Alternatives Evaluation

East CKD Area
Revision 3.0 – August 31, 2009
Little Traverse Bay CKD Release Site
Emmet County, Michigan

Prepared for CMS Land Company and CMS Capital, LLC

U.S. EPA Docket No. VW-05-C-810

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1.0 Introduction

1.1 Report Purpose and Organization

This Alternatives Evaluation (AE) report has been prepared for the East CKD (ECKD) Area at the Little Traverse Bay CKD Release Site, in Emmet County, Michigan. This AE has been completed pursuant to Section VIII of the February 22, 2005 Administrative Order on Consent (AOC), Docket No. VW-05-C-810, between the United States Environmental Protection Agency (U.S. EPA) and CMS Land Company and CMS Capital, LLC (referred to collectively as CMS).

The purpose of this AE Report is to evaluate potential remedial action alternatives that provide a range of protection for human health and the environment and a range of technical feasibility and potential costs. This evaluation addresses the requirements and scope for evaluating alternatives for long-term remedy selection contained in the AOC, as described in Section VIII, Paragraph 15, Subsection X and will enable decision-makers to review the selection of an appropriate long-term remedy for the ECKD Area only. The preparation of this report also fulfills the requirements for development, screening, and evaluation of remedial alternatives and for preparation of an AE Report as outlined in Section 6.2.1: Draft Feasibility Report, of the *Final Approved Removal Action Work Plan,* (Work Plan) for the ECKD Area (Barr, 2005).

The AE Report is also intended to be consistent with the State of Michigan Administrative Rules for Part 201, Environmental Remediation, of the Natural Resources and Environmental Protection Act (NREPA, 1994 PA 451), specifically Rule 530 (R 299.5530) which provides guidelines for a feasibility study for department approval, Rule 607 (R 299.5603) which includes a list of evaluation criteria for selection of a remedial action, and Rule 705 (R 299.5705) Part 7, which provides rules applicable to Interim Response Actions Designed to Meet Cleanup Criteria (IRDC).

1.1.1 Scope

The scope of the AE Report as defined in the Work Plan is to evaluate alternative response actions that build on the investigation results, and which attempt to address the following goals:

- Preventing unacceptable exposures to surface waters and sediment impacted by CKD waste material;
- Preventing discharge of groundwater containing hazardous substances at concentrations above state criteria to surface waters of the State;

- Preventing unacceptable risk from human direct contact with CKD waste material;
- Preventing exacerbation, new releases, and unacceptable exposure to CKD waste material; and
- Ensuring that any other unacceptable exposures are adequately addressed.

The scope of this AE Report includes:

- The conceptual Site model and identification and quantification of affected media.
- Summary of the implemented interim response (IR) actions at the Site.
- Remedial action objectives (RAOs) for affected media.
- Development of general response actions and identification, screening, and documentation of remedial technologies for affected media.
- Assemblage of technologies into remedial alternatives, each of which addresses all affected media.
- Screening of assembled alternatives on the basis of effectiveness (short term and long term), implementability, and cost.
- Detailed analysis of retained alternatives against the set of nine evaluation criteria identified in the National Contingency Plan (NCP).
- Comparative analysis of alternatives using the same nine criteria.

The scope outlined above is consistent with the U.S. EPA guidance for feasibility studies (U.S. EPA, 1988) and U.S. EPA correspondence from June 16 and July 29, 2009 and conference call on July 22, 2009. The AE Report is intended to provide the basis for remedy selection and subsequent approval of this report by the U.S. EPA.

1.1.2 Organization

This AE Report is organized into four sections:

- Section 1 includes a description of the purpose of the report and provides a brief summary of the background information including the conceptual Site model and IR actions.

- Section 2 summarizes the development of the RAOs for soil, groundwater, and surface water at the Site, provides the identification and screening of potential remedial technologies and process options, and assembles and evaluates screening alternatives.
- Section 3 contains the development and screening of comprehensive remedial alternatives.
- Section 4 provides detailed and comparative analyses of the targeted alternatives.

1.2 Background Information

A detailed summary of the Site background information including the remedial investigation work performed under the Work Plan, the nature and extent of contamination, the Site conceptual model, and a baseline risk assessment is included in the Removal Action Investigation/Remedial Investigation Report, East CKD Area (Barr, 2009e) (referred to here as RI or RI Report), that has been submitted to the U.S. EPA. Therefore, only a brief summary of the Site background information is included in this AE Report.

1.2.1 Site Location

The Little Traverse Bay CKD Release Site is located along five miles of shoreline on Little Traverse Bay of Lake Michigan. The Site is approximately five miles west of the City of Petoskey, and located in Resort Township, Emmet County, Michigan (Township 34N, Range 6W, Sections 2 through 10). The ECKD Area, the focus of this AE, is located on the eastern portion of the Little Traverse Bay CKD Release Site as shown on Figure 1.

1.2.2 Site Description

The ECKD Area is bounded by Lake Michigan on the north, a Bay Harbor marina complex to the west, East-unnamed creek #2 to the east, and a wooded area with a bike trail to the south. The ECKD Area is currently owned by Resort Township and is used for recreational purposes. The ECKD Area includes CKD, which has been consolidated into a smaller area and is covered with a flexible membrane liner (FML) as part of the IR actions, and the undeveloped rocky beach area north of the CKD, as shown on Figure 2. A park area with parking facilities, sanitary facilities, picnic area, and open areas has been reconstructed on the consolidated, recontoured, capped, and covered CKD.

1.2.3 Site History

The Little Traverse Bay CKD Release Site is located on a former limestone mining and cement manufacturing plant operated by the Penn-Dixie Company from approximately 1870 through 1980. Bay Resort Properties Limited Partnership purchased the property in stages beginning in the late

1980s and ending in the 1990s. The Partnership donated the ECKD Area Site to Resort Township in December 1995 with the intent that the Site be used as a park. The ECKD Area was contoured to enhance precipitation runoff and covered with soil to provide for use of the Site as a park.

1.2.4 Nature and Extent of Contamination

The volume of CKD located within the ECKD Area is estimated to be approximately 360,000 cubic yards (CY) as shown in Table 1. The CKD limits are shown on Figure 3. The thickness of CKD varies from 0 to 46 feet, with the thickest CKD located near boreholes B4002, B4015, and B4016 (see Figure 2 for boring locations). From 25 to 50 percent of this material is located below the water table, based on the evaluation of geophysical and borehole data collected as part of the RI.

CKD is a by-product of portland cement production and is a particulate mixture of partially calcined and unreacted raw limestone feed, clinker dust, and fuel ash, enriched with alkali sulfates, halides, and other volatile inorganic materials. The results of the chemical analysis of CKD samples collected during the RI show that the dominant chemicals include calcium, magnesium, aluminum, iron, sulfate, chloride, potassium, and sodium. Many of these chemicals are present as oxides that will react with water to form hydroxides. The CKD material also contains small quantities or trace amounts of metals and inorganic compounds including arsenic, barium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium, vanadium, and zinc (see Table 2-2 in the RI Report).

An elevated pH has been measured in the leachate, which is groundwater (or, to a lesser extent, infiltration water) that has come into contact with CKD at the Site. The Site groundwater discharges to Lake Michigan, where elevated pH values have been measured in surface water and pools along the shoreline of Lake Michigan during three targeted shoreline survey water quality events performed in May 2005, October/November 2005, and May 2006. The results of these survey events are shown on Figure 4. Readings above pH 9 were identified in three zones, including the western, central, and eastern discharge zones, as shown on Figure 4. Additional data from dates when U.S. EPA monitored the lake are not shown in the figure, but are consistent with the extent of the zones shown on Figure 4.

Surface water samples were collected by the U.S. EPA (March 15, 2005 – one sample) and Barr (January 22, 2006 – two samples; and May 10 and May 12, 2006 – five samples). In addition, central leachate collection system (CLCS) and west leachate collection system (WLCS) surface water samples were collected by Barr during effectiveness monitoring conducted from November 24, 2006 through September 27, 2007 to assess general water quality conditions in the lake adjacent to the ECKD Area. Two additional sampling events were conducted June 27 (pH only), and July 7, 2008 downgradient of the CLCS and WLCS for both events. All surface water monitoring locations

through June 30, 2009 are shown on Figure 5. The results from the surface water quality investigation, discussed in detail in the RI Report (RI Report Sections 2.1.4 and 3.1.5.2), are briefly summarized here. Review of the results has identified elevated levels of general parameters, including chloride, pH, total dissolved solids (TDS), and sulfate. Metals, including aluminum, arsenic, copper, mercury, selenium, and vanadium, were observed. However, the concentrations of these parameters were significantly lower than those observed in the groundwater samples. The anticipated contaminants of concern (COCs) for surface water quality are pH and mercury.

Mercury was reported at a concentration of 3.3 nanograms per liter (ng/L) in one sample from January and 2.44 ng/L in one sample from May 2006 and was not detected at detection limits of 200 ng/L (U.S. EPA sample), 0.5 ng/L (January sample) and 1 ng/L (four May samples). The mercury measurements from two samples collected downgradient of the CLCS in July 2009 were below detection limits (<1 ng/L). The mercury measurements from two samples collected downgradient of the WLCS in July 2009 were below detection limits (<1 ng/L) and 1.29 ng/L.

Other concentrations of COCs exceeding surface water quality standards in these samples are vanadium and selenium. These parameters exceeded the Michigan Final Chronic Value (FCV), but not Final Acute Value (FAV) for surface water in one or more samples. Vanadium exceeded the Michigan FCV of 12 micrograms per liter (μg/L) in one January sample and two May samples. Selenium exceeded the Michigan FCV of 5 μg/L in one January sample and none of the five May samples. WLCS Sample 1 exceeded criteria for antimony on April 20, 2007. WLCS Sample 2 exceeded criteria for zinc and antimony on April 20, 2007. CLCS Sample 1 exceeded criteria for antimony on July 18, 2007 and CLCS Sample 2 exceeded criteria for antimony on November 24, 2006. No metals were detected in any of the four samples collected from the CLCS and WLCS in July 2009.

1.2.5 Contaminant Fate and Transport

Contaminants present in the CKD have the potential to impact human health and the environment through direct contact with the CKD, by migration of the CKD or by migration of contaminants derived from groundwater contact with CKD. Because the CKD in the ECKD Area has been covered, there is no potential for airborne migration. Migration due to physical movement by erosion and runoff has been eliminated by installation of the flexible membrane liner (FML) cover system as part of the IR actions completed at the Site.

After consolidating and covering the CKD, the only remaining pathway for potential contaminant migration is via the groundwater. Water that infiltrates through the CKD or groundwater that passes

through the CKD below the water table in the ECKD Area migrates in the direction of Lake Michigan. Groundwater moving through the ECKD Area that has come into contact with the CKD (leachate) can transport some contaminants and may impact the surface water. Prior to CKD consolidation and operation of the collection system, impacts to the pH of surface water along the shore of Lake Michigan near the ECKD Area were documented during the three targeted shoreline survey water quality events performed in May 2005, October/November 2005, and May 2006. The results of these survey events are shown on Figure 4 and further described in the RI Report (see RI Report Section 3.1.5.2). Readings above pH 9 were identified in three zones, including the western, central, and eastern discharge zones, as shown on Figure 4. The results from these surveys confirm that the high pH in the CKD leachate historically migrated via groundwater to the surface water of Lake Michigan. Additionally, high pH leachate migrating via groundwater had been detected at the west face of the ECKD Area, along Village Harbor. This data along Village Harbor from April through June 2006 is also shown on Figure 4. The migration of other parameters in the CKD leachate, such as metals and inorganic compounds, may be attenuated by numerous mechanisms, including physical (dilution via differential permeability, dispersion, and diffusion) and chemical (adsorption, chemical reactions, and precipitation) processes, as discussed in Section 5.0 of the RI Report. Any metals and inorganic compounds not attenuating below surface water criteria will be included in the compliance monitoring plan required by state law.

A groundwater model has been developed for the ECKD Area to help describe and quantify the flow of the groundwater. This model, which is described in detail in the RI Report (see RI Report Appendix T), has been used to evaluate the potential effectiveness of remedial alternatives in this AE.

1.3 Interim Response Activities

This section summarizes the status of the IR actions already performed and being implemented through June 30, 2009 at the ECKD Area.

1.3.1 Current Status of Interim Response Activities

IR actions carried out at the ECKD Area include leachate migration control and leachate generation control activities.

- Leachate Migration Controls
  - Central and West Leachate Collection Systems (CLCS, WLCS) were installed and have been operational since November 15, 2006.

  - Slurry wall vertical barrier was installed downgradient of WLCS and has been operational since November 15, 2006.
  - Upgradient diversion wells and forcemain were constructed in 2008 and 2009
- Leachate Generation Controls
  - CKD excavation from the eastern portion of the Site (bottleneck) and consolidation above the water table in west area was completed in September 2006.
  - Storm sewer system improvements were constructed in 2006 – 2008.
  - West cover system construction was completed in 2007.
  - East cover system construction was completed in 2008.
  - Upgradient diversion wells and forcemain were constructed in 2008 and 2009.

Figure 6 shows the existing conditions based on the IR actions implemented at the Site.

1.3.2 Effectiveness of Interim Response Activities

The effectiveness of the IR activities is evaluated through the following three lines of evidence: (1) effectiveness monitoring; (2) mercury flux analysis; and (3) surface water quality data. The review of these three lines of evidence leads to the consistent conclusion that the leachate collection system is highly effective at protecting the lake.

1.3.2.1 Effectiveness Monitoring

Implementation of IR actions (CLCS, WLCS, slurry wall, bottleneck CKD excavation and consolidation, west cover system) are protecting human health and the environment by mitigating CKD leachate discharge to Lake Michigan as demonstrated through effectiveness monitoring. No pH measurements above 9 lakeward of the WLCS or CLCS have been observed in 2009 as shown on Figure 7. With completion of the cover system in 2008, the continued effectiveness of the IR has been clearly demonstrated in 2009.

1.3.2.2 Mercury Flux Analysis

The second line of evidence of the effectiveness of the IR activities is from an analysis of the flux of mercury from the Site. Significant mercury flux reduction is being realized by the IR actions based on modeling results using the approach provided in Appendix A. An analysis of mercury flux in groundwater was performed to estimate the amount of mercury flux towards Lake Michigan before the implementation of the IR actions as compared to conditions after the implementation of the 2006 IR actions.

The flux evaluation is based on the approach developed with the U.S. EPA and the MDEQ. The approach is a straightforward application of Darcy's Law for flow through porous media and the concentration distribution of mercury in the groundwater. The mercury concentration distribution is based on groundwater surface interface (GSI) monitoring well data near the lake. Darcy's Law states that flow is equal to the product of the groundwater gradient, hydraulic conductivity, and cross-sectional area through which a fluid flows. The product of groundwater flow and mercury concentration is the mass flux of mercury in the groundwater through the cross section. The mass flux of mercury was calculated using Excel spreadsheets.

The mercury flux analysis calculations for three rounds of mercury sampling are in Appendix A.

1.3.2.2.1 Prior to Interim Response Action Conditions

Flux estimates prior to IR actions were calculated using water quality data collected between February and March 2006. These calculations are believed to be representative of the Site conditions before implementation of any IR actions. The mass loading of mercury prior to IR actions, including the western discharge zone, as well as the north side encompassing the central and eastern discharge zones, was calculated to be 18.2 milligrams per day (mg/day). Prior to the IR actions, the concentration of mercury averaged over the discharge through the cross section was about 7.7 ng/L.

1.3.2.2.2 Current Conditions

Current flux estimates were calculated using updated 2008 and 2009 groundwater quality data. These calculations are a reasonable approximation (but biased toward the high side) of the current Site conditions recognizing partial completion of the IR actions. Additional details of the analysis are in Appendix A. The estimates of mercury flux from the ECKD Area are 6.8, 14.3, and 1.2 mg/day, for the sampling in the 4th quarter (1st round) 2008, 1st quarter (2nd round) 2009, and the 2nd quarter (3rd round), 2009, respectively. The flux divided by the flow through the cross section area provides an average mercury concentration of the water flowing towards Lake Michigan and does not account for attenuation between the location of the calculation cross section and the lake. The average equivalent mercury concentrations are 3.3, 6.1, and 0.6 ng/L, for the sampling in the 1st, 2nd, and 3rd rounds of discrete mercury flux analysis, respectively

1.3.2.3 Surface Water Quality

The third line of evidence for the effectiveness of the IR actions is surface water quality data. Surface water samples were collected prior to implementation of the IR actions and a series of surface water samples have been collected after construction and operation of the leachate collection system. A

review of those samples suggests a very high effectiveness of the system. The most representative parameter for calculating the effectiveness is potassium, as that is a parameter associated with CKD and it is relatively conservative in migration and transport. Other parameters that provide confirmation of the potassium results are pH, aluminum, vanadium, and mercury. Table 2 shows the water quality data for these parameters for selected monitoring points at the ECKD Area. The points were selected in areas where there are samples both prior to and after the construction and operation of the leachate collection system. The location of the samples is shown on Figure 5. There were a number of additional samples collected and a much longer parameter list analyzed. That information is available in the RI.

