April 26, 2013

Executive Summary

This report provides Exponent's third-party independent environmental review of a specific set of issues identified by the U.S. Department of State (DOS) in consultation with the U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration (PHMSA) and the U.S. Environmental Protection Agency (the agencies) that relate to the Keystone XL Project (Project) preliminary risk assessment (Risk Assessment) prepared by AECOM and Dynamic Risk Assessment Systems, Inc., on behalf of TransCanada Keystone Pipeline, LP (Keystone). These issues are described in Section 1 of our environmental review. The Risk Assessment document is presented in Appendix P– *Pipeline Risk Assessment and Environmental Consequence Analysis* dated July 2009 contained within the Final Environmental Impact Statement (FEIS) prepared for DOS by Cardno ENTRIX, contractor for DOS. The agencies thought it advisable to have an additional environmental review of the Risk Assessment because of the highly technical nature of the issues involved, and the desire to ensure that the Project-specific Special Conditions are properly implemented in the event that a Presidential Permit is issued. To address the issues identified by the agencies, we relied on information in the Risk Assessment and FEIS as well as information we obtained that related to the issues identified by the agencies. The report addresses comments on Exponent's draft report. Exponent's review was based on the initial route for the pipeline; the modifications of that route have not been specifically evaluated. However, the general recommendations made in this report are broadly applicable.

The agencies determined that Keystone should commission an engineering analysis that would, at a minimum, assess the advisability of additional valves and/or the deployment of external leak detection systems in areas of particularly sensitive environmental resources. Battelle was chosen by the agencies to provide that ***engineering review***. Exponent was tasked by the agencies to provide the ***environmental review***, part of which was to consider the presence of other sensitive environmental resources along the Project that may warrant additional environmental protection. These potentially sensitive environmental resources were in addition to those that had been the focus of the Risk Assessment. Based on the Scope of Work described in Section 1 of this environmental review, Exponent performed the following tasks:

1. Provided an overview of the overall Keystone Risk Assessment methodology
2. Examined the characteristics of the crude oil being transported
3. Evaluated transport and fate characteristics of spilled crude oil
4. Addressed sensitive issue Area 1: Shallow groundwater
5. Addressed sensitive issue Area 2: Small stream crossings less than 100 ft in width and associated ecological concerns.

This executive summary provides a brief overview of each of these tasks, along with our key findings and recommendations. Exponent's findings will be used, in part, by Battelle to make recommendations related to engineering considerations that could be used to address environmental safety issues related to the Project.

Review of Crude Oil Composition

Exponent reviewed Keystone's consideration of the chemical and physical characteristics of the oil blends

to be transported in the pipeline, and compiled crude oil compositional data required in the subsequent sections of our report. Exponent compared the characteristics of diluted bitumen (dilbit) and synthetic crude oil (SCO) to typical crude oil using data from a number of publically available sources.

Key Findings/Conclusions

The physical and chemical characteristics of dilbit are consistent with a heavy crude oil

The physical and chemical characteristic of SCO are consistent with a medium gravity crude oil

The benzene concentrations of both oils are within the range of typical crude oils

The chemical compositions of the oils are within the range of typical crude oils, although there are some significant gaps in our knowledge about all the constituents

For the factors considered by Keystone in the Risk Assessment, we agree with their conclusion that dilbit and SCO are sufficiently similar to crude oil and that they should not result in an excess risk in case of a release.

Recommendations

While not required at this stage in the process, Keystone should consider obtaining additional information on the chemistry of the oils as this information will be needed for developing clean-up and remediation plans

Knowledge on the chemistry of dilbit continues to increase, and that new information should be incorporated into planning and operations as appropriate (e.g., to improve spill response planning).

Transport and Fate of Spilled Oil

To address questions about potential environmental consequences of oil spills raised by the agencies, Exponent conducted additional transport and fate analyses to better describe the behavior of potential spills. Our review relied on information provided in the Risk Assessment and FEIS as well as on information and data in the scientific literature such as the viscosity of the oil and distance that oil spills have been known to travel in surface water. We conducted screening-level calculations to quantitatively check statements made in the Risk Assessment about the behavior of oil spills, and to support other aspects of our evaluation.

