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Downstream Areas Data Assessment Report

Mayflower Pipeline Incident Response
Mayflower, Arkansas

March 2014

Revision 5

ARCADIS

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Acronyms and Abbreviations

95% UCL	95 percent upper confidence limit on the mean
95% UTL	95 percent upper tolerance level
ADEQ	Arkansas Department of Environmental Quality
AGFC	Arkansas Game and Fish Commission
ARCADIS	ARCADIS U.S., Inc.
ATSDR	Agency for Toxic Substances and Disease Registry
bgs	below ground surface
bss	below sediment surface
COPEC	constituent of potential ecological concern
cy	cubic yards
DARSP	Downstream Areas Remedial Sampling Plan
DTI	Dakota Technologies, Inc.
EcoSSLs	Ecological Soil Screening Levels
EMPCo	ExxonMobil Pipeline Company
ERA	ecological risk assessment
ESV	ecological screening value
FOD	frequency of detection
GPS	global positioning system
HMW	high molecular weight
LIDAR	Laser Imaging, Detection, and Ranging
LIF	laser-induced fluorescence
LMW	low molecular weight
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
mg/kg	milligrams per kilogram

mg/L	milligrams per liter
MNR	monitored natural recovery
MS	matrix spike
MSD	matrix spike duplicate
NAD83	North American Datum of 1983
NAPL	nonaqueous phase liquid
NAVD88	North American Vertical Datum of 1988
NGS	National Geochemical Survey
PAH	polycyclic aromatic hydrocarbon
PID	photoionization detector
QA	quality assurance
QC	quality control
RAO	remedial action objectives
RCRA	Resource Conservation and Recovery Act
report	Downstream Areas Data Assessment Report
RPD	relative percent difference
SDG	sample delivery group
site	Mayflower Pipeline Incident Response located in Mayflower, Arkansas
SOP	Standard Operating Procedure
SPE	solid-phase extraction
TCE	trichloroethene
TEH	total extractable hydrocarbon
TOC	total organic carbon
TSS	total suspended solids
TU	toxic unit

USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
UCL	upper confidence level
UTL	upper tolerance level
VOC	volatile organic compound

Executive Summary

Introduction

This Downstream Areas Data Assessment Report for the Mayflower Pipeline Incident Response located in Mayflower, Arkansas presents the results of environmental sampling conducted in accordance with the Downstream Areas Remedial Sampling Plan (DARSP), which was approved by the Arkansas Department of Environmental Quality (ADEQ) on July 12, 2013. The DARSP was designed to evaluate soil, sediment, and surface water conditions following the emergency response actions that were implemented immediately after a release of Wabasca heavy crude oil from the Pegasus Pipeline. Sampling and investigation work targeted three general areas downstream of the release location as shown on Figure 1-1 (drainage ways, Dawson Cove, and Lake Conway), as well as background locations in the drainage ways and Lake Conway to meet the primary objectives:

- Characterize current soil, sediment, and surface water quality.
- Compare analytical results for soil, sediment, and surface water to established quantitative risk-based screening levels.
- Develop a preliminary assessment of background soil and sediment quality in Lake Conway and in the drainage ways.

In addition to the primary objectives, this report includes a refined risk evaluation of the soil and sediment sampling results, a summary of sheen monitoring results in the drainage ways and Dawson Cove, and an evaluation of remedial alternatives potentially capable of mitigating surface water sheens that are related to crude oil from the Pegasus Pipeline.

Sampling Program

Soil and sediment sampling activities were completed between July and August 2013; additional activities included a topographic survey in Dawson Cove and a depositional assessment in Lake Conway. Surface water sampling has been ongoing since March 29, 2013. The key findings of these sampling activities are summarized below.

Sediment and Soil Sampling

A total of 99 soil samples and 178 sediment samples were collected from 83 locations and submitted for laboratory analysis in July and August 2013. In addition, six background soil samples and 12 background sediment samples were collected from 18 locations and submitted for laboratory analysis. Samples were collected from the drainage ways, Lake Conway, Dawson Cove and background locations. Out of the 101 sampling locations, 18 were background locations. Samples were analyzed for polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs), and metals; surface samples were also analyzed for grain size, black carbon, and total organic carbon. Additionally, a total of 18 sediment samples were collected from the six Lake Conway locations that were re-sampled in November 2013. These samples were analyzed for the same compounds as the original samples.

Surface Water Sampling

More than 2,900 samples were collected as part of a daily surface water monitoring program focused primarily on Lake Conway, but also including locations in the drainage ways and Dawson Cove, from March 29, 2013 through October 31, 2013. Surface water samples were analyzed for PAHs, VOCs, total metals, dissolved metals, and oil and grease. In August 2013, six surface water samples were also collected from the drainage ways and Dawson Cove as part of a one-time event for the DARSP activities. The DARSP surface water samples were also analyzed for total suspended solids. A weekly surface water sampling program was initiated on November 1, 2013 for PAH analyses only, as approved by the ADEQ. As a part of this program, a total of 233 samples have been collected from the drainage ways, Dawson Cove, and Lake Conway between November 1, 2013 and February 9, 2014.

Data Evaluation

The data collected as part of this program were compared to ecological screening values (ESVs) and background concentrations in accordance with the approach described in the DARSP. The ESVs are concentrations below which risk to ecological receptors is considered de minimus. Concentrations above the ESVs do not necessarily imply that ecological risk exists; only that a refined risk evaluation is warranted. Based on direction from the ADEQ, the risk screening process is focused on ecological risks.

The screening approach consisted of the following:

- Evaluate whether the analyte was associated with the crude oil at concentrations that could have resulted in the observed concentrations in the sampling media.
- Compare detected concentrations of metals to Arkansas background, and if the concentrations are above Arkansas background, compare to ESVs.
- Compare detected concentrations of VOCs to ESVs.
- Compare detected concentrations of PAHs to ESVs, and evaluate toxic units for PAH mixtures in sediment and DARSP surface water samples. The toxic unit value is used to evaluate whether concentrations of PAHs in sediment are acceptable for the protection of benthic organisms and whether concentrations of PAHs in surface water are acceptable for the protection of aquatic organisms.

Topographic survey data from Dawson Cove were used to identify the transitional area associated with seasonal fluctuations in Lake Conway. Sample data from this transitional area were screened against both sediment and soil screening values.

Results of Screening Data Evaluation

The screening data evaluation process eliminated a number of constituents from further consideration because they were not associated with crude oil, were below the ESVs, or were indicative of background conditions. The constituents that were not eliminated were further assessed in a refined ecological risk evaluation. The following provides a summary of the soil and sediment evaluation by area, and a summary of the overall surface water sampling results.

Drainage Ways Soil and Sediment Results

A total of 45 soil samples were collected at 15 locations along the banks of the drainage ways. Based on the screening results, 42 of the 45 soil samples do not require further evaluation. Three soil samples had a benzene concentration or PAH summation above the ESV; therefore, a refined risk evaluation for those constituents in soil was conducted. Based on the results of the refined risk evaluation, no adverse effects are expected to ecological populations from exposure to those constituents in soil in the drainage ways.

A total of 35 sediment samples were collected at 13 locations in the drainage ways. Based on the screening approach, sediment in the drainage ways does not warrant further evaluation.

Dawson Cove Soil and Sediment Results

A total of 54 soil samples were collected at 15 locations in Dawson Cove. Based on the screening results, concentrations in 50 of 54 soil samples were at levels that do not require further evaluation. Four samples had a PAH summation above the ESV, therefore, a refined risk evaluation for PAHs in soil was conducted. Based on the refined risk evaluation, no adverse effects are expected for ecological populations from exposure to PAHs in soil in Dawson Cove.

A total of 125 sediment samples were collected at 34 locations in Dawson Cove. Based on the screening results, concentrations in 118 of 125 sediment samples were at levels that do not require further evaluation. Seven samples had xylenes and/or isopropylbenzene above the ESV; therefore, a refined risk evaluation for those constituents in sediment was conducted. Based on the refined risk evaluation, no adverse effects are anticipated for aquatic life in Dawson Cove sediment.

Lake Conway Sediment Results

A total of 18 sediment samples were collected at six locations in Lake Conway. Based on the screening results, sediments in Lake Conway do not warrant further evaluation. As requested by ADEQ, these six locations were re-sampled in November 2013, and additional 18 sediment samples were collected. The Lake Conway sediment results from November 2013 are consistent with the original sampling results from July and August 2013.

Surface Water Results

More than 3,200 surface water samples have been collected between March 29, 2013 and February 9, 2014 as part of an ongoing surface water monitoring program focused primarily on Lake Conway, but also including locations in the drainage ways and Dawson Cove. The data evaluation results for recent surface water samples indicate that no further action is warranted, however, monitoring will continue on weekly basis.

Sheen Monitoring

Daily sheen monitoring activities in the drainage ways and Dawson Cove were initiated on October 21, 2013, in accordance with the Sheen Monitoring and Maintenance Plan submitted to the ADEQ on October 18, 2013. Two sheen sampling events were also conducted in November 2013 and January 2014. Based on the data evaluation, the limited areas with crude-oil-related sheens appear to be primarily located in the Dawson Cove Inlet Channel and the Open Water Area (west of the heavily vegetated area).

Recommended Path Forward

Ongoing Surface Water Sampling

Based on the surface water evaluation, continued weekly surface water sampling for PAHs is recommended at two locations in Dawson Cove and three locations in Lake Conway.

Ongoing Sheen Monitoring and Maintenance

Based on the sheen monitoring and sampling evaluation, continued sheen monitoring and removal of sheens in Dawson Cove will continue one time per week and following rainfall events. In addition, a weekly assessment of the sorbent boom capacity to sorb sheens will be completed to evaluate the frequency of replacing the booms. Sheen monitoring in the drainage ways will be discontinued.

Design and Implementation of Preferred Remedial Alternative

The remedial action objective (RAO) identified for the site is to mitigate surface water sheens related to crude oil from the Pegasus Pipeline, to the extent practicable. The areas for remedial action (Figure 12-1) are based on the sheen monitoring, which indicates that sheens related to the crude oil from the Pegasus Pipeline are primarily located in the Dawson Cove Inlet Channel and Open Water Area. In addition, it is anticipated that a portion of the Heavily Vegetated Area still contains sheen-bearing material related to crude oil. Based on the screening data evaluation and refined ecological risk evaluations, no further mitigation of the soil and sediment in drainage ways, Dawson Cove, or Lake Conway is necessary for the protection of ecological receptors.

A screening evaluation of potential remedial options was completed to identify technologies to achieve the site RAO. The retained technologies were assembled into five site-wide remedial alternatives for the Inlet Channel, Open Water Area, and Heavily Vegetated Area. The evaluation was conducted using a seven-criteria matrix. Based on the ranking, the preferred remedial alternative to meet the site RAO is to use a combination of targeted removal in the Dawson Cove Inlet Channel, reactive capping in the Open Water Area, and targeted in-situ amendment placement in the Heavily Vegetated Area. A pre-design study will be conducted to confirm and refine the mitigation areas, verify the preferred remedial approach, support the permitting of the preferred remedial alternative, and to support the development of a Mitigation Action Plan. Concurrent with the development of the Mitigation Action Plan, the permitting process will be initiated.

1. Introduction

ARCADIS U.S., Inc. (ARCADIS) has prepared this Downstream Areas Data Assessment Report (report) for ExxonMobil Environmental Services Company on behalf of ExxonMobil Pipeline Company (EMPCo) for the Mayflower Pipeline Incident Response located in Mayflower, Arkansas (the site). For the purposes of this report, the site consists of areas located downstream from the residential neighborhood affected by the incident. This report presents the results of environmental sampling conducted under the Downstream Areas Remedial Sampling Plan (DARSP; ARCADIS 2013a), which was approved by the Arkansas Department of Environmental Quality (ADEQ) on July 12, 2013. ARCADIS conducted the sampling activities in July and August 2013 in the areas shown on Figure 1-1. This report also presents a refined risk evaluation of the soil and sediment sampling results, a summary of sheen monitoring results in the drainage ways and Dawson Cove, and an evaluation of remedial alternatives potentially capable of mitigating surface water sheens that result from crude oil from the Pegasus Pipeline.

ARCADIS submitted the Downstream Areas Data Assessment Report to the ADEQ on October 11, 2013. A revised report (Revision 1) was submitted on November 1, 2013, to incorporate comments received from ADEQ and the Arkansas Game and Fish Commission (AGFC) on October 24, 2013. The second revised report (Revision 2) was submitted on November 8, 2013, to incorporate the final laboratory data validation results. The third revised report (Revision 3) was submitted on December 2, 2013, to incorporate a second round of comments received from ADEQ and AGFC on November 19, 2013. This fourth revised report (Revision 4) was submitted on January 17, 2014, and incorporates results from sampling that was conducted after the October 11, 2013 submittal, as well as additional comments received from ADEQ on December 13, 2013. This current report (Revision 5) incorporates additional comments received from ADEQ on February 19, 2014.

1.1 Background

On March 29, 2013, a breach in a pipeline operated by EMPCo (the 20-inch Pegasus Pipeline) released crude oil into a residential neighborhood in Mayflower, Arkansas. The crude oil was identified to be Wabasca heavy crude oil (herein referred to as “crude oil”). An emergency response action was implemented immediately to mitigate the release, and removed a substantial amount of the crude oil. The area addressed by the DARSP (ARCADIS 2013a) includes a drainage way that leads from a residential neighborhood near the Pegasus Pipeline release point to a shallow drainage swale along North Main Street, which then flows east under Highway 365 and Interstate 40 (I-40) into a marsh known as Dawson Cove (Figure 1-1). Dawson Cove is separated from Lake Conway by Highway 89, with water conveyed between the cove and Lake Conway by two culverts beneath the highway.

The DARSP (ARCADIS 2013a) was designed to evaluate the current conditions in soil, sediment, and surface water following the response actions. Specifically, the DARSP defines five operational areas where sediment, soil, and surface water samples were collected in July and August 2013 (Figure 1-1). These areas are in sequence from upstream to downstream and are described below:

- Subsection A-Main – shallow ditch along North Main Street
- Subsection A-365W – shallow ditch between North Main Street and Highway 365
- Subsection A-365E – shallow ditch between Highway 365 and I-40
- Subsection B-Dawson Cove – marsh located between I-40 and an area labeled for purposes of the response as Division B-On Water
- Subsection B-On Water – open water area located between Division B-Dawson Cove and the Highway 89 bridge

In addition to these five areas, sediment sampling was conducted at locations in Lake Conway, north of Highway 89, to verify that sediments in Lake Conway have not been affected by the Mayflower Pipeline release. Lastly, background locations were targeted for soil and sediment sampling to characterize soil and sediment unaffected by the crude oil release; these samples were obtained from drainage ways upstream of the release area and distant locations within Lake Conway (see Figure 1-2).

The following terms are used in this report to describe the three general areas downstream of the release point where post-response conditions were assessed:

- *Drainage ways*. Subsections A-Main, A-365W, and A-365E, which are the shallow drainage ditches from the neighborhood to Dawson Cove
- *Dawson Cove*. Subsections B-Dawson Cove and B-On-Water
- *Lake Conway*. Lake Conway (not including Dawson Cove)

Samples were classified as soil or sediment based on their location. In the drainage ways, samples from along the banks were classified as soil and locations within the flow channel were classified as sediment, regardless of whether there was water present at the time of sampling. In Dawson Cove, where water levels fluctuate seasonally, locations submerged at the time of sampling were classified as sediment, and those not submerged were classified as soil. For risk screening purposes, data for samples in the transitional zone between seasonal high and low water levels were screened as both soil and sediment.

1.2 Objectives

The data generated as part of the DARSP (ARCADIS 2013a) sampling activities the primary objectives:

- Characterize current soil, sediment, and surface water quality.
- Compare analytical results for soil, sediment, and surface water to established quantitative risk-based screening levels.
- Develop a preliminary assessment of background soil and sediment quality in Lake Conway and in the drainage ways.

Details of the field sampling effort, including the specific methodologies and analyses, are discussed further in Section 2.

In addition to the DARSP field effort, a sheen monitoring program was implemented on October 21, 2013 (EMES 2013) with the following primary objectives:

- Observe and characterize sheens daily in the downstream areas (i.e., drainage ways, Dawson Cove, and Dawson Cove Outlet to Lake Conway).
- Conduct sampling and analysis of sheens to support the determination of whether sheens are related to the crude oil or to other sources of sheens (e.g., naturally-occurring and road/rail/parking runoff).
- Remove petrogenic sheens, to the extent practicable, from the downstream areas.

Sheen monitoring results are discussed further in Section 11.

1.3 Report Organization

The remainder of this report is organized into the following sections:

2 – Summary of Sampling Program	Summarizes the sampling activities that were conducted for soil, sediment, and surface water (including background locations); Dart sampling in soil and sediment; and assessing sediment depositional layers in Lake Conway.
3 – Topographic Survey	Discusses the topographical survey activities conducted at the site and the water levels in Lake Conway and Dawson Cove.
4 – Data Quality and Data Management	Describes the data reviews that were performed to evaluate the data quality, and the management and handling of the data.
5 – Data Evaluation Methods and Screening Approach	Presents the screening approach and data evaluation process used to compare the data collected as part of this program to applicable screening values.
6 – Soil Sampling Evaluation and Results	Discusses the analytical results and data analysis for soil samples collected in the drainage ways and Dawson Cove.
7 – Sediment Sampling Evaluation and Results	Discusses the analytical results and data analysis for the sediment sampling in the drainage ways, Dawson Cove and Lake Conway.
8 – Surface Water Sampling Evaluation and Results	Summarizes the analytical results and data analysis for surface water samples collected from the drainage ways, Dawson Cove, and Lake Conway.
9 – Summary of Analytical Findings and Screening Evaluation Results	Presents a summary of the screening results for each area of the site.

10 – Refined Ecological Risk Evaluation	Presents a summary of the refined risk evaluation results for the locations identified for further evaluation based on the screening results.
11 – Sheen Monitoring and Sampling	Summarizes the results of the sheen monitoring program, and discusses the data analysis for sheen samples collected in the downstream areas.
12 – Remedial Alternatives Evaluation	Describes the remedial alternatives evaluation process, which included screening remedial technologies, developing site-wide alternatives, and evaluating alternatives to select a preferred option.
13 – Recommended Path Forward	Presents a recommended path forward.
14 – References	Lists the references cited throughout this report.

Tables and figures are also included to provide further detail, as appropriate, and a series of appendices has been compiled to provide supporting data for the discussions included in the main text. The appendices are as follows:

- Appendix A – Field Notes
- Appendix B – Sediment and Soil Photo Logs
- Appendix C – Lake Conway Depositional Layer Assessment Photographs
- Appendix D – Topographic Survey Data and Channel Cross-Sections
- Appendix E – Dart Sampling and Laser-Induced Flourescence Results
- Appendix F – Analytical Data Tables
- Appendix G – Laboratory Reports
- Appendix H – Box Plots
- Appendix I – Ecological Effects Evaluation
- Appendix J – Toxic Unit Calculations
- Appendix K – Analytical Data Tables – Detected Analytes Only

- Appendix L – Refined Ecological Risk Evaluation
- Appendix M – Sheen Monitoring and Sampling Summary
- Appendix N – Remedial Alternatives Evaluation
- Appendix O – Pre-Design Study

2. Summary of Sampling Program

The DARSP activities occurred during three primary mobilizations in July and August 2013. A topographic survey and utility clearance were conducted between July 15 and 20, 2013, with additional survey activities completed as needed in August 2013. Soil, sediment, and surface water sampling associated with DARSP was conducted between July 27 and August 16, 2013, and included Dart sampling in soil and sediment. An assessment of sediment depositional layers in Lake Conway was conducted between August 27 and 29, 2013. Dart sampling is described in the DARSP (ARCADIS 2013a), and involves the temporary deployment of an adsorbent fiber into the soil or sediment, followed by laboratory observation for light fluorescence, which indicates the presence of polycyclic aromatic hydrocarbons (PAHs). Field notes from the sampling activities described in this section are presented in Appendix A.

2.1 Topographic Survey

The topographic survey conducted in accordance with the DARSP (ARCADIS 2013a) included a total of 13 topographic cross sections in the drainage ways and 16 topographic/bathymetric cross sections in Dawson Cove at approximately 300-foot intervals. The survey was conducted using a real-time kinematic global positioning system (GPS). Coordinates were recorded in North American Datum of 1983 (NAD83) and elevations in North American Vertical Datum of 1988 (NAVD88).

In addition to the survey activities, a staff gage was installed on July 18, 2013 in Dawson Cove near the culverts beneath Highway 89 and the gage was read daily to record water levels.

2.2 Soil Sampling

Soil samples were collected at a total of 30 locations in the drainage ways and in Dawson Cove. Background soil samples were collected at six locations adjacent to Lake Conway. Sample locations were surveyed using a handheld GPS unit and soil samples were collected using hand auger or hand trowel techniques according to the process outlined in Section 2.5.2 of the DARSP (ARCADIS 2013a). Soil sample locations along the drainage ways and in Dawson Cove are shown on Figures 2-1, 2-2, and 2-3. Background soil sampling locations are shown on Figure 2-5.

Surface soil samples (0 to 0.5 foot below ground surface [bgs]) were collected as five-point composite samples, except in drainage way A-365E, where only one core sample was collected due to the steep slope of the banks. Appendix B (B-1 through B-39) presents photos of the ground conditions at the composite sample locations. Shallow subsurface soil samples (0.5 to 1 foot and 1 to 1.5 feet bgs) were collected using a hand auger at the center of each composite grid. At three soil sampling locations in Dawson Cove, a hand auger was used to collect deep soil cores to a target depth or refusal, with a goal of at least 3 feet.

Samples were collected and processed according to the Standard Operating Procedures (SOPs) in Attachment A of the DARSP (ARCADIS 2013a). At each sample location, soil to be analyzed for volatile organic compounds (VOCs) was collected from the center sample point only. After the VOC sample kits were filled for the surface soil, the soil was placed in aluminum pans designated for each sample depth interval and the VOC sample kits were filled for the subsurface soil. At a secondary location, each sample interval was screened with a photoionization detector (PID), photographed, described according to Unified Soil Classification System, homogenized, and placed into soil chemistry jars. Tables 2-1 and 2-2 summarize the soil and background soil sampling locations, and include core depths, sample depth intervals, and the number of samples sent for laboratory analysis. Appendix B (B-1 through B-39) presents photos of the soil samples.

Ninety-nine soil samples and six duplicate samples were submitted for laboratory analysis, including 30 surface soil samples (26 from five-point composite sampling grids) and 69 subsurface samples. Surface soil samples from six background locations (six samples) were also submitted for analysis. Soil samples were analyzed for VOCs, PAHs (two- to six-ring PAHs including Priority Pollutant PAHs and two- to four-ring PAH alkyl groups), and metals (eight Resource Conservation and Recovery Act [RCRA] metals, plus nickel and vanadium)[1]; Table 2-3 lists the individual analytes. Surface soil samples were also analyzed for grain size, black carbon, and total organic carbon (TOC). The soil samples submitted for analysis and associated laboratory methods are summarized in Table 2-4.

Some soil sample locations targeted in the DARSP (ARCADIS 2013a) were adjusted or reclassified based on site conditions at the time of sampling. Variations from the DARSP are described below:

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[1] The nine deep subsurface soil samples (deeper than 1.5 feet bgs) were held for possible future analysis of metals and/or PAHs. Due to short holding times for VOC analysis, the samples were analyzed for moisture content and VOCs.

- Two soil sample grids along Main St (SO-DA-001 and SO-DA-002) were enlarged slightly to accommodate an adequate buffer around a shallow buried utility line.

- Thirteen soil locations in Dawson Cove, including two targeted for deep cores and Dart sampling, were reclassified in the field as sediment matrix samples when the locations were found to be inundated with water.

- The two background locations farthest north in Lake Conway were relocated from the west side of I-40 to the east side of I-40 due to restricted access from a construction site near the original target locations.

