Final Report

Site Characterization Report
State Street Mystery Site

Prepared for

Alaska Department of Environmental Conservation

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Abbreviations

AAC	*Alaska Administrative Code*
ADEC	Alaska Department of Environmental Conservation
BLEVE	boiling liquid/expanding vapor explosion
BTEX	benzene, toluene, ethylbenzene, and xylenes
CFR	*Code of Federal Regulations*
DRO	diesel-range organic
EPA	U.S. Environmental Protection Agency
°C	degrees Celsius
°F	degrees Fahrenheit
gpm	gallons per minute
GRO	gasoline-range organic
µg/L	micrograms per liter
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
PID	photoionization detector
ppm	parts per million
QA	quality assurance
QAPP	quality assurance program plan
QC	quality control
SAP	Sampling and Analysis Plan
TOC	top of casing

SECTION 1

Introduction

1.1 Overview

The purpose of this Site Characterization Report is to present the results for soil and groundwater samples that were collected during fieldwork performed from February 26 through March 2, 2003, and provide an evaluation of the potential sources and extent of contamination at the State Street Mystery Site in Skagway, AK. Results of two rounds of groundwater monitoring conducted April and June 2003 and a free product recovery test are also discussed in this report. Based on the site characterization findings, recommendations are provided for future site activities. CH2M HILL is preparing this report for the Alaska Department of Environmental Conservation (ADEC) under Contract No. 18-7000-15.

The site is located near the corner of 20th Avenue and State Street in Skagway, Alaska. The site location is shown in Figure 1-1.

1.2 Background

On November 17, 1998, Sullivan Construction was digging a foundation on a lot owned by Ms. Mary Lou Moe at the northern corner of 20th Avenue and State Street. An excavation area of approximately 40 feet by 75 feet was completed to a depth of five feet with no evidence of contamination. While trying to remove an area of spongy soil in the southeastern corner of the lot, Sullivan Construction intercepted groundwater with free-phase diesel product at seven feet below ground surface (bgs). Sullivan Construction was able to recover approximately 100 gallons of the fuel product (ADEC, 2002a).

Smith Bayliss LeResche, Inc. (SBL), conducted a site investigation for Ms. Moe on December 3, 1998. SBL excavated six test pits around the property (numbered Test Pit 1 through Test Pit 6), sampled soil from five Geoprobe locations (numbered TB-1 through TB-5), and field screened soil samples obtained from the foundation excavation (numbered FS-1 through FS -8). The sampling locations are shown in Figure 1-2. Test Pit 1 contained about three inches of free product at the water table at a depth of 5.4 feet. The excavation crew struck a water line while excavating Test Pit 2 in 20th Avenue. Although there was no free product in this test pit, the presence of contaminated soil along the water line and heavy rainbow sheen on water in that test pit suggested the diesel might be following the utility lines (SBL, 2000). This investigation did not locate the source of the fuel.

The City of Skagway contracted SBL to conduct further Geoprobe investigation near utility lines upgradient of the Moe property. On December 8th and 9th, 1998, nine more Geoprobe borings were made around the water line in State Street and where other lines branch off under 20th and 21st Avenues (GP-1 through GP-9). This investigation was also unable to locate the source of the fuel (SBL, 2000).

In July 1999, SBL began excavating soils under an ADEC-approved Corrective Action Plan, but stopped excavating when free-phase hydrocarbon was noticed flowing into the excavation from the southeast corner of the lot adjoining State Street.

In October 1999, SBL was contracted by the Alaska Department of Transportation and Public Facilities (ADOT&PF) to look for the source and extent of product observed that July. Eight test pits (numbered TP-1 through TP-8) were excavated and four Geoprobe borings (B-1 through B-4) were completed around TP-6 as part of this investigation.

