

**Site-Specific Risk Assessment
for Keystone XL Project's
Missouri River Crossing**



Prepared for:
TransCanada Keystone Pipeline
LP

Prepared by:
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Sign-off Sheet

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Acronyms

| | |
|----------|--|
| °F | degrees Fahrenheit |
| AOPL | Association of Oil Pipelines |
| API | American Petroleum Institute |
| bbbl | barrels |
| BTEX | benzene, toluene, ethylbenzene, and xylenes |
| CFR | Code of Federal Regulations |
| cfs | cubic feet per second |
| ERP | emergency response plan |
| FBE | fusion-bonded epoxy |
| GRP | geographic response plan |
| HDD | horizontal directional drilling |
| IMP | Integrity Management Plan |
| Keystone | TransCanada Keystone Pipeline LP |
| MCL | maximum contaminant level |
| mg/L | milligrams per liter |
| MP | milepost |
| mph | miles per hour |
| NOAA | National Oceanographic and Atmospheric Administration |
| OCC | Operations Control Center |
| OSHA | Occupational Health and Safety Administration |
| PAH | polycyclic aromatic hydrocarbons |
| PHMSA | Pipeline and Hazardous Materials Safety Administration |
| Project | Keystone XL Pipeline Project |
| PVC | polyvinyl chloride |
| SCADA | supervisory control and data acquisition |
| SSRA | Site-specific Risk Assessment |
| Stantec | Stantec Consulting Services, Inc. |
| U.S. | United States |
| USACE | United States Army Corps of Engineers |
| USDOS | United States Department of State |
| USEPA | United States Environmental Protection Agency |
| USGS | United States Geological Service |
| WCD | worst case discharge |

SITE-SPECIFIC RISK ASSESSMENT FOR KEYSTONE XL PROJECT'S MISSOURI RIVER CROSSING

Purpose

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1.0 PURPOSE

Keystone Pipeline LP (Keystone) proposes to construct and operate the Keystone XL Pipeline Project (Project) that transports crude oil from Hardisty, Canada, to Steele City, Nebraska. A portion of the Project crosses the Missouri River below the Fort Peck Reservoir in Montana. Keystone has requested that Stantec Consulting Services, Inc. (Stantec) identify the probability of a release, the probable size of a release, the possibility of a release from the crossing entering into the Missouri River, and describe the types and magnitude of potential environmental effects from a crude oil release.

SITE-SPECIFIC RISK ASSESSMENT FOR KEYSTONE XL PROJECT'S MISSOURI RIVER CROSSING

Background
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2.0 BACKGROUND

2.1 SITE DESCRIPTION

The Project crosses the Missouri River in Montana at Milepost (MP) 89.65, downstream of the Fort Peck Reservoir (**Figure 1**). Keystone has conducted geotechnical analyses of the crossing location and proposes to cross beneath the river using the horizontal directional drilling (HDD) method. The HDD would use heavier walled steel pipe than other areas and a protective abrasion-resistant coating would be applied over the fusion-bonded epoxy (FBE) coating. The horizontal crossing distance is 2,582 feet; the HDD pipe length is 2,592 feet of pipe. The pipe will be located up to 58 feet below the riverbed. **Figure 2** provides a schematic representation of the proposed HDD crossing.

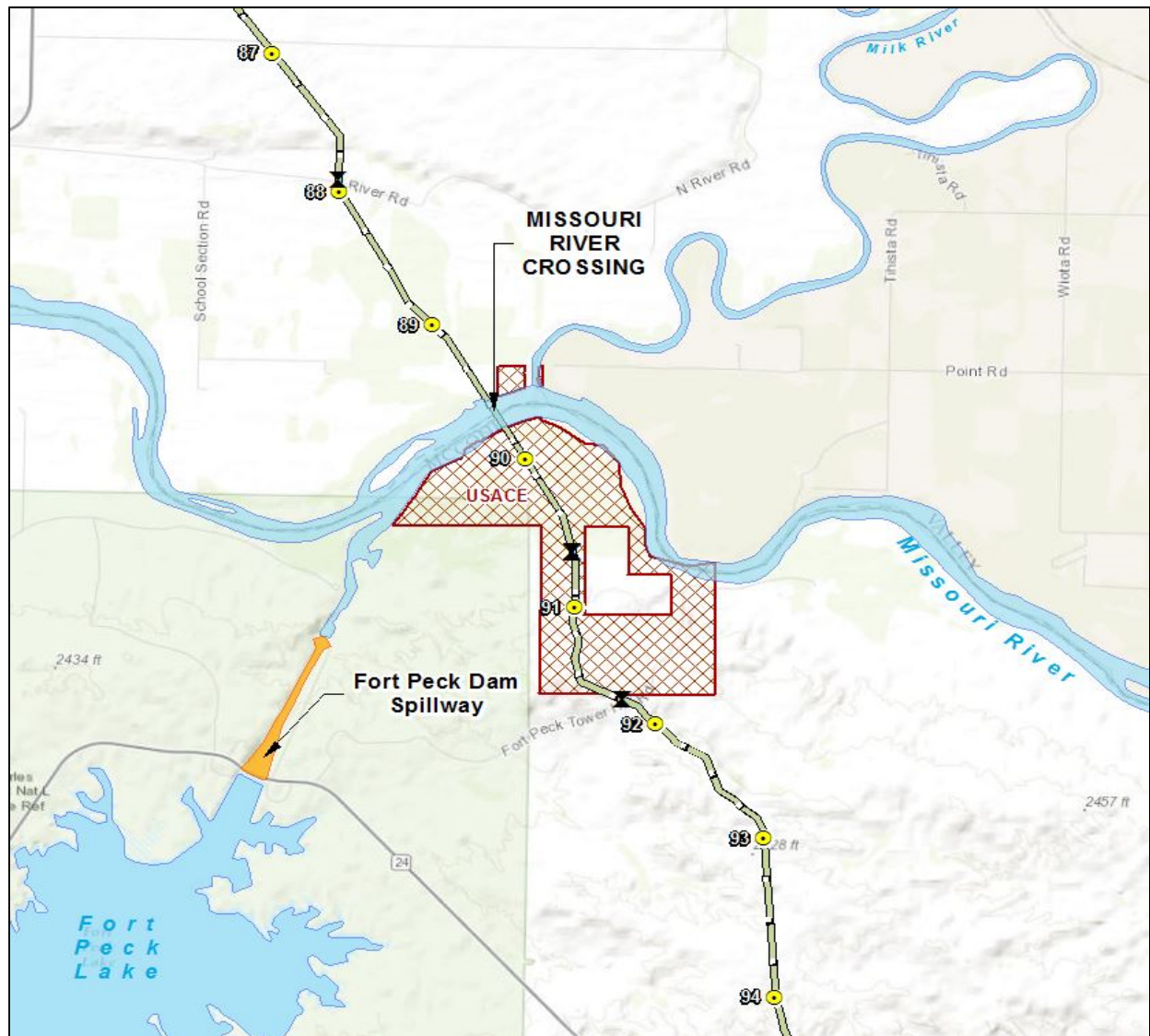
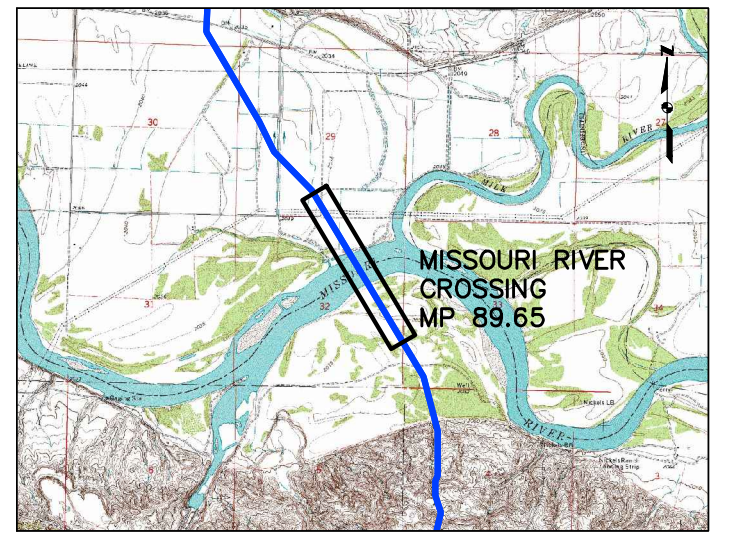
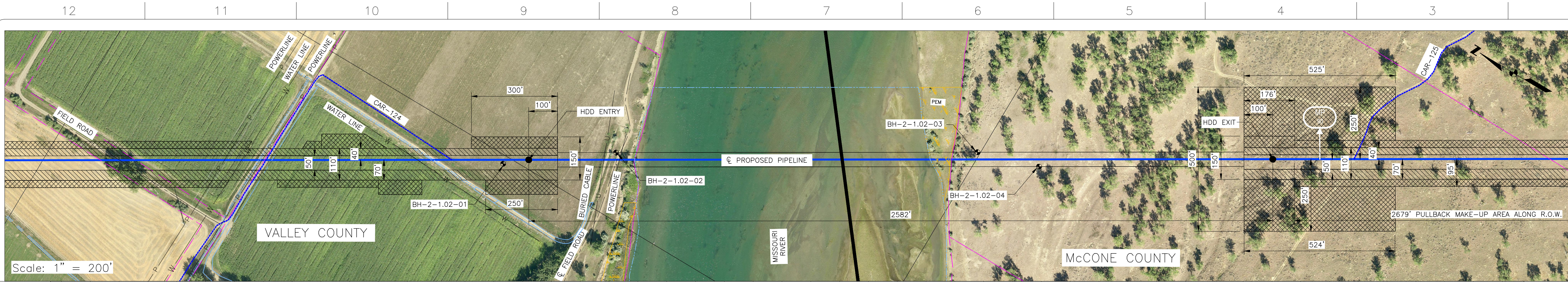
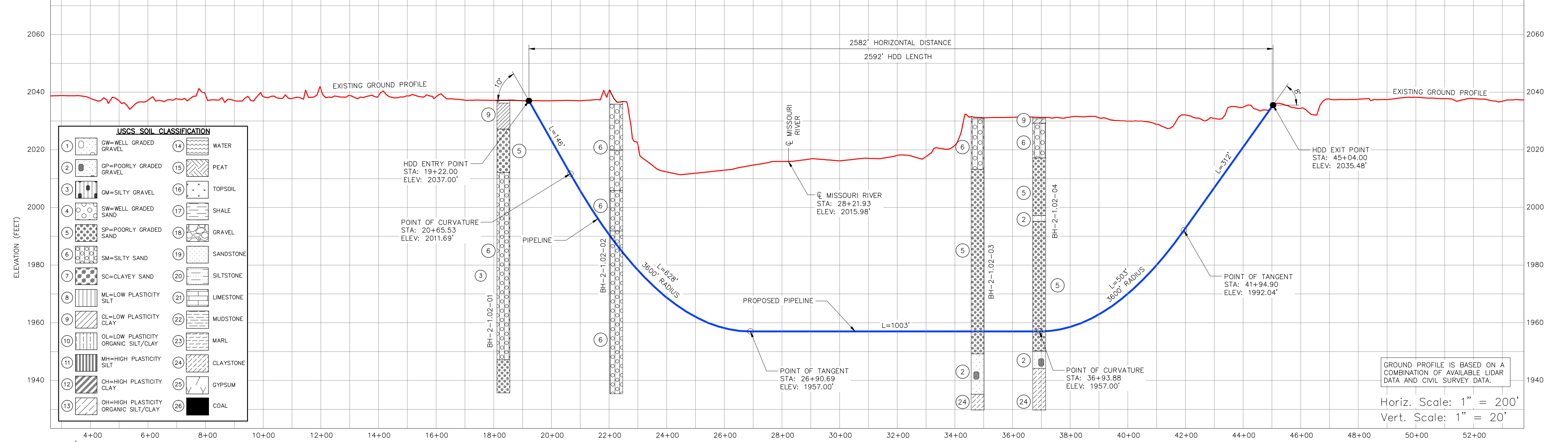


Figure 1 Keystone XL Pipeline Project



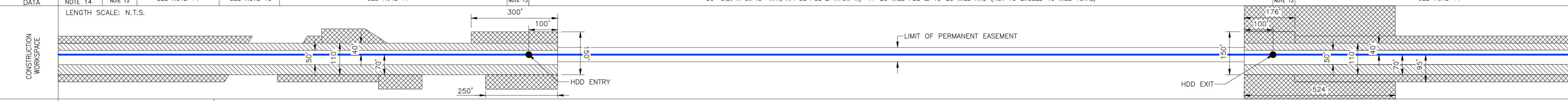
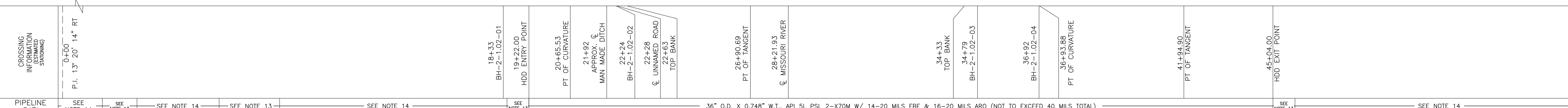
INSTALLATION NOTES

- ACCESS: ALL EQUIPMENT MUST ACCESS THE SITE ALONG THE CONSTRUCTION RIGHT-OF-WAY FROM PUBLIC OR APPROVED PRIVATE ROADS.
- WORK SPACE: WORK SPACE LIMITS ARE DEPICTED. CLEARING WILL BE RESTRICTED TO THE WORK SPACES INDICATED AT THE ENTRY AND EXIT POINTS AND PULLBACK MAKE-UP AREA ALONG THE RIGHT-OF-WAY. NO CLEARING BETWEEN THE ENTRY AND EXIT POINTS OF THE HDD EXCEPT WHERE APPROVED BY THE ENVIRONMENTAL INSPECTOR.
- WATER SOURCE: DRILL WATER AND PRE-INSTALLATION HYDROSTATIC TEST WATER SHALL BE OBTAINED FROM AN APPROVED SOURCE. THE CONTRACTOR SHALL SCREEN THE WASTE HOSE TO PREVENT THE ENTRAPMENT OF FISH OR DEBRIS AND IN ACCORDANCE WITH THE CONSTRUCTION MITIGATION AND RECLAMATION PLAN (CMRP) AND PROJECT REQUIREMENTS, THE HOSE SHALL BE KEPT OFF THE BOTTOM OF THE WATER BODY.
- HYDROSTATIC TEST: PRE-INSTALLATION HYDROSTATIC TEST SHALL BE CONDUCTED IN ACCORDANCE WITH PERMIT REQUIREMENTS. THE CONTRACTOR SHALL DISCHARGE HYDROSTATIC TEST WATER IN ACCORDANCE WITH PROJECT PERMITS. DISCHARGES WILL BE SENT TO AN UPLAND LOCATION NEAR THE WITHDRAWAL POINT AS DIRECTED BY THE ENVIRONMENTAL INSPECTOR. DISCHARGES SHALL NOT CAUSE EROSION OR SEDIMENTATION TO REDUCE THE VELOCITY OF THE DISCHARGE. THE CONTRACTOR SHALL UTILIZE AN ENERGY-DISSIPATING DEVICE AS DESCRIBED IN THE CMRP.
- SPILL-PREVENTION: ALL PUMPS SHALL BE SET IN SECONDARY CONTAINMENT AND IN ACCORDANCE WITH THE SPILL PREVENTION CONTROL AND COUNTERMEASURE PLAN (SPCC). EQUIPMENT AND PUMPS OPERATING WITHIN 100 FEET OF ANY WATER BODY OR WETLAND SHALL BE OPERATED AND REFUELED IN ACCORDANCE WITH THE SPCC PLAN. EQUIPMENT REFUELING AND STORAGE OF HAZARDOUS MATERIALS, FUELS, ETC. SHALL BE CONDUCTED AT LEAST 100 FEET FROM WATER BODIES AND WETLANDS. EACH CONSTRUCTION CREW SHALL HAVE ON HAND SUFFICIENT TOOLS AND MATERIALS TO STOP LEAKS AND SUPPLIES OF ABSORBENT AND BARRIER MATERIALS TO ALLOW RAPID CONTAINMENT AND RECOVERY OF SPILLED MATERIALS.
- EROSION AND SEDIMENT CONTROL: CONTRACTOR SHALL SUPPLY, INSTALL AND MAINTAIN SEDIMENT CONTROL STRUCTURES IN ACCORDANCE WITH CONTRACT DOCUMENTS. CONTRACTOR SHALL INSTALL ADDITIONAL EROSION CONTROL STRUCTURES AS DIRECTED BY THE ENVIRONMENTAL INSPECTOR.
- PRIOR TO PIPE PULLBACK, CONTRACTOR'S ACTUAL DRILL PROFILE SHALL BE SUBMITTED TO KEYSTONE FOR APPROVAL.
- INSTALLATION: THE PIPE SECTION FOR THE DRILLED CROSSING SHALL BE MADE UP WITHIN THE RIGHT-OF-WAY AT THE DRILL EXIT POINT AS SHOWN. CONTRACTOR SHALL ASSESS THE NEED FOR AND SUPPLY APPROPRIATE BALLAST DURING PULLBACK.
- MUD DISPOSAL: CONTRACTOR SHALL DISPOSE OF EXCESS DRILLING MUD AS DIRECTED BY THE COMPANY REPRESENTATIVE IN ACCORDANCE WITH PERMIT CONDITIONS. UNDER NO CIRCUMSTANCES SHALL DRILLING FLUID BE DISPOSED OF IN WATER BODIES OR WETLANDS. ANY DRILLING MUD WHICH INADVERTENTLY EXITS AT POINTS OTHER THAN THE ENTRY AND EXIT POINTS SHALL BE CONTAINED AND COLLECTED TO THE EXTENT PRACTICAL AND DISPOSED OF AS DIRECTED BY THE COMPANY REPRESENTATIVE IN ACCORDANCE WITH PERMIT CONDITIONS.
- CLEANUP/STABILIZATION/RESTORATION: ALL DISTURBED AREAS SHALL BE RETURNED TO THE ORIGINAL CONTOURS. DISTURBED AREAS SHALL BE SEEDING AS SPECIFIED IN PROJECT DOCUMENTS.
- NOMINAL WORKING SPACE DIMENSIONS ARE SHOWN. LARGER AREAS MAY BE REQUIRED IN IRREGULAR TERRAIN. UPDATED DIMENSIONS MAY BE PROVIDED AFTER LOCAL TOPOGRAPHICAL SURVEYS ARE PERFORMED.
- CONTRACTOR SHALL FOLLOW REFERENCE SPECIFICATIONS. REFER TO KEYSTONE CMRP, KEYSTONE CONSTRUCTION SPECIFICATIONS, PROJECT ENVIRONMENTAL REQUIREMENTS FOR THIS SITE SPECIFIC DETAIL, PART 155 OF THE CODE OF FEDERAL REGULATIONS (LATEST EDITION), 40CFR 831.4, AND API 1102.
- 36" O.D. X 0.618" W.T., API 5L PSL 2-X70M W/14-20 MILS & 16-20 MILS ARO (NOT TO EXCEED 40 MILS TOTAL)
- 36" O.D. X 0.465" W.T., API 5L PSL 2-X70M W/14-20 MILS FBE
- MAINLINE EQUIPMENT MUST DRIVE AROUND THIS CROSSING ON EXISTING ROADS.
- EQUIPMENT IS TO BE CLEANED AND DRIED PRIOR TO MOVING TO THE R.O.W. AND BEFORE LEAVING THE DRILL SIDE ON THE SOUTH SIDE OF THE RIVER.
- MATURE COTTONWOOD TREES SHOULD BE PRESERVED WHERE PRACTICAL ON THE CONSTRUCTION R.O.W. SOUTH OF THE RIVER.



USCS SOIL CLASSIFICATION

| | | | |
|----|--------------------------------------|----|-----------|
| 1 | OW=WELL GRADED GRAVEL | 14 | WATER |
| 2 | GP=POORLY GRADED GRAVEL | 15 | PEAT |
| 3 | GM=SILTY GRAVEL | 16 | TOPSOIL |
| 4 | SW=WELL GRADED SAND | 17 | SHALE |
| 5 | SP=POORLY GRADED SAND | 18 | GRAVEL |
| 6 | SM=SILTY SAND | 19 | SANDSTONE |
| 7 | SC=CLAYEY SAND | 20 | SILTSTONE |
| 8 | ML=LOW PLASTICITY SILT | 21 | LIMESTONE |
| 9 | CL=LOW PLASTICITY CLAY | 22 | MUDSTONE |
| 10 | OL=LOW PLASTICITY ORGANIC SILT/CLAY | 23 | MARL |
| 11 | MH=HIGH PLASTICITY SILT | 24 | CLAYSTONE |
| 12 | CH=HIGH PLASTICITY CLAY | 25 | GYPSSUM |
| 13 | OH=HIGH PLASTICITY ORGANIC SILT/CLAY | 26 | COAL |



| ENVIRONMENTAL MITIGATION/RECLAMATION | ENVIRONMENTAL MITIGATION/RECLAMATION |
|--------------------------------------|--------------------------------------|
| TOPSOIL SALVAGE METHOD | |
| STREAMS | |
| WETLANDS | |
| TIMING CONSTRAINTS | |
| MILEPOST | |
| MONITORING | |
| RECLAMATION | |
| SPECIAL CONSIDERATIONS | |

LEGEND

| | | |
|----------------------------------|--------------------------------|-----------------|
| CL P.I. | UNDERGROUND UTILITY | HEADCUT AREA |
| ENTRY OR EXIT POINT | TELEPHONE LINE | EXCLUSION FENCE |
| GEOTECHNICAL BOREHOLE | PROPERTY PARCEL | |
| WARNING SIGN | SECTION LINE | |
| PIPELINE ROUTE | COUNTY LINE | |
| CATHODIC PROTECTION TEST STATION | PERMANENT EASEMENT | |
| | BOUNDARY | |
| | TEMPORARY WORKSPACE | |
| | ADDITIONAL TEMPORARY WORKSPACE | |
| | PERMANENT ACCESS ROAD | |
| | TEMPORARY ACCESS ROAD | |
| | EXISTING GROUND | |
| | WATER BODY | |
| | WETLAND BOUNDARY | |

REFERENCE DRAWINGS

| DRAWING No | TITLE |
|-------------------|-----------------|
| 4360-03-ML-02-027 | ALIGNMENT SHEET |

REVISION

| REV No | DATE | DESCRIPTION |
|--------|------------|-------------------------|
| 00 | 2013-05-31 | ISSUED FOR CONSTRUCTION |
| 0A | 2016-12-12 | ISSUED FOR REVIEW |

APPROVAL

| PROJECT CODE | DRAFTER | DRAFTING CHECKER | DESIGNER | DESIGN CHECKER | PROJECT MANAGER | COMPANY |
|--------------|---------|------------------|----------|----------------|-----------------|---------|
| 2095406 | EXP | TLB | BLS | KJM | KJM | EXP |
| 2095406 | EXP | ALS | DS | KJM | BW | EXP |

PROFESSIONAL ENGINEER/RPT

FIRM: EXP ENERGY SERVICES, INC.
FIRM LICENSE: F057873

PERMIT/ ENG. APPROVAL

DATE: _____

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Tulalasse, FL 32308
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KEYSTONE XL (NPS 36 2014) VALLEY SECTION
CHAINAGE: MP 89.65 DISCIPLINE # 03

MISSOURI RIVER HDD INSTALLATION
KEYSTONE XL PROJECT
VALLEY & McCONE COUNTY, MONTANA

SCALE AS SHOWN DRAWING No 4360-03-ML-03-002 REV 0A

Background
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Additional discussion of HDD as a preventative risk mitigation measure is discussed in Chapter 5.0, HDD Crossing Design.

2.2 RELEASE VOLUMES

Examination of more than a decade of recent pipeline incident data (Pipeline and Hazardous Materials Safety Administration [PHMSA] 2017) indicates that most pipeline releases are relatively small, with 50 percent of the spills consisting of 3 barrels (bbl) or less. **Table 1** data demonstrate that most pipeline spills are relatively small and large releases of 10,000 bbl or more are extremely uncommon.

Table 1 Distribution of Release Volumes

| Release Volume (bbl) | % of Releases (Equal to or Smaller ¹) |
|----------------------------|---|
| 3 | 50.0% |
| 50 | 81.8% |
| 1,000 | 95.9% |
| 10,000 | 99.6% |
| Worst Case Discharge [WCD] | 99.8% |

¹ Values derived from PHMSA historical incident data (2002 to 2017).

Worst Case Discharge

In addition to the range of release volumes in **Table 1** that are routinely evaluated for permitting purposes, Keystone also calculated the WCD for the Missouri River crossing (**Appendix A**). The method used to calculate the WCD follows requirements specified in 49 Code of Federal Regulations (CFR) 194.105. The WCD scenario is a guillotine rupture of the pipeline. A release of this volume is extremely improbable and, based on the PHMSA incident database, only 0.2 percent of releases are this size or larger (PHMSA 2017).

2.3 SITE-SPECIFIC INCIDENT FREQUENCY

Incident frequency for the crossing was determined using data from the PHMSA incident database, which contains over 200,000 miles of liquid pipelines, providing a robust statistical analysis. These data were used since the PHMSA dataset is comprehensive in the types of data collected, thus allowing for a detailed analysis of causal factors. Further, many pipelines built in the 1930s and earlier are still in operation. Because the majority of pipelines in the United States (U.S.) were constructed in the pre-modern era, these frequencies reflect incident rates associated with earlier pipeline design and construction methods that often do not meet current regulatory requirements or best management practices. Therefore, the spill frequencies generated for the Project are expected to overestimate the probability of a release.

The Project-wide incident frequency statistic is 0.000287 incidents/mile-year (**Appendix A**)¹. Use of the HDD crossing method and the pipe's increased wall thickness would reduce or eliminate some pipeline threats (e.g., excavation damage, natural outside force) and would reduce the

¹ The Project incident frequency has been updated and was derived from PHMSA data from 2002 to 2017. The incident frequency includes all incident causes identified within PHMSA's incident database.

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site-specific incident frequency by 10.6 percent at the Missouri River. Based on site-specific reductions in risk, the Missouri River site-specific incident frequency is 0.000256 incidents/mile-year. Based on that statistic, the Missouri River crossing was evaluated to determine frequencies for a variety of release volumes. Occurrence intervals (the predicted time period between incidents for any single mile of pipeline) are calculated by taking the inverse of an incident frequency.

$$f_{\text{occurrence}} = 1/(f_{\text{incident}})$$

Where:

$$f_{\text{occurrence}} = \text{occurrence interval for an incident}$$

$$f_{\text{incident}} = \text{incident frequency}$$

Occurrence intervals for specific segments of the pipeline (e.g., Missouri River crossing) can be calculated by incorporating length into the calculation.

$$f_{\text{segment}} = 1/(f_{\text{incident}} \cdot \text{mile}_{\text{segment}})$$

Where:

$$f_{\text{segment}} = \text{occurrence interval for an incident for a specific segment of the Project}$$

$$f_{\text{incident}} = \text{incident frequency}$$

$$\text{mile}_{\text{segment}} = \text{length of the specific pipeline segment in miles}$$

Based on the site-specific incident frequency statistic, the incident frequency for the Missouri River crossing was calculated based on spill volumes shown in **Table 2**.

Table 2 Occurrence Interval by Spill Volume

| Location | Crossing Distance (mi) ¹ | Occurrence Interval (years) by Spill Size | | | | |
|----------------|-------------------------------------|---|--------|-----------|------------|-----------|
| | | 3 bbl | 50 bbl | 1,000 bbl | 10,000 bbl | WCD |
| Missouri River | 0.748 | 10,400 | 28,700 | 127,000 | 1,35,000 | 2,230,000 |

¹ Crossing length includes the stream width plus 500 feet on each side of the river to account for overland flow.

The probability of a release of any size occurring at the Missouri River crossing is once in 5,200 years². **Table 2** breaks down the occurrence intervals for various sized releases. For example, the median release volume of 3 bbl or less has an associated occurrence interval of 10,400 years.

The probability of a WCD release is extremely remote, with occurrence interval of 2,230,000 years. While a release of the WCD at the Missouri River is statistically improbable, the WCD does

² If the Project incident frequency were used, not accounting for site-specific risk mitigation, the occurrence interval for any size release would be 4,700 years and 2,000,000 years for a WCD release.

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represent an important value for Keystone emergency response planning to ensure sufficient resources and equipment are available, regardless of the statistical improbability.

2.4 CRUDE OIL PROPERTIES AND CHARACTERISTICS

A variety of crude oils will be transported by the Project. These can be categorized into three general categories: conventional light crude oil, synthetic crude oil, and diluted bitumen. A summary of crude oil characteristics is provided in **Table 3**. For informational purposes, a conventional heavy crude was included for comparison with the diluted bitumen.

Table 3 Physicochemical Properties of Crude Oils

| Parameter | Unit | Measure | Bakken | Suncor Synthetic | Western | Heavy |
|----------------------------|------------|-------------------|---------------------------------|-------------------|--------------------------------|-----------|
| | | | Light Conventional ³ | A Sweet Synthetic | Canadian Blend Diluted Bitumen | |
| Density ¹ | g/ml | Range | 0.82-0.84 | 0.84-0.86 | 0.92-0.93 | 0.91-0.93 |
| | | Mean ⁷ | 0.82 | 0.86 | 0.93 | 0.93 |
| Gravity ¹ | API | Range | 37.6-42.1 | 30.5-36.4 | 20.6-21.8 | 20.1-23.1 |
| | | Mean ⁷ | 42.1 | 32.6 | 20.6 | 20.9 |
| Viscosity ^{2,4} | cSt @ 38°C | Range | 2.7-4 | 2.4-6.5 | 44.0-63.0 | 28.0-63.0 |
| | | Mean ⁷ | 3.4 | 4.5 | 63 | 43.4 |
| Benzene | vol % | Range | 0.25-0.41 | 0.03-0.05 | 0.06-0.29 | 0.02-0.21 |
| | | Mean ⁷ | 0.28 | 0.04 | 0.16 | 0.13 |
| Toluene | vol % | Range | 0.58-1.52 | 0.15-0.25 | 0.24-0.5 | 0.11-0.44 |
| | | Mean ⁷ | 0.92 | 0.19 | 0.29 | 0.26 |
| Ethylbenzene | vol % | Range | 0.24-0.45 | 0.10-0.15 | 0.05-0.14 | 0.04-0.17 |
| | | Mean ⁷ | 0.33 | 0.13 | 0.06 | 0.1 |
| Xylenes | vol % | Range | 0.76-1.52 | 0.32-0.54 | 0.29-0.53 | 0.19-0.49 |
| | | Mean ⁷ | 1.4 | 0.46 | 0.29 | 0.34 |
| Total BTEX ¹ | vol % | Range | 1.98-3.27 | 0.61-1.49 | 0.80-1.24 | 0.59-1.26 |
| | | Mean ⁷ | 2.93 | 0.82 | 0.80 | 0.78 |
| Naphthalene ⁵ | vol% | Range | - | - | - | - |
| | | Mean ⁷ | 0.042 | 0.003 | 0.0028 | - |
| Sediment | Ppmw | Range | - | - | 91-360 | 163-333 |
| | | Mean ⁷ | - | - | 179 | 242 |
| TAN | mgKOH/g | Range | - | - | 0.9-2.4 | 0.2-1.8 |
| | | Mean ⁷ | - | - | 1.7 | 0.9 |
| Pour Point ^{2,4} | °C | Range | - | - | - | - |
| | | Mean ⁷ | 3 | -72 | -45 | -36 |
| Flash Point ^{2,4} | °C | Range | - | - | - | - |
| | | Mean ⁷ | - | <-21 | <-35 | 11 |

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Table 3 Physicochemical Properties of Crude Oils

| Parameter | Unit | Measure | Bakken | Suncor Synthetic A | Western Canadian Blend | Heavy Conventional ⁶ | |
|------------------------|-------------------------|----------|---------------------------------|--------------------|------------------------|---------------------------------|-----------|
| | | | Light Conventional ³ | Sweet Synthetic | Diluted Bitumen | | |
| Distillation Fractions | Naphtha ² | mass % | Range | 33.3-37.7 | 10.38-25.46 | 14.33-20.66 | 11.8-19.3 |
| | | recovery | Mean ⁷ | 34.8 | 17.32 | 17.48 | 14.1 |
| | Distillate ² | mass % | Range | 24.5-28.8 | 31.67-61.83 | 11.7-16.67 | 16.2-21.6 |
| | | recovery | Mean ⁷ | 26.8 | 47.2 | 14.34 | 19.5 |
| | Gas Oil ² | mass % | Range | 22.1-25.2 | 23.35-51.8 | 24.44-26.74 | 22.0-31.7 |
| | | recovery | Mean ⁷ | 23.7 | 35.39 | 25.64 | 24.6 |
| | Residuum ² | mass % | Range | 13.9-15.6 | 0 | 41.43-42.98 | 34.7-45.6 |
| | | recovery | Mean ⁷ | 14.7 | 0 | 42.54 | 41.8 |

¹ Benzene, toluene, ethylbenzene and xylenes (BTEX). Data from CrudeMonitor.ca 5-year averages.

² Data from Environment Canada's Crude Oils Database.

³ Shafizadeh 2010.

⁴ Publicly available viscosity, pour point, and flash point data is lacking. Therefore, sample size is small.

⁵ Naphthalene concentrations from Yang et al. 2011.

⁶ Although not a representative crude oil, Heavy Conventional is provided for comparison.