2.3 Sediment Sampling

Sediment samples were collected at 53 locations within the drainage ways, Dawson Cove, and Lake Conway. Sediment sample locations are shown on Figures 2-1 through 2-4. Background sediment samples were collected from six distant locations in Lake Conway upstream of the generalized flow path from Dawson Cove to the Lake Conway dam (see Figure 2-5) and six locations in shallow ditches upstream of the primary drainage path from the residential area to Dawson Cove (see Figure 2-6). At most locations, sediment samples were collected by hand driving a 3-inch-diameter Lexan core tube. Where shallow utilities or minimal water was present, hand trowel or hand auger techniques were used. Sediment was collected to a depth of 12 or 18 inches, except at a subset of 9 sediment sample locations where cores were pushed to a depth of up to 3 to 4 feet. Tables 2-5 and 2-6 summarize the sediment and background sediment sampling locations and include core recovery depths, number of samples sent for analysis, and number of samples currently on hold at the laboratories. Appendix B (B-40 through B-104) presents photos and descriptions of each sediment core.

Samples were collected and processed according to the SOPs in Attachment A of the DARSP (ARCADIS 2013a). Sediment cores collected with Lexan tubes were photographed and then cut open length-wise using electric shears. The open core was then sectioned into a surface sample (0 to 0.5 foot bgs) and subsurface sampling intervals (0.5 to 1 foot, 1 to 1.5 feet, 1.5 to 2 feet bgs; and subsequent 1-foot intervals). From the open core, VOC sample kits were filled, and the sediment was screened with a PID, photographed, and described. Each sample interval was then homogenized in an aluminum pan and placed into sediment chemistry jars. Sediment collected using hand trowel or hand auger techniques were processed in the same manner as the soil samples described in Section 2.2.

A total of 178 sediment samples (eight of these had duplicate samples) were submitted for laboratory analysis from the area of interest, including 53 surface sediment samples and 125 subsurface samples (in addition to the duplicates). Surface sediment samples from 12 background locations (12 samples, plus one duplicate sample) were also submitted for analysis. All sediment samples were analyzed for VOCs, PAHs (two- to six-ring PAHs including Priority Pollutant PAHs and 2- to 4-ring PAH alkyl groups)[2], and total metals (RCRA 8 metals, plus nickel and vanadium)[3]; Table 2-3 lists the individual analytes. Surface sediment samples were also analyzed for total extractable hydrocarbons (TEH), grain size, black carbon, and TOC. Table 2-4 summarizes the sediment samples submitted for analysis and the associated laboratory methods.

Some sediment sample locations targeted in the DARSP (ARCADIS 2013a) were adjusted or the sample methodology was modified based on site conditions at the time of sampling. Variations from the DARSP are described below:

- Thirteen sample locations (initially planned as soil) in Dawson Cove were classified in the field as sediment after observing that the locations were inundated with water.

- One background location farthest north in Lake Conway was relocated from the west side of I-40 to the east side of I-40 due to restricted access from a construction site near the original target locations.

- Hand trowels were used instead of Lexan core tubes to collect sediment samples from drainage ways where shallow utilities were present (sediment sample locations along North Main St. and two background drainage way locations [SED-DA-BG-001 and SED-DA-BG-002]).

- Hand augers were used instead of Lexan core tubes to collect sediment samples from drainage ways where minimal water was present and the consolidated nature

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[2] Up to 88 individual PAH compounds were analyzed in the surface sediment samples; however, many of these compounds, primarily heterocyclic PAHs, were analyzed for forensic (i.e., source identification) purposes, and are not included for risk screening evaluations.

[3] The 26 deep subsurface soil samples (deeper than 1.5 feet bgs) were held for possible future analysis of metals and/or PAHs. Due to short holding times for VOC analysis, the samples were analyzed for moisture content and VOCs.

of the materials resulted in inadequate recovery using the Lexan tube technique (locations SED-DA-005 through SED-DA-008, and SED-DA-010 through SED-DA-013 and one background drainage way location SED-DA-BG-003).

Six sediment locations in Lake Conway (Figure 2-4) were re-sampled on November 19 and 20, 2013, as requested by the ADEQ. These samples were collected to a depth of 18 inches by hand driving a 3-inch-diameter Lexan core tube into the sediment. Six surface sediment samples (plus one duplicate sample) and 12 subsurface sediment samples were collected and analyzed for the same compounds as the original Lake Conway sediment samples (Table 2-3, Table 2-4, and Table 2-5). Appendix B (B-105 through B-110) presents photographs and descriptions of each re-sampled sediment location.

2.4 Soil and Sediment Dart Samplers

Dart samplers were installed at deep core locations (three soil and seven sediment) in Dawson Cove to provide a profile of relative PAH concentration versus depth in soil or sediment. Dart locations are identified in Tables 2-1 and 2-5.

Dart samplers were provided by Dakota Technologies, Inc. (DTI) and were installed according to the SOP and Sampling Approach included in Attachments A and C of the DARSP, respectively (ARCADIS 2013a). Dart sampling is a passive sampling technique that evaluates the presence of polycyclic aromatic hydrocarbons (PAHs) present in crude oil. Darts were installed by hand to a depth of approximately 4 feet using a modified slide hammer. Darts were left in place for 48 hours to equilibrate with the surrounding PAH concentrations, allowing PAHs to sorb into the solid-phase extraction coating of the Dart fiber. After 48 hours, Darts were retrieved, wiped clean of any large pieces of residual soil or sediment, wrapped in aluminum foil, and shipped to DTI for reading. The Darts were run through a laser-induced fluorescence (LIF) reader to create a graphical log of florescence response that correlates to the total available PAH content of the soil or sediment versus depth. Results of the Dart readings are included in Appendix E.

2.5 Surface Water Sampling

This section summarizes the surface water sampling activities conducted in the downstream areas. Daily surface water sampling began on March 29, 2013 and continued through October 31, 2013; sampling transitioned to weekly beginning on November 1, 2013. Sampling focused primarily on Lake Conway, but also included locations in the drainage ways and Dawson Cove. In addition, six surface water samples were collected from the drainage ways and Dawson Cove on August 13 and 15, 2013 as part of the DARSP activities.

2.5.1 Daily Surface Water Sampling Program

To monitor surface water quality in the downstream areas, surface water samples were collected daily from historical and current sample locations (13 total) between March 29 and October 31, 2013 (see Figure 2-7). These samples were collected from the drainage ways, Dawson Cove, and Lake Conway in accordance with the Surface Water Sampling and Analysis Plan (Attachment B of the DARSP; ARCADIS 2013a). Samples were collected as grab samples from the surface and/or from discrete depth interval samples at each location. The 13 sampling locations are shown in the table below:

Surface Water Monitoring Locations	Location ID	Depth Interval (feet)
Locations accessed by foot		
Background drainage way (when flowing)	WS-BKG-002	Surface
Drainage way along North Main Street (when flowing)	WS-008	Surface
Dawson Cove	WS-007	0.5-1.0
Lake Conway near Dawson Cove	WS-001	0.5-1.0
	WS-006	0.5-1.0
Lake Conway downstream from Dawson Cove	WS-002	Surface
Lake Conway Dam	WS-003	Surface
Lake Conway background	WS-005	Surface
Palarm Creek	WS-018	Surface
Locations accessed by boat		
Lake Conway near Dawson Cove	WS-010	1.5-2.0, 80% of water depth
Lake Conway downstream from Dawson Cove	WS-011	1.5-2.0, 80% of water depth
	WS-012	1.5-2.0, 80% of water depth
Lake Conway north of Dawson Cove	WS-014	1.5-2.0, 80% of water depth

Samples collected from these areas were analyzed for VOCs, PAHs (Priority Pollutant PAHs), total metals (RCRA 8 metals plus nickel, vanadium, calcium, and magnesium), dissolved metals (RCRA 8 metals plus nickel and vanadium), and oil and grease

(Table 2-8). In addition, pH, conductivity, temperature, turbidity, and dissolved oxygen are measured at each sample location.

2.5.2 Weekly Surface Water Sampling Program

Surface water monitoring transitioned from daily to weekly in November 2013 in accordance with the Surface Water Sampling and Analysis Plan that was submitted to ADEQ on November 1, 2013 (ARCADIS 2013b). A total of 233 surface water samples were collected from the drainage ways, Dawson Cove, and Lake Conway between November 1, 2013 and February 9, 2014 (see Figure 2-8). Samples were collected as grab samples from the surface and/or from a discrete depth interval at each location. Weekly samples are collected from the following 13 locations:

Surface Water Monitoring Locations	Location ID	Depth Interval (feet)
Locations accessed by foot		
Drainage way along North Main Street (when flowing)	WS-008	Surface
Dawson Cove	WS-004	0.5-1.0
	WS-007	0.5-1.0
Lake Conway near Dawson Cove	WS-001	0.5-1.0
	WS-009	Surface
	WS-021	Surface
Locations accessed by boat		
Dawson Cove	WS-020	Surface
Lake Conway near Dawson Cove	WS-006	0.5-1.0
	WS-010	1.5-2.0, 80% of water depth
Lake Conway downstream from Dawson Cove	WS-011	1.5-2.0, 80% of water depth
	WS-012	1.5-2.0, 80% of water depth
Lake Conway north of Dawson Cove (background)	WS-014	1.5-2.0, 80% of water depth
	WS-015	1.5-2.0, 80% of water depth

The weekly surface water samples are analyzed for Priority Pollutant PAHs only (Table 2-8). In addition, pH, conductivity, temperature, turbidity, and dissolved oxygen were measured at each location.

2.5.3 One-time Surface Water Sampling Event

On August 13 to 15, 2013, surface water samples were collected from the drainage ways and Dawson Cove at the locations shown on Figure 2-9 and summarized in Table 2-7.

Samples were collected as grab samples from six locations (six samples, plus one duplicate sample) (Figure 2-9). Samples in the drainage ways were collected from the surface of the flowing water. Samples in Dawson Cove were collected from the midpoint of the water column.

The samples were submitted for analysis of VOCs, PAHs (Priority Pollutant PAHs and 2- to 4-ring PAH alkyl groups)[4], total metals (RCRA 8 metals plus nickel, vanadium, calcium, and magnesium), dissolved metals (RCRA 8 metals plus nickel and vanadium), total suspended solids (TSS), and oil and grease (Table 2-8). Field parameters including pH, conductivity, temperature, turbidity, and dissolved oxygen were measured in the field at each sample location using a water quality probe (YSI 556).

2.6 Lake Conway Depositional Layer Assessment

A visual assessment of the near-surface sediment stratigraphic profile was performed to evaluate the potential presence of newly deposited sediment layers that may be associated with the emergency response at 12 locations in Lake Conway and at four distant background locations in Lake Conway. Depositional layer assessment locations are shown on Figure 2-10 and summarized in Tables 2-9 and 2-10. Sediment sample photographs from this effort are presented in Appendix C.

The near-surface sediment stratigraphy was visually inspected by a geologist using core samples obtained with 3-inch-diameter clear, colorless Lexan tubes pushed by hand approximately 8 inches into the sediment, which were then capped and brought to the surface. This approach was used in lieu of the box core technique due to field limitations in the deployment and operation of the box corer device. Field experimentation showed that high-quality samples were obtained using the Lexan tube

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[4] Up to 88 individual PAH compounds were analyzed in the surface water samples; however, many of these compounds, primarily heterocyclic PAHs, were analyzed for forensic (i.e., source identification) purposes, and are not included for risk screening evaluations.

technique. If a box core had been used, the sediment column would subsequently have been carefully subsampled with a Lexan core tube for inspection. This sampling approach was consistent with the DARSP (ARCADIS 2013a), which stated the depositional layer assessment will be performed with a Sediment Profiling Imagery approach, a box core, or other sampling device.

Once the core was obtained by direct-push method, the Lexan tube was wiped clean and visually inspected and photographed on the deck of the sampling boat. The inspection was performed immediately upon recovery to avoid alteration of the sediment-water interface or any near-surface depositional layer during transport or storage of the cores. Following the visual inspection, the sediment was extruded into an aluminum pan for visual classification and description of sediment grain size distribution.

3. Topographic Survey

ARCADIS conducted topographical survey activities in July and August 2013 to support the development of topographic cross sections and maps of the drainage ways and Dawson Cove in accordance with the DARSP (ARCADIS 2013a). The survey included the following points:

- Ground surface and top of sediment elevations along 29 transects throughout the survey area.
- Points defining channel cross sections (including top of bank, top of sediment, and channel centerline) along transects in reaches A-Main, A-365W, and A-365E; and the creek channel at the west end of Dawson Cove, where a defined channel exists.
- Points defining the boundary of heavily vegetated areas in Dawson Cove at the time of the survey, on transects established in this area.

Coordinates (recorded in NAD83) and elevations (feet; NAVD88) for each survey point, as well as the channel cross sections, are provided in Appendix D (see Figures D-1 through D-6 in Appendix D). All survey points are shown on Figure 3-1.

In addition to the activities described above, a pre-existing Laser Imaging, Detection, and Ranging (LIDAR) dataset was obtained from the United States Department of Agriculture (USDA) to assist with topographic mapping of the area adjacent to the cove. This dataset was acquired for the Lake Conway watershed from January 13 to May 10, 2012 under leaf-off conditions, and was available as bare-earth digital elevation models at a nominal horizontal resolution of 0.5 meter. The root mean square error vertical precision of these data is reported to be within 9.25 centimeters (USDA 2012). These data were converted to feet (NAVD88) to develop a topographic map of adjacent portions of the study area not included in the topographic survey activities (as shown on Figure 3-2).

To create the topographic map, survey data collected during field activities were interpolated by the Inverse Distance Weighting method using an optimized power term to develop a digital elevation model for the area shown on Figure 3-1. This interpolation used all survey points except those within the creek channel on the west end of Dawson Cove (see Figure 3-1). The interpolation was not used to map the topography of the channel due to the sinuous and localized nature of the channel (see cross sections in Appendix D). Where needed, the LIDAR data were used to set boundary elevations to perform the interpolation (see Figure 3-2). Based on the resulting interpolated topography, a contour map was generated for the Dawson Cove area, as shown on Figure 3-3.

3.1 Water Levels in Lake Conway and Dawson Cove

From April 15 through November 15, the water surface elevation in Lake Conway is controlled by the dam elevation, which is at approximately 262.87 feet (NAVD88). During winter, November 15 through April 15, the lake level is lowered to an elevation of approximately 261.87 feet (NAVD88) for flood control purposes. These elevations are specified in the Lake Conway Management Plan (AGFC and Lake Conway Citizen Advisory Committee 2003); however, actual water surface elevations appear to vary as discussed below.

Water surface elevations from February 18, 2008 through September 16, 2013, as recorded by the AGFC at the staff gauge at the Mayflower Enforcement Training Center, are shown on Figure 3-4. During this data collection period, Lake Conway water levels fluctuated between approximately 261.07 and 268.32 feet (NAVD88). The average and median summer levels were 262.64 and 262.70 feet (NAVD88), respectively. During winter, the average and median levels were approximately 262.41 and 262.22 feet, respectively. Short-term water level fluctuations occur due to heavy precipitation events (Figure 3-4).

Water levels in Dawson Cove fluctuate in response to fluctuations in Lake Conway, except when water levels in Lake Conway drop below the controlling elevations of the two culverts (each culvert is 48 inches in diameter) that convey water flow beneath Highway 89 (Figure 3-1). The minimum water surface elevation where Dawson Cove and Lake Conway are in direct communication is 262.2 feet (NAVD88); this is the lower invert elevation at the north (upslope) ends of the culverts beneath Highway 89. Due to the controlling effect of the culverts (invert elevation of 262.2 feet [NAVD88]), normal seasonal water levels in Dawson Cove are 262.2 feet (NAVD88) during winter (or possibly lower) and 262.87 feet (NAVD88) during summer, as controlled by the Lake Conway dam. Figure 3-3 indicates the approximate edge-of-water position in Dawson Cove that corresponds to these elevations.

4. Data Quality and Data Management

This section describes the reviews performed to evaluate the quality of data received from the analytical laboratories, and the management and handling of these data. Field activities and data quality reviews were completed in accordance with the quality assurance (QA)/quality control (QC) procedures established for the project.

4.1 Field Quality Control Samples

Field QC samples were collected during implementation, in accordance with the DARSP (ARCADIS 2013a):

- *Soil.* ARCADIS collected seven matrix spike (MS) and matrix spike duplicate (MSD) samples and six field duplicate samples. Field duplicate samples were analyzed for the surface soil analyte list, with the exception of grain size. To verify the effectiveness of field decontamination procedures, six equipment rinsate blanks were collected by rinsing laboratory-supplied deionized water over decontaminated field equipment (e.g., stainless steel hand auger). Ten trip blanks (one per cooler containing samples to be analyzed for VOCs) were analyzed to assess whether samples were affected by non-site-related VOCs during storage and transport.
- *Sediment.* ARCADIS collected 11 MS/MSD samples and 11 field duplicate samples. Field duplicate samples were analyzed for the surface sediment analyte list, with the exception of grain size. These samples were collected using dedicated, disposable equipment (e.g., the Lexan core tubes and disposable aluminum pans and plastic scoops used for sample homogenization). To confirm the cleanliness of the dedicated equipment, nine equipment rinsate blanks were collected by pouring laboratory-supplied deionized water over the unused equipment. Eighteen trip blanks (one per cooler containing samples to be analyzed for VOCs) were included to assess whether samples were affected by non-site-related VOCs during storage and transport.
- *Surface Water.* ARCADIS collected one MS/MSD sample and one field duplicate sample. To verify the effectiveness of field decontamination procedures, equipment rinsate blanks are also collected as part of the ongoing surface water sampling program; a separate equipment rinsate blank was not required for these surface water samples.

One sample of laboratory-supplied deionized water used for equipment rinsate blanks was analyzed for forensic-level PAHs to evaluate the presence of analytes in the laboratory-supplied water. The QA/QC samples are presented in Table 4-1.

4.2 Data Verification and Validation

Laboratory data packages were checked for completeness to confirm that the deliverable requirements specified to each laboratory for this project were met.

Data validation is a standardized review process for judging the analytical quality and utility of a discrete set of laboratory results, and is used to confirm that data of known and documented quality are used for the project. It involves a systematic evaluation of data to ascertain its completeness, correctness, and consistency. Validation procedures were consistent with the U.S. Environmental Protection Agency (USEPA) Contract Laboratory Program National Functional Guidelines for Organic Data Review (1999) and USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review (2004).

A tiered validation approach was used for the dataset presented in this report, and Tier II validation was performed on 100 percent of the data generated. A Tier III validation was performed on one sample delivery group (SDG) per medium per parameter group, or approximately 10 percent of the data. Each of these tiers is described below.

Tier II data validation was performed on all SDGs and included review of the following:

- Chain of custody completeness
- Holding times
- Laboratory control samples/laboratory fortified blank recoveries
- Surrogate recoveries
- MS, MSD recoveries, and relative percent difference (RPD)
- Field duplicate RPD
- Method blanks, trip blanks, and field/equipment blanks

Tier III data validation was performed on 10 percent of the data packages. This level of evaluation involves the review of calculations, compound identification, and/or potential transcription errors. Tier III evaluation includes the parameters listed above for Tier II evaluation, in addition (but not limited) to the following:

- Detection limit records
- Instrument calibration records
- Continuing calibration records
- Gas chromatography/mass spectrometry instrument tune records
- Internal standard records
- Target compound calculated results

At the completion of the Tier II and Tier III data validation process, a data validation summary report was prepared specifying suitable uses for the data (see Appendix G). The data validation qualifiers were entered into the database through the use of a web-based validation form.

4.3 Data Usability

The decision on whether data are usable is based on the validation results. Following validation, the data were flagged (i.e., qualified) as appropriate, and any data use restrictions were noted. The USEPA guidance identifies a goal that 90 percent of the data points will not be rejected or deemed unusable. The goal of at least 90 percent useable data was met under the scope of the DARSP (ARCADIS 2013a). Therefore, the data are acceptable for use as qualified.

The notable data restrictions following data validation include:

- Many data results for perylene were not recoverable because the associated surrogate failed.

For each analyte that was detected in crude oil (discussed in Section 5), the final reporting limit and the method detection limit in the soil and sediment sampling results from July and August 2013 were compared to applicable screening level (presented in Section 5; Table 4-2 and 4-3). For most analytes, except selenium, the majority of the reporting limits and all of the method detection limits are below the applicable screening. The selenium reporting limit in soil/sediment (ranged from 2 to 18 milligrams per kilogram [mg/kg]) was above the applicable screening levels (1.7 mg/kg in soil and 2 mg/kg in sediment); however, the selenium method detection limit was less than the applicable screening levels in at least 76 percent of the soil samples and 81 percent of the sediment samples. Therefore, the selenium data are considered useable.

4.4 Data Management

This section refers to key data handling procedures used to develop this report.

4.4.1 Duplicates

Sections 6, 7, and 8 focus on parent samples and do not include duplicate results. Duplicate results are reported in the data tables, but are excluded in statistical evaluations or graphical representation, unless a duplicate result affects the screening evaluation at a location (e.g., the field duplicate exceeds the screening levels where the parent sample does not). In those cases, the duplicate result is noted in the discussion.

4.4.2 Calculated Totals

The data assessment included calculating total concentrations of PAH compounds, grouped by high molecular weight (HMW) and low molecular weight (LMW), as needed, for ecological risk screening. These specific summations and USEPA guidance are discussed in Section 5. In all summations and calculations, non-detect samples for individual analytes in a compound group are treated as zero values. Because PAH lists vary depending on the screening evaluation, laboratory-calculated total PAHs were not included in the data assessment, but are provided in the laboratory reports.

5. Data Evaluation Methods and Screening Approach

The data collected as part of this program were compared to background concentrations and ecological screening values (ESVs) in accordance with the hierarchy recommended by the ADEQ and the approach described in the DARSP (ARCADIS 2013a). Based on direction from the ADEQ, the risk screening process is focused on ecological risks (ARCADIS 2013a). Human exposure to constituents in soil and sediment at the site is possible, but unlikely to be significant due to site conditions; in particular, the dense vegetation that develops naturally along the drainage ways and in Dawson Cove limits direct human exposure to site media. More details regarding the risk screening process, including applicable USPEA guidance, is included in Appendix I.

The screening approach used for soil and sediment samples is illustrated on Figure 5-1, and includes the following steps:

1. *Evaluate whether the analyte was associated with the crude oil at concentrations that could have resulted in the observed concentrations in soil and sediment (Sections 5.1 and 5.3).* Analytes were screened out in this first step because they were not detected in crude oil samples or were only present at low concentrations in crude oil samples (i.e., below Arkansas background concentrations).

2. *Compare detected concentrations of VOCs to ESVs.* Concentrations of crude-oil-related VOCs detected above the ESVs are highlighted in the data tables and on the figures. These values were compared to site background concentrations to evaluate whether the detections above the ESVs are comparable with site background concentrations (Section 5.4).

3. *Compare detected concentrations of PAHs to ESVs, and then evaluate toxic unit (TUs) for PAH mixtures.* Concentrations of PAHs detected above the ESVs are highlighted in the data tables and on the figures. To evaluate whether the detections above the ESVs in soil are comparable with site background concentrations (Section 5.4), concentrations of PAHs in soil were compared to site background concentrations. For sediment samples, the samples with concentrations above an ESV were then evaluated using Equilibrium Sediment Benchmark Toxic Units (TU; Section 5.2.2) to identify potential risk based on the mixture of PAHs.

4. *Compare detected concentrations of metals to Arkansas background concentrations and ESVs*. Concentrations of metals above both Arkansas background concentrations and ESVs are highlighted in the data tables and on the figures. These values were then compared to site background concentrations to evaluate whether the detections above both Arkansas background and ESVs are comparable with site background concentrations (Section 5.4).

The screening approach used for surface water samples is illustrated on Figure 5-2. Similar to the soil and sediment screening, the first step evaluated whether the analyte was associated with crude oil at concentrations that could have resulted in the observed concentrations in surface water (Section 5.1). Then, the concentrations of detected analytes were compared to surface water ESVs. Concentrations of analytes detected above the ESVs are highlighted in the data tables and on the figures.

This section describes the data evaluation process, including:

- Measured concentrations of constituents in crude oil
- ESVs for soil, sediment, and surface water
- Toxic units (TUs) for PAHs in sediment and surface water
- Arkansas background concentrations for soil and sediment
- Site background concentrations for soil and sediment

5.1 Crude Oil Comparison

Two bulk samples of crude oil from the Pegasus Pipeline were collected along with samples split with the USEPA on April 5, 2013, and analyzed for VOCs, PAHs, TEH, and metals. Crude oil sample results used for data screening in this report are presented in Table 5-1 and the laboratory reports are included in Appendix G. The results by chemical class are summarized below:

- *VOCs*. Twelve of the VOCs analyzed in soil, sediment, and surface water samples were detected in crude oil samples. The remaining VOCs were not detected in site media and are not typical petroleum hydrocarbon constituents.
- *PAHs*. All but two PAHs (benzo(a)fluoranthene and 18a-oleanane) analyzed in soil, sediment, and surface water samples were also detected in crude oil samples.
- *Metals*. Cadmium, lead, and mercury were not detected in crude oil samples.