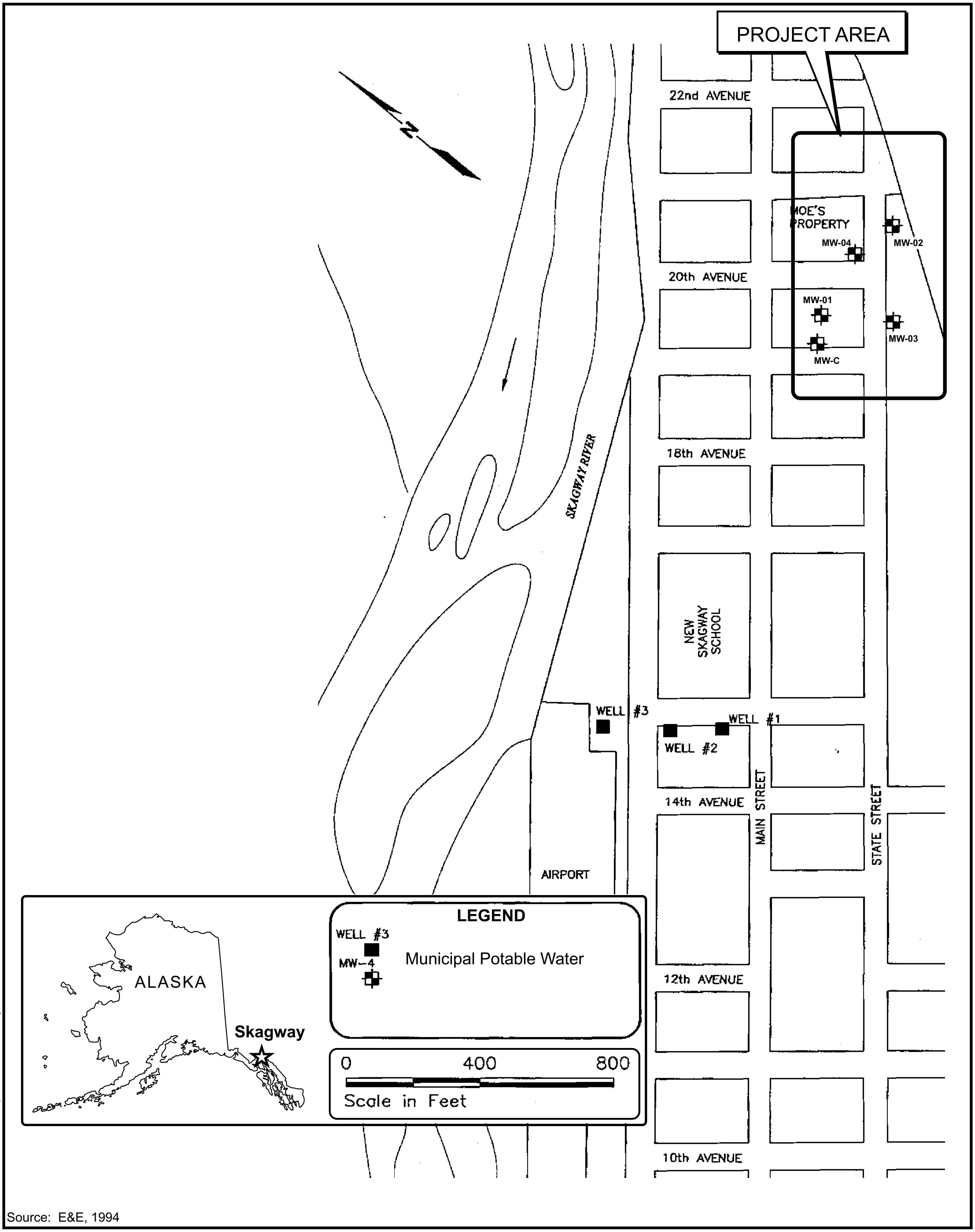
Free product was not present in either TP-1 or TP-2, but sheen was observed in TP-1. Contaminated soil was encountered in TP-3, at a depth of 3.5 feet, just beneath the storm drain culvert piping. No signs of diesel or diesel-contaminated soil were observed within TP-4, located at the northwest corner of 22nd Avenue and State Street. TP-5 was located in the State Street right-of-way in front of the White Pass and Yukon Route railroad yard, north of the 22nd Avenue intersection. Soil samples from TP-5 had a hydrocarbon/solvent odor and a photo-ionization detector (PID) reading of 32 parts per million (ppm); however, no sheen was observed and a soil sample collected from just above the water table was analyzed for diesel-range organics (DRO) by AK102 and was found to have concentrations below the ADEC method one cleanup level. Diesel contaminated soil was encountered at 2.5 feet bgs in TP-6, continuing to the water table at seven feet bgs, where free product was observed. Contamination was not noted at TP-7 and TP-8, located northeast of TP-6. Results of this investigation indicated that diesel fuel entered ADOT&PF property at State Street, north of 21st Avenue from the White Pass and Yukon Route railroad property (SBL, 2000).

The White Pass Railroad and Yukon Railroad contracted Golder Associates to conduct a site characterization at the Coach Cleaning Shop (east of the Moe property). Approximately 150 cubic yards of contaminated soil was removed from the site. However, the extent of contamination was limited and did not appear to be the source of the free-phase hydrocarbon observed at the Moe property (Hart Crowser, 2002).

On September 7, 2001, SBL was contracted once again by Ms. Moe to excavate two additional test pits (Test Pits 7 and 8). One soil sample was collected from each test pit at 7 feet bgs, which was about 6 inches above the groundwater table elevation at the time of sampling. DRO was not detected at Test Pit 7, but the Test Pit 8 soil sample contained DRO at 11,000 mg/kg. The soil appeared to be uncontaminated from the ground surface down to 4 feet bgs (SBL, 2001).

Four monitoring wells (MW-01 through MW-04) were installed in February 2002 by Hart Crowser for the ADEC. MW-01 was installed within the southeast corner of the foundation excavation attempted by Sullivan Construction. MW-02 was installed in an area upgradient of the site, and MW-03 and MW-04 were installed at locations downgradient of the site (Hart Crowser, 2002). Figure 3-1 illustrates the locations of these monitoring wells. MW-C was installed in 1994 by Ecology & Environment; however, it was not located during Hart Crowser's February 2002 investigation and may have been destroyed. Of the four monitoring wells installed, only MW-01 exhibited a measurable product thickness (0.06 feet). Analytical results for MW-02, MW-03, and MW-04 did not reveal the presence of hydrocarbons in groundwater.

All the studies to date have been inconclusive in determining an onsite source for the original diesel fuel discovered at the Moe property in November of 1998.



Source: E&E, 1994

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Figure 1-1
Site Location Map
State Street Mystery Site

Skagway, Alaska

SECTION 2

Preliminary Cleanup Goals

Title 18, Chapter 75, Article 3 of the *Alaska Administrative Code* (AAC), Discharge Reporting, Cleanup, and Disposal of Oil and Other Hazardous Substances (as amended through January 30, 2003), has been used to evaluate preliminary cleanup action goals for the site. The ADEC 18 AAC 75 regulations present a tiered approach to determining cleanup levels that include both conservative default cleanup values and options for developing site-specific values through risk assessment. The numerical cleanup standards for soil presented in Method 2 (Tables B1 and B2) of the 18 AAC 75 regulations are the most stringent standards potentially applicable to the site. Table B2 includes petroleum hydrocarbon cleanup standards for gasoline, diesel, and residual range petroleum hydrocarbons that include both the total carbon molecule chain and separate aliphatic (straight chain) and aromatic (ring structure) hydrocarbon chain structures. In addition to Method 2 cleanup standards, Method 3 regulations allow calculation of site-specific alternate cleanup standards with the use of site-specific soil data and input parameters approved by ADEC. Method 4 may also be used to develop a site-specific risk assessment to calculate alternate cleanup levels according to ADEC risk assessment procedures.

