North Pole Refinery Technical Meeting
August 28, 2013
Alaska Department of Environmental Conservation, Fairbanks Office
Fairbanks, Alaska

In Attendance

Rebecca Andresen	Arcadis
Brian Angerman	Barr Engineering
Dr. Dave Barnes	UAF, Civil and Environmental Engineering, Department Chair
Cody Black	ERM/OASIS Environmental
Stephanie Buss	SPB Consulting, Toxicologist
Tamara Cardona	ADEC, Contaminated Sites Program, Project Manager
Dave Dahlstrom	Barr Engineering
Andy Davis	President, Geomega
Ann Farris	ADEC
Loren Garner	FHRA, Groundwater Program, Program Manager
JoAnn Grady	Grady and Associates, Team Facilitator
Patrick Haas	P.E. Haas and Associates
Steven Humphrey	Geomega
Dave Lipson	Arcadis
Mark Lockwood	Shannon & Wilson
Gordon McCurry	Geomega
Andrew Ohrt	Arcadis
Jane Paris	ERM/OASIS Environmental
Britt Phillips	Geomega
Gary Remple	Barr Engineering
Max Schwenne	ERM/OASIS Environmental, Project Manager
David Smith	Koch Remediation and Environmental Services
Eric Zentner	Boreal Communications Strategies

OVERVIEW OF THE STATUS OF DR. BARNES RESEARCH

- **ITEMS DISCUSSED**
  - Dr. Barnes summarized the status of his efforts to identify discontinuities in the permafrost within the project area. He explained that the results of an analysis of the isotopic fractionation patterns of oxygen-18, oxygen-16, and hydrogen and deuterium from project samples indicate that the water in the sub-permafrost and supra-permafrost regions of the aquifer originate from different sources. He said that the preliminary results of his analysis of isotopic patterns in water samples seem to indicate whether the samples are from areas in the sub-permafrost, the supra-permafrost regions, or areas of discontinuities in the permafrost where waters originating from the two regions are in contact with each other. Dr. Barnes added that the temperature of field samples also

differs depending on their region of origin. He noted that the temperature of groundwater increases as its depth below the permafrost increases. Dr. Barnes said that water taken from within the potential discontinuities show specific, increasing trends in temperature that are associated with increasing depth. Dr. Barnes showed a series of slides demonstrating the correlation between trends in water temperature and isotopic fractionation patterns in areas where he believes that discontinuities in the permafrost exist. He said that he hopes that further sampling and analysis will clarify the trends so that they can be used to identify additional areas of potential discontinuity and, to ultimately determine their role in the movement of sulfolane between the sub-permafrost and supra-permafrost regions of the aquifer.

        - Dr. Barnes said that the correlations between temperature and fractionation patterns suggest that there are areas of discontinuity in the vicinity of Badger Slough and near the down-gradient property boundary of the refinery.
    - The team discussed the possibility of performing age-dating on the samples being taken for this project.
- **OUTSTANDING QUESTIONS**
    - Dr. Barnes pointed out a few wells, such as MW-161, which are outliers on the correlation chart. He said that his team will continue to investigate these data points as the project continues.
    - The extent to which water from the Tanana will mix with the ground water being sampled in the project, particularly when the energy in the Tanana system is high.
        - Dr. Barnes noted that the temperature and isotope data from samples taken just before breakup – when the energy of the Tanana system is low – seem to indicate that such dilution is minimal during that event.
        - Dr. Barnes noted that gravel pits in the area may have influenced the results from some of the samples.
        - The team suggested that Dr. Barnes consider taking samples from the Tanana River.
        - Mr. Haas suggested that the team consider the possibility of analyzing water samples from private wells to see if they can discern a specific signature in the ratio of the metals that they contain. He noted that specific ratios of metals might provide evidence as to their point of origin.
- **AGREEMENTS**
    - The team agreed that it would allow a reasonable amount of time for its members to review the data coming in from Dr. Barnes research before any requirements are made that it be considered in a formal deliverable such as the Conceptual Site Model (CSM).
- **IMPASSE**
    - None noted
- **ACTION ITEMS**
    - Mr. Lockwood will check the locations of wells sampled near Badger Slough to determine whether they are representative of water near the permafrost or whether they are representative of an area where the water from the wells may be interconnected.
    - Dr. Barnes will determine the locations on the Tanana River from which the samples reported in literature were taken.

