4 INVESTIGATION OBSERVATIONS AND RESULTS

This Section summarizes the nature and extent of MGP residuals in various media (soil, water, sediment, and vapor) within the areas of concern identified in the SSWP CSM (NRT, April 2007). The discussion for each media addresses the potential for residual MGP contaminant sources at the site and physical conditions that may affect their distribution and trends.

4.1 Soil

Soil analytical results are compared to soil screening benchmarks (SSBs) listed in Table 3 to identify concentrations that may be of concern with respect to specific receptors or pathways. Source references for the SSBs for each parameter are also listed on Table 3. Locations for areas sampled in 2007 are shown on Figure 5 and corresponding analytical results are summarized for each COPC in Tables 4 through 6. Benzene, benzo(a)pyrene (B(a)P), naphthalene, arsenic, and lead results for the soil samples discussed below are also shown on Figures 9 and 10.

4.1.1 North Property Boundary Surface Soil Sampling

Surface soils at borings SB-301 and SB-302 consisted of silty sands with an organic topsoil layer and well-developed root zone. There were no visual or olfactory indications of MGP residuals. Analytical results indicated the following:

- PAH concentrations at both locations were below MDLs or their respective SSBs (Table 4). MDLs were below the SSBs for the PAHs as well as other analyzed parameters;
- PVOC and phenol concentrations were also below the MDL in both samples (Table 5); and
- Cyanide and metals were below the SSBs (Tables 5 and 6, respectively). The exception was arsenic (690 to 1400 µg/kg), which exceeded the residential SSB (Table 6), but is below typical background concentrations for central Wisconsin (refer to Risk Assessment, Appendix H).

4.1.2 Pfiffner Pioneer Park Surface Soil Sampling

Surface soils in the park (borings SB-303 through SB-308) consisted of silty topsoil underlain by sand fill to a depth of two feet bgs. There were no visual or olfactory indications of MGP residuals in any of the borings completed in the park. Analytical results indicated the following:

- B(a)P concentrations in boring SB-303 exceeded the SSB (Table 4 and Figure 9). All other PAHs in this sample and at other five locations were below the SSB and/or MDL; and

- PVOCs were also below the MDL in these borings (Table 5).

4.1.3 Former Slough Borings

Borings SB-309 through SB-321 were performed to assess soil quality within and beneath the former slough (in the area east of the pond). Most of the borings were terminated in the underlying native sand, with the exception of borings SB-313a, SB-315, and SB-315a, which were terminated due to refusal at 5, 13, and 10 feet bgs, respectively. Borings SB-309 through SB-318 were completed in the vicinity of the pond and borings SB-319 through SB-321 were completed within the former slough at locations near the facility boundary further east and north of the pond (Figure 9).

The fill material in the slough was dominated by sand with wood chips present at various locations and intervals. The slough bottom was generally identified by the presence of visually stained silt/silty soils that exhibited an odor. The silt was typically observed about 14 feet bgs in the vicinity of the pond and at approximately 12 to 13 feet bgs in the borings north and east of this area. Relatively homogeneous native sand and gravel glacial/alluvial deposits were identified beneath the base of the slough, and the slough bottom is below the water table.

Boring observations are summarized below and on Figure 11 for the borings completed in the vicinity and east of the pond. Notable observations include wood and/or wood chips, odor, sheen, and trace MGP residuals at isolated locations. Wood was present where there were observations of odor, sheen, and tar. Observations for borings located further east along the facility boundary are discussed separately below

Boring	Depth	Silt (base)	Wood	Odor	Sheen	Tar
SB-309	20'	14-15'	7.5-14'	7.5-19'	15-19'	Not noted
SB-310	20'	12.5-15'	7.5-10'	7.5-15'	10-12.5'	Not noted
SB-311	20'	14-15'	7.5-14'	13-15'	Not noted	Not noted
SB-312	25'	14-15'	Not noted	8-18.5'	10-18.5'	trace 13-15'
SB-313	20'	13.5-14'	7.5-10'	10-15'	Not noted	Not noted
SB-314	25'	14-15'	10-14'	7.5-20'	Not noted	Not noted
SB-315	13'	Not noted	9-10'	10-13'	10-13'	Not noted
SB-316	25'	14.5-15'	Not noted	15-20'	15-20'	Not noted
SB-317	20'	13-14.5'	5-13'	10-18'	Not noted	Not noted
SB-318	20'	13-15'	5-10'	10-18'	10-18'	trace 13-15'

A naphtha odor commonly associated with MGP residuals was noted in every boring completed in the former slough. Typically, the odor was noted beginning at a depth of approximately 7 to 8 feet bgs and extending to the base of the former slough. The sheen on the soil, which also generally exhibited an MGP odor, was noted in borings centrally located in the slough (Figure 11). The sheen was absent in borings SB-311/SB-314 and SB-313/SB-317 located along the apparent southern and northern edge of the former slough. Trace tar was noted in borings SB-312 and SB-318, with an oilier appearance at SB-312. The trace tar at SB-318 was more viscous, although not completely desiccated. The tar observed in these borings was not present in sufficient quantity to be considered mobile (i.e., non-flowable).

Similar conditions were observed in the borings completed along the southeastern facility boundary adjoining the City parking lot.

Boring	Depth	Silt (base)	Wood	Odor	Sheen	Tar
SB-319	20'	12-18'	Not noted	5-6 & 13-15'	13-15'	trace 13-15'
SB-320	20'	Not noted	15'	5-18'	5-18'	trace 10-15'
SB-321	20'	13-17'	Not noted	12-20'	12-17'	Not noted

Silt was present at depths of 12 to 13 feet bgs in borings SB-319 and SB-321. The silt was not observed in boring SB-320 but the presence of wood at 15 feet bgs in this boring suggests the slough may have extended to this location

MGP odor and sheen were observed in all three borings and trace tar was present in borings SB-319 and SB-320. The tar in SB-319 was viscous similar to SB-318, and a more oily in boring SB-320, similar to SB-312. Although tar was noted in these four borings, it was viscous (i.e. non-flowable) in nature and occurred sporadically, rather than as a continuous layer extending over an appreciable area.

Analytical results are shown on Figure 9 and 10 and indicate the following:

- PAH concentrations were above the SSBs at most sampling locations for benzo(a)anthracene; B(a)P; benzo(b)fluoranthene; benzo(k)fluoranthene; dibenz(a,h)anthracene; and/or indeno(1,2,3-cd)pyrene (Table 4). Elevated concentrations did not always correlate to locations where trace tar was observed.