Groundwater cleanup standards for specific hazardous substances are included in 18 AAC 75.345, Table C, for groundwater that is currently used or could reasonably be used as a drinking water source.

Table 2-1 summarizes the preliminary cleanup goals for soil and groundwater with respect to the contaminants of concern (DRO and benzene). The annual average total precipitation for the Skagway area is 26.45 inches (Western Regional Climate Center, 2003), which places the site in the "under-40-inch" precipitation zone. The "migration to groundwater" pathway goals are the lowest soil cleanup goals applicable to the site. Cleanup goals for other contaminants are specified in the referenced regulations.

TABLE 2-1
Alaska Department of Environmental Conservation Cleanup Goals for Selected Petroleum Hydrocarbons

Petroleum Hydrocarbon Range	Soil (mg/kg)			Groundwater (mg/L)
	Ingestion	Inhalation	Migration to Groundwater	
Benzene	150	9	0.02	0.005
Diesel-Range Organics	10,250	12,500	250	1.5

mg/kg = milligrams per kilogram
mg/L = milligrams per liter

SECTION 3

Site Characterization Results and Discussion

The site characterization fieldwork included collecting soil and groundwater samples to evaluate the extent of contamination and installing groundwater level data loggers in monitoring wells MW-02, MW-03, and MW-04 to evaluate seasonal fluctuations in groundwater table elevation and flow direction. This section summarizes the results of these activities.

3.1 Delineation of Source Area and Extent of Contamination

The approach to delineating the source and extent of contamination was to use driven samplers and probes to obtain soil and groundwater samples. Thirteen locations were sampled:

- Four locations (DP-01 through DP-04) near the water main beneath State Street
- Four locations (DP-05 through DP-07 and DP-13) in 20th Avenue
- Four locations (DP-08 and DP-10 through DP-12) on the Moe property
- One location (DP-09) across the alley from the northern corner of the Moe property

The probe sampling locations are show in Figure 3-1.

Samplers were driven continuously from or near the ground surface to below the groundwater table to examine the vertical distribution of contamination and identify potential surface source areas for the free product. The soil samples were screened visually and with a PID. The PID screening results are summarized in Figure 3-1. An ADEC-approved laboratory (Analytica Alaska in Juneau and Anchorage) analyzed the selected samples for benzene, toluene, ethylbenzene, and xylenes (BTEX) and DRO compounds. Analytical soil results are presented in Figure 3-2.

Perforated probes were driven into the holes to allow collection of groundwater samples. The probes were left in place overnight to allow the free product and water levels to equilibrate within the wells; however, it appeared that fine grained soils partially plugged some of the probes and not all the water levels came to equilibrium during the sampling event. Measurable product thickness was observed in only one of the thirteen probes installed (0.01 foot at DP-06). Due to an obstruction at 2.69 feet deep in DP-09, product thickness and water level measurements were not obtainable at this location. Measured groundwater elevations are provided in Figure 3-3 and are referenced to an assumed elevation of 100.00 feet on the top nut of the fire hydrant located near monitoring well MW-01. TOC elevations were also surveyed for the existing monitoring wells MW-01 through MW-04 and are presented in Table 3-1.

TABLE 3-1
Survey TOC Elevations for Existing Monitoring Wells

Monitoring Well ID	TOC Elevation (ft)
MW-01	97.87
MW-02	98.81
MW-03	96.21
MW-04	96.69

Note: Vertical datum referenced to top nut of fire hydrant near MW-01, assumed 100.00 feet

Groundwater samples were collected from each driven probe (with exception of DP-09 due to obstruction) using a peristaltic pump. Due to slow groundwater recharge rates in some of the probes, conventional low-flow sampling techniques as outlined in the Work Plan and Quality Assurance Program Plan (CH2MHILL, 2003a) were not practicable. In most cases, pumping groundwater from the probes achieved complete drawdown during sampling and required multiple attempts over the course of several hours to obtain adequate sample volume. Field screening parameters (dissolved oxygen, oxidation–reduction potential, pH, conductivity, temperature, and turbidity) were not collected from groundwater obtained from the driven probes. After groundwater samples and measurements were obtained, the probes were removed and the holes backfilled with bentonite. Holes that were installed in State Street or 20th Avenue were patched with asphalt to match the existing road surface.

Conventional low-flow sampling techniques were employed in sampling the four existing groundwater monitoring wells (MW-01 through MW-04) using a peristaltic pump. The well purge and sampling field sheets containing the results of field screening are included in Appendix A.

The laboratory analyzed groundwater samples from the probes and the four existing site-monitoring wells for BTEX and DRO compounds. Samples from DP-05 through DP-08 were also submitted for analysis of gasoline-range organic (GRO) compounds. In addition, samples for geochemical analyses (nitrate, dissolved iron and manganese, sulfate, methane, and alkalinity) were collected from MW-01 and MW-02 to provide data for natural attenuation modeling. Figure 3-3 summarizes the analytical results. Laboratory reports and data quality review memorandum are provided in Appendix B.