- For the purpose of determining whether additional samples need to be taken along the Tanana River, Dr. Barnes will find the location of the Tanana River samples.
- Dr. Barnes will send the PowerPoint portion of his presentation to Mr. Garner.
- Dr. Barnes will report to the team whether or not he is interested in conducting age-dating on water being sampled for his isotope project.

OVERVIEW ON DUAL POROSITY

- **ITEMS DISCUSSED**
  - Mr. Lipson gave an overview on the history and applications of the Dual Porosity model. Mr. Lipson described the following lines of evidence which he believes supports the assertion that the behavior of sulfolane in the plume is consistent with dual porosity mechanisms:
    - A comparison of the rate of the movement of the sulfolane plume relative to the groundwater velocity. Mr. Lipson presented an overview of key scientific publications published in peer-reviewed literature which demonstrated that the retention and tailing of a solute in a heterogeneous soil matrix increases as the difference between the permeability of its respective soil types increases. Mr. Lipson presented a summary of conclusions from the peer-reviewed literature that the speed of the movement of the plume will be slowed down, or retarded, relative to the average linear groundwater velocity, and, given the heterogeneity in the soils in the project aquifer; this is consistent with the dual porosity mechanism.
    - The results of the 2012 Tracer Test Study: Mr. Lipson presented a series of slides showing the predictions of a mathematical model for dual porosity mechanism. The slides showed the predicted changes in the concentration of a pulse of a hypothetical tracer as it is moves from an injection source to a down-gradient monitoring well in a ground water system. The slides compared the concentration curve of the tracer as predicted by an advection/dispersion model and that of a dual porosity model. Mr. Lipson pointed out that there were two main differences between the two models as follows: (1) Dual-porosity mechanism results in retardation of the velocity of the peak; and (2) dual-porosity mechanism results in a long-asymptotic tail of concentrations. Mr. Lipson described the soils observed at various depth intervals at the location of INJ-MW-4, a well inserted during the 2012 Tracer Test Study to measure tracer breakthrough curves. Mr. Lipson presented a series of slides showing the graph of the concentration of the tracers used in the tracer test as they were measured from INJ-MW-4. He commented that the graph of the concentration of the tracers features the long, asymptotic tail which is not characteristic of a purely advective system and which is consistent with a dual porosity mechanism. He suggested that this tail, and the heterogeneity in the soils observed between different depths in the well, represents a line of evidence that the dual porosity model is applicable to the movement of sulfolane in that area. Mr. Lipson

acknowledged that the concentrations were only measured for a few days, but he added that his team would perform additional injection studies and soil sampling to further pursue this line of potential evidence.

        - A comparison of sulfolane concentrations taken in soil samples at various depths and locations with the soil type observed at those depths and locations: Mr. Lipson presented a series of slides showing the locations of soil samples taken from areas in the unsaturated zone near a known release of sulfolane that occurred in 1993. Mr. Lipson said that he compared the concentration of sulfolane in samples taken from areas around the release with the soil descriptions that were available from the soil boring logs. Mr. Lipson presented a graph showing the correlation between increasing sulfolane concentrations and the decreasing grain size of the soils sampled. Mr. Lipson cited this correlation as additional evidence for dual porosity at the site since it suggests that higher concentrations of sulfolane may be being stored in the fine grain soils.