The following sections describe the ESVs that were identified for the detected VOCs, PAHs, and metals. For analytes that were detected in site soil, sediment, and surface water samples collected under the DARSP (ARCADIS 2013a), but were not detected in crude oil samples, the data and associated ESVs are presented, if available, for completeness; however, the analytes were not evaluated further.

5.2 Ecological Screening Values and Toxic Units

The ESVs used to evaluate the data in this report were identified and included in the DARSP (ARCADIS 2013a). In addition, a TU approach was employed for evaluation of PAHs, also in accordance with the DARSP (ARCADIS 2013a). The following sections summarize ESVs and TUs, and their application for screening site media.

5.2.1 Identification of Ecological Screening Values

The data evaluation involves comparing soil, sediment, and surface water analytical results to ESVs. Under the USEPA's ecological risk assessment (ERA) paradigm, (USEPA 1997, 1998), ESVs are constituent concentrations in environmental media below which risk to ecological receptors exposed to those media is considered *de minimus* (i.e., if there are no exceedances of the ESV, then the constituent being screened is eliminated from any further ecological risk evaluation). However, the reverse is not necessarily true; concentrations exceeding ESVs do not automatically imply that ecological risk exists, only that further ecological risk evaluation may be warranted. A hierarchy was used to develop the list of ESVs, because any given source of ESVs typically does not contain ESVs for all of the analytes that are evaluated in this report. The DARSP (ARCADIS 2013a) described the hierarchy for the ESVs; the hierarchy is also presented in Appendix I. Table 5-2 lists the ESVs for soil, sediment, and surface water, including the literature source for each value.

Soil and sediment ESVs also include values for PAHs grouped and summed based on their molecular weight: LMW PAH summations include PAHs with three or fewer benzene rings, and HMW PAH summations include PAHs with four or more benzene rings. To evaluate the potential risks of multiple PAH, an additive approach was used (USEPA 2003). Consistent with USEPA guidance (USEPA 2001a, 2007a, 2009), PAHs were grouped and summed based on their molecular weight; however, USEPA guidance does not specify which PAHs should be included in PAH summations, which may vary due to site-specific conditions. Summation of PAHs for soil and sediment samples is further discussed below.

5.2.2 Total Polycyclic Aromatic Hydrocarbon Summations for Soil and Sediment

The rationale for PAH screening is presented in greater detail in Appendix I. The specific summations conducted for this screening evaluation for soil and sediment are discussed below:

- *Soil*. Soil ESVs for LMW and HMW PAHs were obtained from the USEPA's Ecological Soil Screening Levels (EcoSSLs; USEPA 2007a); the USEPA's EcoSSLs do not provide soil screening levels for individual PAHs. The USEPA's soil ESVs for both LMW and HMW PAHs were developed based on toxicity studies for a single PAH compound and can be applied for one PAH compound or for a summation of multiple PAHs (USEPA 2007a). USEPA guidance (USEPA 2007a) does not specify which PAHs should be included in PAH summations for comparison to the ESV. For this report, 38 PAHs[5] were used in the summations for the initial soil screening (Table 5-3). These 38 PAHs are hereafter referred to as the "long list of PAHs."

- *Sediment*. Sediment ESVs for PAHs were obtained from the USEPA's Region 4 sediment screening values (USEPA 2001a). Several uncertainties are associated with these ESVs as well as the PAH summations, both of which are important to consider in the screening evaluation. A brief description is included here and additional information is presented in Appendix I.

  The sediment ESV for LMW PAHs is based on the laboratory practical quantitation limit for PAHs, which is not a risk-based value (USEPA 2001a). The sediment ESV for HMW PAHs is based on a threshold effect level using six PAHs in a marine toxicity study (other PAHs may also have been present, but were not analyzed for) and thus has uncertainty with respect to application to freshwater and PAH mixtures that include other PAHs. USEPA guidance (USEPA 2001a, 2007a, 2009) does not specify which individual PAHs should be included in the summations for comparison to the ESV; therefore, PAHs were summed in two ways for comparison to ESVs: 1) an initial conservative approach was conducted using the long list of PAHs[6] for the summations and 2) a more typical approach summed the

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[5] The long list of PAHs for soil includes 16 priority pollutant PAHs, two additional non-alkylated PAHs (benzo(e)pyrene and perylene), and 20 alkylated PAHs (Table 5-3).

[6] The long list of PAHs for sediment included 16 priority pollutant PAHs, four additional non-alkylated PAHs (benzo(a)fluoranthene, benzo(b)fluorene, benzo(e)pyrene, and perylene) and 20

Priority Pollutant PAHs plus 1-methlynaphthelene and 2-methlynaphthelene for a total of 18 PAHs (referred to hereafter as “Priority+2 List”). This list is summarized in Table 5-3.

5.2.3 Toxic Unit Calculation

The cumulative toxicity of PAHs in sediment was also evaluated consistent with USEPA guidance (USEPA 2003). The concept of equilibrium partitioning of PAHs with organic carbon holds that sediment toxicity is attributable to the concentration of a constituent that is dissolved in the interstitial pore water, and therefore, biologically available. The TU value is used to evaluate whether concentrations of PAHs in sediment are acceptable for the protection of benthic organisms and whether concentrations of PAHs in pore water and surface water are acceptable for the protection of aquatic invertebrates.

The guidance presents methods for estimating the TU of a mixture of up to 34 PAHs (Table 5-3) in surface sediment. The TU is a conservative screening metric with respect to overall ecological risk because it provides a protective benchmark for the organisms that are most closely associated with the sediments and most highly exposed to chemicals in the sediments.

If the sample TU is 1 or less in a given sediment sample, the concentration of the PAH mixture in sediment is considered acceptable for the protection of benthic organisms. If the TU is greater than 1, further evaluation is recommended.

Several models are available to estimate PAH pore water concentrations (USEPA 2012). In this evaluation, the TU for each sample was calculated using simple model, referred to as the one-carbon model (USEPA 2003). Generally, if a TU for a sediment sample exceeds a value of 1 and black carbon is detected in the sample, a more rigorous two-carbon model could be used to recalculate the TU for that sample (USEPA 2012). The two-carbon model was used for one sample in this evaluation (because the other TU values using the one-carbon model were 1 or less; see Section 7). An example calculation for one sediment sample is included in Appendix I, along with a more detailed description of the methods.

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alkylated PAHs. Benzo(a)flouranthene and benzo(b)fluorene were only measured in surface sediment samples.

A TU approach was also used to assess the cumulative effects of PAHs in surface water using criteria established by the USEPA for up to 34 PAHs (USEPA 2003). The method used in the evaluation of surface water is described in detail in Appendix I and a sample calculation is also provided.

5.3 Arkansas Background Metals Concentrations in Soil and Sediment

The U.S. Geological Survey (USGS) along with other federal and state government agencies, industry, and academia, is currently conducting the National Geochemical Survey (NGS) to produce a body of geochemical data for the United States (Arkansas Geological Survey 2013). The NGS incorporates geochemical data from a variety of sources, including existing data in USGS databases, re-analyses of samples in USGS archives, and analyses of newly collected samples (Arkansas Geological Survey 2013). In Arkansas, 348 soil samples[7] and 605 stream sediment samples were collected and analyzed between 2003 and 2004. For this project, these data were accessed through the USGS website (USGS 2013).

Based on USEPA guidance (USEPA 2007b), the Arkansas background concentrations can be considered in the screening evaluation. The available data were compiled and a 95 Percent Upper Tolerance Limit[8] (95% UTL) was calculated for each of the metals evaluated. Table 5-4 presents the 95% UTL for soil and sediment (herein referred to as “Arkansas background”) for arsenic, barium, chromium, lead, mercury, nickel, selenium, and vanadium.

Each of these Arkansas background concentrations (95% UTL) was compared to the concentration detected in the site-specific crude oil samples (see Table 5-5). Cadmium,

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[7] Based on discussions with J Michael Howard with Arkansas Geological Survey (pers. com. July 3, 2013), Arkansas was divided into 100-square-kilometer grids. One location per grid was selected using a random number generator. Samples were collected at 0 to 0.5 foot and 1.5 to 2 feet bgs; the data were combined for statistical evaluation.

[8] Tolerance limits are the estimated range that contains a certain percentage of each individual measurement in the population, with the upper range referred to as the UTL. Because tolerance limits are based upon only a sample of the entire population, 100 percent confidence is not possible. Therefore, two different proportions are associated with the tolerance limits: a degree of confidence, and a percent coverage. For this site, with 90 percent coverage, 95 percent of the population will be equal to or less then the calculated 95% UTL concentration.

lead, and mercury were not detected in the crude oil, as discussed in Section 5.1. For arsenic, barium, and chromium, the range of concentrations in crude oil was less than the Arkansas soil and sediment background value. And in addition, the range of vanadium concentrations in crude oil is less than the Arkansas soil background value. Therefore, crude oil concentrations of these metals likely do not pose concerns relative to media-specific background; however concentrations of these metals are still screened against ESVs as presented in Section 5.2.

5.4 Site Background Concentrations in Soil and Sediment

Site background soil and sediment samples were collected from three general areas in accordance with the DARSP (ARCADIS 2013a) to generate an additional, local background dataset. The site background samples were analyzed for VOCs, PAHs (full list of 88), total metals (RCRA 8 metals, plus nickel and vanadium), TEH, grain size, black carbon, and TOC. Although the local dataset is limited, it provides an indication of background associated with local or regional sources that may not be presented in the state-wide background study (e.g., sources with direct tributary or runoff inputs to the drainage ways and Dawson Cove, or Lake Conway). The following site background datasets were developed through sampling:

- Site background soil locations (Figures 5-3.1 and 5-3.2)
- Site background sediment locations in drainage ways (Figures 5-4.1 and 5-4.2)
- Site background sediment locations in Lake Conway (Figures 5-5.1 and 5-5.2)

Table 5-6 shows the summary statistics for the site-specific background sampling results. Key observations for the background sampling results include:

VOCs. Three VOCs (acetone, 2-butanone, and trichloroethene [TCE]) were detected in site-specific background samples for both sediment and soil; however, they were not detected in crude oil and are not crude oil-related constituents. Therefore they were eliminated from further consideration, but are discussed below:

- Acetone was detected in all background soil and sediment samples, and may be present from laboratory, anthropogenic, and natural sources. Acetone is a common laboratory contaminant, but based on the data validation, the detection of acetone is not attributed to laboratory contamination. However, acetone concentrations may be a result of interferences due to sample preservation by acidification for USEPA Method 5035 for extraction of VOCs (USEPA 2002a). USEPA has recognized that acidification of certain soils with sodium bisulfate may produce a false positive acetone artifact of 100 to 200 micrograms per kilogram (µg/kg) or even higher concentrations (USEPA 2002a). In addition, samples that contain aluminum silicates may act as a catalyst in the conversion of methanol to acetone (Texas Natural Resource Conservation Commission 2002). Acetone is a manufactured chemical, but also occurs naturally in plants, trees, gas from volcanoes, and forest fires (Agency for Toxic Substances and Disease Registry [ATSDR] 1994, Delaware Health and Social Services 2009). It is estimated that 77 percent of acetone in the environment is from natural sources, including forest fires (Environment Canada 2013). Acetone is an oxidation product of natural humic substances, and is excreted as a metabolic by-product from many organisms, including mammals, plants, and microorganisms (Environment Canada 2013). Because oxidation of humic substances can result in acetone production, soil and sediment with high organic content can contain natural acetone concentrations (ATSDR 1994, Environment Canada 2013).

- 2-Butanone was detected in one-half of the background soil and sediment samples, and may be present from laboratory, anthropogenic, and natural sources. 2-Butanone is a common laboratory contaminant, but based on the data validation, the detection of 2-butanone is not attributed to laboratory contamination. However, 2-butanone concentrations may be a result of interferences or false positive due to sample preservation by acidification for USEPA Method 5035 (USEPA 2002a). Some ketones, such as 2-butanone, may react with preservatives under low pH conditions, yielding analytical results not representative of the soil and sediment sampled (USEPA 2002a). 2-Butanone is a manufactured chemical and a naturally occurring compound. It is naturally produced in the environment by some trees, and can be released as a result of car and truck exhausts or from decomposition of other organic compounds (ATSDR 1992).

- TCE was detected in one-half of the background soil and sediment samples, and may be present from anthropogenic and natural sources. Primary sources of TCE in the environment are metal cleaning and degreasing operations. It is a chlorinated hydrocarbon and is not associated with crude oil. TCE is also released to the environment by water treatment facilities through volatilization and air-stripping procedures, and by gaseous emissions from landfills. TCE may naturally occur in several temperate, subtropical, and tropical macroalgae and in at least one species of microalgae (ATSDR 1997, USEPA 2001b).

PAHs. Numerous PAH compounds were detected in site-specific soil and sediment background samples. Concentrations of some individual PAHs (in site background sediment samples in the drainage ways and Lake Conway) were above the ESVs. The HMW PAHs ranged from 5 to 19,500 µg/kg and the LMW PAHs ranged from 19 to 1,190 µg/kg in soil and sediment site background samples. The highest PAH concentrations in site background samples were observed in a drainage way sediment sample collected along Highway 365 (SED-DA-BG-004).

Metals. Metals were commonly detected in the site-specific background soil and sediment samples.

The site background data are compared to the soil and sediment data in Sections 6 and 7, respectively. For analyte concentrations that were above the ESVs (and Arkansas background values for metals), but are within the range of site background, it is interpreted that site-specific background conditions contribute to the exceedances of ESVs.

6. Soil Sampling Evaluations and Results

This section discusses the analytical results and data analysis for soil samples collected in the drainage ways and Dawson Cove. Soil samples were submitted for laboratory analysis, as described in Section 2.2. The table below summarizes the number of soil samples (excluding duplicates) collected from each area.

Area	Surface Samples	Subsurface Samples	Deep Subsurface Samples	Total Number of Samples
Drainage Ways	15	30	0	45
Dawson Cove	15	30	9	54

Notes:
"Surface Samples" includes samples from 0 to 0.5 foot bgs.
"Subsurface Samples" includes samples from 0.5 to 1 foot and 1 to 1.5 feet bgs
"Deep Subsurface Samples" includes samples deeper than 1.5 feet bgs. As discussed in Section 2.2, deep subsurface samples were not analyzed for the full analytical suite.

Table 6-1 summarizes the grain size results for surface soil samples, Table 6-2 presents the drainage way soil analytical results, and Table 6-3 presents the Dawson Cove soil analytical results.

As described in Section 5, the following data summaries and evaluations were completed:

- Drainage way and Dawson Cove soil data summary statistics are provided in Tables 6-4 and 6-5.
- Concentrations of key analytes at each of the sample locations are shown for the drainage ways and Dawson Cove on Figures 6-1.1, 6-1.2, 6-2.1, and 6-2.2. These figures present the maximum detections for each key analyte at each location, and the associated sample depth interval at which the maximum detection occurred (i.e., 0 to 0.5 foot bgs, 0.5 to 1 foot bgs, or 1 to 1.5 feet bgs).
- Box plots for metals and PAHs compare the concentrations in surface soil for drainage ways, Dawson Cove, and site background locations. The box plots are provided in Appendix H, and the comparisons discussed in this section.
- VOCs and PAHs were screened as shown on Figure 5-1. For the analytes detected in soil samples, as well as crude oil, the individual analytes were compared to ESVs (Table 5-2). Total LMW and HMW PAHs (Long List) were calculated according to Table 5-3 and compared to ESVs (Table 5-2).

- Metals were screened in accordance with Figure 5-1, including comparison to ESVs (Table 5-2).

The following subsections discuss the analytical results for physical characteristics and by each chemical class (e.g., metals, PAHs, and VOCs).

6.1 Summary of Grain Size Results

Grain size distribution is determined by measuring the percentages of the sample mass that pass through specifically sized sieves, and results are reported as percent dry weight. A useful measure of grain size is percent silt and clay (defined as the fraction of sediment by weight that passes through a 75-micrometer sieve); this is the fraction that will be examined. Organic chemicals in sediment are preferentially associated with fine-grained particles, which have larger total surface area per unit mass of sediment, and tend to correlate with higher, naturally occurring organic content (USEPA 2005).

Grain size distribution analyses were conducted on surface soil samples from the drainage ways, Dawson Cove, and site background locations, as described below. Grain size data for the drainage ways and Dawson Cove are summarized in Table 6-1; Table 5-6 summarizes grain size data from the background locations.

Area	Number of Surface Samples (0 to 0.5 foot bgs)	Fines Content (Fraction of Silt and Clay)
Drainage Ways	15	58 to 90%
Dawson Cove	15	79 to 97%
Site Background	6	17 to 91%

6.2 Summary of Volatile Organic Compounds in Soil Samples

Soil samples were analyzed for a list of 66 individual VOCs (Table 2-3). Of the 66 VOCs analyzed, 59 were not detected (Tables 6-2 and 6-3). Three detected VOCs (2-butanone, acetone, and TCE) are not associated with the crude oil as discussed in Sections 5.1 and 5.4; therefore, those VOCs are not discussed further in this section. Four VOCs (benzene, p-isopropyltoluene [cymene], isopropylbenzene [cumene], and toluene) were only detected in the drainage way soil samples (Table 6-2). The statistics for each of these detected compounds by area are presented in Tables 6-4 and 6-5, and the frequency of detection (FOD) for crude-oil-related analytes is summarized in the table below.

Analyte	Frequency of Detection		
	Drainage Ways	Dawson Cove	Site Background
Benzene	7% (3/45)	Not detected	Not detected
Isopropylbenzene	7% (3/45)	Not detected	Not detected
p-Isopropyltoluene	9% (4/45)	Not detected	Not detected
Toluene	13% (6/45)	Not detected	Not detected

Three of the four detected VOCs were below soil ESVs in all sampled areas (Tables 6-4 and 6-5). Benzene was detected in three samples in the drainage ways; one of these benzene detections was above the 10 µg/kg soil ESV (34 µg/kg in the surface [0 to 0.5-foot] depth interval at location SO-DA-015).

6.3 Summary of Polycyclic Aromatic Hydrocarbon Concentrations in Soil Samples

Figures 6-1.1 and 6-2.1 show the maximum concentrations of total LMW and HMW PAHs (Long List; see Section 5) measured at each soil location for the drainage ways and Dawson Cove, respectively. The statistics for each of the individual PAHs are presented for the drainage ways and Dawson Cove in Tables 6-4 and 6-5. PAHs were detected in all site background soil samples, and in all soil sample locations in the drainage ways and Dawson Cove.

Two drainage way soil samples were above the soil ESV for total HMW PAHs (1,100 µg/kg). These exceedances were in the surface (0 to 0.5 foot bgs) interval at sample locations SO-DA-003 and SO-DA-005, with calculated HMW PAH totals of 2,280 and 1,640 µg/kg, respectively. All samples at these locations were below the soil ESV for total LMW PAHs. In addition, concentrations in soil samples upstream and downstream of both of these locations were below the ESVs.

For Dawson Cove soil samples, the total LMW PAHs (Long List) results were below the soil ESVs in all samples, and the total HMW PAHs (Long List) were below the soil ESVs in 41 of 45 samples. In four Dawson Cove soil samples, the total HMW PAHs (Long List) were above the soil ESV of 1,100 µg/kg:

- *SO-DA-019*. The surface sample (0 to 0.5 foot bgs) at this location had a calculated total HMW PAH (Long List) result of 1,180 µg/kg. One subsurface sample (0.5 to 1 foot bgs) was also above the soil ESV for total HMW PAHs, with a result of 1,270 µg/kg. In addition, concentrations in adjacent soil samples (SO-DA-018 and SO-DA-021) were below the ESVs.

- *SO-DA-022*. The surface sample (0 to 0.5 foot bgs) at this location had a calculated total HMW PAHs (Long List) result of 1,760 µg/kg. The subsurface samples at this location were below the soil ESV for total HMW PAHs.
- *SO-DA-023*. The surface sample (0 to 0.5 foot bgs) at this location had a calculated total HMW PAHs (Long List) result of 1,220 µg/kg. The subsurface samples at this location were below the soil ESV for total HMW PAHs.

The duplicate of the surface sample (0 to 0.5 foot bgs) at location SO-DA-018 had a calculated total HMW PAHs (Long List) result above the ESV; however, the average of the parent and duplicate concentrations was below the ESV and therefore this sample is not further evaluated.

The total LMW and HMW PAHs (Long List) in surface soil samples are presented on box plots in Appendix H for all three areas. Surface soil results were plotted because maximum total LMW and HMW PAH (Long List) concentrations at each location were most frequently associated with the surface sample (0 to 0.5 foot bgs). Within the drainage ways and Dawson Cove, 72 of 90 samples were within the range of site background soil sample results for LMW PAHs (Long List). For HMW PAHs (Long List), 83 of 90 samples from the drainage ways and Dawson Cove were within the range of results reported for site background soil sample results (see Figure 5-1.1 for background sample locations).

6.4 Summary of Metals Concentrations in Soil Samples

The following subsections discuss metal concentrations and are grouped according to the screening evaluations in Section 5:

- Cadmium, lead, and mercury – the three metals that were not detected in crude oil samples.
- Arsenic, barium, chromium, and vanadium – the four metals that were detected in crude oil samples at concentrations below the Arkansas soil background values (95% UTL).
- Nickel, selenium, and silver – the remaining three metals that samples were analyzed for.

6.4.1 Cadmium, Lead, and Mercury in Soil Samples

As discussed in Section 5.1, cadmium, lead, and mercury were not detected in crude oil samples. However, the detected concentrations of these metals for the soil samples were compared to the ESVs (bolded results in Tables 6-2 and 6-3) and are summarized below.

- *Cadmium.* Concentrations were below the ESV (0.36 mg/kg) in 41 of the 45 drainage way soil samples. In four drainage way soil samples, concentrations were above the ESV. This included all three soil samples at location SO-DA-004, with the highest concentration (0.97 mg/kg) detected in the deepest sample interval, and the surface soil sample at SO-DA-006 (0.64 mg/kg). Cadmium concentrations were below the soil ESV in all Dawson Cove soil samples.

- *Lead.* Concentrations were above the soil ESV (11 mg/kg) in 32 of the 45 drainage way soil samples and in 43 of the 48 Dawson Cove soil samples. For comparison, the lead was not detected in crude oil at a reporting limit of <1.5 mg/kg (Table 5-1) – below the ESV of 11 mg/kg and the Arkansas background value of 29 mg/kg.

- *Mercury.* Concentrations were below the soil ESV (0.1 mg/kg) in all 45 drainage way soil samples and all 48 Dawson Cove soil samples. In addition, all mercury concentrations were below the Arkansas background value of 0.06 mg/kg.

6.4.2 Arsenic, Barium, Chromium, and Vanadium in Soil Samples

As discussed in Section 5.3, arsenic, barium, chromium, and vanadium were not detected in the crude oil samples above their respective Arkansas soil background values. However, the detected concentrations of these metals for all soil samples were compared to the ESVs (bolded results in Tables 6-2 and 6-3) and are summarized below.

- *Arsenic*. Concentrations were below the soil ESV in all drainage way soil samples and in 46 of the 48 Dawson Cove soil samples. In two Dawson Cove soil samples (0.5 to 1 foot and 1 to 1.5 feet at SO-DA-027), the arsenic concentrations were above the ESV (18 mg/kg); the co-located surface sample was below the ESV. For comparison, the arsenic concentrations detected in crude oil samples were 0.361 and 1.02 mg/kg (Table 5-1) – below the ESV of 18 mg/kg and below the Arkansas background value of 14 mg/kg.

- *Barium*. Concentrations were below the soil ESV of 330 mg/kg in all 45 drainage way soil samples and all 48 Dawson Cove soil samples. For comparison, the barium concentrations detected in crude oil samples were 0.108 and 0.145 mg/kg (Table 5-1) – below the ESV of 330 mg/kg and below the Arkansas background value (95% UTL) of 753 mg/kg.