Surface water samples were collected from high pH areas of the central discharge zone (off-shore from the central leachate collection system near the former Quarry Drive). Three samples collected prior to the leachate collection system installation in this area are ECKD Samples 2 and 3 and ECKD SW001. For comparison, three samples collected within the limits defined by those three prior samples are CLCS Sample 1 (dated 11/24/06); CLCS Sample 2 (dated 4/20/07); and CLCS Sample 2 (dated 5/18/07). As seen in Table 2, the average potassium concentration in the surface water samples prior to the IR actions was around 460 milligrams per liter (mg/L). By comparison, the average potassium concentration after the IR actions were put into effect was about 2 mg/L. This improvement indicates in excess of 99.5 percent of the leachate in this zone is being collected.

These results are corroborated by examination of the other parameters shown in the table. The pH in the samples prior to the IR actions ranged from 10.4 to nearly 12. After IR actions were implemented, the pH ranged from about 8 to 8.5. The average aluminum concentration prior to the IR actions is approximately 1,700 µg/L, while after it is nondetect at 50 µg/L. Using one-half the detection limit, 25 µg/L, as the estimate of the concentration after IR actions, this reduction indicates a capture efficiency of over 98.5 percent. The average vanadium concentration prior to the IR actions is a little over 100 µg/L, whereas after implementation of the IR actions, the vanadium concentration is nondetect at a detection limit of 4 µg/L, a capture efficiency of 98 percent. The mercury data are included as a further confirmation of the effectiveness of the system. The mercury concentrations dropped from an average of slightly over 2 ng/L in the samples prior to the IR actions to consistently nondetect following implementation of the IR actions.

The conclusion from this evaluation of the surface water quality data just offshore of the central leachate collection system is that the IR actions is capturing 98 percent or more of the leachate and is protecting Lake Michigan surface water quality for all parameters that are associated with leachate.

A similar evaluation was performed for samples from the east end of the ECKD Area Samples 4 and 5 collected on May 10, 2006 were compared to CLCS Sample 2 collected November 24, 2006 and CLCS Sample 2 collected December 16, 2006. As shown in Table 3, the average concentration of potassium in the surface water samples declined from about 60 mg/L to about 5 mg/L after implementation of the IR actions, a leachate reduction of over 90 percent. The potassium results are consistent with the reduction in pH in the samples from 9.35 to 9.6 before IR actions, as compared with 7.6 to 8.6 following the IR actions.

At the east end of the ECKD Area, the pH levels in the surface water were not as elevated as in the area close to Quarry Drive. Nonetheless, the surface water sample data indicates that the IR actions have had a favorable effect on water quality.

The consistent finding from the post-IR actions surface water quality sampling is that mercury has not been detected in the surface water, that the potassium levels have been reduced from concentrations in the tens or hundreds of mg/L down to single-digit concentrations. For parameters of concern, including mercury and vanadium, concentrations are consistently nondetect in the post-IR actions surface water quality samples.

In summary, the surface water quality data is a third line of evidence that strongly supports the conclusion that the IR actions in the ECKD Area have been effective at intercepting leachate and protecting the surface water quality. In the areas of greatest importance, the data suggests that the portion of leachate being captured is in excess of 98 percent, and may be higher than 99 percent. These results are consistent with the effectiveness monitoring which has shown only rare occurrences of pH exceeding 9 since implementation of the IR actions. These results are also consistent with the mercury flux analysis in concluding that there has been a substantial reduction in mercury flux to the lake. In fact, the surface water quality data indicate that the mercury flux analysis may underestimate the effectiveness of the IR actions in intercepting and controlling mercury flux from the ECKD Area to Little Traverse Bay of Lake Michigan. The mercury analysis does not factor in all the flow effects of the collection system, such as capturing water that has passed under the trenches (see Figure 10), or stagnating water that is between the trenches and the lake. The mercury analysis also does not account for any reduction in mercury concentrations due to natural attenuation, which would be reflected in the surface water samples.

1.3.3 GSI Criteria Exceedance

The RI report contains a discussion of the exceedances of generic Part 201 GSI and Residential & Commercial I Drinking Water criteria at the wells on the beach. This section focuses on existing wells that are near the beach and are either downgradient of the collection trenches, or do not have an upgradient collection trench. Wells that were abandoned due to collection trench construction are not considered in this evaluation. Figure 8 shows the relationship of the onsite wells to the collection trenches. For purposes of this discussion, well nests at B4017, B4019r, B4022, B4023r, B4025, B4026r, B4027r, B4030r, B4074, B4075, B4079, B4080, B4081, B4082, and B4083 will be evaluated.

Data from the most recent sampling event reported in the RI Report will be used in the evaluation. IR actions have improved the baseline conditions at ECKD Area. Therefore, the most recent data is the most relevant to the current baseline conditions. Current baseline conditions will be used to assess the need for additional response actions to supplement the initial response actions that either are already in place or will be constructed.

Table 4 shows the most recent full round of analytical data collected at each of the wells of interest. This data was collected between October 6, 2008 and February 10, 2009. Wells W4322, W4323r, W4423r, W4126r, W4326r, W4430r, W4474, W4479, W4481, and W4483 had no exceedances of generic GSI criteria in the most recent round of sampling and will not be considered further in this evaluation.

The remaining wells are either downgradient of the collection trenches (W4123r, W4223r, W4226r, W4426r, W4127r, W4227r, W4327r, W4174, W4274, W4175, W4275, W4375, W4180, W4181, W4281, W4381, W4183, W4283, and W4383), or are located near the beach but do not have collection trenches upgradient (W4117, W4217, W4317, W4119r, W4219r, W4319r, W4122, W4222, W4125, W4225, W4325, W4130r, W4230r, W4330r, W4179, W4279, W4379, W4182, W4282, and W4382). These two types of well locations will be discussed separately.

The wells downgradient of the trenches may be located in one of two general zones: (1) the capture zone of the trench for water that has traveled under the trench and then is captured by the collection trenches; or (2) the stagnation zone behind the collection trenches where, although the water is not being captured by the collection trenches, its travel velocity is slowed down by the flattening of the hydraulic gradients induced by the operation of the collection trenches.

The concentrations observed in the wells that exceed generic GSI criteria were compared with preliminary mixing zone-based criteria. The mixing zone that was assumed for the data was a factor of ten mixing (referred to below as "mixing zone" for simplicity), consistent with Michigan Part 31 rules, for all parameters except pH and mercury. The mitigation of the pH and mercury flux is discussed in Section 1.3.2 in this report.

As discussed above, data from the last full sampling round of the wells located downgradient of the collection trenches was compared with an assumed mixing zone for GSI criteria. All of the GSI exceedances, except for copper, in the sample collected on November 3, 2008 from monitoring well W4283 are below preliminary mixing zone-based criteria by this comparison. Completion of the actions at the ECKD Area is expected to have beneficial effects on groundwater quality at W4283. Accordingly, submitting an application for the MDEQ to develop final mixing zone-based GSI cleanup criteria should be based on the monitoring data from the appropriate wells, the status of remedy approval, and the pertinent Michigan rules and guidance.

The groundwater quality of the wells that are near the beach and not downgradient of the collection trenches was also compared with the preliminary mixing zone-based criteria and no parameters at these wells exceeded the criteria. As with the wells that are downgradient of the trenches, mercury and pH were not included in this evaluation. Mercury and pH are addressed in Section 1.3.2.

In summary, the IR actions appear to be successfully mitigating all of the parameters considered in this evaluation. An application for the MDEQ to develop final mixing zone-based GSI cleanup criteria will be pursued as appropriate for the Site remedy.

Even without the additional enhancements that are scheduled for ECKD Area and without the additional flushing of the groundwater system that will occur with time, it appears that the IR actions are successfully protecting the environment from the contaminants that are present in the leachate.

1.4 Site Conceptual Model

Site Description and Interim Response Actions

The ECKD Area consists of a covered CKD pile and a rocky beach as shown on Figure 2. The ECKD Area is bounded by Little Traverse Bay of Lake Michigan to the north, Village Harbor to the west, East Unnamed Creek #2 to the east, and wooded areas with bike trails to the south.

The ECKD Area conceptual Site model has been developed and refined with observations and data from the investigation activities conducted at the Site. Additionally, observations, data collection, and analysis from the IR actions and the subsequent operational and effectiveness monitoring of the IR actions have been used to refine the conceptual Site model for the ECKD Area. Investigation activities completed at the Site include the following:

- Pre-Work Plan – Includes activities and investigations conducted prior to approval of the Final Approved Removal Action Work Plan (RAWP) (Barr, 2005). Including review of available information regarding the Site setting, surface geophysical investigations, preliminary lakeshore evaluation, limited beach pool sampling, and geologic mapping.

- Work Plan – Includes the Expedited Removal Actions (targeted shoreline survey and overflights), IR Actions (construction of the IR components discussed further below and the operational monitoring and effectiveness monitoring of the IR components), and Removal Action (RA) Investigation Activities (topographic surveys, extent and characterization of CKD piles, hydrogeological investigations, determination of geologic and hydrogeologic properties, surface water investigations, geophysical investigation, baseline ecological investigation, and other investigations included in the RI Report (Barr, 2009e)).

- Supplemental Investigation – Includes additional boreholes to further refine the extent of CKD during design.

- Flux Investigation – Includes an evaluation of mercury flux using data from RAWP activities, installation of additional shoreline wells, slug testing of all shoreline wells, conducting mini pumping tests of all shoreline wells, and mercury sampling and analysis.

- Diversion Well Design – Includes installation of diversion wells and observation wells, conducting pumping tests, and groundwater modeling.

The ECKD Area consists of the three discharge zones defined by high pH (pH >9.0) levels recorded during the targeted shoreline surveys. These surveys were conducted in 2005 and 2006 prior to the installation of the IR components (Figure 4). The discharge zones are the western discharge zone, the central discharge zone, and the eastern discharge zone, as shown on Figure 4. The western discharge zone is located on the western edge of the ECKD Area along Village Harbor. The central discharge zone is located north of the central portion of the ECKD pile along the shore of Little Traverse Bay. The eastern discharge zone is located north of the eastern portion of the previous ECKD pile

(bottleneck) along the shore of Little Traverse Bay. The pH ranged from 9.24 to 9.40, 9.00 to 12.40, and 9.25 to 11.23 for the western, central, and eastern discharge zones, respectively. Results of the targeted shoreline surveys are included in Appendix L of the RI Report. These initial discharge zones have been further investigated and verified through additional shoreline wells installed in 2008.

IR activities have been conducted at the Site to address the high pH discharge zones in accordance with the AOC. The IR activities conducted at the Site include: installation of the Central and West Leachate Collection Systems (CLCS and WLCS), installation of a groundwater flow barrier (slurry wall) downgradient of the WLCS, excavation of CKD from the eastern portion of the Site (bottleneck), consolidation of CKD on the western and central portions of the Site, construction of a geomembrane cover system, stormwater improvements, upgradient interflow diversion, and partial installation of a groundwater diversion system (RI Report Appendix X). The groundwater diversion system is only partially complete (wells and conveyance piping installed). The installation of the pumps and final connections have not yet been completed. The CLCS and WLCS were installed to control migration of leachate to the central and western discharge zones, respectively. The CKD in the bottleneck was excavated and consolidated on the western portion of the Site to address the generation of leachate impacting the eastern discharge zone. Consolidation of CKD, construction of the geomembrane cover system, and the stormwater improvements were conducted to reduce the generation of leachate from infiltration in the central and western portion of the Site. Prior to the IR actions, three areas of high infiltration existed: (1) a low spot in southwest corner of Site, (2) the ditches along old Quarry Drive upgradient of west leg of CLCS, and (3) the parking lot infiltration system. Regrading of the CKD and installation of a new stormwater management system were conducted to address the three areas of high infiltration. The upgradient interflow diversion was installed to address the shallow groundwater observed upgradient of the CKD pile during storm drain and forcemain installation. These measures have resulted in a reduction in leachate pH at the Site. In particular, the pH in the central discharge area has significantly decreased as demonstrated by pH in EP-2 (Barr, 2009e).

The groundwater diversion system is designed to reduce leachate generation from groundwater contacting CKD and to reduce the volume flowing through the remaining saturated CKD.

Geology and CKD Location

The ECKD Area consists of one CKD pile situated parallel to Little Traverse Bay, with its long axis having an east-west orientation, as shown on Figure 2. The surface area of the ECKD pile was

approximately 11.4 acres prior to the IR actions, as shown on Sheet C-01R included in Appendix X of the RI Report (Barr, 2009e). As a part of the IR actions, CKD from the eastern portion of the Site was excavated and consolidated on the western portion of the Site. The surface area of the current extent of CKD is approximately 10.2 acres, as shown on Figure 2. The extent of CKD was originally mapped based on surface geophysical data. The lateral extent was determined using resistivity and EM data, and the vertical extent was determined using resistivity and seismic refraction data. The results and analyses of the surface geophysical investigation are presented in RI Report Appendix D. Data from boreholes were used to confirm the interpretation of the surface geophysical data. Boring logs for the boreholes are included in Appendix G of the RI Report. Additionally, Geoprobe® borings (B4032-B4073), the borehole B4075, and an investigation in the lake north of the CKD Area (RI Report Appendix W) were completed to delineate the lateral extent of CKD.

The uppermost bedrock under the ECKD pile is weathered limestone that is present beneath the ECKD Area at depths ranging from two feet to 55 feet below ground surface, as shown in geologic cross sections (RI Report Figures 3-3 to 3-10). The buried bedrock surface has significant topography to it and forms an east-west oriented trough-shaped feature with a closed eastern end, likely the result of historical quarrying activities. Based on the geophysical data, the uppermost portion of the limestone bedrock is interpreted to be weathered (contains low-velocity zones) and thus is more highly fractured at the bedrock surface. The weathered (low-velocity) bedrock zone is likely due to natural weathering processes and anthropogenic effects such as quarrying. The interpreted weathered bedrock zone is mapped on the cross sections and ranges from 5 to 45 feet thick across the ECKD Area (RI Report Figures 3-3 to 3-10). The weathered bedrock topography is shown on RI Report Figure 3-12. The top of more competent limestone is based on seismic refraction modeling of the Site and is shown on the geologic cross sections at depths ranging from 3 feet to 92 feet. The competent bedrock topography is shown on RI Report Figure 3-11.

Horizontal/near horizontal fractures along/parallel to bedding planes and high-angle fractures with dips of 70° or more are abundant in the limestone bedrock based on geologic mapping and interpreted acoustic televiewer readings in boreholes (RI Report Appendix R). Two main strike orientations were observed for the high angle fractures: approximately 300° and 60°. These orientations are consistent with the observed orientations from the field mapping of geologic outcrops. The width of the fractures observed during the geologic mapping ranged from approximately 1 mm to 100 mm. Spacing of the high angle fractures is generally consistent between outcrops and ranges from approximately one to two feet. Based on borehole logging, the average fracture density for each borehole ranges from 0.8 to 1.4 fractures per foot, and the average among

all boreholes is 1.0 fracture per foot. RI Report Figures 3-27a, 3-27b, and 3-27c show the plots of fracture spacing with depth. In general, the plots suggest uniform fracture density through many of the boreholes with a trend toward higher fracture densities near the surface. As the CKD overlies the more fractured bedrock, CKD and leachate are likely located within the bedrock fractures near the surface. In boreholes B4012, B4015, and B4027, CKD mixed with shattered limestone or limestone fragments/chips was observed below the CKD pile indicating that CKD has migrated downward into the weathered limestone.

Shale was observed interbedded within the limestone in a few intervals at the ECKD Area, generally in layers less than three feet thick. Most shale units were found to be discontinuous in this area and the downhole geophysics identified no intervals with significant clay content. Therefore, the shale that is present is not a significant factor in leachate flow in this area.

Based on the geophysical surveys (RI Report Appendix D) and drilling investigations conducted at the ECKD Area, soil fill and/or CKD fill were placed in a topographic low (quarry), as shown on the geologic cross sections (RI Report Figures 3-3 through 3-10). At the deepest portions of the ECKD pile, Site data show that the regional groundwater table contacts the CKD. Based on water elevation data from monitoring well nests at boreholes B4002R, B4016, B4020R, and B4024, the regional groundwater table is located above the bottom of CKD at these boreholes. Boreholes B4PW1, B4005, B4007R, B4011R, B4013, B4015, B4016, B4018A, B4020, and B4020R show evidence of wet/saturated CKD located below the regional groundwater table in the western and central portions of the pile (RI Report Appendix G). Additionally, boreholes B4032, B4037, B4061, and B4064 showed evidence of wet/saturated CKD located in the bottleneck prior to the IR actions. During the diversion well design, the conceptual Site hydrogeologic model was refined with water elevation data from the monitoring well W4176 installed in 2008. The water level in W4176 was approximately six feet lower than previously interpreted water elevations in that vicinity, thus, resulting in a flatter hydraulic gradient across the CKD pile and less saturated CKD. The bottom contours of the ECKD pile and the boreholes on which the contours are based are shown on RI Report Figure 3-23. The current extent of saturated CKD is shown on RI Report Figure 3-24.

Site Hydrogeology

As discussed in the RI Report Section 3.1.8, the regional groundwater flow system at the ECKD Area is predominantly through a dense interconnected fracture system within the bedrock. Based on Site/regional topography and water elevations from monitoring wells, the regional horizontal

groundwater flows north toward Lake Michigan for the majority of the ECKD Area while the regional horizontal groundwater flows to the west toward Village Harbor on the western portion of the area. This general flow pattern is illustrated in the groundwater elevation contours maps (RI Report Figures 3-14a, 3-14b, 3-14-c, and 3-14d). The regional hydraulic gradient of the Site is generally steeper upgradient of the CKD pile and shallower across the CKD pile (Barr, 2009e). Groundwater elevations measured in monitoring wells indicate that both vertical downward gradients and vertical upward gradients are present at the Site. Groundwater elevation contours on RI Report Figures 3-16, 3-20 and 3-21 show that deep regional groundwater migrating towards Lake Michigan has an upward trend and discharges within close proximity of the shoreline. The ECKD Area regional water table shows only minor seasonal variation. No evidence of influence by municipal well pumping was observed in ECKD wells (RI Report Section 3.1.8.15).