⁷ Mean for specific crude oil listed (Bakken, Suncor Synthetic A, and Western Canadian Blend). Overall mean for Heavy Conventional.

2.4.1 Light Conventional Crude Oil (Bakken)

Bakken crude oil is classified as a light sweet crude oil. Some primary physical properties are identified in **Table 4**. Bakken crude oil has a very high American Petroleum Institute (API) gravity of 42.1. Because oils with API gravities greater than 10 will float on water, Bakken crude oil would be extremely buoyant and float on the water's surface following a release. The oil also has a very low viscosity (2 to 4 centistokes at ambient temperatures), indicating that the oil would spread across the water's surface and form a thin slick on top of water in the case of a release. Spreading increases the surface area of the crude oil and would facilitate evaporation, the primary environmental fate process governing the fate of volatile organic compounds within the oil, like benzene. Bakken crude oil contains 0.28 percent benzene by volume (Shafizadeh 2010).

Table 4 Properties of Bakken Crude

| Parameter | Unit | Bakken Crude |
|-------------|--------------|---------------------|
| Viscosity | mPa•s @ 40°C | 2.76 |
| Gravity | API | 42.1 |
| Benzene | vol% | 0.28 |
| Naphthalene | vol% | 0.0418 ¹ |
| Pour Point | °C | -12 |

¹ Naphthalene content of Bakken crude oil was unavailable. Therefore, the median concentration of naphthalene within conventional crude oil was utilized (Yang et al. 2011).

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2.4.2 Synthetic Crude (Suncor Synthetic A)

Raw bitumen can be partially refined (i.e., upgraded) to create synthetic crude oil, a process that removes many of the high molecular weight compounds present in the bitumen (e.g., asphaltenes). Synthetic crude is comparable to mid-weight conventional crude oils. The representative synthetic crude oil, Suncor Synthetic A, has an API gravity of 32.6, indicating that it will initially float on water (5-year average; Crude Monitor 2017).

Environmental processes (e.g., spreading, evaporation, emulsification) will be intermediate in comparison to Bakken crude oil and Western Canadian Blend. As a result of its intermediate characteristics, environmental, physical, and chemical effects from synthetic crude also will be intermediate in comparison with the other two representative crude oils.

2.4.3 Diluted Bitumen (Western Canadian Blend)

The raw petroleum product extracted from the Alberta oil sands is called bitumen, which is highly viscous. In order for the bitumen to be transported by pipeline, it is blended with a diluent (i.e., a lighter petroleum hydrocarbon product, such as condensate or synthetic crude oil) and transported as diluted bitumen. While the precise composition of diluted bitumen will be determined by shippers and is considered proprietary information, critical information regarding its composition is available on publicly available databases (e.g., CrudeMonitor.ca, Environment Canada Oil Properties Database). Chemical assays are routinely performed on these oils and the data used in this assessment represent 5-year average values. Diluted bitumen is similar in both its physical characteristics and chemical composition to other naturally occurring heavy crude oils derived from various locations throughout the world, such as portions of California, Venezuela, Nigeria, and Russia (Shafizadeh 2010; Crude Monitor 2011; Environment Canada 2011). Additionally, Keystone places limits on the amount of impurities (e.g., water, sediment) within the crude oils it ships. This ensures that the products provided to Keystone by its customers will not harm the pipeline system.

Like all the crude oils transported by the Project, diluted bitumen has an API gravity higher than 10, indicating that it will float on the water surface (**Table 3**). It is more viscous than either synthetic or conventional light crude oils, so it will spread over land and across water at a slower rate, reducing the area affected in a given period of time. Due to their high viscosity, heavy crude oils do not disperse in the environment as much or as quickly as light crude oils (Section 2.5.4, Crude Oil Environmental Fate Modeling). Like other crude oils, diluted bitumen can form emulsions (i.e., water-in-oil mixtures). Due to the greater proportion of heavy molecular weight compounds (e.g., asphaltenes, resins), Western Canadian Blend emulsions tend to be more stable and have longer environmental persistence than emulsions formed by lighter crude oils but comparable to other heavy crude oils (Fingas 2014).

2.4.4 Benzene

While most crude oil constituents are not very soluble in water, benzene has a comparatively high water solubility compared to other petroleum hydrocarbons. Benzene has an optimal solubility of 1,800 milligrams per liter (mg/L, equivalent to parts per million [ppm]). If crude oil was released into water, benzene preferentially stays within crude oil rather than dissolving into the water and the concentration of benzene in water would be well below its optimal solubility. While only a comparatively small amount of benzene potentially would solubilize into water from an oil release, this is an important fate process as it can affect water quality. Studies of 69 crude oils found that benzene was the only aromatic or polycyclic aromatic hydrocarbons (PAH)

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compound tested that is capable of exceeding drinking water protection values (i.e., benzene's maximum contaminant level [MCLs] or Water Health Based Limits) (Kerr et al. 1999 as cited in O'Reilly et al. 2001).

Effects to water quality were evaluated based on the conservative estimation of benzene in water compared with drinking water standards. Benzene is ideally suited for screening for potential water quality effects from a crude oil release because benzene has: 1) relatively high water solubility compared to other crude oil constituents; 2) the lowest drinking water standard; and 3) the capacity to cause acute aquatic toxicity at concentrations lower than other crude oil constituents.

Benzene tends to be the most toxic crude oil constituent based on drinking water standards and aquatic toxicity. **Table 5** demonstrates how the combination of solubility and toxicity result in a relative toxicity that is orders of magnitude greater than other crude oil constituents. In addition, the drinking water standard (MCL) for benzene, 0.005 mg/L, is one of the lowest of any drinking water contaminant. Consequently, screening for environmental effects based on benzene concentrations is considered a conservative method of analysis.

Table 5 Acute Toxicity of Crude Oil Hydrocarbons to *Daphnia magna*

| Compound | 48-hr LC ₅₀ (mg/L) ^{1,2} | Optimum Solubility (mg/L) | Relative Toxicity ² |
|----------------------------|---|------------------------------|--------------------------------|
| 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 |

¹ The LC₅₀ is the concentration of a compound necessary to cause 50% mortality in laboratory test organisms within a predetermined time period (e.g., 48 hours) (U.S. Environmental Protection Agency [USEPA] 2000).

² Relative toxicity = optimum solubility/LC₅₀.

2.5 ENVIRONMENTAL FATE AND TRANSPORT

This section of the Site-specific Risk Assessment (SSRA) describes the environmental fate processes and behavior of crude oils. Overall, the environmental fate of crude oil is controlled by many factors and persistence is difficult to predict with great accuracy. The speed and efficiency of emergency response containment and cleanup largely dictates the fate and extent of transport within the environment. This section, however, discusses environmental fate and transport of crude oil, without accounting for the benefits of emergency response. Major factors affecting the environmental fate of crude oil 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. Fate and transport of released crude oil, in addition to primary degradation processes, are discussed below.

2.5.1 Releases into Terrestrial Environments

Overview. If released in soil at pipeline depth, the released oil can volatilize, sorb to soil particles, constituents can dissolve into the groundwater, or reside within the interstitial spaces in the soil and subsoils (Spence et al. 2001). The movement of crude oil and the physical and chemical transformations of its constituents are influenced by a variety of factors and processes as discussed in the following list.

- Physical factors. The movement of crude oil across the soil surface is governed by slope, soil permeability, and, to a lesser extent, ambient temperature. Spreading across environmental surfaces reduces the bulk quantity of crude oil present in the immediate vicinity of the spill, but increases the spatial area within which adverse effects may occur. Spreading and thinning of spilled crude oil in soils or water also increase the surface area of the slick, thus enhancing surface dependent fate processes such as evaporation, degradation, and dissolution.
- Evaporation. The majority of the volatile hydrocarbon fractions will evaporate quickly from pooled oil on the soil surface. Crude oil that has dispersed downward in the soil profile will evaporate more slowly because of less oil surface area exposed to the air, and the presence of other binding forces (see sorption below). The rates of evaporation primarily are controlled by soil porosity and soil temperature.
- Sorption. Crude oil dispersed in soil will bind (adhere) to soil particles. Crude oil usually will bind most strongly with soil particles in organic soils; crude oil usually will bind less strongly with soil particles in sandy soils.
- Dissolution. Although most components of crude oil are relatively insoluble (Neff and Anderson 1981), crude oil released into soil can migrate toward water where certain constituents can dissolve into groundwater or surface water in limited amounts. Dissolution is not a major process controlling crude oil's fate as most crude oil constituents are more soluble in oil than water and, therefore, preferentially remain in the crude oil.
- Photodegradation. Photodegradation (breakdown of hydrocarbon molecules under exposure to sunlight) is an important process for soils directly exposed to sunlight at the soil surface. Crude oil that has penetrated deeper into the soil profile is not affected by this process.
- Biodegradation. With time, soil microorganisms capable of consuming crude oil generally increase in number and the biodegradation process naturally remediates the previously

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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.

2.5.2 Releases into Water Environments

If released into water, crude oil will float to the water's surface. If crude oil is left on the water's surface over an extended period of time, some constituents within the oil will evaporate, some may disperse into the water, other fractions will dissolve, and eventually, some material may sink. The following is a summary of the major processes that occur during crude oil dispersion and degradation. Section 2.5.4, Crude Oil Environmental Fate Modeling, quantifies these environmental fate processes for three representative crude oils and a variety of environmental conditions.

- **Physical Factors.** Crude oil mobility in flowing water increases with wind, stream velocity, and increasing temperature, whereas surface ice will greatly reduce the downstream movement of crude oil. In comparison to confined and stationary waterbodies, effects to water quality resulting from released crude oil in flowing waterbodies tends to cause transitory effects as the material evaporates, disperses, becomes stranded on riverbanks, and is removed from the area. Although reduced in temporal intensity, a crude oil release into flowing waters tends to move over a much larger area. Crude oil spreads and thins across the water's surface, increasing the oil's surface area, thus enhancing surface-dependent fate processes, such as evaporation, degradation, and dissolution.
- **Evaporation.** Over time, evaporation is the primary mechanism of loss of low molecular weight constituents and light oil products. Evaporation is responsible for the reduction in crude oil volume, particularly over the first few days following a release. In field trials, bulk evaporation of crude oil accounted for an almost 50 percent reduction in volume over a 12-day period, while the remaining oil was still sufficiently buoyant to float on the water's surface (Shiu et al. 1988). Evaporation increases with increased spreading of a slick, increased temperature, and increased wind and wave action. As lighter components evaporate, remaining crude oil becomes denser and more viscous. Evaporation tends to reduce crude oil toxicity, but enhances crude oil persistence.
- **Dispersion.** While crude oil does not dissolve in water the same way that, for example, salt dissolves in water, turbulent water is able to drive small droplets of the oil into the water column. Experimental data suggest that the maximum size of these droplets is approximately 70 microns (Delvigne and Sweeney 1988). If the droplets are small enough, natural turbulence in the water will prevent the oil from resurfacing, just as turbulence in the air keeps small dust particles afloat (National Oceanographic and Atmospheric Administration [NOAA] 2013). This process is called dispersion. Environmental conditions dictate the importance of dispersion. For oil releases on water during storm events, dispersion can be the chief removal mechanism of the slick. During storms, the majority of the oil can be dispersed into the water column. For releases under more normal weather conditions, dispersion generally is nominal and evaporation is the primary environmental fate process (NOAA 2013).

Chemically induced dispersion may be considered an appropriate method to clean up high volume crude oil releases, particularly those that occur in large bodies of water. In some cases, enhancement of dispersion by using chemical dispersants is used as part of clean up since dispersion into the water column facilitates natural weathering processes such as biodegradation and oxidation, thus reducing exposure of aquatic organisms to

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elevated oil concentrations. The decision to use chemical dispersants must be coordinated with applicable agencies.

- Dissolution. Dissolution of crude oil in water is not a substantive process controlling crude oil's fate in the environment because most components of oils are relatively insoluble (Neff and Anderson 1981). Moreover, evaporation tends to dominate the reduction of crude oil, with dissolution slowly occurring with time. As discussed previously, overall solubility of crude oils tends to be less than their constituents because solubility is limited to the partitioning between the oil and water interface and individual compounds are often more soluble in oil than in water, thus preferentially remaining in the oil. Nevertheless, dissolution is one of the primary processes affecting the toxic effects of a release, 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.
- Sorption. In water, heavy molecular weight hydrocarbons will bind to suspended particulates. As crude oil weathers, this process can be especially significant in highly turbid or eutrophic waters. Organic particles (e.g., biogenic material) in soils or suspended in water tend to be more effective at adsorbing 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 persistent and can cause shoreline effects. See Section 2.5.3, Submersion of Crude Oil, for additional details.
- Photodegradation. Photodegradation of crude oil in aquatic systems increases with greater solar intensity. It can be a substantive factor controlling the reduction of a slick, especially of lighter oil constituents, but it will be less important during cloudy days and winter months. Photodegraded crude oil constituents can be more soluble and more toxic than parent compounds. Extensive photodegradation, like dissolution, may increase the biological effects of a release event.
- Biodegradation. In the immediate aftermath of a crude oil release, natural biodegradation of crude oil will not tend to be a substantive process controlling the fate of released crude oil in environments 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.

2.5.3 Submersion of Crude Oil

Diluted bitumen, synthetic crude oil, and other crude oils that would be transported by the Project have API gravities much greater than 10 (**Table 4**) and therefore initially will float on the surface of water. All crude oils weather (i.e., light end hydrocarbons evaporate and hydrocarbons break down from photolysis and microbial degradation) when exposed to the environment. Evaporation is the dominant environmental fate process immediately following a release, where approximately 30 percent of a crude oil release may evaporate within the first 24 hours and up to 60 percent within the first few days (NOAA 2017). With time, the remaining

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crude oil becomes denser as the proportion of light hydrocarbons decreases. Eventually, the weathering process can result in residual crude oil sinking. This weathering process is not unique to diluted bitumen and occurs with all types of crude oils, regardless of their origin (Rymell 2009).

Typically, weathering is only partially responsible for sinking crude oil. Crude oil also has a strong affinity to particulates, particularly organic matter. As crude oil weathers, the oil also adheres to particulate matter, increasing its density. Under turbulent flood conditions, crude oil will form emulsions with water and particle matter (e.g., sediment, rocks, woody debris). These amalgamations can cause crude oil to sink more rapidly than by weathering alone. Enbridge's Line 6b release into the Kalamazoo River demonstrated the complex environmental processes that led to submerged oil as a sediment-debris-crude oil amalgamation. Within approximately 2 weeks of the Enbridge Kalamazoo release, remaining crude oil that had not been cleaned up due to flood conditions began to sink as the crude oil weathered and accumulated sediment and debris (USEPA 2015). The presence of a roller dam and over-the-bank flood conditions of the river helped introduce sediment, rocks, and debris into the weathered crude oil and contributed to the formation of debris-crude oil amalgamation that eventually sank in the water column.

Environmental conditions, including water temperature and salinity, also can influence the behavior of crude oil in an aquatic environment. The viscosity of the crude oil increases with decreasing temperature, so at lower temperatures, the crude oil is more likely to form solid globules and be limited in its dispersal. Temperature fluctuations also affect density as higher temperatures are associated with lower crude oil densities. Several releases have shown that temperature fluctuations can have substantive effects on crude oil behavior. In the Morris J. Berman release, which occurred in 1994 off the coast of Puerto Rico, crude oil was reported to sink when temperatures lowered and resurfaced during the afternoons when sunlight increased the temperature of released crude oil (Rymell 2009).

Techniques for recovery and cleanup of submerged oil are discussed in Section 7.1.2, Crude Oil Containment, and Section 7.1.3, Crude Oil Recovery.

2.5.4 Crude Oil Environmental Fate Modeling

The NOAA developed a computer program (ADIOS2®) that models how different types of crude oil undergo physical and chemical changes over the initial days following a release. Using the ADIOS2® model, several release scenarios based on WCD were evaluated to determine the environment fate of the crude oil within the first 5 days after a release (**Appendix B**).

Each of the three representative crude oils were modeled under summer and winter conditions as described in **Table 6**. Input variables included water temperature, sediment load, and wind speed, while other input variables (e.g., salinity, river velocity [mean – 3.3 feet/second]) were held constant.

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Table 6 Summary of Input Variables and Environmental Fate Results Using ADOIS2®

| INPUT VARIABLES | | | | RESULTS | | | | |
|------------------------|---|-------------------------|---|-------------|--------|------------|--------|--|
| Scenario | Water Temperature (degrees Fahrenheit [°F]) | Sediment Load (mg/L) | Wind Speed (miles per hour [mph]) | Evaporation | | Dispersion | | Density (grams per cubic centimeter) |
| | | | | 24 hours | 5 days | 24 hours | 5 days | 5 days |
| SUNCOR SYNTHETIC A | | | | | | | | |
| Summer | 60 | 50; 500 | 2 | 23 | 32 | 0 | 0 | <1.0 |
| | | | 10 | 24 | 30 | 2 | 2 | <1.0 |
| Winter | 32 | 50; 500 | 2 | 18 | 26 | 0 | 0 | <1.0 |
| | | | 10 | 20 | 24 | 1 | 1 | <1.0 |
| BAKKEN CRUDE OIL | | | | | | | | |
| Summer | 60 | 50; 500 | 2 | 36 | 45 | 0 | 0 | <1.0 |
| | | | 10 | 40 | 42 | 25 | 57 | <1.0 |
| Winter | 32 | 50; 500 | 2 | 30 | 39 | 0 | 0 | <1.0 |
| | | | 10 | 34 | 39 | 20 | 59 | <1.0 |
| WESTERN CANADIAN BLEND | | | | | | | | |
| Summer | 60 | 50; 500 | 2 | 18 | 21 | 0 | 0 | <1.0 |
| | | | 10 | 20 | 21 | 0 | 0 | <1.0 |
| Winter | 32 | 50; 500 | 2 | 13 | 20 | 0 | 0 | <1.0 |
| | | | 10 | 16 | 20 | 0 | 0 | <1.0 |

Key results from Project-specific crude oil environmental fate modeling include:

- Each of the three oils would remain floating for the initial 5-day period (i.e., densities <1.0).
- Most evaporation occurred in the first 24 hours, though evaporation did continue through the 5-day period for each crude oil.
- Elevated water temperatures (60°F) increased evaporation rates. Even in cold water conditions (32°F), evaporation was the most dominant overall fate process.
- Altering the river's sediment load (50 or 500 mg/L) did not substantively change environmental fate results for evaporation, dispersion, or density.
- Dispersion did not occur under low wind speed (2 mph) for any of three crude oils evaluated. At sustained wind speeds of 10 mph directly against river flow, dispersion occurred for some crude oils.
- Dispersion was most pronounced in light crude (Bakken) during the summer scenario, in which virtually 100 percent of Bakken crude oil would either evaporate or disperse within the 5-day period. The amount of crude oil lost via dispersion continued to increase over the 5-day period.
- For Suncor Synthetic A crude oil, dispersion occurred within the first 24 hours, then stabilized. Dispersion's contribution to crude oil's overall environmental fate was small compared to losses due to evaporation.
- For Western Canadian Blend crude oil, dispersion did not occur, regardless of wind speed or water temperature.

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2.5.5 Environmental Fate During Winter

During the winter, the Missouri River freezes over with a thick layer of ice. This generally occurs between December and April (USACE 2012). If crude were released into the Missouri River, this layer of ice will trap oil released below the river's surface and substantively reduce the evaporation of benzene and other light hydrocarbons. Therefore, during the winter, evaporative loss will be negligible. Natural undulations at the water-ice interface will trap the material and prevent it from spreading horizontally, and will severely limit the downstream movement of the oil. Crude oil will pool in these natural undulations and offer opportunities for cleanup crews to drill through the ice and remove the crude oil. Where oil is in contact with water for extended periods of time, there is the potential for localized effects to organisms in prolonged contact with the near-surface water (e.g., phytoplankton), though the rate of dissolution would be reduced by water temperature. Fish have greater mobility and reside deeper in the water column and benzene concentrations are unlikely to result in significant adverse effects (Section 3.2, Water Quality Thresholds).

3.0 METHODOLOGY

The SSRA quantitatively evaluated the downstream transport of a crude oil release and potential effects to water quality. In Section 3.1, Downstream Transport, a probabilistic analysis of downstream transport of crude oil was conducted based on historical USGS river discharge data.

In Section 4.2.6, Surface Water, a surface water dilution model was used to assess the potential effects to water quality based on an assumption that a hypothetical release occurs at the Missouri River crossing and crude oil enters the Missouri River. Reductions in water quality are quantified by estimating benzene concentration in the water and comparison with its national drinking water standard and screening-level thresholds for aquatic life.

As discussed in Section 2.2, Release Volumes, the probability of an incident and the subsequent ability of a crude oil to enter the Missouri River is extremely remote and the use of the HDD technique further reduces the possibility of a release from ever reaching the Missouri River (Chapter 5.0, HDD Crossing Design). Nevertheless, the following assessment assumes a release hypothetically reaches the waters of the Missouri River and is transported downstream.

Highly conservative modeling assumptions were used for these analyses and include:

- Key Assumption 1: River velocity was uniform throughout the river channel to overestimate downstream transport of the crude oil.
- Key Assumption 2: Calculated downstream transport distances assume no ice cover, since ice cover substantially reduces the downstream movement of crude oil.
- Key Assumption 3: The analysis assumes the entire volume of oil released would enter the Missouri River. The analysis does not account for loss of crude oil due to adhesion to vegetation or shorelines.
- Key Assumption 4: The model assumed that the half-life of benzene, as a result of volatilization, is 4.8 hours based on empirical data (Kuykendall 2010).
- Key Assumption 5: The model assumed that 100 percent of the benzene within the released oil would solubilize directly into the water. This is an extremely conservative (over estimation) assumption given the dominating fate process of evaporation and the low solubility of benzene. Under field conditions, actual concentrations of benzene would not approach optimal solubility limits because benzene preferentially remains in the crude oil or evaporates rather than dissolving into the water.

3.1 DOWNSTREAM TRANSPORT

3.1.1 Fort Peck Reservoir Water Management

Operated by the U.S. Army Corps of Engineers (USACE), the Fort Peck Reservoir is the uppermost reservoir used to manage water within the Missouri River Basin (USACE 2017, 2012). Throughout the year, water is metered out of the reservoir to meet authorized uses while mitigating downstream flooding and to balance water supplies in other USACE-operated reservoirs located downstream (e.g., Garrison, Oahe, and Fort Randall). The reservoir also provides important water storage capacity for drought years.

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Because of the highly regulated outflow from the Fort Peck Reservoir, the average monthly discharge at the USGS sampling site is relatively constant, with slightly higher average discharges observed during both winter (December-January-February) and summer (June-July-August) months (**Figure 3**). Monthly variability also is muted by summary statistics that compile decades of information.

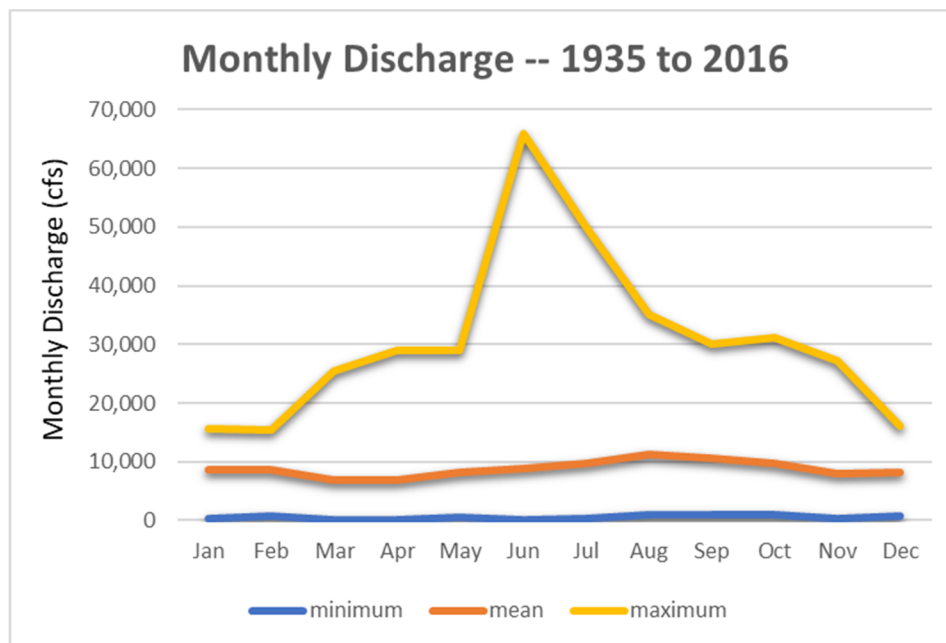


Figure 3 Monthly Discharge on Missouri River below Fort Peck Reservoir (sampling site 06132000)

In contrast, maximum monthly discharge rates are based on a single monthly value and are therefore quite variable and have been driven by extreme weather conditions. The pronounced maximum discharge peak in **Figure 3** is attributable to heavy regional snowpack conditions in 2011 (USACE 2012). Inflows into Fort Peck Reservoir were up to 3 times monthly averages, more than 40 percent higher than previous historical records observed in 1975. As a consequence, historic releases from Fort Peck Reservoir occurred during the summer of 2011, with discharges up to 2 times of previous historic discharges and more than 6 times the monthly average river discharge (USACE 2012).

Within this analysis, understanding the historic range of hydrological conditions where the pipe crosses the Missouri River is important in: 1) evaluating the appropriateness of the preferred pipeline crossing method, and 2) evaluating downstream transport of crude oil.

Tributary Contributions to Discharge

Discharge data were obtained from the USGS gaging station near Wolf Point (sampling site 0677000). Discharge data from this sampling site account for the contributions of several major tributaries of this reach of the upper Missouri River, including the Milk, Poplar, and Redwater rivers, and Wolf Creek. Monthly discharge data from the USGS gaging station on the Missouri River near Wolf Point are presented in **Figure 4**. Discharge is relatively constant throughout the year based on monthly averages, but weather events in 2011 resulted in extreme runoff and resulted in Missouri River discharges up to seven times average monthly discharge rates. The graph is very similar to the graph of discharge below Fort Peck (**Figure 3**), both in shape and

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magnitude of discharge, suggesting limited effects from discharge contributions from the Milk River and other tributaries.

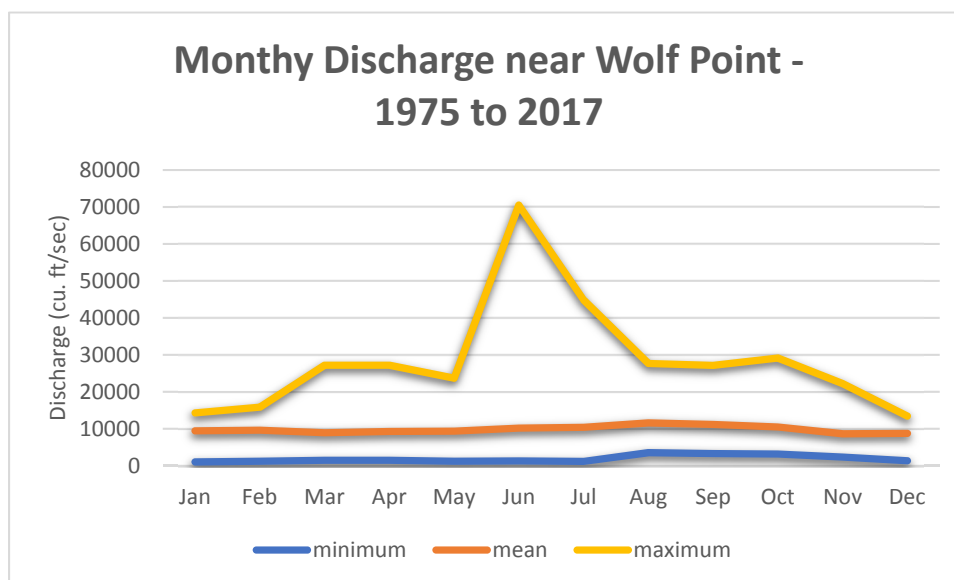


Figure 4 Monthly Discharge on Missouri River near Wolf Point, Montana (sampling site 06177000)

3.1.2 Velocity

To evaluate velocity of the Missouri River below Fort Peck, data from several USGS gaging sites were examined, including site 06132000 below Fort Peck, site 06175100 near Fraser, site 06175520 near Oswego, and site 06177000 near Wolf Point. Only the datasets from the USGS gages below Fort Peck and near Wolf Point contain velocity data. Velocity data are necessary to determine downstream transport distance in subsequent sections of this report.

3.1.2.1 Missouri River Below Fort Peck

Velocity and discharge data for the Missouri River were obtained from the USGS for sampling site 06132000 – Missouri River below Fort Peck Dam Montana and included data from 1985 to 2016 (USGS 2017). As illustrated in **Figure 5**, velocity and discharge data are logarithmically distributed with a high correlation ($R^2 = 0.95$).

3.1.2.2 Missouri River near Wolf Point

Velocity and discharge data for the Missouri River were obtained from the USGS for sampling site 06177000 – Missouri River near Wolf Point MT and included data from 1975 to 2017 (USGS 2017). As illustrated in **Figure 6**, velocity and discharge data are logarithmically distributed with a high correlation ($R^2 = 0.82$).

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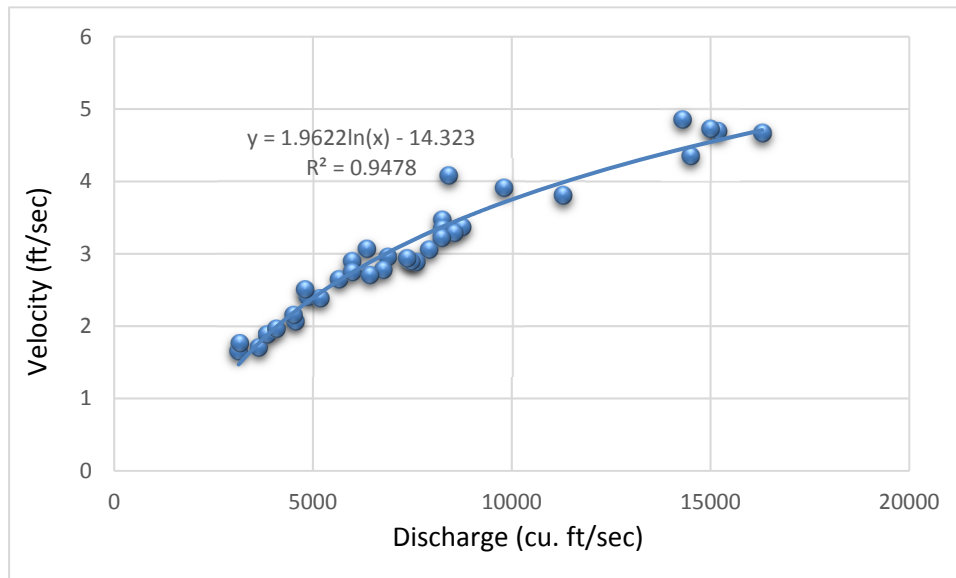


Figure 5 Relationship between Discharge and Velocity on Missouri River below Fort Peck Reservoir (sampling site 06132000)

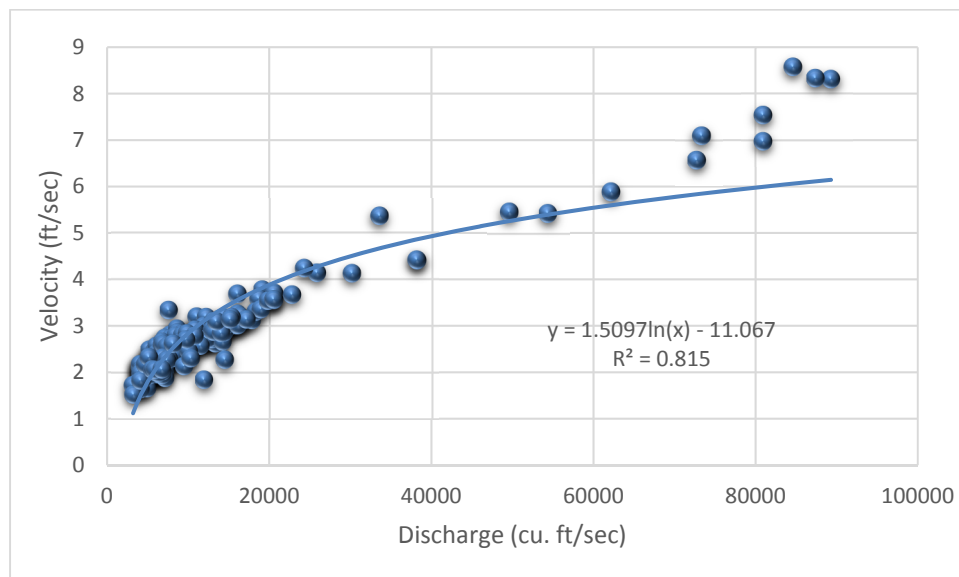


Figure 6 Relationship between Discharge and Velocity on Missouri River near Wolf Point (USGS sampling site 06177000)

3.1.2.3 Velocity Regression Equations

The regression equations for each sampling site represent mathematical models that depict the relationship of discharge and velocity. River hydrodynamics suggest that the discharge:velocity relationship may be less accurate at extreme discharge events. This analysis assumes that the

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calculated velocity represents the average velocity for the river reach (i.e., the time for a unit of water to move from Point A to Point B). It is recognized that river hydrology is complex, varying both horizontally and vertically, within the river channel. Velocity within a river tends to be laminar, with velocity highest in the middle of the channel and slower along the river margins and river bed. River channels, however, are complex with backwater areas and undulating and curving river banks and river bed. By assuming uniform and constant velocity at the river's surface, the analysis provides an estimation of downstream transport distance for different discharge conditions (Section 4.1, Downstream Transport Distances).