Our evaluation of possible risks to sensitive areas of groundwater and surface waters depends in part on how the spilled oil will behave when released from a buried pipeline. Therefore, we evaluated how quickly large and small spills might reach aquifers and the behavior of dissolved constituents in these aquifers. Our screening calculations are not an exhaustive transport and fate analysis. The detailed analyses that are required by Special Condition 14 and PHMSA regulations, as part of the Integrity Management Program, will be conducted after the final route is selected as part of the final design of the project. The rate of migration of an oil spill to and in groundwater is an important consideration in the development of the Environmental Response Plan (ERP). It bears directly on response time and the ability to contain and clean up spills that might occur. Similarly, the distance that oil spilled into surface waters of small streams could

travel is important for identifying ecologically sensitive areas or other high consequence areas (HCAs) that might be impacted.

Quantitative screening-level estimates of the potential transport of oil to groundwater are provided for two scenarios: a large volume spill or rupture, and a small leak. We also provide a discussion on the potential transport of oil overland. Exponent's analyses are based on the general range of conservative conditions and are intended to provide a sense of scale of potential oil impact. Thus, findings are expected to be a conservative characterization of what could happen along the pipeline. Based on these analyses, Exponent considered the ramifications of the findings in light of the implications they would have on the final Project design and ERP. The following are Exponent's key findings/ conclusions, followed by our recommendations.

Key Findings/Conclusions

The flow of oil overland is affected by many variables including spill rate, topography, soil type, and vegetation. To provide a sense of scale, a highly simplified case of a sudden spill of 25,000 bbl to a flat surface is presented. If the spill flows in a radial pattern, is 1 ft deep, and there is no spill response, it would spread with a radius of about 200 ft. A pool with a depth of 0.1 ft would spread to a radius of about 700 ft. If a surface spill was influenced by topography and flowed in a channelized manner, the distance traveled could be on the order of thousands of feet, depending on the steepness of the terrain, presence of vegetation, etc. Keystone conservatively assumed in the Risk Assessment that a large spill would be capable of moving overland up to 1 mile. Therefore, considering our analyses, the 1 mile distance criterion used in the Risk Assessment is considered adequate. Where HCAs are located within 1 mile of the pipeline, Keystone is required to perform a site-specific evaluation of overland flow (spreading analysis).

Exponent applied a numerical screening model, the hydrocarbon spill screening model or HSSM, to estimate the behavior of a large spill of dilbit from the pipeline in an area with a high permeability shallow aquifer. The HSSM modeling simulation showed that groundwater impacts from a large spill would likely occur first from infiltration from the trench near the rupture and not from oil spread across the ground surface. Oil in the potentially filled trench near the rupture could begin forming a non-aqueous phase liquid lens at the water table in less than 1 day if the water table is 1 ft below the trench (8 ft below ground surface), in 7 days if the water table is 3 ft below the trench (10 ft below ground surface), and in 50 days if the water table is 10 ft below the trench (17 ft below ground surface). In contrast, oil infiltrating from the ground surface would reach a water table 8 ft below ground surface after approximately 240 days.

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17 Results from HSSM simulations of a large spill (25,000 bbl) illustrate that plume lengths for dissolved hydrocarbons (i.e., benzene at or above the under typical groundwater gradients could be between 100 and 900 ft in length. This range is consistent with those reported in the literature; most reported plumes are less than 200–300 ft and a very small number of plumes exceed 1,000 ft. HSSM simulations were also performed to explore an elevated groundwater gradient, representing the potential influence of groundwater extraction (irrigation wells) near the pipeline. When coupled with a simulated low degradation rate (representing an upper bound condition), the higher groundwater gradient could extend the plume length to as much as 2,600 ft.

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17 Modeling results agree with the conclusions in the Risk Assessment that a small leak going undetected indefinitely is unlikely. More likely, oil from a small "pin hole" leak (28 bbl/day) would reach the ground surface on a time scale of a few months. Based on the screening-level modeling, a benzene

plume that may form because of a small leak was estimated to travel downgradient by as much as 600 ft.

