

Table 1 - RI/FS Components and Schedule

TASK	SCOPE	SCHEDULE
NA	AOC II	Signed April 5, 2004
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TASK 1	Draft and Final Site Management Strategy (SMS) Document	Draft: 60 days after effective date of order, June 4, 2004. Final: 60 days after receipt of USEPA comments, September 13, 2004.
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TASK 2	Draft and Final RI/FS Work Plan and Field Sampling Plan	Draft: 60 days after USEPA approval of SMS. Final: 60 days after receipt of USEPA comments.
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TASK 3	Conduct Remedial Investigation	Schedule as determined in USEPA-approved RI/FS Work Plan and Field Sampling Plan.
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TASK 4	Draft and Final RI Report	Draft: 90 days after collection of final field sample. Final: 60 days after receipt of USEPA comments.
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TASK 5	Draft and Final Human Health and Ecological Risk Assessment Reports	Draft: 60 days after USEPA approval of RI Report. Final: 60 days after receipt of USEPA comments.
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TASK 6	Remedial Action Objectives (RAO) Technical Memorandum	30 days after USEPA approval of Risk Assessment Reports.
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TASK 7	Alternatives Screening Technical Memorandum	60 days after receipt of USEPA comments on the RAO memorandum.
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TASK 8	Draft and Final FS Report	Draft: 90 days after USEPA approval of Alternatives Screening Technical memorandum. Final: 60 days after receipt of USEPA comments.

Table 2 - RI/FS Process and Role of Site Management Strategy (SMS)

Aspects of the RI/FS, with Objectives	Examples of Work that may be Performed	Strategy Components presented in SMS
<p><u>Preliminary conceptual model</u> (Part of SMS) (AOC II SOW Task 1)</p> <p>Purpose: To establish baseline of what information is known about the area to be studied</p>	<ul style="list-style-type: none"> • Includes geology, hydrogeology, surface water hydrology, ecological habitats, groundwater-surface water interactions, nature and extent of constituents, fate and transport of constituents, potential sources, pathways to potential receptors, and potential human health and ecological receptors 	<p>Known information summarized in SMS</p>
<p><u>Geologic/hydrogeologic characterization</u> (Part of RI) (AOC II SOW Tasks 2, 3, 4)</p> <p>Purpose: To understand groundwater flow in the subsurface, a primary mechanism of constituent migration</p>	<ul style="list-style-type: none"> • Use available information (e.g., USGS) • Test pits, borings, wells to examine geology • Measure groundwater and surface water levels to determine horizontal and vertical directions of groundwater flow • Conduct hydrogeologic tests to quantify aquifer properties (e.g., hydraulic conductivity) • Evaluate changes seasonally/temporally • Evaluate groundwater use • Update conceptual model 	<p>Groundwater characterization</p>
<p><u>Characterization of surface water hydrology</u> (Part of RI) (AOC II SOW Tasks 2, 3, 4)</p> <p>Purpose: To identify the physical nature of the surface water system, which represents a potential receptor for groundwater and habitat for ecological receptors</p>	<ul style="list-style-type: none"> • Use available information (e.g., USGS) • Area reconnaissance • Characterize surface water flow directions, rates, seasonality • Identify wetlands • Update conceptual model 	
<p><u>Characterization of ecosystems/habitats</u> (Part of RI) (AOC II SOW Tasks 2, 3, 4)</p> <p>Purpose: To identify the ecological setting upon which to base evaluation of ecological risk</p>	<ul style="list-style-type: none"> • Area reconnaissance • Identification of ecological habitats of interest • Identification of reference areas for comparison • Identification of potential receptors of interest • Update conceptual model 	<p>Ecological Risk Assessment</p>

Table 2 (continued) - RI/FS Process and Role of Site Management Strategy (SMS)

Aspects of the RI/FS, with Objectives	Examples of Work that may be Performed	Strategy Components presented in SMS
<p><u>Groundwater-surface water relationship</u> (Part of RI) (AOC II SOW Tasks 2, 3, 4)</p> <p>Purpose: To understand potential pathway for constituents to migrate from groundwater to potential receptors in surface water</p>	<ul style="list-style-type: none"> • Measure groundwater and surface water levels to understand recharge/discharge relationships • Measure surface water flow rates • Collect samples of groundwater and surface water to understand connections • Update conceptual model 	<p>Groundwater characterization</p>
<p><u>Distribution of CCBs</u> (Part of RI) (AOC II SOW Tasks 2, 3, 4)</p> <p>Purpose: To evaluate potential exposure of receptors to CCBs and potential source of CCB-derived constituents to groundwater</p>	<ul style="list-style-type: none"> • Compile available information on presence of CCBs • Field verify information and identify additional areas • Evaluate factors that may contribute to leaching of constituents from CCBs to groundwater • Evaluate potential for human health risks • Update conceptual model 	<p>Evaluate CCB leaching factors</p> <p>Collect CCB samples during water line installation</p>
<p><u>Evaluation of potential sources</u> (Part of RI) (AOC II SOW Tasks 2, 3, 4)</p> <p>Purpose: To understand behavior of CCBs in site-specific environment</p>	<ul style="list-style-type: none"> • Use available information (e.g., USGS) • Collect samples of soil and water to characterize natural background concentrations • Analyze samples for constituents to evaluate potential sources • Understand flow and transport to evaluate potential contributions • Update conceptual model 	<p>Accelerated investigation of selected areas</p> <p>Evaluate CCB leaching factors</p> <p>Sampling of CCBs from Yard 520</p>
<p><u>Nature and extent of CCB-derived constituents in groundwater and ecosystems</u> (Part of RI) (AOC II SOW Tasks 2, 3, 4)</p> <p>Purpose: To understand location of CCB-derived constituents in the environment</p>	<ul style="list-style-type: none"> • Collect environmental samples • Characterize background concentrations • Update conceptual model 	<p>Groundwater characterization</p>

Table 2 (continued) - RI/FS Process and Role of Site Management Strategy (SMS)

Aspects of the RI/FS, with Objectives	Examples of Work that may be Performed	Strategy Components presented in SMS
<p><u>Fate and transport</u> (Part of RI) (AOC II SOW Tasks 2, 3, 4)</p> <p>Purpose: To understand environmental fate and transport of CCB-derived constituents to identify current and future behavior of the system</p>	<ul style="list-style-type: none"> • Collect samples to characterize geochemical conditions • Evaluate seasonal/temporal variability • Evaluate potential future migration of CCB-derived constituents • Update conceptual model • Calculate exposure point concentrations, if needed, for risk assessments 	<p>Groundwater characterization</p>
<p><u>Human health risk assessment</u> (AOC II SOW Task 5)</p> <p>Purpose: To identify potential risks to human health associated with potential exposure to CCB-derived constituents in the environment</p>	<ul style="list-style-type: none"> • Summarize and evaluate RI data • Update conceptual model 	<p>Screening evaluation of CCB data collected during water line installation; bioavailability studies</p>
<p><u>Ecological risk assessment</u> (AOC II SOW Task 5)</p> <p>Purpose: To identify potential risks to the environment associated with potential exposure to CCB-derived constituents in the environment</p>	<ul style="list-style-type: none"> • Summarize and evaluate RI data • Conduct screening-level ecological risk assessment in accordance with USEPA guidance • Update conceptual model • If appropriate, conduct baseline ecological risk assessment 	<p>Tiered ecological risk assessment</p>
<p><u>Establish Remedial Action Objectives</u> (AOC II SOW Task 6)</p> <p>Purpose: To identify remedial action objectives for CCB-derived constituents identified in the risk assessments to pose an unacceptable risk to human health or the environment</p>	<ul style="list-style-type: none"> • Develop site-specific, risk-based remedial action objectives • Evaluate applicable or relevant and appropriate requirements (ARARs) 	

Table 2 (continued) - RI/FS Process and Role of Site Management Strategy (SMS)

Aspects of the RI/FS, with Objectives	Examples of Work that may be Performed	Strategy Components presented in SMS
<p><u>Treatability Studies</u> (Part of RI and FS) (AOC II SOW Tasks 2, 3, 4)</p> <p>Purpose: To evaluate effectiveness of alternatives for treatment</p>		
<p><u>Feasibility Study</u> (Part of FS) (AOC II SOW Tasks 7, 8)</p> <p>Purpose: To evaluate and select potential remedies, includes development and screening of remedial alternatives</p>	<ul style="list-style-type: none"> • Develop list of response actions and remedial alternatives • Initial screening of alternatives • Detailed analysis of alternatives • Apply nine evaluation criteria in accordance with USEPA guidance 	

2.0 BACKGROUND INFORMATION REVIEWED

In accordance with the AOC II SOW, available information and data for the Area of Investigation and surrounding area were reviewed. File reviews were conducted at USEPA Region 5 and IDEM offices. Information was compiled from Weaver Boos Consultants, who have provided environmental and engineering services to the Yard 520 Restricted Waste Facility. General information was obtained from the United States Geological Survey (USGS), United States Fish and Wildlife Service (USFWS), historical aerial photographs, research on the chemistry of CCBs, and research on the toxicology and potential health risks of CCB-derived constituents, including boron and molybdenum.

A list of specific documents reviewed as part of this background review is provided in Appendix A. Electronic copies of any documents can be provided to USEPA on request, subject to copyright laws.

In addition, the Respondents contracted to have the area flown to generate a current base map with topography. This base map is in the process of being finalized, and will be forwarded to the USEPA upon completion.

3.0 PRELIMINARY CONCEPTUAL MODEL

Based on the available information reviewed, a preliminary conceptual model has been developed. A conceptual model describes the system in which a site is located, and typically includes information about the geology and hydrogeology, land use and topography, surface water hydrology and ecological habitats, potential sources of constituents, constituents of potential concern, the nature and extent of constituents in various media, fate and transport of constituents in various media, pathways to receptors, and potential receptors. The conceptual model is the foundation for the RI and FS and provides structure for the information and data gathered, aids in identifying data gaps, and helps to identify what evaluations may need to be performed.

The conceptual model presented in this section is preliminary in that it is based on review of the available information obtained to date. The conceptual model will continue to be refined and updated throughout the RI as additional, site-specific data are generated.

3.1 Regional Setting

The limits of the Pines Area of Investigation as defined by AOC II are shown in Figure 1. The area is located primarily in the Town of Pines, in Porter County, Indiana. It is located immediately west of the city limits of Michigan City, Indiana, and about 1500 feet south of the southern shore of Lake Michigan. The Indiana Dunes National Lakeshore (IDNL), managed by the National Park Service, is located between Lake Michigan and the Town of Pines. A small portion of the IDNL is included within the Area of Investigation for the RI/FS. Figure 2 is a USGS topographic map showing specific features in the vicinity of the Area of Investigation.

The land use in the region varies from the relatively undeveloped areas of the IDNL, where the land has been preserved for recreational uses, to the highly developed industrial zones such as Burns Harbor and Michigan City. Industrial land use includes coal-fired power generating stations and fully-integrated steel mills. Selected areas have also been developed for residential housing, including the Town of Pines and Beverly Shores, which is located north of the Town of Pines along the shore of Lake Michigan. Within some of these residential areas, each house may have its own drinking water well or septic system or both. In other areas, such as Michigan City, a municipal water distribution service and/or sewage collection system supplies drinking water and treats sewage.

3.2 Geology and Hydrogeology

The Pines Area of Investigation is located within the physiographic province called the "Calumet Lacustrine Plain" located between Lake Michigan and the Valparaiso Morainal Area. This area occupies the lake bottom of former Glacial Lake Chicago (Fenelon, et al., 1994). This area is bounded on the south by the Valparaiso Morainal Area, which consists of the Valparaiso, the Tinley, and the

Lake Border moraines. Appendix B includes several figures from various regional studies concerning geology and hydrogeology, including the referenced physiographic provinces.

The surface elevation of the region ranges from approximately 700 feet above mean seal level at the northern edge of the Valparaiso Moraine south of the Area of Investigation to approximately 580 feet at Lake Michigan. The topography is characterized by local uplands (dunes or moraines) and local lowlands (wetlands and marshes between the uplands) drained by man-made ditches.

3.2.1 Regional Geology

The depth to bedrock is in excess of 120 feet below land surface in this area (Shedlock, et al., 1994) and can be up to 250 feet below land surface. The bedrock consists of shale and carbonate rocks of Mississippian, Devonian, and Silurian age. Based on cross-sectional diagrams prepared by Shedlock, et al. (1994), parallel to the shoreline, the depth to bedrock is fairly consistent. Note that in a figure showing the regional bedrock elevation contours (Appendix B), the Pines Area of Investigation lies above a regional bedrock high with the elevation dropping to the north, east, and west. Perpendicular to the shoreline, the bedrock has a slight northward pitch; that is, the elevation of the bedrock is greater beneath the Valparaiso Moraine and less at the lake shore. Beneath the Area of Investigation, the bedrock (Appendix B) consists of the Antrim Shale, a black shale of Devonian age (Fenelon, et al., 1994).

The unconsolidated materials above the bedrock consist of 100 feet or more of glacially-derived materials such as tills, glacio-fluvial deposits, and lacustrine deposits associated with Glacial Lake Chicago (Fenelon, et al., 1994). These Pleistocene deposits are overlain by recent deposits associated with Lake Michigan. These include dune-beach complexes alternating with low-lying marsh and wetland areas (Fenelon, et al., 1994; Shedlock, et al., 1994). In the vicinity of the Area of Investigation, there are three dune-beach complexes: the Lakeshore/Tolleston Dune-Beach Complex forming the current shore of Lake Michigan, the Calumet Dune-Beach Complex on which the Town of Pines was developed, and the Glenwood Dune-Beach Complex, which is located to the south (Appendix B). The three dune-beach complexes represent previous locations of the Lake Michigan shoreline. The geology of the dune-beach complexes consists of windblown sands and beach sands with small lenses of silts and clays or peat representing small, intradunal wetlands (Shedlock, et al., 1994).

Between the higher elevation dune-beach complexes are low-lying swamps or marshes. To the north of the Town of Pines, the Great Marsh located within the IDNL is one of these lowlands. South of the Town of Pines and within the Area of Investigation, another low-lying marsh area is drained by Brown Ditch (see Figure 2). The geology of these low-lying areas consists of peat and muck at the surface overlying sands of the dune-beach complexes (Shedlock, et al., 1994).

Beneath these recent deposits are lacustrine silts and clays deposited by Glacial Lake Chicago and glacial tills at depths ranging from approximately 2 to 25 feet (Shedlock and Harkness, 1984).

3.2.2 Regional Hydrogeology

Regional USGS studies document three to four aquifers separated by confining units in this area of Indiana (Shedlock, et al., 1994; Fenelon, et al., 1994). One of these aquifers, the Valparaiso Aquifer, exists only south of the Little Calumet River; therefore it is not present in or near the Pines Area of Investigation (see figures in Appendix B). The remaining aquifers have been termed the surficial aquifer, the sub-till aquifer, and the basal sand aquifer from the ground surface down (Shedlock, et al., 1994).

At the ground surface is the surficial aquifer, which includes the dune-beach complexes described above. The surficial aquifer consists of lacustrine and eolian sands, with an average hydraulic conductivity of 50 ft/day (Shedlock and Harkness, 1984). It is generally the most laterally extensive of the three aquifers in northwest Indiana, and is termed the Calumet Aquifer to the west. The saturated thickness in the surficial aquifer ranges from 0 to 80 feet increasing from the east (Michigan City) to the west (Gary) (Shedlock, et al., 1994). In the vicinity of the Area of Investigation, the thickness appears to be about 2 to 30 feet (Fenelon, et al., 1994; Shedlock, et al., 1994). Calcareous clay lenses or organic silt/clay/peat may function locally as confining layers (Shedlock, et al., 1994). The surficial aquifer extends an unknown distance northward beneath Lake Michigan (Fenelon, et al., 1994).

The surficial aquifer rests on and pinches out to the south against lacustrine silts and clays and/or glacial tills. This material is laterally continuous in northwestern Indiana and forms the base of the surficial aquifer (Fenelon, et al., 1994). This confining unit is described by Shedlock et al. (1994) as a clay layer separating the surficial aquifer from the underlying aquifers. The clay unit has been observed and is considered a confining unit in the vicinity of the Pines Area of Investigation (Fenelon et al., 1994).

Within the glacial deposits underlying the lacustrine deposits of Glacial Lake Chicago are one to two confined aquifers (Fenelon, et al., 1994). The sub-till aquifer is characterized by several relatively small and discrete sandy, permeable layers. These layers are surrounded by a till that is typically clay, but can also include silt. The sub-till aquifer may be locally present beneath the Pines Area of Investigation, but it may not be continuous regionally (Appendix B).