- Field observations strongly suggest MGP residuals are not present at and near the surface in these areas. PAH concentrations exceeded SSBs near the pond in samples between 7 feet bgs and the base of the former slough. PAHs exceeded SSBs from 2 to 6 feet bgs in borings SB- 319 and SB-320 further east along the slough, as well as at 10 and 12 feet bgs where trace tar was observed.

- When present, traces of tar occurred along and near the base of the slough, typically at depths of approximately 10 to 15 feet bgs. All samples collected below 16 feet were below SSBs and/or MDLs, indicating that tar is not migrating vertically.

- PVOCs concentrations were detected above the MDL, but below the SSBs.
- Cyanide and metals were below the SSBs (Tables 5 and 6), with exception of arsenic at concentrations up to 2.5 mg/kg, again, within background range (Appendix H).

4.1.4 Well Boring Sampling Results

Soils encountered at borings OW-16/PZ-16 and OW-17 consisted of the following:

Material	OW-16/PZ-16	OW-17
	Depth (ft bgs)	Depth (ft bgs)
Top soil and sandy fill	0-8 ft	0-10 ft
Organic silt layer (speculated to be historic sediment).	8-9 ft (50% woody debris)	10-12 ft (40% organics but only trace woody debris)
Elastic silt	Absent	12-14 ft
Sand	9 to 44 ft	14 to 18 ft
Bedrock	44 ft	18 ft

The logs for the borings indicate subsurface conditions differ significantly at these two locations. Analytical results are shown on Figure 10 and indicate the following:

- PZ-16 (12-14 feet bgs), on the northwest edge of the pond, exceeded SSBs for PAH compounds similar to those in soils east of the pond area. (Table 4). B(a)P is the only PAH that exceeded the SSB in boring OW-17.
- PVOCs were also detected at PZ-16 only, and were below the SSBs (Table 5).
- Arsenic exceeded the SSB in all three samples from these two borings (Table 6), at concentrations ranging from 0.8 to 2.6 mg/kg, again below background levels (Appendix H).

4.2 Groundwater

This section summarizes groundwater analytical results through March 2011 and concentration trends. This section also discusses the sampling results from the storm sewers in and around the former MGP facility, and a related evaluation of the potential for these lines to act as preferential groundwater migration pathways.

Post-remediation monitoring has been performed to assess the extent of groundwater impacts as well as the efficacy of monitored natural attenuation. Samples have been collected in accordance USEPA and ASTM low-flow sampling methods since November 2003. Groundwater analytical results are compared to either the federal MCL or the State of Wisconsin enforcement standard (ES) for PAHs that do not have a federal MCL.

4.2.1 Groundwater Flow Direction and Gradients

4.2.1.1 Groundwater Flow Direction and Conceptual Model

Groundwater elevation is measured in all monitoring network wells during each sample event (Table 1). Groundwater flow between July 2007 and March 2011 was eastward, away from the Wisconsin River (Figures 12 through 25). This flow pattern has remained consistent with historic observations; therefore, not all sampling events were mapped.

The easterly flow direction is caused by the river water pooled behind the Main Street dam, 0.5 mile downstream of the site, which is recharging the aquifer. Groundwater elevations at OW-17, about 40 feet from the river, are lower than the average daily flowage elevation on the upstream side of dam, as listed below.

Date	OW-17 Groundwater Elevation (ft)	Flowage Elevation (ft)
July 24, 2007	1,086.37	1,087.01
Oct. 22, 2007	1,086.28	1,086.99
Jan. 14, 2008	1,086.14	1,086.99

As groundwater flows to the east, it eventually turns toward the south around the dam and then flows back to the river downstream of the dam.

The conceptual groundwater flow model (Figure 26) illustrates how local groundwater flow in the vicinity of the facility and regional flow from areas further to the east are diverted toward the south and discharge below the dam. The area where the two flow systems converge will move closer to or further from the river in response to changes in pool elevation or regional precipitation which is driving hydraulic heads/groundwater levels in the regional flow system.

Data were reviewed for four Stevens Point GIS Registry properties in the site vicinity for which WDNR had approved closure (Appendix L). The generalized direction of groundwater flow (Figure 27) at these sites is consistent with the conceptual model presented herein (Figure 26) as well as the groundwater flow maps shown on Figures 12 through 25. The Lullabye site reflects the regional groundwater flow system, while the WPSC, Schierl, Cooper Oil, and Belts sites are within the local flow system influenced by recharge from the dam.

Based on this conceptual flow model, interpretation of Site data should consider the following:

- The extent to which groundwater flows to the east will be limited by the regional flow system;

- Enhanced dilution and dispersion of dissolved constituents can be expected to occur where groundwater flow from beneath the site converges with the regional flow system; and,

- The existing monitoring well network is located appropriately to monitor the dynamics of these converging flow systems.

4.2.1.2 Hydraulic Gradients

Horizontal gradients measured from the water table contour lines on the shallow groundwater flow maps range from approximately 6×10^{-3} to 1×10^{-2}, and are similar to previous observations. Using historic hydraulic conductivity values, groundwater velocities at the site are high and range from about 40 to 140 ft/year.

Vertical hydraulic gradients are variable across the site (Table 7) and are summarized below.

Well Nest	Vertical Gradient (over time)
OW-3R/PZ-3B	Upward
OW-5R/P-5B	Generally Downward or Flat
OW-7A/PZ-7B	Downward
OW-9/PZ-9B	Generally Flat
OW-10/PZ-10B	Variable (Equally Down, Up & Flat)
OW-11R/PZ-11B	Upward
OW-12/PZ-12B	Variable (Predominantly Up or Flat)
OW-14/PZ-14B	Downward
OW-15/PZ-15B	Flat (Negligible)
OW-16/PZ-16B	Predominantly Upward

Vertical gradients vary in direction and magnitude as groundwater moves across the Site. More of the locations have an upward or flat gradient, which reflects the river as the regional discharge point for groundwater. It appears bedrock competency also strongly influences vertical gradients at the site. Piezometer PZ-14B is completed in extremely competent bedrock and has a consistently very steep downward gradients ranging from 0.1 to 1.0. It appears the bedrock may be comparatively more competent at piezometers P-5B and PZ-7B than at other piezometers (like PZ-9B and PZ-10B, which penetrate a weathered zone before being completed in more massive bedrock). Piezometer PZ-15B is completed in sand, which reflects that the well and piezometer are screened in the same aquifer.

