**MEMORANDUM**

**Date: July 1, 2010**

**From: Donald Maynard, The Johnson Co., Inc.**

**To: Thor Helgason, de maximis**

**Re: Pine Street Canal Superfund Site, Shallow Overburden Groundwater Quality Data**

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## Background

As part of the compliance monitoring requirements for the Pine Street Canal superfund Site in Burlington, Vermont, groundwater monitoring is performed twice a year (April and October). The monitoring requirements include shallow (less than 50 feet below ground surface) overburden groundwater monitoring near the railroad on the peninsula between the Canal and Lake Champlain (see Figure 1).

Recent (since 2008) significant increases in benzene concentrations in several wells between the Canal and the Lake, along with the intermittent presence of measurable thickness of dense non-aqueous phase liquid (coal tar or DNAPL), has created cause for concern. Benzene concentrations have been reported in these wells above the Federal Maximum Contaminant Level (MCL) and Vermont Groundwater Enforcement Standard (VGES) of 5 parts per billion (ppb), including benzene at 530 ppb in April 2010 in a well located outside of the Class IV groundwater boundary (an institutional control that classifies the groundwater as non-potable).

Following are summaries of: the geology and stratigraphy of the area (which delineates the probable contaminant migration pathways); the hydraulic gradient (which influences groundwater, dissolved contaminant and DNAPL (coal tar) flow directions and rates; and observations of DNAPL and water quality. Also provided is a brief description of possible sources and causes for the DNAPL and groundwater contamination observations and migration.

## Geology and Stratigraphy

The overburden geology below the peninsula between Lake Champlain and the Canal was controlled by the retreat of the Wisconsian Glacier and subsequent marine and lacustrine environments. These created a thick (greater than 50 feet) relatively impermeable layer of silt and clay below the peninsula. There is considerable evidence that the silts and clays do not transmit significant quantities of contamination.

Historically, a small stream flowed from the northeast into the present location of the Turning Basin, and formed a delta beneath the Turning Basin and the northern end of the peninsula. The peninsula extended to the south as the predominant northwest waves washed the deltaic sediments down the beach. Occasional storm events created east-west trending wash-over fans and their associated thin “shoe-string” gravel channels. These are believed to be the primary pathways for contaminant migration.



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Eventually the peninsula formed a barrier spit in response to wave action in Lake Champlain. A peat bog developed beneath the southern end of the Canal in the protected waters behind the peninsula. Peat did not form below the Turning Basin and northern end of the peninsula due to the presence of the deltaic sediments being deposited from the stream.

Based upon numerous tests, the peat is generally highly porous, but has a low hydraulic conductivity relative to the sands, limiting its capacity to transmit groundwater and contaminants. The peat hydraulic conductivity is further decreased when it has been compacted (as would be expected from the filling for railroad construction along the peninsula in the mid-1800's and the subsequent weight of the trains). In 1868 the Canal was dredged.

The current stratigraphy of the peninsula is shown on the cross sections provided as Figures 2 through 5. The gravel channels formed either as deltaic distributaries or as wash-over fans are highlighted on the cross sections, as they act as preferential pathways for fluid flow in the subsurface. The peat and the sands interfinger with each other, and the sands pinch out and are not present to the south and east. The inferred southern and eastern limit of the sands is shown on Figure 1.

**Groundwater Gradient**

The groundwater hydraulic gradient (slope) on the peninsula is mostly controlled by the relative water elevations in the Canal and the Lake. The width of the peninsula between the Canal and the Lake is about 230 feet. When the Lake and Canal are the same elevation above the outlet weir, there is virtually zero hydraulic gradient and no groundwater flow in the peninsula. When the Canal level is higher than the Lake level, the hydraulic gradient and groundwater flow is towards the west (and the Lake).

Prior to autumn 2001, flow from the outlet of the Turning Basin to the Lake was controlled by the elevation of the bottom of the outlet located below the railroad bridge, and by intermittent beaver dams constructed below and east of the bridge. The Canal elevations fluctuated between approximately 94.5 and 96.5 feet NAVD88 as shown on the hydrograph from 1994-1995 in Figure 6. In general, the Canal level was 1-2 feet higher than the Lake during that period, except during periods of seasonal high Lake levels such as the January thaw, and during and after the spring snow melt.