Overlying the bedrock is a unit called the basal sand aquifer. It is characterized by discontinuous sandy zones. It is thickest and most extensive in the area of Porter County. Because of its depth, its extent is less well-known compared to the aquifers above it. However, it is expected to be present in the Area of Investigation (Shedlock, et al., 1994).

The bedrock is characterized by very low yield (less than 10 gallons per minute (gpm)) (Arihood, 1975) and forms a confining unit.

The surficial aquifer forms a water table aquifer except where it may locally be confined by lenses of lower permeability material. The depth to groundwater ranges from 0 where groundwater is at the ground surface, up to 60 feet below the ground surface (Shedlock, et al., 1994). Depth to groundwater tends to be deeper at greater distances from Lake Michigan and beneath the dune-beach complexes. Groundwater is at or near the ground surface in the low-lying wetlands.

Regional groundwater studies (Fenelon, et al., 1994; Shedlock, et al., 1994) indicate groundwater in the surficial aquifer flows from the dune-beach uplands to the low-lying areas, with discharge into man-made ditches. A copy of a groundwater contour map is included in Appendix B. These local-scale flow systems divert groundwater into these ditches, and there does not appear to be any direct connection between the surficial aquifer and Lake Michigan except at the immediate edge of the lake. In deeper confined aquifers, the regional flow is northward to the lake, so vertical gradients are generally upward from lower units including bedrock into the surficial aquifer (Shedlock, et al., 1994; Shedlock and Harkness, 1984) (Appendix B).

3.2.3 Local Geology

The primary information available on local geology in the Pines Area of Investigation relates to the Yard 520 Restricted Waste Facility, including construction and closure documents as well as groundwater studies. The location of Yard 520 is shown on Figure 1. A hydrogeologic assessment was performed in 1989 (ATEC, 1989), which included evaluation of the subsurface geology at Yard 520. Appendix C includes copies of maps from various studies at Yard 520. Cross-section A-A', shown in Appendix C, transects Yard 520 from roughly the southwest to the northeast. The cross-sections suggest that the original land surface was at an elevation of approximately 600 feet and that the surficial geology consisted of predominately a gray and brown sand, equivalent to the surficial aquifer. Beneath this, the formation becomes more dense and fine grained; the cross-sections describe the soils as "stiff to hard gray silty clay to silty clay loam with trace gravel." This unit is consistent with the confining clay layer (Shedlock, et al., 1994). Unlike the overlying formation which is relatively uniform in thickness (8 to 19 feet), the denser silts and clays varied in thickness from approximately 11.5 feet to in excess of 61 feet in the area of Yard 520. Lenses of differing soil type were observed in several locations within this silty clay; these lenses tended to contain more sand and loam, but were still described as dense. Without knowing the extent and degree of connectedness of these discrete layers, it is difficult to say if they can correctly be characterized as an element of the subsoil aquifer.

Underlying the silty clay is a formation described as "soft to stiff silt loam with very fine sand." This too is characterized as a confining unit similar to that above, but with slightly different composition. These soils were mainly observed in the southern portion of Yard 520 and transitioned to the silty clays in the

northern section. Like the silty sand, the silty loam contains a number of smaller lenses of different soils. These are characterized as slightly more dense than the surrounding soils (silty loams) and also coarser in grain-size (larger percentage of sands).

Cross-section B-B', shown in Appendix C, transects Yard 520 from the northwest corner to the southeast portion. The geologic strata depicted here is similar to that described based on cross-section A-A'. The upper strata is generally described as a gray and brown fine sand with thickness ranging from approximately 5 to 20 feet thick (surficial aquifer); this is underlain by a silty clay ranging from approximately 15 to 25 feet (confining unit), which is then underlain by a dense gray silt of uncertain thickness (confining unit). Lenses of differing soil types were not as common as seen in cross-section A-A', but a pocket of peat was observed in the northwest corner of Yard 520.

It appears that the borings installed during this investigation may not have extended to depths to encounter either the basal sand aquifer or underlying bedrock.

In addition to the natural geologic materials, CCBs have been disposed at Yard 520, and CCBs appear to have been used as road base and/or fill in other areas within the Area of Investigation. The nature and extent of these deposits are not described quantitatively in the available literature. The northern area of Yard 520 is closed and has been capped with a vegetated clayey soil cover (Weaver Boos, 1996a). The southern area was excavated to the clay confining unit, with sidewalls constructed of clay. The southern area is currently undergoing closure (Weaver Boos, 2003c). A 10-ft clay barrier separates the northern and southern area of Yard 520. The presence and nature of CCBs are described in detail in Section 3.6.

3.2.4 Local Hydrogeology

A description of the local hydrogeology is presented in ATEC's Hydrogeologic Assessment (1989). The upper gray and brown sand unit, which corresponds to the surficial aquifer, is 19 feet at its thickest and is underlain by a silty clay and silt confining unit that thickens from south to north. In one location on the south side of Yard 520, a water-bearing unit was encountered within the confining unit at approximately 50 feet below grade, or elevation of approximately 570 feet. Shedlock and Harkness (1984) report that the saturated thickness local to the Brown Ditch Basin ranges from 2 feet in and near Brown Ditch itself to 25 feet in the dune ridges, and that the total thickness of the unconsolidated sediments ranges from 100 feet to 300 feet in the shoreline dune-beach complex.

Falling head permeability testing was completed and presented in ATEC's (1989) report. The summary of calculated hydraulic conductivity is presented here:

Table 3 - Hydraulic Conductivity Data - Yard 520

Boring Location	Depth	Material	Hydraulic Conductivity	
			cm/s	ft/day
PL-1	42.0-44.0	Silty Clay	1.80E-08	5.10E-05
PL-1	54.0-56.0	Silty Clay	2.60E-08	7.37E-05
PL-2	7.5-9.0	Sand	3.10E-04	8.79E-01
PL-2	20.0-22.0	Silty Clay Loam	2.10E-08	5.95E-05
PL-3	24.0-26.0	Silty Clay	2.10E-08	5.95E-05
PL-4	30.0-32.0	Silty Clay Loam	2.00E-08	5.67E-05
PL-4	57.5-59.0	Silt	3.40E-06	9.64E-03
PL-5	28.0-30.0	Silty Clay	2.50E-08	7.09E-05
PL-2	13.0-15.0	Silty Clay	3.11E-08	8.82E-05
PL-3	23.5-25.0	Silty Clay	2.58E-08	7.31E-05
PL-5	23.5-25.0	Silty Clay	1.38E-08	3.91E-05
B-2	13.0-15.0	Silty Clay	3.11E-08	8.82E-05
B-3	15.0-16.5	Silty Clay	2.58E-08	7.31E-05
B-5	23.5-25.0	Silty Clay	1.38E-08	3.91E-05

The method of conductivity testing is unclear from the report (i.e., lab tests, slug tests, etc.). Note that all but one of the permeability tests was performed on the confining unit; data indicate that the formations tested have very low permeability. Even the test in sand (apparently the surficial aquifer) yielded a hydraulic conductivity value of less than 1 foot per day. Hydraulic conductivity data collected as a part of the Brown Ditch study (Shedlock and Harkness, 1984) indicated an average of 50 feet per day for the surficial aquifer. These data were obtained by analyzing specific-capacity tests in 18 USGS observation wells. This value (50 feet per day) represents a regional average developed by the USGS, so it is different than the site-specific data presented on Table 3. Site-specific hydraulic conductivity will be evaluated in the Area of Investigation during the RI.

Prior to the Hydrogeologic Assessment (ATEC, 1989), there was no significant evaluation of hydrogeologic conditions at Yard 520. Although groundwater monitoring was performed from the early 1980s, its primary purpose was to monitor groundwater quality, not water levels. The monitoring program consisted of three wells installed in line with one another on the north side of Brown Ditch, just south of the landfill. These three wells provide insufficient data to evaluate historical groundwater flow directions. Available data from the project file are included in Appendix L.

The ATEC (1989) report more comprehensively discusses groundwater conditions after the construction of the new, southern portion of Yard 520. The groundwater contour map from that study is included in Appendix C and is based on groundwater elevation data collected on February 9, 1989. This contour map represents the conditions prior to the clay barrier wall construction (discussed in Section 3.5) and prior to the re-location of Brown Ditch to its new location south of the southern portion of Yard 520, but after the initial development of the southern portion of Yard 520. The southern portion

was excavated to the clay confining unit and the clay walls were constructed in 1986 to 1988 (ATEC, 1989). A more current depiction of groundwater flow patterns and gradients is presented in the Source Investigation and Groundwater Flow Evaluation (Weaver Boos, 2003a) (see Appendix C).

Groundwater studies at Yard 520 generally indicate groundwater flow consistent with regional interpretations. That is, groundwater generally flows towards Brown Ditch. This overall flow direction may be affected by local conditions. In particular, a 10-ft clay barrier was installed between the northern and southern areas of Yard 520. The southern area is lined on the four sides and the base, which separates this area from the groundwater. As a result, groundwater flow is deflected around the area. In addition, both historical studies and more recent studies have indicated at least a component of flow in this area to the north (Weaver Boos, 2003b; groundwater contour maps prepared by Weaver Boos for monitoring in January 1994, January and June 1995, January and July 1996, and January and November 1997). A recent groundwater flow study (Weaver Boos, 2003a), demonstrated that there is local, temporary northward flow during short periods of time near the northern edge of Yard 520. According to the consultant for Yard 520, the previous interpretation of northward flow was based on insufficient data.

3.2.5 Groundwater Sources and Sinks

Groundwater is recharged from precipitation (rainfall and snowfall). Average annual precipitation is 39.3 inches per year (ATEC, 1989). Of this, some water recharges the aquifer. The amount of recharge to the aquifer depends largely on the land use. It is estimated that between 5 and 15 inches per year recharges the groundwater table (Watson, et al., 1989). The surficial aquifer is recharged from local precipitation; the deeper aquifers are recharged further south, for example, from the Valparaiso Moraine. The surficial aquifer also receives recharge due to upward flow from the underlying formations (Shedlock, et al., 1994).

Regionally, the surficial aquifer is used very little as a source of drinking water due to its thinness (2 to 30 feet) and to its susceptibility to contamination (Fenelon, et al., 1994). Lake Michigan is the primary source of drinking water. However, the surficial aquifer may be tapped by households that do not have access to a municipal water supply. The surficial aquifer is also used for discharge of household septic wastes. In the Town of Pines in the Area of Investigation, all residences used the surficial aquifer both for water supply and discharge of septic wastes until 2003, when a portion of the town was connected to a municipal water supply. The water supply service will be extended to additional homes in 2004-2005 (AOC I amended, 2004). The surficial aquifer will continue to be used for the discharge of household septic wastes.

The use of the confined aquifers in the Area of Investigation is not known or documented. However, some use of these deeper aquifers is suspected due to the reported depths of some private wells.

The groundwater also supports the hydrology of the wetland systems, including Great Marsh, located within the IDNL. These natural low-lying areas are partially drained by man-made ditches which were originally constructed in the late 1800s (Shedlock and Harkness, 1984).

The groundwater water balance (i.e., balance of sources and sinks) is currently in flux. The connection of hundreds of residents to the municipal water system will reduce the amount of shallow groundwater being withdrawn. However, the majority of the water brought into the community via the municipal water service will ultimately be directed to septic systems. This will result in an increase in the amount of recharge to the groundwater system in the Area of Investigation. In addition, the closure of Yard 520 may locally affect the water balance.

3.3 Surface Water Hydrology

The major significant surface water feature near the Pines Area of Investigation is Brown Ditch (see Figure 2). Brown Ditch is an interconnected network of man-made channels extending into locally-significant interdunal wetlands, including the eastern portions of the Great Marsh and the so-called Calumet-Glenwood wetlands, as well as a small portion of the Lake Border Moraine (Shedlock and Harkness, 1984). These wetlands are located between the three distinct sand dune ridges (Tolleston Dune-Beach Complex, Calumet Dune-Beach Complex, Glenwood Dune-Beach Complex), which are aligned in a southwest-northeast orientation parallel to the Lake Michigan shoreline and represent former lake stages (beaches) of Lake Michigan. Brown Ditch is only one of a number of channels that were excavated in the vicinity of the Area of Investigation in the early 1900s to drain and convey water from these wetland areas (e.g., Burns Ditch, Derby Ditch, Kintzele Ditch) (Arihood, 1975; Shedlock and Harkness, 1984).

Brown Ditch has several long east-west channels south of the Calumet dune. It crosses the dune ridge in a short north-south channel just prior to entering the IDNL. From there, Brown Ditch flows northeast through Great Marsh to join as a tributary to Kintzele Ditch, which then flows into Lake Michigan (see Figure 2). Inspection of aerial photographs of the period 1970-1990 indicates that a portion of a channel of Brown Ditch was relocated during the 1980-1990 interval (PCRTPC, 1970; NIRPC, 1980; 1990; 2000). The segment of the channel that had previously crossed through the middle of the current Yard 520 (Figure 2) was relocated to the south to run along the southern border of Yard 520 parallel to Railroad Avenue (see Figure 1). This is documented in the Yard 520 records (e.g., Appendix D). The original channel is rejoined just east of Yard 520. This work was conducted in 1989 (ATEC, 1989), and consisted of excavating soil materials to re-locate the channel of the ditch, not dredging the existing channel.

Representative photographs of Brown Ditch are shown in photographs #1 – #4. Brown Ditch is a low-gradient channel with representative slopes of between 0.03 – 0.11% in the areas south of the IDNL and about 0.2% between Route 12 and its confluence with Kintzele Ditch. This low-gradient profile translates into generally low flow conditions, with several sections subject to ponding upstream of the

IDNL (Shedlock and Harkness, 1984). The drainage basin for Brown Ditch is estimated at 4.7 square miles (sq. mi.), with approximately 1.0 sq. mi. located in the IDNL (Shedlock and Harkness, 1984).

Flow measurements in Brown Ditch near the Town of Pines are typically low. Flow measurements were taken near the north-south channel which crosses through the Calumet dune ridge prior to its entry into the IDNL in the 1970s and 1980s (Arihood, 1975; Shedlock and Harkness, 1984). These values were 1.02 cubic feet per second (cfs) (10/15/73) and 0.79 cfs (7/16/82) during base flow or low flow months and 18.6 cfs (1/22/74) and 2.6 cfs (4/23/74) during winter-spring conditions. Estimating the area of the Brown Ditch watershed prior to its entry into the IDNL at 3.7 sq. mi. (as noted above), this places the base flow yield of the ditch at approximately 0.21 to 0.28 cfs/sq. mi. at that time.

The main sources of water to Brown Ditch are precipitation, surface water runoff, and groundwater discharge. Shallow groundwater discharge into Brown Ditch comes from the low relief water table mounds located below the dune ridges (Shedlock and Harkness, 1984). In 1982, the east channel of Brown Ditch sat within the organic peat layer that is the underlayment of the Calumet-Glenwood wetlands and Great Marsh, with shallow penetration into the sand layer in sections closer to the lakeshore (Shedlock and Harkness, 1984). In 1983, the east channel of Brown Ditch was dredged down into the sand layer to improve drainage and reduce flooding (Shedlock and Harkness, 1984). The section of Brown Ditch that was dredged is located east of Ardentale, south of East Johns and Second Place, on a different branch of the ditch system from Yard 520.



Photograph #1. Brown Ditch at southwest corner of Yard 520 (looking west, upstream), April 1, 2004.



Photograph #2. Brown Ditch at southwest corner of Yard 520 (looking east, downstream, along Railroad Avenue), April 1, 2004.



Photograph #3. Brown Ditch at Route 12 crossing (looking south, upstream), April 1, 2004.



Photograph #4. Brown Ditch at Route 12 crossing (looking north, downstream, to railroad crossing and IDNL), April 1, 2004.

Based on observations made at crossings (see photographs), the channel bottom is largely comprised of either fine organic materials or fine sand with little or no rock substrate.

3.4 Groundwater-Surface Water Interactions

Groundwater in the surficial aquifer in the Area of Investigation flows primarily towards Brown Ditch. As described in Section 3.3 and shown on Figure 2, there are several channels of Brown Ditch running through the Area of Investigation. Therefore, groundwater is likely to flow in several directions to reach the ditch. Groundwater may also flow towards and into the swamps and wetlands that the ditch was designed to drain, without actually reaching the ditch itself.

Studies performed at Yard 520 indicate that groundwater in the vicinity of Yard 520 flows towards and discharges to Brown Ditch (Weaver Boos, 2003a). However, it is unclear whether the groundwater-surface water interactions in this area have been studied either quantitatively or seasonally.