Data loggers were installed in monitoring wells MW-02 through MW-04 on March 2, 2003, to record groundwater level information once every twelve hours. The data loggers were downloaded on June 27, 2003, and a summary of the data are provided in Appendix C. This data is used to assess changes over time in groundwater table elevation, flow direction and gradient. The data collected over the 140-day period between installation and download indicated that the groundwater elevation varied approximately one foot. During March 2003, the groundwater elevation decreased by approximately 0.3 feet, and the groundwater flow direction and gradient remained approximately constant at 223° from north and 0.0087 ft/ft. Between April 5 and 16, a change of elevation at MW-04 suggests a possible change in groundwater flow direction up to 241° from north, while the gradient was approximately 0.0085 ft/ft. From April 16 to June 27, the groundwater elevation increased

approximately 0.8 feet and the flow direction and gradient was approximately 222° from north and 0.0084 ft/ft.

Monitoring wells MW-01 through MW-04 were sampled for DRO and BTEX compounds on April 2/3 and June 26/27, 2003. The results for these events are also presented in Figure 3-3. The well purge and sampling field sheets and data quality review memorandums are included in Appendixes A and B, respectively.

3.2 Product Recovery Test

Free product has been observed in MW-01 located at the northern corner of 20th Avenue and State Street. This well was installed on February 8, 2002, and the measured product thickness was initially 0.06 feet (Hart Crowser, 2002). CH2M HILL remeasured the product thickness and found 1.61 feet on March 1, 2003, and 1.37 feet on April 3, 2003. Approximately 1 liter of product was pumped out of the well on April 3, reducing the thickness to 0.04 feet, and several measurements were made to determine how quickly the product flowed back into the well. Within 5 minutes, the product thickness rebounded to 0.11 feet. Over the following 24 hours, the thickness rebounded to 0.44 feet.

A product skimmer pump (Magnum Spill Buster pump manufactured by Clean Earth Technology, Inc.) was installed in MW-01 on May 15 and operated until June 26, 2003. Less than 1 gallon of product was recovered during this period. The recovered product was turned over to the City of Skagway Department of Public Works for reuse in their oil-fired heater and the skimmer pump was demobilized on June 27, 2003.

3.3 Discussion

The site characterization work performed to date has attempted to delineate the extent of contamination and determine potential sources for the free product observed in monitoring wells and test pits at the Moe property. The current investigation expanded the evaluation of the bedding material around the water mains in 20th Avenue and State Street as potential conduits for migration of free product, and further evaluated the contamination on the northern portion of the Moe lot, just south of a stream that crosses the lot. The extent of site contamination appears to have now been delineated on three sides; the southwest side of 20th Avenue (Test Pit 3 and TB-5), the southeast side of State Street (DP-01 through DP-04), and the northeast side of the Moe lot (Test Pits 6 and 7, DP-09 and DP-11) all had no sheen on groundwater samples and low or non-detectable soil contamination. The northwestern portion of the Moe lot on the south side of the stream appears to have the highest soil contamination detected to date (11,000 mg/kg DRO was detected in samples from both Test Pit 8 and DP-08). Groundwater samples from this area also had high concentrations of DRO (15,000 µg/L at DP-08 and 24,000 µg/L at DP-10). Further investigation on the north side of the stream was not continued because this was off the Moe property. One probe installed further north on 20th Avenue (DP-13) appeared to delineate the extent of contamination in this direction.

The site characterization results suggest that the source of contamination may be near the northwestern portion of the Moe lot or from an area north of the Moe property, across the stream and/or the alley. A trailer fire was reported to have occurred at the site in January

1997. The trailer was located at the northwest corner of the Moe property, with the diesel heating oil tank located off of the northwest side of the trailer (SBL, 2001). The City of Skagway Fire Department reported that the heating oil tank underwent a boiling liquid/expanding vapor explosion (BLEVE). It is unknown how much of the oil volatilized and how much spilled on the ground during the explosion. It is expected that low molecular weight, high volatility compounds such as benzene would have evaporated or burned to a greater extent than the high molecular weight, low volatility diesel components. Field screening of soil samples indicated shallow soil contamination above the groundwater table at 2 to 4 feet deep in DP-08, suggesting that the contamination came from a surface source at this location. It is unknown if any clean fill material was placed over the site during cleanup of debris after the trailer fire.

If the source of the free product was the northwestern portion of the Moe lot or from an area north of the Moe property, the product appears to have migrated to the southeastern corner of the lot near MW-01. A sheen has been observed on the groundwater at other probe and test pit locations around MW-01, but not a substantial thickness of free product. The geology around MW-01 (poorly graded sandy gravel) may be conducive for product to accumulate at greater thickness than at other areas around the site with finer-grained sand and silt soils.

SECTION 4

Groundwater Modeling

This section describes groundwater flow and contaminant transport modeling that was performed to evaluate the potential for hydrocarbon contamination detected at the site near 20th Avenue and State Street to impact City water supply wells in the future. Specifically, the modeling addresses the following questions:

- Is groundwater passing through the site eventually captured by the City of Skagway municipal water supply wells?
- Do site contaminants naturally attenuate to non-detectable concentrations before they could reach the municipal water supply wells?

4.1 Hydrogeologic Setting

Skagway is in a large glacial valley on parts of the delta and lower valley floor of the Skagway River. The geologic units exposed in the area are composed of intrusives (bedrock) and overlying unconsolidated deposits (Yehle and Lemke, 1972). The intrusive rocks are mostly Jurassic and Cretaceous quartz diorite and granodiorite but include some basalt and aplite dikes. Metamorphic rocks are also present, but in limited amounts (Balding, 1975).