- *Chromium.* Concentrations were below the soil ESV in 34 of the 45 drainage way soil samples and 39 of the 48 Dawson Cove soil samples. Chromium concentrations were above the ESV (26 mg/kg) in 20 of the 93 drainage way and Dawson Cove soil samples combined. At all locations with chromium concentrations above the ESV (26 mg/kg), the maximum concentrations were detected in a subsurface sample (e.g., 0.5 to 1 foot or 1 to 1.5 feet) and not in the surface sample. For comparison, the chromium concentrations detected in the crude oil samples were 0.229 and 0.278 mg/kg (Table 5-1) – below the ESV of 26 mg/kg and below the Arkansas background value of 69 mg/kg.

- *Vanadium*. Concentrations were above the ESV (7.8 mg/kg) in all drainage way and Dawson Cove soil samples. However, all vanadium concentrations were below the Arkansas background value (95% UTL) of 146 mg/kg.

6.4.3 Nickel, Selenium, and Silver in Soil Samples

Tables 6-4 and 6-5 present the summary statistics for nickel, selenium, and silver. The table below summarizes the FOD, number of samples with concentrations above the Arkansas background and soil ESVs, and number of samples with concentrations above site background.

Analyte	Drainage Way			Dawson Cove		
	FOD	N > AR BKG & ESV	N > Site BKG	FOD	N > AR BKG & ESV	N > Site BKG
Nickel	100% (45/45)	1	1	100% (48/48)	0	0
Selenium	51% (23/45)	4	2	29% (14/48)	3	0
Silver	31% (14/45)	0*	0	8% (4/48)	0*	1

Notes:
N > AR BKG & ESV = Number of samples above the Arkansas soil background (95% UTL) and respective soil ESVs.
N > Site BKG = Number of samples above the maximum detection in site background soil samples.
* = Arkansas soil background value not available for this analyte.

These results are discussed below:

- *Nickel*. Figures 6-1.2 and 6-2.2 show the maximum nickel concentrations at each soil sample location and the associated sample depth interval with the maximum detection. Nickel concentrations were below the screening criteria in all Dawson Cove soil samples and in 44 of 45 drainage way soil samples. In one drainage way soil sample, the nickel concentration was above the Arkansas soil background value of 40 mg/kg and the ESV of 38 mg/kg at the deepest sample depth only (SO-DA-006 at 1 to 1.5 feet, 65 mg/kg). This sample was also slightly above the range of site background concentrations (7.9 to 51 mg/kg, Table 5-6). However, nickel was detected in crude oil at concentrations of 50.3 and 50.5 mg/kg (Table 5-1), indicating that crude oil from the Pegasus Pipeline would not contribute nickel at the maximum concentration detected in soil. These results indicate that nickel in soil is consistent with background conditions in the area and is not associated with crude oil.
- *Selenium*. Figures 6-1.2 and 6-2.2 show the maximum selenium concentrations at each soil sample location and the associated sample depth interval with the maximum detection. Selenium concentrations were below the screening criteria in 41 of 45 drainage way soil samples. Selenium concentrations in four drainage way samples were above both the Arkansas soil background value of 1.7 mg/kg and the ESV of 0.52 mg/kg, but only two samples had selenium concentrations above the range of site background concentrations (non-detect to 2.5 mg/kg; Table 5-6). Each of those samples was from subsurface depth intervals at locations SO-DA-001 and SO-DA-005 (1 to 1.5 feet bgs and 0.5 to 1 foot bgs, respectively). In Dawson Cove, selenium concentrations were below the screening criteria in 45 of the 48 soil samples. Selenium concentrations in three Dawson Cove samples were above both the Arkansas soil background and the ESV, but none of the samples had selenium detections above the range of site background concentrations (Table 5-6). Although selenium is detected in the crude oil at concentrations of 1.82 and 2.66 mg/kg (Table 5-1) (slightly above the Arkansas soil background value of 1.7 mg/kg), these results indicate that selenium in soil is consistent with background conditions and is not associated with crude oil.
- *Silver*. Figures 6-1.2 and 6-2.2 show the maximum silver concentrations at each soil sample location and the associated sample depth interval with the maximum detection. Silver concentrations were below the soil ESV of 330 mg/kg in all 45 drainage way soil samples and all 48 Dawson Cove soil samples.

6.5 Summary of Total Organic Carbon and Black Carbon

Thirty surface soil samples were analyzed for TOC and black carbon. TOC concentrations range from 0.28 to 3.3 percent in 15 drainage way soil samples and from 0.61 to 2.5 percent in 15 Dawson Cove soil samples. The drainage way and Dawson Cove soil sample TOC concentrations are similar to site background soil TOC concentrations (0.53 to 2.4 percent).

Black carbon was detected in soil samples collected at three drainage way locations, at concentrations ranging from 0.2 to 0.31 percent. Black carbon was not detected in the soil samples collected from Dawson Cove. The concentration ranges of black carbon in drainage way soil samples are similar to site background soils (non-detect to 0.48 percent).

6.6 Evaluation of Deep Soil Cores for Additional Analysis

In Dawson Cove, deeper samples (1.5 to 2, 2 to 3, and 3 to 4 feet bgs) were collected from three soil locations and held at the laboratory: SO-DA-019, SO-DA-021, and SO-DA-023. A provision of the DARSP (ARCADIS 2013a) is that, if the sample collected from at 1 to 1.5 feet bgs “exceeds screening criteria, these deeper samples will also be submitted for analysis.” At all three of these locations, the VOC and PAH concentrations were well below the ESVs in samples collected from 1 to 1.5 feet bgs, and the metals concentrations were below the screening criteria (i.e., not above both the Arkansas background and sediment ESV). In addition, a review of the soil photo logs and sample descriptions (Appendix B) did not indicate any evidence of crude oil (e.g., odor and sheens). Therefore, further analysis of the deeper samples was not warranted.

6.7 Evaluation of Soil Samples in Transitional Area to Screening Criteria

As discussed in Section 3, normal seasonal water levels in Dawson Cove range from 262.2 feet (NAVD88) during winter to 262.87 feet (NAVD88) during summer, as controlled by the Lake Conway dam and the outlet culvert invert elevation from Dawson Cove. Six soil sample locations in Dawson Cove (SO-DA-023, SO-DA-025, SO-DA-026, SO-DA-027, SO-DA-028, and SO-DA-029) are located within a transitional area that was exposed during the sampling period, but is likely inundated for an extended period of time based on the expected range in seasonal water levels. Therefore, these soil samples were also screened using sediment ESVs, and the results are discussed in Section 7.

6.8 Summary of Soil Sampling and Screening Evaluation Results

Soil samples were collected at 30 locations in the drainage ways and in Dawson Cove. All soil samples were analyzed for VOCs, PAHs, and metals. Based on the screening results, concentrations in 92 of 99 samples were at levels that do not warrant further evaluation. In the remaining samples, an individual analyte or PAH summation was above the screening criteria. The following presents a summary by chemical class (i.e., VOCs, PAHs, and metals).

VOCs. Crude-oil-related VOC concentrations were either non-detect or below the ESVs in all soil samples except for benzene in one sample collected in the drainage way at SO-DA-015. The surface sample (0 to 0.5 foot bgs) at this location had a benzene concentration of 34 µg/kg, which was above the ESV of 10 µg/kg. Benzene was not detected at the upstream soil sample location (SO-DA-014), or in any downstream soil sample locations in Dawson Cove.

PAHs. The total LMW PAH results were below the soil ESVs in all samples. The total HMW PAH were below the soil ESV of 1,100 µg/kg in 93 of 99 samples. The total HMW PAH summation was above the soil ESV in the following locations that warrant further consideration (see Section 9).

Area	Location	Sample Depth	Analyte	Value
Drainage Ways	SO-DA-003	Surface (0 to 0.5 foot bgs)	Total HMW PAH	2,280 µg/kg
	SO-DA-005	Surface (0 to 0.5 foot bgs)	Total HMW PAH	1,640 µg/kg
Dawson Cove	SO-DA-019	Surface (0 to 0.5 foot bgs)	Total HMW PAH	1,180 µg/kg
		Subsurface (0.5 to 1 foot bgs)	Total HMW PAH	1,270 µg/kg
	SO-DA-022	Surface (0 to 0.5 foot bgs)	Total HMW PAH	1,760 µg/kg
	SO-DA-023	Surface (0 to 0.5 foot bgs)	Total HMW PAH	1,220 µg/kg

Metals. The concentrations of metals are consistent with background conditions in the area and/or are below the ESVs based on the screening approach described in Section 5. Therefore, no further assessment of metals concentrations in soils is necessary.

7. Sediment Sampling Evaluation and Results

This section discusses the analytical results and data analysis for the sediment sampling in the drainage ways, Dawson Cove, and Lake Conway. Sediment samples were submitted for laboratory analysis, as described in Section 2.3. The table below summarizes the number of sediment samples (excluding duplicates) collected from each area.

Area	Surface Samples	Subsurface Samples	Deep Subsurface Samples	Total Number of Samples
Drainage Ways	13	22	0	35
Dawson Cove	34	65	26	125
Lake Conway	6	12	0	18
Lake Conway Re-Sampling	6	12	0	18

Notes:
Surface Samples are samples from 0 to 0.5 foot bgs.
Subsurface Samples are samples from 0.5 to 1 foot and 1 to 1.5 feet bgs.
Deep Subsurface Samples are samples deeper than 1.5 feet bgs. As discussed in Section 2.2, deep subsurface samples were not analyzed for the full analytical suite.

Table 7-1 summarizes the grain size results for surface sediment samples, Table 7-2 presents the sediment analytical results for the drainage ways, Table 7-3 presents the sediment analytical results for Dawson Cove, and Table 7-4 presents the sediment analytical results for Lake Conway (original samples and re-sampled locations).

The following data summaries and evaluations were completed:

- Sediment data summary statistics for the drainage ways, Dawson Cove, and Lake Conway are provided in Tables 7-5, 7-6, and 7-7, respectively.
- Concentrations of key analytes at each of the sample locations are shown on Figures 7-1.1 through 7-3.3. Data associated with the re-sampled sediment locations in Lake Conway are shown on Figures 7-3.1 through 7-3.3. These figures present the maximum detections for each key analyte at each location, and the associated sample depth interval at which the maximum detection occurred (i.e., 0 to 0.5 foot bgs, 0.5 to 1 foot bgs, or 1 to 1.5 feet bgs).
- The VOC and PAH screening was completed following the procedure shown in Figure 5-1. For the analytes detected in the sediment samples, as well as the crude oil, the individual analytes were compared to ESVs (Table 5-2). Total LMW and HMW PAHs (Long List) were calculated according to Table 5-3 and compared

to ESVs. The one-carbon model TU calculation was completed for the surface sediments PAHs (provided in Appendix J) and compared to the ESV.

- The metals screening was completed following the procedure shown in Figure 5-1, including comparison to ESVs (Table 5-2).
- Box plots for metals and PAHs compare the concentrations in surface sediments for the drainage ways, Dawson Cove, Lake Conway, and site background locations. These box plots are provided in Appendix H.

The following subsections discuss the analytical results for physical characteristics and by each chemical class (e.g., VOCs, PAHs, metals). Analytical results for re-sampled sediment locations in Lake Conway are discussed in Section 7.6.

7.1 Summary of Grain Size Results

Grain size distribution analyses were conducted on surface sediment samples from the drainage ways, Dawson Cove, Lake Conway, and site background locations. Grain size data for the drainage ways, Dawson Cove, and Lake Conway are presented in Table 7-1; Table 5-6 summarizes grain size data for the background locations. The fines content expressed as a percent of combined silt and clay is summarized in the table below.

Area	Number of Surface Samples (0 to 0.5 foot bgs)	Fines Content (Silt and Clay Fraction)
Drainage Ways	13	26 to 86%
Dawson Cove	34	61 to 99%
Lake Conway	6	77 to 94%
Site Background	12	55 to 99%

7.2 Summary of Volatile Organic Compounds in Sediment Samples

Sediment samples were analyzed for 66 individual VOCs (Table 2-3). Of the 66 VOCs analyzed, 51 were not detected (Tables 7-2, 7-3, and 7-4). Four detected VOCs (2-butanone, acetone, methylene chloride, and TCE) are not associated with the crude oil as discussed in Sections 5.1 and 5.4; therefore, those VOCs are not discussed further in this section. The remaining 11 VOCs were detected in the drainage ways and Dawson Cove, but none of these were detected in Lake Conway. These 11 VOCs were also not detected in site background samples. The statistics for each of these detected compounds are presented by area in Tables 7-5, 7-6, and 7-7, and the FOD is summarized in the table below.

Analyte	**Frequency of Detection**			
	Drainage Ways	**Dawson Cove**	**Lake Conway**	**Site Background**
1,2,4-Trimethylbenzene	Not detected	16% (20/125)	Not detected	Not detected
1,3,5-Trimethylbenzene	6% (2/35)	18% (23/125)	Not detected	Not detected
2-Phenylbutane	Not detected	7% (9/125)	Not detected	Not detected
Benzene	11% (4/35)	8% (10/125)	Not detected	Not detected
Ethylbenzene	3% (1/35)	7% (9/125)	Not detected	Not detected
Isopropylbenzene	Not detected	6% (8/125)	Not detected	Not detected
n-Butylbenzene	Not detected	8% (10/125)	Not detected	Not detected
n-Propylbenzene	Not detected	7% (9/125)	Not detected	Not detected
p-Isopropyltoluene	6% (2/35)	9% (11/125)	Not detected	Not detected
Toluene	3% (1/35)	10% (13/125)	Not detected	Not detected
Xylene (Total)	9% (3/35)	17% (21/125)	Not detected	Not detected

Note: Background statistics include samples from site background locations in the drainage ways and Lake Conway.

Nine of the 11 detected VOCs were below sediment ESVs in all samples (Tables 7-5, 7-6, and 7-7). The two VOCs with detections above the sediment ESV include isopropylbenzene (cumene) and total xylenes. These two VOCs are discussed below:

- *Isopropylbenzene (Cumene)*. Isopropylbenzene was below the sediment ESVs in the drainage ways, and was not detected in Lake Conway or the background locations. In Dawson Cove, isopropylbenzene was below the sediment ESV in 124 of 125 samples. In one subsurface sample (SED-DA-017, 0.5 to 1 foot bgs), the isopropylbenzene concentration (280 µg/kg) was above the sediment ESV of 86 µg/kg.
- *Total xylenes*. Total xylenes was below the sediment ESVs in the drainage ways, and was not detected in Lake Conway or the background locations. In Dawson Cove, total xylenes concentrations were below the sediment ESV in 118 of 125 samples. In seven samples, the total xylenes concentration was above the ESV (25 µg/kg) at five locations (SED-DA-015, SED-DA-017, SED-DA-039, SED-DA-045, and SED-DA-048).

7.3 Summary of Polycyclic Aromatic Hydrocarbon Concentrations in Sediment Samples

Figures 7-1.1, 7-2.1, and 7-3.1 show the maximum concentrations of total LMW and HMW PAHs (Priority+2 List and Long List; see Section 5) measured at each sediment location for the drainage ways, Dawson Cove, and Lake Conway, respectively. PAHs were detected in all site background sediment samples, and in all sediment sample locations in the drainage ways, Dawson Cove, and Lake Conway. PAH concentrations in sediment samples collected from the drainage ways, Dawson Cove, and Lake Conway are discussed in Sections 7.3.1, 7.3.2, and 7.3.3.

7.3.1 Summary of Polycyclic Aromatic Hydrocarbon Concentrations in Drainage Ways

The statistics for the individual and total PAHs are presented for the drainage ways in Table 7-5. None of the individual PAHs were above their respective ESVs. The FOD for the total LMW and HMW PAHs compared to their respective ESVs is summarized in the table below.

Analyte	Drainage Way		Site Background
	N > ESV	N > Site Bkg	N > ESV
Priority+2 List			
Total HMW PAHs	1	0	3
Total LMW PAHs	0	0	2
Long List			
Total HMW PAHs	2	0	3
Total LMW PAHs	3	2	2
Toxic Unit			
One-Carbon Model TU*	0	0	0

Notes:
N > ESV = Number of samples (excludes duplicates) above the respective sediment ESVs
Site background refers to background sediment locations in the drainage ways.
* Summary for surface sediment samples only. The TU calculations for drainage way sediment samples are provided in Appendix J.

In 33 of 35 samples in the drainage ways, the total HMW and LMW PAHs (both Priority+2 and Long Lists) are below the sediment ESVs. The TUs for the surface sediment samples were all 1.0 or less. In two samples (and one duplicate) in the drainage ways, PAH summations were detected above the ESVs; these samples are discussed below:

- *SED-DA-004*. In the surface sample at this location, the total HMW PAHs (Priority+2 List) and the total HMW and LMW PAHs (Long List) summations were above the sediment ESVs. The one-carbon model TU for the surface sample was 1.0, indicating no unacceptable risk to benthic ecological receptors.
- *SED-DA-006*. In the subsurface sediment sample collected at the 0.5 to 1 foot bgs, the total LMW PAHs (Long List) summation was above the sediment ESV. The one-carbon model TU was 1.3 using the TOC value for the surface sample at this location, which was slightly above 1.0. The TU values cannot be evaluated further using the two-carbon model because black carbon was not detected in the surface sample. However, benthic and aquatic receptors are not generally exposed to sediment at depth intervals below the biologically active zone, which is typically about 10 centimeters thick. The 0 to 0.5-foot surface sediment sample interval includes the biologically active zone, and therefore, there is not a complete exposure pathway to subsurface samples at deeper depth intervals. Because it is unlikely that benthic receptors will be exposed to sediments deeper than 0.5 foot, and moreover, the TU value was only slightly above 1.0 using the one-carbon model; it is concluded that risks to benthic and aquatic receptors are not expected at this location.
- *SED-DA-007 (Duplicate Sample)*. In the duplicate for the surface sample at this location, the total HMW and LMW PAHs (Long List) summations were above the sediment ESVs. The one-carbon model TU for the surface sample was 0.5, indicating no unacceptable risk to benthic ecological receptors.

Therefore, no further evaluation of PAHs in drainage way sediment is necessary.

7.3.2 Summary of Polycyclic Aromatic Hydrocarbon Concentrations in Dawson Cove

The statistics for the individual and total PAH summations are presented for Dawson Cove in Table 7-6. The individual PAHs were below sediment ESVs in 101 of 105 samples in Dawson Cove; four samples had one or more individual PAHs above the sediment ESV of 330 µg/kg and are described below:

- *SED-DA-015*. The surface sediment sample (0 to 0.5 foot bgs) had a phenanthrene concentration of 331 µg/kg.
- *SED-DA-017*. The subsurface sediment sample (0.5 to 1 foot bgs) had a phenanthrene concentration of 416 µg/kg and a 2-methylnaphthalene concentration of 395 µg/kg.

- *SED-DA-028*. The surface sediment sample (0 to 0.5 foot bgs) had a benzo(b)flouranthene concentration of 386 µg/kg.
- *SED-DA-045*. The surface sediment sample (0 to 0.5 foot bgs) had a phenanthrene concentration of 669 µg/kg.

These samples are evaluated further using the PAH summations and the TU calculation. Total LMW and HMW PAHs compared to their respective ESVs and to the maximum detection in the site background are summarized in the table below.

Analyte	**Dawson Cove**		**Site Background**
	N > ESV	**N > Site BKG**	**N > ESV**
Priority+2 List			
Total HMW PAHs	4	2	1
Total LMW PAHs	14	25	0
Long List			
Total HMW PAHs	47	16	5
Total LMW PAHs	47	21	4
Toxic Unit			
One-Carbon Model TU*	1	0	0

Notes:
N > ESV = Number of samples above the respective sediment ESVs.
Site background refers to background sediment locations in Lake Conway.
* Summary for surface sediment samples only. The TU calculations for Dawson Cove sediment samples are provided in Appendix J.

In 52 of 105 samples in Dawson Cove, the total HMW and LMW PAHs (both Priority+2 and Long Lists) were below the sediment ESVs. In the remaining 53 samples (32 surface and 21 subsurface), at least one of the summations was above the sediment ESVs. The TU calculation is applicable to the surface sediment sample concentration, which is where ecological exposures occur. For 31 of the 32 surface sediment samples, the one-carbon model TU was 1.0 or less, indicating no unacceptable risk to benthic ecological receptors. The one-carbon model TU in one surface sediment sample (SED-DA-045) was 1.2, which was slightly above 1.0. The TU was recalculated using the two-carbon model and the result was 0.4, which was below 1.0 (Appendix I, Table I-2). Therefore, risk to benthic receptors from exposure to PAHs in surface sediments is not expected in Dawson Cove.

The TU was also calculated for the 21 subsurface samples, with at least one of the PAH summations above the sediment ESV, to provide additional information regarding these samples. The TOC value for the surface sample at each location was used for the TU calculation. For 20 of these 21 subsurface samples, the TU was also 1.0 or less, indicating no unacceptable risk to benthic ecological receptors. The TU value for one sample (SED-DA-017, 0.5 to 1 foot) was 1.3, which was slightly above 1.0. The TU value cannot be further evaluated using the two-carbon model because black carbon was not detected in the surface sediment sample at this location. However, benthic and aquatic receptors are not generally exposed to sediment at depth intervals below the biologically active zone, which is typically about 10 centimeters thick. The 0 to 0.5-foot surface sediment sample interval includes the biologically active zone, and therefore, there is not a complete exposure pathway to subsurface samples at deeper depth intervals. Because it is unlikely that benthic receptors will be exposed to sediments deeper than 0.5 foot, and moreover, the TU value was only slightly above 1.0 using the one-carbon model; it is concluded that risks to benthic and aquatic receptors are not expected at this location.

Therefore, no further evaluation of PAHs in Dawson Cove sediment is necessary.

7.3.3 Summary of Polycyclic Aromatic Hydrocarbon Concentrations in Lake Conway

The statistics for the individual and total PAHs summations are presented for Lake Conway in Table 7-7. None of the individual PAHs were above their respective ESVs. Total LMW and HMW PAHs compared to their respective ESVs are summarized in the table below.

Analyte	**Lake Conway**		**Site Background**
	N > ESV	**N > Site BKG**	**N > ESV**
Priority+2 List			
Total HMW PAHs	0	0	1
Total LMW PAHs	0	0	0
Long List			
Total HMW PAHs	12	0	5
Total LMW PAHs	3	0	4
Toxic Unit			
One-Carbon Model TU*	0	0	0

Notes:
N > ESV = Number of samples above the respective sediment ESVs.
Site background refers to background sediment locations in Lake Conway.
* Summary for surface sediment samples only. The TU calculations for Lake Conway sediment samples are provided in Appendix J.

For the 18 sediment samples collected in Lake Conway, the total Priority+2 List HMW and LMW PAHs are below the sediment ESVs. In 12 of 18 samples, one or more of the

Long List HMW and LMW PAHs are above the sediment ESVs. The one-carbon model TU was less than 1 in all of the surface samples, indicating no unacceptable risk to benthic ecological receptors. The TU was also calculated for the six subsurface samples, with at least one of the PAH summations above the sediment ESV, to provide additional information regarding these samples, even though benthic receptors will most likely not be exposed to subsurface sediment as they dwell in surface sediment. The TOC value for the surface sample at each location was used for the TU calculation. For all six of these subsurface samples, the TU was also less than 1, indicating no unacceptable risk to benthic ecological receptors.

Therefore, no further evaluation of PAHs in Lake Conway sediment is necessary.

7.4 Summary of Metals Concentrations in Sediment Samples

The following subsections discuss the metals concentrations grouped according to the screening evaluations in Section 5:

- Cadmium, lead, and mercury – the three metals that were not detected in crude oil.
- Arsenic, barium, and chromium – the three metals that were detected in crude oil at concentrations below the Arkansas sediment background values (95% UTL).
- Nickel, selenium, silver, and vanadium – the remaining four metals that samples were analyzed for.

7.4.1 Cadmium, Lead, and Mercury in Sediment Samples

As discussed in Section 5.1, cadmium, lead, and mercury were not detected in the crude oil. However, the detected concentrations of these metals for all sediment samples were compared to the ESVs (bolded results in Tables 7-2, 7-3 and 7-4) and are summarized below.