4.2.2 Groundwater Quality and Trends

Groundwater samples were analyzed for PAHs, benzene, and several MNA indicators including dissolved iron, nitrate/nitrite, sulfate and DO. The analytical results are summarized on Tables 8, 9, and 10. Field parameters (water temperature, conductivity, pH, dissolved oxygen, and oxidation/reduction potential) are also listed on Table 10. The laboratory reports for April 2007 through March 2011 are included in Appendix M and concentration trend plots (regression analyses) are included in Appendix N.

Benzene and naphthalene concentrations in the wells and piezometers through March 2011 are summarized on Figures 28 and 29. Naphthalene is typically the PAH of concern in site groundwater, although B(a)P, benzo(b)fluoranthene, and chrysene are also present at low levels. Groundwater results indicate these PAHs continue to exceed the MCL and/or ES in select site wells (Table 8).

Monitoring wells that historically exceeded the benzene or naphthalene screening levels are highlighted on Figure 28 and the March 2011 groundwater plume in these wells are shown on Figures 30 and 31, respectively. Wells with lower concentrations delineate the groundwater plume to the north, south, east, and west. Downgradient to the east, benzene and naphthalene concentrations in well OW-9 have been generally stable since 2004. Further east in well OW-10, the concentrations have varied since 2004, though concentrations have been decreasing in the last four sampling events. At OW-14, benzene only slightly exceeds the MCL and the benzene and naphthalene trends have been decreasing since this well was installed. Wells OW-15, OW-19, OW-20, OW-21, and TW-2 define the plume to the south and east.

The plume is limited at depth in the aquifer. Piezometer PZ-12B was the only location where benzene exceeded the MCL in March 2011 (Figure 29). Previously, naphthalene exceeded the ES in P-5B and PZ-7B but concentrations were below the ES in March 2011. Low concentrations in the piezometers to the south and east indicate the plume extent is greater near the water table than at depth.

Regression plots were prepared to evaluate the relationship between groundwater concentrations, elevation, and time for monitoring wells and piezometers with either 1) elevated benzene or naphthalene concentrations or 2) which are located within or on the edge of the plume. The 95% confidence limit for the regression is also plotted to provide an additional indicator of correlation. Precipitation data are illustrated on additional plots for each well. Regression analysis statistics for each well/piezometer are listed on Table 11 and the plots are included in Appendix N.

Evaluating all groundwater data since 2000, monitoring wells OW-9 and OW-10 exhibit potential increasing concentration trends (however, the regression plots appear to have stabilized since 2004). Wells OW-3, OW-5, PZ-11B, PZ-12B, and OW-14 show decreasing trends for the same time period (Table 11). There is no correlation between groundwater concentrations, elevations, and time at wells OW-5, OW-6, and OW-7, which are central to the former MGP facility. Possible explanations for the observed concentration trends at OW-5, OW-9, and OW-10 may be related to deminimus MGP residuals detected along the base of the slough under the City parking lot, fluctuating groundwater levels, and/or convergence of regional and local flow systems on the eastern end of the Site.

Mann-Kendall statistical tests were completed using the January 2008 through March 2011 (the last 10 events) benzene and naphthalene results (Appendix N). Wells evaluated were within or on the leading edge of the plume and include OW-5R, OW-6, OW-7A, OW-9, OW-10, OW-14, P-5B, PZ-7B, and PZ-12B. Benzene concentrations were stable or declining in all nine of these locations. Naphthalene concentrations eat OW-10 and P-5B exhibited non-stable trend; however, wells located downgradient from these locations exhibited stable or declining trends, and along with the regression analyses the results indicate the plume is stable and not expanding.

Contaminant transport velocity was estimated for benzene and naphthalene based on the groundwater flow velocity values of 40 to 140 feet/year (Table N-1, Appendix N). Contaminant transport estimates for benzene and naphthalene range from 40 to 130 feet and 10 to 30 feet per year, respectively. These transport results have been used to estimate the distance the contaminants could be expected to travel over period of 60 years, which coincides with approximate closure of the MGP facility in the early 1950s. OW-9 was selected as the point of origin based on its historical impacts since this well was installed (Figure 28). Using a groundwater flow velocity of 40 feet per year and the associated contaminant flow velocities, benzene and naphthalene were estimated to travel 2,200 and 550 feet respectively. These calculated distances indicate benzene and naphthalene should have traveled well beyond wells OW-18 through OW-21, TW-2, and OW-15 during this time period. This evaluation of contaminant flow velocity suggests natural attenuation mechanisms (such as biodegradation, dispersion, and dilution) are present and have restricted plume expansion over time

Many of the MNA parameters yield confounding results for site wells, which likely reflects convergence of the two groundwater flow systems in the site vicinity. Iron, nitrate, sulfate, and DO results are plotted with benzene and naphthalene concentrations for wells near or within the plume, and the graphs indicate many of the MNA parameters fluctuate with the benzene and/or naphthalene concentrations (Appendix N). The MNA average results have been determined for benzene and naphthalene concentrations that are near the MDL, below the MCL/ES (5 µg/L and 100 µg/L), and above the MCL/ES (Table 12).

The MNA results for the shallow and deep groundwater from March 2011 are plotted on Figures 32 through 35, and they show the variability present at the site. The March 2011 benzene and naphthalene plumes are shown on Figures 32 and 34 for the water table monitoring wells, and there appears to be little correlation. Based on site characteristics, the MNA result variability could be related to water quality of the river flowing into the aquifer or degradation of organics in the subsurface. It is likely a combination of the two and the regional flow system that is responsible for overall plume stability.