3.2 WATER QUALITY THRESHOLDS

Although Keystone has identified three crude oils (Western Canadian Blend, Suncor Synthetic A, and Bakken crude oil) representative of those that will be transported by the Project, this assessment utilized Bakken crude oil to screen for effects to water quality since it has the highest concentration of benzene and thus can be used as a conservative surrogate to screen for water quality impacts from a release of crude oils proposed for transport by the Project. Concerns about sinking oil, as well as a generalized discussion of environmental fate encompassing all three oil types, is addressed in Section 2.5, Environmental Fate and Transport.

3.2.1 Drinking Water

This SSRA evaluated impacts to downstream drinking water sources by comparing projected surface water benzene concentrations with the national drinking water standard (i.e., MCL). This analysis is predicated on the assumption that a crude oil release at the Missouri River crossing could reach the waters of the Missouri River, and does not account for the protective barrier provided by the HDD crossing method (Chapter 5.0, HDD Crossing Design).

Benzene concentrations were calculated at 24-hour post-release, accounting for evaporative loss and hypothetically assumed all remaining benzene within the crude oil dissolved into Missouri River water. The estimated benzene concentrations were then compared with the national human health drinking water MCL for benzene of 0.005 mg/L. Results of the analysis are presented in Section 4.2.6.1, Drinking Water.

3.2.2 Aquatic Life

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 (**Table 5**). Because benzene is relatively soluble compared to other petroleum hydrocarbons and it is highly toxic, benzene is commonly used to screen for potential effects to water quality (Section 2.4.4, Benzene).

The potential impacts to aquatic organisms of various-sized releases to waterbodies were modeled assuming the benzene content was completely dissolved in the water. The benzene concentration was predicted based on amount of crude oil released and river discharge in a 24-hour period. The estimated benzene concentrations were compared to conservative acute and chronic toxicity values for protection of aquatic organisms.

Table 7 summarizes the acute toxicity values (USEPA 2000) of benzene to a range of freshwater species. Acute toxicity refers to the death or complete immobility of an organism within a short period of exposure, typically 48 or 96 hours. **Table 8** summarizes chronic toxicity values (most frequently measured as reduced reproduction, growth, or weight) of benzene to freshwater biota. Based on **Tables 7** and **8**, the lowest acute and chronic toxicity thresholds for benzene

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were established at 7.4 mg/L and 1.4 mg/L, respectively, based on the lowest values observed in standardized toxicity tests (USEPA 2000). These toxicity threshold values are considered protective of acute and chronic effects to aquatic biota.

Table 7 Acute Toxicity of Benzene to Freshwater Organisms

| Species | Toxicity Values (mg/L) |
|--|------------------------|
| | Benzene |
| Carp (<i>Cyprinus carpio</i>) | 40.4 |
| Clarias catfish (<i>Clarias</i> sp.) | 425 |
| Coho salmon (<i>Oncorhynchus kisutch</i>) | 100 |
| Goldfish (<i>Carassius auratus</i>) | 34.4 |
| Guppy (<i>Poecilia reticulata</i>) | 56.8 |
| Medaka (<i>Oryzias</i> sp.) | 82.3 |
| Rainbow trout (<i>Oncorhynchus mykiss</i>) | 7.4 |
| Rotifer (<i>Brachionus calyciflorus</i>) | >1,000 |
| Zooplankton (<i>Daphnia magna</i>) | 30 |
| Zooplankton (<i>Daphnia pulex</i>) | 111 |
| Algae (<i>Selenastrum capricornutum</i>) | 70 |

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

Table 8 Chronic Toxicity of Benzene to Freshwater Biota

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

Note: Test endpoint was reproduction for those denoted with an asterisk (*). The test endpoint for other studies was growth.

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4.0 RESULTS

4.1 DOWNSTREAM TRANSPORT DISTANCES

The average monthly discharge over decades is a summary statistic that moderates daily and yearly variability (e.g., the discharge event observed during 2011). To account for variability and its effect on downstream transport distance, river discharge and velocity were calculated for eight discharge categories. **Table 9** describes the metrics associated with each of these categories for each USGS sampling site.

Table 9 Discharge categories and resulting downstream transport distances for the Missouri River

| Discharge Category | Percent of Historic Annual Discharge | Discharge (cubic feet per second [cfs]) | Velocity (ft/s) | Downstream Transport Distance (miles) |
|--|--------------------------------------|---|-----------------|---------------------------------------|
| Missouri River below Fort Peck | | | | |
| Very low flow | 5% | 1,530 | 0.066 | 0.27 |
| Low flow | 10% | 3,340 | 1.598 | 6.54 |
| Moderately low flow | 25% | 5,500 | 2.576 | 10.54 |
| Median flow | 50% | 7,800 | 3.262 | 13.34 |
| Moderately high flow | 75% | 11,200 | 3.972 | 16.25 |
| High flow | 90% | 14,500 | 4.479 | 18.32 |
| Very high flow | 95% | 29,485 | 5.871 | 24.02 |
| Record 2011 historic flood (maximum discharge) | 100% | 65,900 | 7.449 | 30.47* |
| Missouri River near Wolf Point | | | | |
| Very low flow | 5% | 4423 | 2.206 | 9.02 |
| Low flow | 10% | 5026 | 2.248 | 9.20 |
| Moderately low flow | 25% | 6590 | 2.358 | 9.64 |
| Median flow | 50% | 8770 | 2.510 | 10.27 |
| Moderately high flow | 75% | 12850 | 2.796 | 11.44 |
| High flow | 90% | 17440 | 3.117 | 12.75 |
| Very high flow | 95% | 28840 | 3.915 | 16.02 |
| Record 2011 historic flood (maximum discharge) | 100% | 89300 | 8.147 | 33.33* |

* The downstream transport for the 2011 flood conditions likely overestimates downstream transport distance of crude oil due to velocity slowing on the river surface as the river overtopped its banks and laterally dispersed, increasing channel width at the river's surface and increasing the roughness coefficient associated with Manning's equation.

Results indicate that the river velocity and associated downstream transport distance is lower at the Wolf Point site. Results from the two gaging sites presented in **Table 9** were condensed into a single table (**Table 10**) that describes the average and range of downstream transport distances used for creating **Figure 6**.

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Table 10 Range of Downstream Transport Distances for the Missouri River

| Discharge Category | Percent of Historic Annual Discharge | Velocity (ft/s) | Downstream Transport Distance (miles) | Average Downstream Transport Distance (miles) |
|--|--------------------------------------|-----------------|---------------------------------------|---|
| Very low flow | 5% | 0.07 | 0.27* | 0.27* |
| Low flow | 10% | 1.6 to 2.2 | 6.5 to 9.2 | 7.87 |
| Moderately low flow | 25% | 2.4 to 2.6 | 9.6 to 10.5 | 10.09 |
| Median flow | 50% | 2.5 to 3.3 | 10.3 to 13.3 | 11.81 |
| Moderately high flow | 75% | 2.8 to 4.0 | 11.4 to 16.3 | 13.85 |
| High flow | 90% | 3.1 to 4.5 | 12.8 to 18.3 | 15.54 |
| Very high flow | 95% | 3.9 to 5.9 | 16.0 to 24.0 | 20.02 |
| Record 2011 historic flood (maximum discharge) | 100% | 7.4 to 8.1 | 30.5 to 33.3** | 31.90** |

* The downstream transport distance at 5% discharge below Fort Peck would only travel 0.27 miles and therefore, transport distance would not be influenced by contributions from the Milk River. All other distances are based on the range identified by the Fort Peck and Wolf Point gages.

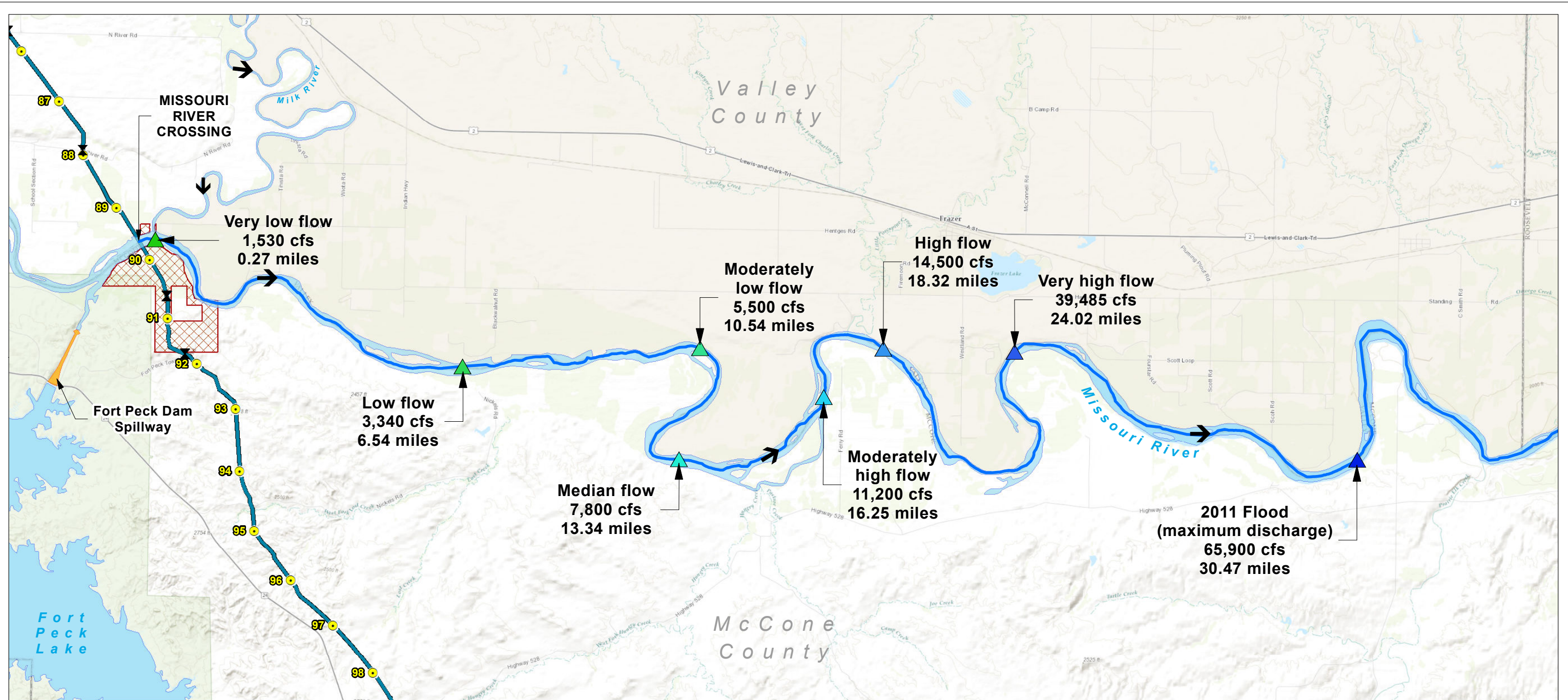
** The downstream transport for the 2011 flood conditions likely overestimates downstream transport distance of crude oil due to velocity slowing on the river surface as the river overtopped its banks and laterally dispersed, increasing channel width at the river's surface and increasing the roughness coefficient associated with Manning's equation.

The downstream transport distances in **Table 10** represent the calculated distances that crude oil might travel within 6 hours, the maximum response time along the Missouri River stipulated by Federal pipeline safety regulations (49 CFR 194). Federal regulations require initial responders to be on-site and initiating containment within 6 hours. Keystone will have resources and pre-positioned emergency response equipment in place to be able to meet this Federal requirement. Additionally, geographic response plans (GRPs) will be prepared in advance and will identify deployment areas, methods, and strategies, covering an array of environmental conditions, allowing emergency response personnel to immediately deploy equipment.

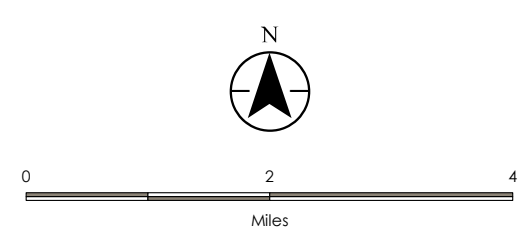
Figure 7 depicts the average downstream transport distances based on the Missouri River discharge categories (**Table 10**). These categories represent statistical probabilities of downstream transport distance designed to over-estimate transport potential. As discussed in Section 4.2.6, Surface Water, most releases would have insufficient volume to be detectable much beyond the release site³.

Only very large releases of crude oil would be capable of being transported long distances (e.g., 24 miles) at discernable concentrations. Calculated downstream transport distances assume no ice cover on the river, since ice greatly reduces the downstream movement of crude oil.

³ Analytical detection limits for benzene in water are often at the drinking water MCL (0.005 mg/L).



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1:100,000 (At Original document size of 11x17)
Coordinate System: NAD 1983 UTM Zone 13N

- | | |
|------------------------------|----------------------|
| KXL Centerline | Very low flow |
| Valve | Low flow |
| Mile Post | Moderately low flow |
| Downstream Transport Pathway | Median flow |
| Army Corps of Engineers | Moderately high flow |
| Fort Peck Dam Spillway | High flow |
| Direction of Flow | Very high flow |
| | Maximum flow |



Figure No. **7**
Title
Downstream Transport Distances

Client/Project
Keystone XL Pipeline Project

Project Location: Northeast Montana
Prepared by: MRP on 2017-11-13
Technical Review by: HT on 2017-07-18
Independent Review by: XXX on xxxx-xx-xx
221900004



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4.2 ENVIRONMENTAL EFFECTS/CONSEQUENCES⁴

An evaluation of the potential effects (potential consequences) resulting from the accidental release of crude oil into the environment is discussed in the following sections by environmental resource.

4.2.1 Soils

Because pipelines are buried, soil absorption of the released crude oil could occur, thus impacting the soils. Subsurface releases to soil tend to disperse slowly and generally are located within a contiguous and discrete area, often limited to the less consolidated soils (lower soil bulk density) within the pipeline trench or within the space surrounding the pipe in a HDD bore hole. Effects to soils can be quite slow to develop, allowing time for emergency response and cleanup actions to mitigate effects to potential receptors.

Within the Missouri River crossing, the depth of overburden would help reduce the potential of a release reaching the river. A detailed discussion of a release within the HDD is discussed in Chapter 5.0, HDD Crossing Design. The terrain on the north side of the Missouri River is a low-lying area where a crude oil release would pool, preventing even a WCD release from reaching the Missouri River and allowing emergency responders to remove the crude oil from the site. While there is no sizable pooling area on the north side of the river, the HDD exit point is located 1,071 feet from the bank of the Missouri River with the slope running parallel to the river, thus substantially reducing the possibility of a release reaching the river by flowing across the soils surface (see Section 5.2, Terrain, for additional detail).

In the event of a release beyond the HDD entry and exit points and within the upland terrain near the Missouri River, high rates of release from the trenched portion of the pipeline would result in a greater likelihood that released materials would immediately escape from the trench and reach the surrounding ground surface. The Keystone XL Final Supplemental Environmental Impact Statement (U.S. Department of State [USDOS] 2014) concluded that even slow release rates such as those arising from a pinhole leak 1/32-inch in diameter also will reach the ground surface within approximately 1 month. Therefore, they would be detectable via standard aboveground aerial and ground surveillance due to product on the soils surface or discoloration of nearby vegetation.

The extent of crude oil movement also would depend on a number of factors, with soil permeability, crude oil viscosity, and site-specific environmental conditions. Once on the soil surface, the crude oil would spread across the soil surface and, in permeable soils, would migrate vertically into the soil. Surface soils at the HDD entry site are classified as low plasticity clay (**Figure 2**), indicating that the soil would severely limit the vertical penetration of crude oil into the soil structure. Clay soils with low plasticity have a maximum permeability rate less than 0.008 inches/hour for water (Geotechdata.info 2013). Crude oil is more viscous than water; therefore, permeability of crude oil would be slower. At the HDD exit site on the south side of the river, the soils are a mixture of low plasticity clays with low permeability as well as silty sands with moderate permeability (permeability range: less than 0.008 inch/hour to 0.7 inch/hour for water) (Geotechdata.info 2013). Less viscous crude oils (e.g., Bakken crude oil) will migrate into the soil structure more than the more viscous diluted bitumen. If present, soil moisture and moisture from precipitation would increase the lateral spread of crude oil. Conversely, cold temperatures and

⁴ For the purposes of this SSRA, the terms "effects" and "consequence" are synonymous.

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frozen soils will slow the lateral and vertical movement of crude oil. Timely and efficient emergency response activities can limit the amount of soil effected by a release.

Both on the surface and in the near subsurface, rapid attenuation of light, volatile constituents (due to evaporation) would quickly reduce the total volume of crude oil, while heavier constituents would be more persistent. Effects to soils would be confined to a relatively small, contiguous, and easily defined area, facilitating cleanup and remediation.

Since the majority of releases are relatively small (3 bbls or less), the amount of soil affected by most releases would be minor. For a WCD event and assuming an average depth of oil of 2 to 4 inches (given small undulations and low lying areas), the areal extent of a WCD release is estimated to be 5 to 10 acres. Given the low to moderate permeability of the soils at the Missouri River, the crude oil is not likely to substantially infiltrate soils prior to cleanup.

In accordance with Federal and State regulations, Keystone would be responsible for cleanup of contaminated soils and would be required to meet applicable cleanup levels. In Montana, the soil cleanup level for benzene from petroleum hydrocarbon release is 0.04 milligram per kilogram (equivalent to ppm). Cleanup requirements for the site will be established by applicable agencies (e.g., Montana Department of Environmental Quality, USEPA). Once remedial cleanup levels were achieved in the soils, no adverse or long-term impacts would be expected.

4.2.2 Vegetation and Soil Ecosystems

Crude oil released to the soil's surface potentially could produce localized effects on plant populations. Terrestrial plants are less sensitive to crude oil than aquatic species. The lowest toxicity threshold for terrestrial plants found in the USEPA ECOTOX database (USEPA 2001) is 18.2 mg/L for benzene, which is higher than the 7.4 mg/L threshold for aquatic species and the 0.005 mg/L 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 mg/L). If concentrations were sufficiently high, however, crude oil in the root zone could reduce respiration and nutrient uptake by individual plants and organisms.

Recovery of soil productivity depends on a variety of factors, particularly the severity of the release and the timeliness and effectiveness of cleanup efforts. In agricultural areas, such as the land on the north side of the Missouri River, recovery can be accelerated by the addition of fertilizers and tilling of soil, which helps aerobic degradation of petroleum hydrocarbons.

While a release of crude oil could result in the contamination of soils (Section 4.2.1, Soils), Keystone will 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.

4.2.3 Wetlands

Although planning and routing efforts have reduced the overall number of wetlands and static waterbody environments crossed by the Project, wetlands and stationary waterbodies with persistently saturated soils are present along and adjacent to the Project 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 condition 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 simply may be areas of saturated soil with no open water. A single wetland can even vary between these two extremes as seasonal

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precipitation varies. Wetland surfaces generally are low gradient with very slow unidirectional flow or no discernible flow. The presence of vegetation or narrow spits of dry land protruding into wetlands also may isolate parts of the wetland. Given these conditions, crude oil entering a wetland 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 crude oil would spread laterally across the water's surface and be readily visible during routine 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. Therefore, it is important that the cost and benefit of each remediation technique, including engaging in no active remediation activities, be considered prior to response. If no active remediation activities were undertaken, natural biodegradation and attenuation ultimately would allow recovery of both soil and groundwater. This likely would require a timeframe on the order of tens of years. In the unlikely event of a crude oil release into a wetland, Keystone will utilize the most appropriate cleanup procedures as determined in coordination with the applicable Federal and State agencies.

4.2.4 Wildlife

Crude oil releases can affect terrestrial organisms directly and indirectly. Direct effects include physical (mechanical) processes, such as oiling of feathers and fur, and toxicological (chemical) effects, which can cause sickness or mortality. 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 crude oil released, the size of the affected area, the type of crude oil released, the species assemblage present, climate, and the emergency response tactics employed.

Wildlife, especially birds and shoreline mammals, typically are among the most visibly affected organisms in a crude oil release. Physical effects of crude oil 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 toxicological 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 mortality. 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

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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 crude oil released 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 areas and food affected by a crude oil release (Sharp 1990; Stubblefield et al. 1995). In a few cases, such as cave-dwelling species, organisms that are obligate users of impacted habitat may be exposed. However, most terrestrial species have alternative, unimpacted habitat available, as will often be the case with localized releases (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 crude oil releases can include the temporary 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 crude oil. 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 release. If mortality occurs to local invertebrate and wildlife populations, the ability of the population to recover will depend upon the size of the impact area and the ability of surrounding populations to repopulate the area.

4.2.5 Groundwater

Multiple groundwater aquifers underlie the proposed Project. Vulnerability of these aquifers is a function of the depth to groundwater and the permeability of the overlying soils. While routine operation of the Project would not affect groundwater, there is the possibility that a release could migrate through the overlying surface materials and reach groundwater. If crude oil is not removed from the environment, groundwater water quality may be effected in a highly localized area. Crude oil contamination does not affect entire aquifers.

Depending on soil properties, the depth to groundwater, and the amount of crude oil in the unsaturated zone, localized groundwater contamination can result from the presence of free crude oil and the migration of its dissolved constituents. Crude oil is less dense than water and would tend to form a floating pool after reaching the groundwater surface. Movement of crude oil generally is quite limited due to adherence to soil particles, groundwater flow rates, and natural attenuation (i.e., microbial degradation) (Freeze and Cherry 1979; Fetter 1993). Those compounds in the crude oil that are soluble in water will form a larger, dissolved "plume." This plume would tend to migrate laterally in the direction of groundwater flow. Movement of dissolved constituents typically extends for greater distances than movement of pure crude oil in the subsurface, but is still relatively limited. The flow velocity of dissolved constituents would be a function of the groundwater flow rate and natural attenuation, with the dissolved constituents migrating more slowly than groundwater.

Unlike chemicals with high environmental persistence (e.g., trichloroethylene, pesticides), the areal extent of the dissolved constituents will stabilize over time due to natural attenuation processes. Natural biodegradation through metabolism by naturally occurring microorganisms is often an effective mechanism for reducing the volume of crude oil and its constituents. Natural attenuation will reduce most toxic compounds into non-toxic metabolic byproducts, typically carbon dioxide and water (Minnesota Pollution Control Agency 2005). Field investigations of more than 600 historical petroleum hydrocarbon release sites indicate the migration of dissolved constituents typically stabilizes within several hundred feet of the crude oil source area (Newell and Conner 1998; USGS 1998). Over a longer period, the area of the contaminant plume may

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begin to reduce due to natural biodegradation. Removal of crude oil contamination will eliminate the source of dissolved constituents impacting the groundwater.

Most crude oil constituents are not water soluble. For those constituents that are slightly water soluble (e.g., benzene), the dissolved concentration is not controlled by the amount of oil in contact with the water but by the concentration of the specific constituent in the oil (Charbeneau et al. 2000; Charbeneau 2003; Freeze and Cherry 1979). Studies of 69 crude oils found that benzene was the only aromatic or PAH compound tested that is capable of exceeding groundwater protection values for drinking water (i.e., MCLs or Water Health Based Limits) (Kerr et al. 1999 as cited in O'Reilly et al. 2001).

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

However, emergency response and remediation efforts have the potential for appreciable adverse environmental effects from construction\cleanup equipment. Therefore, it is necessary that the cost and benefit of each remediation technique, including engaging in no active remediation activities, be considered and evaluated prior to response. If no active remediation activities were undertaken, natural biodegradation and attenuation ultimately would allow recovery of both soil and groundwater. Depending on the amount of crude oil reaching the groundwater and natural attenuation rates, this likely would require up to tens of years. Keystone will utilize the most appropriate cleanup procedure as determined in cooperation with the applicable Federal and State agencies.

4.2.6 Surface Water

4.2.6.1 Drinking Water

The estimated benzene concentrations were then compared with the national human health drinking water MCL for benzene of 0.005 mg/L (**Table 11**). The results of the analysis indicate that most releases that enter the Missouri River would not exceed the national MCL for benzene. Only very large releases potentially would exceed the drinking water MCL. The results also show that the probability of a very large release that is sufficient to exceed MCLs within this model is more than 1,000,000 years.

Although the model assumptions used are highly conservative and, thus, overestimate the theoretical benzene water concentrations, the analysis reinforces the importance for notifying downstream water users so that drinking water intakes could be closed as a precautionary measure until water quality is deemed acceptable for human consumption by applicable regulatory agencies.

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Table 11 Comparison of Estimated 24-hour Benzene Concentrations with the Benzene Drinking Water MCL

| Streamflow | Stream Flow Rate (cfs) | Benzene MCL (mg/L) | Product Released | | | | | | | | WCD | |
|--|------------------------|--------------------|-------------------------------|-----------------------------|---------------------------|-----------------------------|---------------------------------|-----------------------------|-------------------------------|-----------------------------|----------------------|-----------------------------|
| | | | Very Small Release: 3 barrels | | Small Release: 50 barrels | | Moderate Release: 1,000 barrels | | Large Release: 10,000 barrels | | Benzene Conc. (mg/L) | Occurrence Interval (years) |
| | | | Benzene Conc. (mg/L) | Occurrence Interval (years) | Benzene Conc. (mg/L) | Occurrence Interval (years) | Benzene Conc. (mg/L) | Occurrence Interval (years) | Benzene Conc. (mg/L) | Occurrence Interval (years) | | |
| Very low flow (5% annual) | 1,530 | 0.005 | 0.00001 | 8,217 | 0.0002 | 22,575 | 0.003 | 100,210 | 0.03 | 1,063,879 | 0.04 | 1,755,825 |
| Low flow (10% annual) | 3,340 | | 0.000004 | 8,674 | 0.0001 | 23,829 | 0.001 | 105,778 | 0.01 | 1,122,983 | 0.02 | 1,853,371 |
| Moderately low flow (25% annual) | 5,500 | | 0.000003 | 10,409 | 0.00005 | 28,595 | 0.0009 | 126,933 | 0.009 | 1,347,580 | 0.01 | 2,224,045 |
| Median flow (50% annual) | 7,800 | | 0.000002 | 15,613 | 0.00003 | 42,892 | 0.0006 | 190,400 | 0.006 | 2,021,370 | 0.009 | 3,336,067 |
| Moderately high flow (75% annual) | 11,200 | | 0.000001 | 31,226 | 0.00002 | 85,785 | 0.0004 | 380,800 | 0.004 | 4,042,740 | 0.006 | 6,672,134 |
| High flow (90% annual) | 14,500 | | 0.000001 | 78,064 | 0.00002 | 214,461 | 0.0003 | 952,000 | 0.003 | 10,106,849 | 0.005 | 16,680,336 |
| Very high flow (99.5% annual) | 29,485 | | 0.0000005 | 1,561,279 | 0.000008 | 4,289,229 | 0.0002 | 19,039,993 | 0.002 | 202,136,985 | 0.002 | 333,606,715 |
| Record 2011 historic flood (maximum discharge) | 65,900 | | 0.0000002 | 3,903,199 | 0.000004 | 10,723,073 | 0.00008 | 47,599,983 | 0.0008 | 505,342,462 | 0.001 | 834,016,788 |

Notes:

- Historical data indicate that the most probable release volume would be 3 bbls or less. However, this entire analysis is based on conservative incident frequencies and a range of release volumes, including WCD, to provide a range of the magnitude of potential effects.
- Estimated concentration is based on Bakken crude oil release and calculation of benzene into water over a 24-hour period with uniform mixing conditions. The calculations hypothetically assume all benzene preferentially dissolves into the water, rather than remaining in the crude oil. In reality, dissolution is a minor fate process.
- Concentrations are based on a 0.28 percent by weight benzene content of the transported material (Marathon Oil data, website: http://www.ndoil.org/image/cache/Peacock_-_March_23_2010_ppt.pdf).
- Shading indicates estimated benzene concentrations that could exceed the benzene MCL of 0.005 mg/L.
- Calculations account for evaporation in the first 24-hours with a half-life of 4.8 hours.

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4.2.6.2 Aquatic Life Effects

Calculated concentrations of benzene were compared with aquatic life thresholds. **Table 12** summarizes the results of the screening-level assessment of acute and chronic toxicity, respectively, to aquatic resources. Results demonstrate that the theoretical concentrations of benzene would not approach acute or chronic toxicity concentrations, even if substantial amounts of crude oil were to enter the Missouri River.

The analysis also demonstrates that the probability of a release into the Missouri River would be very low (**Table 12**). Although not quantified, the use of HDD further reduces the possibility of a release reaching the waters of the Missouri River due to the depth of the HDD.

This analysis focuses on the potential for toxicity within the mainstem of the river, but recognizes that toxicity may be possible in certain localized areas (e.g., backwaters) if crude oil were to reach the waters of the Missouri River. Timely and efficient emergency response, containment, and cleanup efforts would help reduce the crude oil volume within the environment and thereby minimize the potential for adverse effects.

The discussion of effects to water quality have emphasized short-term impacts. Given the extremely low probability of an incident at the Missouri River, the likelihood that a release would be relatively small, and the additive protection that the HDD provides in preventing a release from reaching the waters of the Missouri River, a quantitative assessment of long-term effects would be extremely speculative. Consequently, the following discussion qualitatively addresses environmental persistent compounds.

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 more soluble compounds. For example, aromatics with four or more rings are not acutely toxic at their limits of solubility (Muller 1987). Based on the combination of toxicity, solubility, and bioavailability, benzene was determined to dominate toxicity associated with potential crude oil releases. While lightweight aromatics such as benzene tend to be water soluble and relatively toxic, they also are highly volatile. Thus, most of the lightweight hydrocarbons released into the environment evaporate over time, and the environmental persistence of this crude oil fraction tends to be low. In contrast, high molecular weight aromatic compounds, including PAHs, are not very water-soluble and have a high affinity for organic material. Consequently, these compounds tend to bind strongly to sediments and 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 and excreted by organisms (Lawrence and Weber 1984; West et al. 1984). There are some indications, however, that prolonged exposure to elevated concentrations of these compounds may result in a higher incidence of growth abnormalities and hyperplastic diseases in aquatic organisms (Couch and Harshbarger 1985). Consequently, if residual oil persists beyond the initial emergency response, cleanup and removal will continue under affected areas to meet cleanup requirements that are protective of human health and the environment. Cleanup and removal of residual oil is discussed in Chapter 7.0, Emergency Response.

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Table 12 Comparison of Estimated 24-hour Benzene Concentrations with the Benzene Acute and Chronic Aquatic Life Thresholds (7.4 mg/L and 1.4 mg/L, respectively)

| Streamflow | Stream Flow Rate (cfs) | Benzene Aquatic Life Thresholds (mg/L) | Product Released | | | | | | | | | |
|--|------------------------|--|-------------------------------|-----------------------------|---------------------------|-----------------------------|---------------------------------|-----------------------------|-------------------------------|-----------------------------|----------------------|-----------------------------|
| | | | Very Small Release: 3 barrels | | Small Release: 50 barrels | | Moderate Release: 1,000 barrels | | Large Release: 10,000 barrels | | WCD | |
| | | | Benzene Conc. (mg/L) | Occurrence Interval (years) | Benzene Conc. (mg/L) | Occurrence Interval (years) | Benzene Conc. (mg/L) | Occurrence Interval (years) | Benzene Conc. (mg/L) | Occurrence Interval (years) | Benzene Conc. (mg/L) | Occurrence Interval (years) |
| Very low flow (5% annual) | 1,530 | Acute: 7.4 mg/L Chronic: 1.4 mg/L | 0.00001 | 8,217 | 0.0002 | 22,575 | 0.003 | 100,210 | 0.03 | 1,063,879 | 0.04 | 1,755,825 |
| Low flow (10% annual) | 3,340 | | 0.000004 | 8,674 | 0.0001 | 23,829 | 0.001 | 105,778 | 0.01 | 1,122,983 | 0.02 | 1,853,371 |
| Moderately low flow (25% annual) | 5,500 | | 0.000003 | 10,409 | 0.00005 | 28,595 | 0.0009 | 126,933 | 0.009 | 1,347,580 | 0.01 | 2,224,045 |
| Median flow (50% annual) | 7,800 | | 0.000002 | 15,613 | 0.00003 | 42,892 | 0.0006 | 190,400 | 0.006 | 2,021,370 | 0.009 | 3,336,067 |
| Moderately high flow (75% annual) | 11,200 | | 0.000001 | 31,226 | 0.00002 | 85,785 | 0.0004 | 380,800 | 0.004 | 4,042,740 | 0.006 | 6,672,134 |
| High flow (90% annual) | 14,500 | | 0.000001 | 78,064 | 0.00002 | 214,461 | 0.0003 | 952,000 | 0.003 | 10,106,849 | 0.005 | 16,680,336 |
| Very high flow (99.5% annual) | 29,485 | | 0.0000005 | 1,561,279 | 0.000008 | 4,289,229 | 0.0002 | 19,039,993 | 0.002 | 202,136,985 | 0.002 | 333,606,715 |
| Record 2011 historic flood (maximum discharge) | 65,900 | | 0.0000002 | 3,903,199 | 0.000004 | 10,723,073 | 0.00008 | 47,599,983 | 0.0008 | 505,342,462 | 0.001 | 834,016,788 |

Notes:

- Historical data indicate that the most probable release volume would be 3 bbls or less. However, this entire analysis is based on conservative incident frequencies and a range of release volumes, including WCD, to provide a range of the magnitude of potential effects.
- Estimated concentration is based on a Bakken crude oil release and calculation of benzene into water over a 24-hour period with uniform mixing conditions. The calculations hypothetically assume all benzene preferentially dissolves into the water, rather than remaining in the crude oil. In reality, dissolution is a minor fate process.
- Concentrations are based on a 0.28 percent by weight benzene content of the transported material (Marathon Oil data, website: http://www.ndoil.org/image/cache/Peacock_-_March_23_2010_.ppt.pdf).
- If present, shading indicates estimated benzene concentrations that could exceed either aquatic life thresholds.
- Calculations account for evaporation in the initial 24-hours with a half-life of 4.8 hours.