The USGS conducted a detailed study of groundwater-surface water interactions along Brown Ditch in the early 1980s (Shedlock and Harkness, 1984). This report states that Brown Ditch (as with many ditches in this area) was constructed at the turn of the century with the express purpose of draining the interdunal wetlands and presumably making land available for use. Brown Ditch is a legal drain under the jurisdiction of the drainage board of Porter County (Shedlock and Harkness, 1984). In 1982, The Town of Pines requested that the ditch be dredged to help mitigate springtime flooding (Shedlock and Harkness, 1984). The USGS study was intended to evaluate the effects of such dredging. The study was focused on the east segment of Brown Ditch (east of Ardendale), the segment that flows northward into the IDNL, and the segment through the Great Marsh. (Note that Yard 520 is located on the western segment of Brown Ditch, west of Ardendale.)

The objectives of the USGS study were to evaluate whether surface drainage in Brown Ditch was being controlled or obstructed and to evaluate the effects on the water table of lowering the stage of the ditch in the lakeshore and in the Town of Pines. The study found that the water table could be lowered by up to 2.0 feet depending on where and how much dredging was completed. The dredging was expected to mitigate seasonal flooding and improve drainage in the ditch.

The USGS report (Shedlock and Harkness, 1984) confirms the understanding that Brown Ditch (and other ditches) is hydraulically connected to the shallow groundwater and serves as a discharge point for shallow groundwater. This water is then conveyed downstream and discharged to Lake Michigan. The report also presents historic and hypothetical ditch bed profiles that may prove useful in evaluating the ditch with respect to the shallow groundwater system. No data, as stated before, is presented for the western segments of Brown Ditch in the USGS study.

In 1983, the proposed dredging on the east branch of Brown Ditch was completed. The USGS study also suggests that the hydraulic connection between the groundwater and the ditch may have been different prior to the early 1980s when the dredging took place.

The Town of Pines issued a permit to Brown Inc. in 1983 to re-locate the west segment of the ditch. The work to re-locate the channel of the west branch of Brown Ditch was performed in 1989 (ATEC, 1989) (note - the existing channel was not dredged).

3.5 Potential Sources

The boron and molybdenum detected in groundwater samples above USEPA RALs has been suspected by USEPA to be attributed to CCBs, particularly fly ash. The physical and chemical properties of CCBs are described in Section 3.6.

In the remainder of this document, all chemical names (i.e., elements and ions) will be referred to using standard chemical notation. These abbreviations are provided at the end of the acronym list included in this document, and may also be found on any standard periodic table. For ease of reading, the full names for boron (B) and molybdenum (Mo) will continue to be used.

3.5.1 Yard 520

Yard 520 is a Restricted Waste Facility permitted by IDEM. The majority of material within Yard 520 is CCBs from NIPSCO's Michigan City Generating Station. Historically, a small amount of construction/demolition debris, such as concrete, lumber, steel, and brush, were disposed at Yard 520. CCBs from NIPSCO's Michigan City Generating Station were legally disposed in the Yard 520 Restricted Waste Facility from the 1960s to 2001. A small amount of CCBs from NIPSCO's Bailly station was also disposed at Yard 520. Yard 520 consists of two areas: the northern area is permitted for Type II wastes, the southern area is permitted for Type III wastes. Restricted waste sites are permitted to accept a single, non-hazardous waste type with similar physical and chemical properties (329 IAC 10-9-4). Type I through Type IV restricted wastes are defined based on their leachable concentrations of certain constituents. Type III wastes have more stringent leaching requirements than Type II. However, IDEM is responsible for making a final waste determination and issuing the waste classification (IDEM, undated).

The location of Yard 520 is shown on Figure 1. Figures in Appendix C show the detail of Yard 520 itself. The northern area was in use until approximately 1986, and was closed in 1986-1987 (Weaver Boos, 1996b). Use of the southern area started at that time. A 10-foot wide clay barrier was constructed between the northern and southern areas (i.e., between the Type II and Type III permit areas, respectively). The southern area is constructed into the clay confining unit with excavated clay forming the four sides (e.g., ATEC, 1989).

The closure plan for the Type III area was approved in September 2003 (IDEM, September 2003). Appendix D presents a brief chronology of the Yard 520 operating history as well as changes in practices at the Michigan City Generating Station that affected the materials disposed at Yard 520.

Groundwater monitoring has been conducted at Yard 520 since at least the early 1980s up through the present (e.g., Weaver Boos, 2004). Boron and molybdenum have been detected in groundwater and surface water in the immediate vicinity of Yard 520. The extent to which these may be above background levels and whether Yard 520 may be a source of boron and molybdenum in groundwater and/or surface water beyond Yard 520 will be determined during the RI.

3.5.2 Other CCBs

IDEM and USEPA files contain information suggesting CCBs may have been placed in the Area of Investigation in areas outside Yard 520. CCBs may have been used as road base in some instances. It also appears that CCBs may have been used to fill low-lying areas. Available information about the occurrence of CCBs outside of Yard 520 has been compiled and is presented in Section 3.6.

As described in more detail in Section 3.6, fly ash and possibly other CCBs placed in certain ways may leach boron and/or molybdenum to groundwater. These constituents are typically available in fly ash. Concentrations in groundwater as a result of leaching would be dependent on the type, extent, and age of any such deposits, and on hydrogeologic characteristics including infiltration rates, groundwater flow rates, available mixing zone, geochemical conditions, and background concentrations.

Other CCBs, such as boiler slag or bottom ash, are likely to contain less available boron or molybdenum compared to fly ash. Therefore, the potential for constituents from these CCBs to leach to groundwater is lower.

The extent to which CCBs have been placed outside Yard 520, and whether they may be a source of boron and molybdenum in groundwater and/or surface water will be determined during the RI.

3.5.3 Natural Background

Boron and molybdenum are both naturally occurring in the environment. Boron in particular is naturally present in most ground waters (Hem, 1992). Available information about background concentrations of these constituents is presented in Section 3.7.

3.5.4 Other Potential Sources of Boron

Boron is a naturally occurring element and is typically present in ground waters (Hem, 1992; ATSDR, 1992). Background concentrations vary regionally. Available information on background concentrations of boron in northwest Indiana is presented in Section 3.7.

Other potential sources of boron include (Hem, 1992; Alloway, 1990; Adriano, 2001; ATSDR, 1992; USGS, 2002c):

- Cleaning aids (i.e., borax, sodium tetraborate);
- Soaps and detergents;
- Fertilizers (boron is an essential nutrient for plants);
- Glass (especially Pyrex®), glass manufacturing, and fiberglass;
- Personal hygiene products including mouthwashes, hair and skin care products, eyewashes, makeup;
- Fungicides, insect deterrents, algacides;
- Septic systems, sewage sludge (due to domestic uses); and
- Landfills (due to domestic products and glass).

Boron is naturally associated with organic materials in soils and rocks, and is present in relatively high concentrations in marine shales (Adriano, 2001), such as the Antrim Shale, the bedrock beneath the Area of Investigation.

3.5.5 Other Potential Sources of Molybdenum

Molybdenum is a naturally occurring element and is present in many geologic materials (e.g., Adriano, 2001). There may also be background concentrations of molybdenum in groundwater in the vicinity of the Pines Area of Investigation. Available information on background concentrations of molybdenum in northwest Indiana is presented in Section 3.7.

Other potential sources of molybdenum include (Hem, 1992; Alloway, 1990; Adriano, 2001; USGS, 2002a):

- Fertilizers (essential to plant growth);
- Metal smelting, steel works, metal alloys;
- Catalysts in chemical and petroleum industries;
- Lubricants;
- Corrosion inhibitors (replacing chromium);
- Ceramics; and

- Wastes associated with these industries.

Molybdenum naturally accumulates in poorly drained soils and soils with high natural organic content (i.e., peats, wetlands) (Adriano, 2001; Alloway, 1990). It is present at high concentrations in “black shales” (Adriano, 2001), which are shale deposits with high organic content (such as the Antrim Shale, the bedrock beneath the Pines Area of Investigation). Molybdenum also accumulates in sewage sludge (Adriano, 2001).

3.5.6 Other Sources of Other Inorganics

In addition to boron and molybdenum, other inorganics including some other metals have been detected in samples from the Area of Investigation. Most inorganics are naturally occurring, and samples of soil and groundwater are expected to have background concentrations of these constituents. Some additional inorganics may be present in and may leach from CCBs under certain conditions. Other than background and CCBs, the following are potential sources for other inorganics that have been or may be encountered during the RI:

- Septic systems and leachfields (especially NO₃, Pb in groundwater);
- Municipal landfills (especially Cl, NH₄, total dissolved solids (TDS) in groundwater);
- Air deposition onto surface soils;
- Road de-icers (Cl, Na in groundwater and soils);
- Iron and steel-making slag that may have been used as fill (Ca, Mg, SO₄, elevated pH); and
- Release or use of organics (for example, from leachfields, municipal landfills, gas stations) that change natural geochemical conditions and result in elevated concentration of certain metals in groundwater (e.g., Fe, Mn, As).

Within the Area of Investigation are two former municipal landfills, known as the Pines Landfill and the Lawrence Dump (ISBH, 1984; ISBH, 1985). These are located south of U.S. Route 20, west of Ardendale. According to Preliminary Assessments prepared by the Indiana State Board of Health (ISBH), the landfills were in operation from 1969 to 1974 (Pines; ISBH, 1984) and 1955 to 1975 (Lawrence; ISBH, 1985). A wide variety of municipal, commercial and industrial wastes were reportedly disposed. Leachate from landfills typically has elevated concentrations of many inorganic constituents, depending on the wastes disposed.

3.6 Description of CCBs

Coal-burning power plants supply more than half of the electricity used in the United States (USGS, 2001). When coal is burned to produce power, unburned residues are left, which are re-usable by-products and therefore are termed coal combustion by-products (CCBs). CCBs include fly ash, bottom ash, boiler slag, and flue gas desulfurization (FGD) material. These residues are considered to be by-products because there are many beneficial re-uses for these materials (USGS, 2001). For example, approximately 19 million metric tons (Mt) of fly ash were used in concrete, structural fill, and waste stabilization in 1999 (USGS, 2001). Fly ash is used in major construction projects, for example, high-strength concrete buildings, decks and piers of highways, major dams, and concrete pavements (USGS, 2001). The use of fly ash to partially replace portland cement in concrete significantly reduces the emissions of carbon dioxide (for example, a reduction of 7 Mt in 1998; USGS, 2001). Five Mt of bottom ash were used in 1999 primarily in structural fill, snow and ice control, road bases, and concrete (USGS, 2001). About 2 Mt of boiler slag, representing nearly all the boiler slag produced in 1999, was used in blasting grit and roofing applications (USGS, 2001).

There is a great deal of literature available on the physical and chemical nature of CCBs (see references in Section 7 and Appendix A). The following sections describe physical and chemical characteristics of various CCBs.

3.6.1 Physical Description

Generally, CCBs are the “inorganic residues that remain after pulverized coal is burned” (USGS, 2001). There are four types of CCBs. Their classification is based on how and when they are generated in the coal combustion process. Bottom ash and boiler slag settle to the bottom of the combustion chamber. Fly ash is also generated in the combustion chamber, but it is lighter and finer than the bottom ash and boiler slag and so is transported in the flue gas and ultimately collected by air emission controls (e.g., electrostatic precipitators or other gas scrubbing systems) (USGS, 2001). To control sulfur oxide emissions, flue gas may also be passed through a scrubber where, in the process of desulfurization, sulfur oxides are removed from the gas by reactions with a sorbent, such as limestone, lime, or less frequently, ammonia. In this process, FGD products are formed (USGS, 2001).

Below are composite descriptions for fly ash, bottom ash, boiler slag, and FGD products from a number of sources (Kalyoncu, 1999; USGS, 2001; OSM; CARRC) including pictures of the products (CARRC, <http://www.undeerc.org/carrc/html/whatiscoalash.html>).

- Bottom ash consists of agglomerated ash particles that are too large to be carried in the flue gases and instead adhere to the boiler walls or fall through open grates to an ash hopper at the bottom of the boiler. Bottom ash is typically a gray to black, coarse, granular material with a porous surface texture. Bottom ash is coarser than fly ash with grain sizes spanning from fine sand to fine gravel (3/8-inch). It is usually a small portion of the total ash produced by the boiler.



- Boiler slag is similar to bottom ash, but represents material that has been melted during combustion in cyclone boilers. It is collected at the base of the boilers and is quenched with water causing it to shatter into black, angular particles that have a smooth glassy appearance. Boiler slag is generally a black, granular, vitreous material and is coarser than fly ash.



- Fly ash is coal ash that exits from a combustion chamber in the flue gas and is captured by air pollution control equipment, such as electrostatic precipitators, baghouses, or wet scrubbers. Fly ash is a fine powder formed from the mineral matter in coal plus a small amount of unburned carbon that remains from incomplete combustion. It is composed primarily of very small, amorphous, glassy spheres of alumina and silica oxides. It is generally light tan in color and consists mostly of silt-sized and clay-sized glassy spheres. The consistency of fly ash resembles talcum powder.



Fly ash has cementitious and/or pozzolanic properties that make it attractive as a building material. Fly ash with a high calcium content is cementitious, meaning that it will harden like concrete when mixed with water. Cementitious ashes are typically generated from low sulfur, western coals. Fly ash with lower calcium content is said to be pozzolanic, meaning that it will harden when mixed with both calcium and water. Pozzolanic ashes are typically generated from high-sulfur, eastern and mid-western coals.

- FGD products are generated from the process of removing sulfur dioxide (SO₂) from flue gas using a sorbent such as lime, limestone, or ammonia. In the United States, 90% of FGD systems use lime or limestone (USGS, 2001). FGD sludge is commonly combined with fly ash to dry and stabilize the material. The physical nature of these materials varies from a wet, thixotropic sludge to a dry, powdered material, depending on the process.

The following table presents a brief summary of physical and chemical properties.

Table 4 - Physical and Chemical Variability of CCBs (from Pflughoeft-Hasset, et al., 2000)

CCB Type	Particle Size	Particle Morphology	Color	Major Composition	Trace Element Composition
Bottom ash	Range from granular to ½ in	Angular	Tan to black	Depends on coal source	Low concentrations
Boiler slag	Granular	Approx. spherical	Black	Depends on coal source	Low concentrations of most traces
Fly ash	High percentage smaller than 325 sieve	Spherical	Tan to gray	Depends on coal source	Enriched in trace elements
FGD	Fine powder	Angular (wet or dry)	White to off-white	Ca and S	May contain some trace elements

Based on these descriptions, fly ash should be visually distinguishable from bottom ash and boiler slag. However, if these materials were mixed (either with other CCBs or soils) or if some cementation of the fly ash takes place, they may be less distinguishable based on their appearance. In these instances, chemical and/or microscopic examination may be useful.

At NIPSCO's Michigan City Generating Station, management of CCBs was performed consistent with industry and regulatory standards. Fly ash was collected from gas in the stack in emission control devices (such as electrostatic precipitators). Prior to 1998, CCBs were flushed from the boiler systems using water. The mixture of water and CCBs was piped to settling ponds at the plant. The CCBs managed this way may have been a mixture of fly ash and bottom ash. In the settling ponds, the CCBs were allowed to settle out of the water. Approximately twice a year, the settling ponds became filled to capacity with CCBs. At that point, the CCBs were removed from the ponds and typically trucked to Yard 520 for disposal. At the time of disposal, the CCBs would have been a wet slurry. In 1998, the Michigan City Generating Station switched to a system that managed the CCBs in dry form. Also, it appears that there were occasions when NIPSCO contracted with other entities (not Brown) for CCB-related services.

The following discussions focus on fly ash, bottom ash, and boiler slag. It is believed that FGD materials are not relevant to environmental conditions in the Pines Area of Investigation, because NIPSCO's Michigan City Generating Station does not use desulfurization equipment.

3.6.2 Chemical Characterization

CCBs are the unburned portion of the coal. Coal is derived from ancient swamp-lands, primarily from organic matter, that is, peat or un-decomposed plant material. However, there are many other contributions to swamps in addition to plant materials. Silts and clays can be deposited from time to time in swamps. In addition, groundwater interaction with swamps can provide constituents to the

swamps that were originally dissolved in the groundwater. During the transformation of the swamplands into coal, many chemical changes take place, resulting in the formation of numerous minerals. It is these non-plant materials that result in CCBs when coal is burned.

Because of the different origins of CCBs in the coal burning process, the chemistry of the different CCBs varies. The primary difference is that bottom ash/boiler slag is formed at the bottom of the boiler whereas fly ash is carried in air. Therefore, the volatile fractions from the coal will tend to be concentrated in the flue gas and the smaller particulates will end up in the fly ash. (Note that the most volatile fractions in the flue gas are not in particulate form and, therefore, may not be present in the fly ash, for example, Hg, Cl, Se). It is also clear that the chemistry of the coal fed to the boiler will affect the chemistry of the CCBs. In general, western coals have a high calcium content and low sulfur content. Eastern and mid-western coals have generally low calcium and high sulfur content. The calcium content influences the beneficial uses for fly ash. The relative amounts of sulfur and calcium will affect the pH of water in contact with the ash.