35 17 Many private wells located near the pipeline do not meet the criteria to be classified as HCAs in the Risk Assessment. Exponent considered potential factors that could be used to identify non-HCA groundwater areas for shallow groundwater (< 50 ft) where more extensive spill prevention measures and monitoring may be warranted. Based on our analysis of possible plume dimensions, we selected a downgradient distance of 1,000 ft from the proposed centerline of the pipeline as a reasonable boundary of a plume for identifying shallow groundwater and associated wells that could be within the influence of an oil spill. This distance recognizes that large spills would be readily detected and remediated and that small leaks that could take longer to be detected would have smaller plumes. Based on an independent review of the NEDNR well database in Nebraska, Exponent identified approximately 260 wells (not screened by depth) within 1,000 ft of the proposed centerline of the pipeline. Most of these wells are used for irrigation purposes but domestic wells are also present, several of which draw from shallow groundwater. This list will need to be revised once the final pipeline is determined.

35 17 The relative vulnerability/sensitivity of groundwater resources to a dissolved hydrocarbon plume from an oil spill can be assessed by considering combinations of several factors: 1) proximity to the pipeline (<1,000 ft); 2) depth from point of the oil release to the water table (e.g., release of oil at or below the water table will affect groundwater quality more quickly than releases many feet above the water table); 3) depths of receptor wells (wells that are tens of feet deep are more vulnerable than wells that are hundreds of feet deep); and 4) the pumping of receptor wells (wells with higher pumping rates are more likely to draw plumes further downgradient than wells with lower pumping rates). This combination of factors could be used to identify groundwater resources that do not meet the listing criteria for HCAs but may be more vulnerable to a dissolved benzene plume emanating from an oil spill. An example of this would be a cluster of irrigation wells and domestic wells located within 1,000 ft of a pipeline segment where a release of oil occurred in or within a few feet of the water table.

35 17 The assessment in the FEIS conservatively assumes that in the event of a worst-case spill in which all of the benzene partitions from the oil into water in streams with a range of flow rates. The assessment is useful for comparison of worst-case benzene concentrations to human health and ecological concentration benchmarks and is discussed further in Section 5 of our review. However, the FEIS does not provide an evaluation of possible transport distances of oil via surface water. This appears to be a gap that needs to be addressed.

35 17 The primarily qualitative assessment of the transport and fate of oil in the event of a spill presented in the Risk Assessment is consistent with our analysis and review of the literature. Ultimately, quantitative analysis of transport and fate in surface waters is required by Special Condition 14 and PHMSA regulations as part of the Integrity Management Program during the final design of the project after the final route is selected. These evaluations should take into account the lessons learned from the pipeline rupture in Enbridge, Michigan, in 2010.

Recommendations

Keystone, as part of the final Project design, should perform further evaluation of overland flow (spreading analysis) of spilled oil, and further evaluation of the transport of spilled oil in small streams (e.g., the downstream distance crude oil could travel from the proposed centerline of the pipeline) for purposes of ERP. These analyses should take into account potential density and

viscosity increases associated with the loss of volatiles from heavy crudes and diluted bitumen.

Keystone should use the screening criteria (e.g., well depth, depth of release compared to water table, lithology between pipeline and aquifer) suggested in our report for identifying vulnerable/sensitive groundwater resources adjacent to the pipeline that do not classify as HCAs but that may be more vulnerable to exposure to a benzene plume in the event of a an oil spill. For example, these could be defined as clusters of both domestic and irrigation wells within 1,000 ft of a pipeline segment where an oil spill could occur in or within a few feet of the water table. Exponent recommends that additional modeling be performed as part of the final design of the Project to further refine the appropriate downgradient distance criteria to be used for identifying sensitive clusters of wells. Exponent recommends that these non-HCA groundwater resources be afforded a degree of protection from the occurrence of an oil spill and from the consequences of a spill similar to what is currently afforded to groundwater resources that are defined HCAs.

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17 Considering the above-mentioned screening analysis, Exponent recommends that Keystone consider how to improve upon external leak detection through more frequent inspections and education of property owners for wells within these areas of sensitive groundwater resources.