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4.2.7 Human Health

Transportation of crude oil by pipeline is the safest mode of transportation for large volumes shipped across the country. As an industry, 99.999% of crude oil is transported without incident (Association of Oil Pipelines [AOPL] 2017). The number of incidents affecting the public or environment has decreased 50% since 1999 (AOPL 2017). Pipelines are 2.5 less likely to have a release than crude oil transported by rail (Fraser Institute 2017a).

4.2.7.1 Fatalities and Injuries

Pipelines have fewer fatalities and injuries to workers and to the public when compared to rail and trucking. Pipeline workers are 30 to 37 time less likely to be injured than workers in the rail and trucking industry, respectively (Fraser Institute 2017b).

Many pipeline incidents occur entirely within the operator's facilities, reducing potential effects to the general public. The probability of being killed by lightning is 75 percent greater than being killed in a pipeline incident (Furchtgott-Roth and Green 2013).

When emergency responders arrive at an incident site, one of the first priorities is to ensure the safety of the public and emergency response workers that enter the site. Emergency responders that arrive at an incident will proactively manage public safety through evacuations and air quality measurements. Emergency responders may evacuate buildings due to potential risk of fire or inhalation hazards.

In approximately 1.5 percent of liquid pipeline incidents, emergency responders evacuated people from nearby structures. Each evacuation temporarily displaced an average of 3 people. Once the area was cleared by safety officials, people were allowed to return to the area.

In the period between 2002 and May 2016, 0.7 percent of the crude oil releases were ignited and 0.1 percent caused an explosion (flash fire). No one in the general public was injured. All but one explosion occurred on operator's facilities, and all injuries (8) and fatalities (1) occurred to contracting employees.

4.2.7.2 Public Health

In the event of a release, emergency responders will take air quality measurements to determine if volatilized petroleum hydrocarbons pose a potential fire risk or inhalation hazard. The Occupational Safety and Health Administration (OSHA) has established the maximum time-weighted average exposure limit is 1 part of benzene vapor per million parts of air (1 ppm) for an 8-hour workday and the maximum short-term exposure limit is 5 ppm for any 15-minute period (OSHA 2017). Based on NOAA's ADIOS2® model as assuming a WCD release, benzene concentrations 1 meter directly above the crude oil will rise initially as the oil spreads, with airborne concentrations peaking within 3 to 6 hours and then exponentially decline. Consequently, emergency responders will measure air quality to protect workers, particularly those in direct contact with the crude oil.

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Concentrations are not expected to affect the general public⁵ due to proactive evacuation by emergency response personnel, the absence of residential areas at the Missouri River crossing, and the rapid dissipation of volatile compounds with distance from the crude oil. For the general public, exposure, if any, would be very temporary and concentrations would not be expected to exceed normal background concentrations of benzene (3 to 20 parts per billion) (NOAA 2017).

Potential effects to public drinking water resources are highly improbable, as discussed in Section 4.2.6.1, Drinking Water. Temporary exceedances of the benzene MCL due to a release at the Missouri River would occur only with very large releases with a predicted occurrence interval of more than 1,000,000 years.

4.2.7.3 Property Damage

Economic losses associated with pipeline releases include property damage to private and public entities, emergency response and remediation costs (including Federal and State agencies as well as the operator), and property damage and losses incurred by the operator. Data from the PHMSA incident database demonstrate that the majority of spills are small, many are contained entirely within an operator's property, and generally result in minor economic costs. In 50 percent of the releases, there is no private property damage and, in 75 percent of incidents, private property damage is less than \$5,000.

Nevertheless, large volume releases can result in substantial property damage. As required by Federal regulations, Keystone is responsible for reimbursement of costs associated with a release, including emergency response costs, environmental remediation, and those costs incurred by property owners and regulatory agencies.

⁵ The Final Supplemental Environmental Impact Statement (USDOS 2014) also concluded that long-term adverse effects to the general public were not expected, and air monitoring and personal protection equipment may be needed to protect emergency response workers during cleanup.

5.0 HDD CROSSING DESIGN

The quantification of downstream transport of a release and potential effects to water quality at the Missouri River crossing is predicated on the assumption that crude oil from the pipeline would be capable of reaching the waters of the Missouri River. However, the design of the Missouri River crossing helps mitigate the possibility of crude oil ever reaching the Missouri River.

5.1 HDD CROSSING DEPTH

Traditional river crossing methods would bury the pipeline with a minimum of 4 feet of cover (49 CFR 195.248). As discussed in Section 2.1, Site Description, the use of the HDD crossing method buries the pipeline up to 54 feet below the Missouri River (**Figure 2**). This additional overburden provides several major benefits:

- 1) Reduces or eliminates several types of threats to the pipe's integrity, including excavation damage and certain types of outside force damage;
- 2) Places the pipeline well below the estimated worst-case vertical scour depth (EXP 2017); and
- 3) Provides a thick barrier that reduces vertical migration of crude oil towards the river.

The overburden does not contain highly impermeable layers that would completely confine a release, but the amount of overburden would be sufficient to reduce the possibility of crude oil from most releases reaching the waters of the Missouri River. If a WCD event were to occur, the crude oil likely would move along the less consolidated materials in the remaining bore hole space as well as into the overburden. Given the volume of the WCD, it is possible that some crude oil might reach the Missouri River. However, the probability of a WCD at the Missouri River is extremely improbable, with an estimated occurrence interval of once in 2,230,000 years.

The HDD entry and exit sites are setback from the river bank. On the north side of the Missouri River, the HDD entry is 341 feet from the top of bank, and the setback on the south side is 1,071 feet. This is important since the setback avoids disturbance of the existing streambanks and keeps the associated riparian vegetation intact, helping to maintain streambank stability. Compared to a typical non-HDD river crossing, the setback distance also increases the overland flow distance for a release from the entry and exit points of the HDD, with most releases being incapable of reaching the Missouri River without assistance from moving water (e.g., rainfall, snowmelt).

5.2 TERRAIN

On the north side of the Missouri River, the HDD entry site is located within an agricultural field that is bounded by an elevated ditch that parallels the river on the south side of the property. Using Light Detection and Ranging (LIDAR) data with a 1-foot elevation resolution, the geospatial analysis determined that the agricultural field is 3 to 4 feet below the top of the ditch. As illustrated in **Figure 8**, there is a sizable area within the agricultural field where crude oil would pool if a release occurred. Further, surface soils at the HDD entry site are classified as low

SITE-SPECIFIC RISK ASSESSMENT FOR KEYSTONE XL PROJECT'S MISSOURI RIVER CROSSING

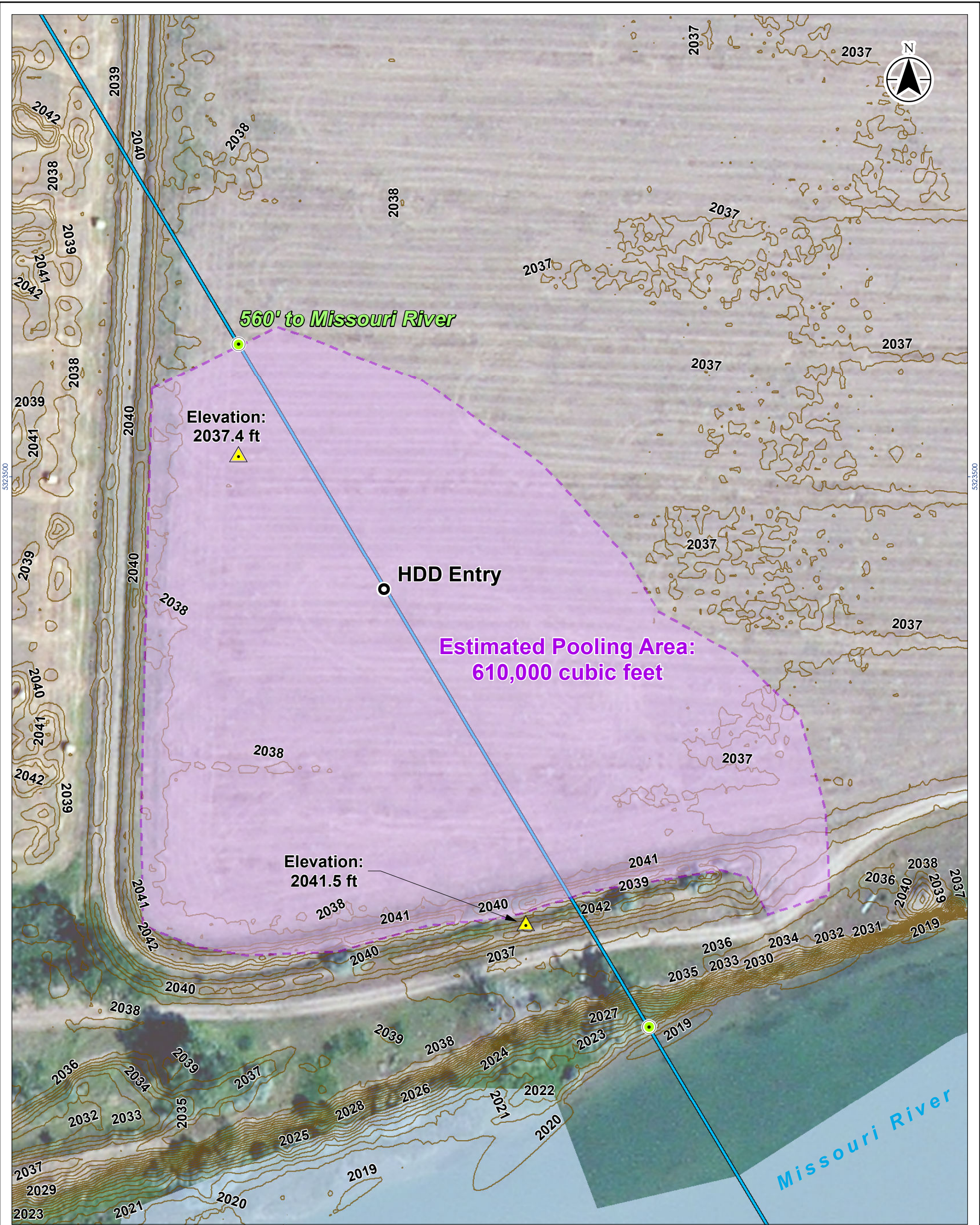
HDD Crossing Design
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plasticity clay (**Figure 2**). This soil type is relatively impermeable, significantly reducing the potential for vertical movement of crude oil into the soil structure, and preventing subsurface transport toward the river.

On the south side of the river, the HDD exit point is higher in elevation than the historic river channels (**Figure 9**). While there is no extensive area for a release to pool on the north side of the Missouri River, the setback distance (1,071 feet) and location of the HDD exit point reduces the risk of pipeline damage from flooding and associated scour events.






5.3 MISSOURI RIVER VALVES

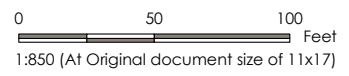
In addition to the HDD crossing method, Keystone will install remotely activated valves on both sides of the river (MPs 88 and 90.7) with backup power sources. These valves act as emergency flow restriction devices that allow Keystone to isolate the pipe in the event of a release, reducing the release volume. The use of remotely activated valves is an important mitigation measure, since the ability to remotely activate and close the valve can occur within minutes, whereas manual valves may take much longer to shut, particularly in inclement weather.



- Notes**
1. Coordinate System: NAD 1983 UTM Zone 13N
 2. Data Sources Include: KXL 2017.

Project Features

-  HDD Entry
-  Elevation Point
-  Keystone XL Centerline
-  Pooling Area
-  Elevation Contour

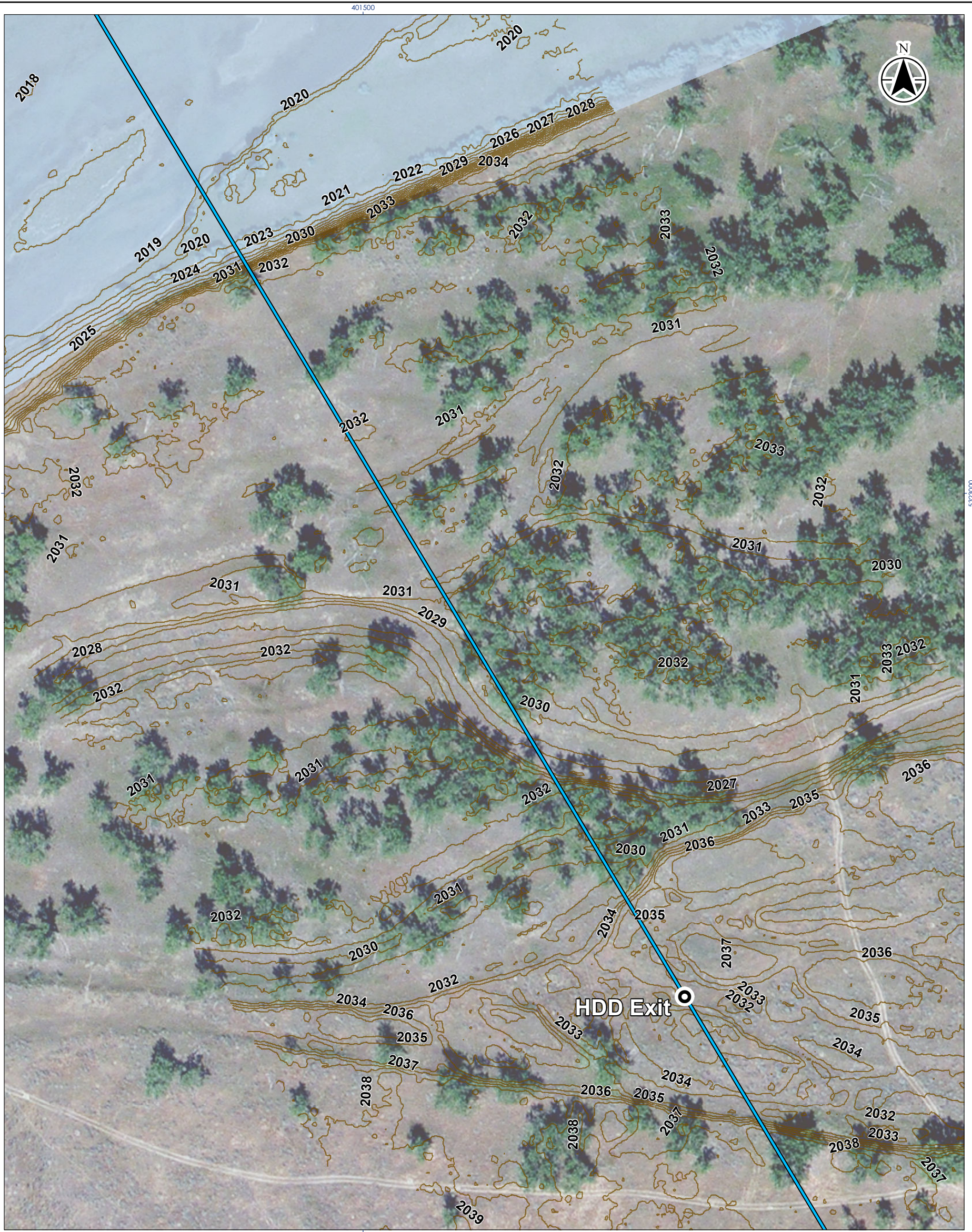


Project Location: Northeast Montana
 Client/Project: Keystone XL Pipeline Project




Figure No.: **8**
 Title:

Pooling Area on the North Side of the Missouri River

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Project Features

-  HDD Exit
-  Keystone XL Centerline
-  Elevation Contour

Notes

1. Coordinate System: NAD 1983 UTM Zone 13N
2. Data Sources Include: KXL 2017.

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0 100 200 Feet
1:1,500 (At Original document size of 11x17)



Project Location: Northeast Montana
 Prepared by MRP on 2017-09-26
 Technical Review by HT on 2017-09-26
 Independent Review by JSB on 2017-09-26

Client/Project: Keystone XL Pipeline Project

Figure No.

9

Title

Terrain on the South Side of the Missouri River

6.0 KEYSTONE PIPELINE SAFETY PROGRAM

Pipelines are the safest and most cost-effective form of overland crude oil transportation. Overland transportation of oil by truck or rail produces higher risk of injury to the general public than the proposed pipeline (U.S. Department of Transportation 2002).

To ensure the integrity of the pipeline, industry standards, Federal pipeline safety regulations, and conditions set forth in the Keystone XL's Presidential Permit will be implemented during operation and maintenance of the Project. These standards, regulations, and conditions stipulate how the pipeline is designed, operated, and maintained for the life of the Project to ensure that the pipeline will perform equal to or better than industry standards.

As discussed previously, one of the most substantive risks associated with operating a crude oil pipeline is the potential for third-party excavation damage. At the Missouri River crossing, the threat of third-party damage is eliminated by using HDD. Beyond the entry and exit points for the HDD, Keystone has taken the proactive measure to increase the typical depth of cover to 4 feet to reduce the potential for excavation damage. To minimize the risk of third-party damage, the pipeline was built within an approved right-of-way and markers are installed at regular intervals at all road, railway, and water crossings.

To mitigate the effects of corrosion on the pipeline, Keystone will use FBE, an anti-corrosion coating that is applied to the surface of the pipe to prevent external corrosion. At the Missouri River crossing, the pipe will be heavier-walled compared to most other locations and coated with an abrasion-resistant coating. A cathodic protection system also will be utilized, comprised of engineered metal alloys or anodes, which are connected to the pipeline. A low voltage direct current is applied to the pipeline; a process that results in the corrosion of the anodes rather than the pipeline. The pipeline would operate in turbulent flow regimes, which keeps water suspended within the oil, thereby reducing the potential for internal corrosion. The pipeline will be inspected with smart in-line inspection tools, which measure and record the pipeline's condition, thereby allowing Keystone the ability to proactively monitor and investigate the pipeline. During operations, the pipeline will be cleaned when necessary using in-line cleaning tools. Keystone's Integrity Management Plan (IMP) ensures the safe and reliable operation of the pipeline.

In addition, the pipeline will be monitored 24 hours a day, 365 days a year from the Operations Control Center (OCC) using a sophisticated supervisory control and data acquisition (SCADA) system. Keystone will utilize multiple leak detection methods and systems that are overlapping in nature and progress through a series of leak detection thresholds and shutoffs, if necessary. The leak detection methods are as follows:

- Remote monitoring performed by the OCC Operator, which consists of monitoring pressure and flow data received from pump stations and intermediate valve sites fed back to the OCC by the Keystone SCADA system. Remote monitoring typically detects releases down to approximately 25 to 30 percent of the pipeline flow rate.
- Software-based volume balance systems that monitor receipt and delivery volumes. These systems typically detect releases down to approximately 5 percent of the pipeline flow rate.
- Computational Pipeline Monitoring or model-based leak detection systems that break the pipeline into smaller segments and monitor each of these segments on a mass balance

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basis. These systems typically detect releases down to a level of approximately 1.5 to 2 percent of pipeline flow rate.

- Computer-based, non-real time accumulated gain/(loss) volume trending to assist in identifying low rate or seepage releases below the 1.5 to 2 percent by volume detection thresholds.
- Direct observation methods, which include aerial patrols, ground patrols, and public and landowner awareness programs that are designed to encourage and facilitate the reporting of suspected releases and events that may suggest a threat to the integrity of the pipeline.

The leak detection system will be configured in a manner capable of alarming the OCC operators through the SCADA system and also will provide the OCC operators with a comprehensive assortment of display screens for incident analysis and investigation. In addition, there will be a redundant, stand-by OCC to be used in case of emergency.

As discussed in greater detail in Chapter 7.0, Emergency Response, Keystone will have an Emergency Response Plan (ERP) and a site-specific GRP in place to respond to incidents should they occur. The ERP and GRP contain comprehensive manuals, detailed training plans, equipment requirements, resources plans, auditing, change management, and continuous improvement processes.

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7.0 EMERGENCY RESPONSE

In accordance with Federal pipeline safety regulations (49 CFR 194), Keystone is required to prepare an ERP to facilitate a coordinated and efficient response to incidents that may occur. Per applicable regulations, the objectives of Keystone's ERP would be to: 1) establish guidelines and procedures to be followed in emergencies to protect the health and safety of the public and responders; 2) minimize hazards resulting from pipeline emergencies; 3) establish procedures for training employees on emergency procedures; and 4) establish guidelines for continuing educational and liaison programs designed to inform community first responders and the public of the procedures to follow in recognizing, reporting, and responding to an emergency condition. As required by Federal regulations, the ERP documents that Keystone has access to sufficient resources and equipment to properly respond to a WCD event.

Keystone's ERP outlines the specific steps and measures that will be implemented in an emergency. This chapter provides a broad overview of emergency response procedures during the emergency phase of the spill response as well as containment and recovery techniques used, depending on site-specific conditions.

7.1 TYPICAL EMERGENCY RESPONSE PHASES

A release event begins with an initiator (i.e., cause) and initial loss of crude oil flowing under pressure from the pipeline. Once the leak is detected, the pipeline operational response unfolds in four phases: 1) leak detection, 2) main pipeline shutdown, 3) leak isolation, and 4) stoppage of flow from the pipe. The duration of each phase ultimately determines the quantity of crude oil that is released. Pipeline flow would not resume until the leak has been repaired, the cause of the release identified, and approval received from the applicable regulatory agencies.

7.1.1 Emergency Notifications

Emergency notification procedures are started immediately after a release event has been discovered. Regulatory agencies and local emergency services are notified immediately following discovery of a reportable release. Concurrently, Keystone internal notifications are conducted to activate an emergency response and the relevant agencies in accordance with pre-established emergency notification procedures. Keystone will have personnel that will be immediately mobilized to the release site to initiate containment and recovery efforts.

7.1.2 Crude Oil Containment

For the Missouri River crossing, Federal regulations require initial responders to be on-site and initiating containment within 6 hours. First response tactics include various containment methods, such as dikes, berms, dams for onshore and booms, combined with recovery procedures, such as skimmers, mechanical and vacuum pumps, use of absorption products (i.e., pads), and soil excavation.

Containment efforts will begin as soon as initial assessment activities are complete and the incident scene is cleared for entry. Containment technologies typically are applied near the pipeline release point and further downstream along backwater areas and other locations where crude oil will accumulate. In the Missouri River, containment actions will be implemented

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to stop crude oil movement as close to the release point as possible. Basic containment and recovery equipment and materials typically used in a crude oil response include:

- Floating containment and deflection booms;
- Floating absorbent booms and pads that absorb free oil, retard water absorption (i.e., hydrophobic), and recover oil;
- Earthmoving equipment (e.g., backhoes, front end loaders, tandem dump trucks, hand shovels), sand bags, and polyvinyl chloride (PVC) pipe to quickly construct earthen containment and underflow dams;
- Tanker trucks equipped with vacuum pumps (e.g., vacuum trucks);
- Mechanical pumps (e.g., centrifugal, impeller, diaphragm);
- Floating oil skimmers of various types;
- Portable storage including tanks and/or transport tanker trucks; and
- Boats.

7.1.3 Crude Oil Recovery

Crude oil recovery efforts are initiated concurrently with containment activities. Initial recovery efforts likely will be conducted where crude oil is pooled at the point of the release on land and at downstream containment areas where crude oil accumulates. Keystone's pre-planning process includes the development of GRPs that proactively identify local staff, pre-positioned response equipment, and resources; probable deployment locations and tactics for a variety of environmental conditions; and sensitive resources in the area that might be affected by a release so that protective measures can be deployed.

Timely and effective response and recovery efforts will limit the area affected, reduce the amount of crude oil in the environment, and limit the duration that crude oil remains in the environment. Each of these aspects of an effective response reduces the magnitude of the event and the potential for significant adverse effects.

Section 2.5, Environmental Fate and Transport, discusses the fate and behavior of crude oil release in flowing rivers. If crude oil is not removed from the environment, crude oil will begin to weather, residual crude oil will become less buoyant, and may begin to sink. This SSRA evaluated specific crude oils that are representative of crude oils that would be transported by the Project. As demonstrated by the results of NOAA's crude oil environmental fate model, crude oil density would remain less than water, indicating that the oil would float for days to weeks even under a variety of environmental conditions (Section 2.5.4, Crude Oil Environmental Fate Modeling).

If crude oil remains in the environment for extended periods of time, crude oil may weather, form emulsions, and, under turbulent conditions, may form crude oil-debris-and sediment amalgamations. As observed in actual releases (Section 2.5, Environmental Fate and Transport), submerged oil may resurface as water temperature increases, turbulence decreases, and with time as rocks and debris separate from amalgamations, providing cleanup crews the opportunity to collect residual oil on the water's surface. While submerged crude oil and crude oil-sediment-debris amalgamations provide a challenge for emergency responders, there are techniques that have been effectively used to contain and recovery submerged crude oil. Keystone responders will be trained to implement these tactics, if the situation occurs.

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Many conventional and unconventional techniques have proven to be quite effective in containment and removal of submerged crude oil, including:

- **Nets:** specialized nets can be utilized to contain submerged globules of weathered crude oil as they migrate downstream or with a current.
- **Bottom booms:** have a heavy ballast to create a seal against the bottom of a waterbody and a float chamber that extends toward the surface of the water. These booms have the potential to be very effective in containing submerged oil.
- **Dams:** watergates, underflow weir dams, and other dams can be set up on the bottom of a waterbody to contain oil as it migrates downstream or with a current. Underflow weir dams can be built using standard spill response equipment (i.e., sandbags, shovels, PVC piping, etc.).
- **Dredging:** well established dredging techniques can be extremely effective in recovering sunken and submerged oils and have been used effectively following releases of high density crude oils.
- **Manual Recovery:** sunken oil has the tendency to collect in depressions and areas of low flow, where it can often be manually recovered. Techniques for manual recovery (e.g., vacuuming) are well established and can be executed using only standard release response materials.
- **Air Injection:** submerged oil can be floated and recovered using injection of air similar to soil vapor extraction techniques used in remediation of contaminated soil.

Assuming a large release occurred and crude oil sedimentation occurred, the material would settle onto the riverbed, with backwater areas tending to accumulate the material. This scenario is unlikely as emergency response would contain and clean up a release prior to substantive weathering and potential sedimentation of crude oil. However, crude oil submergence and amalgamations have been observed in some recent incidents with extenuating circumstances (e.g., over-bank flooding and a roller dam increased turbulence and incorporation of debris into weathered crude oil during the Enbridge Line 6B incident). Since the Missouri River discharge is heavily regulated, it may be possible to facilitate recovery efforts by temporarily reducing discharge from Fort Peck Reservoir. Keystone would consult with the appropriate regulators to address potential issues associated with submerged oils and establish cleanup levels for long-term protection of human health and the environment.

7.1.4 Winter Containment and Cleanup

The traditional strategy for dealing with oil under the ice in a river or lake is to cut slots in the ice to aid in recovery. Ice slots can be cut using chain saws, handsaws, ice augers, or some form of trencher. Another effective variation of this technique is the diversionary plywood barrier method, which deflects crude oil to collection areas.

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8.0 SUMMARY

This SSRA quantitatively evaluated the site-specific probability of a release at the Project's Missouri River crossing, the environmental fate of Project-specific crude oils, potential downstream transport distances, potential effects on water quality, and emergency response procedures and tactics that could be deployed to contain and remove crude oil from the environment.

A supplemental SSRA was conducted for Bear Creek (**Appendix C**).

To provide a fulsome discussion on the environmental fate and behavior of crude oil, potential effects to water quality, and emergency response practices, much of the SSRA is predicated on the assumption that a release could reach the Missouri River, despite the extreme improbability of such an event.

The results of the SSRA are summarized as follows:

A release capable of reaching the waters of the Missouri River crossing is unlikely for the following reasons:

- 1) Based on the site-specific incident frequency and a crossing distance of 0.748 mile (including a 500-foot buffer beyond the HDD entry and exit points on both sides of the river⁶), the probability of a release at the Missouri River is once in 5,200 years.
 - a. Most releases are small (3 bbl or less) with an occurrence interval of once in 10,400 years or more.
 - b. The probability of a release of WCD is estimated to be no more than once in 2,230,000 years.
- 2) The HDD crossing method reduces risk at the Missouri River crossing.
 - a. Certain site-specific threats, such as excavation and outside force damage, would be reduced or eliminated. This was accounted for in the site-specific incident frequency.
 - b. The pipe would be buried up to 54 feet below the Missouri River. The overburden would reduce the potential for crude oil to reach the Missouri River.
- 3) The HDD entry and exit locations are setback 341 and 1,071 feet, respectively, from the river.
 - a. On the north side of the Missouri River, the HDD entry site is located within an agricultural field bounded from the river by an elevated ditch. The storage capacity of the area would entirely contain a release, including a WCD event, preventing crude oil from reaching the Missouri River.

⁶ The 500-foot buffer distance beyond the HDD entry and exit points was used for consistency with the previous Keystone risk assessments, which is normally measured from top-of-bank. Given the HDD setback distances and site-specific terrain considerations, the additional buffer is hyper-conservative from an overland transport perspective. Nevertheless, the buffer was retained since it increased the river crossing distance and, therefore, increased the incident frequency (i.e., intentional overestimates predicted risk).

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- b. On the south side of the river, the setback distance of 1,071 feet from the top of the river bank. This distance is further than a large release would flow over land, and the intervening terrain would further increase the overland transport distance.
- c. Remotely activated valves in proximity to and on either side of the Missouri River.

In the unlikely event that a release at the crossing reached the Missouri River, effects to water quality are improbable because:

- 1) The burial depth of the HDD crossing would reduce the potential for crude oil to reach the Missouri River.
- 2) All representative crude oils are predicted to float on the surface of the water for 5 days or more, allowing time for containment and cleanup.
- 3) Under most discharge conditions, the downstream transport distance before containment would be 13.3 miles or less. In winter when the river is covered with ice, downstream transport would be substantially reduced.
- 4) Assuming a crude oil release was to reach the Missouri River and all of the benzene within the crude oil release was dissolved into the water, it would require very large volumes of crude oil (e.g., 10,000 bbls) to adversely affect drinking water quality. The probability of such an event is once in more than 1,000,000 years.
- 5) Based on comparison of benzene concentrations with aquatic life thresholds, neither acute or chronic effects to aquatic life are expected.

Emergency response tactics would further reduce the potential for effects to water quality.

- 1) In the event of a release into the Missouri River, Keystone would notify downstream water users, allowing them to proactively shut off their water intake system until the water was tested and deemed suitable for use.
- 2) Emergency response equipment and trained personnel would be pre-positioned to provide a prompt emergency response to a release into the Missouri River. Federal regulations stipulate that a pipeline operator, such as Keystone, have sufficient resources available so the company could respond to a WCD event.
- 3) Pre-prepared GRPs would identify tactics and equipment to deploy, allowing responders to arrive and begin implementation of the plan rather than planning a response once the event has occurred.
- 4) Although effects to drinking water are not anticipated, Keystone has made a Project-wide commitment to provide potable water to the public if drinking water was affected by a release.

Emergency response would contain and cleanup crude oil from the environment.

- 1) The representative crude oils are predicted to float for days to weeks, allowing emergency responders time to contain and cleanup crude oil using traditional cleanup methods.
- 2) Even in winter, emergency response teams can contain and cleanup crude oil, with tactics that have been successfully employed in other incidents.
- 3) Submerged crude oil takes time to form and is facilitated by flooding and other causes of turbulence that incorporates sediment and debris into weathered oil. If submerged oil

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does occur, crude oil may rise to the water surface with changes in environmental conditions and loss of debris from the amalgamations. There are multiple techniques used to recover submerged oil.

- 4) Keystone would be responsible for costs associated with a release, including cost reimbursement for Federal and provincial agency employees deployed to the site.
- 5) Keystone would not be legally released from the site until applicable regulatory agencies are satisfied that appropriate end points have been reached.

The SSRA concludes that the possibility of a release at the Missouri River would be extremely improbable, and the risk is further reduced by HDD and associated entry and exit sites that are setback from the river. In the unlikely event of a release, the release likely would be relatively small and unable to reach the river. If the crude oil were to reach the river, it would require a very large, and highly improbable, release to potentially affect downstream drinking water users. Crude oil would float on the river's surface for days or longer. Keystone would activate emergency response procedures to notify appropriate agencies and downstream water users. Responders would be on-site within 6 hours and would implement pre-planned tactics that are appropriate for the site and environmental conditions. Cleanup and recovery would continue until applicable regulatory agencies concurred that cleanup levels protective of the human health and the environment had been met. Compliance with regulations, application of Keystone's IMP and ERP, as well as adherence to safety procedures, will help to ensure long-term environmentally responsible and safe operation of the pipeline.