A zone of perched and semi-perched groundwater is located upgradient of the CKD pile in the vicinity of B4078. Evidence of a perched/semi-perched groundwater zone in this area was identified during the large scale pumping tests conducted for diversion well design in 2008. Water elevations observed in monitoring well W4178 are approximately 20 feet higher than water levels measured in any other well at the Site. Additionally, no measurable response to pumping of diversion well EPDW-7, located 45 feet from B4078, were observed in W4178. In comparison, a maximum drawdown of 17.2 feet due to pumping of diversion well EPDW-7 was measured in W4278. Till composed of sandy lean clay with gravel and a one-foot-thick underlying layer of shale were observed between the screened intervals of W4178 and W4278. These units act as low permeability barriers and are responsible for the observed perched groundwater conditions at this location. The forested wetland/lowland conifer area located south of the well nest at boring B4078 gives further indication of localized perched groundwater conditions. Based on the surface elevation and available hydrogeologic information for the Site, it appears likely that the wetland/lowland is not well connected with the regional groundwater system. The wetland/lowland is likely dominated by surface water and shallow soil water flow (e.g., interflow), typically on a seasonal basis, and is slow to drain.

Hydraulic conductivities of the Site were determined using the results of the aquifer testing conducted as a part of the RA Work Plan (packer testing and slug tests) (RI Report Rev 2.0 Table 2-6). As a part of the diversion well design, the characterization of hydraulic conductivities continued by performing pumping tests on the ECKD diversion wells in July 2008. The pumping tests provided a large- scale estimate of hydraulic conductivities for the ECKD Area. The results of the diversion well pumping tests are provided in the Preliminary ECKD Diversion Well Design Technical Memorandum dated January 9, 2009 (Barr, 2009a). As a part of the flux investigation, slug

tests and mini pumping tests were conducted on all of the shoreline wells at the ECKD Area to determine the hydraulic conductivities near the shoreline. Slug tests were performed in 36 wells distributed among ten boreholes in the fall of 2008. The slug test results confirmed the understanding of the subsurface near the shoreline. Additionally, mini pumping tests were conducted on all 50 of the shoreline monitoring wells to further verify the hydraulic conductivities of the nearshore subsurface. Hydraulic conductivities from the mini pumping test results were similar to the hydraulic conductivities from the slug tests (see Figure 3-30 of the RI for a histogram of hydraulic conductivities). Along the floor (e.g., top of weathered bedrock) of the former quarry, at the western discharge zone, higher fracturing was indicated in well W4180. The results of the mini pumping tests are provided in the ECKD Mini Pumping Test Report dated June 30, 2009 (Barr, 2009b).

Surface Water

Prior to the IR actions, areas of low/flat topography and an insufficient surface water management system limited surface water runoff from the ECKD Area. Surface water that did not runoff or evapotranspirate infiltrated into the CKD pile. The original surface water management infrastructure consisted of only vegetated swales and ditches, and several areas of low/flat topography were undrained. One area of low topography and high infiltration was located in the southwest corner of the Site in the vicinity of boreholes B4016 and B4051 (RI Report Figure 3-1a). The ditches along old Quarry Drive upgradient of the western portion of the CLCS and the original parking lot infiltration system allowed surface water infiltration as well.

An extensive surface water management system was installed as a part of the IR actions to prevent surface water infiltration from contacting the CKD pile and to drain water from the cover system and roadways. The infrastructure for the surface water management system is included in the construction record drawings in RI Report Appendix X. Generally, the surface water is routed to Lake Michigan or Village Harbor through storm sewer piping, drain tile, or as runoff.

Leachate Generation

Prior to implementation of the IR actions, the primary sources of leachate generation at the ECKD Area were CKD saturated by regional groundwater and, to a lesser extent, infiltration. However, the sources of leachate generation at the ECKD Area have been altered as a result of the IR actions.

Infiltration

At the ECKD Area, generation of leachate from infiltration was a result of either surface water infiltrating into the CKD or surface water infiltration flowing along the surface of the CKD as interflow. Typically, CKD is less permeable than unconsolidated soils, making it more likely for surface water infiltration to flow across the top of the CKD pile rather than travel through the CKD pile. The median permeability of shallow (<10 feet bgs) non-CKD soils at the Site was 1.0×10^{-5} cm/sec, and the median permeability of CKD at the Site was 5.6×10^{-7} cm/sec (RI Report Appendix I); therefore, surface water infiltration was expected to flow along the CKD surface through overlying unconsolidated soils potentially generating leachate. However, moist/wet CKD located above the regional groundwater table was observed in several of the ECKD Area boreholes located in the middle of the CKD pile indicating that some surface water infiltrated into the CKD pile.

Areas of higher infiltration existed at the ECKD Area prior to the IR actions as mentioned above in the *Surface Water* section. For example, an area of lower topography was located upgradient of the southwest corner of the Site in the vicinity between boreholes B4016 and B4051 (RI Report Figure 3-1a). High pH levels observed during the targeted shoreline survey along the shoreline in the southwest corner (Figure 4) were likely a result of leachate generated from infiltration in this low area. Subsequent to the IR actions, effectiveness monitoring conducted along the shoreline near the southwest corner of the CKD pile resulted in no pH readings greater than 9.0. The results of the effectiveness monitoring are summarized on Figure 7. Another area of suspected high infiltration was located upgradient of the western portion of the CLCS along the old Quarry Drive alignment. Poorly-drained ditches allowed surface water to infiltrate into the CKD pile. Elevated pH readings were recorded during the targeted shoreline survey downgradient of the old ditches. Subsequent to IR actions, the pH observed in piezometer EP2-PZ1 (located in the western portion of the CLCS trench) was between 7 and 9, indicating a substantial reduction in leachate generation in this area. The pH measurements taken in the CLCS piezometers are shown in Appendix X of the RI Report. The original parking lot was designed to drain water to an infiltration area where surface water likely infiltrated the CKD pile generating leachate. These areas of higher infiltration were eliminated as a result of the IR actions.

The consolidation of the CKD, installation of the geomembrane cover system, and stormwater improvements have eliminated most leachate generation from infiltration in the western and central portions of the ECKD Area. Additionally, excavation of the CKD from the bottleneck has eliminated most leachate generation from infiltration in that portion of the ECKD Area.

Saturated CKD

At the ECKD Area, the main mechanism of leachate generation pre- and post-IR actions is regional groundwater contacting CKD. The extent of saturated CKD is shown on RI Report Figure 3-24. Excavation of CKD from the bottleneck has eliminated most of leachate generation from saturated CKD in this portion of the ECKD Area. While some CKD remains entrained in the fractured bedrock after the excavation of the bottleneck area, leachate generation from these residuals have not caused pH exceedances in the lake. Subsequent to the excavation of CKD, effectiveness monitoring conducted along the eastern discharge zone resulted in no pH exceedances, which provides clear evidence that the removal of the CKD has been effective in reducing pH in this area. The results of the effectiveness monitoring are summarized on Figure 7.

As a component of the final remedy, a groundwater diversion system has been designed to reduce leachate generation from groundwater contacting CKD and to reduce the volume of groundwater flowing through the remaining saturated CKD, as discussed further in Section 3.1.2. The preliminary design work for the groundwater diversion system consisted of the analysis of two high-capacity (>50 gallons per minute (gpm)) pumping tests conducted on EPDW-2 and EPDW-7 and groundwater modeling. The results of the design are included in the Preliminary ECKD Diversion Well Design memorandum dated January 9, 2009 (Barr, 2009a). Based on the groundwater modeling and the results of the pumping tests, a cumulative pumping range of 100 to 120 gpm is the target range to effectively lower the gradient of the groundwater across the CKD pile without infringing upon the plume of leachate. For this range of pumping, the upgradient groundwater was drawn down resulting in an approximate water table head drop across the CKD pile of two feet. By drawing down the groundwater upgradient of the CKD pile and flattening the hydraulic gradient across the Site, the volume of saturated CKD would be reduced and, thus, reducing the amount of leachate generated from saturated CKD.

Perched Groundwater Interflow

Interflow from upgradient perched groundwater contacting CKD is another source of leachate generation at the ECKD Area. Perched groundwater was identified in the vicinity of B4078 as discussed above in the *Site Hydrogeology* section. Additionally, shallow groundwater was encountered during the installation of storm sewer and the LCS forcemain upgradient of the CKD pile. Drain tile was installed along the west diversion well header pipe trench and along the southern forcemain and storm sewer pipe trenches, as shown in the record drawings (RI Report Appendix X).

The drain tile was installed to collect this shallow upgradient groundwater, reducing the amount of perched groundwater contacting CKD. Water collected in the drain tile is routed to the storm sewer system and ultimately discharges into Lake Michigan. The amount of leachate generated from perched groundwater contacting CKD is not expected to be significant with relation to the amount the leachate generated from saturated CKD.

Groundwater Flow and Leachate Migration

Shallow leachate migrates towards Lake Michigan and Village Harbor through the CKD pile and underlying soil as evident in water quality data from shallow monitoring wells (e.g., W4174 and W4123r). Regional groundwater elevation contours are shown on Figures 3-14a, 3-14b, 3-14c, and 3-14d of the RI Report (Barr, 2009e). Shallow leachate also migrates downward through the CKD and underlying soil to the regional groundwater table as evident in pH exceedances in deep monitoring wells (e.g., W4418). Groundwater contours on RI Report Figures 3-16, 3-20 and 3-21 show that deep regional groundwater migrating towards Lake Michigan has an upward hydraulic gradient and discharges within close proximity of the shoreline. Additionally, groundwater pH exceedances are not evident in deep monitoring wells located adjacent to the Lake Michigan shoreline (e.g., W4474 and W4423r). These trends indicate that leachate produced in the ECKD Area infiltrates into the deep regional groundwater, but is contained and diluted by the regional groundwater via the upward vertical hydraulic gradient. The results of the Village Harbor investigation (Barr, 2006b) conducted before IR actions, confirmed that leachate discharged nearshore along the WLCS based on conductivity measurements (Figures 4-1, 4-2, and 4-3). In March of 2007, the MDEQ completed an investigation through the ice cover along the ECKD Area to identify preferential flow paths. The MDEQ conducted pH monitoring near the shoreline and further out in Little Traverse Bay. Based on the MDEQ data, the only locations to have pH that exceeded 9.0 were located along the shoreline which confirms that the leachate from the ECKD Area discharges nearshore. The results of the MDEQ study are provided in Appendix Q of the RI Report.

The main receptors of leachate generated in the ECKD Area would be the regional groundwater discharge points, Lake Michigan and Village Harbor; however, the IR collection drains (WLCS and CLCS) installed along the western and central discharge zones and the slurry wall installed along the western discharge zones have been proven to be effective at controlling pH in Lake Michigan and Village Harbor. Effectiveness monitoring data collected since the installation of the IR drains and the slurry wall are included in Appendix Y of the RI Report (Barr, 2009e). These data verify that the IR actions have been highly effective (i.e., pH <9.0 in the lake) since their installation.

COCs

The identified COCs for the ECKD Area are summarized in Table 7 (for soil) and Table 8 (for groundwater).

Chloride, sulfate, pH, and TDS are general parameters that are associated with CKD, exceed generic Part 201 criteria, and have demonstrated ability to migrate the ECKD pile to a potential point of exposure (RI Report Table 2-5). Aluminum, arsenic, copper, iron, lead, manganese, mercury, nickel, selenium, silver, sodium, and vanadium are metals that are associated with CKD, exceed generic Part 201 criteria, and have demonstrated ability to migrate from the ECKD pile to a potential point of exposure (RI Table 2-5).

pH is a parameter which originally defined the impacted shoreline and remains the best indicator of leachate impacts at the Site. pH is representative of other COCs and can be used as a surrogate for alternative evaluation purposes.

Mercury has been identified at the ECKD Area during the Work Plan activities and during the flux investigation. Mercury is an important COC since it has a very low GSI criteria and mercury exceeds criteria to greater extent than other COCs (Barr, 2009e). Therefore, control of mercury will control the remaining COCs.

Summary

The main leachate generation mechanism at the ECKD Area is regional groundwater saturating CKD on the western and central portions of the Site as indicated by the Site data collected during all investigation phases. The IR actions have significantly changed the sources of leachate generation and the pathways of leachate migration. Excavation of CKD has eliminated most leachate generation from infiltration, interflow, and saturated CKD in the bottleneck area, the geomembrane cover system has eliminated the generation of leachate from infiltration, and the future groundwater diversion system is expected to further reduce the generation of leachate from groundwater contacting CKD. Additionally, the leachate that continues to be generated in the ECKD Area discharges to and is effectively controlled by the WLCS and the CLCS. A representation of the ECKD Area Site conceptual model is provided on Figure 10.

2.0 Identification and Screening of Technologies

2.1 Introduction

This section presents the RAOs for the ECKD Area. RAOs have been developed for the source material (CKD) and for groundwater. RAOs provide a basis for evaluating potential remedial technologies and remedial action alternatives. Development of Site-specific RAOs has included consideration of the Applicable or Relevant and Appropriate Requirements (ARARs) and the results of the conceptual model for the ECKD Area presented in the RI Report and Section 1.4.

This section also presents the development and screening of potential remediation technologies for the ECKD Area. The evaluation of these technologies is consistent with the information presented in Section 1, along with U.S. EPA guidance. A broad range of potential remediation technologies was considered in the screening, assembled into alternatives, and evaluated.

2.2 Remedial Action Objectives and ARARs

The RAOs for the ECKD Area are:

- Protection of human health by reducing exposure (direct contact, ingestion, inhalation) to soil (including CKD and CKD-impacted soil), groundwater (including leachate and leachate-impacted groundwater), or surface water that exceeds applicable water quality standards; and

- Protection of the environment by minimizing the offsite migration of leachate that causes surface water to exceed applicable water quality standards.

Development of RAOs for CKD and leachate at the Site includes consideration of current as well as potential future risks which may be associated with the use of the Site. The current land use for the ECKD Area is recreational. The Site is expected to continue to be used as a park (recreational land use). As discussed in the RI Report, the groundwater at the ECKD Area needs to be managed in order to protect human health and the environment.

CERCLA requires that RAOs comply with ARARs under federal environmental laws and state environmental laws or facility siting laws, or provide grounds for seeking a waiver of the requirement. In addition to ARARs, other advisories, criteria, or guidelines may be considered in developing RAOs, as appropriate.

ARARs are classified as location-specific, chemical-specific, and action-specific. Potential location-specific and chemical-specific ARARs for soil (including CKD and CKD-impacted soil), groundwater (including leachate and leachate-impacted groundwater migrating to surface water), and surface water are listed in Tables 5 and 6, respectively.

Most of the location-specific ARARs are not applicable to the ECKD Area. Those that may potentially apply to remedial actions at the Site include the existing Administrative Order on Consent (AOC), and those that address work in or near waters of the State including wetlands, rivers, streams, coastal zones, or floodplains, as shown in Table 5. ARARs that apply to these locations will be addressed in the discussion of specific actions that would be anticipated in or near these zones as applicable to specific alternatives.

Additional details on chemical-specific ARARs for leachate are described below (Section 2.2.1) and in Table 6.

Action-specific ARARs (e.g., Resource Conservation and Recovery Act [RCRA], NPDES Discharge, MDEQ Part 327 "large quantity withdrawal") are linked to specific remedial actions and will be addressed in the context of detailed remedy evaluations in Section 4.

In accordance with the goals of the long-term remedy identified in Section VIII of the AOC, further response activities will accomplish all of the following:

- Integrate the IR actions as appropriate;
- Prevent unacceptable exposures to surface waters and sediment impacted by CKD waste material;
- Design, construct, and operate long-term response activity to prevent discharge of groundwater containing hazardous substances above state criteria from the Site to surface waters of the state;
- Prevent unacceptable risk from human direct contact with CKD waste materials;
- Prohibit exacerbation, prevent new releases and unacceptable exposure, and place land use and resource use restrictions related to CKD waste material;
- Construct and maintain erosion control measures for underlying CKD waste material;

- Ensure adequate financial resources are available in an acceptable form and amount to assure the performance of the response activities necessary to protect human health or the environment in perpetuity; and

- Ensure that any other unacceptable exposures are adequately addressed and assure the effectiveness and integrity of the long-term response activities.

2.2.1 Chemical-Specific RAOs for Soil/CKD

Michigan Environmental Remediation Standards Natural Resources and Environmental Protection Act (NREPA), §20104 of 1994 PA 451 Part 201 establishes cleanup standards for achieving soil quality at remediation sites. Direct contact soil criteria are developed in R299.5720. Criteria based on soil leaching hazardous substances to groundwater are included in R299.5722. Criteria for soil based on indoor inhalation of hazardous substance vapors volatized from soil are included in R299.5724. Criteria for soil based on inhalation of hazardous substances in ambient air are included in R299.5726. Criteria for contaminated environmental media based on other injury are included in R299.5728.