In the Skagway River valley, the bedrock is covered by unconsolidated surficial deposits of Pleistocene and Holocene age. The unconsolidated deposits include alluvium, glacial drift, colluvium, and manmade fill. Alluvial deposits include terrace and flood-plain alluvium of the Skagway River, deltaic deposits of the intertidal zone, and alluvial-fan deposits. The alluvial deposits may contain well sorted to poorly sorted subrounded boulders, cobbles, gravel, sand, and silt. Colluvial deposits include generally loose, unsorted, angular material that has moved downslope or is moving downslope under the influence of gravity. They are composed of talus and other types of landslide deposits (rockfalls, rockslides, earthflows, and avalanche debris).

Geophysical measurements near First Avenue indicate that there is about 585 feet of alluvial fill in that part of the valley. The general lithologic sequence includes about 25 feet of alluvium overlying 120 feet of sandy, deltaic deposits that, in turn, overlie 440 feet of glacial and glaciomarine deposits (Balding, 1975).

4.2 Hydraulic Groundwater Flow Model

This section describes the development of the groundwater flow model grid, the assignment of boundary conditions, the selection of the aquifer properties used in the modeling effort, and the results of the model simulations performed.

4.2.1 Model Code Description

Micro-FEM is a fully integrated, three-dimensional, finite-element groundwater flow modeling package. As a pre-processor it is used to prepare a groundwater model based on the grid data produced through one of the two Micro-FEM grid generators, and by specifying the number of layers and the values for all hydraulic parameters. After preparation, the model data can be saved and processed for determination of steady-state or transient groundwater heads, and to calculate three-dimensional flowlines. As a post-processor, Micro-FEM is used for the graphical interpretation of results such as heads, draw-downs, flow-vectors, flow lines, and vertical flow components. Water balances can be computed for any selected node or model area. The current version of Micro-Fem, Version 3.60, is capable of simulating groundwater flow with a model grid of up to 50,000 surface nodes and 25 layers (Hemker, 2003).

4.2.2 Model Grid

The groundwater flow model grid is oriented along the length of the Skagway River. The grid extends from the downstream end of the Skagway River Valley at the Taiya Inlet approximately 20,500 feet up the valley. The grid is delimited on the canyon edges by outcrops of igneous bedrock. The extent of the model grid is shown in Figure 4-1.

The model grid spacing was selected to provide more detailed resolution of groundwater levels in areas of specific interest. The finite grid node spacing is approximately 10 feet in the vicinity of the State Street site as well as in the vicinity of the three City of Skagway production wells. The model node spacing increases to approximately 100 feet or more in remote areas of the model grid, where less resolution is required.

4.2.3 Model Layering

The Skagway model was developed as a 12 layer model. The shallow layers were assigned small thicknesses to provide more detailed vertical resolution of groundwater flow conditions in the upper portions of the aquifer, where groundwater contamination resides. Model layers 1 through 5 represent the alluvial materials, layers 6 through 11 represent the deltaic deposits, and layer 12 represents the glaciomarine deposits. The layer thicknesses and compositions assumed in the model are summarized in Table 4-1.

4.2.4 Boundary Conditions

Model boundary conditions define the flux of water or hydraulic head at each of the model boundaries. The boundary conditions used in the Skagway model consist of a combination of no-flow, specified flux, and head dependent boundary conditions as described below.

Specified Flux Boundaries

The upstream edge of the model was defined as specified flux boundary representing the movement of groundwater into the model from areas upgradient of the model boundary. The specified flux values were calculated based on a Darcy's Law calculation incorporating the assumed transmissivity of each layer, the horizontal hydraulic gradient present in that location of the model, and the width of each model element where the flux was specified. Flux values were applied to all 12 model layers.

TABLE 4-1
Assumed Layer Thickness and Lithology in Skagway Groundwater Model

MODEL LAYER	THICKNESS (feet)	LITHOLOGY
1	5	Alluvium
2	5	Alluvium
3	5	Alluvium
4	5	Alluvium
5	5	Alluvium
6	10	Deltaic Deposits
7	20	Deltaic Deposits
8	20	Deltaic Deposits
9	25	Deltaic Deposits
10	25	Deltaic Deposits
11	25	Deltaic Deposits
12	400	Glaciomarine Deposits

The second set of specified flux boundaries were applied to the lateral edges of the model along the canyon walls, representing the recharge to the groundwater aquifer from the run-off of rainfall and snowmelt from the surrounding mountains. This flux was calculated by assuming that the surrounding mountains have a slightly higher precipitation quantity than the City of Skagway; 40 inches per year as opposed to 26 inches measured in the city. It was further assumed that 50 percent of the precipitation was consumed by evapotranspiration and the remaining 50 percent was available for run-off. A simple geometric calculation was then performed based on the distance from the model boundary to the watershed divide, and that quantity of water was applied to the model edge along the valley walls. The specified flux was only applied to model layer 1. To verify that these assumptions were reasonable, the total recharge to the groundwater aquifer from this boundary was totaled and compared to the baseflow in the Skagway river. The groundwater recharge rates should be somewhat less than the baseflow in the river because additional sources of recharge contribute to baseflow such as flow from upstream river reaches and recharge of precipitation falling in the valley. The calculations discussed above resulted in an estimate of 14 cubic feet per second (cfs) recharging the model from this boundary. The measured baseflow in the Skagway river varies from 21 to 58 cfs, with a mean of about 29 cfs (Balding, 1975).

The final specified flux boundary was the recharge of rainfall and snowmelt falling within the model area. It was assumed that 10 inches of the 26.3 inches of precipitation recharges the groundwater aquifer.