A summary of groundwater quality and trends indicate the following:

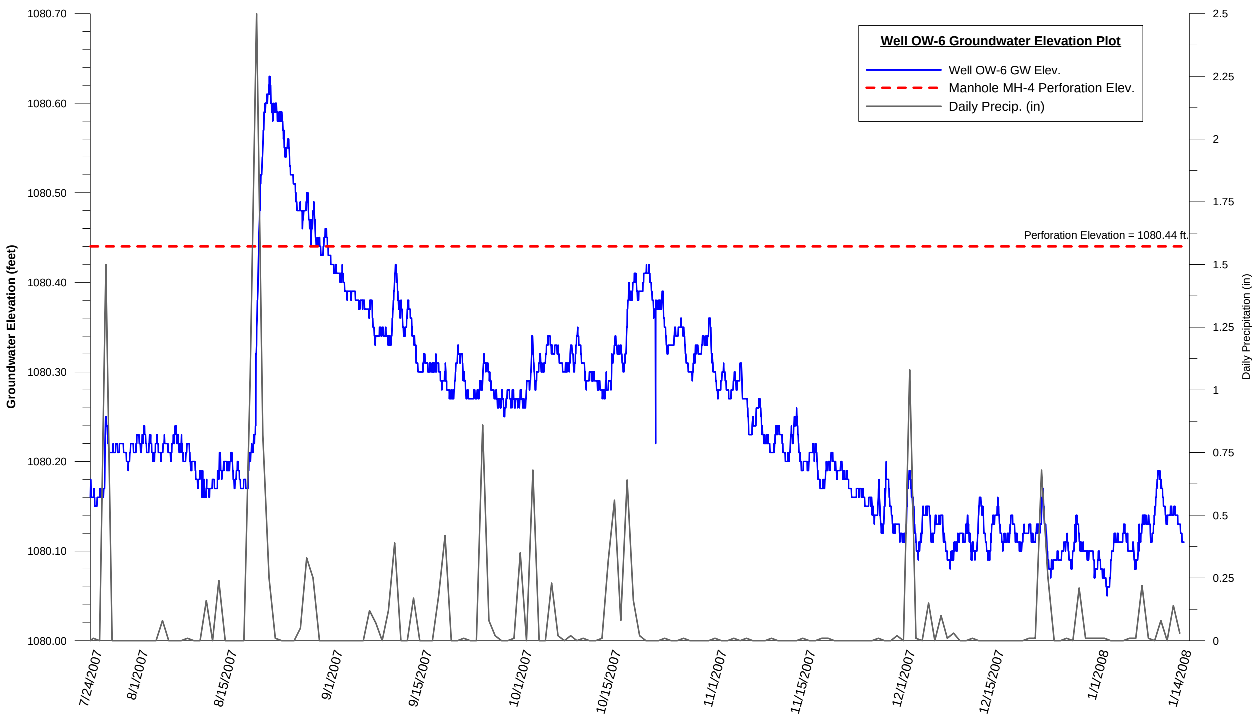
- The groundwater plume is well defined by the well network;
- The regression plots and Mann-Kendall tests indicate generally stable or decreasing trends, especially for wells outside of the plume in both the shallow and deep flow systems;
- The contaminant transport assessment indicates natural attenuation mechanisms (such as biodegradation, dispersion, and dilution) have restricted plume expansion over time; and,
- The MNA geochemical indicator parameters are confounding, likely due to the presence of two groundwater flow systems that converge in the vicinity of the site.

Thus, groundwater sampling results indicate natural attenuation mechanisms are present and the plume is stable rather than expanding at the site regardless of contaminant concentration variability at individual wells.

4.2.3 Storm Sewer Monitoring

Between July 2007 and January 2008, the water levels in monitoring well OW-06 (adjacent to manhole MH-4) were continuously recorded using a pressure transducer. Well OW-6 groundwater elevations, plotted below, exceeded the elevation of the storm sewer perforations near manhole MH-4 for a period of approximately 11 days (August 20 through August 31, 2007) confirming groundwater may enter the storm sewer. The groundwater elevation at OW-6 apparently increased in response to a storm event.

PAH and PVOC concentrations (Tables 13 and 14, respectively) in storm sewer water samples from July and October 2007 and January 2008 were relatively low, compared to concentrations within the plume. Concentrations were highest at manholes MH-3 and MH-4 (Figure 4). No PAH MCLs/ESs were exceeded and the benzene MCL/ES was only slightly exceeded. These storm sewer water samples were collected when the groundwater elevation was lower than the sewer perforations.



The OW-6 elevations since 2000 indicate groundwater exceeded the storm sewer perforations elevation on five of the 33 sampling occasions. Overall, these findings suggest groundwater may seep into the storm sewer sporadically for relatively brief periods. However, the sewer is not a preferential pathway based on the alluvial sands present at the site. Benzene and naphthalene concentrations in the storm sewer are low and do not account for the higher concentrations observed at wells OW-9 and OW-10.

Date	OW-6 Elevation (ft)	Preceding Precipitation (in)	Date	OW-6 Elevation (ft)	Preceding Precipitation (in)
10/28/02	1080.46	4.8 (Oct)	04/28/08	1080.49	5.8 (Apr)
06/16/03	1080.59	7.9 (May/Jun)	10/20/10	1080.54	10.2 (Sep/Oct)
07/20/04	1080.66	8.6 (Jun/Jul)			

Precipitation for the month or two prior to sampling appears to have influenced groundwater elevations at OW-6. In well OW-6, naphthalene exceeded the ES during four of the five sampling events (June 2003 was the exception); benzene exceeded the MCL only during the June 2003 event.

4.3 River Investigation Results

The nature and extent of MGP residuals in sediment and substrate materials in the Wisconsin River and park pond were previously identified. This effort focused on collecting samples to compare current site conditions with previous results. Little soft sediment occurs on the river bottom in the area of investigation. Where possible, substrate samples, including native soils were collected from as deep as 10 feet below the river bottom, and sampling extended to 2.5 feet below the base of the pond.

Analytical results are compared to sediment screening benchmarks (SSBs) for the purpose of identifying concentrations that may be of concern with respect to risks for specific receptors or pathways. The SSBs were derived from more than one authoritative study typically cited by federal and/or state regulators, and are listed on Table 15. Surface water analytical results for the river and pond are also discussed herein.

4.3.1 Wisconsin River Investigation

4.3.1.1 River Morphology and Flow

The multi-beam bathymetry and side scan sonar surveys, along with maps and aerial photos, facilitated evaluation of the river morphology and flow regime. The bathymetry survey results in the immediate vicinity of the site are shown on the map in Appendix K. Observations from bathymetric survey regarding the east bank of the river, using the pond as the reference point, indicate the following:

- The river is approximately 1,100 feet wide at the upstream end of the survey, and less than 600 feet wide downstream at the Hwy 10 bridge.

- Upstream of the pond, shallow water depths (less than 4 feet or elevation 1083) extend approximately 200 feet from shore (Appendix K). A point bar has developed near the island between the boat launch and pond due to the river geometry, which results in lower stream flow velocities, quiescent waters, and overall deposition along the upstream, east river bank.