Trace element content also varies with coal source and type of ash. According to a study by the Cooperative Research Centre for Coal for Sustainable Development (CCSD, Australia), elements that are associated with the organic content of the coal or in sulfide minerals in the coal will tend to volatilize during combustion, whereas elements associated with silicates, oxides, or carbonates in the coal will not tend to volatilize. The chemical composition of bottom ash/boiler slag is similar to fly ash for non-volatile elements (i.e., major elements such as Ca, Mg, Al, Si, K, Fe, Na) (e.g., EPRI, 1987a), whereas fly ash generally has a higher concentration of elements that tend to volatilize in the coal combustion process (such as As, B, Be, Cd, Co, Cr, Sb, Cl, F, S, Se) (e.g., EPRI, 1987a; CCSD). Concentrations of trace elements tend to increase with decreasing particle size (EPRI, 1993). High-sulfur eastern coals tend to have a higher content of many trace elements (USGS, 2002b) as they are present in the coal in sulfide minerals, such as pyrite.

In addition to the relative concentration of constituents, the occurrence of these constituents in the different CCBs affects their behavior in the environment. Boiler slag has been melted and then fused on cooling. Therefore, all the constituent components are bound up in a relatively inert matrix that does not exhibit much chemical reactivity. Fly ash consists primarily of tiny spheres of alumina and silica oxides with trace elements largely deposited as surface coatings on the spheres (e.g., EPRI, 1993). The surface coatings have a larger surface area and increased availability for chemical reactions. The composition of bottom ash, having not been melted, but also without appreciable surface coatings would place it between boiler slag and fly ash with respect to chemical reactivity.

3.6.3 Potential for Leaching from CCBs

There is a significant amount of research concerning the potential for leaching from CCBs. The majority of this research is focused on fly ash and not bottom ash or bottom slag. It appears that there is less potential for leaching from these latter materials relative to fly ash, and so the research has

generally focused on fly ash. This interpretation is consistent with the chemical characteristics of the materials as noted above (i.e., some trace elements concentrated in fly ash, occurrence of trace elements on surface area of fly ash) and with the few references in the literature. As stated in the abstract of a study by the Electric Power Research Institute (EPRI, 1987b): “Trace elements from flue ash leached more easily than did those from bottom ash when these ashes were generated through conventional coal combustion.” In addition, “the four types of CCBs vary in particle size and in their leaching potentials for the various chemical constituents contained in them” (Murarka, 2002). Information provided to NiSource from EPRI in November 2003 (see Appendix E) indicates that both boron and molybdenum are leached from fly ash (from bituminous, eastern coals), while they were leached from fewer samples of bottom ash.

There is much research evaluating the environmental performance of fly ash during beneficial use (e.g., concrete building products, soil amendment, mine reclamation, etc.). While these studies are interesting, they are not particularly relevant to the case of fly ash disposed in a disposal facility or used simply as fill. The general results of various studies specifically related to CCBs in a fill or disposal situation are summarized below.

Leaching studies for fly ash have fallen into three primary categories: batch tests, column tests, and field studies. Batch tests consist of mixing the fly ash with a leaching solution. Toxicity Characteristic Leaching Procedure (TCLP) and Synthetic Precipitation Leaching Procedure (SPLP) are examples of batch tests. In column tests, a leaching solution is passed through a column filled with ash material. Field studies may consist of sampling pore water within an ash matrix and/or sampling groundwater outside areas of fly ash disposal. Most research indicates that standard batch-type tests are not suitable to accurately predict leaching of fly ash. The three reasons for this are: (1) the length of time for the tests is not adequate for the system to reach equilibrium, (2) the chemistry of the leaching solution is not typically representative of field/environmental conditions, and (3) there are many possible geochemical reactions that may take place during transport from ash to groundwater that cannot be accounted for in batch tests.

The leachability of trace elements is dependent on their occurrence within the ash matrix (EPRI, 1986), with elements located on the exterior of the spheres being more leachable and those within the spheres inaccessible and so not readily soluble. In the same study, EPRI researchers noted that some metals may leach from the surfaces of the spheres but then may be attenuated elsewhere within the ash. That is, although some metals may be easily leachable, they may be attenuated prior to reaching the environment (i.e., groundwater).

While there are numerous individual studies on the leaching of constituents from fly ash, the overall conclusions have been succinctly summarized by Murarka (2002). This summary included no specific references, but the conclusions were generally consistent with the findings of the other studies reviewed. The primary points are summarized below and augmented with technical references and additional information where available.

- The major constituents of CCBs are not typically of interest for leaching and groundwater impacts. These major elements include Si, Al, Ca, Mg, and Fe. For some fly ashes with high Ca content (western coals), the highly alkaline conditions could mobilize Al (Murarka, 2002). The lack of interest in these elements could be due to limited leaching, limited migration, and/or limited toxicity. EPRI field studies have noted that Ca, Fe, and SO₄ are the predominant dissolved species associated with fly ash (EPRI, 1998a). Another EPRI study (1986) notes that Ca, Mg, K, and SO₄ are commonly elevated in groundwater:
- Hg and Ag are typically present in CCBs at relatively low concentrations, and so they are not of interest (Murarka, 2002). EPRI field studies have found that Ag is typically not detected in porewaters residing in CCBs (EPRI, 1998a).
- Ni, V, Cu, and Zn are present in ashes and have been shown to leach, but data suggest that environmental impacts (to groundwater) tend to be limited. Similarly, Ba is leachable from CCBs, but at concentrations that are typical of many background groundwater conditions (Murarka, 2002).
- Cd, Cr, and Pb typically do not leach from CCBs at concentrations of interest, but there may be site-specific geochemical conditions that could lead to enhanced mobility (such as high or low pH or redox conditions) (Murarka, 2002). An EPRI field study (1998a) found Cd, Cr, Pb, Cu, and Zn in about 50% of samples collected from porewater in contact with ash. Most researchers have noted that pH affects the leaching of many metals from fly ash. EPRI field research suggests that groundwater in the immediate vicinity of ash basins and impoundments may show impacts from fly ash leaching, but not typically at greater distances or deeper (EPRI, 1997).
- SO₄ is highly soluble and often present in groundwater at elevated concentrations. Boron and molybdenum in CCBs are relatively soluble (Murarka, 2002). Concentrations of boron in porewater in contact with ash ranged up to 170 milligrams per liter (mg/L) (EPRI, 1998a). Boron and molybdenum appear to be mobile and not well attenuated in groundwater systems because they occur as anions rather than cations (Hem, 1992; Adriano, 2001). On-going EPRI research demonstrates groundwater impacts of boron and molybdenum (EPRI, 1997). EPRI notes that boron and SO₄ are common in groundwater beneath unlined fly ash landfills. The data provided to NiSource from EPRI in November 2003 (see Appendix E) indicates that all fly ash samples in laboratory tests leached molybdenum above 0.1 mg/L, and about 50% of samples tested leached boron above 0.1 mg/L.
- Se and As are both leachable from CCBs. As has a high potential for attenuation in groundwater systems. The geochemistry of Se is complex (as it is for As) (Murarka, 2002). As appears to be mobile because it occurs in an oxyanion form. After boron and molybdenum, these two elements seem to be the most likely candidates for potential groundwater impacts.

- The relationship between CCBs and Mn is unclear (Murarka, 2002). There are many natural and anthropogenic sources of Mn in groundwater, including local changes in redox due to septic systems. A recent EPRI study found Mn in groundwater associated with fly ash, but noted that Mn is not a good indicator of fly ash. Mn concentrations do not necessarily correlate well with boron and SO₄ (EPRI, 2002).
- Sr has been observed to leach from fly ash. Natural groundwaters also contain Sr as a minor element (Hem, 1992).
- An early evaluation by EPRI (1986) of potential impacts to groundwater indicated that the following elements were not detected in waters associated with fly ash: Ag, Be, Ti, and Zr. Cu, Co, and V were present in porewaters in contact with ash, but not in groundwater (i.e., these metals attenuated before reaching groundwater).

This summary indicates that there is the potential for certain constituents to leach from fly ash under certain circumstances. However, many of these constituents can be attenuated in the ash and/or groundwater system. From a mass-balance perspective, CCBs will not be infinite sources of constituents to groundwater; i.e., leaching will decrease and eventually stop at some point in time. The time involved for this to occur would depend on the nature and extent of the deposit and specific environmental conditions.

3.6.4 Potential Locations of CCBs in the Area of Investigation

CCBs are known to have been disposed in the Yard 520 Restricted Waste Facility under a permit issued by IDEM. In addition, USEPA and IDEM files suggest CCBs may have been used as road bed and/or fill in areas of the Town of Pines. Sources of information on CCB locations included IDEM, USEPA, USGS, and Yard 520 documents. The sources included narrative descriptions based on visual observations, interviews, and soil sample descriptions, and maps created by IDEM and USEPA outlining potential CCB distribution areas. Information about the possible locations of CCBs has been compiled and presented in Appendix F. The information has also been posted on the map in Figure 3. It is important to recognize that all of this information is anecdotal at this stage and has not been field verified.

The information presented in Appendix F suggests CCBs may have been used as fill, road base, and residential driveway material within the Pines Area of Investigation. Much of the information available regarding the placement of CCBs is based on observations collected through interviews by the USEPA and IDEM. This has not yet been field verified by the Respondents. Little formal documentation regarding the exact location of placement or type of CCBs throughout the Area of Investigation is available. In most cases, the actual area and thickness and type of the CCB material has not been noted or is not known. There are several reports of CCBs used as road bed or driveway material (see Appendix E). Additional information was obtained during the installation of city water mains and monitoring wells at Yard 520. Observations during the city water main installation along Columbia Street in 2003 suggest the presence of 10 to 11 feet of CCB material below the roadway (USEPA, see

Appendix E). Two areas where CCBs were encountered during the city water main installation were at the south ends of Florida Avenue and Delaware Avenue. The CCBs encountered in these areas were excavated and stockpiled off-site. Prior to disposal, a sample was collected from each stockpile. Initial observations suggest that the material may be bottom ash.

Additional anecdotal information suggests that during the installation of a new septic system at the Town Hall, at least 6 feet of CCB material was observed below the ground surface (IDEM, see Appendix E). These observations of deeper thickness suggest CCBs may also have been used as fill material. Figure 3 suggests that CCBs may have been used more extensively in the eastern portion of the Town of Pines. The use of CCBs as road base or fill was not conducted by Brown or by NIPSCO.

The extent to which CCB deposits may be the source of boron and molybdenum to groundwater and surface water will be evaluated during the RI.

3.7 Chemical Information

This section presents available information on the constituent concentrations in various media in the Area of Investigation. Groundwater information is available in the form of sampling results from private wells. However, because well construction information is sparse, interpretation of these results is not clear. There are also groundwater monitoring data from Yard 520. Various USGS studies have provided information on background groundwater quality in the region. Surface water data are available from surface water monitoring at Yard 520.

A sample from each of the two stockpiled excavated CCBs (described above in Section 3.6.4) was collected and submitted for laboratory analysis for total metals. The results are discussed in Section 5.3.6.

3.7.1 Constituents of Potential Concern

The constituents of potential concern for the RI/FS identified to date are boron and molybdenum, because they have been detected above the USEPA RALs. Manganese has also been detected in some samples above the USEPA RAL, but manganese is commonly naturally present at elevated levels in many groundwater systems.

Based on the information reviewed earlier in this section, the main constituents potentially associated with CCBs include:

B, Mo (primary); and
As, Se, Cr, Cd, Pb, Ca, SO₄, Sr, and Li (secondary).

These constituents are also naturally present in many geologic materials and can be naturally present in groundwater as well. They can also be associated with other sources, such as road salt, septic systems, and/or municipal landfills. The following constituents are primary indicators of releases from other potential sources:

Cl (road salt, municipal landfills);
Na (road salt);
NO₃ (septic systems);
NH₄ (municipal landfills, septic systems); and
Dissolved organic carbon/total organic carbon (DOC/TOC) (septic systems, municipal landfills, other sources of organics).

Constituents that occur naturally in groundwater and will aid in characterization of general water quality and interpreting results include:

HCO₃, Na, K, Mg, Ca, Cl, SO₄ (major elements);
Fe, Mn, B, F, Sr, Si, Al (minor elements); and
Specific conductance/TDS, pH, redox, temperature, dissolved oxygen (indicators).

3.7.2 Background Groundwater Quality

All of the inorganics that will be studied during the RI/FS, including boron and molybdenum, are naturally occurring, and many are expected to be found in environmental samples (soil, groundwater, surface water) at some naturally-occurring concentration. Available information has been reviewed for data about background concentrations in groundwater in northwest Indiana.

The USGS conducted a water quality study in a portion of the IDNL in the late 1970s (Hardy, 1981). For comparison purposes, the study established several sampling locations that were considered background. In Table 2 of the report, Hardy presents a statistical summary of general water quality data, and in Table 4, Hardy presents data for trace metals. All the groundwater data appear to be from the shallow, surficial aquifer. These two tables are presented in Appendix B and a summary of the background data is presented here:

Table 5 - Summary of Background Groundwater Quality Data - Hardy (1981)

	Dissolved Solids Concentration	pH ¹	Alkalinity as CaCO ₃	Silica ²	Calcium	Magnesium	Sodium ³	Potassium	Sulfate	Chloride ³	Fluoride	Dissolved Organic Carbon
Mean	213	6.9	83	7.4	40	18	5.7	2.0	66	7.1	0.1	9.4
Standard Deviation	0.7	--	1.1	5.4	0.8	9.3	1.3	0.2	28	1.1	0.1	0.8
Minimum Value	79	6.1	24	ND	15	6.1	2	0.7	13	4.3	ND	2
Maximum Value	442	8.3	220	14	85	32	12	4.1	130	14	0.2	28
Number of Observations	35	36	35	35	35	35	23	35	35	23	35	19

All data except pH are in milligrams per liter; samples collected and analyzed by USGS; ND, not detectable.

¹ - Median values of pH.

² - Indicates statistical information calculated from non-transformed data.

³ - Chloride and sodium data from locations unaffected by road salting.

	Aluminum	Arsenic	Barium ¹	Beryllium	Boron	Cadmium ¹	Chromium	Cobalt ¹	Iron	Lead	Mercury	Manganese	Molybdenum	Nickel	Selenium	Strontium	Zinc
Mean	22	<1	<100	<10	220	8	1	<1	90	1	<0.5	40	2	2	2	120	10
Standard Deviation	3	<1	80	2	2	42	2	<1	6	1	0.2	5	2	1	3	<1	4
Minimum Value	ND	ND	ND	ND	30	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	80	ND
Maximum Value	110	5	300	10	840	220	10	2	2700	7	0.5	1500	23	10	5	220	170
Number of Observations	28	28	16	6	28	28	6	18	35	28	6	35	28	28	3	28	28

Concentrations are in micrograms per liter; samples collected and analyzed by USGS; ND, not detectable.

¹ - Indicates statistical information calculated from non-transformed data.

Other regional groundwater quality data are presented in Table 6 of Shedlock, et al. (1994). In this document, median values are reported for a number of different constituents or parameters for various geologic strata. These data represent typical groundwater quality in northwest Indiana; results that were clearly elevated were excluded from the statistics (Shedlock, et al., 1994). This table is presented in Appendix B, and duplicated from Shedlock, et al. (1994) here:

Table 6 - Summary of Background Groundwater Quality Data - Shedlock, et al., 1994

Water-quality constituent or property (median values)	Water Source				
	Wetland Surface Water	Surficial Aquifer	Subtill Aquifer	Basal Sand Aquifer	Valparaiso Aquifer ⁵
Specific Conductance ¹	275	535	767.5	750	54
pH ²	6.55	7.05	7.35	7.5	7.1
REDOX potential ³	337	148	137.5	111	7.8
Temperature (°C)	11.65	11.2	11.85	12.25	10.8
Dissolved Oxygen	1.2	0.025	0.1	0.1	0.1
Calcium	26	60.5	63.5	49.5	61
Magnesium	9.45	22	48.5	30.5	24
Sodium	14.5	16	34.5	75	7.9
Potassium	1.7	1.5	2.75	3.8	2.1
Alkalinity, as calcium carbonate	60	190	365	290	270
Sulfate	35	51	37.5	7.65	1.8
Chloride	13.5	15	13.5	23.5	3.6
Dissolved Solids ROE @ 180°C	249	356	428.5	410.5	287
Boron ⁴	160	130	365	730	100
Iron ⁴	415	1950	490	385	120
Manganese ⁴	120	130	85	35	50
Dissolved Organic Carbon	17	7.9	4.4	3.3	2.6
Number of Samples	20	46	12	14	5

Unless stated otherwise, unit of measure is milligrams per liter (mg/L); REDOX, oxidation reduction potential; °C, degrees Celsius; ROE, residue on evaporation.