The Michigan chemical-specific remediation standards for soil for each of these pathways were compared directly to the Site-specific analytical results for unconsolidated materials in Table 2-2 of the RI Report. Chemicals in the soil samples (including CKD and CKD-impacted soil; RI Table 2-2 annotates the samples according to field observation of CKD) that exceed these criteria were noted in the RI Report table. The chemicals of concern that exceed the direct contact exposure criteria (R299.5720) in the soil samples that were reported to contain CKD are summarized in Table 7.

2.2.2 Chemical Specific RAOs for Groundwater and Surface Water

Numerous potential chemical-specific ARARs have been promulgated by both the federal and state governments for groundwater and surface water. The potential chemical-specific ARARs are summarized in Table 6. The following sections address the potential application of these ARARs in accordance with regulations promulgated by the State of Michigan for addressing groundwater at contaminated sites.

2.2.2.1 Federal Standards for Groundwater

The Safe Drinking Water Act (SWDA) established maximum contaminant levels (MCLs) and maximum contaminant level goals (MCLGs) for public drinking water systems. The MCLGs set at levels above zero are potential ARARs for current or potential sources of drinking water. The State of Michigan has adopted MCLs for inclusion in the Part 201 rules for groundwater that may be used

as drinking water. The state rules are equal to or more stringent than the federal rules and, therefore, state standards have primacy. The state rules are discussed below.

2.2.2.2 State Standards for Groundwater

Michigan Environmental Remediation Standards NREPA, §20104 of 1994 PA 451 Part 201 establishes groundwater quality standards that are developed for relevant exposure pathways. Criteria for adverse aesthetic impacts to aquifers are developed in R299.5709. Criteria based on ingestion of groundwater as drinking water are included in R299.5710. Criteria based on human dermal contact with groundwater are included in R299.5712. Criteria for groundwater based on hazardous substance vapors emanating from groundwater to indoor air are included in R299.5714. Criteria for groundwater based on protection of surface water resources (waters of the state) from hazardous substances in venting groundwater are included in R299.5715.

The Michigan chemical-specific remediation standards for groundwater for each of these pathways were compared directly to the Site-specific analytical results for groundwater from the ECKD Area in Table 2-5 of the RI Report. Concentrations of chemicals in the groundwater analytical results that exceed these criteria were noted in the RI Report table. The chemicals of concern in the groundwater that exceed any of the above-listed criteria are summarized in Table 8.

2.2.2.3 Federal Ambient Water Quality Criteria for Surface Water

The Federal Ambient Water Quality Criteria (FAWQC) established under Section 303 or 304 of the Clean Water Act (CWA) for priority pollutants may be relevant and appropriate, depending on the circumstances of the site (40 CFR 310.430(e)(2)(i)(E)). The FAWQC for human health are promulgated for exposures that include (1) drinking water and consuming fish and (2) consuming fish only. The FAWQC are also promulgated for aquatic life protection. The FAWQC are not considered ARARs for protection of human health at the Site because the State of Michigan has water quality standards that are more stringent and, thus, take primacy. FAWQC may be relevant and appropriate for the protection of aquatic life. However, at the time of the development of the FAWQC for aquatic life protection, sufficient data were not available to derive aquatic life criteria for all priority pollutants. Therefore, the lowest reported effects levels (LRELs) available in the scientific literature for these chemicals were published in lieu of criteria. The LREL are To Be Considered (TBC) values.

2.2.2.4 State Standards for Surface Water

Michigan Environmental Remediation Standards NREPA 1994 PA 451 Part 31 establishes water quality standards for waters of the State for which there is no specific designation. These standards include: acute standards applicable to the mixing zone, chronic standards applicable after the mixing zone, and wildlife standards. These values are incorporated into the standards established for groundwater venting to surface water, which were described above and provide the basis for identifying COCs for the ECKD Area. Compliance with these standards is to be determined for the ECKD Area in accordance with R 299.5716.

2.2.3 Site-Specific Chemicals of Concern (COCs)

The identification of Site-specific chemicals of concern was based on the comparison of known source material (CKD) and groundwater quality at the Site to the soil and water quality ARARs. As noted in the previous sections, the State of Michigan Part 201 Rules have been identified as the most stringent ARARs for both CKD leachate and surface water impacted by groundwater venting.

Analytical data obtained from samples of unconsolidated material collected from the borings installed during the RI were compared with the applicable soil standards in Table 7. As shown in the table, the following COCs have been identified for source materials at the Site: chloride and arsenic.

Groundwater quality data obtained from samples collected from the monitoring wells installed during the RI were compared with the applicable groundwater quality standards in Table 8. As shown in the table, the following COCs have been identified for groundwater at the Site: inorganics – chloride, % ammonia that will become NH_3 in surface water, pH, total dissolved solids (TDS), sulfate; and metals – aluminum, antimony, arsenic, chromium, copper, iron, lead, manganese, mercury, selenium, sodium, and vanadium.

2.3 General Response Actions

Identification of general response actions capable of meeting the Site-specific RAOs is the first step in the process of developing and screening potential remedial alternatives for the Site (U.S. EPA, 1988).

General response actions are broadly defined as actions that can be used to address the impacted media at a given site. General response actions are evaluated to determine whether they can meet the Site-specific RAOs, as discussed in Section 2.2. The following general response actions are evaluated for the impacted media at the ECKD Area.

Source Materials/Cement Kiln Dust (CKD)

- No action
- Institutional controls
- Removal
- Containment and Isolation
- Other Engineering Controls
- Disposal

Groundwater

- No action
- Institutional controls
- Removal (collection of CKD-Impacted Water)
- Containment and Isolation
- Other Engineering Controls
- Disposal

These actions are also intended to address surface water by limiting leachate migration to surface water. Each of these general response actions includes one or more remedial technologies or process options that are screened (see Section 2.4) in order to develop alternatives (see Section 2.5) for the Site.

2.3.1 Identification of Areas and Volume of Impacted Media

Identification of the volumes and areas of the affected media is the second step in the process of developing and screening potential remedial alternatives for the Site (U.S. EPA, 1988).

The approximate extent of CKD in the ECKD Area is shown on Figure 3 and occupies a footprint area of approximately 10 acres. The extent of CKD was determined by geophysical surveys using Electromagnetic Induction (EM); Direct Current Resistivity Imaging (DCR); and Seismic Refraction (Refraction) methods, and confirmed at various locations with the installation of soil borings, as described in the RI Report. The eastern CKD limits are based on surveys after CKD was consolidated as part of the IR actions in 2006. Geoprobe borings were placed May 3-5, 2006 for the purpose of improving the delineation of the limits of CKD. The updated limits are illustrated on the figures. Estimated surfaces for the top of CKD, top of weathered bedrock, and top of competent bedrock were created in Land Development Desktop (LDD) software using the results from the geophysical surveys. The volume of CKD was estimated by calculating the volume between the 'top of CKD' surface and the 'top of weathered bedrock' surface. The result of this calculation is shown in Table 1. The estimated volume of CKD on the Site is approximately 360,000 cubic yards (CY). The volume of CKD located below the water table is 25 to 50 percent of the total. The eastern portion of the CKD (referred to in this AE as the 'bottleneck') which contained a calculated 35,736 CY of CKD was excavated and moved to the central and western parts of the Site in the consolidation work in 2006.

Three high pH (pH>9) discharge zones from the ECKD Area into Lake Michigan were identified during three targeted shoreline survey events, performed in May 2005, October/November 2005, and May 2006. In addition, elevated pH readings were observed along the western edge of the ECKD Area in Village Harbor in April – June 2006. Data from the targeted shoreline surveys and the readings along the west side of the ECKD Area are shown on Figure 4. These high pH discharge zones have been divided into three generalized locations as follows: (1) Western Discharge Zone, (2) Central Discharge Zone, and (3) the Eastern Discharge Zone. As discussed in the conceptual model, groundwater and, to a lesser extent, infiltration, contacts buried CKD and results in the shallow downgradient CKD-impacted groundwater (leachate) exhibiting an elevated pH. Leachate migrates through the upper portion of the saturated zone and discharges to Lake Michigan near the shoreline at the three discharge zones. This discharge can result in areas where lake water pH is above 9 in the nearshore area.

2.4 Identification and Screening of Technology Types and Process Options

Identification and screening of technologies and process options is the third step in the process of developing and screening potential remedial alternatives for the Site (U.S. EPA, 1988).

2.4.1 Identification and Screening of Technologies

In accordance with U.S. EPA guidance, three criteria are used to screen technologies and process options: effectiveness, implementability, and cost (U.S. EPA, 1988). These three criteria are described below. Using these three criteria, Tables 9 and 10 present the initial screening results for the possible technologies and process options identified for CKD and CKD-impacted groundwater.

2.4.1.1 Effectiveness

The evaluation of effectiveness is based on the following factors: (1) the ability of a process option to address the COCs at the Site; (2) the ability of the process option to function under the conditions specific to the Site; and (3) the potential for adverse impacts to occur during implementation of the process option. This evaluation incorporates the consideration of both short-term and long-term impacts to the Site. The proposed rule entitled *Standards for the Management of Cement Kiln Dust* (U.S. EPA, 1999) and the *Draft Technical Background Document on Ground Water Controls at CKD Landfills* (U.S. EPA, 1998) were also used in assessing the degree of effectiveness of several treatment technologies and process options for COCs. Other references, as footnoted on the tables and previous experience were also used to evaluate the effectiveness of specific technologies and process options.

2.4.1.2 Implementability

The implementability evaluation is based on technical and logistical feasibility. Technical implementability includes the status and performance of a technology for the given Site conditions. Logistical feasibility is based on infrastructure and nontechnical aspects of implementability including: the availability of treatment, storage, and disposal services (including capacity); the availability of necessary equipment and skilled workers to implement the technology; potential obstacles in securing acceptance for remedial technologies; the ability to secure approvals for onsite, as well as offsite, actions; and the potential resistance of residents, governmental entities, or organizations to the collateral impacts or perceived deleterious effects of proposed actions.

2.4.1.3 Cost

The cost evaluation in Tables 9 and 10 shows approximate unit costs or relative cost characterizations for application of each technology. The costs do not include associated functions such as Site preparation, material preparation, or Site restoration. Where technologies are not well-represented by a unit cost, the overall cost of implementation is characterized as low, medium, or high relative to other general response actions. At this stage in the screening process, the cost analysis is made on the basis of engineering judgment. Each process option is evaluated as to whether costs are high, low, or medium relative to other process options in the same technology type.

2.4.1.4 Results

Evaluation results are shown in Tables 9 and 10. Those options that display certain characteristics including: (1) ineffectiveness; (2) non-implementability; (3) poor suitability to the Site conditions, or (4) considerable expense relative to other alternatives within the same technology group are eliminated from further consideration at the completion of this screening step, as noted in the far right column of each table.

The evaluation results also indicate that certain classes of general responses, remedial technologies and options must be combined in order to yield effective, implementable remedies at the Site. For example, ex situ water treatment must be combined with groundwater extraction and discharge processes in order to be implemented. Such effective, implementable, and cost-efficient combinations are retained for further analysis.

2.4.2 Evaluation of Technologies and Selection of Representative Technologies

Table 11a presents the remedial technologies and process options retained for the development of alternatives for CKD and groundwater. Development of the remediation alternatives consists of

refining the general responses into Site-specific responses and assembling them into effective combinations. The following sections provide a detailed discussion of this process.

2.4.2.1 CKD

The general response actions retained for CKD include: no action, institutional controls, removal, containment and isolation, and other engineering controls. Site-specific response actions are formulated based on these retained general response actions and applicable remedial technology. The Site-specific response actions for CKD include no action, institutional controls, excavation with offsite disposal, excavation and reuse, excavation and treatment with offsite disposal or reuse, containment and isolation by onsite consolidation and covering, and in-situ treatment. The No Action response was retained as a basis for comparison with the other response actions (in accordance with the requirements of the NCP). Institutional controls include land development and use restrictions. Land development and use restrictions could include continued land use as a park to protect human health from exposure to CKD that is left in place.

Excavation with offsite disposal was retained because it is a commonly used response action and meets the RAOs. Excavation with offsite disposal is the most viable disposal option when compared with construction of a lined, onsite disposal facility because of the limited Site size and the implementability challenges of temporarily storing CKD during construction of a RCRA containment cell onsite. For offsite disposal, consistent with requirements in Michigan law, CKD would be disposed in a local RCRA Subtitle D landfill.

Excavation and reuse was not retained because of the anticipated implementability and effectiveness challenges associated with this technology. Potential reuse options considered in the evaluation included recycling at another cement kiln and land application as a nutrient or soil amendment. Some of the challenges associated with reusing CKD material in one or more of these scenarios included: the potential need for extensive chemical and physical testing requirements to determine an appropriate loading rate for land application as a soil amendment, identification of a market large enough to handle the calculated volume of CKD, and potential to create a more widespread exposure scenario at land application fields.

Excavation and reuse as feedstock for cement kiln was also not retained because of the uncertainties associated with the ability of cement kiln facilities to accept large volumes of CKD. In addition, excavated CKD would have to be stored and transported in batches, depending on the requirements of the cement kiln facilities, leading to additional storage fees and possible exposure scenarios. The

potential distance from the Site to any facility large enough to use the available volume also limits the potential for beneficial reuse of the CKD.

Excavation and treatment (ex situ) of the CKD was not retained because of the anticipated implementability and effectiveness challenges associated with available treatment technologies. The challenges would include: extensive testing to determine effective reagent additions and processing requirements, and identification of a market large enough to handle a calculated volume of treated materials.

Onsite consolidation, compaction and contouring, and installation of an improved soil cover is the most viable containment and isolation technology when compared with other containment and isolation technologies. The soil cover option was retained because it is commonly used in containment applications and meets the RAOs. The combination of consolidation, compaction and contouring, and installation of an improved soil cover will reduce the potential for direct contact with CKD, reduce the potential for water or wind erosion of CKD, and provide a base for establishing vegetation which will enhance erosion resistance. Onsite consolidation of CKD aids in reducing exposure to CKD by minimizing the area that CKD will occupy on the Site. Contouring and surface water management improvements reduce infiltration. In addition, compaction of the consolidated CKD can reduce the permeability of the CKD material to values that are consistent with a low permeability cap, alleviating the need for a cap layer above the CKD (Todres, et al., 1992a; Todres, et al., 1992b). CKD consolidation, compaction and contouring, drainage improvements, and a soil cover also benefit the long-term geotechnical stability of the pile, improving resistance to slope failure.

The option of incorporating a flexible membrane liner in the cover system was also retained. Negotiations with the U.S. EPA and Michigan DEQ have resulted in this being the option implemented for the IR action at ECKD Area. Consequently, the flexible membrane liner cover system is the version of the cover carried forward in the balance of the AE.

Other covering and capping options were evaluated and not retained for further consideration. These included a clay cap and an evapotranspiration cap.

The option of a low-permeability clay cap was not retained for use as an onsite containment and isolation technology because it was not more effective than a soil cover at restricting exposure to the covered material, but was more expensive than a soil cover system. In addition, an acceptable, local clay source would have been difficult to find. Clay would have also been susceptible to freeze-thaw

and wet-dry cycling. Considerable maintenance would be required to keep deep-rooted plants from becoming established in the cover soil above the clay cover. An evapotranspiration cap was not retained because seasonal variations in evapotranspiration potential may limit the effectiveness of this type of cap. It is also more expensive than a soil cover system.

In situ chemical encapsulation was not retained because it is an unproven technology and, therefore, not previously implemented or demonstrated to be effective in this application. Application of any chemical to encapsulate the CKD would introduce large quantities of additional 'inactive' chemicals, companion ions in particular, and may create unacceptable groundwater quality impacts. Since this technology is expected to restore the groundwater, long-term evaluation of the restored microbial community influence would be required to ensure encapsulation material integrity. The ability to uniformly deliver reactant is not expected to be practicable given the known heterogeneity of the in-place CKD permeability. Also, laboratory and pilot-scale tests would be required to determine feasibility and effectiveness. If proven to be effective, during years of column studies, implementation of a full-scale system would take additional years. Bottom liner such as injection of grout/cement below the CKD was not retained because it would not be effective at eliminating exposure to CKD and eliminating infiltration. It would also be difficult to implement due to the depth of the CKD and bedrock. Vertical barriers such as slurry wall and grout injection were retained for their utility in isolating the bulk of the CKD on the west side of the Site. Sheetpile wall was not retained because it was not as implementable in this geology as other vertical barriers. No vertical barrier technology was retained for any portion of the Site except the west end. Implementation can be an issue since the depth of the material exceeds the practical limit of most equipment. Bedrock also limits options for barrier construction.

Dynamic compaction was not retained because the acceptance of this technology by neighboring property owners is questionable due to ground vibrations and noise pollution created during the process of dynamic compaction. Other engineering controls such as in-situ treatment using Accelerated Carbonation Technology (ACT) was not retained because of the uncertainty associated with the ability of this process to fully remediate all CKD in-situ. Bench-scale and pilot-scale testing would be required to evaluate effectiveness of this process option. There is insufficient demonstration of this unproven technology and it would be expected to take a long time to implement after a lengthy technology testing process.