- The former slough channel is evident in the bathymetry contours immediately west of the pond. The location of the former channel is identifiable through the “indented” contour lines where flow from the slough eroded bank material in this area.

- The river is at its narrowest point at the Hwy 10 Bridge and this geometry affects flow. Water depths exceed 4 feet (elevation 1083) approximately 20 feet from the shore in the vicinity of the pond and downstream to the bridge.

- Downstream of the pond, the east bank of the river is a cut bank, where river velocities are likely higher and deposition is minimal. This is evidenced by the step channel bank, compared with upstream areas or the west river bank, as well as the presence of the greatest water depths (elevation 1065 or less) near the east bank close to the bridge.

Results for the side scan sonar survey are shown on the map in Appendix K and indicate the following:

- The location of the fiber optics line that crosses the river just upstream of the Hwy 10 bridge is not identifiable. Additionally, the survey did not identify any underwater obstacles in the immediate vicinity of former slough outlet (Appendix K).

- Two areas of “clutter” were identified in the central part of the channel. The “clutter” piles are located at least 250 feet from the slough outlet in areas where the bottom elevation is less than 1070. No other debris was identified.

- Five “post like” structures are located downstream of the pond; four of these are grouped together while the other is closer to the Hwy 10 bridge. These are also located in the central portion of the channel where water depths are greatest (Appendix K).

- The overall resolution of the survey does not provide enough clarification for identifying large, contiguous areas where soft sediment is present on the river bottom.

The bathymetric survey data were used to determine the cross sectional area of the river, and estimating flow velocities in the area just off shore from the pond. The cross sectional area was determined for a point extending from the pond outlet to the far shore, a distance of about 800 feet. The river was divided into segments using the bathymetry contours and an assumed water elevation of 1,087 feet, and the cross-sectional area was calculated to be approximately 11,000 square feet for this segment.

The CWPC discharge data for the period of January 2006 through April 2008 was used to calculate the following stream flow velocities:

	Discharge Values	**Stream Flow Velocities**	
	(cfs)	**(feet/sec.)**	**(cm/sec)**
Daily Average	3,476	0.32	9.8
Monthly Average	3,220	0.29	8.9
Maximum, Apr. 20, 2008 (Apr. 2008 Average)	39,250 (17,235)	3.57 (1.57)	108.8 (47.9)
Minimum, Sept. 4, 2007 (Sept. 2007 Average)	897 (1,316)	0.08 (0.12)	2.4 (3.7)

The monthly averages for maximum and minimum discharge values indicate the variability in river discharge and stream velocities near at the site. The cross sectional area and flow calculations, along with the discharge data, are included in Appendix F.

4.3.1.2 Sediment Distribution

Little fine grained sediment was observed at the Site, with only thin layers of silt/clay material over the sand/gravel substrate identified in a few areas through poling and sampling efforts (Figure 8 and Table 2). This distribution is expected, based on the estimated flow velocities and river morphology.

The plot at right shows the erosion, transport, and deposition velocities for various sized particles in the stream environment[3]. The range of estimated velocities are approximated on the plot and indicate they are great enough to inhibit the deposition of silt, clay, and fine sand particles in the vicinity of the site, as well as downstream past the Hwy 10 bridge, based on the site geometry.

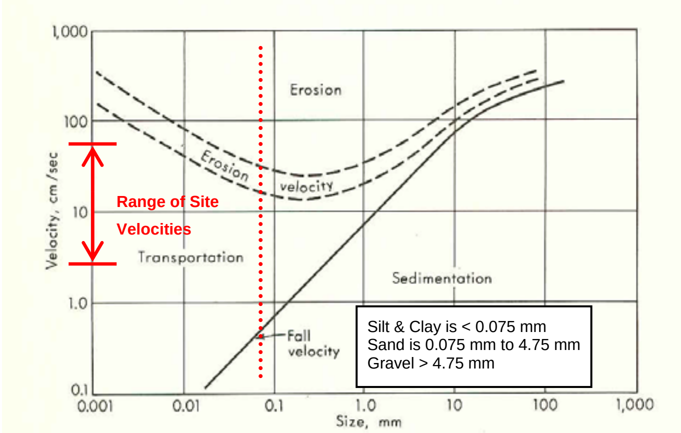


Fig. 4.4 Curves of erosion and deposition for uniform material. Erosion velocity shown as a band. [Redrawn from Hjulstrom (1935).]

When present, the soft sediment distribution was greatest in the area near and just downstream of the island, decreasing downstream (Figure 8). As the plot above indicates, flow velocities in the vicinity of the slough outlet (between 2.5 and 54 cm/sec) are generally high enough to inhibit deposition of silt/clay particles, limiting the overall presence and thickness of sediment on the substrate. Once silt/clay particles are deposited in an area, it takes much larger velocities to suspend these compared with fine sands. This is due to the fact that: 1) silt/clay particles adhere to each other more than sand, and 2) the overall particle shape and smoothness (compared with sand) does not provide a surface that allows them to be re-suspended as easily. Thus, the presence of some silt/clay in the vicinity of the outlet is expected. The accumulation of sediment in the area may also be facilitated by the former slough channel observed on the bathymetry map (Appendix K). This former channel appears to be slightly depressed, and may act as a sediment trap.

4.3.1.3 Substrate Observations and Sampling Results

MGP residuals were observed in the area immediately downstream of the former slough outlet. At sampling location T3-A1, viscous/sticky tar was observed intermixed with the sand and gravel at a depth of approximately 1.5 to 4.5 feet below the river bottom (not at the surface), and had a strong odor of MGP residuals (naphtha odor). This is the only location where tar was observed in any of the substrate sampling locations, and was confirmed by the analytical results discussed below.

MGP odors similar to those noted T3-A1 were noted in adjacent borings T7-A1 and T7-B1. These results, along with the analytical data, suggest MGP related impacts in the river are confined to the near shore areas immediately downstream of the former slough outlet. Wood chips were noted in borings

[3] Morisawa, M. 1968. Streams: Their Dynamics and Morphology. McGraw-Hill Book Company. 175 pp.

T3-A3, T4-A1, T5-A1, T6-A1, and T6-B1, but are not attributed to MGP residuals based on the corresponding observations and analytical data.

Bedrock was encountered in many of the borings completed in the river, especially those located furthest from shore. The only locations where bedrock was not encountered were in near shore borings that extended 10 feet or less into the river bottom. The predominantly sandy substrate encountered in these borings was similar to the native sands observed in the upland borings.