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Appendix A
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APPENDIX A

Analysis of Incident Frequencies and Spill Volumes for Environmental Consequence Estimation for the Keystone XL Project

Appendix A

Analysis of Incident Frequencies and Spill Volumes for Environmental Consequence Estimation for the Keystone XL Project

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APPENDIX A

Introduction

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1.0 Introduction

This appendix evaluates the potential incident frequency and worst-case spill volumes for the Project. The results of this analysis have been incorporated into Keystone's KXL Site-Specific Risk Assessment for the Missouri River. Key design parameters associated with the entire length of the Project are identified in **Table A-1**.

Table A-1 Project Design Parameters

| Parameter | Value |
|--|---|
| Pipe Specifications | 36-inch-diameter high-strength steel (X70). |
| Coating | Fusion bond epoxy (FBE) coating. |
| Maximum Pump Station Discharge Pressure | 1,440 psig. |
| Maximum Operating Pressure | 1,440 psig, 1,600 psig. ¹ |
| Depth of Cover | Generally 4 feet of cover, exceeding federal requirements. |
| Aboveground versus Belowground Piping | Pipe will be belowground except within pump stations, valve sites, and terminal facilities. |
| Pipe Wall Thickness | Varies due to engineering and regulatory requirements (0.465 inch to 0.748 inch). |
| Intermediate Remotely Operated Mainline Valves | 37 remotely operated intermediate mainline valves. |
| Intermediate Mainline Check Valves | 12 intermediate mainline check valves and mainline/check valve sets. |
| Pump Stations | 19 pump stations in the U.S. |
| Leak Prevention Program | Multiple overlapping and redundant systems, including: <ul style="list-style-type: none">• Quality Assurance program for pipe manufacture and pipe coating;• FBE coating;• cathodic protection;• non-destructive testing of 100 percent of the girth welds;• hydrostatic testing to 125 percent of the maximum operating pressure (MOP);• periodic internal cleaning and high-resolution in-line inspection;• depth of cover exceeding federal standards;• bi-weekly aerial surveillance in accordance with federal requirements;• public awareness program;• Supervisory Control and Data Acquisition (SCADA) system; and• Operations Control Center (OCC) (with complete redundant backup) providing monitoring of the pipeline every 5 seconds, 24 hours a day, every day of the year. |

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| Parameter | Value |
|---|--|
| Leak Detection Systems | <ul style="list-style-type: none">• Remote Monitoring with SCADA;• volume balancing systems; and• computational pipeline monitoring;• non-real time volume trending analysis; and• direct observation. |
| Direct Observation Surveillance Frequency | Aerial surveillance: 26 times per year, not to exceed 3-week intervals; and periodic Close Interval Survey integrated with in-line inspection assessments. |

¹ The design of the Project pipeline system is based on a maximum 1,440 pounds per square inch gauge (psig) discharge pressure at each pump station. The result is that the MOP of the pipeline between pump stations is generally 1,440 psig. In liquid pipelines, some sections at lower elevations relative to the pump station discharge may be exposed to slightly higher pressures due to the combined station discharge pressure and hydrostatic head.

The values within this document overestimate risk associated with the Project to a level much greater than what actually is anticipated to occur. Keystone's expectation is that the incident frequencies and release volumes presented in this analysis are not likely to occur, but are provided as a highly conservative framework to ensure agency decisions are based on knowledge of the potential range of effects.

This document discusses the procedures used to estimate incident frequencies and spill volumes for the Project. Chapter 2.0 identifies the primary causes of pipeline incidents.¹ Chapter 3.0 discusses the potential threats to the pipeline for the Project. Chapter 4.0 provides an overall, project-wide incident frequency. Chapter 5.0 discusses maximum spill volumes estimated for the Project and compares these values with historical spill volume data.

¹ The term "incident" can range from a small drip to a complete pipeline rupture. The volume of the most common incident is small, consisting of three barrels or less, as discussed in Chapter 5.0.

2.0 Applicable Threats

In order to establish the particular incident threats that would apply to the Project at service initiation, three key points were considered:

- This is a new construction project, developed with the benefit of TransCanada's more than 50 years of pipeline construction and operating experience;
- The Project will be constructed and operated in accordance with comprehensive regulatory guidelines (49 Code of Federal Regulations [CFR] 195) and pipeline design standards (American Society of Mechanical Engineers [ASME] B31.4); and
- PHMSA has identified 59 Special Conditions regarding the design, construction, and operation of the Project. These Special Conditions are supplemental requirements that exceed industry standards and current federal regulations.

Taking these factors into consideration, the applicable threats can be determined using ASME B31.8S and American Petroleum Institute (API) 1160 as guidance.

2.1 Corrosion

2.1.1 External and Internal Corrosion

Corrosion is a pertinent threat to all steel pipelines. On a newly constructed pipeline, external corrosion is not considered to be a primary integrity threat. Nonetheless, corrosion is an important threat to pipelines. Industry standards currently require frequent internal inspections (at least every 5 years per 49 CFR Part 195), govern material selection on new pipe, and require use of active cathodic protection along the entire pipeline. These industry practices have caused significant reductions in the number of incidents in recent years.

Keystone will have multiple safeguards in place over and above these current, minimum industry standards to further reduce the likelihood of corrosion-related incidents, including:

- Use of high performance FBE external coating;
- Use of abrasion-resistant coatings for trenchless installation;
- Temperature monitoring and management along the pipeline and at pump stations in order to prevent potential coating damage;
- Installation of a cathodic protection (CP) system and an initial CP survey within 6 months of being placed in service. Additionally, a close interval survey will be performed within 1 year of placing the pipeline in service and these data will be integrated with in-line inspection data;
- Implementation of alternating current and direct current control program when paralleling high voltage power lines; and
- Conducting high-resolution magnetic flux leakage (MFL) in-line inspections (ILI) as a baseline integrity assessment within 3 years of the in-service date and on a periodic reassessment schedule that meets or exceeds federal requirements.

In a new pipeline system, such as this Project, the probability of incident due to corrosion prior to the first MFL inspection is very remote. Utilizing conservative assumptions about corrosion growth rate and feature incidence rate and projecting to the time of baseline inspection, the external corrosion incident probability would be nearly zero. Even with conservative assumptions about growth rate (1 millimeter a month, with a standard deviation of 0.25 millimeter), it would be 15 years before the external corrosion incident probability would become appreciable.

Sediment and water are the largest contributors to internal corrosion risk. Keystone will limit sediment and water by tariff specifications to 0.5 percent by volume and will report compliance with these limitations to PHMSA. The pipeline will not transport crude oil with a sour service designation under NACE MR0175 Part 2, Annex C/CSA Z662. Additionally, cleaning pigs will be run through the line twice in the first year of operation and then as necessary, based on monitoring programs. Cleaning pigs will aid in removing sediment and water, though build-up of these materials is expected to be minimal due to designed turbulent flow within the pipeline. With the baseline MFL inspection occurring 3 years from in-service, the internal corrosion incident probability during this time period would be negligible as well.

2.1.2 Stress Corrosion Cracking

Stress corrosion cracking (SCC) refers to localized pipe damage (cracks) caused by the combined influence of a susceptible pipeline coating, conducive environment (e.g., corrosive soils), operational stresses, and to a limited extent, temperature of the pipe. The coating system to be used on the Project is a high performance FBE. This coating system provides excellent protection against SCC due to the performance of the primer and the durability of the applied epoxy coating. According to Canadian Energy Pipeline Association Recommended Practices, 2nd Edition, Section 5.1.1.1, Coating Type and Coating Condition, “No SCC has been documented in association with FBE, field applied epoxy or epoxy urethanes, or extruded polyethylene” and according to PHMSA,² “applying special coatings (fusion bonded epoxy) will protect the pipeline from the occurrence of SCC.” Additionally, the cathodic protection system will be monitored to prevent cathodic protection overcharging, which could promote SCC growth. Consequently, SCC is not considered to be a viable threat for the Project.

2.2 Excavation Damage

Damage due to third-party excavation/mechanical damage is the most prevalent threat to most buried pipelines. This threat is considered to be a primary threat to the Project and will be continuously assessed both during design and operation phases of the Project.

Excavation damage leading to pipeline incidents includes damage to the pipe caused by third parties or pipeline operators. Historically, third-party damage is one of the leading causes of pipeline damage. Operator damage is less frequent because operating safety procedures are required to be followed for all maintenance activities. Consequently, installation of pipelines in sparsely populated areas, adequate depth of cover, use of pipeline markers, and frequent aerial surveillance that targets excavation activities near or within the pipeline right-of-way, are all factors that minimize the risk of excavation damage and, thereby, contribute to the overall safety of a pipeline.

Pipelines can leak from third-party damage either due to immediate puncture or through delayed failure from gouging, which is detectable by routine ILI inspections. Because the probability of puncture is dependent on the yield strength and impact toughness of the pipe material, the force required to puncture the pipe can be calculated.

² PHMSA Fact Sheet on Stress Corrosion Cracking 120604 <http://primis.phmsa.dot.gov>.

The PHMSA Special Permit requirements are expected to include several key factors designed to reduce the likelihood of impact, which Keystone will implement, including the following:

- Resistance to puncture from an excavator weighing up to 65 tons;
- Depth of cover (4 feet) exceeds regulatory requirements;
- Line-of-sight pipeline markers;
- Common Ground Alliance³ best practices to be used in damage prevention program;
- One-call system in place; and
- Bi-weekly aerial surveillance.

Using an industry-based reliability model (Chen and Nessim 1999), the frequency of a puncture as a result of a pipeline strike can be calculated. The model takes into account the preceding PHMSA conditions and supplemental measures as well as the probability of the pipeline being struck by excavation equipment. In the case of the pipe to be used on the Project, the probability of immediate puncture is very low (less than 5.0E-06 incidents/mile-year), as its puncture resistance is in excess of 65 tons and, according to heavy equipment industry surveys, approximately 98 percent of all excavators in North America have a maximum digging force of less than 35 tons and no excavator has a digging force greater than 40 tons (equivalent to an excavator weighing less than 65 tons⁴).

2.3 Materials and Construction

Pipeline incidents associated with materials and construction can be caused by improper selection of materials and lack of quality control and inspection during the manufacturing and construction process. Many of the historical releases contained within PHMSA's data set relate to "pre-modern" pipelines where pipeline failures were related to deficiencies in these factors.

Federal regulations currently govern material selection on new pipe and require non-destructive testing (e.g., radiographic or ultrasonic) of 10 percent of the girth welds and hydrostatic testing to 125 percent of MOP. These regulations are designed to detect and remove material defects and construction deficiencies prior to an operational incident. TransCanada has leveraged over 50 years of pipeline operating experience into a complete set of practices for the specification, procurement, transportation, construction, inspection, and quality assurance of any pipeline it constructs. In addition to TransCanada's proprietary specifications and quality management system, the PHMSA Special Permit is expected to have several conditions related to the manufacture and construction of the pipeline, including:

- Extensive requirements for quality of steel used in manufacture of pipe, over and above the requirements of API 5L Product Specification Level 2 – 44th Edition;
- Comprehensive fracture control plan relating to pipe quality and toughness;
- Extensive inspection of pipe steel and pipe seam;

³ Common Ground Alliance is an association of pipeline companies, underground facilities owners, and excavators to address issues related to damage prevention of underground facilities. The group published a full range of safe practices, including the establishment of "One Call" centers; procedures for excavation, mapping, locating and landmarking; compliance; planning and design; reporting and evaluation; public education and emerging techniques.

⁴ J. Keifner. Impact of 80 percent of SMYS Operation on Resistance to Third Party Mechanical Damage. March 21, 2006.

- Inspection of seam of delivered pipe for signs of seam fatigue from transportation;
- Mill hydrostatic test to 95 percent SMYS;
- Pre-commission hydrostatic test to 100 percent SMYS and 125 percent MOP (in areas at 80 percent SMYS);
- Documentation and quality control of all fittings, flanges, and valves;
- Extensive welding quality control requirements, including complete inspection of 100 percent of all girth welds;
- Comprehensive construction quality program; and
- A plan to assess any potential flaw growth after 2 years in service.

In addition to the conditions expected to be contained in the PHMSA Special Permit, Keystone's current internal quality management system (which includes mill inspection and ongoing surveillance, as well as material and chemical testing) will ensure the highest quality steel pipe is used. Manufacturing defects, such as the presence of hard spots or long seam defects are extremely unlikely.

In addition to the conditions expected to be contained in the PHMSA Special Permit, the Project's proprietary construction specifications will require Keystone to follow exacting procedures, along with rigorous testing and inspection, to ensure the highest quality construction practices are used.

2.4 Equipment

Equipment-related incidents are incidents associated with certain equipment used on pipelines, such as flange gaskets, regulator valves, set point drift on regulators, O-rings, valve seals, and packings. The Project will not have any flanges below grade (only located aboveground within pump stations), as all mainline valves will be manufactured as weld-end valves. As required by 49 CFR Section 195.420, each mainline valve must be inspected twice per year. All sub-assemblies will be hydrostatically tested in the fabrication shop to a minimum of 125 percent of MOP for 4 hours. For such aboveground equipment, a small leak is the typical failure mode if an incident occurs.

2.5 Hydraulics

Incorrect operations or failure to follow standard operating procedures can lead to an overpressure event or hydraulic surge. Although a series of human and mechanical errors would need to occur for a hydraulic event to take place, it is considered a potential secondary threat to the operations of any liquid system.

Hydraulic events, such as pressure surges (the "water hammer" effect), are caused by sudden changes in flow and can be caused by operator error, failure of pressure controls, or failure of pressure relief equipment.

As part of the requirements expected in a PHMSA Special Permit, several items relating to SCADA control and operator qualification are directly aimed at reducing the likelihood of a pipeline release. These include:

- Overpressure protection to 110 percent of MOP per 49 CFR 195.406(b);
- Increased training for SCADA alarm management and response;
- Use of SCADA pipeline model and simulator, with use of simulator in training, as well as for controller recognition of abnormal operating conditions; and

- Compliance with the requirements of ASME B31Q Pipeline Personnel Qualification Standard as part of an enhanced training and qualification plan for all SCADA operating personnel, which includes extensive training requirements, qualification, and re-qualification procedures.

Hydraulic events can be mitigated by devices that prevent quick stoppages. In an emergency situation, Keystone's SCADA system would allow the operator to shut down the Project in a controlled sequence, with complete shutdown of pump stations and valves occurring in 12 minutes. Prior to operation, the pipeline would be hydrostatically tested to 125 percent of the MOP per federal regulations, providing a safety factor if a hydraulic event occurred. If a hydraulic event occurred on the pipeline, Keystone would be required to report the event to PHMSA, investigate the cause, and assess the pipeline to determine if any adverse effects occurred before restarting normal operations.

2.6 Natural Hazards (Ground Movement/Flooding)

Hydrological and geological concerns are very site-specific issues that are considered in the routing and design of the project. The route selection is conducted to avoid, inasmuch as practical, potentially geologically unstable slopes, meandering streams, saturated soils, and active seismic hazards. The natural hazard category encompasses several different threats, including earth movement due to geological (landslide or seismic) hazards, and flooding (heavy rains or storm surges). The threat of damage from these potential threats also is somewhat dependent upon the pipe's ability to withstand these external forces. Historically, "pre-modern" era pipe had more difficulty dealing with these stresses than modern pipe due to the field welding quality, pipelines using mechanical couplings or threaded joints, lower toughness steel with less fracture control properties, and other factors. Field data show that modern pipe is very robust and more capable of withstanding these external forces than older pipe. Because the threat cannot be completely eliminated, it is considered a secondary threat.

2.6.1 Ground Movement

Ground movements, such as landslides and seismic events, can threaten the integrity of a pipe. Ground movement is a minor cause of pipeline incidents, accounting for less than 1 percent of pipeline incidents (PHMSA 2017). Routing can minimize the exposure of the pipeline to such hazards. In active seismic areas, surface breaking faults and low stability soils (which may liquefy due to seismic shaking) are avoided when practical. To mitigate risk from landslides, steep slopes, which exhibit signs of instability, are avoided when practical. However, it is not always possible to avoid the threat in all cases. In areas susceptible to ground movement, pre-construction engineering and design can minimize the potential effects of ground movement on the pipe. During operation, aerial surveillance will look for signs of any ground movement (e.g., slumping, sloughing, surface fissures, leaning trees), which could be used as indications of slope instability. Areas where ground movement is suspected will be investigated. In some cases, geometric ILI tools may be used to investigate potential ground movement.

2.6.2 Flooding and Washout

Flooding covers a broad spectrum of potential threats to the line, including storm surges due to hurricanes. The most common event is stream scour associated with seasonal flooding. Stream scour occurs when stream velocities are higher than normal, causing erosion of the soil covering the pipeline within the streambed, as well as erosion of the banks of the stream. If the storm scour is severe or the scour area is not remediated, the pipe eventually may become partially or completely exposed. Exposed pipe can be susceptible to a number of hazards, such as fatigue due to vortex shedding (where a long span is exposed), loading due to debris pile up (material transported down the stream), or damage due to impacts from falling debris or passing boats. To reduce these potential hazards, steps are taken at the design phase to

determine the scour depth of a stream, as well as its potential for bank erosion, and including factors such as thalweg depth and bankfull conditions in a rare event flood (e.g., a 1-in-100-year flood event).

Keystone will conduct a scour analysis at stream crossings susceptible to scour. Where stream scour may be an issue, the Project will be buried at depths below the anticipated scour depth.

2.7 Other Outside Forces

Other Natural Forces covers a variety of miscellaneous threats that cause physical damage to the pipeline system, particularly those facilities that are aboveground and close to highways or large population and industrial centers. KXL was routed primarily through rural areas, which reduces this threat. Other Outside Force Damage can include:

- Vehicle or equipment contact not related to excavation (e.g., an automobile crash into an aboveground valve, pumping station, or other piece of pipeline equipment);
- Damage caused by accidents or fires from other businesses or industries that are nearby;
- Vandalism; or
- Sabotage or terrorism.

Federal pipeline design and construction regulations require that operators secure their facilities and protect them from unauthorized access. KXL's aboveground facilities will be protected by fencing with locked gates, remotely monitored surveillance cameras, and other security measures. To protect against terrorism and sabotage, additional security requirements have recently been promulgated, with protective measures implemented in accordance with security-based assessments of critical or key facilities.

2.8 Other

When a reportable incident occurs, pipeline operators are to file an Incident Report with PHMSA within 30 days of the event. In some cases, the cause of the incident may not neatly fall into a single, specific category or the operator may still be investigating the root cause of the incident. In these cases, some operators categorize the incident as "Other Incident Cause." Because this is an issue of reporting and not an actual threat to a pipeline system, there is no supplemental mitigation Keystone can implement to address this issue.

For this analysis, reported incidents where the "Cause" was not identified (i.e., blank cell within the database) also were included in this category to be inclusive of all incidents when calculating the incident frequency.

2.9 Comparison of ASME Threat Categories and PHMSA Incident Categories

The ASME identifies nine pipeline threat categories per ASME B31.S. These threat categories are generally aligned, but are not identical to PHMSA's Incident Categories used for incident reporting and recorded within its national incident database, as shown in **Table A-2**. PHMSA incident data were used to calculate incident frequencies for the Project.

Table A-2 Incident Frequencies Identified by ASME Threat and PHMSA Incident Categories

| ASME Threat Category | PHMSA Incident Category | Project-specific Incident Frequency |
|------------------------------------|--------------------------------|--|
| Internal Corrosion | | |
| External Corrosion | | |
| Stress Corrosion Cracking | Corrosion | 2.50E-05 |
| Third-party damage | Excavation Damage | 6.82E-07 |
| Incorrect Operations | Incorrect Operation | 1.95E-04 |
| Manufacturing | Material Defects/Construction | |
| Construction | Deficiency | 1.87E-05 |
| Equipment | Equipment | 7.47E-06 |
| Weather-related and Outside Forces | Natural Forces | 2.67E-05 |
| | Other Outside Force | 1.26E-05 |
| No ASME Category | Other | 9.34E-07 |
| | TOTAL | 2.87E-04 |

3.0 Conclusion

This study was completed to provide conservative incident frequency values for the purposes of estimating the environmental risks for the Project. The pertinent threats were identified, analyzed, and incident frequencies were calculated.

The estimated incident frequency is based on conditions when the pipeline is placed into service. Although the risk from time-dependent threats may change over time, Keystone believes that the analysis will remain conservative and applicable for the service life of the project and beyond for the following reasons:

- The analysis is based on historical data. Analysis of these data demonstrates a marked decline in pipeline incident rates over the last 10 years, primarily due to a reduction in corrosion-related events. The decline is attributed to the industry's increased use of in-line inspection tools, improved coatings, and use of cathodic protection.
- The analysis is based on a historical database where the majority of pipe is 'pre-modern' construction. Because of improving steel quality and properties, construction practices and inspection requirements, pipelines installed today will have much lower incident frequencies than pre-modern pipes.
- The adjustment factors are conservative and the analysis, therefore, overestimates actual risk, even over a period of decades.
- Industry best management practices and the regulatory environment will continue to evolve, resulting in improved inspection and protection of pipelines. As a consequence, there will be a continued decline in the frequency of pipeline incidents.

For each state, the overall incident frequency was calculated by summing the likelihood of each individual root cause.

$$f_{\text{total}} = f_{\text{co}} + f_{\text{ex}} + f_{\text{md}} + f_{\text{hy}} + f_{\text{gm}} + f_{\text{wo}}$$

Where:

f_{total} = total leak frequency

f_{co} = leak frequency from corrosion

f_{ex} = leak frequency from excavation

f_{md} = leak frequency from material defects or construction deficiency

f_{hy} = leak frequency from a hydraulic event

f_{gm} = leak frequency from ground movement

f_{wo} = leak frequency from a washout event

The resultant Project-wide leak frequency is 2.87E-04 incidents/mile- year, which is equivalent to one incident in 3,500 years per mile of pipe.

4.0 Spill Volumes

4.1 Methodology

Keystone has evaluated maximum spill volumes that potentially could occur along the Project for the purpose of emergency response planning. This approach is consistent with the requirements of 49 CFR Section 194.105, which requires an operator to determine the worst-case discharge of each of its emergency response zones. The worst-case discharge is defined as the largest volume based on the maximum release time, maximum shut down response time, maximum flow rate, and the largest line drainage volume after shut down of the line section within the response zone. This section describes the methodology used to estimate maximum spill volumes for the Project.

4.2 Leak Detection

In an event of a leak or rupture, Keystone would implement multiple leak detection methods and systems that are overlapping in nature and progress through a series of leak detection thresholds. The leak detection methods are as follows:

- Remote monitoring performed by the OCC Operator, which consists of monitoring pressure and flow data received from pump stations and valve sites fed back to the OCC by the Keystone SCADA system. Remote monitoring is typically able to detect leaks down to approximately 25 to 30 percent of the pipeline flow rate.
- Software-based volume balance systems that monitor receipt and delivery volumes. These systems typically are able to detect leaks down to approximately 5 percent of the pipeline flow rate.
- Computational Pipeline Monitoring or model-based leak detection systems that break the pipeline into smaller segments and monitor each of these segments on a mass balance basis. These systems typically are capable of detecting leaks down to a level of approximately 1.5 to 2 percent of pipeline flow rate.
- Computer-based, non-real time accumulated gain/(loss) volume trending to assist in identifying low rate or seepage releases below the 1.5 to 2 percent by volume detection thresholds.
- Direct observation methods, which include aerial patrols, ground patrols, and public and landowner awareness programs that are designed to encourage and facilitate the reporting of suspected leaks and events that may suggest a threat to the integrity of the pipeline.

While large, rapid releases are quickly detected, a pinhole leak with a slow rate of release may not be immediately detected by the first four detection mechanisms above, and patrolling and public awareness may be the first to detect these small leaks. PHMSA data indicate that pipeline spills are usually detected within 1.2 days and 97 percent of spills are detected within 7 days (PHMSA 2009). Even when leaks were not detected within the first 48 hours, PHMSA data indicate that the total spill volumes were not catastrophic, rather the median total spill volume for spills not detected within the first 48 hours was 15 barrels, and the maximum spill volume was 12,000 barrels (detected after 4 days).

4.3 Methodology

The total spill volume is based on three leak duration periods:

- The pre-pump-closure period;
- The pre-valve-closure period; and
- The after-valve-closure period.

Prior to the pump shut-down sequence to stop the pipeline in the event of a release, the pressure in the pipeline can be estimated through well-defined friction loss equations in combination with gravity head calculations. The total volume released before pump shut-off is the culmination of a constant leak rate over the duration of a leak.

After pump shutdown, the intermediate mainline valves will require a few minutes to close; where a check valve is installed, this type of valve enables “immediate one-way” closure of the valves after pump shut down to prevent backflow caused by gravity drainage. After pump shutdown, the liquid could drain out of the line under the gravity head difference between the leak and the adjacent elevated pipeline segments. This free draining process is modeled as a multi-loop “U” tube, with the middle open to the atmosphere and the other two ends connected to up and downstream valves. This concept is illustrated in **Figure A-1**.

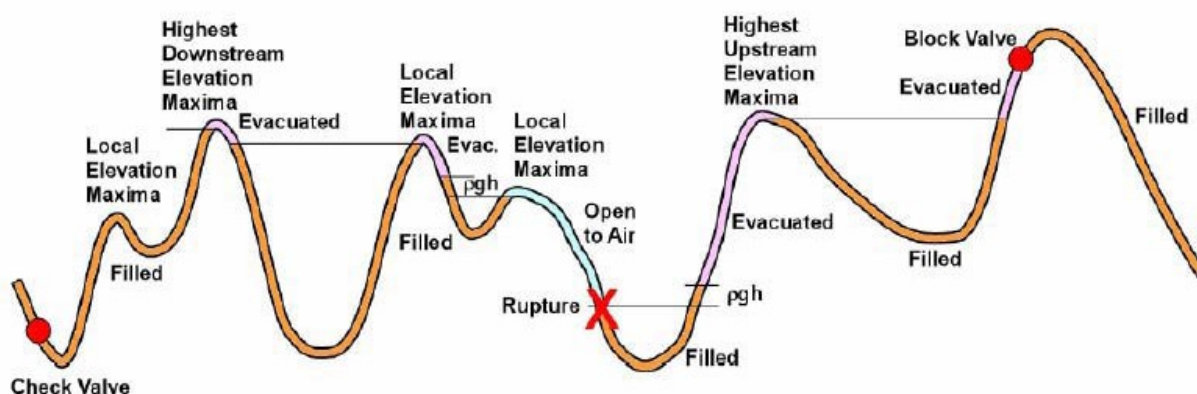


Figure A-1 Schematic of Drained Segments after Valve Closure

There are three ways draindown can occur depending upon the proximity of the segments to the leak location:

1. If a leak is in proximity, upstream or downstream, to an adjacent segment with a higher elevation than the leak location, the segment will be fully drained. On the other hand, if the adjacent segment elevation is lower than the leak location, the first segment will still be filled with liquid in the line.
2. In situations where vapor pressure can be assumed to be zero, there must be a liquid segment of height with equivalent pressure of pgH^5 to balance atmospheric pressure. If there isn't enough elevation above this height, there will be no further drain-down. If there are segments that have

⁵ See Section 6.4 for equation defining “pgH.”

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Spill Volumes

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more than ρgH equivalent pressure, then more segments in the line will be drained. In this case, the second drained segment immediately adjacent to the first drained segment will be at least “H” above the first drained segment. In situations where vapor pressure is considered, a conservative approach is used to assume there is no head (ρgH) balancing atmospheric pressure.

3. In addition, adjacent to the second drained segment, the pressure is only balanced by the vacuum. Therefore, the elevation of the one end of the drained segment will be the same as the other end of the previous drained segment. This scenario will be the same for any further drained segments.

Before pump-closure, the leak volume is the leak rate computed from the Bernoulli equation, where pressure is the result of local gravity and operating pressure. After pump shut-off but before valve closure, drainage is calculated using the whole pipeline including check valves, which prevent backflow. This period is relatively short compared to the after-valve-closure period. Given that all the segments of the whole pipeline can possibly drain down without valve restrictions, the drainage process needs to be considered as time-dependent. This consideration is especially important for small leak sizes, because within the response time of closing the valves, a limited number of segments are susceptible to drainage based on the Bernoulli equation. The time dependent-manner of this drainage is caused by reduced gravity head along with the draining process. This draining needs to satisfy the following equation:

At any time (t):

$$\rho gH = \frac{1}{2} \rho v^2$$

Where:

H = the maximum relative elevation above the leak in the pipeline at instant t

g = gravity acceleration

ρ = fluid density

After a short time interval, H is reduced and is recomputed based on the leak rate (v) for each time interval. This calculation uses the drained volume, which is measured using the cross-sectional area of the pipe, the average slope of the draining segments, and the number of U-tube sections being drained: sections with elevations higher than the fluid level at time t .

The maximum fluid level above the leak is updated after each time interval to the Bernoulli equation to compute the updated leak velocity. This process is iterated until total time is elapsed when pump shutdown exceeds the valve closure response time and the total drained down volume is computed by this time.

After all the valves are closed, the liquid drainage only occurs between the two nearest block valves. The analysis also can be considered similar to the aforementioned scenario, but the volume drainage analysis is confined between the two adjacent valves that enclosed the leak location. However, a conservative and simpler approach is to assume that the leak cannot be stopped in time and all oil that should be drained down will be freely drained out of the pipeline. This simplification eliminates the need to do iterative calculations described above.

The release volumes from the above three phases can be combined to produce a total outflow volume for the overland spill model simulations. Repeating these calculations at multiple points along the pipeline can identify areas of greatest concern in accordance with federal requirements and evaluate the effectiveness of valve placement for the protection of HCAs.

4.4 Worst-Case Discharge

Keystone estimated worst-case discharge were calculated using the outflow model described above. Based on historical averages, spills of these proportions are rare. Nevertheless, Keystone will be prepared to respond to spills of any size in accordance with Federal requirements.

A worst-case discharge was defined as a hole in the pipeline with a diameter equal to the pipeline's diameter. In this case, as the release rate will be similar to the operating flow rate, the leak detection system will detect the leak virtually instantaneously due to the pressure drop in the line. Following detection, an emergency shutdown procedure is initiated, with pumps shutting down first (9 minutes for shutdown), followed by approximately 3 minutes for intermediate remotely operated valve closure.

4.5 Comparison of Worst-Case Spill Volumes with Actual Spill Volumes

Examination of the current PHMSA dataset (2002 to June 2017) indicates that the vast majority of pipeline spills are relatively small, with 50 percent of the spills consisting of 3.0 barrels or less (**Table A-3**). In 86 percent of the cases, the spill volume was 100 barrels or less. In over 95 percent of the cases, spill volume was less than 1,000 barrels. Oil spills of 10,000 barrels or greater only occurred in 0.4 percent of cases. These data demonstrate that most pipeline spills are small and very large releases of 10,000 barrels or more are extremely uncommon.

Table A-3 Actual Release Volumes – 2002-2017

| | Spill Volume (barrels) |
|-------------------|-------------------------------|
| Mean (barrels) | 238 |
| Median (barrels) | 3.0 |
| Minimum (barrels) | 0.0 |
| Maximum (barrels) | 49,000* |

Data Source: PHMSA 2017

*The maximum release volume did not involve a pipeline, but occurred within a terminal when the bottom of a 74-year old storage tank failed due to corrosion.

While the majority of historical pipeline spills have been relatively small, it is critical to evaluate worst-case discharge for the purposes of design refinement (e.g., placement of valves) and emergency pre-planning purposes, allowing for optimal valve placement and pre-positioning of personnel and equipment.

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Conclusion

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5.0 Conclusion

Spill volume data from actual pipeline incidents reported between 2002 and 2017 show that the majority of releases consist of only 3 barrels or less (PHMSA 2017). In contrast, Keystone is estimating maximum release volumes to prepare for the worst-case scenario. These maximum worst-case discharge volumes will be used for emergency planning purposes, such as the identification of the amount of equipment and resources that could be potentially required to respond to an event. Keystone also will use these data combined with fate and transport analyses to pre-position emergency response personnel and their response equipment. In the unlikely event of an incident, the actual size of a release is expected to be significantly smaller than the worst-case discharge.

6.0 References

Chen, Q. and M. Nessim. 1999. "Reliability-based Prevention of Mechanical Damage to Pipelines," Pipeline Research Council International, Inc. (PRCI), Catalog No. L51816, 1999.

Pipeline and Hazardous Materials Safety Administration (PHMSA). 2017. PHMSA Pipeline Incident Statistics. Internet website: <http://primis.phmsa.dot.gov/comm/reports/safety/PSI.html>.