- **OUTSTANDING QUESTIONS**
    - Dr. Barnes questioned whether sulfolane is really being trapped and stored in soils with lower permeability or whether the sulfolane is simply moving through these layers at a slower rate without being retained in significant quantities. Dr. Barnes said that these questions are largely dependent on factors such as the extent to which various transport mechanisms are at play in the various soils. He remarked that the question of whether sulfolane is really being stored in fine-grained soils in significant amounts has important implications for the types of remedial systems that will be considered by the team.
        - Dr. Barnes and Mr. Haas commented that the radius of influence of any injected amendments will be dependent of the transport mechanism that is dominant in a given area. They noted that in areas where advection is the dominant transport mechanism, the amendment will quickly move through the more permeable soils and move much more slowly through less permeable soils. They cautioned the team against designating a radius of influence for injection points that is based only on the preferential movement of an amendment through more permeable soils since this is not necessarily representative of its movement through all of the soil type located in the radius of influence.
    - Dr. Barnes commented that the shape of the concentration curves of the tracers may be due to differences in the head pressure that were caused by the injection process. He commented the asymptotic tail may have been caused by cutting off the injection and reducing the head pressure in the system.
        - Dr. Barnes reiterated the concern that the 5-day monitoring period for the Tracer Test is not long enough to assert, with confidence, that the concentration curve for the tracer is characteristic of the dual porosity mechanism.
    - The team discussed other possible ways that sulfolane may be being retained in the soils in the project area. Mr. Haas remarked that the team should not rule out the possibility that sulfolane is being sorbed to soils below the water table. He noted that there is a general lack of information on the sorbtion properties of sulfolane and he added that the possibility of sorbtion should be considered since sulfolane can go back into its solid phase when it is exposed to low temperatures. Ms. Andresen remarked the team has yet

to find evidence that sulfolane is being sorbed to soils. Dr. Barnes noted that he is perplexed that sulfolane is not being found in higher concentrations in the fine grained soils. Mr. Lipson suggested that this may be an artifact of the sampling procedure which includes pore water in addition to soil. Some team members suggested that existing soil data indicates that soil contamination seems to be relatively confined to the upper layers of soil and this could be a function of its proximity to the source rather than a function of a particular transport mechanism. Dr. Barnes suggested the team consider placing wells with discrete sampling ports that are inches apart. Several team members expressed their hope that this curiosity would be resolved as more detailed soil sampling is carried out.

- **AGREEMENTS**
  - Dr. Barnes commented that, while it is likely that a dual porosity mechanism is in effect in the transport of sulfolane at the site, the team must exercise caution in its interpretation of the evidence cited in the presentation for the reasons listed above.
- **IMPASSE**
  - None noted.
- **ACTION ITEMS**
  - None noted.

GRAPHICAL ("CARTOON") DEPICTION OF ERM'S CONCEPTUAL SITE MODEL

- **ITEMS DISCUSSED**
  - DEC's team presented a graphical depiction of part of their conceptual site model.
    - The cartoon was conceived to demonstrate a theory about how sulfolane could have migrated from the water table at the refinery source areas to greater than 200 feet below ground surface, below permafrost, approximately a mile down-gradient of the refinery. A goal of the conceptual site model is to provide a possible explanation for the sulfolane detections above 500 micrograms per liter (ug/L) in residential well PW-1230. A current theory is that those concentrations are the result of the plume being split into sub and supra-permafrost sections as it flows around a large wedge of permafrost located just off the refinery.
    - How to address the unknowns outlined in the cartoon.
      - The actual location where the plume splits is unknown. Pressure transducer data from nested wells in this area is expected to provide information about vertical gradients once the SOP for data logger error has been finalized and groundwater gradient analysis has been performed.
      - The current monitoring network does not appear to be sufficient to delineate sub-permafrost migration beyond the conceptual stage. The feasibility of using additional residential wells and/ or installing sub-permafrost monitoring wells was discussed.
        - Ms. Paris suggested using Private Well-1230 as a target area for additional monitoring wells. Monitoring wells could be installed

in a triangular orientation around this area to gain a better understanding of its geometry and transport.