In 2001, a concrete weir was constructed to hold the Canal at a minimum elevation of 96 feet NAVD88. In the summer of 2002 through the spring of 2003 the Canal water was pumped down for construction of the cap. This caused the hydraulic gradient to reverse, and groundwater flowed east from the Lake towards the Canal. This is shown as a negative gradient on Figure 7, which presents the hydraulic gradient based upon manual measurements from 2001 through 2009.

Beavers constructed dams below the railroad bridge at the Canal outlet in 2007, 2008 and 2009. These dams were periodically removed by the Performing Defendants as indicated on Figure 7. While the dams were present, the hydraulic gradient to the Lake was seasonally

increased beyond its historic levels. However, the gradient still returned to zero each spring as snow melt water increased the Lake level to a point above the beaver dam (see Figure 7).

**DNAPL**

Dense non-aqueous phase liquid is present on-site as a result of releases from a former coal manufactured gas plant (MGP). The extent of coal tar DNAPL in the subsurface was evaluated based upon its visual presence in soil and sediment cores, and in wells. Figure 1 includes a delineation of the known extent of DNAPL in 2000, prior to the remedial action, in the vicinity of the Turning Basin and northern Canal.

Due to its physical properties, including viscosity and its characteristic as a non-wetting fluid, the DNAPL generally cannot penetrate into fine grained sediments, including medium and fine grained sands. These theoretical calculations completed during the Additional Remedial Investigation (ARI) were confirmed during coring, including the piston cores collected at BO-70 in 2000, and at PZ-3 in 1994 (see Figure 1 for locations). In both these cores, the DNAPL was present only in gravel lenses, and not in adjacent fine, medium and/or coarse sand layers.

DNAPL was observed in thin (less than one foot) gravel layers at both borings BO-70 and PZ-3. As a result, additional soil cores were collected east of PZ-3 at PZ-3A, and north and south of BO-70 (at BO-71, BO-72 and BO-73 as shown on Figure 1). There was no DNAPL in these additional core locations, even though gravel layers were present.

Due to the presence of DNAPL at BO-70, the pre-existing well MW-17, located approximately 50 feet east of BO-70 (towards the Canal), was re-examined in 2000. DNAPL was discovered in this well at that time, and a review of the records of previous sample events indicated that it could have been present all along, as no-one had dropped a probe to its total depth since the time of its installation.

Monitoring of DNAPL thicknesses in MW-17 and MW-23B (installed at BO-70) has been conducted in April and October of each year since 2001. After measurement of the DNAPL thickness, any DNAPL present was removed by bailer or pump. Additional monthly DNAPL thickness monitoring was also conducted in 2009, including both an increase in the frequency of monitoring, and the number of locations.

Also in 2009, the recharge of DNAPL to the wells after its removal was monitored. In general, the DNAPL did not re-enter the wells in measurable quantities in the 24-hour period following its removal.

The DNAPL thickness in MW-23B has always been equal to or greater than that in MW-17. A graph of DNAPL in well MW-23B is provided as Figure 8. The data show that the DNAPL thickness increased to almost two feet in the two years following installation of MW-23B. Later, the DNAPL thickness declined to nearly zero during the Canal dewatering in 2002-2003 (during cap construction). The DNAPL thickness remained at less than 0.1 foot in MW-23B until 2008. DNAPL thicknesses began increasing in October 2008, and increased to more than three feet in the spring of 2009 and 2010. These increases were first measured approximately

16 months following the July 2007 beaver dam construction and the associated increase in hydraulic gradient towards the Lake.

**Water Quality**

There have been 20 monitoring wells installed on the peninsula since the 1980's (see Figure 1). Five monitoring well nest pairs (MW-20 through MW-24) were installed in 2000. The shallow member of each of these pairs is indicated with an "A" suffix (e.g. MW-20A), and the deeper with a "B" suffix. These wells have been sampled at least twice a year, in April and October, since 2001. The results are shown on graphs presented on Figures 7 and 8.

Benzene is a constituent of coal tar. In its dissolved phase it is one of the most mobile constituents and one that is known to be a carcinogen and thus has low regulatory levels (the MCL and VGES is 5 ppb as discussed above).