Constant Head Boundaries

The only constant head boundary in the model is specified at the Taiya Inlet to reflect the presence of the coastal boundary. The model head was set at 0 feet MSL. Tidal fluctuations were ignored in the modeling effort, as the site of concern is a significant distance upstream of the inlet, and small variations in the sea level at the inlet will have an insignificant impact on the groundwater flow conditions in the vicinity of the City supply wells.

Head Dependent Boundaries

The Skagway river was represented in the model as a head dependent boundary condition. The flux of groundwater into or out of the model at this boundary is dependent on the difference in hydraulic heads between the river stage and the groundwater levels in the underlying aquifer. If the river stage is higher than underlying groundwater levels, surface water will recharge the groundwater system. If the groundwater levels in the aquifer are higher than the river stage, then groundwater will discharge to the river system. The flux of water at each river element depends not only on the magnitude of the head difference, but also on the river geometry and the permeability of the riverbed sediments. The river stage was assigned to each river element based on elevation data obtained from the USGS Skagway (B-1) NW, Alaska quad sheet. The permeability of the river bed was assumed to be equal to the hydraulic conductivity of the shallow sediments in model layers 1 through 5 (100 feet/day) with a 100 to 1 horizontal to vertical anisotropy. Therefore, the vertical riverbed hydraulic conductivity assumed in the model was 1 ft/day.

No-flow Boundaries

The only no-flow boundary in the model is the bottom boundary. This boundary was assigned a no-flow condition as it represents the low permeability bedrock underlying the alluvial valley fill, and a relatively small quantity of groundwater likely moves across that boundary.

4.2.5 Model Calibration

The calibration of the groundwater flow model was performed by comparing model predictions to two site features; measured groundwater elevations, and observed horizontal hydraulic gradients.

Groundwater Elevations

The comparison of model simulated and measured groundwater elevations at the site was complicated by the fact that no formal geographic survey has been performed to establish local benchmarks. Previous work in the area performed by Hart Crowser uses a local coordinate system that is based on a temporary benchmark located on the southeast abutment of the Skagway River Bridge. The temporary benchmark was assigned an elevation of 74.00 feet based on as-built drawings and the plan geometry of the abutment (Hart Crowser, 1991). Subsequent work performed by Hart Crowser assumed a temporary benchmark at a fire hydrant located at the intersection of 20th Avenue and State Street with an arbitrary assigned elevation of 100.00 feet (Hart Crowser, 2002).

For the purposes of this modeling effort, the temporary benchmark established by Hart Crowser at the Skagway River Bridge was assumed to be sufficiently accurate to provide a basis for comparison between model simulated and measured groundwater elevations. The groundwater elevation at the well nearest the State Street Site, MW1990-1A, was reported to be 52.49 feet MSL on November 28, 1990 (Hart Crowser, 1991). [Note that "1990" was added to the well identifiers for wells installed by Hart Crowser in November 1990 to differentiate these wells from wells MW-01 through MW-04 that Hart Crowser installed at the 20th Avenue and State Street site in February 2002.] Groundwater elevations simulated by the groundwater model at that same location are about 52.8 feet MSL. A comparison of simulated and measured groundwater elevations at several other monitoring wells that span an area between the City production wells and the rail yard northeast of the site are summarized in Table 4-2. The locations of these wells are shown on Figure 4-2. Although this water level comparison is approximate, the flow model provides simulated groundwater elevations that compare favorably with measured groundwater elevations in the area of concern between the City water supply wells and the State Street Site.

Horizontal Hydraulic Gradients

The comparison of measured and simulated horizontal hydraulic gradients was used as an additional measure of calibration of the groundwater model. The calculated hydraulic gradient based on groundwater levels measured in wells MW-01 through MW-04 at the site

TABLE 4-2
Simulated versus Measured Groundwater Elevations near State Street Site

Monitoring Well	Measured Groundwater Elevation	Simulated Groundwater Elevation
MW1990-1A	52.49	52.8
MW1990-2	57.32	56.2
MW1990-3	60.39	59.5
MW1990-4	43.40	43.3

Notes:

1. Measured groundwater elevations relative to a temporary benchmark established on the Skagway River Bridge. See Hart Crowser, 1991, for further information.
2. Groundwater elevations measured November 28, 1990.

in February and March 2003, suggest a gradient of 0.0087 foot per foot. Horizontal hydraulic gradients in the groundwater flow model at that location are 0.0072 foot per foot.

4.2.6 Model Simulation Results

Groundwater Conditions

The groundwater elevations simulated by the groundwater flow model and the associated groundwater flow directions are shown on Figure 4-2. It can be seen that groundwater in the vicinity of the site flows in a southwesterly direction, paralleling the general orientation of the Skagway River. This flow regime is typical for alluvial valleys dominated by a braided stream system. Groundwater simulations predict that the groundwater flow velocity in the shallow alluvial sediments is approximately 4.0 feet per day or 1,460 feet per year. This velocity estimate assumes an aquifer transport porosity of 0.2.

Groundwater Flowpath Analysis

To evaluate the potential for contaminated groundwater present at the site to reach the City of Skagway production wells, a groundwater flowpath analysis was performed. The first step in this process was to define the extent of non-aqueous phase liquid (NAPL) at the site, commonly known as the source area. The extent of the source area for the State Street site, shown on Figure 4-2, was based on observations of sheen or free product in wells and probes sampled by CH2M HILL in February 2003. The definition of a source area also requires an assumption of the depth of groundwater contamination. No definitive data from the site is available to estimate the overall depth of the hydrocarbon contaminant plume. For the purposes of this evaluation, two plume depths were assumed-- 5 feet and 10 feet beneath the water table.

