.1	197,149	**22**	**36,948**	**220**	**151,921**
Upper Moderate Flow Stream	1,000	7.4	0.11	147,862	2.2	27,711	**22**	**113,941**
High Flow Stream	10,000	7.4	0.01	84,493	0.2	15,835	2.2	65,109

Notes:

-Predicted rates apply for each stream crossing.

-Estimated proportion of benzene in the crude oil 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 crude oil released divided by 96 hours 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 a predicted incident frequency of 0.19 spills/year along the entire Keystone Pipeline (**Appendix A**) 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 Estimated Crude Oil Concentrations Compared to the Chronic Toxicity Threshold for Aquatic Life for Streams Crossed by the Proposed Action

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	
			Concentration (ppm)	Occurrence Interval (years)	Concentration (ppm)	Occurrence Interval (years)	Concentration (ppm)	Occurrence Interval (years)
Low Flow Stream	10	1.4	0.07	457,042	1.3	63,562	13	342,782
Lower Moderate Flow Stream	100	1.4	0.007	319,930	0.1	44,494	1.3	239,947
Upper Moderate Flow Stream	1,000	1.4	0.001	239,947	0.01	33,370	0.1	179,690
High Flow Stream	10,000	1.4	0.0001	137,113	0.001	19,069	0.01	102,835

-Predicted rates apply for each stream crossing.

-Estimated proportion of benzene in the crude oil 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 crude oil 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 a predicted incident frequency of 0.14 spills/year along the entire Keystone Pipeline (**Appendix A**) 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 Estimated Crude Oil Concentrations Compared to the Chronic Toxicity Threshold for Aquatic Life for Streams Crossed by the Proposed Action

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	
			Concentration (ppm)	Occurrence Interval (years)	Concentration (ppm)	Occurrence Interval (years)	Concentration (ppm)	Occurrence Interval (years)
Low Flow Stream	10	1.4	0.07	281,692	1.3	52,783	13	217,030
Lower Moderate Flow Stream	100	1.4	0.007	197,149	0.1	36,948	1.3	151,921
Upper Moderate Flow Stream	1,000	1.4	0.001	147,862	0.01	27,711	0.1	113,941
High Flow Stream	10,000	1.4	0.0001	84,493	0.001	15,835	0.01	65,109

-Predicted rates apply for each stream crossing.

-Estimated proportion of benzene in the crude oil 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 crude oil 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 a predicted incident frequency of 0.19 spills/year along the entire Keystone Pipeline (**Appendix A**) 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 Mileage Summary of USDOT-Defined HCAs Identified Along the Keystone Pipeline Project

	Miles of Pipeline				Number of Spills in 10 years *(occurrence interval)*			
	Highly Populated Areas	**Drinking Water**	**Ecologically Sensitive Area**	**Total in HCAs[1]**	**Highly Populated Areas**	**Drinking Water**	**Ecologically Sensitive Area**	**Total HCAs**
North Dakota	0.0	7.0	2.0	9.0	NA	0.007 (1,300 yrs)	0.002 (4,700 yrs)	0.01
South Dakota	0.0	7.8	22.5	26.9	NA	0.008 (1,200 yrs)	0.024 (420 yrs)	0.03
Nebraska	0.0	7.9	9.3	12.6	NA	0.008 (1,200 yrs)	0.009 (1,000 yrs)	0.01
Kansas	0.0	8.4	18.3	26. 7	NA	0.008 (1,100 yrs)	0.019 (510 yrs)	0.03
Missouri	0.1	16.7	59.0	69.6	NA	0.018 (560 yrs)	0.063 (160 yrs)	0.07
Illinois	3.9	16.8	7.3	25.2	0.004 (2,500 yrs)	0.018 (560 yrs)	0.007 (1,300 yrs)	0.03
Keystone Mainline subtotal	*4.0*	*64.6*	*118.4*	*169.9*	*0.004 (2,500 yrs)*	*0.069 (145 yrs)*	*0.13 (79 yrs)*	*0.18*
Nebraska	0.0	0.0	0.0	0.0	NA	0.0	0.0	0.00
Kansas	0.0	45.3	47.7	59.7	NA	0.048 (210 yrs)	0.051 (200 yrs)	0.06
Oklahoma	0.0	18.3	7.7	11.4	NA	0.019 (510 yrs)	0.008 (1,200 yrs)	0.01
Cushing Extension Subtotal	*0.0*	*63.6*	*55.4*	*71.1*	*NA*	*0.068 (150 yrs)*	*0.060 (170 yrs)*	*0.07*
Project Total	**4.0**	**128.2**	**173.8**	**0.0**	**0.004 (2,500 yrs)**	**0.14 (73 yrs)**	**0.19 (54 yrs)**	**0.00**

[1] Numbers do not add up because some miles overlap in the different types of HCAs.

Note: NA indicates no highly populated area within the segment.

Table 4-14 Release and Spill Volume Occurrence Interval Associated with the Keystone Pipeline Project

	Miles of Pipe[1]	Number of Spills in 10 years (occurrence interval)				
		Total Number	<50 barrels (bbls)	50 to 1,000 bbls	1,000 to >10,000 bbls	>10,000 bbls
KEYSTONE MAINLINE						
Populated Areas	3.9	0.004 (2,500 years)	0.0004 (23,000 years)	0.002 (4,000 years)	0.0007 (14,000 years)	0.0006 (18,000 years)
Drinking Water Areas	64.6	0.069 (140 years)	0.007 (1,300 years)	0.04 (250 years)	0.01 (820 years)	0.01 (1,000 years)
Ecologically Sensitive Areas	118.4	0.13 (77 years)	0.014 (710 years)	0.075 (130 years)	0.023 (430 years)	0.018 (560 years)
CUSHING EXTENSION						
Populated Areas[2]	0.0	0.0	0.0	0.0	0.0	0.0
Drinking Water Areas	63.6	0.068 (150 years)	0.007 (1,400 years)	0.039 (260 years)	0.012 (830 years)	0.010 (1,000 years)
Ecologically Sensitive Areas	55.4	0.060 (170 years)	0.006 (1,700 years)	0.035 (290 years)	0.011 (910 years)	0.008 (1,250 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.