- *Cadmium*. Concentrations were below the sediment ESV in all 35 drainage way sediment samples, in 100 of the 101 Dawson Cove sediment samples, and in all 18 Lake Conway sediment samples. The detected cadmium concentration of 1.99 mg/kg in one Dawson Cove sediment sample (SED-DA-025) was above the ESV (1 mg/kg).

- *Lead*. Concentrations were below the sediment ESV in all 35 drainage way sediment samples, in 72 of the 101 Dawson Cove sediment samples, and 13 of the 18 Lake Conway sediment samples. The lead concentration was above the sediment ESV (30.2 mg/kg) in 29 of the 101 Dawson Cove samples and in 5 of the 10 Lake Conway samples. For comparison, the lead was not detected in crude oil at a reporting limit of <1.5 mg/kg (Table 5-1) – below the ESV of 30.2 mg/kg and the Arkansas background value of 36 mg/kg.

- *Mercury.* Mercury concentrations were below the sediment ESV in all 35 drainage way sediment samples, in 95 of the 101 Dawson Cove sediment samples, and all 18 Lake Conway sediment samples. Detected mercury concentrations were above the sediment ESV (0.13 mg/kg) in 6 of the 101 Dawson Cove samples, with the highest concentration (0.788 mg/kg) detected in the deepest sample depth interval at location SED-DA-026.

7.4.2 Arsenic, Barium and Chromium in Sediment Samples

As discussed in Section 5.3, arsenic, barium and chromium were not detected in the crude oil above their respective Arkansas sediment background values. However, the detected concentrations of these metals for all sediment samples were compared to the ESVs (bolded results in Tables 7-2, 7-3 and 7-4) and are summarized below.

- *Arsenic*: Concentrations were below the sediment ESV in 22 of the 35 drainage way sediment samples, in 70 of the 101 Dawson Cove sediment samples, and in 13 of the 18 Lake Conway sediment samples. Detected arsenic concentrations were above the ESV (7.24 mg/kg) in the 49 of the 154 sediment samples. For comparison, the arsenic concentrations detected in crude oil samples were 0.361 and 1.02 mg/kg (Table 5-1) – below the ESV of 7.24 mg/kg and below the Arkansas background sediment value of 14 mg/kg.

- *Barium*. A sediment ESV was not available for barium. However, detected barium concentrations in the 154 sediment samples were all less than Arkansas background sediment value of 558 mg/kg.

- *Chromium.* Concentrations were below the sediment ESV in 34 of the 35 drainage way sediment samples, in 98 of the 101 Dawson Cove sediment samples, and in all 18 Lake Conway sediment samples. Chromium concentrations were above the ESV (52.3 mg/kg) in 4 of the 154 sediment samples. For comparison, the chromium concentrations detected in crude oil samples were 0.229 and 0.278

mg/kg (Table 5-1) – below the ESV of 52.3 mg/kg and below the Arkansas background sediment value of 80 mg/kg.

7.4.3 Nickel, Selenium, Silver and Vanadium in Sediment Samples

Tables 7-5, 7-6, and 7-7 present the summary statistics for nickel, selenium, silver, and vanadium. The table below summarizes the FOD and number of samples with concentrations above the Arkansas background and sediment ESVs.

Analyte	**Drainage Way**		**Dawson Cove**		**Lake Conway**	
	FOD	**N > AR BKG & ESV**	**FOD**	**N > AR BKG & ESV**	**FOD**	**N > AR BKG & ESV**
Nickel	100% (35/35)	1	100% (101/101)	5	100% (18/18)	0
Selenium	34% (12/35)	5	6% (6/101)	1	17% (3/18)	2
Silver	14% (5/35)	2	1% (1/101)	0	0% (0/18)	0
Vanadium*	100% (35/35)	0	100% (101/101)	0	100% (18/18)	0

Notes:
N > AR BKG & ESV = Number of samples above the Arkansas sediment background (95% UTL) and respective sediments ESVs.
* = No ESV available for vanadium

These results are discussed below:

- *Nickel*. Figures 7-1.3, 7-2.3, and 7-3.3 show the maximum nickel concentrations at each sediment sample location and the associated sample depth interval with the maximum detection. In one drainage way sample, the nickel concentrations was above the both the Arkansas background and the sediment ESV (SED-DA-004 at 0 to 0.5 foot [42.8 mg/kg]), but within the range of site background concentrations (17 to 66 mg/kg; Table 5-6). In four Dawson Cove sediment samples, the nickel concentrations were above both the Arkansas background and the sediment ESVs (SED-DA-020 at 0 to 0.5 foot [38.6 mg/kg], SED-DA-025 0 to 0.5 foot [36.0 mg/kg], SED-DA-026 at 0.5 to 1 foot [74 mg/kg], and SED-DA-029 at 0 to 0.5 foot [61.8 mg/kg]). Three of these samples were within the range of site background concentrations (17 to 66 mg/kg; Table 5-6) and one was slightly above the range of site background concentrations. Nickel was detected in pure crude oil at concentrations of 50.3 and 50.5 mg/kg (see Table 5-1), which are lower than the maximum detected concentrations in sediment; therefore, it is unlikely that the nickel concentrations in sediment are due to crude oil.

- *Selenium*. Figures 7-1.3, 7-2.3, and 7-3.3 show the maximum detected selenium concentrations at each sediment sample location and the associated sample depth interval with the maximum detection. Selenium concentrations were below the ESV in 30 of 35 drainage way sediment samples. Five drainage way sediment samples have selenium concentrations above the ESV. Two of these samples were subsurface samples collected at SED-DA-006 (1 to 1.5 feet bgs [2.03 mg/kg]) and SED-DA-007 (1 to 1.5 feet bgs [3.05 mg/kg]). The other three samples were all collected at different depth intervals at SED-DA-010 (3.39 to 6.11 mg/kg). Selenium concentrations were below the ESV in 100 of the 101 Dawson Cove sediment samples; one subsurface sample was above the ESV (SED-DA-016 at 0.5 to 1 foot bgs [2.93 mg/kg]). In Lake Conway, selenium concentrations were below the ESV in 16 of 18 sediment samples; two surface samples were above the ESV (SED-DA-035 at 2.89 mg/kg and SED-DA-038 at 3.24 mg/kg). Selenium is detected in the crude oil at concentrations of 1.82 and 2.66 mg/kg (see Table 5-1), indicating that crude oil from the Pegasus Pipeline would not contribute selenium up to the concentrations detected in sediment, especially in the deeper subsurface sample at SED-DA-010. These results suggest that selenium is consistent with background conditions and is not associated with crude oil.

- *Silver*. Figures 7-1.3, 7-2.3, and 7-3.3 show the maximum silver concentrations at each sediment sample location and the sample depth interval associated with the maximum detection. In two drainage way sediment samples, the silver concentrations were above the sediment ESVs. Both of these samples were subsurface samples at the same location (SED-DA-010 at 0.5 to 1 foot and 1 to 1.5 feet bgs); the associated surface sediment sample at this location was below the sediment ESV. Silver does not have an associated Arkansas background screening level (see Table 5-5). Both sample concentrations (28.7 to 34.3 mg/kg) were above the range of site background concentrations (0.68 to 1.3 mg/kg; Table 5-6). Silver was detected in crude oil at concentrations of 0.600 to 0.613 mg/kg (see Table 5-1) indicating that crude oil from the Pegasus Pipeline could not have contributed silver at the concentrations detected in sediment. These results indicate that silver in sediment samples is associated with background sources, and the limited concentrations above the ESV are not associated with crude oil.

- *Vanadium*. A sediment ESV was not available for vanadium. However, vanadium concentrations in 151 of the 154 sediment samples were less than the Arkansas background value of 88 mg/kg (Table 5-4) and vanadium concentrations in all 154 sediment samples were within the range of the Arkansas background sediment samples (4 to 190 mg/kg; Table 5-4).

7.5 Summary of Total Organic Carbon and Black Carbon

Fifty-three surface sediment samples were analyzed for TOC and black carbon to facilitate ecological risk screening, specifically the TU calculations. TOC concentrations range from 0.14 to 1.35 percent in 13 drainage way sediment samples, from 0.17 to 13.3 percent in 34 Dawson Cove sediment samples, and from 2.2 to 5.91 percent in six Lake Conway sediment samples.

Black carbon was detected in sediment samples collected from Dawson Cove (ranging from 0.16 to 0.42 mg/kg) and Lake Conway (ranging from 0.22 to 0.31 mg/kg). Black carbon was not detected in the sediment samples from the drainage way.

7.6 Summary of Lake Conway Re-Sampling Data

Six sediment locations in Lake Conway (SED-DA-033 through SED-DA-038) were re-sampled on November 19 and 20, 2013 (SED-DA-033R through SED-DA-038R) to evaluate whether conditions in Lake Conway are consistent with the results from the first (original) sampling event conducted in July and August 2013. Eighteen additional sediment samples were collected, and results are provided in Tables 7-1 and 7-4. Table 7-7 provides the statistics for the individual analytes that were re-sampled, along with the data for the original samples. Appendix H presents figures that plot the results of the November 2013 samples collected in Lake Conway. This subsection discusses the analytical results and data analysis for these re-sampled sediment locations for each chemical class (e.g., VOCs, PAHs, metals).

- *VOCs.* Similar to the original sample results, the two detected VOCs (2-butanone and acetone) are not associated with the crude oil, as discussed in Sections 5.1 and 5.4. No other VOCs were detected.

- *PAHs.* Similar to the original sample results, PAHs were detected at all re-sampled sediment locations in Lake Conway. The concentrations of individual PAHs were below their respective ESVs, and the ranges of total HMW and LMW PAHs were similar to the results from the original samples. For the 18 sediment samples collected in Lake Conway in November 2013, the total Priority+2 List HMW and LMW PAHs were below the sediment ESVs, which is consistent with the original samples. In 5 of these 18 samples, the Long List HMW PAHs are above the sediment ESVs, and in an additional 2 of the 18 samples, both the Long List HMW and LMW PAHs are above the sediment ESVs (Table 7-7). The sample depth intervals for the Long List HMW and LMW PAH summations in samples from original locations and re-sampled locations in Lake Conway are summarized below.

	Sample Depth Interval with PAH Summations above the ESVs	
Location ID	**Original Sampling (July and August 2013)**	**Re-Sampling (November 2013)**
Total HMW PAHs		
SED-DA-033	0 to 0.5 foot bgs	None
SED-DA-034	0 to 0.5 and 0.5 to 1 foot bgs	0 to 0.5 foot bgs
SED-DA-035	0 to 0.5 and 0.5 to 1 foot bgs	0 to 0.5 and 0.5 to 1 foot bgs
SED-DA-036	0 to 0.5 and 0.5 to 1 foot bgs	0 to 0.5 foot bgs
SED-DA-037	0 to 0.5, 0.5 to 1, and 1 to 1.5 feet bgs	0 to 0.5 foot bgs
SED-DA-038	0 to 0.5 and 0.5 to 1 foot bgs	0 to 0.5 and 0.5 to 1 foot bgs
Total LMW PAHs		
SED-DA-035	0 to 0.5 foot bgs	None
SED-DA-037	0.5 to 1 foot bgs	0 to 0.5 foot bgs
SED-DA-038	0 to 0.5 foot bgs	0 to 0.5 foot bgs

In addition, the one-carbon model TU results for re-sampled locations (ranging from 0.02 to 0.06) are similar to the one-carbon model TU results for original samples (ranging from 0.01 to 0.07).

- *Cadmium, Lead, and Mercury.* These three metals were not detected in the crude oil. The sample results from the November 2013 re-sampling event were similar to the original sample results. Cadmium and mercury concentrations were either non-detect or below the respective ESVs. Lead concentrations were above the sediment ESV (30.2 mg/kg) in three of the 18 November 2013 samples (similar to the 2 of 18 original samples that were above the sediment EVS). The lead concentrations in the original samples and the November 2013 samples ranged from 9.94 to 47.2 mg/kg and 11.4 to 43.6 mg/kg, respectively.

- *Arsenic, Barium, and Chromium.* These three metals were detected in crude oil at concentrations below the Arkansas sediment background values (95% UTL). Similar to the original sample results, detected arsenic concentrations were above the ESV (7.24 mg/kg), but less than the Arkansas background value of 14 mg/kg in two of the November 2013 surface sediment samples. The arsenic concentrations in the original samples and in the November 2013 samples ranged from 1.59 to 9.13 mg/kg and 1.30 to 7.55 mg/kg, respectively. Detected barium and chromium concentrations in all 18 of the November 2013 samples were less than the sediment ESV and/or the Arkansas background sediment value, which was consistent with the original sample results.

- *Nickel, Selenium, Silver, and Vanadium.* The November 2013 sampling results were similar to the original sample results, with nickel and vanadium concentrations below the Arkansas sediment background value and sediment ESV. Selenium and silver were not detected in the November 2013 sediment samples; selenium had been detected above the ESV in two of the original surface sediment samples.

In summary, the Lake Conway sediment results from November 2013 are consistent with the original sampling results from July and August 2013. No further sampling of Lake Conway sediments is necessary.

7.7 Evaluation of Deep Sediment Cores for Additional Analysis

In Dawson Cove, deeper samples (1.5 to 2, 2 to 3, and 3 to 4 feet) were collected from nine sediment locations and held at the laboratory: SED-DA-018, SED-DA-019, SED-DA-021, SED-DA-022, SED-DA-023, SED-DA-024, SED-DA-026, SED-DA-027, and SED-DA-029. A provision of the DARSP (ARCADIS 2013a) is that, if the sample collected from at 1 to 1.5 feet bgs "exceeds screening criteria, these deeper samples will also be submitted for analysis." At all nine of these locations, the VOC and PAH concentrations were below the ESVs in the in samples collected from 1 to 1.5 feet bgs sample, and the metals concentrations were below the screening criteria (i.e., not above both the Arkansas background and sediment ESV). Therefore, further analysis of the deeper samples was not warranted.

7.8 Evaluation of Soil Samples in Transitional Area to Polycyclic Aromatic Hydrocarbon Screening Criteria

As discussed in Section 3, normal seasonal water levels in Dawson Cove range from 262.2 feet (NAVD88) during winter to 262.87 feet (NAVD88) during summer, as controlled by the Lake Conway dam and the outlet culvert invert elevation from Dawson Cove. Six soil sample locations in Dawson Cove (SO-DA-023, SO-DA-025, SO-DA-026, SO-DA-027, SO-DA-028, and SO-DA-029) are located within a transitional area that was exposed during the sampling period, but is likely inundated for an extended period of time based on the expected range in seasonal water levels.

Therefore, these soil samples were also screened using sediment ESVs. Few analytes at these transitional locations were above sediment ESVs, as summarized below:

- *SO-DA-023*. In the subsurface sample (1 to 1.5 feet bgs) collected at this location, the nickel concentration was 37.7 mg/kg, which was slightly above the Arkansas sediment background of 35 mg/kg (and the sediment ESV of 15.9 mg/kg). Given the depth of this sample, this result indicates that nickel in this sample is consistent with background conditions in the area and is not associated with crude oil.
- *SO-DA-023, SO-DA-025, and SO-DA-027*. In the surface samples (0 to 0.5 foot bgs), the total LMW PAHs (Long List only) concentrations were above the sediment ESV. However, the one-carbon model TUs were less than 1, indicating no unacceptable risk to benthic ecological receptors.

These locations do not need to be evaluated further based on the sediment screening results.

7.9 Evaluation of the Dart Samplers

ARCADIS conducted Dart sampling at 10 locations in Dawson Cove (three soil locations and seven sediment locations) to qualitatively assess the vertical profile of PAHs and to evaluate the Dart sampling technique for potential future soil and sediment delineation sampling. Dart sampling is a technology developed by DTI that uses solid-phase extraction (SPE) and LIF principles to detect PAHs and PAH-containing nonaqueous phase liquids (NAPLs) in soil and sediment. A Dart sampler consists of a rod coated with an SPE medium, which sorbs PAHs. The sampler is inserted into the soil or sediment, allowed to equilibrate, removed, and analyzed with an LIF reader for PAH/NAPL concentrations as a function of depth[9]. Sampling activities, as well as the outcome of a calibration study for the Darts, are detailed in Appendix E. Sampling results are summarized here.

The Dart readings were compared to the field observations from co-located cores and the total PAH (both Priority+2 List and Long List PAHs) analytical results to evaluate the Dart results. As detailed in Appendix E, the Dart sampling method appears to have limited use in quantifying crude-oil-related PAHs in sediment and soil at the site. However, Dart samplers may have some use as a qualitative tool.

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[9] Additional information regarding the Dart technology can be found on DTI's website (http://www.dakotatechnologies.com/index.php/Service/Darts.html), and in Attachment C of the Downstream Areas Remedial Sampling Plan (ARCADIS 2013a).

7.10 Lake Conway Depositional Assessment Results

In August 28 and 29, 2013, ARCADIS conducted a depositional assessment in Lake Conway to evaluate whether the Mayflower Pipeline Incident Response activities within Dawson Cove, which temporarily increased surface-water turbidity within the cove, produced a discernible deposition of new, surficial sediment within Lake Conway. Such deposition, if any, would be evidenced by a surficial sediment layer and would most likely occur near the Dawson Cove outlet, where Dawson Cove discharges into Lake Conway. This assessment was performed at the request of the Arkansas Game and Fish Commission. The assessment was qualitative, based on visual descriptions of sediment core samples. The assessment was performed in accordance with the DARSP (ARCADIS 2013a).

During the Mayflower Pipeline Incident Response activities, a silt curtain was installed, temporarily blocking the outflow from Dawson Cove to Lake Conway. The water level in Dawson Cove was maintained by pumping, as needed, from a temporary structure that was designed to minimize entrainment of sediment.

7.10.1 Sampling Locations

The sediment core locations included in the depositional assessment are shown on Figure 2-10. ARCADIS collected twelve sediment cores (DEP-01 through DEP-12) along a transect in Lake Conway leading from near the outlet of Dawson Cove toward the Highway 89 eastern bridge that crosses Lake Conway (herein referred to as south Lake Conway cores; Figure 2-10). ARCADIS also collected four background sediment cores (BG-008, BG-010, BG-011, and BG-012) for comparison with the south Lake Conway cores. The background samples were collected in the northern area of Lake Conway, where the overall surface water flow direction is toward the south.

The sediment descriptions are presented in Tables 2-9 and 2-10. Photographs of the cores are presented in Appendix C, and stratigraphic profiles are summarized on Figures 7-4.1 and 7-4.2.

7.10.2 Characteristics of South Lake Conway Samples

Sediment cores DEP-01 through DEP-07 were collected closest to the outlet of Dawson Cove (Figure 2-10). These cores were collected to a depth of between 4 to 10 inches below sediment surface (bss). These cores exhibited a surficial sediment layer approximately 0.04 to 0.08 inches thick, composed of brown silt (see Figure 7-4.1). The observation of silt is consistent with the relatively quiescent setting of these samples, within a cove west of the main part of Lake Conway. This brown silt layer was underlain by gray silt, with a thickness of approximately 1 to at least 9 inches, in all of these cores. Brown clay was present below the gray silt in some of these south Lake Conway cores.

Cores DEP-08 through DEP-12 were collected within the main part of Lake Conway. These cores were collected to a depth of between 7 to 9 inches bss. In contrast with the brown silt surficial layer observed at locations DEP-01 though DEP-07, cores DEP-08 through DEP-12 had a surficial layer of gray silt with trace sand, silt with little sand, or sand with some silt (see Figure 7-4.2). The sand content generally increased toward the east; core DEP-12 had the highest sand content. The absence of the brown silt layer at these locations may be related to higher energy within the main part of the lake due to the main flow velocities associated with discharge of Lake Conway near the constriction under the Highway 89 eastern bridge, longer wind fetch, and boat traffic; it is interpreted that higher energy conditions have either prevented the deposition of the surficial brown silt layer or removed it by natural scouring.

7.10.3 Characteristics of Background Samples

Background sediment cores BG-008, BG-010, BG-011, and BG-012 were collected in the northern area of Lake Conway. These cores were collected to a depth of between 6 to 13 inches bss. The general stratigraphy of these background cores was similar to that at the DEP-01 through DEP-12 locations. Three of the four background sediment cores (BG-010 through BG-012) had a surface layer approximately 0.04 to 1 inch thick of brown silt and sand, sand and silt, or sand with some silt, underlain by gray silt with a thickness of approximately 0.5 to at least 8 inches, and then by clay. Two of these background locations (BG-010 and BG-011) had a similar thickness of brown surficial sediment as observed in samples DEP-01 through DEP-07, discussed above (approximately 0.04 to 0.08 inches).

Background sediment core BG-008 contrasted with the other background samples, in that it lacked a brown surficial layer; rather, it contained gray sand and silt, underlain by brown clay. The general stratigraphy of this background core was similar to that at DEP-08 through DEP-12.

7.10.4 Evaluation of Physical, Chemical, and Biological Parameters

The assessment of whether the Mayflower Pipeline Incident Response activities within Dawson Cove produced a discernible layer of new, surficial sediment in Lake Conway is summarized in Sections 7.9.2 and 7.9.3, and primarily relied on inspection of sediment stratigraphy. This included limited qualitative evaluation of various physical characteristics of the near-surface sediment profile in relation to background samples. While more extensive information about the near-surface sediment conditions and characteristics are available through detailed inspection of sediment profile imagery (as listed in the DARSP), not all of these characteristics are relevant to the evaluation of presence/absence of a new sediment layer in Lake Conway. For completeness with respect to the types of information identified in the DARSP, a brief listing and discussion of these follows.

- *Grain size*. Visual characterization/classification of sediment type and texture is principally based on grain size as discussed in Sections 7.9.2 and 7.9.3.

- *Surface boundary roughness*. Surface boundary roughness at the sediment-water interface governs bottom boundary layer thickness in the water column. Surface boundary roughness is used to represent how flow across that roughness will affect boundary layer flow. The grain size of the sediment together with presence of any larger scale irregular features or objects such as woody debris, rocks, sediment clumps (for example from recently disturbed bed surface or recent deposition of sediment clumps or debris) and other organic matter can affect surface boundary roughness. Surface boundary roughness, as observed through the sediment cores, did not vary to any considerable degree among samples and thus, had limited significance with respect to the depositional layer assessment.

- *Depth of apparent redox potential discontinuity*. The brown silt surficial layer observed in south Lake Conway cores DEP-01 through DEP-07 and background cores BG-010, BG-011, and BG-012 are most likely oxidized sediment. The underlying gray sediment may reflect reduced conditions associated with oxygen consumption via biological decomposition of organic sediment. Diffusion, burrowing organisms, and physical mixing introduce oxygen in the surface sediments. Oxygen is typically rapidly consumed such that the surface oxidized layer is often thin. Oxygen will usually penetrate approximately 2 to 3 millimeters into the sediment by molecular diffusion (Aller 1994). Within a few millimeters of the sediment-water interface organic sediment will often be anoxic, exhibiting a darker color. In a 2004 survey of Lake Conway, dissolved oxygen was present in surface water near the sediment water interface (Shostell and Williams 2007), indicating the potential for oxidized sediment at the sediment water interface, which explains the thin light brown silty surface layer.

- *Erosional or depositional features*. Potential erosional and depositional processes affect the stratigraphy and grain size of the sediments and are discussed in Sections 7.9.2.

- *Subsurface methane gas pockets*. The standard profile of sediment respiration consists of a series of oxidants that are consumed in order of free energy release, that order being: oxygen, nitrate, manganese oxides, iron oxides/hydroxides, sulfate, and carbon dioxide (Berner 1980; Froelich et al. 1979; Stumm and Morgan 1981). Generally, the lower free-energy oxidants will not be utilized until the higher free-energy oxidants have been consumed. The degradation of organic matter using the oxidant carbon dioxide results in the production of methane and other gases which can produce gas pockets or voids in the sediment profile. Gas pockets were not observed to any notable degree in the south Lake Conway cores or in the background cores and thus, have little, if any significance to the depositional assessment.

- *Observation of benthic organisms*. Observation of benthic organisms is listed in Tables 2-9 and 2-10.

7.10.5 Discussion of Results

If a significant depositional event occurred in Lake Conway during the response activities, a surficial sediment layer would be visible in the core stratigraphy, particularly in the area near the Dawson Cove outlet. As discussed above, a very thin (0.04 to 0.08 inches) surficial layer of brown silt was observed in cores DEP-01 through DEP-07. It is possible that this layer was deposited, at least in part, during the response activities. However, two of the four background samples BG-010 and BG-011, also contained a very thin (0.04 to 0.08 inches) surficial layer of brown sediment. The brown surficial layer at DEP-01 through DEP-07 may reflect natural, long term depositional processes. As discussed in Section 5, the analytical results of sediment samples collected from Lake Conway indicate no discernible effect on lake sediments as a result of the Mayflower Pipeline Incident.