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APPENDIX B

Environmental Fate of Representative Crude Oils

APPENDIX B

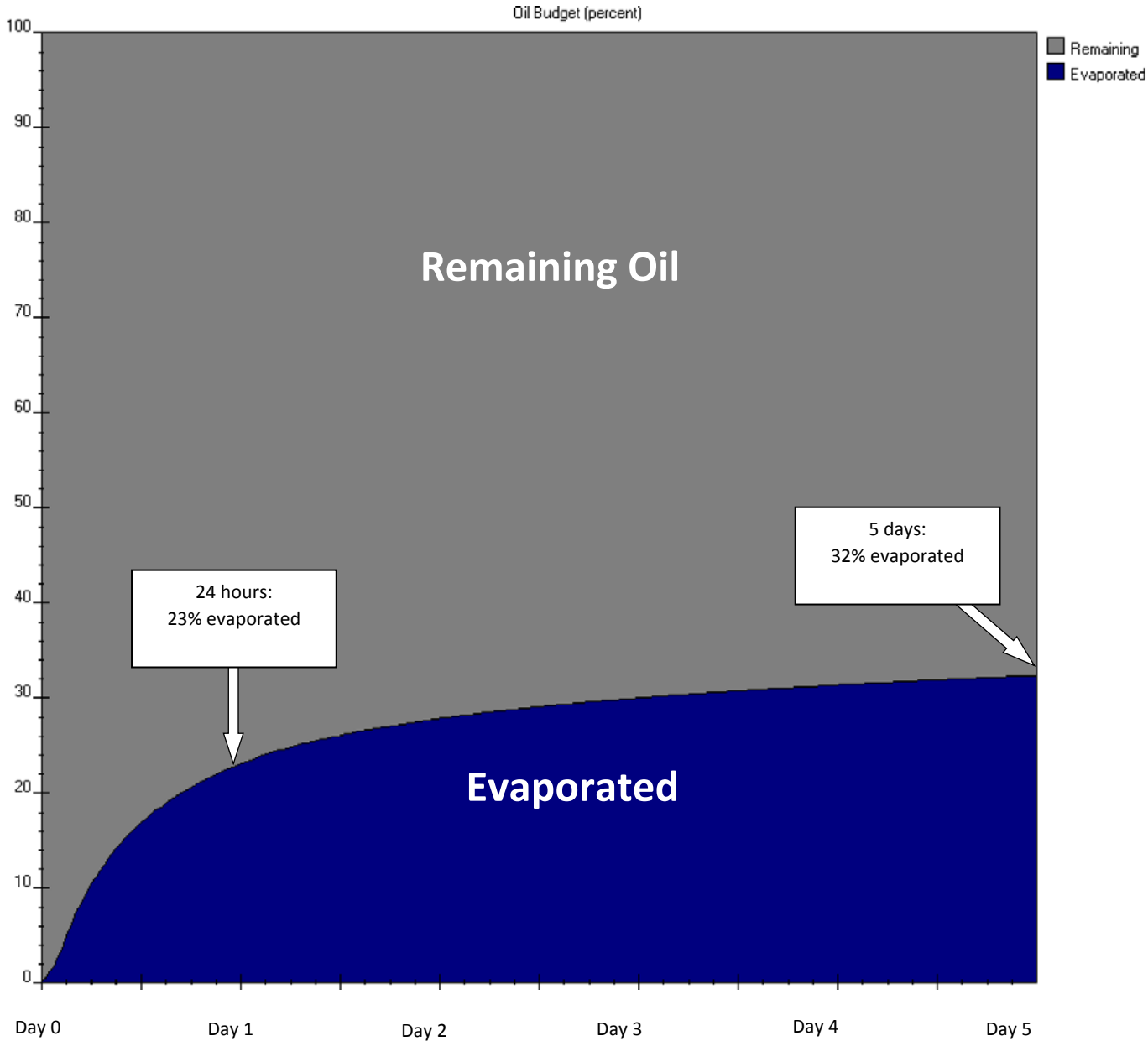
Environmental Fate of Representative Crude Oils

| Scenario | Water Temperature (degrees F) | Sediment Load (mg/L) | Wind Speed (mph) |
|--------------------------------|--|---------------------------------|-----------------------------|
| SUNCOR SYNTHETIC A | | | |
| Summer | 60 | 50; 500 | Calm (2) |
| | | | Windy (10) |
| Winter | 32 | 50; 500 | Calm (2) |
| | | | Windy (10) |
| BAKKEN | | | |
| Summer | 60 | 50; 500 | Calm (2) |
| | | | Windy (10) |
| Winter | 32 | 50; 500 | Calm (2) |
| | | | Windy (10) |
| WESTERN CANADIAN SELECT | | | |
| Summer | 60 | 50; 500 | Calm (2) |
| | | | Windy (10) |
| Winter | 32 | 50; 500 | Calm (2) |
| | | | Windy (10) |