¹ - Unit of measure is microsiemens per centimeter at 25 degrees Celsius.

² - In Standard Units.

³ - Unit of measure is millivolts.

⁴ - Unit of measure is micrograms per liter.

⁵ - The Valparaiso Aquifer is not a part of the Pines Area of Investigation.

According to Shedlock, et al. (1994), “the basal sand aquifer has higher median values and generally higher ranges of values for sodium, pH, fluoride and boron. The higher values of these constituents could be due to leakage of water from the bedrock into the basal sand aquifer.”

The purpose of establishing background conditions, as presented in the above tables, is to provide some frame of reference for evaluating groundwater quality data. It is apparent from these data that natural groundwater includes many inorganics. It will be important in the RI to distinguish between

naturally occurring or anthropogenic concentrations of constituents, and concentrations that may be derived from CCBs.

3.7.3 Site-Specific Groundwater Data

The USEPA and IDEM have collected groundwater samples from many private wells in the Area of Investigation. This information has been compiled into a database and is being provided to USEPA under separate cover. The reported concentration ranges of boron and molybdenum from the IDEM and USEPA sampling events are posted on the maps in Figures 4 and 5, respectively. Samples with concentrations above the current USEPA RALs are generally located in the North and South Areas (see Figure 1), with a few sporadic locations outside these areas. Available information about the construction of private wells is provided in Appendix M.

As noted previously, there are many potential sources for these constituents in groundwater, including natural background, CCBs, septic systems, municipal landfills, and other sources. The data presented on these figures is difficult to interpret due to the lack of local information about groundwater flow directions, unknown well construction details, and many possible sources, including the many septic systems widely distributed throughout the area.

Groundwater monitoring has been conducted at Yard 520 since the early 1980s. The monitoring data from 1998 to 2003 has been provided electronically by Weaver Boos (2004), and is available electronically upon request. Boring and well construction logs for the current monitoring wells at Yard 520 are provided in Appendix K. Monitoring reports for monitoring conducted in the early 1980s are provided in Appendix L. It should be noted that these probably do not represent all the monitoring conducted, but only copies of reports present in the current project file.

The nature and extent of CCB-derived constituents in groundwater will be evaluated during the RI.

3.7.4 Background Surface Water Quality

Limited water quality data are available for establishing background surface water concentrations. Some potentially useable data were reported by Hardy (1981) from an interdunal pond at the western edge of Great Marsh that was considered background for a project site located in the Dunes Creek drainage area. A total of 17 measurements of boron were obtained at two locations in the pond. The range of measured values was 0.07 to 0.76 mg/L, with the two sites averaging 0.26 to 0.43 mg/L for boron (Hardy, 1981). A total of 17 measurements of molybdenum were obtained at two locations in the pond. The range of measured values were non-detected to 0.019 mg/L, with the two sites averaging less than 0.001 to 0.002 mg/L for molybdenum (Hardy, 1981). Data collected from Brown Ditch immediately upstream from Yard 520 is discussed in the following section.

3.7.5 Surface Water Quality in Brown Ditch

The surface water quality in Brown Ditch was evaluated based on the available data, with emphasis on concentrations of boron and molybdenum.

Limited water quality data are available from Brown Ditch prior to the development of Yard 520. The surface water quality in Brown Ditch was measured during base flow conditions in August and October 1973 at the Route 12 crossing upstream of the IDNL and downstream of the Area of Investigation (Arihood, 1975). Dissolved oxygen ranged from 6.7 to 7.5 mg/L and pH was 7.5 and 7.2. General water quality characteristics included hardness (230 mg/L as CaCO₃), alkalinity (121 to 175 mg/L as CaCO₃), and specific conductance at 430 to 600 microsiemens (uS). The range of the specific conductance was slightly greater than that found in the east (360 to 420 uS) and west (180 to 330 uS) channels of Brown Ditch upstream of Route 20. Total Fe and Mn concentrations in Brown Ditch at the Route 12 crossing in August 1973 were 2.1 mg/L and 0.24 mg/L, respectively. Nitrate-nitrogen was measured at 0.46 mg/L. Neither boron nor molybdenum was measured during the 1973 sampling event.

The monitoring program for Yard 520 includes sampling at locations on Brown Ditch (Weaver Boos, 2004). An electronic copy of these data is available on request. Upstream sampling locations included SG-1, located off the southwest corner of Yard 520 (see Photo #2 in Section 3.3) which was used from 1991 to 2002 and subsequently abandoned, and SG-1A located upstream of the Birch Street crossing (see Photo #1 in Section 3.3) which has been sampled in 2003. The downstream sampling location is SG-2, located on the east side of Yard 520. These locations are shown on a map in Appendix C.

TetraTech conducted one round of surface water sampling in this portion of Brown Ditch in May 2002 (TetraTech, 2004). The sampling locations were similar to those described above with SW-3 equivalent to SG-1A; SW-1 equivalent to SG-1, and SW-2 equivalent to SG-2 (see Figure A-5A, TetraTech, 2004).

Three parameters were considered from this time period: boron, molybdenum, and specific conductance (a general measure of dissolved ions). Boron was measured at SG-1 from June 1991 to October 2002; at SG-1A from May 2002 to November 2003, and at SG-2 from June 1991 to October 2003. Molybdenum was sampled twice at SG-1, in May and October 2002 (and was not detected on either date); at SG-1A in May 2002, January 2003, and November 2003, and at SG-2 from May 2002 to October 2003. Specific conductance was measured at SG-1 from June 1991 to April 2002; at SG-1A in April and October 2003, and at SG-2 from June 1991 to October 2003. The range of results, the average and median values for these three parameters are shown in the table below.

Table 7 - Boron, Molybdenum, and Specific Conductance; Brown Ditch (1991-2003)

Constituent	Units	Statistics	Upstream SG-1A	Upstream SG-1*	Downstream SG-2
Dissolved Boron	(mg/L)	minimum	0.12	0.00	0.00
		maximum	0.17	0.33	13.5
		average	0.15	0.14	2.78
		median	0.16	0.15	0.70
Dissolved Molybdenum	(mg/L)	minimum	0.00	only two data points both "ND"	0.03
		maximum	0.05		0.90
		average	0.02		0.27
		median	0.01		0.27
Specific Conductance**	(uS)	minimum	379	560	558
		maximum	512	995	1043
		average***	446	716	744
		median***	446	693	720

Notes: data from Weaver, Boos, 2004; TetraTech, 2004 (B and Mo data only)
 * = location abandoned in 2002; replaced by SG-1A
 ** = combination of lab and field measurements
 *** = only 2 values available.

3.8 Fate and Transport in Aqueous Systems

As noted above, certain constituents may leach from certain types of CCBs placed in the environment in certain ways. Other releases to the environment in the Area of Investigation may include: leaching from other wastes or materials in the area (such as municipal landfills), direct discharge through domestic septic systems and leachfields, and releases of liquids to soils (such as at former gas stations) and subsequent leaching to groundwater. In addition, many constituents are naturally present in soils and groundwater. Once constituents are present in the groundwater system, they will migrate with groundwater flow. During this transport, various processes will take place that may change the concentration and/or form of the constituents. These processes are evaluated through a "fate and transport" assessment. Similarly, once the groundwater is discharged to surface water, the constituents may be transported by the surface water and subjected to additional fate and transport processes.

The primary mechanism of movement of constituents in aqueous systems is via transport by the water, either groundwater or surface water. In groundwater systems, there are two primary transport mechanisms: advection and dispersion. Advection is the simple movement of constituents downgradient in the direction of groundwater flow. The direction and rate of migration can be affected by local variabilities (heterogeneities) and properties (e.g., permeabilities, anisotropy) of aquifer

materials. Dispersion is the micro-scale movement of constituents in groundwater as they move around individual grains or heterogeneities in geologic materials. Dispersion leads to a decrease in concentration over space, but also a spreading of constituents other than in the primary direction of flow. Constituents can also be removed from a groundwater system when groundwater is discharged to surface water or during transpiration by plants. In surface water, during transport downstream, dilution typically takes place as the flow becomes greater.

In addition to these physical processes, there are chemical processes that affect constituent migration. CCBs, and especially fly ash, potentially contain many different metals and inorganics. Available literature indicates that while many of these constituents may initially leach, the geochemical conditions within the ash itself will cause them to be attenuated and relatively few of them have the potential to reach a groundwater system. The constituents that appear to have a greater potential to reach groundwater include As, Se, Mo, Fe, Mn, Ca, SO₄, B, Sr, and Li (see Section 3.6). Once they reach the groundwater system, the physical and chemical conditions of that system will affect their migration. Metals (generally positively charged cations) tend to precipitate out of solution or be adsorbed onto grains within an aquifer. This tends to reduce metals concentrations in groundwater during transport. By contrast, constituents that are present in groundwater as anions (negatively charged) are less affected by these processes and so tend to be more mobile and less attenuated during groundwater transport. Constituents associated with fly ash that may leach as anions include molybdenum, boron, and SO₄.

Different chemical conditions affect different constituents differently. The primary geochemical conditions that affect transport in groundwater are:

- Redox (oxidation-reduction potential). Some metals occur in more than one oxidation state. The most common of these is iron. Ferric iron (Fe⁺³) is a more oxidized form, ferrous iron (Fe⁺²) is reduced. In groundwater systems that are oxidized (aerobic, having oxygen), Fe⁺³ will tend to be the more common form. Fe⁺³ will bond with oxygen ions to create a ferrous oxide that is insoluble. Therefore, in oxidized groundwater systems, there tends to be little dissolved iron in the groundwater. Mn, As, and Cr are additional metals whose mobility in groundwater is affected by redox. There are many natural groundwater systems that have elevated concentrations of these metals due simply to redox conditions. In addition, Fe, Mn, and As that may be naturally present but insoluble in an oxidized groundwater system, can become reduced and therefore mobilized if that system becomes anaerobic, typically through the addition of organic matter such as from septic systems, municipal landfills, or releases at gasoline stations. Surface water systems tend to be fully oxidized, so there could be a change in chemical conditions at the groundwater-surface water interface along with a phase change of the constituent.
- pH. The pH or acidity of a groundwater system will affect the mobility of certain ions. Many metals will be leached out of or dissolved from soils when pH is low (when water is acidic). These metals may then be mobile and migrate in the low pH groundwater until

conditions return to neutral, when they may be removed from solution. The following metals tend to be more mobile in acidic systems: Pb, Cd, Cr, and As. In contrast, there are also metals that tend to be more mobile in systems with elevated pH.

- Sorption and/or Ion Exchange. Groundwater flows through aquifers that are made up of soils and rock consisting of various minerals. Depending on the chemical make-up of these minerals, constituents dissolved in groundwater can be taken into the mineral structure and removed from the groundwater. In some cases, absorption of one constituent may release another one into the groundwater (ion exchange). Clay minerals, because of their chemical structure, are very effective at adsorbing many different constituents. The primary mineral that makes up sand, quartz, is not very reactive chemically. However, sand grains in an aquifer are often coated with iron or aluminum oxides. These oxides also have the ability to adsorb other elements into their structures. Finally, organic carbon that may be associated with aquifer materials can bind various constituents.

During the RI/FS, it will be important to understand the effect these processes may be having on migration of CCB-derived constituents.

3.9 Potential Receptors

The final component of the conceptual model is the identification of potential receptors. Both ecological and human health receptors are considered.

3.9.1 Human Health Conceptual Site Model

The conceptual site model (CSM) for human health is used to guide identification of appropriate exposure pathways and receptors for evaluation in the risk assessment. The purpose of the CSM is to identify source areas, potential migration pathways of constituents from source areas to environmental media where exposure can occur, and to identify potential human receptors.

The first step in the developing the CSM is the characterization of the setting of the site and surrounding area. Current and potential future site uses and potential receptors (i.e., residential or industrial receptors who may contact the impacted environmental media of interest) are then identified. Potential exposure scenarios identifying appropriate environmental media and exposure pathways for current and potential future site uses and receptors are then developed. Those potential exposure pathways for which constituents of potential concern (COPCs) are identified and which are complete are evaluated quantitatively in the risk assessment. The CSM is meant to be a “living” model and will be updated and modified as additional data become available.

The Area of Investigation contains residential areas. Each house may have its own drinking water well or septic system or both. In other areas, a municipal water distribution service may have been

installed. Human receptors may potentially contact surface CCBs that have been used as fill in the area as well as CCB-derived constituents that have potentially leached from CCBs into groundwater, surface water, and sediment. Potential human receptors include town residents, recreational receptors (i.e., people who visit the site but do not reside in the area), and construction workers. Potential receptors and how they may contact CCBs are described in greater detail below.

- **Residents.** Residents (adults and children) may potentially contact surface CCBs directly via incidental ingestion and dermal contact. Additionally, residents (adults and children) may inhale CCB particulates entrained in dusts. Where groundwater is used as a source of drinking water, residents (adults and children) may ingest CCB-derived constituents that have leached into groundwater. The potential drinking water pathway is only complete for those residents who are not on municipal water. Those residents not receiving municipal water may also potentially contact CCB-derived constituents in groundwater while bathing. Residential children who play in the local ditches/wetlands may contact CCB-derived constituents that have potentially discharged into surface water and sediment (via incidental ingestion and dermal contact).
- **Recreational Visitors.** Recreational visitors may be adults who fish in the local ditches/wetlands or children who play in the local ditches/wetlands. Recreational visitors may inhale CCB particulates entrained in dusts. Additionally, recreational fishers and recreational children may contact CCB-derived constituents that have potentially discharged into surface water and sediment (via incidental ingestion and dermal contact). Recreational fishers may also be exposed to CCB-derived constituents in fish tissue via consumption. Recreational visitors may also ingest groundwater as drinking water.
- **Construction Workers.** Construction workers may potentially contact surface and subsurface CCBs directly via incidental ingestion and dermal contact. Additionally, construction workers may inhale CCB particulates entrained in dusts. Construction workers may also directly contact CCB-derived constituents in groundwater via incidental ingestion and dermal contact if groundwater is encountered during an excavation. Construction workers may also ingest groundwater as drinking water.

3.9.2 Preliminary Ecological Conceptual Site Model

A preliminary ecological CSM was developed to provide a clear and concise description of how ecological receptors may come into contact with ecological constituents of potential ecological concern (COPECs) via release mechanisms and exposure to soil, sediment, and/or surface water. The CSM will be finalized as part of the Problem Formulation step of the Screening-level Ecological Risk Assessment (SERA), including information from the RI, and will explicitly identify the ecological resources that are to be evaluated. These will be defined within the risk assessment process as a set of assessment endpoints. Assessment endpoints will be selected to evaluate wildlife and habitats of ecological and/or socioeconomic importance. Finally, the CSM will describe how potential risk to

assessment endpoints will be quantified through a series of analyses or measurement endpoints. A preliminary discussion of the ecological communities and potential receptors is given below.

The Brown Ditch drainage system is associated with a series of wetland communities around the Area of Investigation. These wetlands are identified on the United States Fish and Wildlife Service (USFWS) 1987 National Wetlands Inventory Map (USFWS, 1987) with a variety of designations including: Palustrine Forested Broad-leaved Deciduous Temporarily Flooded (PFO1A), Palustrine Forested Broad-leaved Deciduous Seasonally Flooded (PFO1C), and Palustrine Emergent Marsh Seasonally Flooded (PEMC). These wetlands are located between the dune ridges and represent areas where Brown Ditch is likely to be ponded and support aquatic vegetation. In these areas, the ecology of Brown Ditch more likely approximates a linear wetland than a flowing channel. Additional information on the wetland communities will be provided as part of the Problem Formulation section in the Tier I Ecological Risk Assessment (ERA). Additional information on the wetland communities will be provided as part of the Problem Formulation section in the SERA.

As part of the SERA, potential ecological risk due to surface CCBs in upland habitat areas will be assessed. Upland areas within the Area of Investigation consist of residential areas within the Town of Pines, forested areas, active or former agricultural areas, transportation corridors, and disposal areas. For purposes of the RI/FS ERA Work Plan, the upland areas of interest will be those where CCB fill was placed or has migrated to surface soils. Further investigation regarding the extent of CCBs will be conducted in the RI to identify potentially affected areas. General ecological habitats will be identified for the Area of Investigation, with special focus on the areas between 2nd Place in the Town of Pines and the northern border of the east branch of Brown Ditch. For purposes of the Problem Formulation, it is assumed that upland habitats of interest will likely include forested area and old-fields (i.e., former agricultural areas reverting to shrubs and saplings).