2.4.2.2 Leachate and CKD-Impacted Groundwater

The general response actions retained for leachate include: no action, institutional controls, removal (collection of leachate and CKD-impacted groundwater), containment and isolation, in-situ treatment, and disposal. Site-specific response actions, including combinations of one or more of these general response actions, were formulated based on the retained general response actions and applicable remedial technologies. The Site-specific general response actions that will be considered for groundwater include no action, institutional controls, removal by extraction wells or collection trenches, containment and isolation by upgradient extraction wells, vertical barriers, soil cover/impermeable cap, and in-situ treatment by neutralization. Those response actions that will generate a leachate or wastewater stream will also require leachate management. The general response actions retained for Site-specific consideration of leachate management include: onsite treatment at a wastewater treatment facility with discharge to surface water via a new NPDES permit; onsite pretreatment and disposal to an offsite POTW for treatment and discharge to surface water via an existing NPDES permit; offsite disposal using deep well injection; offsite land application of collected leachate; and evaporation of leachate using an offsite evaporation pond. Leachate management response actions are described in Section 2.4.2.3.

Institutional control would include groundwater use restrictions. Groundwater use restrictions would prohibit the use of groundwater from beneath the Site as a drinking water source.

Each of the retained removal and containment and isolation technologies is suited for certain portions of the Site and can be effective and implementable in aggregate, as discussed in Section 3.0. These technologies were retained because they are commonly used as groundwater migration control/containment applications and meet the RAOs.

Collection of the CKD-impacted water using extraction wells and collection trenches was retained because these are demonstrated technologies that can be effective at controlling groundwater migration and are capable of collecting large volumes of water. These are also readily implementable options.

Containment and isolation using upgradient extraction wells was retained because it is potentially effective in minimizing groundwater flow through the contaminated media, can be used to collect a large volume of water in order to contain the groundwater at the Site and is readily implementable. Upgradient isolation and extraction wells would only be used in conjunction with downgradient leachate collection, treatment, and discharge technologies in order to meet the RAOs. An upgradient

collection trench was not retained because it is not as effective as the other containment technologies and it would be more difficult to implement than a series of collection wells.

Containment using slurry wall/grout injection was retained because it can be effective at limiting migration of groundwater containing chemical compounds. Installation in bedrock, however, would require special grout injection procedures. This option would be effective if used in conjunction with leachate collection processes. A vertical barrier using sheetpile was not retained because bedrock will impede installation (piling cannot be driven into bedrock) in certain portions of the Site. Therefore, sheet pile would not be technically implementable except possibly on the west side of ECKD Area. A vertical barrier using an infiltration gallery was retained because it will reduce the hydraulic gradient to the lake. This particular option is well suited to alternatives which include upgradient diversion as the diversion water could be used as a source of infiltration gallery feed water.

Downgradient hydraulic containment using an infiltration gallery was retained because it reduces groundwater gradient through contaminated media and provides localized barrier to transmission of upgradient groundwater. It is a readily implementable option and relies on a source of clean water and, therefore, is well-suited to use in combination with upgradient groundwater diversion which supplies ample water.

The horizontal barriers retained for screening of remedial technologies for CKD-impacted groundwater are the same as the ones retained for CKD and are discussed in Section 2.4.2.1.

In situ treatment of groundwater by the physical/chemical treatment process of neutralization was retained because it has demonstrated effectiveness in treating high pH waters. A Site-specific test of this technology is in progress at the Pine Court drain line. Monitored natural attenuation was retained even though targeted shoreline survey results have shown that attenuation is not effective at preventing alkaline groundwater from discharging to the lake as a stand-alone technology. Site evidence shows attenuation lowers the concentrations of the various parameters (see Section 3.1.2).

2.4.2.3 Leachate Management Response Actions

Several methods of water management were evaluated to determine the most feasible response actions for treatment and disposal of the collected leachate. Any final remedial alternatives that will include leachate collection will also require collection and disposal of water as a long-term remedy component. Technologies and process options evaluated for treatment and disposal of collected leachate include:

- Onsite treatment at a wastewater treatment facility with discharge to surface water via a new NPDES permit.
- Onsite pretreatment and disposal to an offsite POTW for treatment and discharge to surface water via an existing NPDES permit.
- Offsite disposal using deep well injection. Onsite disposal at a deep well was included in the screening of process options as per the U.S. EPA's requirement. However, this is not an option that will be carried forward for further evaluation because no known suitable geologic formation is available onsite for deep well injection.
- Offsite land application of collected leachate.
- Evaporation of leachate using an offsite evaporation pond.

Potential remediation actions involving water collection at ECKD Area are likely to produce a flow of approximately 10,000 to 40,000 gallons per day (gpd), based on a projected average flow of 7 to 27 gpm from the leachate collection systems after remedial action implementation. This range of values represents the collection rates observed during IR operation and is summarized in the RI Report, Appendix X (Barr, 2009e). Preliminary data on the quality of the leachate generated at ECKD Area during the interim actions are summarized in Appendix C. These results show that pH, organic carbon, total dissolved solids, and mercury are likely to be the primary criteria that will affect consideration of leachate management options. The following paragraphs provide a detailed evaluation of the above listed leachate management options using the flows and water quality from ECKD Area.

Onsite Treatment at a Wastewater Treatment Facility with Discharge to Surface Water via a New NPDES Permit

Onsite leachate treatment would likely consist of a multi-step effort. The first step would likely be neutralization to reduce the pH. It is anticipated that reducing the pH will result in the precipitation of solids that would be expected to remove an incidental portion of the metals of concern. This precipitate would then be rendered suitable for offsite disposal as a solid waste. After neutralization and precipitation, some chemicals of concern may remain in the leachate at concentrations above the chemical-specific ARARs for NPDES discharge. It is unlikely that a well-established treatment process could materially improve mercury removal as the mercury in the leachate solution is already at a very low concentration. The data in Appendix C show mercury concentrations influent to the

ECKD treatment system are generally in the range of 6 to 20 ng/L, with one sample reading of 47 ng/L. These levels, which cannot be materially reduced by treatment, are above the proposed effluent limit of 1.3 ng/L for any new direct discharge sources to the Great Lakes, including Lake Michigan.

Treatment alone is unable to reduce mercury concentrations to the Great Lakes effluent limit. The work done in support of the permit application showed, through pilot testing with water from the development area of the Site, that treatment can be of significant benefit when much higher initial mercury concentrations are present. The mercury concentrations are much higher in the development area than the highest concentration of mercury observed in the ECKD Area. The initial total mercury concentration in the groundwater used in the pilot-tests was as high as 600 to 700 ng/L, which is thirty to one hundred times higher the typical range of concentrations observed in the influent groundwater at the ECKD treatment facility. The treatment process studied in the pilot-testing included neutralization to a pH between 7 and 7.5, enhanced chemical precipitation using a metal precipitating reagent (MCX), and filtration. Results from the pilot testing showed that this combination of physical/chemical treatment processes had the potential to lower the mercury concentration in the treated leachate from approximately 500 to about 20-30 ng/L. The preliminary results from this pilot testing were presented to the U.S. EPA and the Michigan DEQ at a meeting with CMS on January 18, 2006..

Based on review of the ECKD groundwater analytical data and the data in Appendix C, an influent concentration of 6 to 20 ng/L is anticipated for a full-scale onsite wastewater treatment facility. This concentration is below the limit of current practicable treatment technologies, meaning that additional treatment should not be expected to provide any reliable reduction in the mercury concentration.

However, even though treatment alone may not achieve the required concentration levels, it may be possible to obtain an NPDES permit for a discharge, provided the concentration could be reduced by blending the treated water stream with upgradient diversion water. The upgradient diversion water may carry some natural background mercury concentration. After mixing with as little as 100 gpm of upgradient diversion water, a treated effluent with a mercury concentration of 10 ng/L could meet a GLI standard of 1.3 ng/L.

Onsite Pretreatment and Disposal to an Offsite POTW for Treatment and Discharge to Surface Water via an Existing NPDES Permit

In the event that an NPDES permit for direct discharge cannot be obtained, leachate pretreated at the Site using the neutralization and equalization processes described previously could be discharged to a sewer for additional treatment at a municipal wastewater treatment facility or publicly-owned treatment works (POTW). Some water from the development Site is currently trucked to Traverse City for disposal into a POTW, and leachate collected from an initial recovery system installed at the Site in the mid-1990s used this method of management to dispose of leachate to the City of Petoskey POTW.

In general, the U.S. EPA is in favor of using POTWs for final treatment and removal of mercury from wastewater, so this approach may meet with acceptance by state and federal agencies.

The ability of a POTW to accept pretreated leachate from ECKD Area is dependent on several factors including the total volume of the flow, the temperature of the water, the organic loading, and the total dissolved solids (TDS) loading. However, the primary consideration for acceptance of treated ECKD Area leachate by a POTW is likely the total mercury and TDS load to the facility. The potential impact of Site mercury and TDS on the receiving POTW will need to be addressed on a case-by-case basis with the receiving POTW.

It should be noted that, if this water disposal approach is adopted, permission to send the remainder of the Little Traverse Bay water (from the development portion of the Site) to the POTW may also be sought.

A potentially serious limitation for this disposal approach is the logistics of getting the pretreated leachate to the POTW. Transport considerations may adversely affect both the implementability (timing and logistics) and cost-effectiveness of this option.

Offsite Disposal Using Deep Well injection

Leachate currently being collected as a component of the interim removal actions at ECKD Area is being disposed offsite into a deep injection well. This well is a commercial waste receiving well located in Johannesburg, Michigan. The well is drilled into the Dundee formation at a depth in excess of 2,000 feet below the ground surface. This area of the subsurface is known to contain fluids that are not suitable for withdrawal and use as potable water, irrigation supply, or industrial make-up. Deep well injection has developed as an effective disposal method for waste streams as it delivers the material through a double-lined well into a deep geologic formation. The well is sealed against

surrounding strata. The existence of multiple layers of nearly impermeable geologic zones between the disposal zone and the usable aquifer above, as well as the density of the leachate (equal to or greater than water) provides certainty that the material does not migrate upward and impact the shallow aquifer that may be used as drinking water. Deep-well injection is engineered to prevent impacts to surface water or groundwater from the waste stream. Due to uncertainties with respect to committed capacity for the commercial well that is currently in use and lack of control over operating and maintenance outages, a CMS-owned and controlled injection well has been permitted. See Appendix E for the application and technical specifications. This technology is currently being used and has been a successful technology in managing this waste stream.

Onsite Disposal Using Deep Well injection

Leachate currently being collected as a component of the IR at the Site is being disposed offsite into a deep-injection well. The onsite disposal using deep-well injection process option assumes a suitable geologic formation exists at the Site and has been retained at MDEQ's request. Limited data exists as to the viability of an injection well drilled within piping distance of the treatment facilities in Emmet County. In addition, an implementable forcemain alignment from the Treatment Plant to the injection well would be needed.

Offsite Land Application of Collected Leachate

Land application of solids and aqueous residuals is a technology used by some industries, as well as wastewater treatment plants. The technology involves the spray application of the residual waste stream onto the surface of land where the water, as well as the contaminants from the waste stream, would be absorbed into surface plant material or adhered to and attenuated by subsurface soils. Maximum attenuation typically occurs with substantive plant growth and non-sandy soils. Most waste streams managed through this technology have a nutrient base that supports plant growth. MDEQ guidance for load application limits the volume of water to 40 inches per year over the load area.

The nature of the leachate waste stream is predominantly mineral with cation and anion COCs including: arsenic, mercury, sulfate and chloride. The high salt nature of the waste stream would likely have a negative impact on surface plant growth and may significantly reduce plant uptake as a method of COC reduction. The high salt content would also limit the duration for which a plot can be used for land application. Significant pretreatment would be required to reduce the salt in the waste stream. Inadequate removal would force relocation of the land application Site to avoid excessive salinity build-up in the soil. Also some metals such as arsenic and mercury are not beneficial to plant

growth and have minimal uptake rates even when plant growth is sustained. Additionally, soils in the area generally have a sand component.

It is anticipated that land application of this waste stream would result in minimal removal of COCs prior to the dilution of the waste stream in the groundwater below the application area. If this technology were selected for the ECKD discharge, it would also need to handle the water from the rest of the Little Traverse Bay Site. In order to manage the total Little Traverse Bay waste stream through land application, the following would be needed:

- Approximately 100 acres of land to handle the volume to assure minimum potential for runoff
- A 100–acre, spray-application system
- Storage for up to 27,000,000 gallons of wastewater due to seasonal and precipitation limits on application
- Nutrient additions to attempt to maintain some surface growth to achieve uptake and minimize erosion

Since this technology relies on specific attenuation methods of plant uptake and soil attenuation to reduce COCs and those methods appear likely to be ineffective with this waste stream, dilution of the wastewater by groundwater below the Site appears to be the predominant attenuation mechanism. Since most areas in the proximity of the Site use the groundwater as drinking water, this technology is likely to be met with significant public opposition. Thus, offsite land application is not likely to be a viable technology for addressing this waste stream and has not been retained.

Evaporation of Leachate Using an Offsite Evaporation Pond

Evaporation/settling ponds have been used for the management of aqueous waste streams where separation of solids can be facilitated. This option envisions the potential use of lined ponds that would not allow for percolation of constituents through the soil and into the aquifer. Over time, the water in the pond would be evaporated and remaining solid residuals would be removed and disposed in a permitted landfill.

In order to manage an aqueous waste stream flow rate of 20,000 to 30,000 gpd, multiple settling units would need to be constructed. The number of units would be based on the stages of separation necessary to promote maximum solids removal. Laboratory testing of the waste stream indicated a natural settling of only a negligible portion of the mineral content of the water in 24 to 48 hours. Even with bench-scale controlled pH adjustments, less than one percent of the volume of the waste steam was separable as a solid phase. This left the remainder of constituents dissolved in the aqueous

phase for natural or energy-assisted evaporation. This is generally considered an insufficient result for use of this technology.

Some additional constraints on this technology include:

- Availability of up to 60 acres of land within underground pipe access from all leachate collection areas
- Construction, operation, and maintenance of bermed, lined and aerated settling ponds with controls for chemical addition
- Drying/rendering transportation and disposal of solids

Additionally, natural evaporation processes are not favored due to moisture saturation of air close to the lake, annual precipitation that exceeds annual evaporation, and relatively low average temperatures. Therefore, energy-assisted evaporation would likely be the principal method employed to address water volumes. This would be prohibitive due to the cost of energy. This alternative is therefore not retained for further consideration.

2.5 Retained Technology Types and Process Options

Section 2.4 provided a detailed discussion for the basis for retaining or screening out the various technology types and process options. This section discusses the rationale behind combining the retained technologies and process options into alternatives.

Table 11a summarizes the retained technology types and process options for CKD and groundwater, Table 11b assembles these process options into a range of alternatives for further screening, Table 11c provides an evaluation of the assembled screening alternatives, and Table 12 summarizes the retained technology and process options as combined into remedial alternatives which are retained for detailed analysis. Below is a detailed discussion of the screening alternatives.

Screening Alternative 1 is the no-action alternative and does not include any remedial actions and is retained for detailed analysis in the Sections 3 and 4 as Alternative 1.

Screening Alternative 2 combines the following technology types and process options: CKD consolidation and cover over the CKD pile with a flexible membrane liner (FML), groundwater migration control (without diversion), natural attenuation, treatment and disposal of groundwater and institutional controls. This combination was selected because of the synergies and mutually-reinforcing benefits of these technologies in this setting. This remedy is identical to screening Alternative 4 except that groundwater diversion wells are not included. This screening alternative is retained for detailed analysis in Sections 3 and 4 as Alternative 2-a.

Screening Alternative 3 combines the following technology types and process options: CKD consolidation and cover over the CKD pile with a flexible membrane liner (FML), groundwater migration control, natural attenuation, groundwater diversion, treatment and disposal of groundwater and institutional controls. This combination was selected because of the synergies and mutually-reinforcing benefits of these technologies in this setting. This remedy is identical to screening Alternative 4 except that some of the diverted groundwater is infiltrated downgradient of the existing collection systems. This screening alternative does not provide significant additional benefit for mercury removal and limited control of the other COCs and is not retained for detailed analysis.

Screening Alternative 4 combines the following technology types and process options: CKD consolidation and cover over the CKD pile with a flexible membrane liner (FML), groundwater migration control, natural attenuation, groundwater diversion, treatment and disposal of groundwater and institutional controls. This combination was selected because of the synergies and mutually-reinforcing benefits of these technologies in this setting.

This remedy reduces leachate generation by several means, and collects that smaller leachate volume for appropriate disposal. Leachate production is reduced by consolidation, the cover system, and upgradient diversion. Consolidation of this CKD has reduced elevated pH in the lake at the eastern discharge zone shown on Figure 9, and has reduced the concentration of metals that leach from the CKD (as can be seen by comparing monitoring well W4119 with W4119r in the RI groundwater data tables). Consolidation is also expected to lead to a significant reduction in mercury loading, as shown in Appendix A. The FML cover system, along with surface water management improvements, reduces the infiltration of precipitation and leachate production. Groundwater diversion will reduce groundwater elevation and, thus, contact with CKD, and will reduce the flow rate of groundwater through the CKD, significantly reducing the volume of leachate to collect. On the downgradient limit of CKD, leachate collection assures that the leachate is captured, protecting the lake. Collection trenches are preferred over extraction wells as the remedial technology type for the collection of the groundwater because collection trenches are already installed at the Site and their continuous nature provides more consistent interception of leachate than individual extraction wells. This alternative also incorporates natural attenuation for reduction of the trace mercury concentrations that may currently exceed GSI levels at monitoring wells as the groundwater migrates to the lake. Attenuation is discussed further in Section 3.1.2. Treatment and disposal options for groundwater are those retained as described in Section 2.4.2.3. This alternative also includes institutional controls which will prohibit the use of groundwater at the Site and limit excavation work in order to protect the cover system. The combination of the above technology types and process options will help achieve

the RAOs by minimizing leachate generation (through consolidation and covering the CKD pile and groundwater diversion), collection of the leachate to prevent its migration to the shoreline, and disposal of the captured leachate. This screening alternative is retained for detailed analysis in Sections 3 and 4 as Alternative 2.