Analysis of Risks Related to Small Stream Crossings

Exponent was asked to evaluate whether there are sensitive environments associated with stream crossings that are less than 100 ft wide that may warrant additional analyses and perhaps mitigation or control measures. Exponent used a set of ecologically-relevant criteria to identify such areas. This part of the environmental review also included an examination of information in the FEIS related to special status species, in particular, the presence of these species and their habitats relative to small stream crossings.

As part of our small stream crossing evaluation Exponent performed the following tasks:

Reviewed the adequacy of the risk characterization of PHMSA-defined HCAs in the Risk Assessment with a specific focus on ecologically sensitive areas (ESAs)

Evaluated whether there were other sensitive environmental resources downstream of small stream crossings not already identified by the PHMSA-defined ESAs

Evaluated the adequacy of relying on benzene as a surrogate chemical to address the magnitude of aquatic toxicity of crude oil spilled into small streams

Evaluated whether the Risk Assessment process adequately considered the presence of special status species (e.g., threatened and endangered species) when defining sensitive ecological resources.

Exponent considered the implications of our findings with respect to the final Project design and ERP. The following are Exponent¡¦s key findings/conclusions, followed by our recommendations.

Key Findings/Conclusions

The Risk Assessment appropriately followed standard PHMSA guidelines for identifying

contributory pipeline segments (CPSs) associated with small stream crossings and the HCAs potentially affected.

Based on our assessment of transport and fate of oil into surface waters, we used a downstream distance of 10 miles as a basis for identifying locations of sensitive areas around small stream crossings. Using a set of ecologically-relevant criteria, Exponent identified at least ten small stream crossings areas that should be considered for additional protection. An additional four small stream crossings were identified as having special water bodies within 10 miles downstream of the proposed centerline of the pipeline that likely have high wildlife habitat value which should also be given further consideration.

Exponent agrees with the assessment of the potential magnitude of risk of an oil spill on aquatic life in the water column associated with the toxicity of dissolved oil as represented by benzene. While the toxicity assessment based on benzene is not rigorous, it appears to be sufficiently conservative for assessing short-term effects to aquatic biota residing in the water column. However, depending upon the characteristics of the water body into which a spill occurs, some portion of the spilled oil could come into contact with sediments along shorelines or the bottom of the water body. The oil and associated chemicals that may be present within sediments could exert longer-term chronic effects on aquatic biota that are not captured by considering benzene alone.

Exponent determined that the list of special status species identified in the FEIS is comprehensive and complete. Exponent also found that the preliminary findings of which species are likely to be adversely affected (one species, the American burying beetle) were arrived at through a sufficiently rigorous review of the distribution, abundance, and biological use of the Project area by special status species.

Exponent believes that there could be habitat utilized now or in the future by special status species that is not specifically identified as PHMSA-designated ESAs.

Exponent believes ongoing natural shifts in resources underpinning the distribution and abundance of special status species and the species they rely upon will likely result in a shifting of locations where special status species occur during the lifetime of the Project. These changes will necessitate that the environmental protection of the areas which these species use as habitat along the pipeline corridor be updated over time.

Recommendations

A distance of at least 10 miles downstream from the proposed centerline of the pipeline should be used for the identification of sensitive areas and for identifying CPSs during the final design phase of the Project.

Based on location-specific analyses of fate and effects of spills that Keystone will undertake prior to construction, Keystone should consider the use of additional valves and/or noninvasive boring technologies at the small stream crossings that Exponent identified as associated with additional potentially sensitive ecological areas, and where Keystone¡¦s release analysis shows the potential exists for medium to very large spills.

Keystone should rely upon stream-specific scour analyses for small stream crossings to identify where the pipeline should be buried deeper than 5 ft or where horizontal directional drilling may

be warranted. The particular small stream crossings identified by Exponent should be given attention in this regard.

Exponent recommends that the ERP consider the possibility that spilled oil may be entrained into sediments and that these types of conditions be anticipated as part of spill response and clean-up.

Exponent recommends that the ERP also take into account the additional ecologically sensitive resources identified in our review. For example, wildlife habitat for special status species, within close proximity of the pipeline could be designated as ¡§special and/or unique areas¡¨ for purposes of the ERP.

Exponent recommends that Keystone develop explicit plans for updating the status and presence of special status species and their habitat every 2 years, and that identified changes be incorporated into the ERP.