7.11 Summary of Sediment Sampling and Screening Evaluation Results

A total of 178 sediment samples were collected at 53 locations within the drainage ways, Dawson Cove, and Lake Conway in July and August 2013. Based on the screening results, concentrations in 171 of 178 samples were at levels that do not warrant further evaluation. In the remaining samples, at least one analyte was above the screening criteria. In addition, as requested by ADEQ, six locations in Lake Conway were re-sampled in November 2013; 18 samples were collected at these locations. The sampling results for these locations were consistent with results from the original July/August sediment sampling; constituent concentrations in the 18 sediment samples were at levels that do not warrant further evaluation.

The following presents a summary, by chemical class (i.e., VOCs, PAHs, and metals).

VOCs. Crude-oil-related VOC concentrations were either non-detect or below the ESVs in all sediment samples in the drainage ways and Lake Conway (including re-sampled locations). In Dawson Cove, total xylenes and isopropylbenzene were detected above the ESVs (25.2 µg/kg and 86 µg/kg, respectively) at the following five locations in Dawson Cove, and these locations warrant further evaluation (see Section 9).

Area	Location	Sample Depth	Analyte	Value
Dawson Cove	SED-DA-015	Surface (0 to 0.5 foot bgs)	Total xylenes	730 µg/kg
		Subsurface (0.5 to 1 foot bgs)	Total xylenes	420 µg/kg
	SED-DA-017	Subsurface (0.5 to 1 foot bgs)	Isopropylbenzene	280 µg/kg
			Total xylenes	2,600 µg/kg
	SED-DA-039	Subsurface (1 to 1.5 feet bgs)	Total xylenes	26 µg/kg
	SED-DA-045	Surface (0 to 0.5 foot bgs)	Total xylenes	110 µg/kg
		Subsurface (0.5 to 1 foot bgs)	Total xylenes	61 µg/kg
	SED-DA-048	Surface (0 to 0.5 foot bgs)	Total xylenes	81 µg/kg

PAHs. A total of 102 of sediment samples collected in the drainage ways and Dawson Cove had individual PAHs and/or PAH summations below the ESVs. Fifty-three of the sediment samples collected in these areas had individual PAHs and/or PAH summations above the ESVs. However, the TU for each surface sample, which accounts for the specific mixture and concentrations of PAHs in pore water and provides a rigorous indication of potential risk to benthic invertebrates, was 1.0 or less in all samples, indicating that there is no unacceptable risk to benthic ecological receptors. Two of the subsurface samples had a TU slightly above 1.0; however, it is concluded that risks to benthic and aquatic receptors are not expected at these locations for two reasons: 1) benthic receptors are unlikely to be exposed to sediments deeper than 0.5 foot, and 2) the TU was only slightly above 1.0 using the one-carbon model. Twelve of the 18 samples collected in Lake Conway in July and August 2013 had a total LMW PAH (Long List only) summation above the ESV; however, the TUs for these samples were well below 1.0. The Lake Conway sediment results from November 2013 are consistent with the original sampling results from July and August 2013. Therefore, no further assessment of PAHs in sediment in the drainage ways, Dawson Cove, or Lake Conway is necessary.

Metals. Based on the results of the screening data evaluation, the concentrations of metals are consistent with background conditions in the area and/or below the ESVs. In addition, metals concentrations from the November 2103 sampling event are consistent with the original sampling data obtained for Lake Conway. Therefore, no further assessment of metals concentrations in sediments is necessary.

Six soil sample locations in Dawson Cove are located within a transitional area that was exposed during the July to August sampling period, but that is seasonally inundated; therefore, these soil samples were compared to sediment ESVs. The results of the PAH evaluation for these samples showed no unacceptable risk to benthic ecological receptors. In addition, the metals concentrations were consistent with background conditions in this area and therefore, are not associated with crude oil. Based on the sediment screening results, no further assessment of these locations within the transitional area is necessary.

The depositional assessment identified a very thin, brown surficial sediment layer at several locations near the Dawson Cove outlet that was similar to a similar surficial sediment layer observed at two of the background locations, and therefore, may reflect natural, long-term depositional processes. These results, combined with the analytical results in Lake Conway indicate no further assessment of sediments in Lake Conway is necessary.

8. Surface Water Sampling Evaluation and Results

This section summarizes the analytical results and data analysis for daily and weekly surface water samples collected from drainage ways, Lake Conway, and Dawson Cove and six surface water samples collected from the drainage ways and Dawson Cove as part of the DARSP activities.

8.1 Daily and Weekly Sampling

More than 2,900 daily surface water samples have been collected from numerous locations in drainage ways, Dawson Cove, and Lake Conway between March 29 and October 31, 2013 (Figure 2-7). These surface water samples were analyzed for VOCs, PAHs, total metals, dissolved metals, and oil and grease (Table 2-8).

As described in Section 2.5, daily surface water sampling was discontinued at the end of October and a weekly surface water sample program was initiated on November 1, 2013. A total of 233 surface water samples were collected from 13 locations in the drainage ways, Dawson Cove, and Lake Conway between November 1, 2013 and February 9, 2014 (Figure 2-8). These samples were analyzed for PAHs (Table 2-8). The analytical results for the weekly samples are discussed in Section 8.1.2, along with the daily sample results.

Surface water data tables for samples are provided in Appendix F. Figures 8-1 through 8-12 present the evaluation of analytical results for these daily and weekly surface water samples. Field parameters measured at the sample locations are summarized in Appendix F.

8.1.1 Summary of Volatile Organic Compounds in Daily Surface Water Samples

VOC results for the daily surface water samples collected between March 29 and October 31, 2013 are summarized on Figures 8-1 through 8-3. Of the 70 individual VOCs analyzed for in approximately 2,930 samples, 45 VOCs were not detected in any samples (Appendix F).

Lake Conway

Detected VOC concentrations in Lake Conway surface water samples were all at concentrations below their associated ESVs (Figure 8-2).

Dawson Cove

Of the 14 VOCs detected in Dawson Cove surface water, only two VOCs were detected at concentrations above their respective ESVs (Figure 8-3):

- Benzene was detected at concentrations above the ESV of 53 µg/L in two samples (79.2 and 102 µg/L) collected at Dawson Cove sampling location WS-004S on April 1 and 2, 2013, respectively. Benzene has not been detected in Dawson Cove surface water samples since May 5, 2013.
- Total xylenes were detected at concentrations above the ESV of 13 µg/L in four samples collected at locations WS-004S (ranging from 13.5 to 59.2 µg/L between April 1 and April 11, 2013) and WS-004D (20 µg/L on April 11, 2013). Total xylenes have not been detected in Dawson Cove surface water samples since May 31, 2013.

Drainage Ways

At drainage way sample location WS-008, only two VOCs were detected at concentrations above their respective ESVs:

- Total xylenes were detected at concentrations above the ESV of 13 µg/L in four samples collected at WS-008 (ranging from 52 to 130 µg/L between April 8 and April 13, 2013). Total xylenes have not been detected in WS-008 surface water samples since May 31, 2013.
- Isopropylbenzene was detected at a concentration above the ESV of 2.6 µg/L in one sample (3.7 µg/L) collected at drainage way location WS-008 on April 11, 2013. Isopropylbenzene has not been detected in surface water samples collected at WS-008 since April 16, 2013.

Benzene, isopropylbenzene, and total xylenes have been below their respective ESVs continuously at all surface water monitoring locations since April 13, 2013.

8.1.2 Summary of Polycyclic Aromatic Hydrocarbons in Daily & Weekly Surface Water Samples

Locations with PAH concentrations above ESVs are shown on Figure 8-4 (daily surface water data; March 29 through October 31, 2013) and Figure 8-5 (weekly surface water data; November 1, 2013 through February 9, 2014). Summary statistics for daily and weekly surface water samples are provided on Figure 8-6 for background surface water sample locations, on Figure 8-7 for Lake Conway samples, and on Figure 8-8 for Dawson Cove samples.

Background (Figure 8-6)

Daily and weekly sampling results (March 29, 2013 through February 2, 2014)[10] for the background locations (WS-005, WS-014, and WS-015) indicated detections of two PAHs (benzo(a)pyrene and pyrene) above their respective ESVs.

- Benzo(a)pyrene was detected at concentrations of 0.019 and 0.018 µg/L above the ESV of 0.015 µg/L in two daily samples collected at WS-005 on May 7 and October 7, 2013. Benzo(a)pyrene was also detected at a concentration of 0.077 µg/L above the ESV in one weekly sample collected at WS-014S on December 12, 2013.
- Pyrene was detected at concentrations above the ESV of 0.025 µg/L in 13 daily samples collected at WS-005 between March 30 and October 16, 2013 and one daily sample collected at WS-014S on October 5, 2013. Pyrene was not detected in any background surface water sample collected since October 16, 2013. The maximum detected pyrene concentration in background surface water was 1.5 µg/L, for a sample collected at WS-005 on August 22, 2013; this concentration was also above the Region 5 alternate ESV for pyrene of 0.39 µg/L[11].

Lake Conway (Figure 8-7)

Daily sampling results (March 29 through October 31, 2013) indicated detections of four PAHs (anthracene, benzo(a)anthracene, benzo(a)pyrene, and pyrene) above their respective ESVs at the following locations: near the Dawson Cove outlet (WS-001, WS-006, and WS-009), Lake Conway (WS-010 and WS-012), the Highway 89 bridge (WS-002 and WS-011), and the boat ramp next to the Lake Conway dam (WS-003).

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[10] During the week of February 3, 2014, no surface water samples were collected at WS-014 and WS-015 due to icy conditions.

[11] The ESV of 0.025 micrograms per liter (µg/L) for pyrene is from Region 3 and is based on a value identified in 1999 by the Canadian Council of Ministers of the Environment. An alternate ESV of 0.39 µg/L was established by USEPA Region 5 as a RCRA Interim Criterion (USEPA 2003) and is also used in the comparison of data.

However, October sampling results indicated detections of only two PAHs (anthracene and pyrene) above their respective ESVs at Lake Conway sampling locations.

- Anthracene was detected above the ESV of 0.012 µg/L in one daily sample during October 2013, which was collected at WS-010S at a concentration of 0.014 µg/L on October 23. From March 29 through September 30, 2013, anthracene was detected above the ESV in seven daily samples collected from Lake Conway.
- Benzo(a)anthracene was not detected above the ESV in the daily sampling during October 2013. From March 29 through September 30, 2013, benzo(a)anthracene was detected above the ESV of 0.018 µg/L in nine daily samples (with a maximum concentration of 0.51 µg/L at WS-006S on July 8, 2013).
- Benzo(a)pyrene was not detected in any of the daily samples collected during October 2013. From March 29 through September 30, 2013, benzo(a)pyrene was detected above the ESV of 0.015 µg/L in 12 daily samples (with a maximum concentration of 0.51 µg/L at WS-006S on July 8, 2013). Benzo(a)pyrene was also detected in background surface water samples at a maximum concentration of 0.077 µg/L.
- Pyrene was detected above the ESV of 0.025 µg/L in two daily samples during October 2013, which were collected at WS-002 (0.031 µg/L) and WS-010D (0.03 µg/L). From March 29 through September 30, 2013, pyrene was detected above the ESV of 0.025 µg/L in 49 daily samples collected at WS-001D, WS-002, WS-003, WS-006S, WS-006D, WS-009, WS-010D, WS-011D, WS-012S, and WS-012D. Of the daily samples, pyrene was detected above the Region 5 alternate ESV for pyrene of 0.39 µg/L in one sample collected at WS-002 and two samples (including one duplicate sample) collected at WS-006. The maximum detected pyrene concentration of 1.0 µg/L in Lake Conway samples is less than the maximum detected pyrene concentration of 1.5 µg/L in background surface water samples.

Weekly surface water sampling results (November 1, 2013 through February 9, 2014) had detections of two PAHs (benzo(a)pyrene and pyrene) above their respective ESVs in Lake Conway samples.

- Benzo(a)pyrene was detected above the ESV of 0.015 µg/L in two weekly samples collected at WS-006D and WS-010D on December 26, 2013 (0.017 and 0.019 µg/L, respectively).
- Pyrene was detected above the ESV of 0.025 µg/L in weekly samples collected at five locations: WS-009, WS-010S, WS-010D, WS-011D, WS-012S, and WS-021.

Pyrene was not detected above the Region 5 alternate ESV of 0.39 µg/L in any weekly samples. The maximum detected pyrene concentration of 0.11 µg/L in weekly Lake Conway samples is less than the maximum detected pyrene concentration of 1.5 µg/L in background surface water samples. Surface water monitoring locations WS-010 and WS-011 are not located adjacent to the Dawson Cove outlet.

Dawson Cove (Figure 8-8)

Daily sampling results (March 29 through October 31, 2013) indicated detections of eight PAHs (anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, fluoranthene, indeno[1,2,3-cd]pyrene, phenanthrene, and pyrene) above their respective ESVs in Dawson Cove samples. However, October daily sampling results indicated no PAH detections above their respective ESVs in Dawson Cove samples. Weekly sampling results (November 1, 2013 through February 9, 2014) indicated detections of three PAHs (benzo(a)anthracene, benzo(a)pyrene, and pyrene) above their respective ESVs in Dawson Cove samples.

- Benzo(a)anthracene was detected above the ESV of 0.018 µg/L in two weekly samples collected at WS-007D (0.019 µg/L) on November 13, 2013 and January 2, 2014. Benzo(a)anthracene was detected above the ESV of 0.018 µg/L in 167 daily samples with a maximum concentration of 10 µg/L in a sample collected at WS-007D on June 26, 2013. Benzo(a)anthracene was not detected in daily samples collected in October 2013.
- Benzo(a)pyrene was detected above the ESV of 0.015 µg/L in three weekly samples collected at WS-007D (0.016 to 0.023 µg/L) on November 13, 2013 and January 2 and 11, 2014. One sample collected at WS-020 on January 11, 2014 also had benzo(a)pyrene concentration (0.024 µg/) above the ESV. Benzo(a)pyrene was detected above the ESV of 0.015 µg/L in 172 daily samples with a maximum concentration of 9.0 µg/L in a sample collected at WS-007D on June 26, 2013. Benzo(a)pyrene was not detected in daily samples collected in October 2013.
- Pyrene was detected above the ESV of 0.025 µg/L in 12 weekly samples collected at WS-004D, WS-007D, and WS-020 between November 20, 2013 and February 6, 2014. The highest concentration detected at these locations (0.044 µg/L) is less than the maximum detected pyrene concentration of 1.5 µg/L in background surface water. Pyrene was detected above the ESV of 0.025 µg/L in 249 daily samples with a maximum concentration of 38 µg/L in a sample collected at WS-

007D on June 26, 2013. Pyrene was not detected above the ESV in daily samples collected in October 2013.

8.1.3 Summary of Oil and Grease in Daily Surface Water Samples

Oil and grease results for all sampling locations (i.e., drainage ways, Dawson Cove, Lake Conway, and background) are provided on Figure 8-9. A total of 1,788 samples have been analyzed for oil and grease since March 29, 2013. One sample collected at WS-008 on May 29, 2013 (location in the drainage way along Main Street) had a detected oil and grease concentration of 10.1 milligrams per liter (mg/L), above the Arkansas Pollution Control and Ecology Commission Regulation No. 2 guideline of 10 mg/L average but below the guideline of 15 mg/L maximum.

8.1.4 Summary of Dissolved Metals in Daily Surface Water Samples

More than 1,500 samples were analyzed for metals between July 15 and October 31, 2013. The analysis of metals focused on October sampling results (October 1 through 31, 2013) for comparison to ESVs that are based on dissolved metals concentrations is presented in Figures 8-10 through 8-12.

Background (Figure 8-10)

Barium was detected at concentrations ranging from 0.0051 to 0.11 mg/L above the ESV of 0.004 mg/L in all dissolved metals samples collected at Lake Conway background monitoring locations WS-005, WS-014S, and WS-014D.

The barium ESV is a secondary chronic value developed by the USEPA for the Great Lakes Water Quality Initiative, as cited in Suter and Tsao, 1996. Suter and Tsao (1996) have the following comment regarding the ESV for barium:

> "*Background water concentrations should be used as a check for these benchmarks* [i.e., ESVs]. *That is, because some of these benchmarks are quite conservative and because the measured concentrations in ambient water may include forms that are not bioavailable, benchmark concentrations may be lower than background water concentrations. If the background concentrations are valid and represent an uncontaminated state and if exposed site does not contain forms of the chemical that are more bioavailable or toxic than the forms at background sites, then screening benchmarks lower than the background concentration should not be used*."

Based on this comment, barium concentrations for other surface water samples were compared against Lake Conway background concentrations.

Dissolved lead was detected at a concentration (0.0049 mg/L) above the ESV of 0.00054 mg/L in one background surface water sample collected at WS-014S on October 24, 2013. Dissolved lead was not detected in any other background surface water samples.

Lake Conway (Figure 8-11)

Two metals, barium and lead were detected at concentrations above their respective ESVs for dissolved samples in October 2013:

- Barium concentrations in the Lake Conway samples ranged from 0.0027 to 0.194 mg/L, which is similar to the range of dissolved barium (0.0051 to 0.11 mg/L) detected in background surface water samples. The average barium concentration in Lake Conway samples collected in October 2013 (0.020 mg/L) is the same as the background samples (0.020 mg/L).
- Lead was detected at concentrations above the ESV of 0.00054 mg/L in five Lake Conway dissolved samples collected on October 24, 2013 (0.0048 to 0.0066 mg/L). Lead was not detected in the remaining Lake Conway dissolved metal samples collected in October 2013.

Dawson Cove (Figure 8-12)

Two metals, barium and lead, were detected at concentrations above their respective ESVs for dissolved samples in October 2013:

- Barium concentrations in Dawson Cove dissolved samples ranged from 0.0047 to 0.0381 mg/L, which are similar to the range of dissolved barium detected in background samples (0.0051 to 0.11 mg/L). Average barium concentration in Dawson Cove samples collected in October 2013 (0.023 mg/L) is similar to the background samples (0.020 mg/L).
- Lead was detected at a concentration of 0.0057 mg/L, above the ESV of 0.00054 mg/L, in one dissolved samples collected at WS-007D on October 24, 2013. Lead was not detected in the remaining Dawson Cove dissolved metal samples collected in October 2013.

Metals in surface water samples collected from Dawson Cove and Lake Conway are derived from background sources. All dissolved metals detected at concentrations above the ESVs are detected in background soil samples collected across Arkansas and in the vicinity of the incident. It is likely that soils contribute to the detected concentrations of metals in surface water. Higher concentrations of total metals are typically associated with higher turbidity, indicating contributions of particulate metals to surface water. In addition, higher concentrations of total and dissolved metals in Dawson Cove are associated with periods of limited or no precipitation indicating that evaporation may play a role in controlling concentrations of total and dissolved metals in surface water. Based on the limited detections of dissolved metals above the ESVs in Dawson Cove and in Lake Conway surface water samples, metals in surface water are of limited ecological concern.

8.2 One-Time DARSP Surface Water Sampling Event

In support of the DARSP, a one-time surface water sampling event was conducted in mid-August 2013. Two drainage way surface water samples (WS-022DA and WS-023DA, located in areas North Main Street and west of Highway 365), were collected from the surface of the water column. Another drainage way surface water sample (WS-024DA located at east of Highway 365) and three Dawson Cove (WS-025DA, WS-026DA, and WS-027DA) surface water samples were collected from the midpoint of the water column (Figure 2-9). Drainage way surface water samples were collected on August 13, 2013 and the Dawson Cove surface water samples were collected on August 15, 2013. As described in Section 2.5, surface water samples were submitted for laboratory analysis of VOCs, PAHs (2- to 6-ring PAHs including Priority Pollutant PAHs and 2- to 4-ring PAH alkyl groups), oil and grease, total metals (RCRA 8 metals, nickel, vanadium, calcium, and magnesium), dissolved metals (RCRA 8 metals, nickel, and vanadium), hardness, and TSS. Table 8-1 provides the analytical results for surface water samples collected during the one-time sampling event.

The data collected from this sampling event were screened as follow:

- Individual analytes were screened against their respective ESVs (see Table 5-2 and Table 8-1).
- Total LMW and HMW PAHs were calculated according to Table 5-3 and screened against ESVs (Table 8-2). Additionally, TUs for surface water samples were calculated in accordance with Table 5-3, as shown on Table 8-2.

The following subsections discuss the analytical results of this sampling event by each chemical class (e.g., VOCs, PAHs, and metals).

8.2.1 Summary of Volatile Organic Compounds in DARSP Surface Water Samples

Surface water samples were analyzed for 66 VOCs (see Table 2-8); 61 of these VOCs were not detected in any surface water sample (see Table 8-1). Four detected VOCs (2-butanone, acetone, TCE, and chloroform) were not detected in the crude oil as discussed in Section 5.1; therefore, these four compounds are not evaluated further in this section. Toluene was the only VOC detected in both crude oil and surface water samples. Detected toluene concentrations were below the toluene surface water ESV in all samples.

8.2.2 Summary of Polycyclic Aromatic Hydrocarbons in DARSP Surface Water Samples

Sixteen Priority Pollutant PAHs were detected in drainage way surface water samples (see Tables 8-1 and 8-2). Anthracene was the only PAH compound detected above the ESV of 0.012 µg/L in two drainage way surface water samples (0.01849 µg/L at WS-022DA and 0.02762 µg/L at WS-023DA). The TUs for drainage way surface water samples were 1.0 or less (see Table 8-1).

Priority Pollutant PAHs were not detected in Dawson Cove surface water sample WS-025DA. Fourteen PAHs were detected in surface water sample WS-026DA (Dawson Cove), 16 PAHs were detected in surface water sample WS-024DA (Dawson Cove), and all 20 PAHs were detected in surface water sample WS-027DA (Dawson Cove). Three PAHs (anthracene, benzo(a)anthracene, and benzo(a)pyrene) were detected above their respective ESVs in Dawson Cove surface water sample WS-027DA. The TU for the four Dawson Cove surface water samples ranged from 0.0 at WS-025DA to 1.0 at WS-027DA.

In summary, few PAHs in drainage way and Dawson Cove surface water samples were detected above the ESVs, and TU values were 1.0 or less for all surface water samples, indicating that there is no unacceptable risk to aquatic ecological receptors.

8.2.3 Summary of Oil and Grease in DARSP Surface Water Samples

Oil and grease were not detected in any of the surface water samples collected from the drainage way and Dawson Cove.

8.2.4 Summary of Metals in DARSP Surface Water Samples

Arsenic, cadmium, mercury, selenium, and silver were not detected in any of the drainage way or Dawson Cove dissolved metals or total metals surface water samples. Chromium, lead, and vanadium were not detected in any of the drainage way or Dawson Cove dissolved metals samples. Dissolved nickel was detected in all three drainage way surface water samples (WS-022DA, WS-023DA, and WS-024DA) and one Dawson Cove surface water sample (WS-025DA), but was below the ESV for all samples. Dissolved nickel was not detected in the other two Dawson Cove surface water samples (WS-026DA and WS-027DA).

Dissolved barium was the only constituent detected in drainage way and Dawson Cove surface water samples at concentrations above the surface water ESV of 0.004 mg/L. Dissolved barium concentrations ranged from 0.0167 to 0.0215 mg/L in drainage way surface water and from 0.0169 to 0.0223 mg/L in Dawson Cove surface water.

As described in Section 8.1.4, drainage way and Dawson Cove surface water sample dissolved barium concentrations were compared to background Lake Conway dissolved barium concentrations. The background Lake Conway samples were collected in accordance with the Surface Water Sampling and Analysis Plan (Attachment B of the DARSP; ARCADIS 2013a). Dissolved barium was detected at concentrations ranging from 0.0051 to 0.033 mg/L in all background Lake Conway surface water samples collected at sampling locations WS-005, WS-014S, and WS-014D from July 15 through September 6, 2013. These results indicate that dissolved barium concentrations in drainage way and Dawson Cove surface water samples were within the range for Lake Conway background. These results demonstrate that dissolved barium concentrations in the drainage way and Dawson Cove surface water are consistent with background conditions.