Screening Alternative 5 combines the following technology types and process options: CKD consolidation and cover over the CKD pile with a flexible membrane liner (FML), groundwater migration control (without diversion), natural attenuation, treatment and disposal of groundwater and institutional controls. This combination was selected because of the synergies and mutually-reinforcing benefits of these technologies in this setting. This remedy is identical to screening Alternative 4 except that targeted leachate collection is added to the existing IR. Since the existing IR system is highly effective at pH control and remaining mercury and COCs are controlled to the extent practicable, targeted leachate collection would result in insignificant mercury and COCs removal while collecting large volumes of lake water at a considerable cost. Since this screening alternative does not provide additional benefit it is not retained for detailed analysis.

Screening Alternative 6 combines the following technology types and process options: onsite CKD consolidation and cover over the CKD pile with a flexible membrane liner, in situ treatment of the leachate using sparge wells, and institutional controls. In-situ treatment of the leachate using CO_2 sparging will neutralize the leachate before it discharges to the lake and thereby eliminate the exposure to high pH leachate on the shoreline. Optional downgradient hydraulic containment may be used in this alternative to further slow groundwater migration and so enhance the effectiveness of the CO_2 sparging. The consolidation and covering of the CKD pile will help reduce the generation of leachate by minimizing infiltration. Institutional controls will prohibit the use of groundwater at the Site and limit excavation work in order to protect the cover system. This alternative will help achieve the RAOs through leachate generation control, treatment of the leachate already generated and institutional controls. This screening alternative is retained for detailed analysis in Sections 3 and 4 as Alternative 3.

Screening Alternative 7 combines complete excavation and onsite consolidation of CKD at the Site, dewatering during the CKD excavation process, neutralization of dewatered flow and discharge to the lake, complete demolition and reconstruction of the park, and institutional controls for groundwater use prohibition. This alternative will meet the RAOs through isolation and containment of the source of contamination from the Site. This screening alternative is retained for detailed analysis in Sections 3 and 4 as Alternative 4-a.

Screening Alternative 8 combines complete removal of CKD from the Site, dewatering during the CKD excavation process, neutralization of dewatered flow and discharge to the lake, complete demolition and reconstruction of the park, and institutional controls for groundwater use prohibition. This alternative will meet the RAOs through removal of the source of contamination from the Site. This screening alternative is retained for detailed analysis in Sections 3 and 4 as Alternative 4.

3.0 Development and Screening of Alternatives

3.1 Development of Detailed Alternatives

Assembling Site-wide alternatives using combinations of remedial technologies or process options to address all affected media is the final step in the process of developing and screening potential remedial alternatives for the Site (U.S. EPA, 1988). This section uses the retained technologies and process options, assembled and screened alternatives from Section 2 and provides six detailed remedial alternatives for the Site. These detailed remedial alternatives are summarized in Table 12 and potential remedy-specific ARARs are included in Table 13. Detailed and comparative analyses of the remedial alternatives developed in this Section are presented in Section 4.

3.1.1 Alternative 1 – No Action

The no action alternative constitutes the absence of any remedial actions. No action is considered in this evaluation as a baseline for comparison to all other potential remedial actions as required by the National Contingency Plan (NCP) and U.S. EPA Guidance for Conducting Remedial Investigations and Feasibility Studies (U.S. EPA, 1988).

The estimated loading of mercury to the lake at the ECKD Area for this alternative is 18.2 mg/day, as detailed in Appendix A. For a 30-year implementation period, this amounts to nearly 200 grams of mercury. The 30-year average equivalent concentration for this alternative is approximately 7.7 ng/L.

Prior to implementation of existing IR actions, lakeshore pH regularly exceeded pH 9.0 at the ECKD Area. Figure 4 shows pH targeted shoreline survey monitoring observations prior to implementation of IR actions. Targeted shoreline survey monitoring data summaries and figures are also presented in Appendix L of the RI Report (Barr, 2009e). Effectiveness monitoring data summaries and figures for both lakeshore and pools pH are presented in Appendix Y of the RI Report (Barr, 2009e).

3.1.2 Alternative 2 – CKD Consolidation and Cover, Groundwater Migration Control, Natural Attenuation, Groundwater Diversion, Treatment and Disposal of Groundwater, and Institutional Controls (Includes Upgradient Diversion)

This alternative consists of onsite CKD consolidation, compaction, and contouring; constructing a cover over the CKD which incorporates a flexible membrane liner; active migration control and treatment for leachate; natural attenuation; and upgradient groundwater diversion. The conceptual layout for this alternative is shown on Figure 11. This alternative maximizes integration of the IR actions with the final remedial alternative for the Site as appropriate, which is one of the objectives

identified in the AOC, Section VIII, paragraph 14, item x. Construction record drawings for the interim leachate collection system and the cover are in Appendix G.

This alternative is representative of existing IR actions with the addition of upgradient groundwater diversion wells. Existing IR actions includes installation of the WLCS and CLCS, installation of the slurry wall vertical barrier downgradient of WLCS, excavation of CKD from the bottleneck area, an upgradient interflow collection drain, and an impermeable cover system.

As a part of this alternative, CKD was removed from the bottleneck portion of the CKD pile. It is calculated that 35,736 CY of CKD was removed from the bottleneck area between August 7, 2006 and September 9, 2006.

Unsaturated and saturated CKD material was blended during excavation and loaded to minimize dust emissions and form a material more conducive to placement and compaction. As a practical matter, saturated CKD, when disturbed, can become gel-like with very low strength, making it difficult to handle (Todres, et. al, 1992a and 1992b). The difficulty of excavation below the water table (with or without dewatering) and the challenges of saturated CKD handling properties resulted in the likelihood that there was some residual CKD not completely removed from below groundwater during the consolidation work. CKD consolidation from this area of the Site has progressively reduced both the elevated pH in the lake at the eastern discharge zone shown on Figure 9 and the transport of metals that leach from the CKD. For instance, a comparison of the water quality sample data from W-4119 (preconsolidation well) to W-4119r (replacement well installed post-consolidation) clearly indicates improvement. Well locations are shown on Figure 8. The pH dropped from 11.92 to 12.36 in W4119 samples down to 6.96 to 7.84 in W4119r samples. Mercury concentrations dropped from 129 to 206 ng/L down to 0.6 to 9.7 ng/L. Aluminum concentrations dropped from 1200 to 2200 µg/L down to less than 50 to 760 µg/L. Potassium dropped from 1100 to 1400 mg/L down to 27 to 220 mg/L. As can be discerned from this brief review, concentrations have dropped by an order of magnitude or more after the consolidation work. A review of the data in Table 2-5 in the RI Report (Barr, 2009e) suggests the concentrations are continuing to trend lower over time.

The monitoring well W-4119r data also show consolidation of this CKD should be expected to lead to a significant reduction in mercury loading. The analysis in Appendix A illuminates the reduction in flux from the east end of the Site. The mercury flux at the bottleneck area is estimated to have decreased from a pre-IR mercury flux of 1.7 mg/day to approximately 0.5 mg/day.

The existing CKD was contoured and compacted to promote runoff and a vegetated 3-foot soil cover system incorporating a flexible membrane liner was placed over the ECKD Area in 2006 and 2008. As noted in the remedial technology review, the flexible membrane liner is included as a result of negotiations with the regulatory agencies. A properly contoured and established vegetated cover system, along with surface water drainage system improvements, will further minimize the quantity of infiltration into the CKD.

This alternative will also include the following combination of groundwater migration control technologies: leachate collection, a vertical barrier, and upgradient groundwater diversion.

On the downgradient limit of the CKD pile, two trench leachate collection systems were installed to intercept high pH leachate currently discharging through the western and central discharge zones. The average collection rate from the combined collection systems was about 20 gpm, consistent with the experience for collection systems in other portions of the Little Traverse Bay CKD Release Site.

Upgradient groundwater diversion will be provided using groundwater diversion wells installed south of the southern limit of the CKD cover. Groundwater diversion aids the leachate collection system by reducing seasonal peaks of groundwater flow from upgradient and reducing groundwater contact with CKD by reducing both groundwater flow and groundwater elevation. Diversion has been found to be beneficial at other CKD sites. These diversion wells would provide some lowering of the head differential across the CKD pile, reducing groundwater flow (and thus, contaminant flux) toward the lake. By responding dynamically to the lake and groundwater elevations, this remedial component provides for additional effectiveness reliability as well as reduce flow variations in collected leachate. This is reflected in lower flows expected at the leachate collection system. The results from preliminary modeling (see Appendix H) showed the groundwater flow collected could be reduced. Additional preliminary design has estimated this reduction to be approximately 40 percent, with the diversion of 100 to 120 gpm from upgradient diversion wells placed along the alignment, as shown on Figure 11. Preliminary design for the ECKD groundwater diversion system has been provided in the *Technical Memorandum, Preliminary ECKD Diversion Well Design, January 9, 2009*. The updated groundwater modeling has been provided in Appendix T of the RI Report (Barr, 2009e). The diversion flow rate has been selected to provide a margin of safety against drawing leachate from the CKD back toward the diversion wells. In addition, sentinel wells are located between the diversion wells and the CKD to allow measurement of groundwater elevations, to confirm that groundwater gradients and flow directions are as planned.

The projected long-term mercury flux for this remedy is less than 3.6 mg/day. The estimated mercury loading to the lake for a 30-year implementation of this alternative is less than 40 grams. The 30-year average equivalent concentration for this alternative is approximately 1.6 ng/L.

The long-term flux estimate of 3.6 mg/day constitutes a 12.1 mg/day reduction from pre-IR conditions and a 3.8 mg/day reduction relative to baseline conditions; existing IR flux is discussed in Section 3.1.3. It is estimated that approximately 1.4 mg/day of mercury flux reduction will be realized in time as the benefits of the existing IR actions continue to manifest themselves at downgradient monitoring locations. It is also estimated that upgradient diversion will provide a net mercury flux reduction in line with estimated groundwater flow rate reductions (40% of remaining flux to the lake or 2.4 mg/day).

Lakeshore pH control for this alternative will be better than baseline conditions for the existing IR actions. Effectiveness monitoring data clearly indicates that the existing IR actions are currently highly effective at controlling lakeshore pH less than 9.0 standard units. As shown on Figure 9, 2009 effectiveness monitoring observations show no lakeshore pH exceedances (April 16, May 5, and June 4).

The role of natural mechanisms at the Site in attenuation of pH and mercury are discussed in detail in the RI Report and are reviewed briefly here. As leachate mixes with groundwater, its chemical properties change. These changes are illustrated using Stiff diagrams that are included in the RI Report (Barr, 2009e). The ratio of divalent cations to monovalent cations (Ca+Mg : Na+K) can be used as an indicator of the degree to which leachate has blended with groundwater. As leachate mixes with groundwater, its constituents of concern are also attenuated. Thus, the ratio of divalent:monovalent cations can be used as an indicator of leachate attenuation. In general, samples with a ratio of divalent:monovalent cations below 0.07 (eq:eq) were considered unattenuated leachate, as this is the approximate point of divergence between trends in pH and chloride. Samples with a ratio of divalent:monovalent cations between 0.07 and 2.0 were considered a mixture of leachate and groundwater. Samples with a ratio of >2.0 were considered unimpacted groundwater, as this is the point where the pH trend flattens. As shown on Figure 5-2 of the RI report, Site samples fall into a wide-ranging continuum with respect to the ratio of divalent:monovalent cations (Ca+Mg : Na+K). As expected, pH is attenuated as the ratio of divalent:monovalent cations increases, due to dilution, precipitation of carbonate alkalinity, and neutralization with groundwater acidity. As shown on Figure 5-3 of the RI report, mercury is also attenuated as the ratio of divalent:monovalent cations increases, due to dilution as well as precipitation of the mercury-bearing fatty acid surfactants. Also included on Figures 5-

2 and 5-3 is chloride concentration. The change in chloride concentration as leachate mixes with groundwater is a reasonable measure of the degree of dilution that occurs. It can be seen that, as the leachate is mixed with sufficient groundwater to affect its chemical properties, trends in pH and mercury concentration begin to diverge from the trend in chloride concentration. This suggests mercury attenuation by the reaction mechanisms previously discussed, in addition to dilution.

Institutional controls will consist of groundwater use limitations. The Site is expected to continue to be used as a park (recreational land use). Maintenance of the engineered cover would be part of the long-term operation and maintenance (O & M) for the Site. Groundwater use restrictions would prohibit the use of groundwater as a drinking water source.

The CKD-impacted groundwater collected from the collection systems would be disposed in one of four ways: (1) the collected groundwater would be piped to the treatment plant to be treated and discharged to surface water using an NPDES permit; (2) the collected groundwater would be conveyed to an offsite POTW, treated at the POTW and discharged to surface water; (3) the collected groundwater would be injected in a deep well onsite, or (4) the collected groundwater would be injected in a deep well offsite. These disposal options are discussed in detail in Section 2.4.2.3. The selection of disposal for the water by any of these four options is a matter of continuing discussion with the relevant agencies and authorities. There are a variety of state and local approvals and commitments that must occur for the option of disposal with any POTW to be viable. CMS has been granted an offsite deep well injection permit (see Appendix E), but well construction has not commenced due to continuing permit appeals. There are variables with each of these options that strongly affect the cost of implementation variables, including the treatment requirements, transportation, and various improvements to facilities and infrastructure. In view of these uncertainties, and the demonstrated willingness of CMS to implement any of these options, the AE does present cost estimates for assumed offsite disposal costs in a deep injection well.

The total cost for this alternative, including long-term O&M costs, is $26 million. Detailed cost estimates for this alternative are provided in Appendix J.

3.1.3 Alternative 2-a – CKD Consolidation and Cover, Groundwater Migration Control, Natural Attenuation, Treatment and Disposal of Groundwater, and Institutional Controls (Excludes Upgradient Diversion)

This alternative consists of onsite CKD consolidation, compaction, and contouring; constructing a cover over the CKD which incorporates a flexible membrane liner; active migration control using beach collection drains and treatment for leachate; and natural attenuation. This alternative is

identical to Alternative 2 except that upgradient groundwater diversion wells are not included in this alternative. This alternative is representative of existing ECKD Area IR conditions. See Section 3.1.2 for a description of the IR actions. The conceptual layout for this alternative is shown on Figure 12.

As described previously, the existing IR actions are highly effective at lakeshore pH control. Effectiveness monitoring data clearly indicates that the existing IR actions are highly effective at controlling lakeshore pH less than 9.0 standard units. As shown on Figure 9, 2009 effectiveness monitoring observations show no lakeshore pH exceedances (April 16, May 5, and June 4).

Existing mercury flux to the lake is estimated to be less than 7.4 mg/day. It is estimated that approximately 1.4 mg/day of mercury flux reduction will be realized in time as the benefits of the existing IR actions continue to manifest themselves at downgradient monitoring locations. The projected long-term mercury flux for this remedy is less than 6.0 mg/day. The estimated mercury loading to the lake for a 30-year implementation of this alternative is approximately less than 66 grams. The 30-year average equivalent concentration for this alternative is approximately 2.5 ng/L.

The total cost for this alternative, including long-term O&M costs, is $30 million. Detailed cost estimates for this alternative are provided in Appendix J.

3.1.4 Alternative 3 – CKD Consolidation and Cover, In Situ Treatment of Groundwater, and Institutional Controls

This alternative consists of onsite CKD consolidation, compaction and contouring, constructing a cover over the CKD pile which incorporates a flexible membrane liner, and in situ treatment of the leachate migrating toward Lake Michigan. The CKD consolidation activities for the material in the bottleneck, along with contouring and placement of a new cover for this alternative, are the same as those described in Alternative 2. The conceptual layout for all the components of this alternative is shown on Figure 13. The institutional controls for this alternative are also the same as those described for Alternative 2. This alternative integrates the IR actions, in that the leachate collection systems installed were designed to accommodate sparging systems should that be a preferred alternative.

For the CKD-impacted groundwater, this alternative consists of in situ groundwater treatment to address leachate discharging to Lake Michigan in the central and western discharge zones. Treatment would include the injection of carbon dioxide (CO_2) through a shallow sparging system into the zone between the source of contamination (CKD) and the discharge point (shoreline). The sparging system

would be designed to treat groundwater at or above an elevation of approximately 572 feet above mean sea level (MSL). The sparge line would be constructed similar to the collection system discussed in Alternative 2, but would include a gas-diffusion line located within the drain tile. This is an innovative application of this technology. A number of factors that influence its effectiveness and O&M, such as the rate of trench fouling by precipitate and solids, would need to be determined prior to full-scale implementation. The sparging system would be similar to the pilot system installed at Pine Court, but improved with a deeper line, designed for CO_2 injection. The leachate control in the central zone may be augmented with hydraulic containment systems downgradient of the sparge lines. Hydraulic containment reintroduces water to produce a barrier to migration in the zone of influence.