Once a source area was defined, the groundwater flow model was used to track the flowpaths and travel time of groundwater originating within the source area. These groundwater flowpaths were tracked downgradient to determine whether the potential exists for contaminated groundwater to reach the City production wells.

The construction specifications and operating flow rates for the City production wells were obtained from the City of Skagway. The well construction specifications were obtained from the Drinking Water Total Coliform Monitoring Plan (City of Skagway, undated), while the well production rates were obtained by personal communication with Tim Gladden with the City of Skagway. The well construction data and flow rates utilized in the model are summarized in Table 4-3.

To conduct the groundwater flowpath analysis, the groundwater production from City wells No. 1 and 2 were assigned to model layer 8, while the production from City well No. 3 was assigned to model layers 7 and 8. The distribution of City Well No. 3 pumping between model layers 7 and 8 was determined based on the relative transmissivity of each layer.

Evaluation Results Assuming a 5-Foot Plume Thickness

The results of the groundwater flowpath analysis assuming a 5-foot plume thickness are shown on Figure 4-3. It is clear from this figure that groundwater originating within the source area eventually flows to the City well field. The flowpath analysis indicates that the shallow groundwater from within the source area will be captured by only City Well No. 2. Simulations suggest that groundwater from the source area is too shallow to be captured by City Well Nos. 1 and 3 as it passes this area. The estimated travel time between the source area and the City wells varies from 0.8 to 1.6 years assuming an aquifer transport porosity of 0.2.

Evaluation Results Assuming a 10-Foot Plume Thickness

The results of the groundwater flowpath analysis assuming a 10 foot plume thickness are shown on Figures 4-3 and 4-4. The flowpaths of the groundwater in the upper 5 feet of the source area, as discussed above, are shown on Figure 4-3. The flowpaths taken by the groundwater in the bottom 5 feet of the source area are shown on Figure 4-4. Note that because the groundwater in the lower 5 feet of the source area starts at a greater depth, the

TABLE 4-3
City Production Well Construction and Pumping Information

Well	Total Depth (ft)	Screened Interval (ft bgs)	Maximum Flow Rate (gpm)
City Well No. 1	80	50 to 80	228
City Well No. 2	75	45 to 75	220
City Well No. 3	120	37 to 67	549

water is deeper when it encounters the area around City Well No. 1, and some of this groundwater is captured by Well No. 1. The remainder of the groundwater originating within the source area is captured by City Well No. 2, and none of this deeper groundwater reaches City Well No. 3.

4.3 Contaminant Transport Model

Groundwater contaminant concentrations are observed to decrease at most sites as the contaminants migrate away from the source area. The reduction in contaminant concentration is due to several fate and transport processes, including dilution, dispersion, sorption, abiotic oxidation, hydrolysis, volatilization, and biodegradation. These naturally-occurring processes are collectively referred to as natural attenuation.

Evidence of natural attenuation at the site is found in the geochemical data from the upgradient and source area wells. Near the center of a contaminant plume, the groundwater would be expected to be depleted of electron acceptors (oxygen, nitrate, and sulfate) and enriched in metabolic by-products (reduced manganese, ferrous iron, and methane) as a result of biodegradation processes. Two wells at the site were sampled for geochemical parameters: MW-01, located within the free product area, and MW-02, located east and upgradient of MW-01 in an uncontaminated area. Both wells did not have any detectable dissolved oxygen or nitrate. The increased concentration of ferrous iron, decreased sulfate, and increased methane within the groundwater plume are all consistent with biodegradation involving iron reducers, sulfate reducers, and methanogens. Table 4-4 summarizes the observed changes in groundwater geochemistry at the site.

Additional evidence of natural attenuation is observed in the diminishing concentrations of hydrocarbons in the downgradient wells. Table 4-5 summarizes the BTEX concentrations in two groups of wells that are aligned approximately parallel to the groundwater flow direction. The BTEX concentrations are shown to diminish from approximately 350 μg/L in the source area wells to non-detect within 130 to 160 feet downgradient.

The natural attenuation of BTEX in the groundwater plume at the State Street Mystery Site was modeled using BIOSCREEN (Newell et al., 1997). BIOSCREEN is a screening model for simulating natural attenuation of petroleum hydrocarbons and has the ability to simulate one-dimensional advection, three-dimensional dispersion, linear adsorption, and first-order or instantaneous reaction biodegradation. The model can be used to simulate changes in BTEX concentrations as a function of distance downgradient of the NAPL source area.

TABLE 4-4
Groundwater Geochemistry at Upgradient and Source Area Wells

Indicator	Upgradient Groundwater at MW-02 (mg/L)	NAPL Source Area Groundwater at MW-01 (mg/L)
BTEX	ND	0.366
DRO	ND	22
Oxygen (O_2)	ND	ND
Nitrate (NO_3^-)	ND	ND
Manganese (Mn^{+2})	2.02	1.95
Ferrous Iron (Fe^{+2})	6.83	22.2
Sulfate (SO_4^{-2})	7.44	2.78
Methane (CH_4)	0.28	0.44
Alkalinity ($HCO_3^- + 2CO_3^{-2} + OH^- - H^+$)	110	101

TABLE 4-5
BTEX Concentrations in Downgradient Monitoring Wells and Probes

Well	Downgradient Distance (ft)	BTEX Concentration (μg/L)
Flowpath A		
DP-08	0	351.6
DP-06	38	154
MW-04	132	ND
Flowpath B		
MW-01	0	365.9
DP-05	34	21.14
MW-03	155	ND

Note: ND = not detected

During the model setup, assumptions were made as to the age of the spill (10 years); the initial source area BTEX concentration at the time of the spill (0.4 mg/L), and the soluble mass of NAPL in the source area (100 kg). The groundwater flow velocity calculated by the hydraulic groundwater flow model described in Section 4.2 was also used as input to the BIOSCREEN model. The model was calibrated to the field data presented in Table 4-5, using a trial and error process to estimate the first-order biodegradation rate for BTEX. For Flowpath A (downgradient of Well DP-08), the estimated biodegradation rate was 0.047 day^{-1}, and for Flowpath B (downgradient of Well MW-01), the estimated biodegradation rate was 0.189 day^{-1}. These rates are within the range of literature values for anaerobic field studies reported by Suarez and Rafai (1999). The input and output screens for the BIOSCREEN runs are shown in Appendix D.