- **OUTSTANDING QUESTIONS**
  - What was the origin and route of sulfolane as it migrated to PW-1230 and where is the sulfolane migrating once it is past PW-1230?
  - Is the sulfolane the result of a long-term source or was it the result of a slug-type release?
    - If the contamination is the result of a slug-type source, why haven't any remnants of the contamination been found in nearby wells?
    - Is there permafrost beneath the refinery and is it affecting the migration of sulfolane?
    - Is the movement of sulfolane driven by density or viscosity factors?
    - Is the relatively high concentration found at MW-154B an artifact of the Pump and Treat System?
  - What is the significance of this migration as it pertains to the capture zone of the Pump and Treat System?
- **AGREEMENTS**
  - The Conceptual Site Model that is being proposed by the FHRA team bears notable similarities to the flow pattern that is depicted in the DEC team cartoon.
- **IMPASSE**
  - None noted
- **ACTION ITEMS**
  - None assigned

FHRA's CONCEPTUAL MODEL AND CAPTURE ZONE ANALYSIS

- **ITEMS DISCUSSED**
  - Mr. Dahlstrom presented a series of slides showing the mechanisms explored by his team in the CSM to explain the movement of sulfolane throughout the aquifer. He said that two mechanisms his team had identified that could contribute to the vertical downward flow suggested in the L-shaped plume model are:
    - Density-driven flow in the source areas. Mr. Dahlstrom commented that his team has noted that cold water has a higher density which may result in downward flow and an L-shaped plume since there is no known permafrost under the refinery.
    - Viscosity effects in the source areas.
  - Mr. Dahlstrom mentioned that the following factors would contribute to a more normal (non L-shaped) plume configuration including focused flow through heterogeneous areas and around barriers throughout the aquifer.
    - Mr. Dahlstrom went on to discuss how recharge, dispersion, and heterogeneities may have contributed to the sulfolane plume splitting into sub-permafrost and supra-permafrost components as it flows around

an impermeable permafrost body near the site (although this has not been documented) or through one or more taliks offsite.

- Mr. Dahlstrom presented results of a 2-D model of flow with permafrost that showed a bifurcation of flow above and below permafrost. Mr. Dahlstrom pointed out the limitations of the simple profile model that was illustrated in the slide and used as a talking point. He noted the model did not account for flow along the sides or the bottom of the modeled area.
- Mr. Dahlstrom presented an overview of the objectives and results of the startup testing that was performed in May-June and an additional capture zone evaluation based on measurements taken in August of 2013. Mr. Dahlstrom said that:
  - The first priority of the testing was to make an evaluation of the capture zone based on field measurements.
  - The second priority was to obtain additional inputs to the groundwater flow model and to test its assumptions concerning the site.
  - The third priority was to determine if the measurements made after the shutdown of the system support the dual porosity model.
- Mr. Dahlstrom described the methodology and results of the testing. He pointed out the approximate location of the capture zone relative to the refinery and he noted that the results of the test were quite similar to those that were predicted by the groundwater flow model.
  - The team discussed the extent to which the operation of the recovery system overcomes preferential flow through areas of high hydraulic conductivity and achieves contaminant capture. The data from the MW-186 well nest were discussed as an example.

- **OUTSTANDING QUESTIONS**
- **AGREEMENTS**
  - The reviewers indicated preliminary agreement with the findings.
- **IMPASSE**
  - None Noted
- **ACTION ITEMS**
  - None noted

SURFACE WATER SAMPLING REPORT

- **ITEMS DISCUSSED**
  - Ms. Paris summarized the results of a two efforts that were recently conducted to take surface water and soil samples from Kimberly Lake and surface water, ground water, and soil samples from Badger Slough and several other lakes located north of the refinery. Ms Paris summarized the methodology and the results of the sampling. She said that sulfolane was not detected in any of the surface water samples and, although it is difficult to detect a contaminant in surface water, the results are good news for the community and they open possibilities for the Feasibility Study. Sulfolane was detected in one sediment sample and one groundwater sample collected near MW-161 in an area of known high

groundwater sulfolane concentrations. Sulfolane was not detected in any samples from the active gravel pit.

- **OUTSTANDING QUESTIONS**
  - Is sulfolane degrading in the surface water?
    - Ms. Paris commented that there is still no conclusive answer to this question.
  - The team discussed a question of whether all of the ponds that were sampled are in communication with the groundwater in the area. The generally agreed that they believe that they are, and that they have not found any evidence to the contrary.
- **AGREEMENTS**
  - None noted
- **IMPASSE**
  - None noted
- **ACTION ITEMS**
  - Ms. Cardona will send Mr. Smith a copy of the work plan and reports for the Kimberly Lake and Badger Slough/Gravel Pit sampling events.