4.3.1.4 PAH Results

This discussion of PAHs focuses on total PAH results rather than on individual compounds due to the additive affects of PAH mixtures for the benthic community in sediments. Samples where total PAHs exceeded the SSB are summarized below and shown on Sheet 2. Refer to Table 16 for individual compounds by sample location and depth. These are listed from upstream to downstream locations.

Total PAHs (mg/kg)

Sample	Results	Sample	Results	Sample	Results
T6-A1 (0"-6")	11	T3-A3 (0"-6")	1,476	T7-B1 (0"-6")	666
T3-A1 (0"-6")	17,990	T3-A3 (6"-18")	7.0	T7-B1 (6"-18")	6.0
T3-A1 (6"-18")	19,623	T3-A3 (18"-30")	3.1	T4-A1 (18"-30")	26
T3-A1 (18"-30")	21,154	T3-A3 (30"-42")	2.9	T4-A1 (30"-42")	15
T3-A1 (30"-42")	466	T3-A3 (42"-54")	4.8	T4-A1 (42"-54")	2.1
T3-A1 (42"-54")	24	T7-A1 (0"-6")	162	T5-A1 (0"-6")	9.3
T3-A1 (54"-66")	6.8	T7-A1 (6"-18")	127		
T3-A2 (18"-30")	1.8	T7-A1 (18"-30")	20		
		T7-A1 (30"-42")	3.4		

Notes: 1) Only locations where PAHs were detected are included herein.
2) Results have been rounded

The total PAH SSBs used for general screening purposes are 1.61 mg/kg, which is the TEC; and 22.8 mg/kg, which is the Probable Effect Concentration (PEC) (MacDonald et. al., 2000). TEC and PEC values represent the concentrations at which toxicity to benthic dwelling organisms are predicted to be unlikely and probable, respectively. All sample locations listed above exceed the TEC, but are below the PEC except the near shore locations on transects T3, T7, and T4.

Over 20 Background samples were collected from various depths from the four sampling locations along background transect T1 (Sheet 2, Table 16) with the following results:

- PAHs were below the MDL in all but one of the background samples, and total PAHs in sample T1-A (30-42) were below the TEC.

- Background conditions in the river, along the point bank deposit located just upstream of the former slough outlet, are very low. PAHs were not detected in sample T2-A1, but low concentrations were present in the surface sample at T6-A1 (Table 16). The presence of the PAHs at this location, but not at T6T3-A1, suggests impacts in this area are isolated and not contiguous with the PAHs observed at T3-A1 and T3-A3.

Samples collected offshore of the former slough/pond outlet had the following results:

- Highest PAH concentrations are present at T3-A1, consistent with prior investigations, and occur where residual tar was observed at depth. Total PAH concentrations ranged between 18,000 and 21,000 mg/kg in the upper 30 inches (2.5 feet), and the highest concentrations are present between 18 and 30 inches (1.5 to 2.5 feet) below the river bottom (Table 16). Individual PAHs exceed the SSBs down to 66 inches (5.5 feet) below the river bottom at this location, and no PAHs were detected below this depth.

- PAHs were detected in samples from T3-A2 (18-30") and T3-A3 (0-6"), but were below SSBs in all other samples and borings along this transect located further from shore (Table 16).

Samples collected downstream of the pond outlet had the following results:

- Surface samples along transect T7 exhibited elevated PAH concentrations in the near shore area, where the water depth exceeded six feet. Individual PAHs exceeded the SSBs to a depth of 42 inches (3.5 feet) at T7-A1, but were limited to the upper 18 inches at location T7-B1 (Table 16). Concentrations at both locations decline with depth, suggesting impacts are related to surface deposition.

- PAHs along transects T4 and T5 are distributed in differing layers depending on the location. Total PAH results are below 26 mg/kg, which are low compared with samples collected on transects adjacent to the pond outlet. Near shore at T4-A1, the surface sample PAHs were below the MDL. Concentrations increased with depth and individual PAHs exceeded the SSBs between 30 and 42 inches (2.5 and 3.5 feet) below the river bottom (Table 16). At all other locations where PAHs were detected on these two transects, the PAHs were either limited to or highest in the surface samples. The results suggest concentrations at T4-A1 were naturally covered since there does not appear to be a separate source of material for these concentrations.

4.3.1.5 PVOC Results

The distribution of PVOCs is similar to PAHs. However, concentrations are below the applicable SSBs everywhere but at location T3-A1. The highest PVOC concentrations are present at a depth of 18 to 30 inches (1.5 to 2.5 feet) in boring T3-A1, and concentrations below this depth decrease significantly, similar to the PAHs (Table 17). This is the only location where benzene exceeded the MDL in river samples. Benzene concentrations ranged from 2,900 µg/kg to 21,000 µg/kg from 6 to 42 inches (0.5 to 3.5 feet) at T3-A1, but was below the MDL in the surface sample at this location (Table 17). Xylene is the most prevalent PVOC detected in river sediments. It is present in a number of samples along transects

T7, T4, and T5, and, again, the distribution is generally similar to the PAHs, although concentrations are generally below the PEC.

4.3.1.6 Metals Results

The range of metals concentrations detected in river substrate samples are summarized below and the results are listed on Figure 36 and Table 17.

Parameter	Concentration Values (mg/kg)			SSBs
	Maximum	Average	Minimum	
Aluminum	24,000	6,180	1,800	NS
Antimony	<MDL	<MDL	<MDL	2
Arsenic	7.3	1.3	<MDL	9.79
Barium	330	59	<MDL	NS
Cadmium	2.6	0.11	<MDL	0.99
Chromium	35	13	<MDL	43.4
Copper	400	28	<MDL	31.6
Iron	44,000	13,500	4,200	20,000
Lead	69	6.0	<MDL	35.8
Manganese	570	199	60	460
Mercury	1.6	0.06	<MDL	0.18
Nickel	29	11	2.4	22.7
Selenium	3.3	0.29	<MDL	NS
Silver	0.62	0.01	<MDL	1.6
Vanadium	110	31	5.7	NS
Zinc	83	25	5.5	121

Notes: "<MDL" indicates concentrations were below the method detection limit.
"ns" indicates there is no SSB for this parameter.