One of the older wells, MW-17, was sampled five times between 1990 and 1994, and contained between 94 and 190 parts per billion (ppb) benzene during that period. The concentrations appeared to be stable and were not increasing. MW-17 water quality is not tested in the compliance monitoring program, and therefore MW-17 data are not presented on Figures 7 and 8.

Well MW-23B has had DNAPL present in it during many of the groundwater quality monitoring events. As shown on Figure 8, when DNAPL is present, the benzene concentration ranges between approximately 100 and 300 ppb.

As Figures 7 and 8 show, concentrations of benzene in two of the wells, MW-21A and MW-24A increased sharply between October 2007 and April 2008. This rise corresponded with an increase in the hydraulic gradient to the Lake (due to the July 2007 construction of the beaver dam) as shown on Figure 7. Benzene in MW-24A then leveled off at approximately 8-10 ppb for the past two years. However, concentrations in MW-21A have continued to rise (albeit at a slower rate) since 2008. Benzene was detected for the first time in MW-21B in April 2010 (at 210 ppb).

A map of the most recent benzene concentrations (sampled in April 2010) is provided as Figure 9. The 5 ppb MCL is exceeded in MW-21A, MW-21B, MW-23B and MW-24A. Three of these wells (not MW-23B) are located outside the Vermont Class IV Groundwater Boundary.

Additional samples were collected from the PZ-2 and PZ-3A well nests in April 2010. 75 ppb benzene was detected in PZ-2A, while lower concentrations or no detections were reported in the other samples.

Cross sections presenting the benzene concentrations reported for the April 2010 samples are provided as Figures 10 and 11.

**Conceptual Site Model**

DNAPL is known to be present in the sediments and peat below the Canal and Turning Basin. It was also observed west of the Canal in the 1990's in thin gravelly stringers which presumably connect eastwards to the DNAPL present beneath the Canal.

Given the multiple locations both north and south of MW-17 and MW-23B that do not contain DNAPL, a preferential pathway for DNAPL migration to the west (probably a gravel layer) between T-6 and T-7 is suggested (see Figure 1).

The decrease in DNAPL in MW-23B during cap construction, when the hydraulic gradient was reversed away from the Lake, provides evidence that DNAPL migration below the peninsula is controlled in large part by the gradient. The later increase in DNAPL when the gradient was increased following beaver dam construction confirms the cause-and-effect relationship between hydraulic gradient and DNAPL movement.

The soil cores indicate that the western MW-21 wells are hydraulically connected to MW-23B and MW-17 via one or more permeable gravel layers. Figure 8 shows that the benzene concentrations in the MW-21 well nest appear to be directly related to the increase in DNAPL thickness in MW-23B and MW-17 to the east.

The benzene concentrations in MW-24A may be related to MGP DNAPL, or may be the result of local releases of petroleum products near the railroad. The identification of trace levels of methyl-tert-butyl-ethene (MTBE, a gasoline additive) in one of the MW-24A analyses, and the on-going non-detect results in MW-20A/B (located between MW-24A and the Canal), support the possibility of an alternate source.

A summary of the conceptual site model presenting the likely source, migration pathways and factors controlling migration is presented below:

- DNAPL present beneath the Canal migrates through thin (less than a foot) high-permeability gravel layers in response to changes in the hydraulic gradient.
- The DNAPL was in equilibrium and stable until increases in the Canal level were caused by beaver dams in 2007. The seasonal increases in the hydraulic gradient due to the beaver dams was sufficient into move the DNAPL westward towards the Lake.
- Once the DNAPL migrates to an area, its viscosity and local permeation into the surrounding aquifer materials keeps a portion of it there, even if the gradient reverses later.
- The north-south width of the gravel layers with potential to transmit DNAPL is less than 300 feet. Soil boring data collected in 2000 in the vicinity of MW-23 demonstrated a north-south width of gravel layers actually containing DNAPL of less than 50 feet.
- Benzene is dissolved from the DNAPL and travels ahead of it with groundwater flow towards the Lake.
- Recent increases in benzene concentrations in the western wells are the result of a sustained shift in the position of the DNAPL westward towards the Lake in response to hydraulic gradient changes.