4.3.2 Drinking Water

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 4-13**). These areas are scattered throughout both the Keystone Mainline and Cushing Extension Pipeline routes. Keystone will conduct a more thorough evaluation to identify HCAs associated with sensitive drinking water resources. HCA will be subject to higher levels of inspection, as per 49 CFR Part 195. Keystone will evaluate the location of valves as a measure to reduce potential risk to highly sensitive drinking water resources.

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 4-13**). These areas are generally associated with major river systems (e.g., Missouri, Platte, and Mississippi Rivers) and the Flint Hills in central Kansas. 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

In this initial assessment, it has been presumed that risk is distributed evenly across the pipeline route. However, risk of a spill tends to concentrate in some areas more than others due to differences in hydraulic gradients, numbers of roads, and other factors (**Appendix A**). Spill frequency and volume was calculated for 1,314 individual segments and two throughput cases.

When the throughput is 435,000 bpd, 25 percent of the overall spill risk predicted for the pipeline is contained within 82 segments (representing 13 percent of the pipeline system length). Within these 82 segments, there are 0.1 mile located within highly populated areas, 0.0 mile within ecologically sensitive areas, and 11.6 miles located within drinking water HCAs.

Similarly, the top 59 segments (representing 9 percent of the pipeline system length) account for 25 percent of the overall spill risk predicted for the pipeline when the throughput is 591,000 bpd. Within these 59 segments, there are 0.0 miles located within highly populated areas, 0.0 mile within ecologically sensitive areas, and 4.3 miles located within drinking water HCAs.

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. In compliance with federal regulations, 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. Furthermore, Keystone will implement additional risk control measures if needed to protect HCAs. Examples of these additional measures may include: enhanced damage prevention programs, reduced inspection intervals, corrosion control program improvements, leak detection system enhancements, installation of EFRDs, and emergency preparedness improvements.

5.0 Keystone's Pipeline Safety Program

Pipelines are one of the safest forms of crude oil transportation. The Keystone Pipeline system will be designed, constructed and maintained in a manner that meets or exceeds industry standards. All pipelines will be built within an approved ROW and highly visible signs will be installed at all road, railway, and water crossings indicating that a pipeline is located in the area to prevent damage or impact to the pipeline. Keystone will manage a crossing and encroachment approval system for all other operators. Keystone will ensure safety near its facilities through a combination of programs encompassing engineering design, construction, and operations; public awareness and incident prevention programs; and emergency response programs.

Historically, the most significant risk associated with operating a crude oil pipeline is the potential for third-party excavation damage. Keystone will mitigate this risk by implementing a comprehensive Integrated Public Awareness program focused on education and awareness. The cornerstone of the program encourages use of the state One-Call system before people begin excavating. Keystone's operating staff also will complete regular visual inspections of the ROW and monitor activity in the area.

Keystone will have a preventative maintenance, inspection and repair program that ensures the integrity of all its pipeline. Keystone's annual Pipeline Maintenance Program will be designed to maintain the safe operation of the pipeline system. The system will include routine visual inspections of the ROW, regular inline inspections, and collection of predictive data, underpinned by a company wide goal to ensure facilities are reliable and in service. Data collected in each year of the program will fed back into the decision making process for the development of the following year's program, which aids in facilitating a safe pipeline system. The pipeline system will be monitored 24 hours a day, 365 days a year.

In compliance with applicable regulations governing the operation of pipelines, periodic in-line inspections will be conducted to collect information on the status of pipe for the entire length of the system. In-line inspection represents the state-of-the-art methodology to detect internal and external corrosion, a major cause of pipeline spills. From this type of inspection, suspected areas of corrosion or other types of damage (e.g., scratch in the pipe from third-party excavation damage) can be identified and proactively repaired. Additional types of information collected along the pipeline will include cathodic protection readings, geotechnical investigations, aerial patrol reports and routine investigative digs. In addition, line patrol, leak detection systems, supervisory control and data acquisition (SCADA), fusion bond epoxy coating and construction techniques with associated quality control will be implemented.

Keystone will carry out routine visual inspections and other operating activities with an awareness of pipeline and facility safety, and the prevention of unauthorized trespass or access.

Keystone will have an Emergency Response Program in place to manage a variety of events. Human health and the environment are of the utmost importance to the Keystone in these types of situations. Risk assessment is an iterative process. As additional engineering and design information and refinements become available, Keystone will update its risk assessment and submit the updated assessment in an expected November 2006 filling with the Department of State.

In summary, the analysis shows that the frequency of incidents is low and the environmental consequences would likely be nominal. In addition, compliance with regulations, use of state-of-the-art inspection methodology and adherence to safety procedures will help to ensure environmentally sound and safe operation of the pipeline.

6.0 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. Cham. 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. 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.

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.

7.0 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.

Blue Barrel (bbl)

In the late 1800's Standard Oil began manufacturing 42 gallon barrels painted blue for the express purpose of transporting petroleum. This blue barrel became the standard in industry. Hence, the abbreviation bbl for 1 barrel of oil.

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 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. 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, the protection of the HCA.

High Population Area (HPA)

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 integrity management program is a documented set of policies, processes, and procedures that are implemented to ensure the integrity of a pipeline. An oil pipeline operator's Integrity Management Program 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 gas transmission lines 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.

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 49CFR 195.6.

Zooplankton

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