BIODEGRADATION UPDATE

- **ITEMS DISCUSSED**
  - Mr. Fish presented an update on efforts underway at the University of Alaska at Fairbanks (UAF) to analyze the biodegradation of sulfolane. He said that UAF is working with the University of Oklahoma to develop laboratory protocols for various kinds of analysis and they have are currently using insitu cultures of known sulfolane-degrading bacteria as a starting point for the biodegradation research. Mr. Fish said that the universities are currently using Liquid Chromatography Mass Spectra (LCMS) analysis to analyze for potential intermediate byproducts of the degradation of sulfolane.
  - Mr. Fish said that ADEC and its contractor ERM/OASIS are pursuing an independent analysis of whether thiolane, a potential degradation product of sulfolane, is present in groundwater at the site. He said that the researchers are currently working with SGS Analytical Laboratories to develop the laboratory protocol for the analysis of thiolane.
    - The team discussed how the analysis of thiolane relates to the site characterization process and the project deliverables that are associated with it. Mr. Smith commented that FHRA must review the work plan and the justification for the analysis in order to provide its point-of-view on ADEC's intended efforts. Ms. Cardona clarified that the Alaska Department of Environmental Conservation (ADEC) would not require that the analysis be included in the Feasibility Study (FS) or Cleanup Plan before the data from the analysis has been fully vetted through the appropriate channels.
- **OUTSTANDING QUESTIONS**
  - None noted
- **AGREEMENTS**
  - None noted
- **IMPASSE**

- None noted

- **ACTION ITEMS**
  - None noted

INTERIM REMEDIAL ACTIONS DESIGN PLANNING UPDATE

- **ITEMS DISCUSSED**
  - Mr. Angerman presented on overview of the site's groundwater extraction system. He briefly described several of the changes and improvements that have been made to the system throughout its operation and the corresponding increases in the system's flow rate and decreasing trends in the concentration of sulfolane at several of its monitoring, observation, and recovery wells. Mr. Angerman noted his team is still observing the complete removal of sulfolane from the treatment system. He added that concentrations of sulfolane at all of the VPT wells are stable, decreasing, or non-detect.
  - Mr. Angerman briefly described the proposed expansion of the groundwater extraction system. He said that two wells; R-47 and R-48, will be placed west of R-42 to expand the system's capture zone to the west. He said that these systems will be connected to a new, separate treatment system. Mr. Angerman said that his group hopes to submit the application for the design of the systems sometime this fall. They hope to have the design and permits approved in order to begin construction in the following April or May and to begin operating the systems by June 30th 2014. Mr. Angerman noted that a number of permits specify that no construction can begin until all permits have been received. Mr. Garner remarked that Flint Hills Resources Alaska (FHRA) would be happy to submit preliminary elements of the design if that would assist ADEC in moving through the permitting process in a timely manner. He agreed to send Ms. Cardona a list of the permits that are required for the approval of the system.
- **OUTSTANDING QUESTIONS**
  - None noted
- **AGREEMENTS**
  - None noted
- **IMPASSE**
  - None noted
- **ACTION ITEMS**
  - Mr. Garner will send Ms. Cardona a list of the permits that are required for the approval of the expansion of the groundwater system.

UPDATE ON THE SITE CHARACTERIZATION REPORT

- **ITEMS DISCUSSED**
  - Mr. Lockwood presented an update on the status of various field work activities including the installation of the Phase 8 wells and the ongoing sampling of off-site monitoring wells, on-site monitoring wells, and private wells. Mr. Lockwood said that the

hydropunch work scheduled for the season has been completed, but his group is currently waiting on road construction to finish the monitoring wells to be installed north of the VPT. Mr. Lockwood pointed out the results of the efforts that are currently underway to resample the buffer zone that FHRA has established, as a safety precaution, around the edge of the plume. He pointed out the location of a small number of properties within the buffer zone where sulfolane was detected for the first time in the last sampling event as well as certain properties which FHRA has not been able to sample. The team discussed the Buffer Zone. Mr. Garner noted that while the Buffer Zone generally extends across the next two property lots located outwardly from the last property wherein sulfolane was detected, the actual dimensions are not determined by a formal calculation, but are left to the professional judgment of those that administer the zone. He added that FHRA reevaluates the buffer zone every year and adds all properties with new detections in the zone to the alternative water supply programs.