OIL TYPE: Suncor Synthetic A

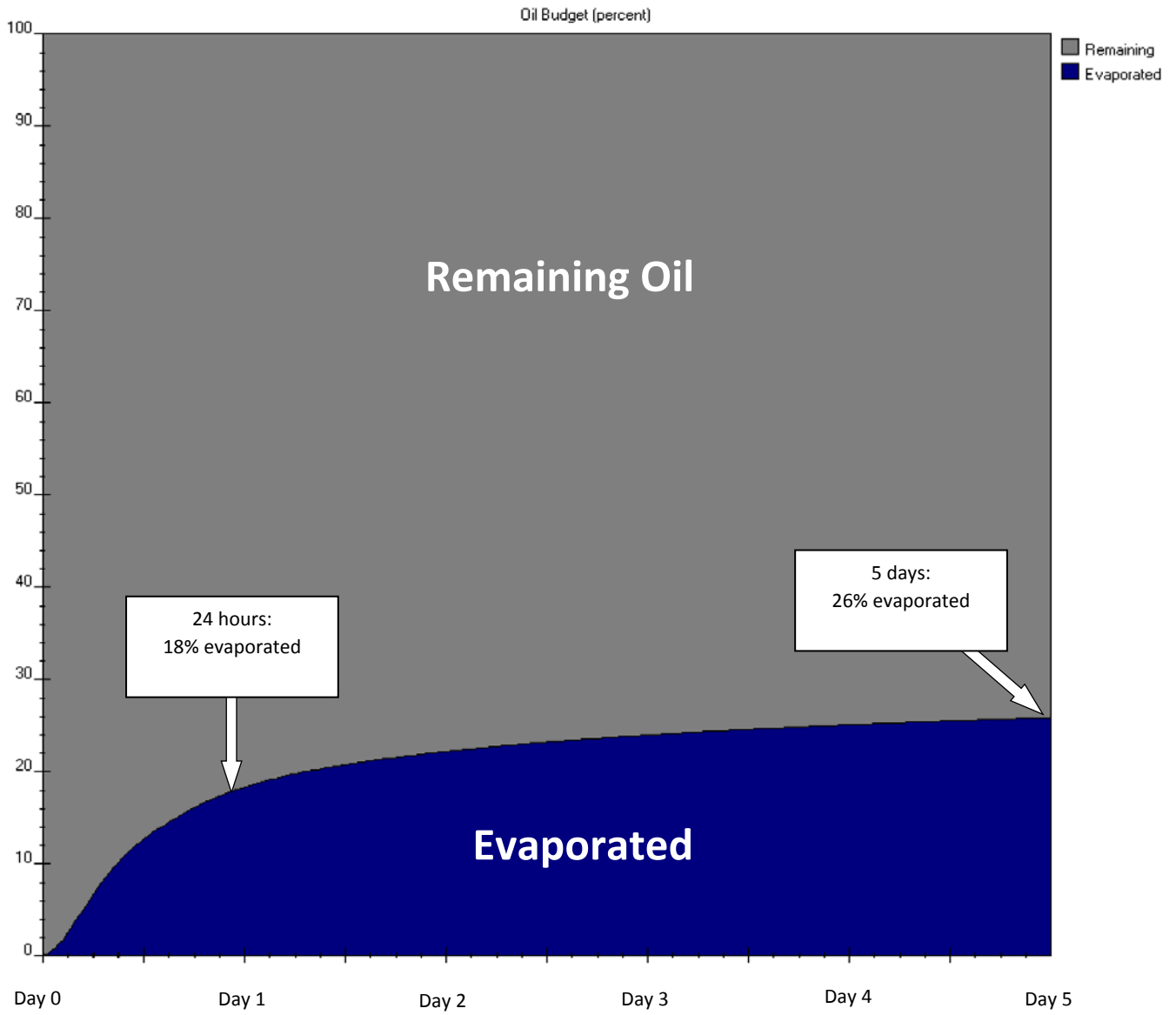
Evaporative Loss – Suncor Synthetic A

Summer Release – Calm Conditions

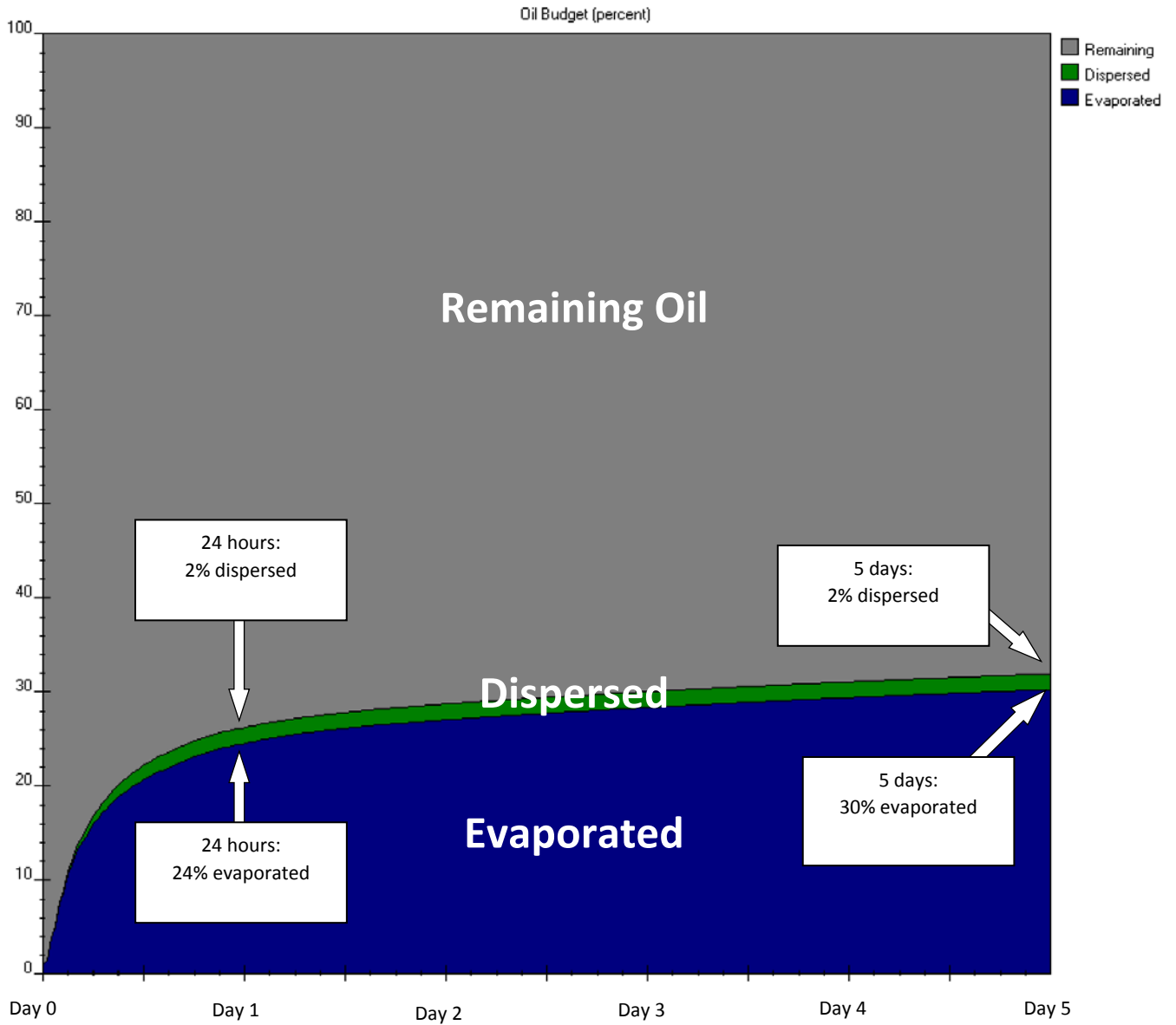


Evaporative Loss – Suncor Synthetic A

Winter Release – Calm Conditions

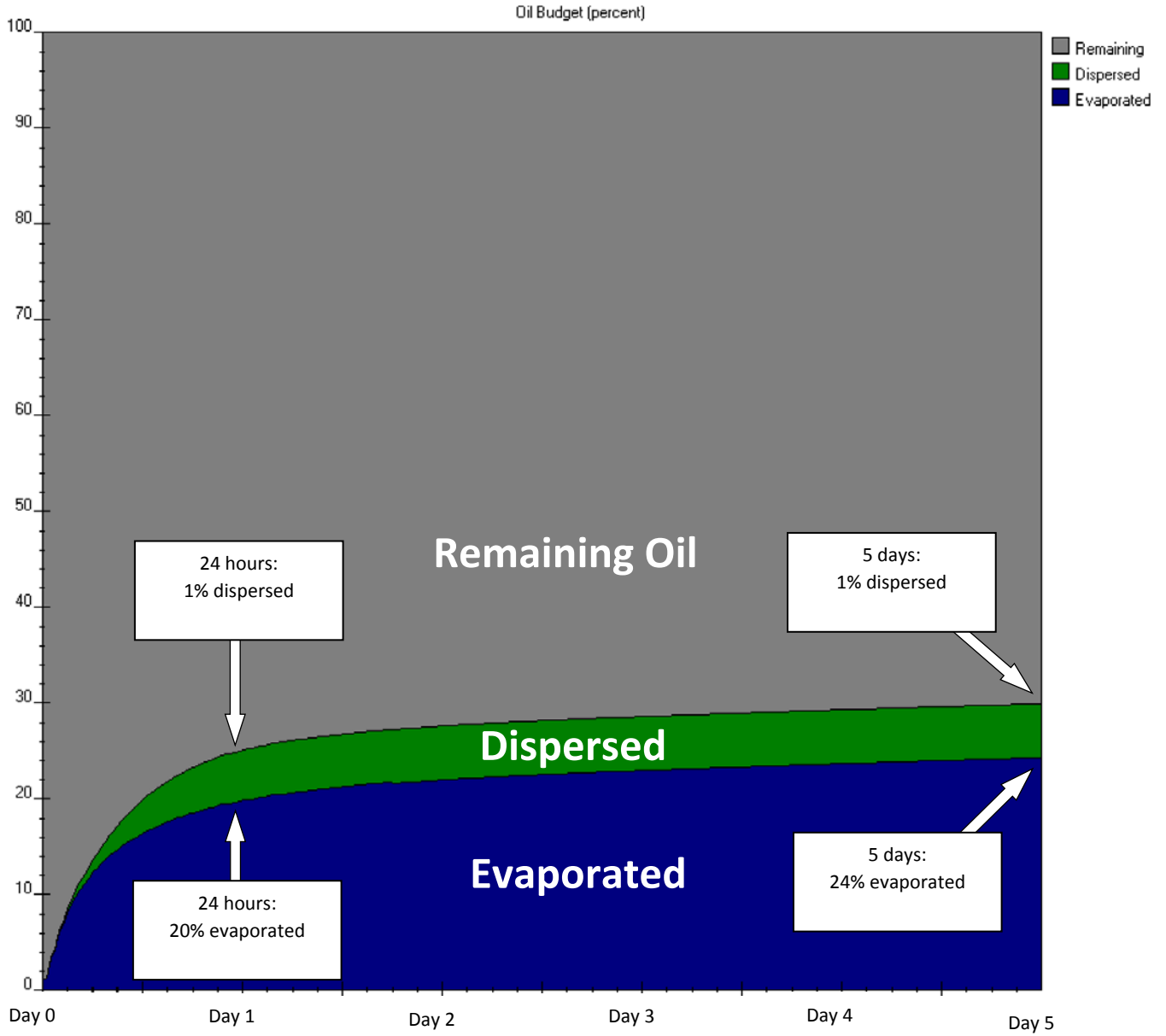


Dispersion – Suncor Synthetic A Summer Release – Windy Conditions

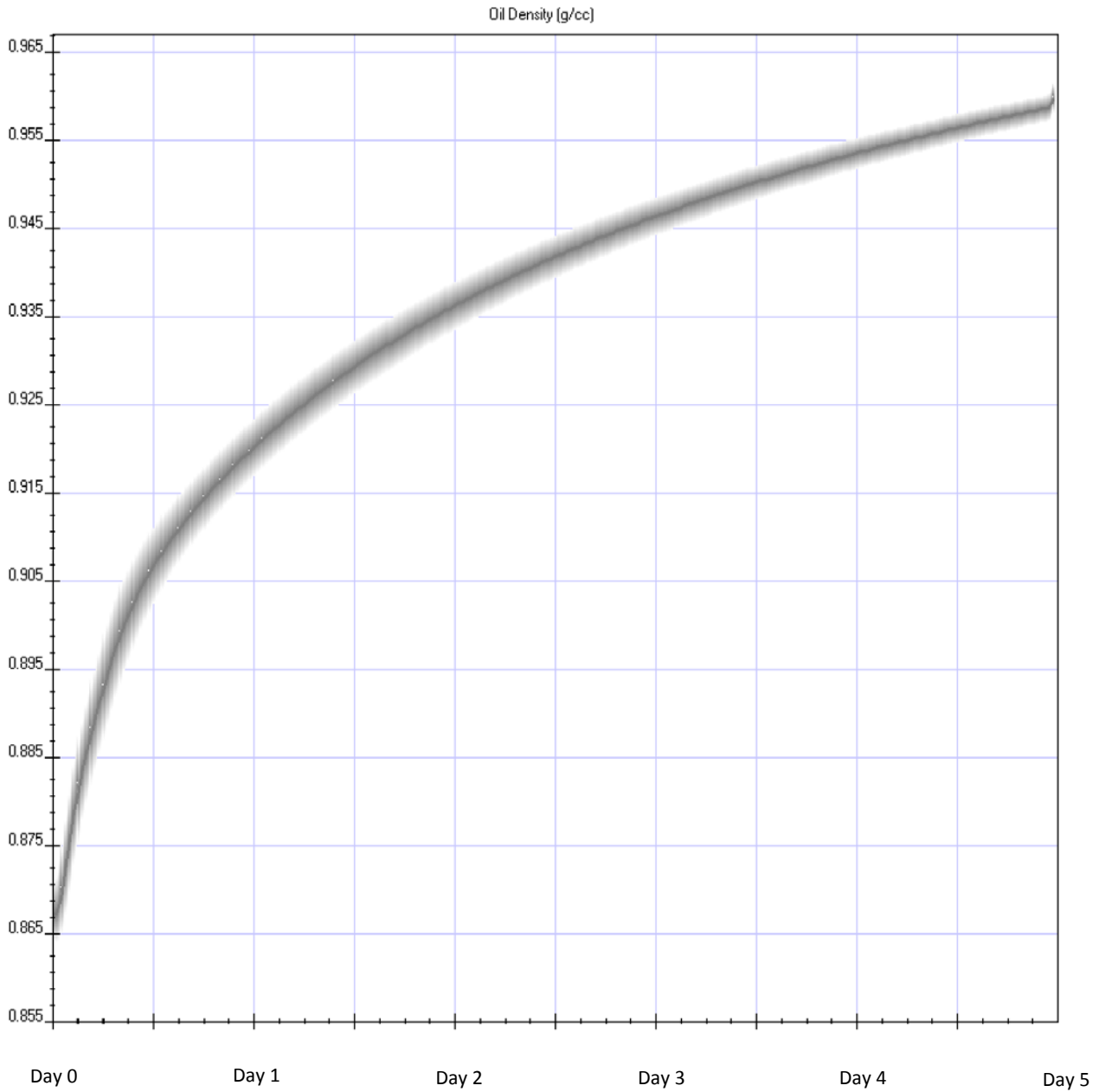


Dispersion – Suncor Synthetic A

Winter Release – Windy Conditions

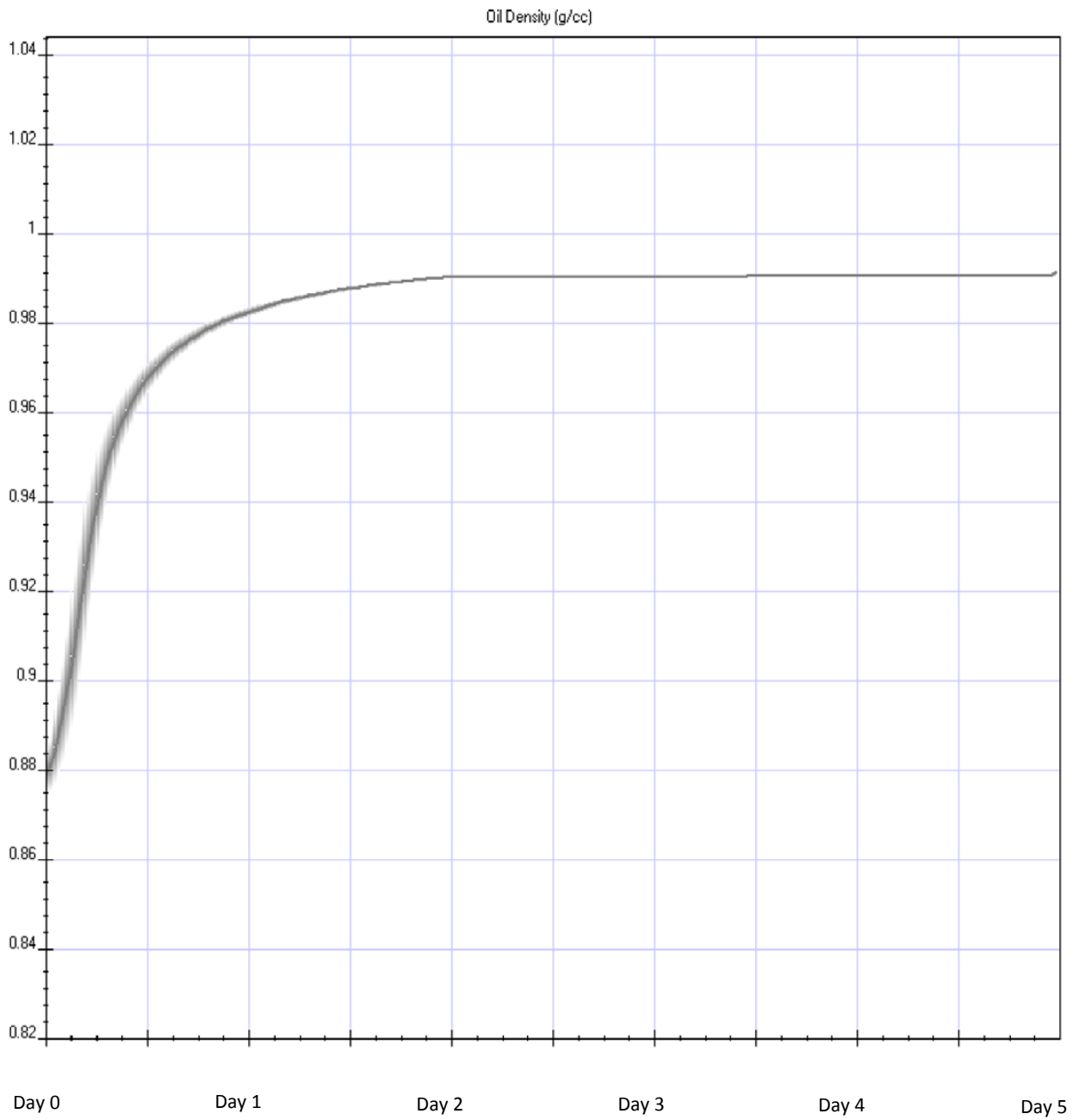


Density of Remaining Oil – Suncor Synthetic A Summer & Winter – Calm Conditions



Density of Remaining Oil – Suncor Synthetic A

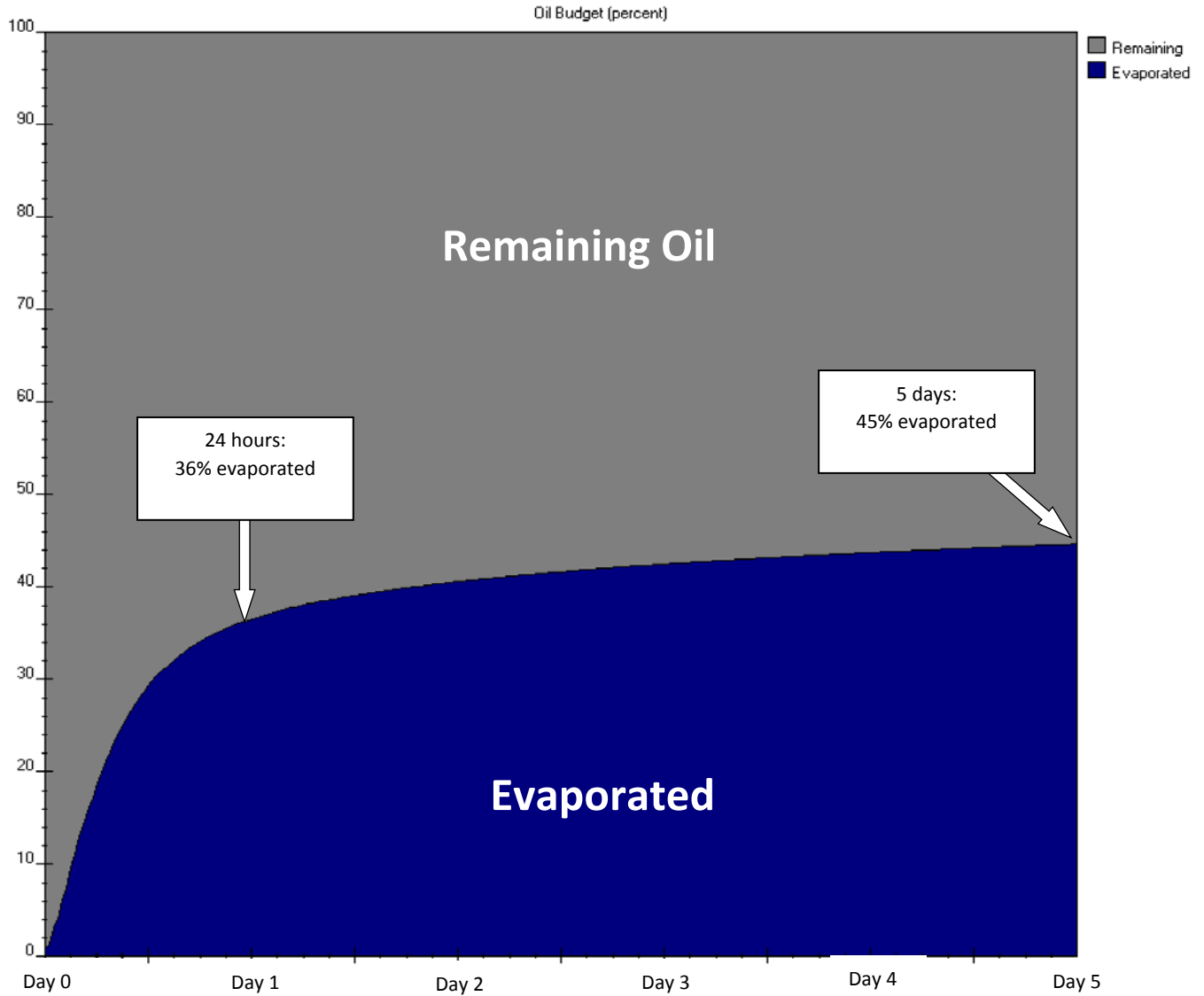
Summer & Winter – Windy Conditions



OIL TYPE: Bakken

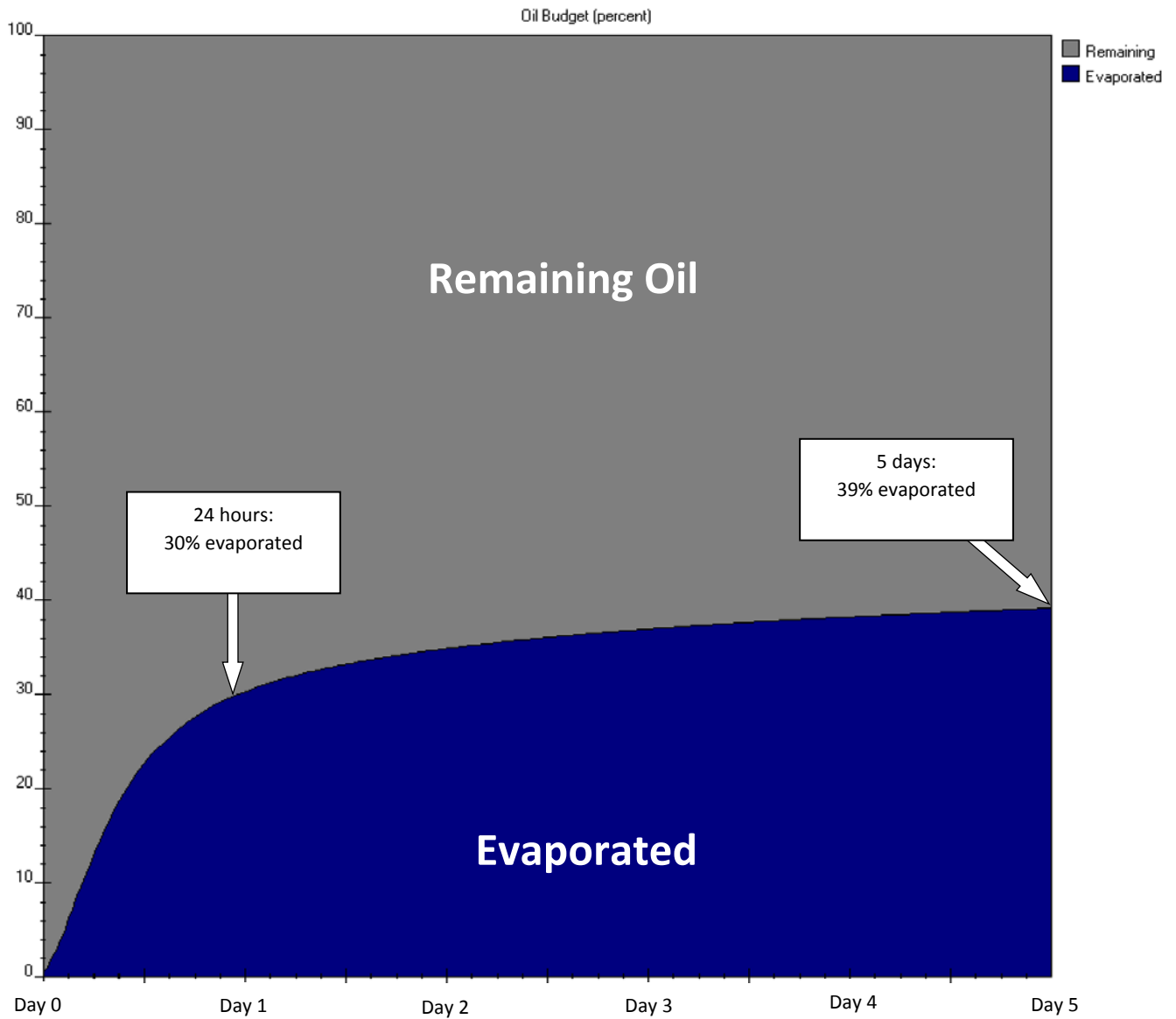
Evaporative Loss – Bakken

Summer Release – Calm Conditions



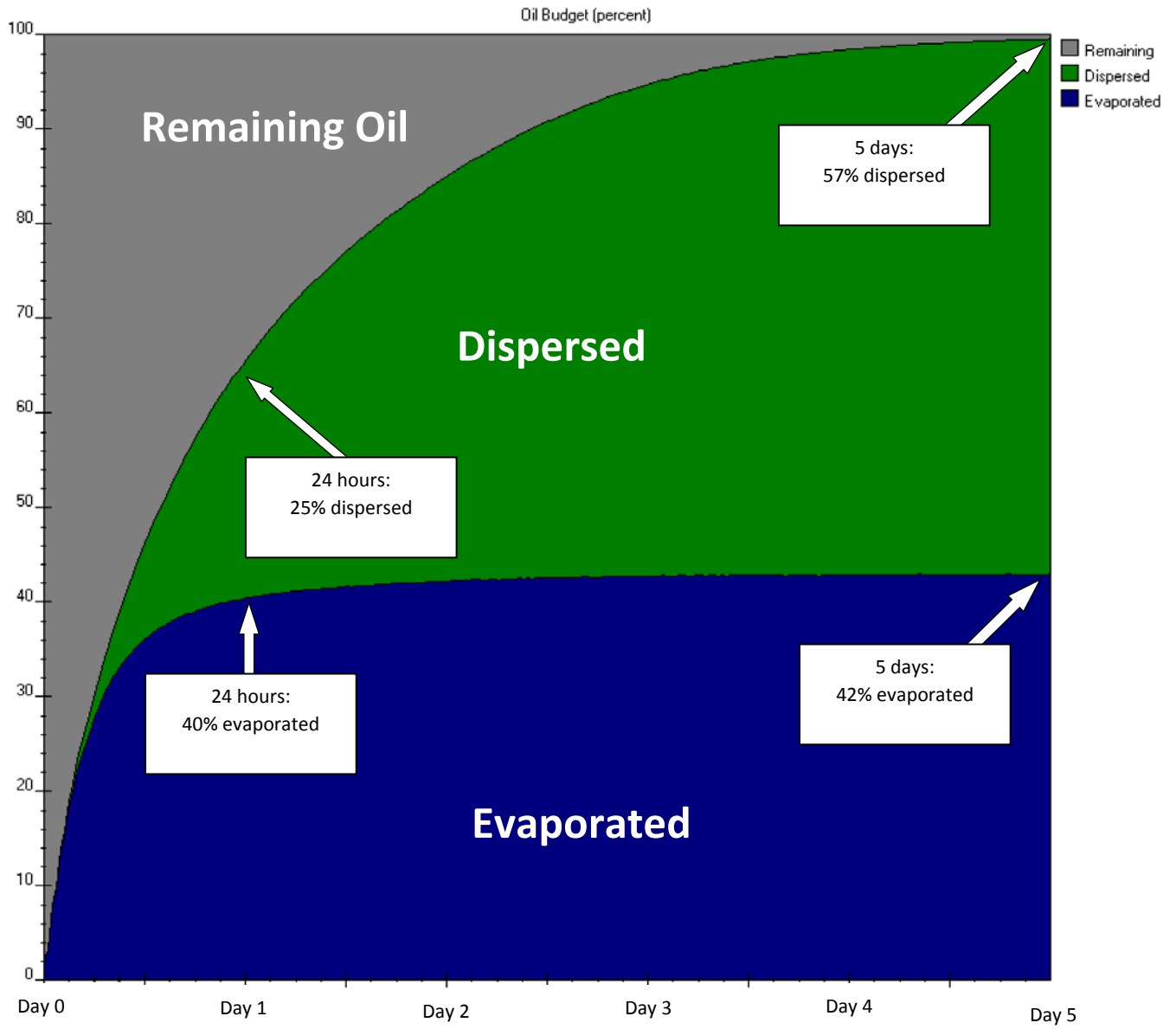
Evaporative Loss – Bakken

Winter Release – Calm Conditions



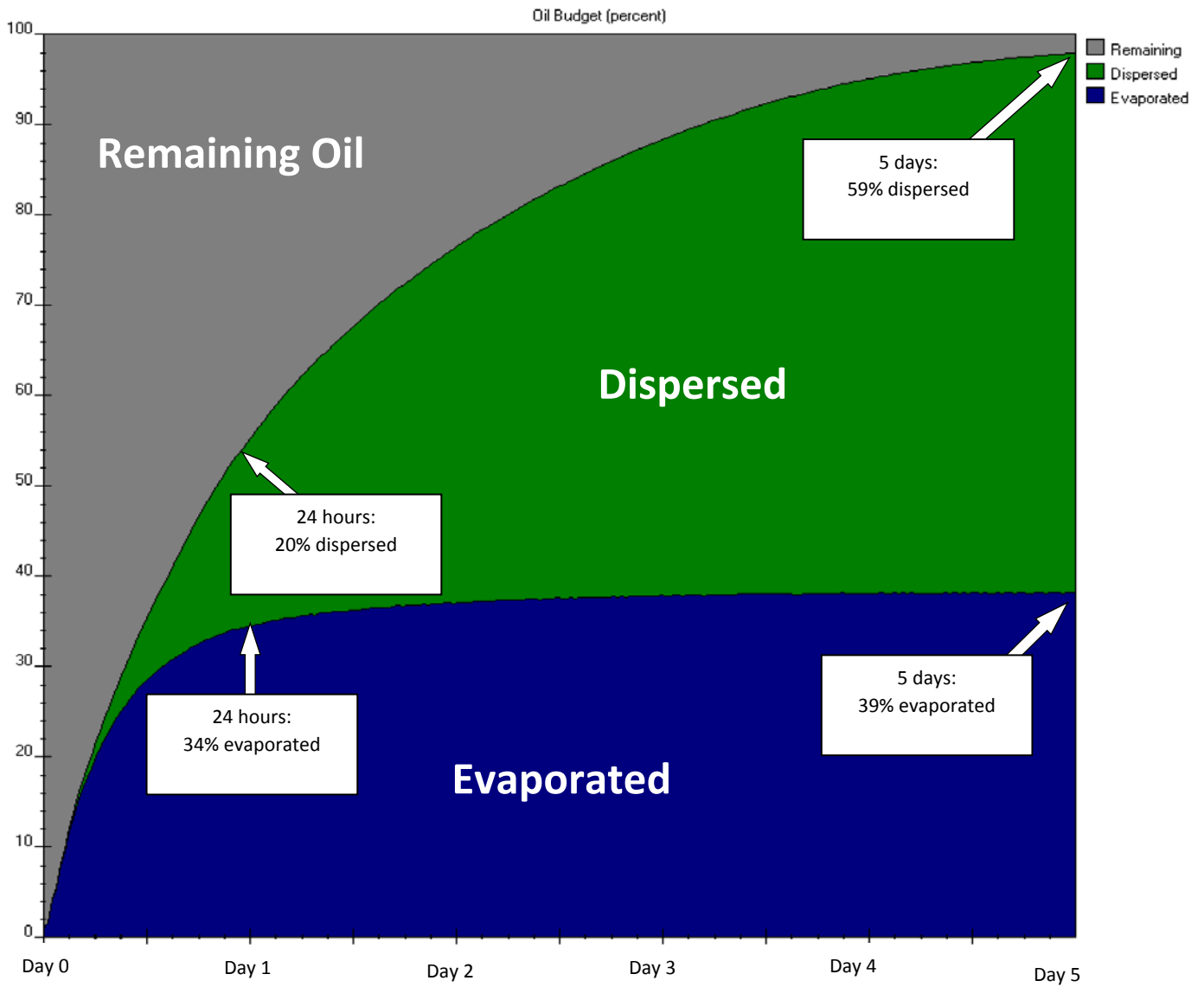
Dispersion – Bakken

Summer Release – Windy Conditions

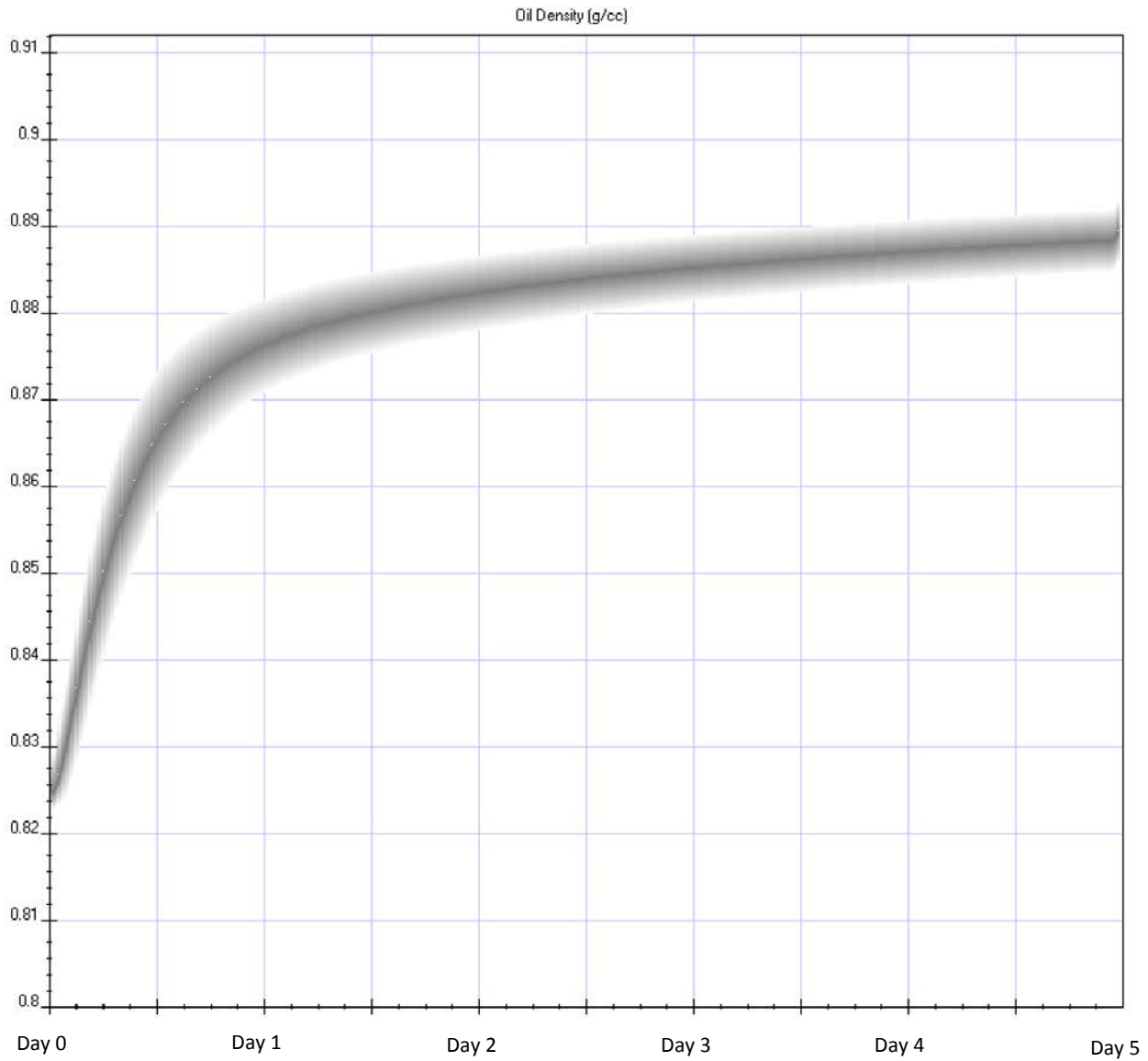


Dispersion – Bakken

Winter Release – Windy Conditions

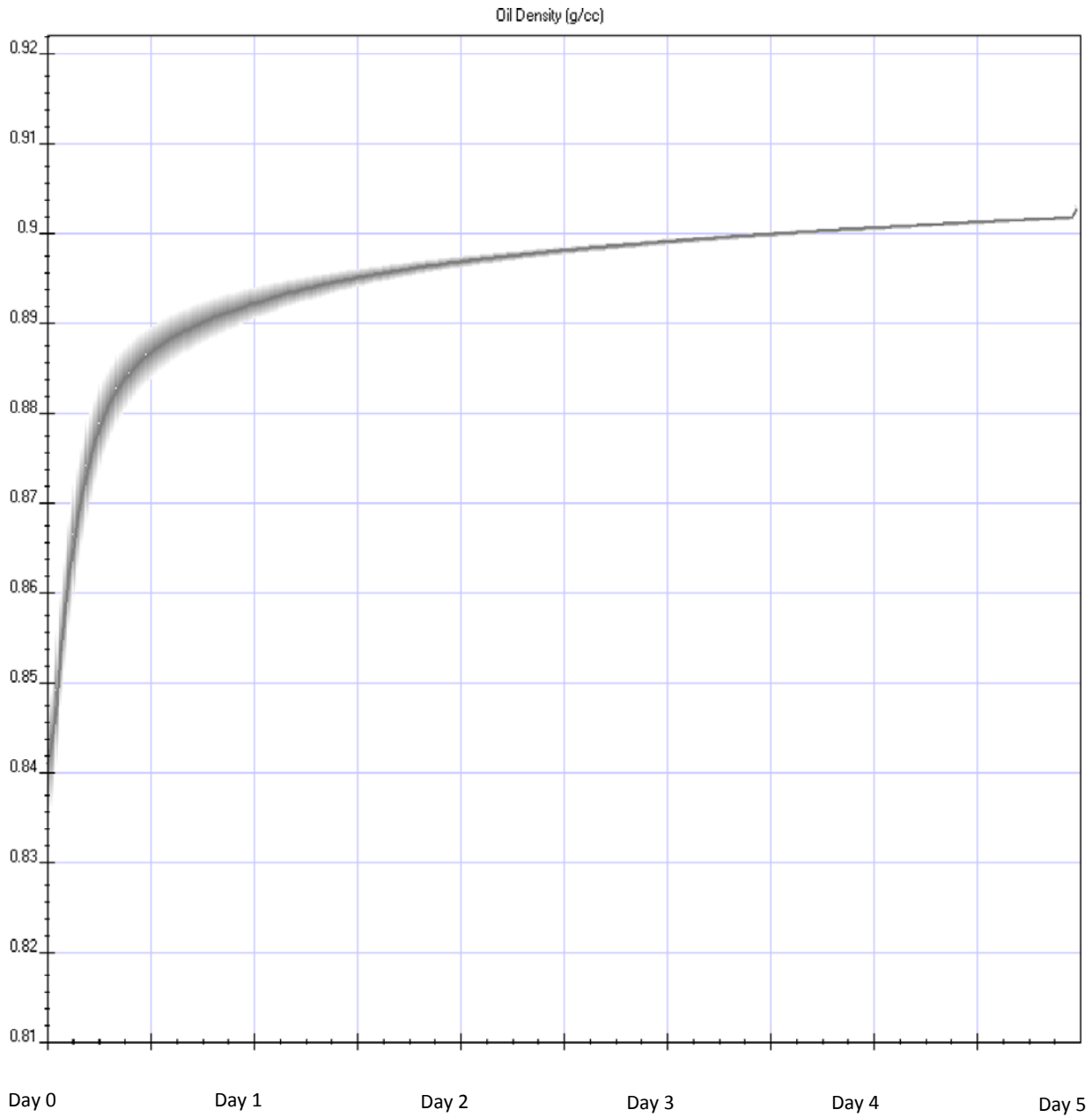


Density of Remaining Oil – Bakken Summer & Winter – Calm Conditions



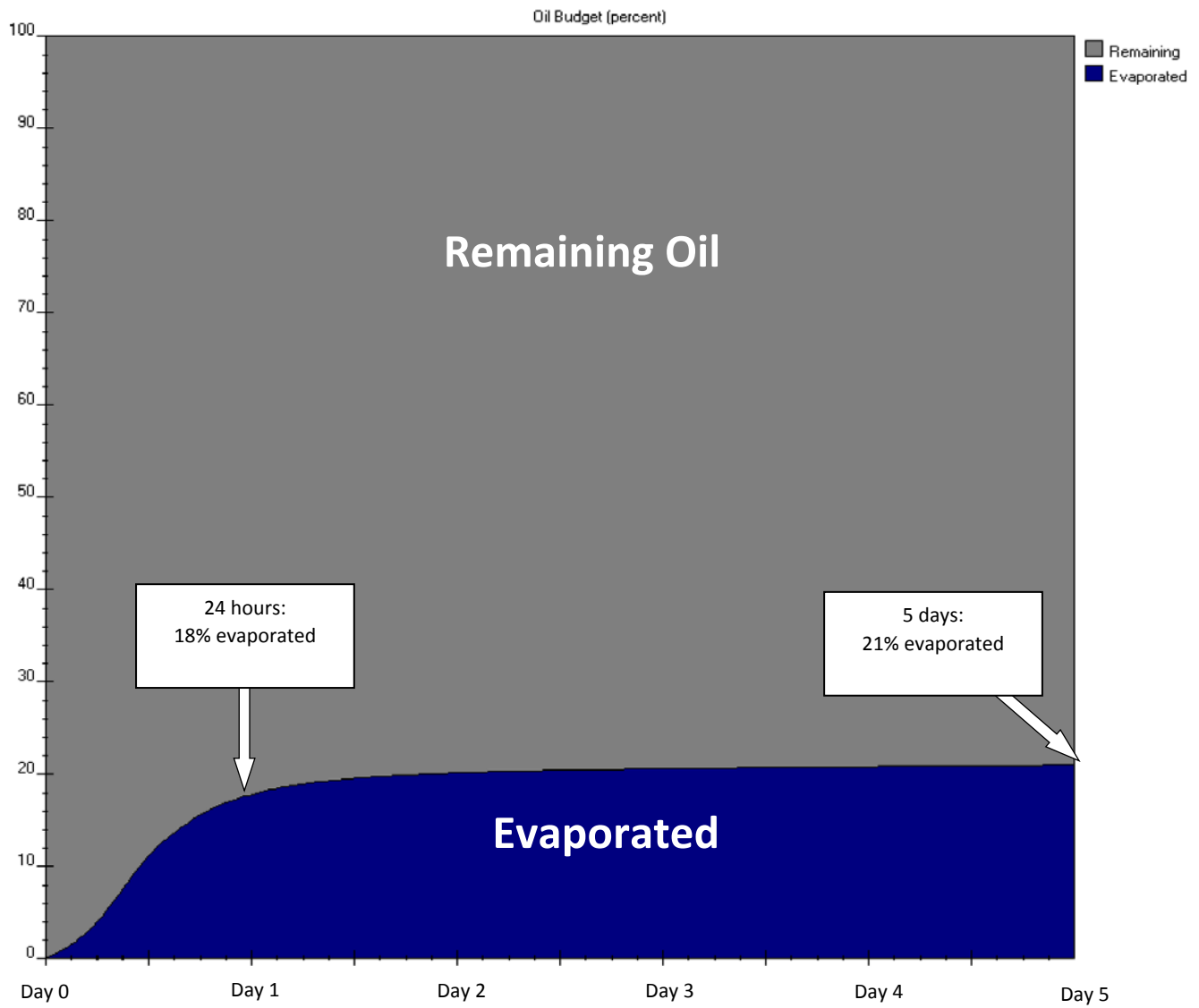
Density of Remaining Oil – Bakken

Summer & Winter – Windy Conditions



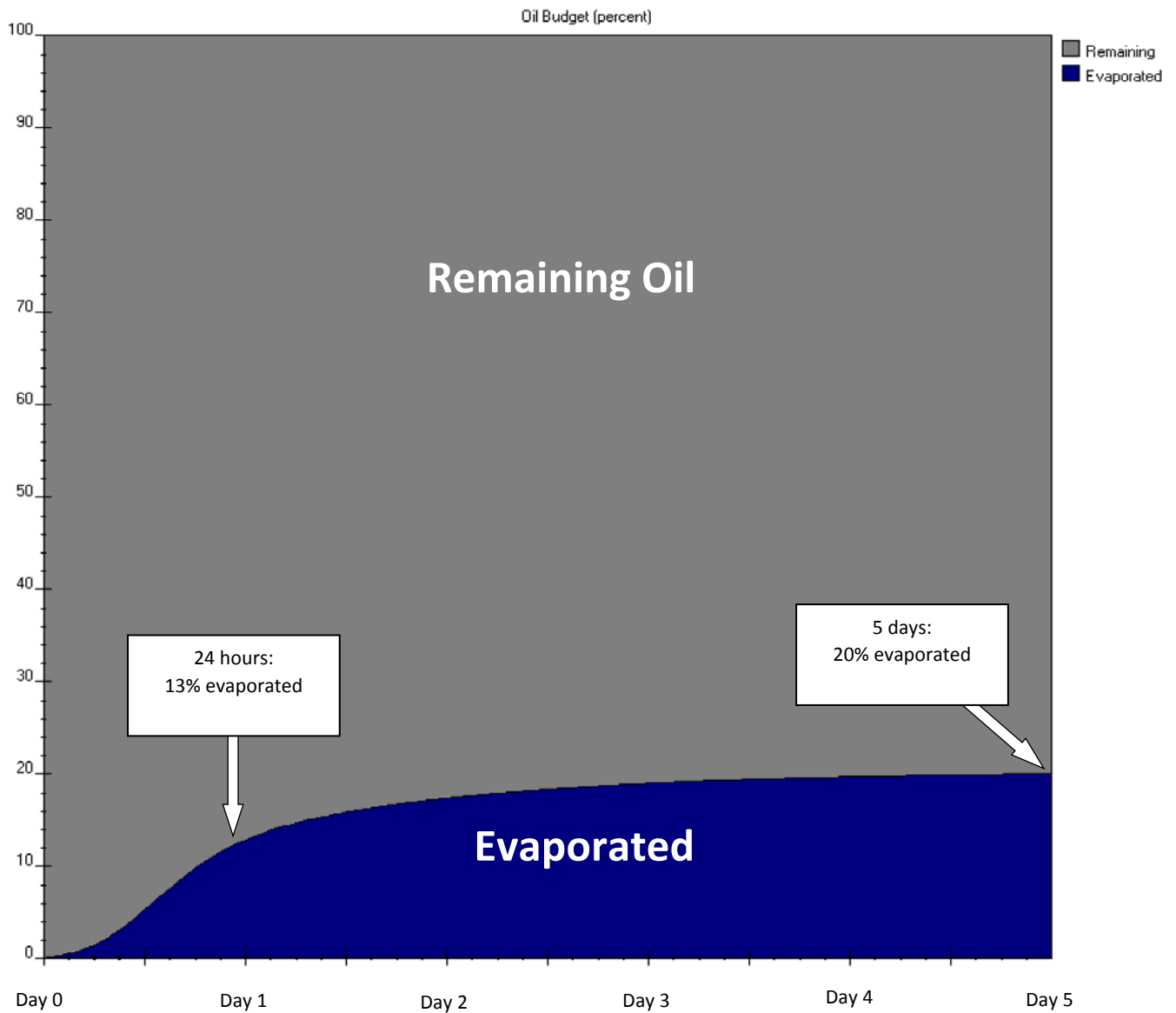
OIL TYPE: Western Canadian Select

Evaporative Loss – Western Canadian Select Summer Release – Calm Conditions

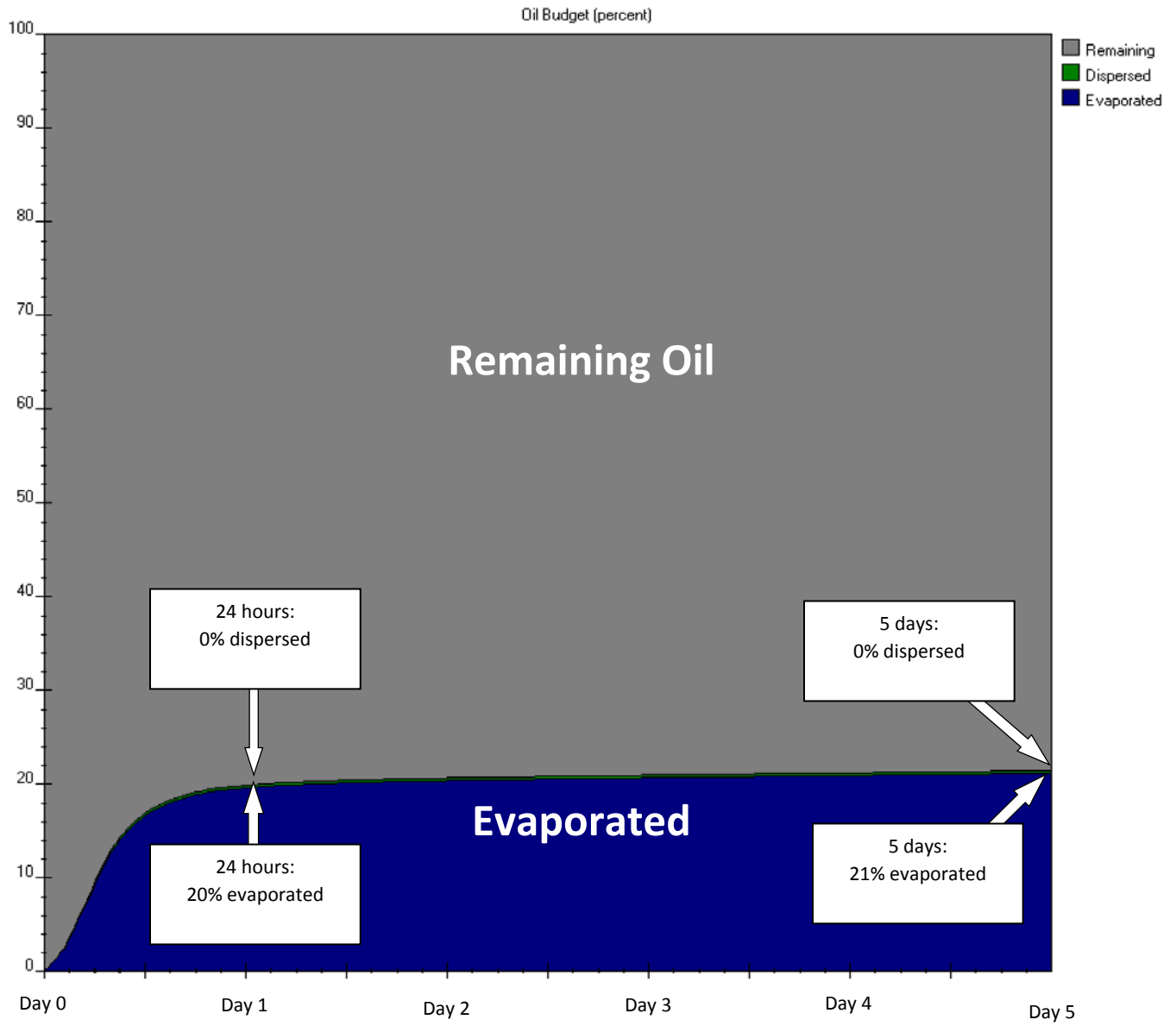


Evaporative Loss – Western Canadian Select

Winter Release – Calm Conditions

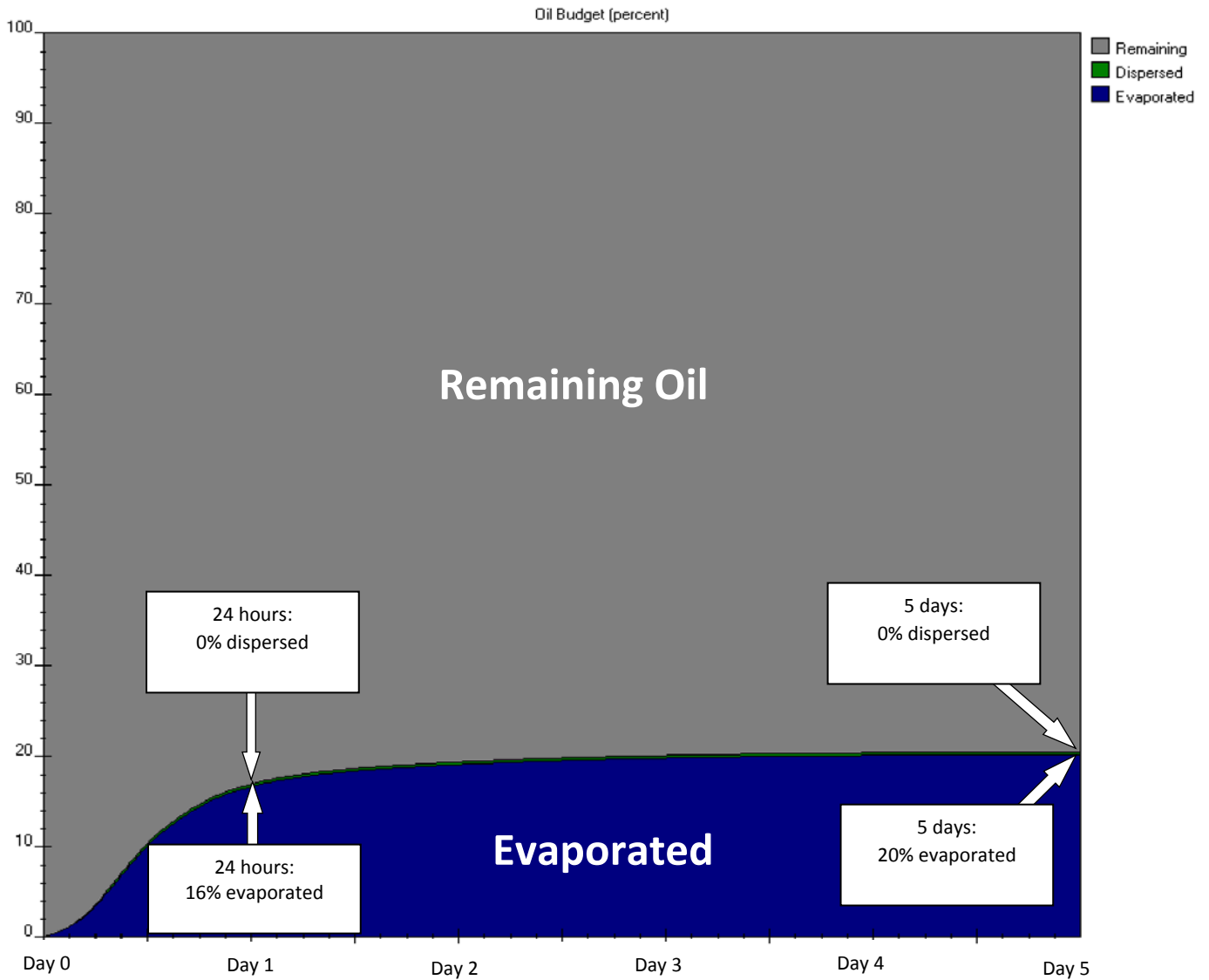


Dispersion – Western Canadian Select Summer Release – Windy Conditions

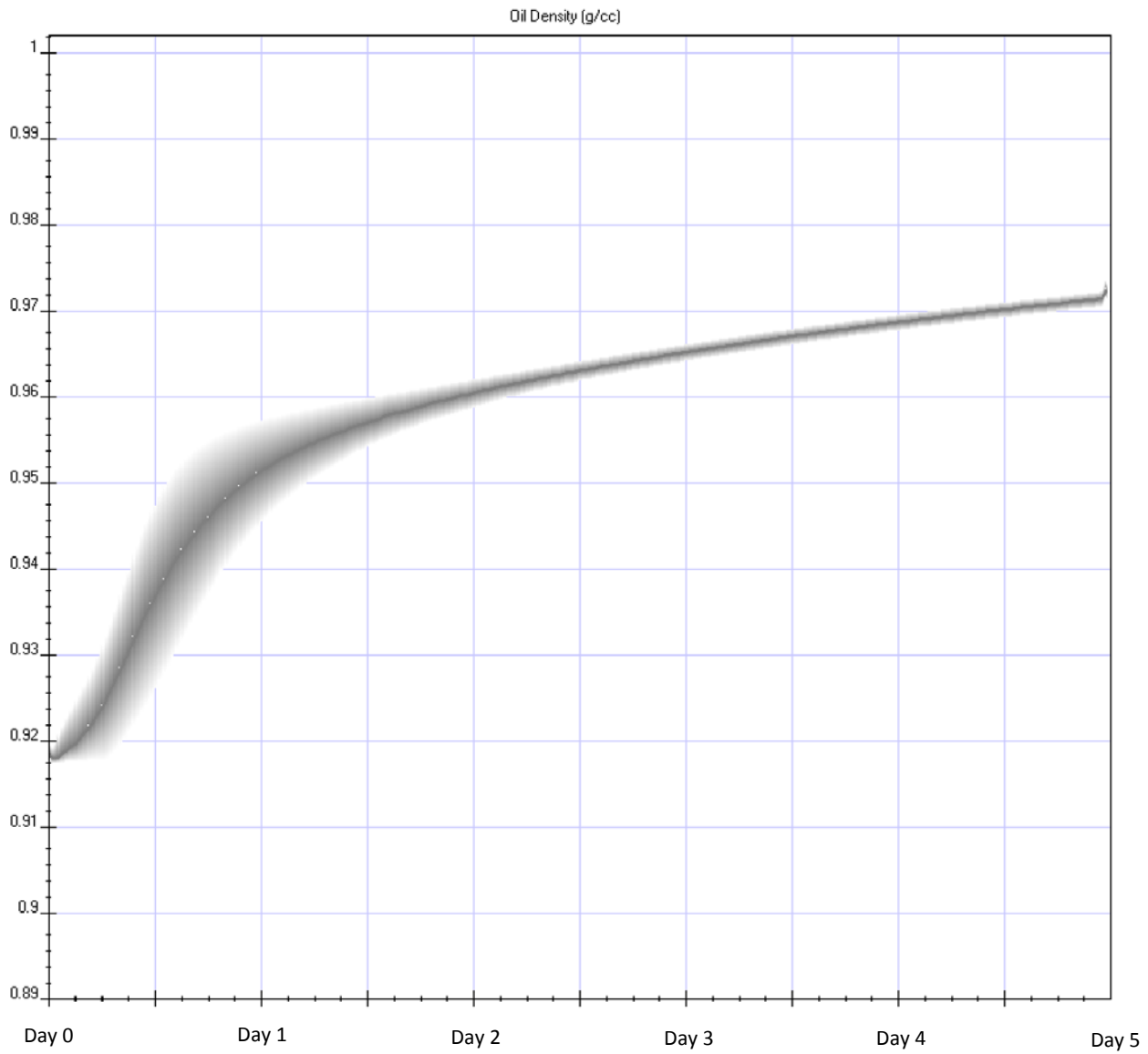


Dispersion – Western Canadian Select

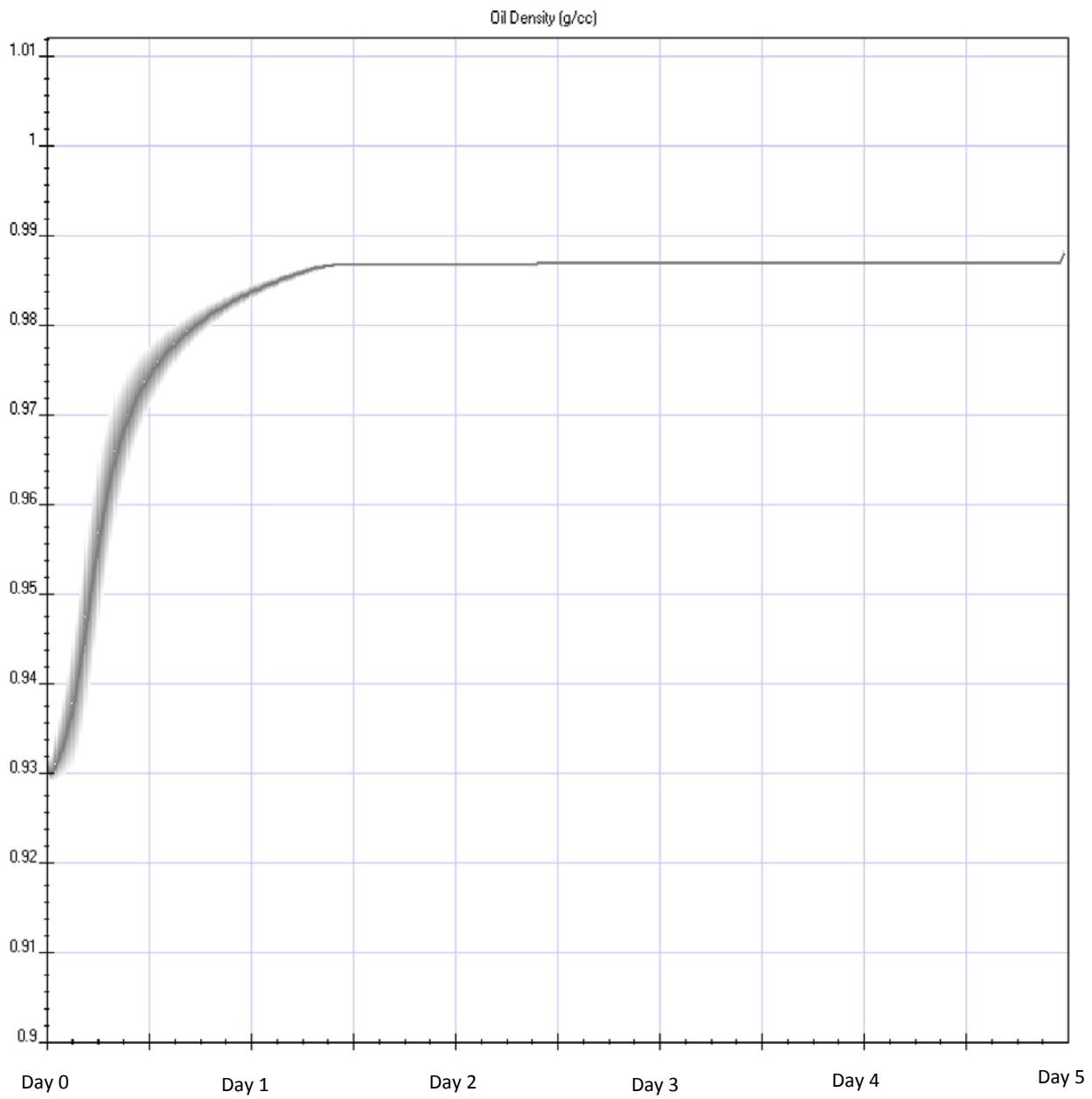
Winter Release – Windy Conditions



Density of Remaining Oil – Western Canadian Select Summer & Winter – Calm Conditions



Density of Remaining Oil – Western Canadian Select Summer & Winter – Windy Conditions



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APPENDIX C

Bear Creek Site-specific Risk Assessment

1.0 Purpose

Per the request of the United States (U.S.) Army Corps of Engineers (USACE), a site-specific risk assessment was conducted for Bear Creek, Montana. As this assessment is related to Keystone Pipeline LP's (Keystone's) proposal to construct and operate the Keystone XL Pipeline Project (Project) in the area of the Fort Peck Reservoir and the Missouri River, this report is provided as an appendix supplementing the original Missouri River SSRA.