8.2.5 Summary of Hardness and Total Suspended Solids in DARSP Surface Water Samples

Surface water samples were analyzed for hardness and TSS, and field parameters were measured (Table 8-1). For drainage way surface water samples, hardness concentrations ranged from 18.2 to 30 mg/L and TSS concentrations ranged from and 28.7 to 50 mg/L In Dawson Cove surface water samples, hardness concentrations ranged from 15.8 to 39.8 mg/L and TSS concentrations ranged from 15 to 110 mg/L.

8.3 Surface Water Data Summary

In summary, extensive monitoring of surface water quality has been conducted between March 29, 2013 and February 9, 2014, with more than 3,200 daily and weekly surface water samples collected from numerous locations in drainage ways, Dawson Cove, and Lake Conway, and six surface water samples were collected from drainage ways and Dawson Cove in support of the DARSP.

For surface water samples collected over an eleven month period from March 29, 2013 through February 9, 2014 there have been limited detections of constituents of concern at concentrations above the ESVs.

- No VOC were detected above the ESVs in Lake Conway surface water samples. Only three of 70 VOCs (benzene, isopropylbenzene, and total xylenes) have been detected at concentrations above the ESVs in the drainage way and Dawson Cove surface water samples. No VOCs have been detected at concentrations above the ESVs since April 13, 2013.
- Eight of 18 PAHs have been detected at concentrations above their respective ESVs in daily samples and/or weekly surface water samples since March 29, 2013. In the weekly surface water samples collected since November 1, 2013, only three PAHs (benzo(a)anthracene, benzo(a)pyrene, and pyrene) have been detected at concentrations above the ESVs in Dawson Cove. Two PAHs (benzo(a)pyrene, and pyrene) were detected at concentrations above the ESVs in weekly surface water samples from Lake Conway (including Lake Conway sampling locations not adjacent to the Dawson Cove outlet). Benzo(a)pyrene was detected at a concentration above the ESV in one weekly background surface water sample.
- Four of 10 metals (barium, cadmium, lead, and silver) have been detected in dissolved surface water samples at concentrations above the ESVs at locations in Dawson Cove and Lake Conway samples. In the daily surface water samples collected in October 2013, only two metals (barium and lead) were detected in dissolved surface water samples at concentrations above the ESV. Dissolved barium concentrations were above the ESV for all surface water samples, including background samples, and the range of barium concentrations in Dawson Cove and Lake Conway samples was similar to the range of concentrations in background samples. Only one of 109 Dawson Cove dissolved metal samples collected in October 2013 was above the ESV for dissolved lead (0.0057 mg/L). Dissolved

metals concentrations in all surface water samples are considered to be representative of background conditions.

For the six DARSP surface water samples collected in August 2013, concentrations of toluene (the only VOC detected in the surface water samples that was also present in crude oil) were below the ESV and PAH TU results were all 1.0 or less. Dissolved barium was detected in surface water samples at concentrations above the ESV; however, concentrations were within the range of background Lake Conway concentrations.

Based on the data evaluation, no further action is warranted; however, a weekly surface water monitoring program will be continued at the locations recommended in Section 13.

9. Summary of Analytical Findings and Screening Data Evaluation Results

Three areas downstream of the release location were assessed to determine post-response conditions; these include the drainage ways from the residential area to Dawson Cove, Dawson Cove, and Lake Conway. Soil, sediment, and surface water samples were collected as part of the response. The following provides a summary of soil and sediment findings by area, and a summary of the overall surface water sampling results. Locations that warranted further assessment based on the screening data evaluation, as presented in earlier versions of this report and summarized in this section, are addressed in the refined ecological risk evaluation presented in Appendix L and summarized in Section 10.

Drainage Ways Soil and Sediment Results

A total of 45 soil samples were collected at 15 locations along the banks of the drainage ways. Based on the screening results, concentrations in 42 of the 45 samples were at levels that do not warrant further evaluation. Crude-oil-related VOC concentrations were either non-detect or below the ESVs in all soil samples except for benzene in one sample. Only two samples had PAH summations above the associated soil ESV. The screening of metals results indicates the concentrations in soil were consistent with background conditions in the area and are not associated with crude oil. The following table summarizes the three soil locations along the drainage ways that warrant further evaluation (presented in Section 10).

Media	Location	Sample Depth	Analyte	Value
Soil	SO-DA-003	Surface (0 to 0.5 foot bgs)	Total HMW PAH	2,280 µg/kg
	SO-DA-005	Surface (0 to 0.5 foot bgs)	Total HMW PAH	1,640 µg/kg
	SO-DA-015	Surface (0 to 0.5 foot bgs)	Benzene	34 µg/kg

A total of 35 sediment samples were collected at 13 locations in the drainage ways. Crude-oil-related VOC concentrations were either non-detect or below the ESVs in all sediment samples. Several sediment samples in the drainage ways and Dawson Cove had individual PAHs and/or PAH summations above the ESVs. However, the TU for each of the surface samples, which accounts for the specific mixture and concentrations of PAHs, was 1.0 or less in all samples. One of the subsurface samples had a TU slightly above 1.0; however, it is unlikely that benthic receptors will be exposed to sediments deeper than 0.5 foot, and the calculated TU value was only slightly above 1.0 using the one-carbon model. Thus, risks to benthic and aquatic receptors are not expected at this location. The metals screening indicated the concentrations in sediment were consistent with background conditions in the area and/or below the ESVs. Based on these results, sediments in the drainage ways do not require further assessment or evaluation.

Dawson Cove Soil and Sediment Results

A total of 54 soil samples were collected at 15 locations in Dawson Cove. Based on the screening results, concentrations in 50 of the 54 samples were at levels that do not warrant further evaluation. Crude-oil-related VOC concentrations were either non-detect or below the ESVs in all soil samples. A limited number of samples had detections above the associated soil ESV for Total HMW PAH (Long List). In addition, the metals screening indicated the concentrations in soil were consistent with background conditions in the area and/or below the ESVs. The following table summarizes the three soil locations in Dawson Cove that warrant further evaluation (presented in Section 10) based on the outcome of the screening process.

Media	Location	Sample Depth	Analyte	Value
Soil	SO-DA-019	Surface (0 to 0.5 foot bgs)	Total HMW PAH	1,180 µg/kg
		Subsurface (0.5 to 1 foot bgs)	Total HMW PAH	1,270 µg/kg
	SO-DA-022	Surface (0 to 0.5 foot bgs)	Total HMW PAH	1,760 µg/kg
	SO-DA-023	Surface (0 to 0.5 foot bgs)	Total HMW PAH	1,220 µg/kg

A total of 125 sediment samples were collected at 34 locations in Dawson Cove. Based on the screening results, concentrations in 118 of 125 samples were at levels that do not warrant further evaluation. Crude-oil-related VOC concentrations were either non-detect or below the ESVs at all sediment sampling locations, with the exception of five locations that had concentrations above the ESVs for total xylenes and isopropylbenzene (25.2 and 86 µg/kg, respectively). Fifty-three sediment samples in Dawson Cove had individual PAHs and/or PAH summations above the ESVs; however, the TU for each of the surface samples was 1.0 or less. One of the subsurface samples had a TU slightly above 1.0; however, it is unlikely that benthic receptors will be exposed to sediments deeper than 0.5 foot, and calculated TU value was only slightly above 1.0 using the one-carbon model. Thus, it was concluded that risks to benthic and aquatic receptors are not expected at this location. The metals screening indicated the concentrations in sediment were consistent with background conditions in the area and/or below the ESVs. The following table summarizes the sediment locations in Dawson Cove that warrant further evaluation (presented in Section 10).

Media	Location	Sample Depth	Analyte	Value
Sediment	SED-DA-015	Surface (0 to 0.5 foot bgs)	Total xylenes	730 µg/kg
		Subsurface (0.5 to 1 foot bgs)	Total xylenes	420 µg/kg
	SED-DA-017	Subsurface (0.5 to 1 foot bgs)	Isopropylbenzene	280 µg/kg
			Total xylenes	2,600 µg/kg
	SED-DA-039	Subsurface (1 to 1.5 feet bgs)	Total xylenes	26 µg/kg
	SED-DA-045	Surface (0 to 0.5 foot bgs)	Total xylenes	110 µg/kg
		Subsurface (0.5 to 1 foot bgs)	Total xylenes	61 µg/kg
	SED-DA-048	Surface (0 to 0.5 foot bgs)	Total xylenes	81 µg/kg

Lake Conway Sediment Results

A total of 18 sediment samples were collected at six locations in Lake Conway. Crude-oil-related VOCs were not detected in any of these sediment samples. Twelve sediment samples in Lake Conway had individual PAHs and total PAH summations above the ESVs; however, the TU for each sample was 1 or less, indicating no unacceptable risk to ecological receptors. The metals screening process indicated the metals concentrations in Lake Conway sediments were consistent with background conditions in the area and/or below the ESVs.

The Lake Conway sediment locations were re-sampled in November 2013 and the results were consistent with the original samples collected in July and August 2013 (see Section 7.6 for a detailed discussion of these results).

Surface Water Results

More than 2,900 surface water samples have been collected to date as part of a daily surface water monitoring program focused primarily on Lake Conway, but also including locations in the drainage ways and Dawson Cove. The daily surface water sampling program was discontinued on October 31, 2013, and a weekly sampling program was initiated on November 1, 2013. From November 1, 2013 through February 9, 2014, 233 surface water samples were collected and analyzed for PAHs only from various locations in the drainage ways, Dawson Cove, and Lake Conway. In August 2013, six surface water samples were also collected from the drainage ways and Dawson Cove as part of a one-time event for the DARSP activities. Detections of crude-oil-related analytes at concentrations above the ESVs are limited, as summarized below (see Section 8 for a detailed discussion of these results).

Lake Conway. VOCs have not been detected at concentrations above their respective ESVs in Lake Conway surface water samples collected to date. Based on weekly sampling results (November 1, 2013 through February 9, 2014), two PAHs were very sporadically detected above the ESVs near the Dawson Cove outlet and at the locations near the Highway 89 bridge and Lake Conway Outlet. Dissolved metals concentrations in surface water samples are representative of background conditions.

Dawson Cove. VOCs have not been detected at concentrations above their respective ESVs since April 13, 2013 in Dawson Cove surface water samples. Based on weekly sampling results (November 1, 2013 through February 9, 2014), three PAHs were detected very sporadically above the ESVs in Dawson Cove. In general, concentrations of PAHs in Dawson Cove surface water have declined since early August 2013. Dissolved metals concentrations in surface water samples are representative of background conditions.

Drainage Ways. VOCs have not been detected at concentrations above their respective ESVs since April 13, 2013 in drainage way surface water samples. Based on the DARSP sampling results in the drainage ways, only one PAH compound was above the ESV; however, the TU for the drainage ways was 1.0 or less in all samples (see Table 8-1). Dissolved metals concentrations in surface water samples are representative of background conditions.

Summary of Screening Evaluation

The screening data evaluation summarized herein indicated that concentrations in soil, sediment, and surface water in the downstream areas were at levels that did not warrant further evaluation, with the exception of three soil locations in the drainage ways, three soil locations in Dawson Cove, and seven sediment locations in Dawson Cove. Concentrations of a few analytes at these locations were above ESVs and therefore, these analytes were carried forward for further assessment in the refined ecological risk evaluation in Section 10.

10. Refined Ecological Risk Evaluation

A refined ecological risk evaluation was conducted to determine whether potential risks to ecological receptors exist from exposure to soil and sediment in the drainage ways and Dawson Cove, and to guide risk management decisions. The refined ecological risk evaluation is provided in its entirety in Appendix L and summarized below.

10.1 Approach and Methodology

The refined risk evaluation was conducted consistent with the USEPA ERA paradigm (USEPA 1997, 1998). This guidance is also referred to on ADEQ's website (ADEQ 2014a); the ADEQ has not published state ERA guidance. The refined ecological risk evaluation focused on the constituents of potential ecological concern (COPECs) that were identified in the screening data evaluation (see Sections 5 through 9).

The refined ecological risk evaluation commences with a description of the habitat and potential ecological receptors, potentially complete exposure pathways, and information on the sources and effects of the stressors as typical in step 1 (problem formulation) of the USEPA ERA paradigm (USEPA 1997, 1998, 2000). Then, based on both the problem formulation (step 1) and the results of the screening data evaluation (Sections 6 through 9), which is similar to step 2 in the USEPA ERA process, the potential risk to ecological receptors from exposure to the COPECs was evaluated using several lines of evidence. Using several lines of evidence to characterize risk provides both a process and a framework for reaching a conclusion regarding confidence in the risk estimate (USEPA 1998).

The lines of evidence used in the refined risk evaluation included consideration of: frequency of detection (FOD), fate and transport characteristics, use of refined exposure estimates, use of refined ESVs, and an evaluation of spatial extent and habitat quality. Fate and transport characteristics of the COPECs are described in detail in Appendix L, including the propensity of these COPECs to attenuate in the environment. Refined exposure estimates in soil for wildlife receptors were based on the mean COPEC concentration, as recommended by USEPA ERA guidance (1997 and 1998). Specifically, the 95 percent upper confidence level on the mean (i.e., the 95% UCL) was used to represent the mean concentration with a high level (e.g., 95%) of confidence that the true arithmetic mean concentration will be less than the UCL (USEPA 2002b). The 95% UCLs were calculated using the most recent version of ProUCL (Version 5.0) statistical software (USEPA 2013). Finally, refined ESVs were identified from the literature and also calculated based on sample-specific characteristics (i.e., sample organic carbon content) consistent with USEPA guidelines (USEPA 1997, 1998, 2008).

10.2 Results

Results of the refined ecological risk evaluation are presented in Appendix L and summarized by medium and location below.

10.2.1 Soil in the Drainage Ways

The screening data evaluation found benzene in one soil sample in the drainage ways (SO-DA-015) at concentrations above the ESV (Section 6.2), and PAH concentrations, specifically HMW PAHs, greater than ESVs (Section 6.3) at two soil sampling locations in the drainage ways (SO-DA-003 and SO-DA-005). Therefore, benzene and HMW PAHs were carried into the refined ecological risk evaluation (Appendix L) for further consideration.

Risk to ecological receptors from exposure to benzene in soil in the drainage ways was found to be negligible in the refined evaluation (Appendix L) based on several lines of evidence including: low FOD, comparison to a refined ESV, fate and transport characteristics, and evaluation of spatial extent, as well as considerations of habitat quality. The FOD for benzene was low: benzene was detected in 3 of 45 (7 percent) samples collected in the drainage ways and was above the conservative ESV of 10 µg/kg in only one of those samples (SO-DA-015 at 0 to 0.5 foot bgs; Table 6-2 and 6-4; Figure 2-2). This benzene detection was also below the refined ESV of 255 µg/kg, which is based on modeled exposure and risk to a small mammal (i.e., masked shrew [*Sorex cinerus*]) through incidental soil ingestion and uptake through the diet (Appendix L). With regard to fate and transport characteristics, benzene is highly volatile and is expected to attenuate relatively quickly in soil. And when considering habitat quality, the sample with this elevated benzene concentration was collected from a vegetated strip of land between I-40 and Highway 365. Higher quality terrestrial habitat is available nearby (around Dawson Cove), which will be preferentially used by ecological receptors. Based on these lines of evidence, the risk to ecological receptor populations from exposure to benzene in soil in the drainage ways is not expected.

Risk to ecological receptor populations from exposure to HMW PAHs in soil in the drainage ways was also found to be negligible in the refined risk evaluation (Appendix L) based on the use of refined exposure estimates and an evaluation of spatial extent, as well as considerations of habitat quality. The 95% UCL for HMW PAHs in soil in the drainage ways, calculated based on 14 surface soil (0 to 0.5 foot) samples, was 1.02 mg/kg (Table L-4), which is lower than the EcoSSL of 1.1 mg/kg, based on exposure to mammals, specifically for a ground insectivore as represented by a shrew, as that was the lowest (and therefore the most protective) mammalian EcoSSL (Appendix L). Further, the two samples where concentrations individually exceeded the EcoSSL (SO-DA-003 and SO-DA-005) were collected in the swale along North Main Street (Figures 2-1 and 6-1.1), which has limited habitat value and is subject to runoff sources from the roadway, whereas high quality habitat is available nearby and therefore, will be preferentially used by ecological receptors.

10.2.2 Soil in Dawson Cove

The screening data evaluation (Section 6.3) found HMW PAH concentrations greater than ESVs at three samples in Dawson Cove soils (SO-DA-019, SO-DA-022, and SO-DA-023; Figures 2-2 and 6-1.2). To refine the risk evaluation, the Dawson Cove soil HMW PAH exposure estimate was calculated and compared to the ESV. The 95% UCL, based on 15 surface soil samples, was 0.78 mg/kg (Table L-5), which is below the conservative screening ESV based on the mammalian EcoSSL of 1.1 mg/kg. This indicates that risk to ecological receptor populations from exposure to PAHs in soil in Dawson Cove is not expected.

10.2.3 Sediment in Dawson Cove

The screening data evaluation in (Section 7.3) for Dawson Cove sediments found three surface samples (SED-DA-015, SED-DA-045, and SED-DA-048) and four subsurface samples at locations SED-DA-015, SED-DA-017, SED-DA-039, and SED-DA-045 with concentrations of xylenes greater than the ESV of 25.2 mg/kg (Figure 2-3). Xylene concentrations were either non-detect or below the sediment ESV in the remaining 118 of 125 samples (Tables 7-3 and 7-6). Further, the results of the screening data evaluation indicated that one subsurface sample at location SED-DA-017 also contained isopropylbenzene at a concentration greater than the ESV of 86 mg/kg in Dawson Cove. Isopropylbenzene concentrations were either non-detect or below the sediment ESV in 124 of 125 samples (Tables 7-3 and 7-6).

In the refined risk evaluation, these sediment concentrations were compared to refined sample-specific ESVs calculated based on sample-specific organic carbon content, as presented in Appendix L Table L-6. Concentrations of isopropylbenzene in both the surface and subsurface samples at location SED-DA-017 were found to be below the sample-specific ESVs. Similarly, concentrations of xylenes were also below the sample-specific ESVs in all samples. Additionally, the xylene levels have most likely been reduced since the sampling took place due to the effect of natural processes, such as volatilization and degradation, over time. Because concentrations of xylenes and isopropylbenzene were 1) below the ESVs computed using sample-specific organic carbon, 2) had a low FOD, and 3) tend to attenuate rapidly in the environment; risk to benthic invertebrate communities from exposure to concentrations of xylenes and isopropylbenzene in Dawson Cove sediment is not expected.

10.3 Conclusions

The conclusions from the refined risk evaluation are provided below:

- Benzene and HMWs PAHs were identified as soil COPECs. However, based on several lines of evidence, no adverse effects are expected for mammalian populations from exposure to the COPECs in soil at the drainage ways and Dawson Cove.

- Xylenes and isopropylbenzene were identified as COPECs for sediment. However, based on comparison to refined ESVs and the low FOD, no adverse effects are anticipated for aquatic life in Dawson Cove sediment.

Based on the results of the refined ecological risk evaluation and in accordance with USEPA guidance (1997), adequate information has been collected to conclude that there is no unacceptable risk to ecological receptor populations from exposure to the COPECs and no further ecological assessment is warranted at the drainage ways and Dawson Cove.

11. Sheen Monitoring and Sampling Summary

Daily sheen monitoring activities were initiated on October 21, 2013, in accordance with the Sheen Monitoring and Maintenance Plan (EMES 2013) submitted to the ADEQ on October 18, 2013. For the daily sheen monitoring program, which is currently ongoing, the site was divided into three sheen monitoring areas within the drainage ways along North Main Street to I-40 (A-Main, A-365W, and A-365E; Figure 11-1) and four areas within Dawson Cove (Figure 11-2):

- Dawson Cove Inlet Channel – main channel between I-40 and the open water area of Dawson Cove
- Dawson Cove Open Water Area – open marsh and water area located between Dawson Cove Inlet Channel and the heavily vegetated area
- B-On Water – heavily vegetated area and open water to the east and north of the heavily vegetated area, located between the Dawson Cove Open Water Area and Highway 89
- Dawson Cove Outlet to Lake Conway (Dawson Cove Outlet) – open water area located within the sorbent boom north of Highway 89

The daily sheen observations made between October 21, 2013 and February 23, 2014 are described in detail in Appendix M and summarized below in Section 11.1. An initial sheen sampling event was conducted in the drainage ways and Dawson Cove on November 4, 2013 and a second sheen sampling event was conducted in the A-Main drainage way on January 24 and 26, 2014. The analytical results from these sampling events are described in detail in Appendix M and summarized below in Section 11.2.

11.1 Summary of Sheen Observations

Daily sheen monitoring activities include visual observation of the water surface (EMES 2013). In-situ sheens are visually identified during a daily walking inspection of the drainage ways and the Dawson Cove Inlet Channel. In the Dawson Cove Open Water Area, six locations were staked (OW-1 through OW-6) along the edge of water, and observations are obtained daily at these locations and nearby areas. In the B-On Water and Dawson Cove Outlet areas, daily observations are performed via boat, depending on weather conditions. The sheens observed at the site are characterized using NOAA-specified terminology (e.g., color, structure; NOAA 2007). Weekly reports summarizing the daily sheen monitoring observations are provided to the ADEQ on a weekly basis (Appendix M). This section summarizes the field observations.

11.1.1 Drainage Way Observations

In the A-Main, A-365W, and A-365E drainage ways, brittle and non-brittle sheens of metallic, silver gray, and/or rainbow colors were observed along the banks and on the water surface in the drainage swale (Figure 11-1) between October 21, 2013 and February 23, 2014. Examples of these are shown in the photos below.

Brittle Rainbow Sheen Cover Observation on December 28, 2013 (A-Main)

Brittle Metallic Sheen Patch Observation on January 4, 2014 (A-365W)

Patches observed at a single location in these monitoring areas covered typically less than one square foot. Sheen streamers observed in these areas varied in size from 1 inch to 20 feet. At approximately 15 percent of the sheen locations, various patches, cover (no particular structure), and/or streamers covering an area up to 20 feet by 40 feet (up to 70 percent of the water surface) were observed. A summary of sheen observations in the drainage ways is included in the following table.

Sheen Monitoring Area	Sheens Observed*	Brittle Sheens	Non-Brittle Sheens	Sheens with Oil Spots
A-Main	207 (~12 per week)	72%	28%	5 (2.4% of Total)
A-365W	109 (~6 per week)	87%	13%	0
A-365E	149 (~8 per week)	66%	34%	1 (0.7% of Total)

* Monitoring Period October 21, 2013 through February 23, 2014.

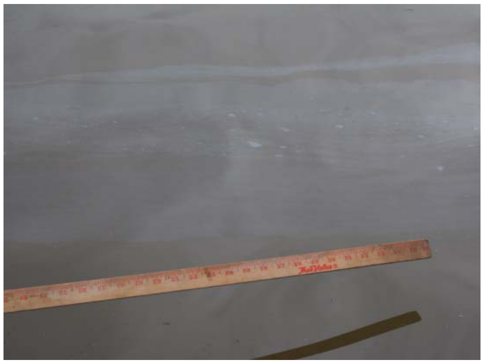
The following observations were made for sheens in the drainage ways:

- In the A-Main drainage way, sheens were consistent in number, location, and observed physical characteristics throughout the monitoring period.
- In the A-365W drainage way, sheens were consistent in the locations observed and were primarily brittle, but there was a decline in the number of sheens observed throughout the monitoring period.
- In the A-365E drainage way, sheens were consistent in the locations observed, but the number of observed sheens increased since January 20, 2014 with an increase in brittle sheens. However, the sheens transitioned from non-brittle to brittle sheens during the entire monitoring period.

11.1.2 Dawson Cove

Mainly non-brittle sheens were observed in two monitoring areas of Dawson Cove – Dawson Cove Inlet Channel and Dawson Cove Open Water Area (Figure 11-2) between October 21, 2013 and February 23, 2014. Similar numbers of brittle and non-brittle sheens were observed in the B-On Water area. One brittle sheen was observed in the Dawson Cove Outlet. Examples of these are shown in the photos below.