There appears to be little specific information about the ecological receptors in Brown Ditch prior to its entry into the IDNL. Information is available concerning the species of fish, macrobenthos, and wildlife communities found in the Grand Calumet River Drainage Basin (at the western end of the IDNL); and this information may be relevant to the Area of Investigation as well (USACE, 1996). In addition, the IDNL has been extensively surveyed and inventoried, and is ranked 7th among National Parks in terms of its native plant diversity. It is reported that 1,445 vascular plant species are located with park boundaries, of which over 90 are on the Indiana threatened or endangered list (NPS, 2004). Additional information on the ecological receptors will be provided as part of the Problem Formulation section in the SERA. The National Park Service (NPS) has provided an extensive list of references regarding ecological inventories and ecological work conducted in the IDNL which will help support the selection of representative species (see Appendix N).

Requests were made to USFWS and Indiana Department of Natural Resources (IDNR) regarding information on federal and state-listed endangered, threatened, or rare species, critical habitat, riparian area, and other sensitive natural resources. Copies of these requests and the responses are included in Appendix G. The USFWS response letter indicated that the Area of Investigation is within the range

of three Federally-listed species: Indiana bat (*Myotis sodalis*), bald eagle (*Haliaeetus leucocephalus*) and pitcher's (or dune) thistle (*Cirsium pitcheri*) (Pruitt, 2004). The IDNR response letter indicated that two state-listed plant species had been recorded to occur with the Area of Investigation, namely the Baltic rush (*Juncus balticus* var. *littoralis*) and Tower-mustard (*Arabis glabra*) (Kiefer, 2004). These species will be taken into consideration when selecting the assessment and measurement endpoints in the SERA.

The ecological CSM will provide a schematic representation of the potential CCB-derived constituent release mechanisms, the exposure pathways, and potential ecological communities or wildlife receptors to be assessed. The two primary release mechanisms for CCB-derived constituents at the Pines Area of Investigation to reach potential ecological receptors are (1) the infiltration and percolation of CCB-derived constituents into the groundwater, with secondary releases occurring via groundwater discharge to surface water and transport to the shallow saturated zones in wetlands; and (2) surface run-off, erosion, or transport of CCB-derived constituents into surface water bodies (e.g., man-made ponds) or shallow soils.

Migration to surface water may lead to increases in constituent concentrations in various aquatic media (i.e., surface water, sediments, and fish tissue) and may result in exposure pathways to higher trophic level ecological receptors. Concentrations of CCB-derived constituents may be transported via the groundwater in the shallow saturated zone and may lead to wetland plant root uptake and translocation into leafy plant tissue. This would result in potential exposure to wetland plants (e.g., phytotoxicity) as well as constituent exposure by foraging herbivores.

The other major potential release mechanism is the migration of CCB from areas of historic placement of fill in roadways into upland soil within sections of the Area of Investigation. This may result in the potential exposure of terrestrial ecological receptors. As noted earlier, the importance of this exposure pathway is uncertain due to the lack of knowledge of where the CCB fill has been placed in or migrated to ecological habitats. As indicated earlier, this pathway will be fully investigated in conjunction with the RI, once areas of ecological habitat and CCB fill have been established.

The relevant potential exposure pathways identified in the preliminary CSM include:

- Potential exposure of aquatic, benthic, plant, amphibian, avian, and mammalian receptors to CCB-derived constituents in surface water of the Brown Ditch system, adjacent man-made ponds/basins, and other potentially affected water bodies (as indicated by groundwater investigation results);
- Potential exposure of aquatic, benthic, amphibian, plant, avian, and mammalian receptors to CCB-derived constituents in sediments of the Brown Ditch system, adjacent man-made ponds/basins, and other potentially affected water bodies (as indicated by groundwater investigation results);

- Potential exposure of wetland vegetation to CCB-derived constituents through root uptake of groundwater from the shallow saturated zone (as indicated by groundwater investigation results);
- Potential exposure of avian and mammalian receptors (herbivores, omnivores, and carnivores) to CCB-derived constituents in Brown Ditch system, adjacent man-made ponds/basins, and other potentially affected water bodies through bioaccumulation by ingestion of food items (e.g., plants, fish);
- Potential exposure of terrestrial vegetation and soil invertebrates to CCB-derived constituents in upland terrestrial habitat areas potentially affected by historic fill areas; and
- Potential exposure of terrestrial avian and mammalian receptors (herbivores, omnivores, insectivores, and carnivores) to CCB-derived constituents in upland terrestrial habitat areas potentially affected by historic fill areas.

In evaluating these exposure pathways, the SERA will consider information on species which are sensitive to CCBs, as well as the more sensitive life stages in selection of representative receptor species. These potential exposure pathways will be further detailed and evaluated in the RI.

4.0 DATA GAPS

The preliminary conceptual model presented in Section 3 is based on available information. It is clear that there is a large quantity of information in the immediate vicinity of Yard 520, and that there is a large amount of regional information. However most of the Area of Investigation is outside of Yard 520, and little detail is known. Even the groundwater chemistry data is difficult to interpret due to lack of knowledge about construction of private wells. The following is a list of general data gaps. Additional information will be needed on these topics in order to complete the RI.

- **Geology.** Characterization is needed for the Area of Investigation, including depth to confining unit, characterization of surficial aquifer, extent of swamp/peat deposits, and an understanding of the deeper aquifers and the extent to which they influence the surficial aquifer.
- **Hydrogeology.** Characterization is needed for the Area of Investigation including groundwater levels, quantitative aquifer characteristics such as hydraulic conductivity, locations of groundwater divides, seasonal changes to the system, and sources and sinks to groundwater, and importance of confined aquifers.
- **Surface water hydrology.** A better quantitative understanding of the relative hydrological contributions of the east and west channels of Brown Ditch is needed, including understanding seasonal changes. If groundwater containing CCB-related constituents is found to discharge to other surface water bodies or wetlands, it will be important to characterize the hydrology of these systems as well.
- **Groundwater-surface water interactions.** It will be necessary to understand where and how much groundwater discharges to Brown Ditch, rates of surface water flow in Brown Ditch, and any seasonal changes to these. If groundwater containing CCB-related constituents is found to discharge to other surface water bodies or wetlands, it will be important to characterize the groundwater-surface water relationships at these locations as well.
- **Ecological habitats.** Additional information is needed on the benthic and fish communities potentially found in these drainage ditches and other relevant water bodies, the wildlife receptors expected there, and the wetland plant communities found there. Evaluation of the potential habitat for terrestrial ecological receptors in CCB fill areas also needs to be conducted.
- **CCBs.** The possible locations of CCBs outside Yard 520 and their chemical composition and physical characteristics will have to be verified to the extent necessary to appropriately characterize potential risks and potential leaching to groundwater. Additional locations of CCBs may have to be investigated. Additional design information about the older portions of Yard 520 may also be useful.

- Groundwater quality. The nature and extent of CCB-derived constituents in groundwater will be determined to the extent necessary to adequately evaluate current and potential future risks. This will include developing an understanding of general groundwater quality conditions in the area as well as background concentrations. Geochemical conditions affecting migration will also be evaluated. In addition, estimates of the site-related CCB-derived constituent concentrations in groundwater entering the IDNL and potentially present in the shallow saturated zone will be needed.
- Surface water and sediment quality. Data gaps to be filled to support characterization of the potential human health and ecological risk associated with Brown Ditch include synoptic surface water samples and sediment samples in the west channel, in the east channel of Brown Ditch, and in background areas (to be determined). Water quality parameters should include the constituents boron, molybdenum, Fe, Mn, and other inorganics, as well as general water quality parameters such as temperature, dissolved oxygen, pH, hardness, specific conductance, nitrate and flow measurements. Sediment quality parameters should also include grain size and total organic carbon.
- Potential Sources. Part of the RI will be to determine to what extent the CCBs may be contributing to the presence of boron and molybdenum above USEPA RALs. Potential contributions from other types of sources will be considered.
- Air quality. A potential human health exposure pathway is the inhalation of particulates derived from CCBs either at the surface or disturbed in an excavation. Due to the numerous potential background sources of CCB-related constituents in air, and the natural hourly, daily and seasonal fluctuations in air quality, it is likely that this data gap will be filled using models provided in USEPA guidance.
- Fish tissue. A potential human health exposure pathway is routine consumption of fish from Brown Ditch. An evaluation will be conducted to determine whether or not Brown Ditch can support a recreational fishery.

5.0 STRATEGY FOR COMPONENTS OF THE RI/FS

One of the purposes of this Site Management Strategy is to present the proposed approach for certain aspects of the RI/FS so they can be reviewed and approved prior to development of the more detailed RI/FS work plans. The RI and FS will include a number of standard investigation approaches and methods. These more standard aspects of the RI/FS will not be presented or discussed here. However, they will be incorporated into the RI/FS work plans. An overview of the entire RI/FS process is presented in Section 1.

Specific aspects of the RI/FS that are discussed in this document include:

- Approach for groundwater characterization;
- Approach for evaluating CCBs as a potential source to groundwater;
- Approach for the human health risk assessment;
- Approach for the ecological risk assessment; and
- Approach to address certain outlying areas of the Area of Investigation.

5.1 Groundwater Characterization

The overall objective of characterizing groundwater conditions during the RI is to evaluate whether there may be any current and/or potential future risks associated with exposure to groundwater. Specifically, this will involve addressing the following issues:

- Understanding the current and potential future extent of CCB-derived constituents and evaluating potential bathing and drinking water exposures outside the municipal water service area;
- Understanding the groundwater-to-surface water pathway and evaluating potential exposures to CCB-derived constituents that may discharge to surface water; and
- Understanding the pathway from groundwater to wetlands and the root zone, including the IDNL, and evaluating potential impacts of CCB-derived constituents along this pathway.

The preliminary conceptual model for the groundwater system was presented in Section 3. General data gaps were presented in Section 4. The purpose of the RI is to fill these data gaps and complete the conceptual model to meet the objectives listed above.

For this Area of Investigation, groundwater is the primary mechanism for movement of constituents. In order to meet the objectives listed above, it will be important to characterize the geologic/hydrogeologic

system in which the constituents are located, the nature and extent of the constituents in the system, their fate and transport, and how constituents may migrate in groundwater to reach surface water. This information will be used to understand the current distribution of CCB-derived constituents in groundwater, the potential migration of these constituents in the future, and enable an evaluation of current and potential risks associated with exposure to groundwater.

The groundwater characterization is likely to include the following types of activities:

- Test pits, soil borings, and/or monitoring wells will be installed to observe geologic conditions, including soil type, geologic variability, depth to confining unit, and the presence of low permeability zones.
- Monitoring wells and/or piezometers will be installed to enable monitoring of groundwater conditions. Locations and elevations of these points will be surveyed. Groundwater levels, vertical and horizontal hydraulic gradients, and aquifer properties will be used to determine directions and rates of groundwater flow. Groundwater samples will be collected to evaluate the extent of CCB-derived constituents.
- Staff gauges, piezometers, and/or streamflow monitoring will be used to understand hydraulic relationships between surface water and groundwater, including locations and rates of discharge, and seasonal variability.
- Groundwater samples will be analyzed for a list of inorganic constituents, including constituents typically associated with CCBs, constituents associated with other potential sources, and other indicator analytes. This information will be used to evaluate natural background levels and potential impacts of CCBs and/or other sources on groundwater. The constituent information will also be used to evaluate fate and transport conditions, including attenuation of constituents and attenuation processes.
- Changes in groundwater levels, gradients, flow directions, and constituent variability seasonally and/or temporally will be evaluated.
- Groundwater modeling may be used to aid in guiding investigation activities and interpreting results. As stated in the SOW to AOC II, if a numerical model is to be used, it will be identified in the RI/FS work plan or a subsequent technical memorandum to the USEPA for approval prior to use.
- The preliminary conceptual model presented in Section 3 will be updated and refined throughout the RI process.
- The potential future movement of CCB-derived constituents will be evaluated, based on the data collected, and, if appropriate, quantitative calculations of future extent and concentrations. Modeling (especially analytical) may be used to support this evaluation, if appropriate.

- Exposure point concentrations (EPCs) for current and potential future receptors of groundwater (including surface water, wetlands, root zone) will be calculated where appropriate for use in the risk assessments.

5.2 CCBs as Source to Groundwater

CCBs may be acting as sources of constituents to groundwater. The potential leaching from these materials will be evaluated during the RI.

As described in the preliminary conceptual model, there are several different types of CCBs whose chemistry and therefore potential for leaching is expected to vary. In addition, how the CCBs were used or placed in the environment is expected to affect leaching. For example, very small, shallow deposits are expected to have less potential as a source to groundwater compared to larger, more extensive, and deeper deposits. The surface cover will also affect leaching as it affects the amount of rainwater that infiltrates to reach groundwater. For example, rainwater is unable to reach deposits that are covered by impermeable surfaces, such as roads, thus reducing or eliminating leaching.

Therefore, in order to streamline and focus the evaluation of the CCBs, the Respondents propose that the first step in this study is to evaluate the site-specific factors that lead to leaching. Groundwater samples will be collected at selected CCB deposits that cover the range of expected factors. Analysis of these groundwater samples will be used to indicate what types of deposits may lead to unacceptable impacts to groundwater. The proposed steps in this evaluation are listed below.

1. The supposed locations of CCBs outside Yard 520 (see Figure 3) will be field verified. Based on the information on these deposits presented in Appendix F and on field observations, deposits will be characterized relative to the following factors:
 - Apparent type of CCB (fly ash, bottom ash/bottom slag, or a mixture, or not CCB at all based on field observations and/or chemical/physical analyses);
 - Areal extent of deposit (size);
 - Vertical extent of deposit (depth);
 - Anticipated depth to groundwater; and
 - Whether deposit may extend into the water table.
2. Based on the characterization of each deposit, a subset of deposits will be selected for further evaluation. The specific deposits will be selected to evaluate the range of factors listed above, and will be selected to minimize interferences from other potential sources.
3. At each of the selected deposits, one or more groundwater samples will be collected from the surficial aquifer. Samples will be analyzed for CCB-derived and other indicator analytes.

4. It is anticipated that the analytical results from these samples will enable identification of factors and the types of CCB deposits which might lead to impacts to groundwater. This information will then be used to focus additional investigation efforts on those factors or deposits meeting those identified criteria.
5. It is possible that additional information may be needed to make these determinations, such as evaluating groundwater impacts in different seasons, or excavating test pits to verify conditions of some of the deposits.

5.3 Human Health Risk Assessment

The purpose of the baseline human health risk assessment (HHRA) is to evaluate potential human health effects of chronic exposures to constituents of potential concern present in samples of environmental media within the Area of Investigation. The baseline HHRA will be conducted in accordance with the four-step paradigm for human health risk assessments developed by USEPA (USEPA, 1989a); these steps are:

- Data Evaluation and Hazard Identification;
- Toxicity Assessment;
- Exposure Assessment; and
- Risk Characterization.

Strategic issues related to each step of the risk assessment process are discussed below.

5.3.1 Data Evaluation and Hazard Identification

The purpose of the data evaluation and hazard identification process is two-fold: 1) to evaluate the nature and extent of CCB-derived constituents present within the Area of Investigation; and 2) to select a subset of these constituents identified as constituents of potential concern (COPCs) for quantitative evaluation in the risk assessment. While the specific COPCs to be evaluated in the risk assessment will not be determined until the data evaluation phase of the risk assessment, major constituent groups for analysis can be defined at this point. Per AOC II, metals will be analyzed. Based on information available to date, boron and molybdenum will be identified as COPCs in groundwater in the risk assessment.

In initial discussions, USEPA considered having a subset of investigation samples in the RI/FS analyzed for polychlorinated dibenzodioxins and dibenzofurans (PCDDs and PCDFs), radionuclides, and polycyclic aromatic hydrocarbons (PAHs). A review of available information was conducted, and the results are presented below.

5.3.1.1 Polychlorinated Dibenzodioxins/Dibenzofurans

USEPA conducted a Groundwater Pathway Risk Assessment (USEPA, 1998a) in order to characterize potential risks to human health and the environment from certain wastes, including coal-fired utility co-mingled wastes, oil-fired utility wastes, fluidized bed combustion wastes, and non-utility fossil fuel combustion wastes. PCDDs and PCDFs were excluded from the risk assessment based on a literature review of available data regarding PCDDs and PCDFs in coal fly ash. A detailed summary of the review is published in Appendix L of the risk assessment (USEPA, 1998a). Sixteen publications were reviewed by USEPA during the first two phases. The third phase consisted of a review of a report by EPRI (1998b).

Of the 16 publications reviewed during the first two phases of the assessment, eight contained information on PCDDs and PCDFs in samples of coal fly ash. The remaining eight summarized laboratory experiments, flue gas data, and theoretical information on the potential for PCDDs and PCDFs to form during the coal combustion process.