Average concentrations of most metals are below the SSBs and there does not appear to be a strong correlation between occurrence of these metals and the MGP residuals at T3-A1. Lead exceeded the SSB in the upper sediment samples at T3-A1 and T7-A1, and cadmium and mercury exceeded the SSBs only at T3-A1. However, sample T1-A also exhibited elevated mercury, suggesting there may also be upstream sources, in addition to cadmium and lead.

Copper, iron, manganese, and nickel exceeded the SSBs across the area, apparently unrelated to the MGP residuals found at T3-A1. The copper and a number of the iron samples could be related to the bedrock material encountered at T1-C1a.

4.3.1.7 Cyanide Results

Cyanide was not detected in any of the river samples submitted for analysis (Table 17).

4.3.1.8 TOC Results

The seven TOC samples collected along transects T1 and T3 indicated there is little organic carbon in the substrate materials. TOC ranged up to 1.1 percent in background location T1-A as indicated below.

Sample	TOC (mg/kg)	TOC (%)
T1-A (0-6")	11,000	1.1
T1-B1 (0-6")	430	0.043
T1-C1a (6-18")	4,700	0.47
T1-D1 (0-6")	3,300	0.33
T3-B1 (0-6")	1,600	0.16
T3-C1 (0-6")	490	0.049
T3-D1a (0-6")	520	0.052

TOC conversion is mg/kg / 10,000 = % TOC

The TOC results indicate the general lack of carbon, which can help bind organic compounds to reduce availability to benthic organisms and limit migration in the system. These results further attest to the lack of soft sediment in the system, since depositional river sediments usually contain a much higher percentage of TOC reflective of the organic matter that is typically present.

4.3.1.9 Geotechnical Results

The geotechnical testing results for the five composite river samples are summarized below.

Sample	Material	Organic Content	Moisture Content	Specific Gravity
T1-B1 (0-90")	F-C sand, some gravel, little silt/clay (SM)	0.9 %	12.2 %	2.72
T3-A1 (0-66")	Organic F-C sand, some gravel, trace silt/clay (SP)	7.7 %	32.7 %	2.52
T3-A3 (0-66")	F-C sand, some gravel, trace silt/clay (SP)	2.3 %	16.2 %	2.64
T3-B1 (0-102")	F-C sand, some gravel, little silt/clay (SM)	1.2 %	8.6 %	2.73
T4-A1 (0-72")	F-C sand, some gravel, little silt/clay, trace organic material (SM)	4.0 %	20.5 %	2.57

Notes: “F-C” indicates fine to coarse sand

The organic content is higher in these sample compared to the TOC results discussed above; however, these are composite samples, and samples T3-A1 (0-66") and T4-A1 (0-72") were collected from locations where elevated PAHs, as well as other MGP residuals, were observed. The moisture contents are typical for sands rather than fine grained sediments.

4.3.2 Pond Sampling Activities and Results

Sediment samples from pond locations Psed-201, Psed-202, and Psed-203 (Figure 8) are also summarized on Tables 16 and 17. Sediment in the pond consisted of organic silt and clay at Psed-202 and Psed-203 while sand was predominant at Psed-201. Cores Psed-202 and Psed-203 are located furthest from the outlet to the river, suggesting river flow and currents may influence the material that settles in various portions of the pond. The odor of decaying organic material was present in all three sediment cores, and a slight MGP odor was also noted in sediment from core Psed-203. This is similar to the historic results for location SD-201, collected in 2000.

Seven of the nine total PAH results exceed the PEC, as summarized below and shown on Sheet 2. It appears the highest concentrations are present in the layer from 0.5 to 1.5 feet below the pond base.

Total PAHs (mg/kg)

Sample	Results	Sample	Results	Sample	Results
Psed-201 (0"-6")	13	Psed-202 (0"-6")	45	Psed-203 (0"-6")	53
Psed-201 (6"-18")	43	Psed-202 (6"-18")	409	Psed-203 (6"-18")	815
Psed-201 (18"-30")	8.1	Psed-202 (18"-30")	386	Psed-203 (18"-25")	292

Notes: 1) Results have been rounded.

The PVOC MDLs were elevated in the pond samples but the reported MDLs were below the appropriate SSBs (Table 17). As discussed in Section 1.3.1, the pond was filled during its creation in the 1980s, and the pond sediments are not the source for the elevated PVOCs detected at 12 to 14 feet bgs in PZ-16, (Tables 5 and 17), which is located within 50 feet of sample Psed-202.

The range of metals concentrations detected in pond samples are summarized below and the results are listed on Table 17.

Parameter	Concentration Values (mg/kg)			SSBs
	Maximum	Average	Minimum	
Arsenic	11	6.5	3.7	9.79
Cadmium	4.0	0.88	<MDL	0.99
Chromium	57	23	<MDL	43.4
Copper	61	29	1.7	31.6
Iron	39,000	17,756	4,400	20,000
Lead	350	175	32	3.58
Mercury	1.1	0.43	0.04	0.18
Nickel	24	10	1.7	22.7
Zinc	430	208	34	121

Notes: "<MDL" indicates concentrations were below the method detection limit.

All the metals listed above exceeded the SSB in Psed-203 (18-25); in fact, this is the only location where arsenic, chromium, manganese, and nickel exceeded the SSBs (Table 17).

The highest arsenic and lead concentrations observed in any Site sediment samples were detected in the pond (Table 17). Arsenic was 11 mg/kg at Psed-203 (18-25). Lead was detected up to 350 mg/kg and exceeded the SSB in seven of the nine samples (Table 17). Mercury and zinc exceeded the SSB in all six samples from Psed-202 and Psed-203 (Table 17), and cadmium, copper, and iron exceeded the SSB in three to four of the samples from Psed-202 and/or Psed-203. The general distribution of PAHs and metals in pond sediments indicates concentrations are highest in the areas with finer grained silt and clay sediments, to which organic compounds and metals are more likely to sorb.

The geotechnical testing results for the pond composite sample is summarized below.

Pond Material Description	Organic Content	Moisture Content	Specific Gravity
Black sandy sedimentary peat, some silt, little clay, trace gravel (PT)	13.4 %	78.9 %	2.46

The higher organic content in the pond compared to the river is consistent with the higher moisture content, reflecting the presence of the fine-grained materials that retain moisture compared with sands and gravels.