The BIOSCREEN simulations predict that the plume is at steady state and is not expanding beyond it's current length of less than 130 feet downgradient of MW-01 and less than 160 feet downgradient of DP-08. The model results also show what the predicted plume length and concentrations would be if no biodegradation was occurring. Without biodegradation, the model predicts that the BTEX plume would be more than 400 feet in length, which is not seen in the field data from sampling downgradient wells MW-03 and MW-04. This indicates that dilution and sorption alone do not explain the observed plume attenuation and, therefore, biodegradation is occurring.

Based on the field data and groundwater modeling results, the dissolved-phase hydrocarbon plume is less than 160 feet long and the plume is not expected to impact the City of Skagway water supply wells, which are approximately 1,600 feet from the site.

SECTION 5

Conclusions and Recommendations

5.1 Conclusions

Data collected during the site characterization at the State Street Mystery Site in February 2003 were evaluated as follows:

- To further characterize the extent of contamination
- To identify potential sources for free product observed in soil and groundwater at the site
- To determine if groundwater passing through the site eventually captured by the City of Skagway municipal water supply wells
- To determine if site contaminants naturally attenuate to non-detectable concentrations before they could reach the municipal water supply wells

The following conclusions are presented based on the data collected and this evaluation.

5.1.1 Site Characterization Conclusions

Soil and groundwater samples were collected from 13 driven probe locations, and three rounds of groundwater sampling were performed at the 4 existing monitoring wells. Conclusions from the evaluation of this new data along with data collected from previous investigations include the following:

- The extent of site contamination appears to have now been delineated on three sides; the southwest side of 20th Avenue (Test Pit 3 and TB-5), the southeast side of State Street (DP-01 through DP-04), and the northeast side of the Moe lot (Test Pits 6 and 7, DP-09 and DP-11) all had no sheen on groundwater samples and low or non-detectable soil contamination.
- The northwestern portion of the Moe lot on the south side of the stream appears to have the highest soil contamination detected to date (11,000 mg/kg DRO was detected in samples from both Test Pit 8 and DP-08). Groundwater samples from this area also had high concentrations of DRO (15,000 µg/L at DP-08 and 24,000 µg/L at DP-10).
- The site characterization results suggest that the source of contamination may be near the northwestern portion of the Moe lot where a trailer fire and heating oil tank explosion occurred in January 1997, or from an area north of the Moe property, across the stream and/or the alley.

5.1.2 Free Product Recovery Conclusions

Free product recovery was conducted at MW-01 between May 15 and June 26, 2003. Although an initial pumpdown – rebound test suggested that product flowed freely into the well, the skimmer pump recovered less than one gallon during the 43-day operating period. Due to the low recovery volume, the product recovery system was demobilized.

5.1.2 Modeling Conclusions

A groundwater flow model of the Skagway Valley was constructed and calibrated to available hydraulic data. The model was used to evaluate the groundwater flow conditions in the area, and to investigate the potential for existing groundwater contamination to impact City of Skagway water supply wells. Specific conclusions from the analysis include:

- Groundwater flow directions in the vicinity of the State Street site are to the southwest, generally paralleling the orientation of the Skagway River
- Groundwater flow velocities in the area are about 4 feet per day or 1,460 feet per year
- Groundwater originating in the contaminated area of the State Street site will eventually be captured by the City of Skagway production wells located approximately 1,600 feet downgradient of the site
- The groundwater travel time between the site and the City wells is between 0.8 and 1.6 years
- Model simulations predict that if the source area at the State Street site extends 5 feet beneath the water table, groundwater that passes through this area will be captured by City Well No. 2.
- Model simulations further predict that if the source area at the State Street site extends 10 feet beneath the water table, then groundwater passing through this area will be captured by City Wells No 1 and No. 2.

Further modeling was used to evaluate the stability of the petroleum hydrocarbon plume and evaluate if detectable contamination would migrate to the City wells. The results of the contaminant transport modeling were the following:

- Biodegradation of petroleum hydrocarbons is taking place by naturally-occurring microorganisms.
- The groundwater plume is at steady state (not expanding).
- Contaminated groundwater from the site attenuates to non-detectable levels less than 130 feet downgradient of MW-01 and less than 160 feet downgradient of DP-08.
- The contaminated groundwater is not expected to impact the City wells located approximately 1,600 feet from the site.

5.2 Recommendations

The extent of contamination has not been fully delineated in an area north of the Moe property across a small stream and alley. Additional investigation in this area would help determine if the free product observed on the Moe property is potentially coming from an offsite source. Further sampling is also recommended in the northwest portion of the Moe lot where a trailer fire and heating oil tank explosion occurred and contamination was detected at 2 to 4 feet deep at probe location DP-08.

SECTION 6
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Appendix A
Well Purge and Sampling Field Sheets

Appendix B
Laboratory Reports and Data Quality Review Memoranda

Appendix C
Data from Groundwater Level Data Loggers

Appendix D
BIOSCREEN Model Results