According to the assessment, three of the eight publications reporting on PCDDs and PCDFs indicated that PCDDs and PCDFs were not detected. The remaining five publications reported very low levels of PCDDs and/or PCDFs. Reported concentrations (as cited in USEPA, 1998a), converted to micrograms per kilogram (ug/kg), are presented below. When combined with current toxic equivalency factors (TEFs) (Van den Berg, 1998), relating the toxicity of each congener to that of 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD), the toxic equivalent concentrations (TEQs) are well below the USEPA Preliminary Remediation Goal (PRG) for 2,3,7,8-TCDD TEQs in residential soil of 1 ug/kg (USEPA, 1998c). Current TEFs and TEFs applicable at the time of the review are shown below.

Table 8 - Toxic Equivalency Factors

Compound	CAS NO.	1998 TEF (a)	1989 TEF (b)
Dioxins			
2,3,7,8-TetraCDD	1746-01-6	1	1
1,2,3,7,8-PentaCDD	40321-76-4	1	0.5
1,2,3,4,7,8-HexaCDD	39227-28-6	0.1	0.1
1,2,3,6,7,8-HexaCDD	57653-85-7	0.1	0.1
1,2,3,7,8,9-HexaCDD	19408-74-3	0.1	0.1
1,2,3,4,6,7,8-HeptaCDD	35822-39-4	0.01	0.01
OctaCDD	3268-87-9	0.0001	0.001
Furans			
2,3,7,8-TetraCDF	51207-31-9	0.1	0.1
1,2,3,7,8-PentaCDF	57117-41-6	0.05	0.05
2,3,4,7,8-PentaCDF	57117-31-4	0.5	0.5
1,2,3,4,7,8-HexaCDF	70648-26-9	0.1	0.1
1,2,3,6,7,8-HexaCDF	57117-44-9	0.1	0.1
1,2,3,7,8,9-HexaCDF	72918-21-9	0.1	0.1
2,3,4,6,7,8-HexaCDF	60851-34-5	0.1	0.1
1,2,3,4,6,7,8-HeptaCDF	67562-39-4	0.01	0.01
1,2,3,4,7,8,9-HeptaCDF	55673-89-7	0.01	0.01
OctaCDF	39001-02-0	0.0001	0.001

Notes:
CAS - Chemical Abstracts Service.
CDD- Chlorodibenzodioxin
CDF - Chlorodibenzofuran.
TEF - Toxicity Equivalency Factor.
(a) - "Toxic Equivalency Factors for PCBs, PCDDs, PCDFs for Humans and Wildlife." Van den Berg, et al. 1998.
(b) USEPA, 1989. Interim Procedures for Estimating Risks Associated with Mixtures of Chlorinated Dibenzop-dioxins and Chlorinated Dibenzofurans (CDDs and CDFs) and 1989 Update.

Reported concentrations and TEQs are listed below:

- American Electric Power Service Corporation, 1994:
 - 0.0003 ug/kg 2,3,4,6,7,8-HexaCDF [TEF = 0.1, TEQ = 0.00003 ug/kg)
 - 0.0014 ug/kg 1,2,3,4,6,7,8-HeptaCDD [TEF = 0.01, TEQ = 0.000014 ug/kg)

- Chiu et al., 1983:
 - 0.000001 to 0.00032 ug/kg (congeners not listed)
- Czuczwa, 1984:
 - 0.000002 to 0.000004 ug/kg OctaCDD [TEF = 0.0001, TEQ = 2E-10 to 4E-10 ug/kg]
- Kuykendal, et al., 1989:
 - 0.01 to 0.07 ug/kg OctaCDD [TEF = 0.0001, TEQ = 0.000001 to 0.000007 ug/kg]
 - 0.01 to 0.2 ug/kg unspecified HexaCDF [TEFs all = 0.1, TEQ = 0.001 to 0.02 ug/kg]
 - 0.01 to 0.2 ug/kg unspecified HeptaCDF [TEFs all = 0.01, TEQ = 0.0001 to 0.002 ug/kg]

The eight publications reviewed by USEPA that did not include fly ash data support the conclusion that appreciable levels of PCDDs and PCDFs are not formed during the coal combustion process. The temperature used to burn coal in a coal-fired power plant differs significantly from the temperature used in waste incinerators and does not promote the formation of PCDDs and PCDFs. In addition, the sulfur dioxide found in coal inhibits the formation of PCDDs and PCDFs.

A review of EPRI (1998b) was included in USEPA's assessment. The EPRI (1998b) report was also reviewed independently for this analysis. This report summarized the results of 15 samples of CCBs collected from 11 disposal sites which were analyzed for PCDDs and PCDFs. In addition to the 15 CCB samples, a sample of ash from a municipal waste incinerator was analyzed as a reference.

The results of the EPRI sampling indicated that PCDDs and PCDFs were either not detected or detected at very low concentrations in the CCB samples. Detection limits ranged from 0.0001 to 0.0031 ug/kg, with the higher detection limits being for congeners with low TEFs (OctaCDD and OctaCDF). 2,3,7,8-TCDD was not detected in any of the samples, and detection limits for this congener were less than 0.001 ug/kg. TEQs were calculated in several different ways for each sample, using full detection limits, one-half detection limits, or zero for congeners reported as not detected, and using either full or one-half values for congeners reported with Estimated Maximum Possible Concentrations (EMPCs). EMPCs are listed when there is evidence that a congener is present, but there is not enough evidence to satisfy all the criteria for listing it as a true detected response.

Calculated TEQ concentrations ranged from non-detect to 0.0021 ug/kg. The maximum calculated concentration of 0.0021 ug/kg, which was calculated using full detection limits and EMPC values and therefore represents the most conservative calculation method, is well below the USEPA PRG for residential soil of 1 ug/kg (USEPA, 1998c). It should be noted that the TEFs used to calculate the TEQ concentrations have been updated since the publication of the report. The TEFs for the 17 congeners are the same with the exception of three congeners. TEFs for OctaCDD and OctaCDF have

decreased by one order of magnitude, such that TEQ concentrations calculated using the updated TEFs would be lower than those presented in the report. The TEF for 1,2,3,7,8-PentaCDD has increased from 0.5 to 1; however, this congener was not detected in any of the CCB samples, thus there would be no change in the TEQ concentrations.

The review of the EPRI (1998b) report published in USEPA (1998a) concluded that while there may be some limitations in the data analysis and validation, the conclusions of the report are supported by the data. The reviewers concluded that the TEQ concentrations calculated assuming zero for non-detects and full EMPC values were the most valid, and these TEQ concentrations ranged from 0 to 0.000064 ug/kg, well below the residential PRG of 1 ug/kg.

Several additional studies have shown that dioxin concentrations in coal fly ash are less than 1 ug/kg on a TEQ basis, and are similar to background concentrations in soils (Sear et al., 2003; Ling et. al., 1998; Voutsas et al., 2004).

Based on the results of the literature review conducted for USEPA (1998a) and the results of the EPRI (1998b) study, any PCDDs and PCDFs which might be in fly ash and CCBs are on a TEQ basis well below the USEPA PRG for residential soil. To confirm this, limited sampling (5 to 10 samples) will be conducted for dioxins in CCBs at Yard 520. Reference samples will be collected from areas with no CCBs to determine site-specific background concentrations. The details of the sampling will be outlined in the RI/FS work plan, or another work plan. If the sampling indicates that dioxins are not present above background or risk-based screening levels (i.e., both human health and ecological risk-based screening levels), no further evaluation will be conducted. Additional evaluation will be recommended only if the sampling indicates that dioxins are present at a level above both site-specific background and risk-based screening levels.

5.3.1.2 Radionuclides

Radionuclides were not included as constituents of potential concern in the USEPA Groundwater Pathway Risk Assessment (USEPA, 1998a) based on a review of available data. In its document responding to comments (USEPA, 2000), USEPA states that radionuclides were not included in the risk assessment because radionuclides in coal and ash have not been found to be a problem in other USEPA studies (USEPA, 1989b; 1989c; and 1995, as cited in USEPA, 2000). USEPA (1989b, as cited in USEPA, 2000) discusses a study that examined potential exposures of workers and nearby residents to radioactivity from ash released from a coal pile through wind and runoff erosion. Exposure from direct contact, inhalation, and ingestion were estimated to fall below natural background radiation exposure levels even for a worker standing on the ash pile.

A fact sheet on radioactive elements in coal and fly ash by the USGS (1997) states that a majority of coal samples have radioactive uranium and thorium at concentrations that are within the same range as found in a variety of common rocks and soils. The concentration of radioactive elements in solid

combustion wastes (fly ash) is approximately ten times the concentration in the original coal. However, the uranium concentration in fly ash (10 to 30 mg/kg) is within the same range as found in some rocks and shales. A series of studies conducted from 1975 to 1985 evaluated the radiation hazard from airborne emissions of coal-fired power plants. These studies concluded that the maximum radiation dose to an individual living within 1 kilometer of a modern power plant has a minor (1 to 5%) increase above the radiation from the natural environment. Studies of dissolved uranium and radium in water leachates of fly ash show that dissolved concentrations of uranium and radium are below drinking water standards. In addition, a study conducted by Sear et al. (2003) concluded that there was no significant increase in radioactive composition in coal fly ash.

Therefore, it is concluded that radionuclides at most might be an insignificant factor in potential risks from CCBs. To confirm this, limited sampling (5 to 10 samples) will be conducted for radionuclides in CCBs at Yard 520 and gross alpha and gross beta activity in groundwater, unless other information becomes available that would lead to a conclusion by both the Respondents and the Agency that this would not be necessary. Reference samples will be collected from areas with no CCBs to determine site-specific background concentrations. The details of the sampling will be outlined in the RI/FS work plan, or another work plan. If the sampling indicates that radionuclides are not present above background or radionuclide PRGs (USEPA, 2004c) or available biota concentration guides (BCGs) (USDOE, 2002), no further evaluation will be conducted. Additional evaluation will be recommended only if the sampling indicates that radionuclides are present at a level above both site-specific background and radionuclide PRGs or BCGs.

5.3.1.3 Polycyclic Aromatic Hydrocarbons

PAHs were not included as constituents of potential concern in the USEPA Groundwater Pathway Risk Assessment (USEPA, 1998a) based on a review of available data. In its document responding to comments (USEPA, 2000), USEPA concluded:

“...that organic constituents, including PAHs, are infrequently present in [fossil fuel combustion] wastes at levels above analytical detection limits. This conclusion is consistent with the expectation that organics are destroyed in the combustion process or pass out the stack. Given this conclusion, the Agency did not consider organics in its risk assessment. EPA also did not include a detailed summary of the organics characterization data from these sources in the docket, because any such summary would consist primarily of non-detects.”

EPRI published a literature review in 1987 which summarized data on inorganics and organics in fossil fuel combustion residues (EPRI, 1987a). The report summarized several publications regarding PAHs in fly ash and fly ash extract.

Results of extract data from Illinois basin coal fly ash indicated that less than 1 mg/L of phenanthrene, pyrene, and chrysene were detected (Roy, et al., 1984, as cited in EPRI, 1987a). In a study of over

100 organic compounds in wet scrubber and electrostatic precipitator ash, pyrene was detected at a concentration of 20 ug/L in extracts (Harrison, et al., 1985, as cited in EPRI, 1987a). Naphthalene was also found in extracts of both fly ash types. However, based on the partitioning coefficient for naphthalene, all PAH compounds identified in the two ash types were determined to “pose little concern for potential groundwater contamination,” with concentrations less than in some drinking water samples (Harrison, et al., 1985, as cited in EPRI, 1987a).

PAH concentrations in fly ash samples ranged from trace to 0.9 ug/kg (total PAHs of 4 ug/kg) in a study of electrostatic precipitator hopper ash (Griest and Guerin, 1979, as cited in EPRI, 1987a). A second study of PAHs in fly ash reported concentrations ranging from 8 ug/kg (benzo(a)pyrene) to 200 ug/kg (2-methylchrysene), with the total of 10 PAHs reported at 833 ug/kg. Four PAHs (2-methylchrysene, chrysene, 3-methylpyrene, and 2-methylphenanthrene) accounted for over 70% of the total PAH concentration (Tomkins, et al., 1983, as cited in EPRI, 1987a).

In several studies of coal fly ash, total PAH concentrations were detected at low levels, generally less than 10 mg/kg, with many reporting levels less than 1 mg/kg (Ariditsoglou, et al., 2004; Sear et al., 2003; Vousta et al., 2004). According to Ariditsoglou et al. (2004), five and six ring PAHs contribute the least to total PAH concentration, which is of interest given this group includes five of the potentially carcinogenic PAHs (benzo(a)anathracene, benzo(b)fluoranthene, benzo(a)pyrene, dibenzo(a,h)anthracene, indeno(1,2,3-cd)pyrene). Another study reported that phenanthrene, pyrene, and fluoranthene were the dominant PAHs in coal fly ash (Vousta et al., 2004).

Based on the EPRI (1987a) report, concentrations of PAHs in both fly ash extract and fly ash are very low and are below regulatory limits. In addition, where PAHs were detected in fly ash samples, the highest concentrations are limited to PAHs exhibiting little toxicity. USEPA’s Groundwater Pathway Risk Assessment (USEPA, 1998a, 2000) reports similar findings. To confirm this, limited sampling (5 to 10 samples) will be conducted for PAHs in CCBs at Yard 520. Reference samples will be collected from areas with no CCBs to determine site-specific background concentrations. The details of the sampling will be outlined in the RI/FS work plan, or another work plan. If the sampling indicates that PAHs are not present above background or risk-based screening levels (i.e., both human health and ecological risk-based screening levels), no further evaluation will be conducted. Additional evaluation will be recommended only if the sampling indicates that PAHs are present at a level above both site-specific background and risk-based screening levels.

5.3.2 Toxicity Assessment/Dose-Response Assessment

The purpose of the dose-response assessment is to identify the types of adverse health effects a constituent may potentially cause, and to define the relationship between the dose of a constituent and the likelihood or magnitude of an adverse effect (response) (USEPA, 1989a). Adverse effects are classified by USEPA as potentially carcinogenic or noncarcinogenic. Dose-response relationships are defined by USEPA for oral exposure and for exposure by inhalation. USEPA’s current dose-response

values are provided in an on-line database, the Integrated Risk Information System (IRIS) (USEPA, 2004a). Oral toxicity values are also used to assess dermal exposures, with appropriate adjustments, because USEPA has not yet developed values for this route of exposure. Combining the results of the toxicity assessment with information on the magnitude of potential human exposure provides an estimate of potential risk.

Boron and molybdenum have been identified as two of the COPCs in groundwater for the human health risk assessment. Neither constituent is identified as a potential carcinogen and both are evaluated quantitatively by USEPA based on potential noncarcinogenic effects. Constituents with known or potential noncarcinogenic effects are assumed to have a dose below which no adverse effect occurs or, conversely, a dose above which an adverse effect may be seen. This dose is called the threshold dose. USEPA currently uses one of two methods for estimating a conservative threshold dose for use in human health risk assessments:

- The application of uncertainty factors to a no observed adverse effect level (NOAEL), which is the highest dose in studies at which no adverse effects were observed, or to the lowest observable adverse effect level (LOAEL), which is the lowest dose in studies at which an adverse effect was observed; or
- The application of uncertainty and/or variability factors to the benchmark dose-lower limit (BMDL), which is a calculated level using the distribution of study data, and generally corresponds to the dose at which 95% of the population would not be expected to exhibit adverse effects.

By applying uncertainty factors to the NOAEL or the LOAEL, Reference Doses (RfDs) for chronic exposure to constituents with noncarcinogenic effects have been developed by USEPA (1997a, 2004a). For constituents with noncarcinogenic effects, an RfD provides reasonable certainty that no noncarcinogenic health effects are expected to occur even if daily exposures were to occur at the RfD level for a lifetime. RfDs and exposure doses are expressed in units of milligrams of a constituent per kilogram of body weight per day (mg/kg-day). The larger the RfD value, the higher is the assumed threshold for effects, i.e., there is a lower potential for effects to occur. The most current RfDs available at the time that a risk assessment is conducted are to be used per USEPA guidance (USEPA, 1989a). Therefore, the most current dose-response information, e.g., RfDs, will serve as the basis for the HHRA for the Pines Area of Investigation, which is a component of the RI/FS. A detailed work plan for the HHRA will be provided as a component of the RI/FS Work Plan for the Pines Area of Investigation.