Injection of the CO_2, or a mixture of CO_2 and an inert gas such as nitrogen, would be bubbled into the shallow groundwater at a dosage rate suitable to achieve neutralization with a minimum of precipitation. Although metals would not directly precipitate, it is anticipated that with a lower pH in the groundwater, the dissolved metals would be more likely to react with aquifer surfaces and be reduced by adsorption and other natural attenuation mechanisms prior to venting at the shore of Lake Michigan. Additional treatability or pilot testing may provide evidence to assess the presence or significance of this effect. The finely-dispersed gas phase will contact groundwater which is assumed to be dominated by calcium hydroxide-saturated solution chemistry. Upon injection, CO_2 will rapidly dissolve, forming carbonic acid, as described in equation 1 below. The initial addition of weak (carbonic) acid will neutralize the excess hydroxide and lower the pH, forming calcium carbonate ($CaCO_3$), according to equation 2. Additional acid will subsequently neutralize the $CaCO_3$ alkalinity, which will shift the groundwater to a bicarbonate dominant system and should result in the redissolution of any precipitated calcium carbonate and potentially some portion of the solid phase in the formation around the sparge line, as described in equation 3.

$$CO_{2(g)} + H_2O_{(l)} \rightarrow H_2CO_{3(aq)} \qquad (1)$$

$$H_2CO_{3(aq)} + Ca(OH)_{2(aq)} \rightarrow CaCO_{3(s)} + 2H_2O_{(l)} \qquad pH > 11 \qquad (2)$$

$$H_2CO_{3(aq)} + CaCO_{3(aq)} \rightarrow Ca(HCO_3)_{2(aq)} \qquad 10.3 > pH > 6.3 \qquad (3)$$

The in situ chemical treatment process can be expected to neutralize the shallow groundwater and correct the high pH condition that is observed along the lakeshore in the ECKD Area. The estimated groundwater fluxes through the shallow groundwater in the western and central discharge zones to a cross-sectional depth of approximately 572 feet MSL are less than 1 gpm and less than 20 gpm,

respectively. The mass flow rate of CO_2 required to treat this groundwater flow, based on the stoichiometric calculations with an average initial pH of 10.5 and a final pH of 8, is estimated to be up to 2 pounds of CO_2 per day (lb CO_2/d). This equates to approximately 0.1 lb CO_2/d for each gallon per minute of flow.

Bench-scale leachate treatability testing with CO_2 sparging was performed by Barr on groundwater collected from monitoring well W4119 in January 2006. A memorandum summarizing the treatability testing is included as Appendix F. The CO_2 dosage rate required to neutralize the leachate from 12 to 8.5 was 0.21 M, which would equate to about 70 lb/d for each gallon per minute of flow. This dosage rate is significantly higher than the rate calculated using the stoichiometric equations, but includes a greater overall change in pH and inefficiencies associated with gas transfer that could be reduced during the development of a full-scale in situ treatment system. A significant loss of CO_2 from the solution during the bench-scale testing is suspected since bubbles were observed at the liquid surface and the treatability test vessel top was open. Pilot-scale testing would be required to identify the appropriate dosage rate for the in situ system. Losses due to incomplete CO_2 dissolution and matrix consumption would also need to be assessed.

The potential to remove mercury by pH amendment was also investigated in the bench-scale leachate treatability testing program (see Appendix F). Neutralized leachate was filtered through a 0.45 micron filter and analyzed for low level mercury. No removal of mercury was observed for the treatability tests. However, as described previously, after pH neutralization, it is anticipated that adsorption to the aquifer surfaces (unconsolidated soil and weathered bedrock) and other attenuation mechanisms in the shallow groundwater would limit the potential for further migration of these COCs. This will be further verified by field measurements and/or bench tests. The presence of these attenuation mechanisms is confirmed by the variability in the concentration of mercury and other metals observed in ECKD Area monitoring wells that are located within or outside the immediate area of the CKD source materials, as described in Section 5 of the RI.

Lakeshore pH control is expected to be similar to existing IR conditions. The projected mercury flux for this alternative is expected to be greater than existing IR flux (Alternative 2-a) because mercury will not be captured in the IR collection drains. The projected long-term mercury flux for this remedy is greater than 6.0 mg/day. The estimated mercury loading to the lake for a 30-year implementation of this alternative is greater than 66 grams. The 30-year average equivalent concentration for this alternative is greater than 2.5 ng/L.

The total cost for this alternative, including long-term O&M costs, is $21 million. Detailed cost estimates for this alternative are provided in Appendix J.

3.1.5 Alternative 4 – CKD Removal

This alternative consists of removal of CKD from the entirety of the Site and is expected to take two construction seasons to complete. It is anticipated that dewatering of groundwater will be required during the removal and the dewatering flow will be treated to neutralize high pH CKD-impacted groundwater and discharged to the lake. The conceptual layout for this alternative is shown on Figure 14. The institutional controls for this alternative are the same as those described for Alternative 2. These institutional controls would remain for an indefinite period of years, as the rate at which Site groundwater will recover to conditions similar to those upgradient of the ECKD Area will depend on many factors, including the presence of residual CKD even after excavation.

This alternative uses none of the IR actions installed at the Site and, in fact, removes all of them. Consequently, this alternative is inconsistent with the AOC, Section VIII, Paragraph 15, item x, which calls for integration of the response activities, as appropriate.

CKD would be removed from the entirety of the Site, loaded into trucks, and transported to a RCRA Subtitle D landfill for disposal as nonhazardous waste. About 360,000 CY of CKD would need to be removed from the Site, of which 25 to 50 percent would be saturated. This saturated material can be very difficult to handle, as disturbing such CKD can produce a low-strength, somewhat flowable gel-like mixture (Todres, et al., 1992a and 1992b). The difficult material-handling properties may dictate the excavation program, and will make complete removal of the CKD below groundwater unlikely. The Site geology also makes complete removal of the CKD challenging. It is difficult to remove CKD retained in weathered bedrock and bedrock fractures. Figure 15 shows the bottom of CKD contours. For context, the surface water elevation is approximately 578 MSL, so the depth of excavation needed for complete removal of CKD is 10 to 15 feet below lake level in large areas. In order to excavate all of the CKD, the existing FML cover and much of the leachate collection system would have to be removed, which would destroy the IR actions that have been constructed on the Site.

Transportation of this volume of material, and the backfill material, will have a substantial impact on the public during the construction. In addition, there may be a need to modify or improve portions of U.S. Highway 31 to accommodate nearly 400,000 CY of CKD removal and backfill.

CKD removal will result in the substantial elimination of the concentrated pH discharge zones, as shown on Figure 4. Some CKD will, however, remain below groundwater. Consequently, COC flux from the former CKD footprint can be expected to diminish over time, but at an unknown rate.

High pH water removed from the excavation would be pretreated onsite to neutralize the water and filter out solids, and would have to be discharged to Lake Michigan, as there would be no offsite treatment or disposal facilities available to handle the high flow rates. Although the water will be treated, a significant proportion of the mercury and other COCs such as dissolved solids, sodium chloride, and sulfate can be expected to remain in the water and be discharged to the lake. Consequently, this remedy will dramatically increase the flux of these parameters to the lake for at least one full construction season. Direct discharge of this water will require an ARAR waiver. If offsite management of the water must be arranged, the duration and cost of the remedy may grow dramatically.

The quantity of leachate to treat is multiplied by construction. Dewatering draws groundwater through the unexcavated portion of the CKD. Excavation in the saturated zone breaks up the wet CKD and mixes it, and exposing the face of the CKD subjects previously covered material to wind and rain, all of which adds to the leachate which must be managed. The leachate and dewatering water management for the CKD removal option will dramatically increase the mass loading of mercury and other metals and inorganics to the lake for the entire period of CKD excavation and saturated zone backfill. Detrimental impacts from other COCs would be substantial.

The projected long-term mercury flux for this remedy is 0.2 mg/day. The estimated mercury loading to the lake for a 30-year implementation of this alternative is 145 grams. The 30-year loading estimate includes discharge of nearly 76 million gallons (MG) of neutralized leachate collected from dewatering activities at an average concentration of 500 ng/L and excludes precipitation. The 30-year average equivalent concentration for this alternative is approximately 5.6 ng/L.

The Site would be backfilled with clean soil to a condition suitable for recreational use. Backfill and final Site grading could be completed to a lower elevation than the current park, with the approval of the township.

The total cost for this alternative including long-term O&M costs is $78 million. Detailed cost estimates for this remedial alternative are included in Appendix J. Cost estimates do not include consequential damages or economic impacts to the community.

3.1.6 Alternative 4-a – Onsite Containment Cell

This alternative consists of removal of CKD from the entirety of the Site, placing imported clean backfill below the groundwater table, constructing an onsite containment cell within the existing CKD footprint, relocating CKD to the onsite containment cell, constructing a cover system, and restoring the existing park with modified grades. This alternative is expected to be completed in several phases in order to accommodate cell construction as CKD is progressively removed, temporarily stored onsite, relocated, and covered. This alternative is expected to take three construction seasons to complete. Similar to complete removal, it is anticipated that dewatering of groundwater will be required during the removal and the dewatering flow will be treated to neutralize high pH CKD-impacted groundwater and discharged to the lake. The conceptual layout for this alternative is shown on Figure 16. The institutional controls for this alternative are the same as those described for Alternative 4. These institutional controls would remain for an indefinite period of years, as the rate at which Site groundwater will recover to conditions similar to those upgradient of the ECKD Area will depend on many factors, including the presence of residual CKD even after excavation.

This alternative uses none of the IR actions installed at the Site and, in fact, removes all of them. Consequently, this alternative is inconsistent with the AOC, Section VIII, Paragraph 15, item x, which calls for integration of the response activities, as appropriate.

Conceptually, CKD removal and cell construction would be completed in three phases: (1) eastern end, (2) central portion, and (3) the west end of the existing CKD footprint. However, prior to removal, temporary water treatment facilities would be constructed in the east bottleneck area and highway modifications would be implemented to permit haul truck traffic at the Site. Each phase of cell construction would begin with stripping and stockpiling existing topsoil and rooting soils. Next, the 1-foot layer of sand bedding over the existing liner, unsaturated CKD, and saturated CKD would be excavated, loaded into trucks, conditioned, and transported to a temporary managed stockpile. The stockpiles would require tarping and /or other controls throughout the entire cell construction process. Saturated CKD would be conditioned/blended with unsaturated CKD to render the mixed material suitable for temporary stockpile placement. Significant conditioning of the CKD is required for placement and compaction based on experience during the onsite consolidation activities in 2006.

Following removal of CKD, clean imported backfill would be placed below and approximately 1 foot above the existing groundwater table. The containment cell would be constructed on a minimum of 1 foot of sand bedding and perforated collection piping would be installed on top of the bottom of the

cell liner in 1 foot of pea gravel to collect leachate produced as a result of existing moisture accumulation or future leaks. CKD would then be progressively placed and compacted in the cell to match existing grades at the perimeter of the existing CKD extent and above existing grades at an approximate 3.5:1 slope until no further storage capacity remained for soil placement. Excess CKD would be disposed of offsite at a RCRA Subtitle D landfill for disposal as nonhazardous waste. It is estimated that there is only sufficient storage capacity to relocate 60 percent of the estimated 360,000 CY of CKD into an onsite containment cell. Coordinating the concurrent excavation, hauling, stockpiling, and cell construction will reduce Site operations and onsite production in order to safely conduct the operation in this alternative requiring at least one additional year of construction relative to removal and offsite disposal.

Of the estimated 360,000 CY CKD total, 25 to 50 percent is estimated to be saturated. All of the saturated CKD handling difficulties described in Alternative 4 apply to this alternative. In addition, saturated CKD handling conditions will be confounded by the fact that less surface area will be available to condition the CKD because of the large amount of CKD that will need to be temporarily stockpiled during cell construction.

The Site would be restored to a condition suitable for recreational use; however, the significant increase in the final ground surface of the park to a higher elevation with decreased surface areas with shallow slopes will require township approval as the majority of the open and accessible space would become a grassy slope. Furthermore, disruption of view sheds from residential property to the south would require consideration during design. The significant ground surface increases proposed in this remedial alternative would require additional fill to reconstruct the only access road to the Site necessary for long-term operation, monitoring, and cell maintenance.

CKD entombment in an onsite containment cell will result in the substantial elimination of the concentrated pH discharge zones, as shown on Figure 4. Some CKD will, however, remain below groundwater. Consequently, COC flux from the former CKD footprint can be expected to diminish over time, but at an unknown rate.

High pH water removed from the excavation would be pretreated onsite to neutralize the water and filter out solids, and would have to be discharged to Lake Michigan, as there would be no offsite treatment or disposal facilities available to handle the high flow rates. Although the water will be treated, a significant proportion of the mercury and other COCs such as dissolved solids, sodium chloride, and sulfate can be expected to remain in the water and be discharged to the lake.

Consequently, this remedy will dramatically increase the flux of these parameters to the lake for at least one full construction season. Direct discharge of this water will require an ARAR waiver. If offsite management of the water must be arranged, the duration and cost of the remedy may grow dramatically.

The quantity of leachate to treat is multiplied by construction. Dewatering draws groundwater through the unexcavated portion of the CKD. Excavation in the saturated zone breaks up the wet CKD and mixes it, and exposing the face of the CKD subjects previously covered material to wind and rain, all of which adds to the leachate which must be managed. The leachate and dewatering water management for the CKD removal option will dramatically increase the mass loading of mercury and other metals and inorganics to the lake for the entire period of CKD excavation and saturated zone backfill. Detrimental impacts from other COCs would be substantial.

The projected long-term mercury flux for this remedy is 0.2 mg/day. The estimated mercury loading to the lake for a 30-year implementation of this alternative is 182 grams. The 30-year loading estimate includes discharge of nearly 95 MG of neutralized leachate collected from dewatering activities at an average concentration of 500 ng/L and excludes precipitation. The 30-year average equivalent concentration for this alternative is 7.0 ng/L.

The Site would be backfilled with clean soil to a condition suitable for recreational use. Backfill and final Site grading could be completed to a lower elevation than the current park, with the approval of the township.

The total cost for this alternative, including long-term O&M costs, is $78 million. Detailed cost estimates for this remedial alternative are included in Appendix J. Cost estimates do not include consequential damages or economic impacts to the community.

4.0 Detailed Analysis of Alternatives

4.1 Introduction

This section presents the detailed and comparative analyses of the alternatives developed in Section 3. The components of these alternatives are summarized in Table 12. The alternatives include:

- Alternative 1 – No Action
- Alternative 2 – CKD Consolidation and Cover, Groundwater Migration Control, Natural Attenuation, Groundwater Diversion, Onsite Treatment and Disposal of Groundwater, and Institutional Controls (Includes Upgradient Diversion)
- Alternative 2-a – CKD Consolidation and Cover, Groundwater Migration Control, Natural Attenuation, Onsite Treatment and Disposal of Groundwater, and Institutional Controls (Excludes Upgradient Diversion)
- Alternative 3 – CKD Consolidation and Cover, In Situ Treatment of Groundwater, and Institutional Controls
- Alternative 4 – CKD Removal
- Alternative 4-a – Onsite Containment Cell

The NCP criteria are used as a basis to compare the relative advantages and disadvantages of each alternative. The criteria include (U.S. EPA, 2003, NCP):

1. Overall Protection of Human Health and the Environment
2. Compliance with ARARs
3. Long-Term Effectiveness and Permanence
4. Reduction of Mobility, Toxicity, or Volume through Treatment
5. Short-Term Effectiveness
6. Implementability
7. Cost
8. State Acceptance
9. Community Acceptance

Criteria included under numbers 1 through 7 and 9 were used in this detailed analysis of alternatives. Important characteristics of the evaluation criteria are summarized in Table 14.

While the criteria for state acceptance will not be evaluated in the remedy analysis process, the effort on the part of CMS to accelerate the investigation and remedy for the ECKD Area is intended to be responsive to state interests. Several of the factors that are responsive to state/public concerns in the remedy development and selection process include addressing public health and direct environmental impacts; starting implementation in the spring of 2006; and restoring public use of the park by 2009.

4.2 Individual Analysis of Alternatives

Detailed analysis summaries of the alternatives based on the eight criteria are included in Tables 15 through 18 and detailed cost estimates for the alternatives are included in Appendix J. The following subsections provide specific details on the evaluation of each alternative in comparison to the criteria and a determination of the overall score for each alternative. The overall score is used to rank the alternatives and is developed from individual scores that are based on the ability of the alternative to meet each of the eight criteria. Each of the eight criteria is weighted evenly and a score between 1 and 5 is assigned. A score of 1 is assigned when low achievement of the criterion is expected, 3 when moderate achievement is expected, and 5 when high achievement is expected. Intermediate scores of 2 and 4 are assigned when low to moderate and moderate to high achievement is expected. The highest achievable overall score is 40.

4.2.1 Alternative 1

Alternative 1 is the no action alternative, which is the absence of any remedial actions. No action is considered in this evaluation as a baseline for comparison to all other potential remedial actions. Under this alternative, no deliberate action is taken to address CKD or impacted groundwater at the Site. However, a new cover system is in place and contaminants will be naturally removed and/or attenuated over time. This alternative is not expected to alter the pH or mercury impacts to the lake in the foreseeable future.