To avoid repeating most of the content of the Missouri River SSRA, the discussion within this appendix focuses on information that differs from the Missouri River SSRA.

2.0 Background

2.1 Site Description

The Project crosses Bear Creek in Montana at Milepost (MP) 106 and 104.1, which are upstream of the Fort Peck Reservoir (**Figure C-1**). There would be 1,107 feet of pipe within the watershed where a release potentially could reach Bear Creek. The downstream distance from the pipeline to the mouth of Bear Creek Bay is 15.0 and 11.7 miles, respectively.

2.2 Release volumes

Examination of more than a decade of recent pipeline incident data (Pipeline and Hazardous Materials Safety Administration [PHMSA] 2017) indicates that most pipeline releases are relatively small, with 50 percent of the spills consisting of 3 barrels (bbl) or less. **Table C-1** data demonstrate that most pipeline spills are relatively small and large releases of 10,000 bbl or more are extremely uncommon.

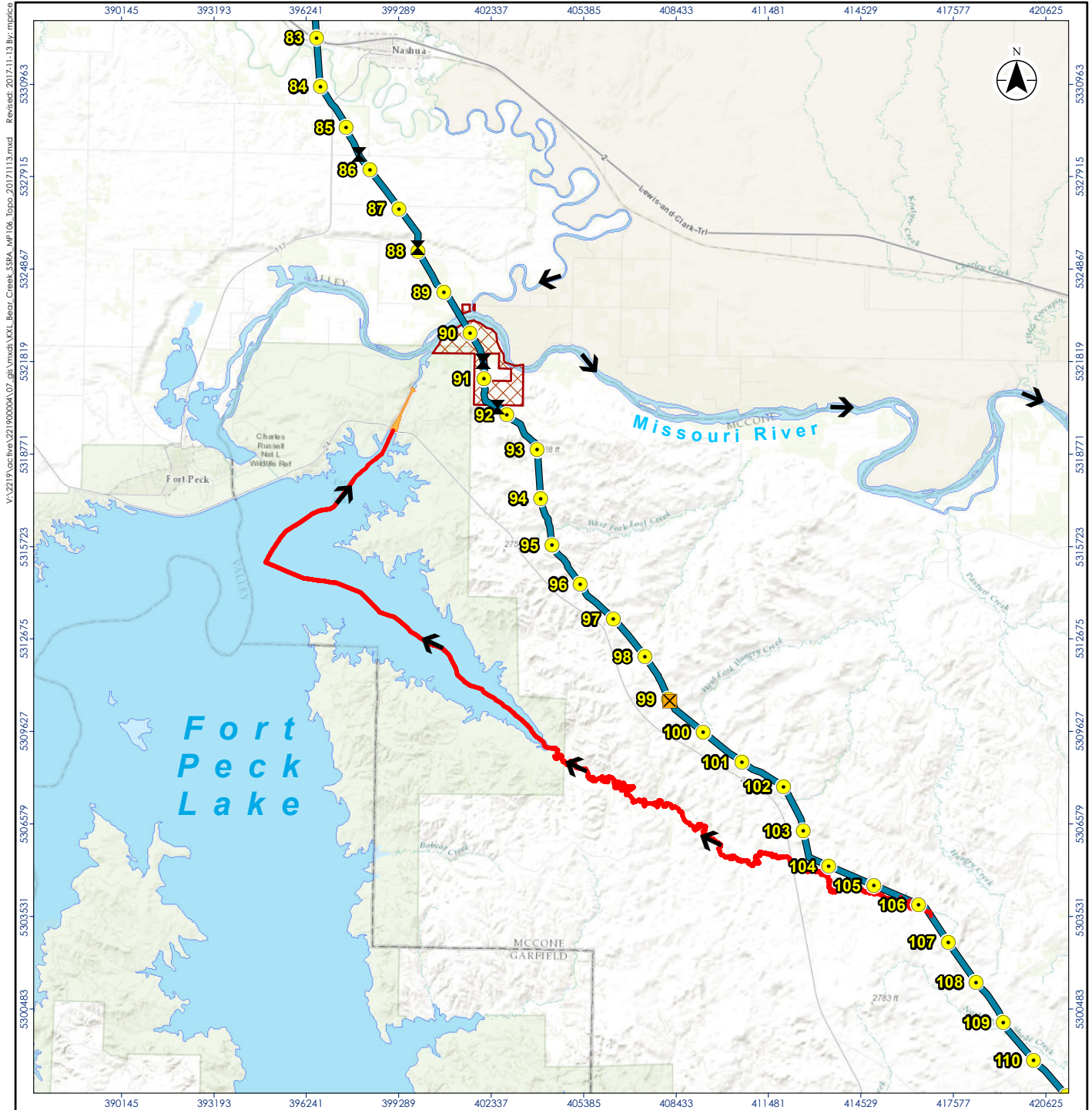
Table C-1 Distribution of Release Volumes

| Release Volume (bbl) | % of Releases (Equal to or Smaller ¹) |
|----------------------------|--|
| 3 | 50.0% |
| 50 | 81.8% |
| 1,000 | 95.9% |
| 10,000 | 99.6% |
| Worst Case Discharge [WCD] | 99.72% |

¹ Values derived from PHMSA historical incident data (2002 to 2017).

Worst Case Discharge

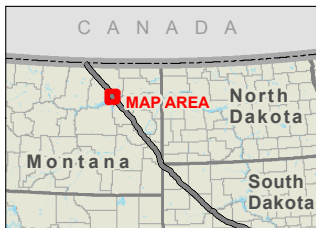
In addition to the range of release volumes in **Table C-1** that are routinely evaluated for permitting purposes, Keystone also calculated the worst case discharge (WCD) for the Bear Creek crossing as described in **Appendix A** of the Missouri River SSRA. The method used to calculate the WCD follows requirements specified in 49 Code of Federal Regulations (CFR) 194.105. The WCD scenario is a guillotine rupture of the pipeline. A release of this volume is extremely improbable and, based on the PHMSA incident database, only 0.28 percent of releases are this size or larger (PHMSA 2017).



V:\2219\csh\2219000A\07\gis\mxd\KXL_Bear_Creek_SSR_A_MF106_Topo_20171113.mxd Reviewed: 2017-11-13 By: mrc/af

390145 393193 396241 399289 402337 405385 408433 411481 414529 417577 420625

5300483 5300531 5306579 5309627 5312675 5315723 5318771 5321819 5324867 5327915 5330963



- Legend**
- KXL Centerline
 - KXL Downstream Transport
 - X Pump Station
 - X Valve
 - Mile Post
 - Fort Peck Dam & Spillway
 - Army Corps of Engineers
 - ➔ Direction of Flow

0 2 4 Miles
1:191,971 (at original document size of 8.5x11)

Stantec **TransCanada**
In business to deliver

Project Location
McCone County, Montana Prepared by MRP on 2017-11-13
Technical Review by HT on 2017-11-13
Independent Review by MW on 2017-11-13

Client/Project
Keystone XL Pipeline
Bear Creek SSRA

Figure No. **C-1** **DRAFT**

Overview of Bear Creek and Fort Peck Reservoir

Notes
 1. Coordinate System: NAD 1983 UTM Zone 13N
 2. Source: KXL 2013, USACE 2017.

Disclaimer: Stantec assumes no responsibility for data supplied in electronic format. The recipient accepts full responsibility for verifying the accuracy and completeness of the data. The recipient releases Stantec, its officers, employees, consultants and agents, from any and all claims arising in any way from the content or provision of the data.

2.3 Site-specific Incident Frequency

Incident frequency for the crossing was determined using data from the PHMSA incident database, which contains over 200,000 miles of liquid pipelines, providing a robust statistical analysis. These data were used since the PHMSA dataset is comprehensive in the types of data collected, thus allowing for a detailed analysis of causal factors. Further, many pipelines built in the 1930s and earlier are still in operation. Because the majority of pipelines in the U.S. were constructed in the pre-modern era, these frequencies reflect incident rates associated with earlier pipeline design and construction methods that often do not meet current regulatory requirements or best management practices. Therefore, the spill frequencies generated for the Project are expected to overestimate the probability of a release.

The Project-wide incident frequency statistic is 0.000287 incidents/mile-year (**Appendix A** of the Missouri River SSRA)¹. **Appendix A** identifies potential threats to pipeline safety and Project-specific mitigation measures that address each threat (e.g., corrosion). The mitigation measures addressed **Appendix A** are identical to the Missouri River, with the exception of the HDD crossing method with heavier walled pipe. For simplicity, the Project-specific incident frequency was unmodified, even though major threats (e.g., third-party excavation) would be less in this area due to the rural nature of the area. Based on that statistic, Bear Creek was evaluated to determine frequencies for a variety of release volumes. Occurrence intervals (the predicted time period between incidents for any single mile of pipeline) are calculated by taking the inverse of an incident frequency.

$$f_{\text{occurrence}} = 1/(f_{\text{incident}})$$

Where:

$$f_{\text{occurrence}} = \text{occurrence interval for an incident}$$

$$f_{\text{incident}} = \text{incident frequency}$$

Occurrence intervals for specific segments of the pipeline (e.g., Missouri River crossing) can be calculated by incorporating length into the calculation.

$$f_{\text{segment}} = 1/(f_{\text{incident}} \cdot \text{mile}_{\text{segment}})$$

Where:

$$f_{\text{segment}} = \text{occurrence interval for an incident for a specific segment of the Project}$$

$$f_{\text{incident}} = \text{incident frequency}$$

$$\text{mile}_{\text{segment}} = \text{length of the specific pipeline segment in miles}$$

Based on the site-specific incident frequency statistic, the incident frequency for the Missouri River crossing was calculated based on spill volumes shown in **Table C-2**.

Table C-2 Occurrence Interval by Spill Volume

| Location | Crossing Distance (mi) ¹ | Occurrence Interval (years) by Spill Size | | | | |
|------------|-------------------------------------|---|--------|-----------|------------|-----------|
| | | 3 bbl | 50 bbl | 1,000 bbl | 10,000 bbl | WCD |
| Bear Creek | 0.21 | 33,200 | 91,300 | 405,000 | 4,150,000 | 5,940,000 |

¹ Crossing length includes the stream width plus 500 feet on each side to account for overland flow based on terrain.

¹ The Project incident frequency has been updated and was derived from PHMSA data from 2002 to 2017. The incident frequency includes incident causes identified within PHMSA's incident database (**Appendix A** of the Missouri River SSRA).

The probability of a release of any size occurring at the Bear Creek crossing is once in 16,600 years. **Table C-2** breaks down the occurrence intervals for various sized releases. For example, the median release volume of 3 bbl or less has an associated occurrence interval of 33,200 years.

The probability of a WCD release is extremely remote, with occurrence interval of 5,940,000 years. While a release of the WCD at Bear Creek is statistically improbable, the WCD does represent an important value for Keystone emergency response planning to ensure sufficient resources and equipment are available, regardless of the statistical improbability.

Descriptions of crude oil properties and characteristics and environmental fate and transport would be identical to Sections 2.4 and 2.5 of the Missouri River SSRA.

3.0 Methodology

The Bear Creek SSRA quantitatively evaluated the downstream transport of a crude oil release and potential effects to water quality. In Section 3.1 and 3.2, an analysis of potential downstream transport of crude oil along an ephemeral/intermittent drainage was conducted. Unlike other areas evaluated in the Missouri River SSRA where the river or stream is a perennial waterbody, Bear Creek typically has no stream flow to help facilitate downstream movement of crude oil. Section 3.3 discusses the behavior and transit times if a crude oil release were to reach Bear Creek Bay.

In Chapter 4.0, extremely conservative assumptions were used to evaluate the theoretical concentrations within Bear Creek Bay and compares these values with drinking water and aquatic life thresholds.

Chapter 5.0 provides an overview of emergency response, including the preparation of a Geographic Response Plan.

Chapter 6.0 summarizes the results of the Bear Creek SSRA.

3.1 Periodicity and Topography

Based on aerial photography of the drainage, Bear Creek streamflow is insufficient to support a substantive vegetative community. Bear Creek likely flows only during localized thunderstorms in warm months and during spring runoff. While Bear Creek is likely an ephemeral stream (i.e., flowing less than 10 percent of the time), for the purposes of this report it is considered intermittent (i.e., flowing less than 50 percent of the time) so that risk is overestimated. As an intermittent stream, there will be zero flow the majority of the time.

The slope from the pipeline to the mouth of Bear Creek Bay of Fort Peck Reservoir is gradual with an average slope of 0.6 percent (**Figure C-2**). The elevation profile and aerial photography indicate a number of locations where vertical impediments exist where the dry creek would widen and oil would pool and spread. Based on Geographic Information System (GIS) measurements, the estimated width of Bear Creek under high flow conditions varies between 20 and more than 80 feet (The Response Group [TRG] 2017).

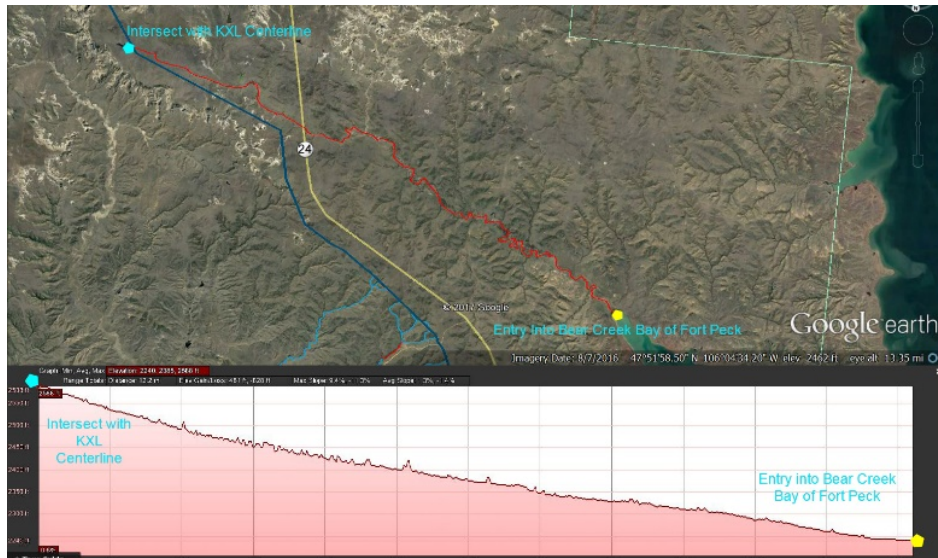


Figure C-2 Aerial View and Elevation Profile fo Bear Creek from MP 106 to Bear Creek Bay

3.2 Stream Transport Times

3.2.1 No Flow Conditions

Crude oil, particularly heavy crude oils have greater viscosity, greater adhesion to streambed and vegetation, thicker pooling, and would have limited overland transport capability, while lighter crude oils (e.g., Bakken) would be capable of greater overland flow distance.

Assuming a WCD-bbl light crude oil release occurred at MP 106 when Bear Creek was not flowing, and accounting for streambed width and pooling, the estimated maximum downstream transport distance of the crude oil would be 2.0 miles for Bakken Crude. For a more viscous crude oil (e.g., Western Canadian Select), the estimated maximum downstream transport would be 1.3 miles. Because the downstream distance from MP 106 to the mouth of Bear Creek Bay is 15 miles, a release from MP 106 would not be expected to reach Bear Creek Bay without the presence of flowing water to help transport the crude oil.

3.2.2 Downstream Transport

The downstream transport distance from the pipe crossing at MP 106 to the mouth of Bear Creek Bay is 15 miles. The following analysis provides an estimation of downstream transport distance for different stream velocities, assuming a uniform and constant velocity at the river's surface. The downstream transport distance was estimated for several velocities that are representative of the area and ranging from 0.0 feet per second (ft/s) to 5.87 ft/s (**Table C-3**).

Table C-3 Estimated downstream transport distances for Bear Creek.

| | Stream Velocity (ft/sec) | | | | |
|------------------------------|--------------------------------|----------|-----------|---------|------------|
| | 0.0 (no flow) | 1.47 | 2.93 | 4.40 | 5.87 |
| Time to reach Bear Creek Bay | Would not reach Bear Creek Bay | 15 hours | 7.5 hours | 5 hours | 3.75 hours |

This analysis suggests that a crude oil possibly could reach Bear Creek Bay when stream flow is present. However, emergency response may contain the release before the crude oil enters Bear Creek Bay (Chapter 5.0, Emergency Response).

3.3 Transport Across Fort Peck Reservoir

3.3.1 Rate of Spreading

If crude oil were to reach Bear Creek Bay, the velocity of the stream would substantially decline and spreading would become the dominate force dictating the movement of the crude oil across the water surface. Both Bakken and Western Canadian Select have American Petroleum Institute gravities greater than 10.0, indicating they would float on the water's surface (Missouri River SSRA, Section 2.4 Crude Oil Properties and Characteristics). Bakken also has a very low viscosity (2 to 4 centistokes at ambient temperatures), indicating that the oil would spread across the water's surface and form a thin slick on top of the water in the case of a release, while more viscous crude oils (such as Western Canadian Select) would spread more slowly. Crude oils tend to spread across surface waters at a rate between 100 to 300 meters (m) per hour (Ramade 1978 as cited in Patin and Stanislav 1998).

Given Bakken crude oil's physical properties, this assessment assumes that Bakken crude oil spreading would occur at 300 m per hour. Spreading increases the surface area of the spill and would facilitate evaporation, the primary environmental fate process governing the fate of volatile organic compounds within the oil, like benzene. However, no evaporation was assumed (see Assumptions within Chapter 4.0). Bakken crude oil contains 0.28 percent benzene by volume (Shafizadeh 2010).

3.3.2 Transit Times

Transit time represents the time for a crude oil release to move from the origin of release to a specific endpoint. For Fort Peck, two potential endpoints were identified: The Fort Peck Dam and the Fort Peck Spillway.

Fort Peck Dam: The distance to the Fort Peck dam is the sum of the downstream distance along Bear Creek, plus the distance across Fort Peck Reservoir. The distance within Bear Creek is 15 miles. The distance from the mouth of Bear Creek Bay to the main portion of Fort Peck Reservoir is 5.85 miles. The distance from there to the Fort Peck dam is 2.69 miles. The total distance from the pipeline to the dam is 23.54 miles.

Fort Peck Spillway: The distance to the Fort Peck spillway is the sum of the downstream distance along Bear Creek, plus the distance across Fort Peck Reservoir. The distance within Bear Creek is 15 miles. The distance from the mouth of Bear Creek Bay to the main portion of Fort Peck Reservoir is 5.85 miles. The distance from there to the Fort Peck spillway is 1.90 miles. The total distance from the pipeline to the dam is 22.75 miles.

Downstream transit times in Bear Creek (based on velocity) is added to transit time across Fort Peck Reservoir to the endpoint of interest (**Table C-4**). Based on a 300 meter/hour (m/hr) spreading rate for Bakken, it would take 31.4 hours for oil that reached Bear Creek Bay to reach the mainstem of Fort Peck

Reservoir. From there, it would take an additional 14.4 hours to reach the Fort Peck Dam or 10.2 hours to reach the Fort Peck spillway.

Table C-4 Transit Times from the KXL Pipeline to Locations within Fort Peck

| | Bear Creek Stream Velocity (ft/s) | | | | |
|---|-----------------------------------|------|------|------|------|
| | 0.0 (no flow) | 1.47 | 2.93 | 4.40 | 5.87 |
| Transit time to Fort Peck Dam from MP 106 (hours) | | | | | |
| Bear Creek (15 stream miles) | Would not reach Bear Creek Bay | 15 | 7.5 | 5 | 3.75 |
| Bear Creek Bay (5.85 mile) | Would not reach reservoir | 31.4 | 31.4 | 31.4 | 31.4 |
| Fort Peck Dam (2.69 miles) | Would not reach reservoir | 14.4 | 14.4 | 14.4 | 14.4 |
| Dam: Total transit time (hours) | Would not reach reservoir | 60.8 | 53.3 | 50.8 | 49.6 |
| Transit time to Fort Peck Spillway from MP 106 (hours) | | | | | |
| Bear Creek (15 stream miles) | Would not reach Bear Creek Bay | 15 | 7.5 | 5 | 3.75 |
| Bear Creek Bay (5.85 mile) | Would not reach reservoir | 31.4 | 31.4 | 31.4 | 31.4 |
| Fort Peck Spillway (1.90 miles) | Would not reach reservoir | 10.2 | 10.2 | 10.2 | 10.2 |
| Spillway: Total transit time | Would not reach reservoir | 56.8 | 49.3 | 46.8 | 47.7 |

In summary, under the scenarios analyzed and NOT accounting for any emergency response intervention, it would take almost 50 hours for a release to reach either the Fort Peck Dam or its spillway, providing ample time for emergency response intervention. As discussed in the Missouri River SSRA (Section 2.5.2 Releases into Water Environments), the presence of ice on a waterbody severely restricts the movement of crude oil.

The general descriptions of environmental and human health effects described in the Missouri SSRA (Chapter 4.0) would be the same for Bear Creek, except as described herein.

The description of horizontal directional drilling (HDD) crossing (Chapter 5.0 of the Missouri River SSRA) would not be applicable to Bear Creek.

4.0 Fort Peck Water Quality

The maximum theoretical concentration of benzene was calculated for portions of Fort Peck Reservoir based on the area affected within 6 hours and within 27 hours. This water quality model is extremely conservative since it makes the following assumptions:

Assumption 1: The entire volume of a hypothetical crude oil release at MP 106 instantaneously arrives at Bear Creek Bay.

Assumption 2: Bakken oil was used for this analysis since it contains the highest concentration of benzene and is least viscous of the crude oils transported by the Project.

Assumption 3: The rate of spreading would occur at 300 m/hr based on the low viscosity of Bakken crude oil. Heavier, more viscous oils would not spread as much or as quickly.

Assumption 4: The model assumed that 100 percent of the benzene within the released oil would solubilize directly into the water. This is an extremely conservative (over estimation) assumption given the low solubility of benzene. Under field conditions, actual concentrations of benzene would not approach optimal solubility limits because benzene preferentially remains in the crude oil or evaporates rather than dissolving into the water. For this model, the entire volume of benzene in the crude oil is assumed to dissolve into the water.

Assumption 5: Benzene was assumed to dissolve within the uppermost meter of water. Concentrations are uniform across the affected area.

Assumption 6: No shoreline stranding occurred.

Assumption 7: Evaporative loss occurs during spreading. The volume lost to evaporation was determined by ADIOS2 based on 6- and 27-hour timeframes.

Assumption 8: No emergency response occurs. Consequently, no crude oil is removed or contained in this hypothetical scenario.

Results of the modeling of benzene concentrations in the water in Bear Creek Bay following a hypothetical spill into Bear Creek are presented in **Table C-5**. Because crude oil and benzene are extremely buoyant, they are not expected to be measurable much beyond the water’s surface. For this assessment, benzene was limited to the uppermost 1.0 meter of water. The drinking water Maximum Contaminant Level (MCL) for benzene is 0.005 milligrams per liter (mg/L) and the aquatic life threshold is 7.4 mg/L. (Note: there are no drinking water intakes in this area.) The results of the hypothetical spill scenario suggest that even spills of 10,000 bbl would not result in benzene concentrations that exceed drinking water or aquatic life thresholds.

Table C-5 Benzene Concentration in Water in Bear Creek Bay

| Bear Creek Bay | Linear transport distance (miles) | Affected Area (m ²) | Drinking water MCL (mg/L) | Acute & Chronic Aquatic Life Thresholds (mg/L) | Release Volume (bbl) | | | | |
|------------------|-----------------------------------|---------------------------------|---------------------------|--|---------------------------------------|----------|---------|--------|--------|
| | | | | | 3 | 50 | 1,000 | 10,000 | WCD |
| | | | | | Benzene Concentration in Water (mg/L) | | | | |
| 6-hour transport | 1.12 | 891,375 | 0.005 | Acute: 7.4 Chronic: 1.4 | 0.000001 | 0.00002 | 0.0004 | 0.004 | 0.004 |
| 27-hr transport | 5.03 | 15,590,545 | 0.005 | Acute: 7.4 Chronic: 1.4 | 0.0000001 | 0.000001 | 0.00002 | 0.0002 | 0.0003 |

The discussion of Keystone’s pipeline safety program and Emergency Response (Missouri River SSRA Chapters 6 and 7, respectively) would be the same for Bear Creek. Additional site-specific information related to the Geographic Response Plan for Bear Creek is provided below.

5.0 Emergency Response

A Geographical Response Plan (GRP) was prepared for the Bear Creek drainage (TRG 2017). Four recover sites were identified along the Bear Creek drainage. Given the intermittency of the stream, it is

anticipated that in the majority of cases, emergency response teams could respond and begin containment before a release were to reach Bear Creek Bay.

The USACE has requested Keystone extend transit models to 27 hours to quantify the theoretical transport distance for a release in this drainage, assuming no emergency response. In the unlikely event of a release that occurred near MP 106 while water was flowing (50 percent * incident probability = 0.00014; equivalent to once in 33,200 years for any size of release) and the volume was sufficient to reach Bear Creek Bay in appreciable quantities and emergency response did not occur for 27 hours, the release would be still be entirely contained within Bear Creek and Bear Creek Bay. A release would take 31.5 hours to move from the mouth of Bear Creek to the mainstem of Fort Peck Reservoir.

6.0 Summary

This SSRA tiers off of the Missouri SSRA. This assessment quantitatively evaluated the site-specific probability of a release within Bear Creek drainage, the potential for downstream transport, transit times and distances to specific locations in the Fort Peck Reservoir, potential effects on water quality, and the GRP that would be used for emergency response to contain and remove crude oil from the environment.

To provide a fulsome discussion on the environmental fate and behavior of crude oil, potential effects to water quality, and emergency response practices, much of the Bear Creek SSRA is predicated on the assumption that a release could reach Bear Creek Bay, despite the low possibility of such an event.

The results of the Bear Creek SSRA are summarized as follows:

A release capable of reaching the waters of the Bear Creek and subsequently Fort Peck Reservoir is unlikely for the following reasons:

- 1) Based on the site-specific incident frequency and a crossing distance of 0.21 mile (including a 500-foot buffer beyond the HDD entry and exit points on both sides of the river²), the probability of a release at the Bear Creek is once in 16,600 years.
 - a. Most releases are small (3 bbl or less) with an occurrence interval of once in 33,200 years or more.
 - b. The probability of a release of WCD is estimated to be no more than once in 2,230,000 years.
- 2) Bear Creek does not flow the majority of the time and crude oil would not reach Bear Creek Bay if water was not flowing.
- 3) If a release occurred when Bear Creek was flowing, the release would move downstream, and in some circumstances, may reach Bear Creek Bay.
 - a. A release would need to be transported 15 miles downstream Bear Creek.
 - b. Once crude oil reached Bear Bay, the oil would spread across the surface of Bear Creek Bay. The rate of spread was assumed to be 300 m/hr.

² The 500-foot buffer distance beyond the HDD entry and exit points was used for consistency with the previous Keystone risk assessments, which is normally measured from top-of-bank. Given the HDD setback distances and site-specific terrain considerations, the additional buffer is hyper-conservative from an overland transport perspective. Nevertheless, the buffer was retained since it increased the river crossing distance and, therefore, increased the incident frequency (i.e., intentional overestimates predicted risk).

- c. Even if crude oil were to reach Bear Creek Bay, it would not move into the mainstem of the Fort Peck Reservoir in either the 6- or 27-hour timeframes.
- d. Based on the scenarios examined, it would take almost 50 hours before crude oil could reach either the dam or spillway of Fort Peck Reservoir.

In the unlikely event that a release reached Bear Creek Bay, significant effects to water quality are unlikely because:

- 1) The amount of crude oil would be insufficient to exceed the drinking water MCL, even with extremely conservative assumptions that overestimate benzene concentrations. Further, no water intakes are located on Bear Creek Bay.
- 2) The amount of crude oil would be insufficient to exceed acute or chronic aquatic life criteria, even with extremely conservative assumptions that overestimate benzene concentrations.
- 3) All representative crude oils are predicted to float on the surface of the water for 5 days or more, allowing time for containment and cleanup.
- 4) In winter when the reservoir is covered with ice, spreading would be substantially reduced.

Emergency response tactics would further reduce the potential for effects to water quality.

- 1) Emergency response equipment and trained personnel would be pre-positioned to provide a prompt emergency response to a release. Federal regulations stipulate that a pipeline operator, such as Keystone, have sufficient resources available so the company could respond to a WCD event.
- 2) Pre-prepared GRPs would identify tactics and equipment to deploy, allowing responders to arrive and begin implementation of the plan rather than planning a response once the event has occurred.
- 3) Although effects to drinking water are not anticipated, Keystone has made a Project-wide commitment to provide potable water to the public if drinking water was affected by a release.

Emergency response would contain and cleanup crude oil from the environment.

- 1) The representative crude oils are predicted to float for days to weeks, allowing emergency responders time to contain and cleanup crude oil using traditional cleanup methods.
- 2) Even in winter, emergency response teams can contain and cleanup crude oil with tactics that have been successfully employed in other incidents.
- 3) Submerged crude oil takes time to form and is facilitated by flooding and other causes of turbulence that incorporates sediment and debris into weathered oil. If submerged oil does occur, crude oil may rise to the water surface with changes in environmental conditions and loss of debris from the amalgamations. There are multiple techniques used to recover submerged oil.
- 4) Keystone would be responsible for costs associated with a release, including cost reimbursement for Federal and provincial agency employees deployed to the site.
- 5) Keystone would not be legally released from the site until applicable regulatory agencies are satisfied that appropriate end points have been reached.

The Bear Creek SSRA concludes that the possibility of a release at the Bear Creek would be highly improbable. In the unlikely event of a release, the release is unlikely to reach Bear Creek Bay because release volumes likely would be small and because the stream is intermittent and unable to reach Fort Peak Reservoir. If the creek was flowing and crude oil were to reach the reservoir, even a very large release would be unlikely to exceed drinking water MCL and aquatic life thresholds. Crude oil would float

on the river's surface for days or longer. Keystone would activate emergency response procedures and responders would be on-site within 6 hours and would implement pre-planned tactics that are appropriate for the site and environmental conditions. Cleanup and recovery would continue until applicable regulatory agencies concurred that cleanup levels protective of the human health and the environment had been met. Compliance with regulations, application of Keystone's Integrity Management Program and Emergency Response Plan, as well as adherence to safety procedures, will help to ensure long-term environmentally responsible and safe operation of the pipeline.

7.0 References

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Ramade, F. 1978. Elements d'ecologie Appliquee Action du l'homme sur la Bioshere. Ediscience, Paris. as cited in Patin, S. 1998. Oil Spills in the Marine Environment.

Shafizadeh, A. 2010. Bakken [Powerpoint slides]. Crude Oil Quality Association. Internet website: http://www.coqa-inc.org/06102010_Shafizadeh.pdf. June 10, 2010.

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