4.3.3 Surface Water Results

Four surface water composite samples were collected from the Site; three from the river transects and one from three locations within the pond. Results are summarized in Tables 18 and 19 and the following results are noted:

- PAHs, PVOCs, and cyanide were below the MDLs in river water.
- Analytical results for metals were slightly higher for a few compounds in sample SWT-2 (located in the immediate vicinity of the pond outlet), compared to the background sample SWT-1.
- Metals concentrations for SWT-3, located downstream of the Hwy 10 bridge, were similar to SWT-1 (Table 19).
- PAHs were present at low concentrations in the pond surface water and PVOCs were below the MDL.

- Metals concentrations in the pond surface water sample are similar to the upstream SWT-1 results, with exception of lead.

Slightly higher concentrations in pond water would be expected due to a more stagnant condition.

4.4 Vapor Intrusion (VI) Sampling Results

The January and March 2011 soil vapor analytical results (Appendix M) were compared to residential and industrial soil gas screening levels for benzene and naphthalene to evaluate the potential VI exposure risk (Appendix O). Samples were collected at locations in the vicinity of nearby buildings and areas where the highest benzene and naphthalene groundwater concentrations are present. Soil gas results are listed on Table 20 and locations where benzene exceeded the screening levels are summarized below.

Point	Sample Date	Benzene (µg/m3)	Point	Sample Date	Benzene (µg/m3)
SV1S	01/25/11	3.2	SV9S	01/18/11	38
SV5S	01/19/11	33		03/16/11	13
SV6S	03/15/11	3.3	SV10S	01/18/11	9.0
SV7S	01/20/11	9.3		03/16/11	3.4
SV8S	01/17/11	4.7	SV12S	01/25/11	6.8
				03/16/11	9.3

Benzene exceeded the screening levels at a few locations while naphthalene was not detected. The highest benzene concentrations were detected in shallow probes SV5S and SV9S in January 2011. Probes SV9S and SV5S are located on the north and south sides of the mall building, respectively, and on the margins of the groundwater plume attributable to the former MGP site (Figures 37 and 38). All probes with benzene concentrations exceeding the residential screening criteria (3.1 $\mu g/m^3$) are located in the immediate vicinity of the former mall building, with the exception of SV-1, which is located in the asphalt along the edge of 1st Street in an area with fill near the surface. Thus, all the areas with elevated results compared to screening levels are parking areas or driveways used frequently for vehicular traffic.

For groundwater to be the source of benzene in the soil vapor, benzene levels should be higher at depth and attenuate with distance away from the water table. With the exception of SV-12 in January 2011, soil vapor results for all locations indicate concentrations are similar or higher near the surface compared to the deeper results just above the water table (Table 20). These differences between the shallow and deep benzene concentrations were greatest in the immediate vicinity of the former mall building during January 2011.

In addition, at soil gas sample location SV-13, near the highest concentrations of benzene and naphthalene detected in groundwater monitoring well OW-9, on-site near the former MGP operations, there was no detection of naphthalene in soil gas, and only a trace of benzene in the soil gas which was below the most conservative residential screening level.

Based on this spatial analysis, the elevated benzene concentrations detected ins surface soil gas above vapor intrusion soil gas screening levels east of Water Street appear to be associated with a surficial source of benzene unrelated to the MGP site. Overall, the MGP residuals are not the source of benzene observed in the soil gas.

The grain size analysis, bulk density, specific gravity, and moisture content for samples collected from the soil vapor probes are summarized below. They indicate subsurface soils in the areas evaluated were dominated by sand.

Location (Depth - ft.)	Sample Description	Bulk Density (wet – pounds per cubic foot)	Moisture Content (%)	Specific Gravity
SV4 (3-3.5)	Fine to Coarse Sand	116.1	6.5	2.49
SV4 (6.5-8)	Fine to Coarse Sand FILL with peat	94.4	29.9	2.29
SV7 (11-12)	Fine to Coarse Sand	111.2	2.6	2.64
SV13 (10-12)	Fine to Coarse Sand with Gravel and organic Silt	Bag Sample	41.4	2.39

4.5 Sample Validation and QA/QC

Trip blanks, duplicate samples and MS/MSD samples were collected and analyzed to satisfy Quality Assurance/Quality Control (QA/QC) requirements in accordance with Section 2 of the Multi Site QAPP.

Shepherd Technical Services, in Austin, Texas validated laboratory procedures and sample results for New Age Landmark, Pace Analytical Services, and STAT as discussed in Section 4 of the Multi Site QAPP.

The validation summaries are included in Appendix P. The data was generally acceptable for use with the exception of select metals and PAH analysis in the sediment samples analyzed in the New Age Landmark, on-site mobile laboratory.

The data validation reports calculated the relative percent differences and percent recoveries to assess precision and accuracy of the data sets. RI activities were performed in accordance with the standard operating procedures included in the Multi-Site FSP and QAPP to minimize errors and ensure representativeness. Data for soil, groundwater, surface water and storm water were 100% complete. Data for sediment were 95% complete. Data comparability is not required because each media and sample were analyzed by the same methods.

Previously collected soil data (collected since 1985) was assessed for use in the BLRA. Data used for the BLRA is presented as sample-by-sample locations in Appendix G Tables A-1 through A-8. In general, samples used in the BLRA are from the 1998 remedial action documentation samples. Samples were collected within the source area excavations and document remaining soil quality in areas which previous sampling indicated were well above standards or had visual evidence of MGP-contamination.

EnChem, Inc. (now known as Pace), a Wisconsin-certified laboratory in Green Bay, Wisconsin, analyzed the 1998 soil samples. USEPA SW-846 Methods were used that were consistent with the methods used in 2007 hence, the methods yield measurement errors and detection limits similar to data collected in 2007. All of the data previously collected has been submitted to WDNR for review. Review of the detection limits versus the corresponding risk-based concentration (RBC) used for screening the soil samples indicates reporting limits are well below the RBC.

The BLRA identified benzene, benzo(a)pyrene, arsenic, and lead as the primary constituents detected in soil at frequencies and/or concentrations which prompted assessment of potential risk. Benzene was primarily detected above the RBC in sub-surface soil (greater than 2 feet bgs) samples collected in 2007. It is likely that benzo(a)pyrene, arsenic, and lead detected in the pre-2007 soil sampling events remain in undisturbed soil at concentrations equal to or less than that previously reported because these constituents tend to sorb to soil particles and are relatively immobile in the natural environment.

Based on the methods, detection limits, and similar parameters detected, the previously collected data is representative and has been included in the database for assessing potential risk to human health and the environment.