- Mr. Lockwood presented a slide showing the varying depths to permafrost across site the as indicated by data from monitoring and residential wells. The team discussed certain shallow wells where sulfolane had not been detected despite being surrounded by other wells with detections. Mr. Garner noted that these wells have a relatively shallow depth to permafrost as opposed to the others around them. He commented that the shallow depth to permafrost appears to have a slowing effect on the movement of sulfolane in these areas.
- Mr. Lockwood pointed out the results of certain monitoring wells located in the supra-permafrost and sub-permafrost regions in the off-site area. He noted that his team is currently trying to find additional residential wells to further delineate the sub-permafrost portion of the sulfolane plume.
    - Mr. Haas suggested that the team consider conducting center-of-mass analysis in the plume to better understand the results of the sub-permafrost residential wells. Mr. Lockwood replied that his team is now gaining more confidence in understanding the sub-permafrost residential wells. Mr. Garner briefly reviewed the existing sub-permafrost well network and wells that may be included in the network. He noted that FHRA is actively looking for additional residential wells that extend below the permafrost. Mr. Garner reminded the team that physical considerations associated with the wells and a dependence on the receptiveness of the well owners pose significant challenges to using those wells as potential monitoring points. He noted that FHRA has been using a fairly rigorous screening process to determine which of the potential sub-permafrost wells should be further investigated to determine that they would be suitable monitoring points.

- Mr. Ohrt said that his team finished the borings for the capillary-fringe work on the previous day and they expect the results from the work to begin coming in soon. The sampling for Perfluorinated Compounds (PFCs) is scheduled to begin in early September and the tracer testing will begin as soon as the work plan for the testing is approved.

- **OUTSTANDING QUESTIONS**

- Whether current and planned efforts to investigate the sub-permafrost portion of the sulfolane plume will be adequate to characterize that portion of the aquifer.
    - The team engaged in a lengthy discussion on whether monitoring, and possibly expanding, the sub-permafrost residential well network will be adequate, in conjunction with the groundwater modeling, permafrost delineation, and other planned site characterization efforts, to understand the sub-permafrost portion of the sulfolane plume, particularly in the southern region where a sulfolane concentration of 603 ug/L was recently discovered (PW-1230). The team discussed the significance of that event and whether it will be necessary to conduct additional site characterization efforts in that area to understand the source of that contamination, and its relation to the strength, extent, and movement of the contamination around it. The team discussed, in detail, whether the 603 ug/L detection represents a point in the center of the plume or a point in its tail. The team agreed that the matter ultimately depends on the amount of uncertainty that is acceptable regarding the concentration and movement of sulfolane in the area. Mr. Smith and Mr. Davis urged the team to allow time to monitor existing wells for concentration trends, to search for suitable sub-permafrost residential wells, to develop the groundwater model, and to gather data from other planned site characterization activities before making any decision regarding whether additional site characterization is needed in the area. Mr. Smith reminded the team that these issues will be revaluated in the 5-year Review and in other ongoing reviews and refinement processes.

- **AGREEMENTS**
    - The team agreed that it needs more data to better understand the sub-permafrost and supra-permafrost portions of the plume. The team diverged, somewhat, on whether this data can be fully obtain through site characterization activities that are underway or planned. Ms. Cardona commented that ADEC is not currently requiring that sub-permafrost wells be installed, or new types of site characterization be performed in the area, but only that the team continues to discuss the incoming data consider whether alternative approaches are needed.
- **IMPASSE**
    - None Noted
- **ACTION ITEMS**
    - None noted