5.3.3 USEPA RALs

The published USEPA RALs (USEPA, 1998b) have been used by USEPA in the area of the Town of Pines as precautionary levels to determine whether bottled water should be offered to residents on a temporary basis. In addition, the RALs have been used by USEPA as the basis for requiring an RI/FS

for the Pines Area of Investigation. RfDs can be used as the basis for developing USEPA RALs for the Superfund program (USEPA, 1998b). RALs are to be used as one factor in determining whether to provide interim alternate water supplies under Superfund removal authority. The USEPA RAL guidance notes that published numeric RALs “do not in any way restrict the flexibility to develop and apply site-specific RALs” (USEPA, 1998b).

The RALs used by USEPA for the Town of Pines were published by USEPA’s Office of Solid Waste and Emergency Response (OSWER) in November of 1998 (USEPA, 1998b) based on the USEPA RAL tables developed by the Agency in April, 1997, which in turn were based in part on the then current (1996) Drinking Water Standards and Health Advisories published by the USEPA Office of Water (USEPA, 1996). For both boron and molybdenum, the USEPA RAL is based on a health advisory for a “longer-term child” scenario. Since the time that the USEPA RALs were developed in 1997, there have been developments for both boron and molybdenum that are discussed below.

5.3.3.1 USEPA RAL for Boron

The RAL used by USEPA for the Town of Pines for boron is 0.9 mg/L. However, it is based on the now out-dated RfD of 0.09 mg/kg-day. Since the USEPA RALs have not been updated by USEPA since 1997, it is not certain when or if they may be updated in the future. However, if the USEPA RAL were to be updated by OSWER using the current RfD of 0.2 mg/kg, an updated RAL could be approximately 2.2 times greater, or 2 mg/L.

Appendix H provides a constituent profile for boron, and a short information sheet on boron is provided in Appendix J of this document.

5.3.3.2 USEPA RAL for Molybdenum

The RAL used by the USEPA for the Town of Pines for molybdenum is 0.01 mg/L and is based on a “longer-term child” scenario from the Drinking Water Regulations and Health Advisory from 1996 (USEPA, 1996). The 2004 Drinking Water Standards and Health Advisories (USEPA, 2004b) provides a value of 0.08 mg/L for molybdenum for the child scenarios, which is 8 times greater than the USEPA RAL and no longer includes a longer-term child scenario. However, a “longer-term child” scenario value calculated following USEPA RAL guidance (USEPA, 1993) could be 0.05 mg/L. This value is 5 times greater than the current USEPA RAL for molybdenum. As noted above, since the RALs have not been updated by USEPA since 1997, it is not certain when or if they may be updated in the future.

Appendix I provides a constituent profile for molybdenum, and a short information sheet on molybdenum is provided in Appendix J of this document.

5.3.4 Exposure Assessment

The CSM for the HHRA, which presents potential exposure pathways and receptors, was discussed in Section 3.9.2.

5.3.5 Risk Characterization

The potential risk to human health associated with potential exposure to COPCs in environmental media is evaluated in this step of the risk assessment process. Risk characterization is the process in which the dose-response information identified in the Toxicity Assessment is integrated with quantitative estimates of human exposure derived in the Exposure Assessment. The result is a quantitative estimate of the likelihood that humans will experience any adverse health effects given the exposure assumptions made. Two general types of health risk are characterized for each potential exposure pathway considered: potential carcinogenic risk and potential noncarcinogenic hazard. For noncarcinogenic hazard, the target risk level is a Hazard Index of one. For potentially carcinogenic effects, USEPA provides a risk range of between 10^{-4} and 10^{-6} as the target level. According to the National Contingency Plan (NCP) in the Code of Federal Regulations (CFR) Section 300.430 (e) (2)(i)(A)(2):

“For known or suspected carcinogens, acceptable exposure levels are generally concentration levels that represent an excess upper bound lifetime cancer risk to an individual of between 10^{-4} and 10^{-6} using information on the relationship between dose and response. The 10^{-6} risk level shall be used as the point of departure for determining remediation goals for alternatives when ARARs are not available or are not sufficiently protective because of the presence of multiple contaminants at a site or multiple pathways of exposure;”

and OSWER Directive 9355.0-30, April 1991 (USEPA, 1991):

“Where the cumulative carcinogenic site risk to an individual based on reasonable maximum exposure for both current and future land use is less than 10^{-4} , and the non-carcinogenic hazard quotient is less than 1, action generally is not warranted unless there are adverse environmental impacts.”

This guidance will be used in the characterization of risk in the baseline HHRA.

5.3.6 Screening Level Risk Assessment

The CSM identifies direct-contact with CCBs as a potentially complete exposure pathway. During the implementation of AOC I (amended), there is an opportunity to conduct some site characterization for the purposes of the AOC II RI/FS, as trenches will be dug along the path of the water supply lines.

The Respondents propose to have an ENSR staff member observe the AOC I excavations (in coordination with the local contractor), and collect samples of suspected CCBs where they are encountered. Samples will be collected for visual inspection and laboratory analysis for total metals and additional analytes. The Respondents have prepared and submitted to USEPA a sampling and analysis plan (SAP) for this work, which will occur in advance of the RI/FS work plan submittal.

The data are proposed to be used to conduct a screening level HHRA for direct contact (ingestion/dermal contact) with CCBs. If the screening level risk assessment indicates that potential risks and hazards are below the target levels, it may not be necessary to conduct a full quantitative HHRA for the direct exposure to CCBs pathways in the RI/FS. The approach for the cumulative screening is presented in Section 5.3.6.1 below.

As noted earlier (Section 3.6.4), two samples of CCBs were collected during the AOC I (2003) project, and analyzed for total metals. As an example of this process, the data were used in a screening level risk assessment using a cumulative risk screen approach, as discussed in Section 5.3.6.2 below.

5.3.6.1 Cumulative Screen Approach

For the purposes of the screening level risk assessment presented in Tables 9 and 10, the USEPA Region 9 PRGs (USEPA, 2002a) were used (the screening levels to be used in the RI/FS human health risk assessment will be identified in the RI/FS Work Plan). The electronic version of the Region 9 PRG table (USEPA, 2002a) provides PRGs for both potential carcinogenic and noncarcinogenic effects, where both exist. To perform a comprehensive cumulative risk screen, constituents are grouped into those evaluated for potential carcinogenic effects and those evaluated for potential noncarcinogenic effects. The same constituent may appear on both lists, as some constituents have USEPA dose-response values for both types of effects. For constituents with potential carcinogenic effects, the maximum detected concentration is divided by the PRG and multiplied by 1×10^{-6} (the target risk level on which the PRGs are based) to obtain an estimated potential carcinogenic risk. For constituents with noncarcinogenic effects, the maximum detected concentration is divided by the PRG to obtain an estimated hazard quotient (HQ). Any constituent with a potential carcinogenic risk greater than 1×10^{-4} or an HQ greater than one is identified as a potential risk driver.

In a second step, constituents whose constituent-specific carcinogenic risk is within or less than the target risk range of 1×10^{-6} to 1×10^{-4} and HQ is less than 1, but may still contribute significantly to total risk, are identified. In this second step, the potential carcinogenic risks and the potential HQs for the remaining constituents are summed to arrive at a total potential carcinogenic risk and a total Hazard Index (HI), respectively. If the total potential carcinogenic risk is greater than the target risk range of 1×10^{-6} to 1×10^{-4} and the total HI (on a toxic endpoint specific basis) is greater than 1, those constituents that cause the exceedance are identified as potential risk drivers. This is accomplished by an iterative step of subtracting the highest constituent-specific carcinogenic risk and non-carcinogenic

HQ from the totals until the sum of the remaining constituent-specific risks and HQs is less than 1×10^{-4} and 1, respectively.

It should be noted that a different approach is used for lead. The PRGs for lead are based on integrated uptake exposure models for human exposure. Lead is not included in the cumulative risk totals, but is compared directly to the PRG. If the concentration is less than the PRG, lead is not identified as a potential risk driver. If the maximum concentration is greater than the PRG, then lead is identified as a potential risk driver.

5.3.6.2 Cumulative Risk Screen Results

Two CCB samples (LP 2 and SP 2) were collected during the implementation of AOC I in 2003. The samples were analyzed for total metals. A cumulative risk screen was conducted on the analytical results of each sample.

As indicated in the tables presented below, the potential carcinogenic risk associated with detected metals in sample LP 2 is 6.09×10^{-5} , which is below the target of 1×10^{-4} . The potential HQ associated with the As concentration in sample LP 2 is 1.05, slightly greater than one. The potential HI associated with the remaining metals detected in LP 2 is 0.73, which is less than the target of one. Additionally, the detected concentration of lead is less than the PRG. Therefore, As is identified as the only potential risk driver in sample LP 2.

The potential carcinogenic risk associated with detected metals in sample SP 2 is 1.73×10^{-5} , which is below the target of 1×10^{-4} . The potential HI associated with metals detected in SP 2 is 0.76, which is less than the target of one. Additionally, the detected concentration of lead is less than the PRG. Therefore, no potential risk drivers are identified in sample SP 2.

Table 9 – Example Human Health Screen for Constituents Detected in Soil Sample LP 2

Constituent	CAS Number	Residential Soil PRG (a) (mg/kg)	Soil Concentration at LP 2 12/4/2003 (mg/kg)	Ratio - Soil Concentration: PRG Standard (c)	Percent of Total Risk or Hazard Index	Does Constituent Contribute to an Exceedance of Target Risk Levels (g)
Potential Carcinogens						
Arsenic	7440-38-2	0.39	23	5.90E-05	97%	NO
Beryllium	7440-41-7	1053	4.2	3.99E-09	0.007%	NO
Cadmium	7440-43-9	1405	2.6	1.85E-09	0.003%	NO
Chromium (total)	7440-47-3	30	(d) 57	1.90E-06	3.12%	NO
Cobalt	7440-48-4	903	6.9	7.64E-09	0.01%	NO
Total Potential Carcinogenic Risk:				6.09E-05	100%	
Noncarcinogens						
Arsenic	7440-38-2	22	23	1.05E+00	--	YES
Aluminum	7429-90-5	76142	14000	1.84E-01	24%	NO
Barium	7440-39-3	5375	110	2.05E-02	2.6%	NO
Beryllium	7440-41-7	154	4.2	2.73E-02	3.5%	NO
Boron	7440-42-8	15622	45	2.88E-03	0.37%	NO
Cadmium	7440-43-9	37	2.6	7.03E-02	9.1%	NO
Calcium	7440-70-2	EN	11000	EN	--	NO
Chromium (total)	7440-47-3	223	(d) 57	2.56E-01	33%	NO
Cobalt	7440-48-4	1380	6.9	5.00E-03	0.65%	NO
Copper	7440-50-8	3129	19	6.07E-03	0.79%	NO
Iron	7439-89-6	EN	37000	EN	--	NO
Magnesium	7439-95-4	EN	3700	EN	--	NO
Manganese	7439-96-5	1762	200	1.14E-01	14.7%	NO
Molybdenum	7439-97-7	391	3	7.67E-03	1.0%	NO
Nickel	7440-02-0	1564	14	8.95E-03	1.2%	NO
Potassium	7440-09-7	EN	2500	EN	--	NO
Sodium	7440-23-5	EN	380	EN	--	NO
Vanadium	7440-62-2	548	38	6.93E-02	9.0%	NO
Zinc	7440-66-6	23463	59	2.51E-03	0.33%	NO
Total Potential Hazard Index:				7.73E-01	100%	
Other Constituents						
Lead	7439-92-1	400	(f) 25	(b)		NO

Notes:

CAS - Chemical Abstracts Service

EN - Essential nutrient. Not included as a constituent of potential concern for human health risk.

PRG - Preliminary Remediation Goal.

(a) - U.S. EPA Region 9 PRG Table. October 2002 (and February 2003 revisions). Value for residential soil. Target risk = 1×10^{-6} , Target Hazard Index = 1.0.

(b) - Ratio not calculated. Standard is compared directly to the soil concentration.

(c) - PRG standards for potential carcinogens based on 1×10^{-6} cancer risk - for these constituents, each ratio is multiplied by 1×10^{-6} to provide the resulting risk. PRG standards for noncarcinogens are based on a target hazard quotient of 1.0 - for these constituents, the unadjusted ratio is the resulting hazard quotient.

(d) - PRG for hexavalent chromium; PRG for total chromium is 210 mg/kg for potential carcinogenic effects (1:6 ratio VI:III).

No PRG is available for total chromium for noncarcinogenic effects; the PRG for chromium III noncarcinogenic effects is 11,700 mg/kg.

(f) - PRG for lead is based on noncarcinogenic effects, but was developed using an exposure model.

(g) - Constituent is considered to contribute to an exceedance of target risk levels if it contributes to a cumulative risk greater than the target risk range of 1×10^{-6} to 1×10^{-4} or a cumulative hazard index greater than 1.

Table 10 – Example Human Health Screen for Constituents Detected in Soil Sample SP 2

Constituent	CAS Number	Residential Soil PRG (a) (mg/kg)	Soil Concentration SP 2 12/9/2003 (mg/kg)	Ratio - Soil Concentration: PRG Standard (c)	Percent of Total Risk or Hazard Index	Does Constituent Contribute to an Exceedance of Target Risk Levels (h)
Potential Carcinogens						
Arsenic	7440-38-2	0.39	6.3	1.62E-05	93%	NO
Beryllium	7440-41-7	1053.4	3.3	3.13E-09	0.018%	NO
Cadmium	7440-43-9	1405	1.7	1.21E-09	0.007%	NO
Chromium (total)	7440-47-3	30 (d)	34	1.13E-06	6.6%	NO
Cobalt	7440-48-4	903	5.1	5.65E-09	0.03%	NO
Total Potential Carcinogenic Risk:				1.73E-05	100%	
Noncarcinogens						
Aluminum	7429-90-5	76142	NA	NA	--	NO
Arsenic	7440-38-2	22	6.3	2.86E-01	37%	NO
Barium	7440-39-3	5375	110	2.05E-02	2.7%	NO
Beryllium	7440-41-7	154	3.3	2.14E-02	2.8%	NO
Boron	7440-42-8	15622	30	1.92E-03	0.25%	NO
Cadmium	7440-43-9	37	1.7	4.59E-02	6%	NO
Calcium	7440-70-2	EN	16000	EN	--	NO
Chromium (total)	7440-47-3	223 (d)	34	1.52E-01	20%	NO
Cobalt	7440-48-4	1380	5.1	3.70E-03	0.5%	NO
Copper	7440-50-8	3129	24	7.67E-03	1%	NO
Iron	7439-89-6	EN	11000	EN	--	NO
Magnesium	7439-95-4	EN	5600	EN	--	NO
Manganese	7439-96-5	1762	280	1.59E-01	21%	NO
Molybdenum	7439-97-7	391	3.6 (f)	9.21E-03	1.2%	NO
Nickel	7440-02-0	1564	12	7.67E-03	1.0%	NO
Potassium	7440-09-7	EN	1800	EN	--	NO
Selenium	7782-49-2	391	1.9	4.86E-03	0.6%	NO
Sodium	7440-23-5	EN	360	EN	--	NO
Vanadium	7440-62-2	548	22	4.01E-02	5.3%	NO
Zinc	7440-66-6	23463	85	3.62E-03	0.5%	NO
Total Potential Hazard Index:				7.64E-01	100%	
Other Constituents						
Lead	7439-92-1	400 (g)	86	(b)		NO

Notes:

CAS - Chemical Abstracts Service

EN - Essential nutrient. Not included as a constituent of potential concern for human health risk.

PRG - Preliminary Remediation Goal.

(a) - U.S. EPA Region 9 PRG Table. October 2002 (and February 2003 revisions). Value for residential soil. Target risk = 1×10^{-6} , Target Hazard Index = 1.0.

(b) - Ratio not calculated. Standard is compared directly to the soil concentration.

(c) - PRG standards for potential carcinogens based on 1×10^{-6} cancer risk - for these constituents, each ratio is multiplied by 1×10^{-6} to provide the resulting risk. PRG standards for noncarcinogens are based on a target hazard quotient of 1.0 - for these constituents, the unadjusted ratio is the resulting hazard quotient.

(d) - PRG for hexavalent chromium; PRG for total chromium is 210 mg/kg for potential carcinogenic effects (1:6 ratio VI:III).

No PRG is available for total chromium for noncarcinogenic effects; the PRG for chromium III noncarcinogenic effects is 11,700 mg/kg.

(e) - PRG for mercury and compounds.

(f) - Two Molybdenum results reported in the February 4, 2004 lab report from Simalabs, (1.5 and 3.6 mg/kg) highest value is included in the screen.

(g) - PRG for lead is based on noncarcinogenic effects, but was developed using an exposure model.

(h) - Constituent is considered to contribute to an exceedance of target risk levels if it contributes to a cumulative risk greater than the target risk range of 1×10^{-6} to 1×10^{-4} or a cumulative hazard index greater than 1.