Brittle Metallic Sheen Patch Observation on November 30, 2013 (Dawson Cove Inlet Channel)



Non-Brittle Rainbow Sheen Streamers Observation on December 28, 2013 (B-On Water)

In the Dawson Cove monitoring areas, observed patches of sheen were approximately 2 to 12 inches wide. Sheen streamers observed in these monitoring areas ranged from 2 to 250 feet in length. At approximately 37 percent of the sheen locations, various patches, covers (no particular structure), and/or streamers were observed covering an area up to 60 feet by 360 feet (up to 70 percent of the water surface). A summary of sheen observations in the Dawson Cove monitoring areas is included in the following table.

Sheen Monitoring Area	Sheens Observed*	Brittle Sheens	Non-Brittle Sheens	Sheens with Oil Spots
Dawson Cove Inlet Channel	235 (~13 per week)	58%	42%	22 (9% of Total)
Dawson Cove Open Water	256 (~14 per week)	18%	82%	153 (60% of Total)
B-On Water	66 (~4 per week)	47%	53%	20 (30% of Total)
Dawson Cove Outlet to Lake Conway	1	100%	0%	0

* Monitoring Period October 21, 2013 through February 23, 2014.

The following observations were made for Dawson Cove sheens:

- Dawson Cove Inlet Channel sheens were consistent in number, location, and observed physical characteristics during the monitoring period. Sheens were generally non-brittle, and oil spots were observed with some of the non-brittle sheens.
- Dawson Cove Open Water Area sheens were primarily non-brittle and oil spots were observed with brittle and non-brittle sheens. The number of sheens observed in this area declined throughout the monitoring period.
- B-On Water sheens were consistent in observed locations, but declined in the number of sheens observed with time. About 53 percent of the observed sheens were non-brittle, and oil spots were observed with some of the brittle and non-brittle sheens. All but four of the sheens with oil spots were observed in the natural channel within the heavily vegetated area.

11.2 Summary of Sheen Chemical Analysis Results

This section summarizes the results of laboratory analyses conducted on 12 sheen samples collected from the drainage ways and Dawson Cove on November 4, 2013 and January 24 and 26, 2014. A detailed analysis is provided in Appendix M. Sheen sampling included the collection of sheens identified during monitoring as both brittle and non-brittle sheens. Brittle sheens are often of natural biogenic origin indicating that the sheens may be associated with microbial activity. Non-brittle sheens are often related to anthropogenic sources, including petrogenic sources (e.g., petroleum hydrocarbons such as crude oil, gasoline, diesel fuel, and asphalt) and pyrogenic sources (e.g., combustion-related materials such as coal tar and creosote). Sheens can also be derived from petrogenic source materials that have been subjected to pyrogenic processes, such as used motor or used hydraulic oil. In addition to the above sheen sampling activities, a sheen net blank and a laboratory-generated sheen sample were analyzed on November 25, 2013.

The sheen samples collected at the site, the sheen net blank sample, and the laboratory-generated sheen sample were analyzed by B&B Laboratories located in College Station, Texas, for the following parameters:

- PAHs by USEPA Modified Method 8270 Select Ion Monitoring
- Aliphatic and TPH by USEPA Modified Method 8015

Because of the complex composition of petroleum hydrocarbons, numerous analytical "forensic" techniques have been developed to characterize petroleum hydrocarbons based on the molecular mass and structure of compounds. Petroleum hydrocarbon products, including gasoline, diesel fuel, motor oil, and crude oil, are complex mixtures consisting of 100s to 1000s of different compounds (Wang and Stout 2007). The chemical composition of petroleum hydrocarbon products varies due to several factors including crude oil source, subsequent refining processes, and weathering processes (e.g., volatilization, dissolution, and biodegradation).

As part of a petroleum hydrocarbon forensic assessment, sample analytical results are compared to analytical results for known or suspected sources. For this investigation, the analytical results for the drainage ways and Dawson Cove sheen samples were compared with the analytical results from a sample of crude oil collected from the Pegasus Pipeline on April 5, 2013, the laboratory generated sheen, the sheen net blank, and literature values for other potential sources of sheens or hydrocarbon constituents.

11.2.1 Drainage Ways

Five drainage ways sheen samples collected on November 4, 2013, in locations where the majority of the sheens were observed during the monitoring, did not resemble the crude oil and are likely associated with urban runoff and/or biological activity. The results of the forensic assessment are described in detail in Appendix M and summarized in the table below.

Sheen Monitoring Area	Location ID	PAHs Resemble Crude Oil*	TPH Resemble Crude Oil*	Sheen Type	Sheen Structure	Sheen Color
A-Main	MAIN-001	No	No	Non-Brittle	Patch	Metallic
	MAIN -002	No	No	Brittle	Patch	Metallic/ Rainbow
	MAIN-003	No	No	Brittle	Patch with oil spot	Rainbow
	MAIN-004	No	No	Non-Brittle	Cover/patch with oil spot	Metallic
A-365W	365W-001	No	No	Brittle	Patch	Metallic
	365W-002	No	No	Non-Brittle	Patch	Metallic
A-365E	365E-001	No	No	Non-Brittle	Streamer	Metallic

Notes: *Crude oil from the Pegasus Pipeline

Oil spots (0.05 to 0.25 inch in diameter) were observed twice in the concrete channel in A-Main drainage way[12] during the October through December 2013 monitoring period, once in the mid-section of the A-Main drainage way and once in the mid-section of the A-365E drainage ways. To characterize the oil spots observed in the drainage ways, two samples of sheens, each with an oil spot, were collected from the A-Main drainage way on January 24 and 26, 2014. The chemical composition of these two sheen samples indicated that they do not resemble crude oil from the Pegasus Pipeline.

11.2.2 Dawson Cove Inlet Channel and Open Water Area

Two sheen samples collected from the Dawson Cove Inlet Channel and Dawson Cove Open Water Area resembled crude oil from the Pegasus Pipeline (see table below). Additionally the chemical composition of one sample from the Dawson Cove Inlet

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[12] The two sheens with oil spots observed in the concrete channel during the week of December 2 to 8, 2013, when a construction crew was paving asphalt on North Starlite Road. It is possible that that the oil spots observed in the concrete channel were associated with the construction activity.

Channel may have resembled crude oil (see table below). Oil spots (0.1 to 5 inch in diameter) have been observed at sheen locations in the Dawson Cove Inlet Channel and Dawson Cove Open Water during the sheen monitoring period.

Sheen Monitoring Area	Location ID	PAHs Resemble Crude Oil*	TPH Resemble Crude Oil*	Sheen Type	Sheen Structure	Sheen Color
Dawson Cove Inlet Channel	INLT-001	Possible	Possible	Brittle	Streamer	Metallic
	INLT-002	Yes	Yes	Non-Brittle	Streamer with oil spots	Metallic
Dawson Cove Open Water	COVE-003	Yes	Yes	Non-Brittle	Streamer with oil spots	Metallic/ Rainbow

Notes: *Crude oil from the Pegasus Pipeline

11.2.3 Dawson Cove B-On Water

B-On Water sheens were consistent in observed locations, but the number of sheens observed declined with time. Two sheen samples collected within the B-On Water monitoring area did not resemble crude oil from the Pegasus Pipeline and may be associated with urban runoff and/or biogenic activity (see table below). About 53 percent of the observed sheens were non-brittle, and oil spots (0.05 to 1 inch in diameter) were observed at 16 sheen locations in the channel between the heavy vegetation in this monitoring area, indicating that some sheens may resemble crude oil. Sheens observed in the downstream B-On Water area did not resemble crude oil.

Sheen Monitoring Area	Location ID	PAHs Resemble Crude Oil*	TPH Resemble Crude Oil*	Sheen Type	Sheen Structure	Sheen Color
B-On Water	COVE-001	No	No	Non-Brittle	Streamer	Metallic
	COVE-002	No	No	Brittle	Patch	Metallic

Notes: *Crude oil from the Pegasus Pipeline

Throughout the sheen monitoring period, only one brittle sheen location was observed at the Dawson Cove Outlet on November 5, 2013. Brittle sheens are often of natural biogenic origin indicating that the sheens may be associated with microbial activity.

11.3 Summary of Findings

Based on the sheen monitoring activities and screening data evaluation, the limited areas with crude-oil-related sheens appear to be primarily located in the Dawson Cove Inlet Channel and the Open Water Area. Ongoing monitoring for sheens in the Dawson Cove is recommended, although at a reduced frequency. Additional investigation activities are recommended in the Dawson Cove Inlet Channel, Open Water Area, and select areas of the B-On Water area to evaluate for possible presence of sheen-bearing sediments. Investigation activities may include sediment and soil probing, shake jar tests on sediment or soil samples, and additional sheen sampling.

12. Summary of Remedial Alternatives Evaluation

A Remedial Alternatives Evaluation was prepared at the request of the ADEQ (ADEQ 2013) to identify an appropriate mitigation action plan that meets the remedial action objectives (RAOs) for the site. Five remedial alternatives were evaluated, and a preferred site-wide remedial alternative was selected based on the following factors: overall protection of ecological receptors, compliance with applicable rules and regulations, short-term effectiveness, long-term effectiveness, protection of existing habitat, implementability and relative cost. The detailed Remedial Alternatives Evaluation is presented in Appendix N, and summarized herein.

The objectives of the Remedial Alternatives Evaluation were to:

- Develop RAOs specific to the site.
- Screen various remedial technologies to identify those that can reliably and effectively achieve the RAOs.
- Based on these technologies, identify potential remedial alternatives to address the RAOs and evaluate the alternatives against the evaluation factors requested by ADEQ.
- Describe an appropriate plan, based on the evaluated alternatives, to mitigate potentially remaining adverse impacts in the downstream areas related to the Pegasus Pipeline Incident.

12.1 Areas for Remedial Mitigation

Based on the environmental sampling results for soil, sediment and surface water, no action is necessary to protect ecological populations at the site. The screening-level data evaluation (Sections 5 through 9) and refined risk evaluation (Section 10) concluded that ecological risks are negligible.

However, based on the sheen monitoring results, the following areas are considered for potential mitigation (Figure 12-1):

- Cove Inlet Channel and Open Water Area – These areas include sheens, some of which appear to be related to crude oil (Section 11).

- Heavily Vegetated Area – Based on observations of some remaining sheens following the response action, it is anticipated that a portion of this area still contains sheen-bearing material related to crude oil.

No mitigation is necessary in the drainage ways. The sheen sampling analysis indicated that sheens observed in this area do not resemble the crude oil (Section 11).

Figure 12-1 shows the current understanding of where crude-oil-related sheens will be further evaluated and mitigated; these areas will be refined based on a pre-design study (Appendix O). The current, anticipated extent of mitigation in the Cove Inlet Channel is the bank-to-bank width along the entire length of the channel from I-40 to the Open Water Area. The current extent of mitigation in the Open Water Area is based on the approximate edge of water corresponding to the normal high water level in Dawson Cove (262.87 feet NAVD88) during summer, and the edge of the existing heavily vegetated area. The current extent of mitigation in the Heavily Vegetated Area is located between the existing floatation boom along the edge of the Open Water Area to the west and extending approximately 200 feet toward Highway 89, including the natural channels between the vegetation in this area.

During the pre-design study, which is described in Appendix O, field activities will be completed in the areas shown on Figure 12-2 to confirm and refine the approximate mitigation areas on Figure 12-1, verify the preferred remedial approach, and support the design and permitting of the preferred alternative.

12.2 Development of Remedial Action Objectives (RAOs)

The RAO identified for the site is to mitigate surface water sheens resulting from the crude oil from the Pegasus Pipeline, to the extent practicable. This RAO was developed based on the results from site sampling activities, the refined ecological risk evaluation, and sheen monitoring and sampling results, as presented in Sections 9, 10, and 11, respectively. Screening and evaluation of remedial technologies and remedial alternatives to control sheens focused on the Dawson Cove Inlet Channel, Open Water Area, and the Heavily Vegetated Area (Figure 12-1).

12.3 Identification and Evaluation of Remedial Technologies and Site-Wide Remedial Alternatives

Potential remedial technologies for achieving the site RAO were identified, evaluated, and screened against the evaluation criteria of effectiveness, implementability, and relative cost, in accordance with the USEPA guidance (USEPA 1988). This process was completed to identify which technologies would be retained for further evaluation and screening. The potential remedial technologies included the following:

- Monitored natural recovery (MNR)
- Enhanced natural recovery
- In-situ sediment amendments
- In-situ enhanced bioremediation via agitation
- In-situ enhanced bioremediation via air sparging
- Non-reactive capping
- Reactive capping
- Targeted removal with off-site disposal
- Ex-situ on-site treatment and reuse

Of these, four technologies (MNR, reactive capping, in-situ sediment amendments, and targeted removal) were retained based on the detailed technology evaluation and the screening scoring system provided in Appendix N, Table N-1. The retained technologies were assembled into five site-wide remedial alternatives, each of which is potentially capable of meeting the established site RAO in the Inlet Channel, Open Water Area, and the Heavily Vegetated Area. The “No Action” alternative, which includes no mitigation activities, and is included as a baseline for comparison purposes only. The assembled remedial alternatives were:

- Alternative 1: No Action
- Alternative 2: MNR in the Inlet Channel, Open Water Area, and Heavily Vegetated Area
- Alternative 3: Reactive capping in the Inlet Channel and in the Open Water Area, and targeted reactive capping in the Heavily Vegetated Area
- Alternative 4: Targeted removal in the Inlet Channel, reactive capping in the Open Water Area, and targeted in-situ amendment placement in the Heavily Vegetated Area
- Alternative 5: Targeted removal in the Inlet Channel and the Open Water Area, and targeted in-situ amendment placement in the Heavily Vegetated Area

Each site-wide remedial alternative was evaluated and screened against the following seven evaluation criteria to rank the alternatives on a relative scoring system ranging from lowest to highest:

- Overall protection of ecological receptors
- Compliance with applicable rules and regulations
- Short-term effectiveness
- Long-term effectiveness
- Habitat protection
- Implementability
- Relative cost

A comparative screening of the site-wide remedial alternatives is presented in Table N-3. Remedial Alternative 4 obtained the highest total score at the end of the screening process and was selected as the preferred and proposed remedial alternative for the site due to its moderate to high rankings on all of the evaluation criteria compared to the other alternatives. Alternative 3 obtained the second highest total score, and it is considered the second most preferred due to moderate to high rankings on all of the balancing criteria and high rankings on the threshold criteria. Alternative 5 is not recommended, particularly in the Open Water Area, as there is the potential for significant ecological receptor exposure due to the disturbance of sheen-bearing material, which could result in some sheen release. Short-term ecological impacts would also be likely, such as the destruction of biota and habitats. Additionally, some residuals may remain after the removal action. Alternatives 2 and 1 may not meet the RAO identified for the site in the short term; and therefore are not recommended.

12.4 Description of the Preferred Remedial Alternative

It is proposed that Alternative 4 be implemented to meet the site RAO. Alternative 4, which is the highest-scoring alternative, consists of targeted removal in the Inlet Channel, reactive capping in the Open Water Area, and targeted in-situ amendment placement in the Heavily Vegetated Area. The main components of Alternative 4 include the following:

- Excavating up to 1 foot of localized sheen-bearing sediments resulting from the Mayflower Pipeline Incident in the Inlet Channel (see Figure 12-3). The excavation depth is based on sampling results presented in this report, which indicated no sheen-bearing material more than 1 foot below the top of sediment. Pre-design sampling would be conducted to determine the horizontal boundaries of sheen-bearing material to be targeted for removal and to evaluate whether a thinner removal thickness would be adequate.

  - Removing vegetation/debris from the target areas, to the extent needed, to allow for excavation using mechanical methods (such as excavators). Large-diameter trees would be left in place.
  - Transporting excavated materials to an on-site staging area using low-ground pressure vehicles.
  - Dewatering and stabilizing excavated material, as needed, for off-site transport.
  - Transporting stabilized excavated materials to the appropriate licensed off-site disposal facility.
  - Placing clean backfill material in the excavated areas to the extent needed for restoration.
  - Restoring the excavated areas by re-grading and re-planting with native species.

- Installing a reactive cap over where sheens have been observed in the Open Water Area (see Figure 12-3). Pre-design sampling would be conducted to determine the horizontal boundaries of the cap based on extent of sheen-bearing material. Additional elements of this remedial alternative are as follows:
  - Removing vegetation/debris from the target areas to the extent needed for cap installation. Large diameter trees would be left in place.
  - The reactive cap would consist of a mixture of sand/organoclay, and the thickness and percentage of organoclay would be determined during remedial design.
  - Cap materials would be placed via broadcasting methods either using dry particle or slurry methods. Staging locations for cap material preparation would be established, as needed, to support cap placement.
  - After the cap is placed, staging areas would be re-graded and restored by planting native vegetation.
- Placing in-situ amendments at targeted locations where sheens have been observed within the Heavily Vegetated Area (see Figure 12-3). Pre-design

sampling would be conducted to identify target areas. Additional elements of this remedial alternative are as follows:

- In-situ amendments (e.g., organoclay) would be placed in accessible areas, such as the existing relatively open surface water channels, using slurry placement methods working from barges or boats. In more difficult to access areas (due to dense vegetation), amendments will be applied to the extent practical manually working from air boats.
- An initial dose of amendments will be applied and then monitored for sheens for approximately a 6-month period. If monitoring shows additional sheen mitigation efforts are warranted and needed in this area, additional application of the in-situ amendments would be conducted using similar and/or enhanced methods of broadcasting additional doses of amendments into areas of remaining sheens.
- Additional measures may also be taken after the monitoring and amendment reapplication period, such as the use of alternative equipment to broadcast and apply the amendment materials and/or partial cutting of vegetation to improve access.

13. Recommended Path Forward

Three areas downstream of the release location were assessed to determine post-response conditions; these include the drainage ways from the residential area to Dawson Cove, Dawson Cove, and Lake Conway. Soil, sediment, and surface water samples were collected as part of the incident response in accordance to the DARSP (ARCADIS 2013a), which was approved by the ADEQ on July 12, 2013. In addition, sheen monitoring and sampling have been conducted in these areas since October 21, 2013. The following provides a summary of soil and sediment results, a summary of the overall surface water sampling results, and a summary of the sheen monitoring and sampling. In addition, a recommended path forward is included for ongoing monitoring activities at the site and to address the surface water sheens resulting from the crude oil from the Pegasus Pipeline.

Soil and Sediment

Soil samples were collected at 30 locations in the drainage ways and in Dawson Cove. All soil samples were analyzed for VOCs, PAHs, and metals. Based on the screening results, constituent concentrations in 92 of 99 samples were at levels that did not warrant further evaluation. In the remaining samples, an individual analyte or PAH summation was above the screening criteria, and therefore, a refined risk evaluation was conducted for those constituents in soil. Based on the results of the refined risk evaluation, no adverse effects are expected to ecological populations from exposure to the constituents in soil in the drainage ways or Dawson Cove.

Sediment samples were collected at 53 locations in drainage ways, Dawson Cove, and Lake Conway in July and August 2013. Based on the screening results, concentrations in 171 of 178 samples were at levels that did not warrant further evaluation. In the remaining samples, one analyte was above the screening criteria, and therefore, a refined risk evaluation was conducted for those constituents in sediment. Based on the refined risk evaluation, no adverse effects are anticipated for aquatic life in Dawson Cove sediment. In addition, as requested by ADEQ, six locations in Lake Conway were re-sampled in November 2013 and the results were consistent with original sampling.

The results from the screening data evaluation and the subsequent refined risk evaluation indicate that there are no unacceptable ecological risks in the drainage ways, Dawson Cove, and Lake Conway. Therefore, no action is necessary to mitigate constituent levels in the soil and sediment in the drainage ways, Dawson Cove, or Lake Conway.

Surface Water

The data evaluation results for the surface water samples collected from March 29, 2013 through February 9, 2014 indicate that no further action is warranted; however, monitoring will continue on a weekly basis until a remedial action is implemented. It is recommended that five sampling locations continue to be monitored for PAHs: two locations in Dawson Cove (WS-004 and WS-007) and three locations near the Dawson Cove outlet (WS-001, WS-009 and WS-021). These locations can be safely accessed from the shoreline and have been retained within the surface water sampling program based on previous data evaluation results. Pending ADEQ's approval of these proposed changes to the surface water program, a revised Surface Water Sampling and Analysis Plan will be submitted to the ADEQ.

Sheens

Daily sheen monitoring activities in the drainage ways and Dawson Cove were initiated on October 21, 2013, in accordance with the Sheen Monitoring and Maintenance Plan (EMES 2013), submitted to the ADEQ on October 18, 2013. Sheen sampling events were also conducted on November 4, 2013 and in January 2014.

Based on the data evaluation, the limited areas with crude-oil-related sheens appear to be primarily located in the Dawson Cove Inlet Channel and the Open Water Area. Based on ADEQ comments (ADEQ 2014b), Sheen Monitoring and Maintenance Plan was updated and the revised program will commence March 12, 2014. The revised program will include weekly sheen monitoring and removal of sheens in Dawson Cove. Sheen monitoring and removal of sheens in Dawson Cove will also occur within 48 hours following the end of a 0.25-inch rainfall event[13], or when site conditions allow safe access. Additional removal activities may be conducted site conditions warrant more frequent removal. After recording the sheen observations during the monitoring event, the sheens will be removed to the extent practicable. Weekly reports summarizing sheen monitoring observations will continue to be provided to the ADEQ.

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[13] A rainfall event is defined as greater than 0.25 inch in 3 hours, and at least 72 hours from the previously measurable (greater than 0.25 inch rainfall) storm event. The USGS gauge 072632966 at Lake Maumelle will be used to monitor the rainfall quantities. http://waterdata.usgs.gov/nwis/nwismap/?site_no=072632966&agency_cd=USGS

In addition, a weekly assessment of the sorbent boom capacity to sorb sheens will be completed to evaluate the frequency of replacing the booms. To complete this assessment, a test boom segment will be removed from the water and then cut open to observe for staining inside the sorbent boom. When approximately 25 percent of the sorption capacity is remaining in the selected test boom (based on visual assessment), the sorbent booms will be replaced. At a minimum, the sorbent booms will be replaced every 3 months until the remedial action is implemented.

Design and Implementation of Preferred Remedial Alternative

The remedial action objective (RAO) identified for the site is to mitigate surface water sheens related to the crude oil release from the Pegasus Pipeline, to the extent practicable. Based on the remedial alternatives evaluation described in Section 12 (and further detailed in Appendix N), the two highest-scoring alternatives are Alternatives 4 and 3. It is proposed that Alternative 4, which uses a combination of targeted removal in the Inlet Channel, reactive capping in the Open Water Area, and targeted in-situ amendment placement in the Heavily Vegetated Area be implemented to meet the site RAO. After approval of this report, the following activities are proposed for design and implementation of the remedial action:

- Conduct a pre-design study to confirm and refine the mitigation areas, verify the preferred remedial approach, and support the permitting of the preferred remedial alternative. Details of the pre-design study are provided in Appendix O.
- Develop a Mitigation Action Plan, which will include results of the pre-design study and the design for the preferred remedial alternative. The Mitigation Action Plan will include the following:
    - Pre-design sampling results
    - Basis of design, design drawings, and specifications
    - Implementation methods and approach
    - Construction quality assurance plan
    - Proposed restoration activities (pending coordination with the permitting agencies)
    - Construction schedule
- Apply and obtain the required permits and authorizations from state and federal agencies.

- Construct and implement the remedial action.

Concurrent with the development of the Mitigation Action Plan, the permitting process will be initiated. Implementation of the preferred remedial alternative will require permits and authorizations from state and federal agencies, as detailed in Appendix N. A U.S. Army Corps of Engineers (USACE) Individual Permit will likely be required, which would include a 404(b)(1) Alternatives Analysis and a preliminary wetland delineation. In addition, an individual National Pollution Discharge Elimination System permit from ADEQ may be required. Pre-application coordination with the USACE and ADEQ will be necessary to facilitate timely review during the permitting process. It is anticipated that obtaining permits and authorizations for the preferred alternative will take an estimated 120 days or more after USACE and ADEQ receive the application.

The anticipated schedule for the Action Plan is shown in the table below.

Milestone	Estimated Schedule
Pre-Design Study Completed	30 days after ADEQ approval of this report
Mitigation Action Plan Submitted to ADEQ	60 days after ADEQ approval of this report

Following ADEQ approval of the Mitigation Action Plan, the required permit applications for construction and implementation will be submitted to the appropriate agencies for review.

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