Table 15 provides a detailed analysis of this alternative and develops scores based on each of the criteria. As shown in Table 15, this alternative is not expected to meet the objectives for any of the following criteria: protection of human health and the environment; compliance with ARARs; short or long-term effectiveness; reduction in toxicity, mobility, or volume (TMV) through treatment; and community acceptance. Therefore, a score of 1 was assigned to each of these criteria categories. The implementation and cost for this alternative are assumed to be monitoring at a level commensurate

with the other alternatives and, thus, this alternative achieves a score of 5 for both implementability and cost. The overall score for this alternative is 16.

4.2.2 Alternative 2

Alternative 2 includes onsite CKD consolidation, compaction, and contouring; a cover system for the CKD; migration controls for groundwater (including upgradient diversion); and institutional controls. Consolidation, compaction, contouring, and covering the CKD would provide a significant barrier to direct exposure to the CKD and minimize the migration of contaminants to groundwater, thereby reducing the mass flux of COCs from source material to groundwater and subsequently to surface water. Downgradient hydraulic containment intercepts the discharge of leachate to Lake Michigan and the upgradient groundwater diversion minimizes the gradient. The quantity of water collected by the diversion system may be considered a large quantity withdrawal, and appropriate procedures for permits for CERCLA actions would be followed. This remedy practically eliminates the potential for direct exposure to leachate along the shoreline and minimizes impacts to surface water. The collected leachate would be treated with physical/chemical processes to reduce TMV. The disposal of the treated water will be to a permitted disposal location. Diversion of upgradient groundwater and reduction of infiltration through consolidation and improved cover limits the volume of leachate generated. Institutional controls provide community protection in the form of groundwater use restrictions and engineered cover maintenance. This combination of technologies is projected to reduce the average mercury flux to the lake to less than 3.6 mg/day.

A detailed analysis of this alternative and development of scores based on each of the criteria is included in Table 16. As shown in Table 16, seven of the eight category scores are 4, with moderate to high achievement of criterion realized. The category for the reduction of TMV was assessed to have a moderate achievement of criterion (3), as there is diversion of groundwater from flowing through the CKD and treatment of the intercepted groundwater. The overall score for this alternative is 31. This alternative is expected to meet the RAOs for soil and groundwater. This alternative is expected to be more acceptable to the community, relative to the other alternatives, since the environmental benefit is high, the community exposure to CKD and CKD-impacted groundwater from construction is eliminated, and the re-opened park is not destroyed. A variance from the State Water Quality Standards for some COCs (sulfate, chloride, TDS, and some metals) in a discharge to Lake Michigan may be required. Demonstration that achievement of the GSI criteria for mercury is technically impracticable may be required.

4.2.3 Alternative 2-a

Alternative 2-a is representative of existing IR actions and includes onsite CKD consolidation, compaction, and contouring; a cover system for the CKD; migration controls for groundwater (does not include upgradient diversion); and institutional controls. Consolidation, compaction, contouring, and covering the CKD provides a significant barrier to direct exposure to the CKD and minimize the migration of contaminants to groundwater, thereby reducing the mass flux of COCs from source material to groundwater and subsequently to surface water. Downgradient hydraulic containment intercepts the discharge of leachate to Lake Michigan. This remedy practically eliminates the potential for direct exposure to leachate along the shoreline and minimizes impacts to surface water. The collected leachate would be treated with physical/chemical processes to reduce TMV. The disposal of the treated water will be to a permitted disposal location. Reduction of infiltration through consolidation and improved cover limits the volume of leachate generated. Institutional controls provide community protection in the form of groundwater use restrictions and engineered cover maintenance. This combination of technologies is projected to, in time, reduce the average mercury flux to the lake to less than 6.0 mg/day.

A detailed analysis of this alternative and development of scores based on each of the criteria is included in Table 16-a. As shown in Table 16-a, five of the eight category scores are 4 with moderate to high achievement of criterion realized, two of the eight category scores are 3 with moderate achievement of criterion, and one of the eight category scores is 2 with low to moderate achievement of criterion. The category for the reduction of TMV was assessed to have a low to moderate achievement of criterion (2), as there is treatment of the intercepted groundwater but no diversion of groundwater from flowing through the CKD. This alternative scores lower than Alternative 2 for long-term effectiveness because this alternative is not expected to significantly reduce the saturated CKD. This alternative is expected to be more acceptable to the community, relative to the other alternatives, since the environmental benefit is high, the community exposure to CKD and CKD-impacted groundwater from construction is eliminated, and the re-opened park is not destroyed. The overall score for this alternative is 28. This alternative is expected to meet the RAOs for soil and groundwater. A variance from the State Water Quality Standards for some COCs (sulfate, chloride, TDS, and some metals) in a discharge to Lake Michigan may be required. Demonstration that achievement of the GSI criteria for mercury is technically impracticable may be required.

4.2.4 Alternative 3

Alternative 3 is similar to Alternative 2 and includes onsite CKD consolidation, a cover system for the CKD pile, addressing migrating groundwater, and institutional controls. However, this alternative

includes in situ treatment for groundwater at the Site (Alternative 2 includes groundwater extraction). In situ treatment transforms the groundwater discharge to Lake Michigan from high pH leachate to neutral pH water, thereby eliminating direct exposure to leachate along the shoreline and minimizing impacts to surface water. In situ treatment would include sparging of shallow impacted groundwater with CO_2. Following neutralization, metals would naturally attenuate by adsorption, resulting in a reduction of TMV.

A detailed analysis of this alternative and development of scores based on each of the criteria is included in Table 17. As shown in Table 17, this alternative received four category scores of 4 (moderate to high achievement of criterion), three category scores of 3 (moderate achievement of criterion), and one category score of 1 (low achievement of criterion). The category for the reduction of TMV was assessed to have a much lower achievement of the criterion than Alternative 2, as the treatment of the intercepted groundwater will correct the pH but the potential impact on the attenuation of other COCs has not been evaluated for full-scale implementation. This alternative may not be as acceptable to the community since mercury and other COC control may be lower than existing IR. Park closure for sparge system installation is not expected or will be short in duration reducing CKD and CKD-impacted groundwater exposure to the community during construction. The overall score for this alternative is 26. This alternative is expected to generally meet the RAOs for soil and groundwater. A variance from the State Water Quality Standards for some COCs (sulfate, chloride, TDS, and some metals) in a discharge to Lake Michigan may be required. Demonstration that achievement of the GSI criteria for mercury is technically impracticable may be required.

4.2.5 Alternative 4

Alternative 4 includes full removal of CKD from the Site and offsite disposal at a RCRA Subtitle D landfill. Removal nearly eliminates the long-term potential for direct exposure to CKD at the Site and greatly reduces the CKD source of contaminants to groundwater at the Site, thereby mitigating the mass flux of COCs from source material to groundwater and subsequently to surface water. After removal, the residual impacted groundwater will naturally attenuate, eventually reducing the long-term potential for direct exposure to leachate along the shoreline and future high pH impacts to surface water. The high pH leachate collected during dewatering will be neutralized and discharged to the lake. Although the reduction in pH is a favorable factor in TMV reduction through treatment, the significant increase in mercury and other COC loading to the lake as a result of dewatering discharge leads to a TMV rating of 1 for this alternative, as it has a 30-year mercury mass loading estimated at 145 grams. Although short-term impacts will be significant and greater than existing

impacts, long-term mercury flux to the lake is estimated to, in time, reduce to 0.2 mg/day with this alternative.

A detailed analysis of this alternative and development of scores based on each of the criteria is included in Table 18. As shown in Table 18, one of the eight category scores is 5, with high achievement of criterion realized. The other seven categories received scores ranging from 1 to 4. There will be significant short-term adverse impacts to the community and an increase in metals mass loading to the lake due to dewatering discharges with this remedy. Full removal of the CKD is not practicable to implement and at the high end of costs relative to Alternatives 1-3. Community acceptance of this alternative is expected to be low since this alternative will result in closure of the re-opened park for one to two years, will increase the mobility of CKD and CKD-impacted water during construction, and an estimated 30,000 dump truck loads will need to travel on US Hwy 31. The overall score for this alternative is 19. This remedy is expected to meet the soil and water RAOs in the long term, but direct discharge of excavation water to the lake will not meet water ARARs in the short term. There may be significant impacts to the community during implementation. Finally, a demonstration that achievement of the GSI criteria for mercury is technically impracticable may be required since residual CKD may remain after removal.

4.2.6 Alternative 4-a

Alternative 4-a includes full removal of CKD from the Site and entombment in an onsite containment cell. Full containment nearly eliminates the long-term potential for direct exposure to CKD at the Site and greatly reduces the CKD source of contaminants to groundwater at the Site, thereby mitigating the mass flux of COCs from source material to groundwater and subsequently to surface water. After full containment, the residual impacted groundwater will naturally attenuate, eventually reducing the long-term potential for direct exposure to leachate along the shoreline and future high pH impacts to surface water. The high pH leachate collected during dewatering will be neutralized and discharged to the lake. Although the reduction in pH is a favorable factor in TMV reduction through treatment, the significant increase in mercury and other COC loading to the lake as a result of dewatering discharge leads to a TMV rating of 1 for this alternative, as it has a 30-year mercury mass loading estimated at 182 grams. Although short-term impacts may be significant, long-term mercury flux to the lake is estimated to, in time, reduce to 0.2 mg/day with this alternative.

A detailed analysis of this alternative and development of scores based on each of the criteria is included in Table 18-a. As shown in Table 18-a, one of the eight category scores is 5, with high achievement of criterion realized. The other seven categories received scores ranging from 1 to 4.

This alternative scored lower for implementability relative to Alternative 4 because the limited surface area at the ECKD Area for temporary stockpiling of CKD during cell construction significantly slows the rate of construction activities and may make cell construction infeasible altogether. Like Alternative 4, there will be significant short-term adverse impacts to the community and an increase in metals mass loading to the lake due to dewatering discharges with this remedy. Full removal and onsite containment of the CKD is the most difficult to implement and at the high end of costs relative Alternatives 1 through 3. This alternative scored lower for community acceptance relative to alternative 4 because: 1) this alternative will result in closure of the re-opened park for two to three years, 2) there will be an increase of CKD and CKD-impacted groundwater mobility during construction because of the longer overall duration and temporary stockpiling of CKD onsite during cell construction, 3) some offsite disposal of CKD will be necessary because of Site constraints 4) the accessible open space will be nearly eliminated except for a maintenance road along the beach, 5) the view of Little Traverse Bay will be partially obstructed for the local community as a result of an increase in the final ground surface, and 6) an estimated 27,000 dump truck loads will need to travel on US Hwy 31. The overall score for this alternative is 17. This remedy is expected to meet the soil and water RAOs in the long term, but direct discharge of excavation water to the lake will not meet surface water ARARs in the short term. This alternative may require a demonstration that achievement of the GSI criteria for mercury is technically impracticable since residual CKD outside of onsite containment may remain after remedial actions.

4.3 Comparative Analysis

The following text provides a detailed comparative analysis of the alternatives based on the eight NCP criteria. A summary of costs and mercury mass discharge to the lake is provided in Table 19a. A comparative analysis of remedial alternative scoring is included in Table 19b. Based on the individual analysis performed on the alternatives in Section 4.2, Alternative 2 is the highest ranking alternative with an overall score of 31, followed by Alternative 2-a with an overall score of 28, Alternative 3 with an overall score of 26, Alternative 4 with an overall score of 19, and Alternative 4-a with an overall score of 17. The baseline alternative (Alternative 1) was the lowest ranking alternative with an overall score of 16.

4.3.1 Protection of Human Health and the Environment

Alternatives 2, 2-a, and 3 scored highest because they incorporate a combination of engineered and institutional controls to meet the cleanup standards and provide protection from existing contamination. Placement of a cover system will reduce exposure to CKD (direct contact, ingestion, and inhalation) and minimize the migration of contaminants in the CKD to groundwater and surface

water by limiting infiltration. Groundwater migration controls (collection system, flow barrier, in situ treatment) eliminate direct exposure to leachate along the shoreline and discharge of leachate to Lake Michigan.

Alternatives 4 and 4-a scored moderate (3) on protection of human health and the environment because of the significant expected impacts to the environment and community during construction. The source of contamination would be removed from the Site, which is favorable, but not materially more protective than covering in place. In contrast to Alternative 2, which reduces mercury loading to the environment, Alternatives 4 and 4-a significantly increases mercury loading over the substantial duration of the CKD excavation activities. Residual impacts to groundwater would attenuate following source removal.

4.3.2 Compliance with ARARs

All of the alternatives are anticipated to result in substantial compliance with the ARARs, except for Alternative 1. The work will be done in a manner consistent with state and federal laws, rules and regulations, as indicated in the ARARs tables (Tables 5, 6 and 13). Therefore, Alternatives 2 through 4-a received a score of 4.

4.3.3 Long-Term Effectiveness

Alternatives 4 and 4-a scored the highest on long-term effectiveness because CKD removal and full onsite containment mitigate risk of direct exposure to CKD on the Site and provide that discharge of high pH leachate at the lakeshore will be alleviated over the long term. For Alternative 4, some risks associated with the CKD would be transferred to a disposal location that is sited, designed, and operated in a manner that effectively manage long-term risk, and there would be a significant component of risk (e.g., mercury emissions, potential for accidents) due to the construction activities themselves. Also, there will be continuing leachate release of unknown magnitude from CKD residuals that will not have been removed during excavation. Alternative 2 received a score of only 4 because source material will remain onsite and engineered and institutional controls will be implemented and maintained to provide long-term effectiveness. Alternative 2-a received a slightly lower score of 3 because downgradient collection does not significantly reduce source generation from regional groundwater contact with CKD. Alternative 3 also received a slightly lower score of 3 because in situ treatment does not significantly reduce source generation from regional groundwater contact with CKD and in situ treatment has not been demonstrated at full-scale so there are greater uncertainties about the character and extent of O&M needed to provide long-term effectiveness.

4.3.4 Reduction of Toxicity, Mobility, and Volume (through Treatment)

Alternative 2 scored the highest on reduction of TMV because the leachate would be collected and treated and source generation from saturated CKD reduction would be realized. Alternative 2-a was rated lower because downgradient collection does not significantly reduce source generation from regional groundwater contact with CKD. Alternative 3 was rated lower than Alternatives 2 and 2-a because the proposed treatment addresses pH but relies on attenuation for the other parameters. Alternatives 4 and 4-a were also rated low on reduction in TMV through treatment because, in contrast to Alternative 2 (which reduces pH and removes mercury and other metals through treatment), Alternatives 4 and 4-a significantly increase mercury and metals loading for the duration of CKD excavation activities. None of the alternatives was considered to reduce the TMV of the CKD itself as the CKD is not treated. This applies to Alternatives 4 and 4-a, as well, because source removal and containment do not treat to address the TMV of the CKD.

4.3.5 Short-Term Effectiveness

Alternatives 2 and 2-a received the highest scores for short-term effectiveness because there would be limited exposure to workers during construction of the remaining remediation systems. The RAOs for the Site would be realized immediately following construction for Alternatives 2 and 2-a. Alternative 3 scored below Alternatives 2 and 2-a because achievement of RAOs may not be realized immediately following construction due to fine-tuning of the in situ treatment system. Alternatives 4 and 4-a scored below Alternatives 2, 2-a, and 3 because there would be extended exposure to workers and the public during CKD removal, the overall time duration from initiation to completion of remedial actions and achievement of RAOs would be longer than the other alternatives, there would be significant community impact from truck traffic, and there would be a dramatic increase in mercury and other metals mass loading to the lake due to the neutralized dewatering water discharge.

4.3.6 Implementability

With the exception of Alternative 1, Alternatives 2 and 2-a scored the highest on implementability because it uses reliable technologies, readily available equipment and area for treatment facilities, and its effectiveness is relatively easy to monitor. Alternative 3 scored below Alternatives 2 and 2-a because of the uncertainties surrounding long-term reliability and, therefore, O&M and frequency of reconstruction for sparging systems. Alternative 4 scored below Alternatives 2, 2-a, and 3 because the engineered facilities, controls, and construction activities necessary to perform a full removal make Alternative 4 very difficult to implement. Alternative 4-a scored the lowest of all alternatives because like Alternative 4, the engineered facilities, controls, and construction activities necessary to

perform a containment and the limited surface area available at the ECKD Area for temporary stockpiling of CKD make Alternative 4 very difficult to implement, if not infeasible altogether.

4.3.7 Cost

With the exception of Alternative 1, Alternatives 2 and 3 scored highest on cost. Alternative 3 would cost approximately $21 million for capital and long-term commitment for O&M. Alternative 2, the next higher cost alternative, is estimated to cost approximately $26 million for capital and long-term commitment for O&M. Alternative 2-a scored slightly lower than Alternatives 2 and 3 and would cost approximately $30 million for capital and long-term commitment for O&M. Alternatives 4 and 4-a received a low score because the total estimated cost is in excess of $78 million, which is significantly higher than the costs for the other alternatives assuming dewatering water discharged to the lake.

4.3.8 Community Acceptance

Community acceptance has been evaluated based on CMS coordination and communication with Bay Harbor residents including both the Village Harbor and Cliffs communities, and with local governing units (e.g., Resort Township and the Health Department of Northwest Michigan) during the previous four years of Site activities. Additional input from the community will be incorporated into this criteria evaluation as this process of coordination and communication continues. Alternatives 2 and 2-a scored highest because they will not result in future closure or alteration of the reopened park and they provide a high degree of environmental protection based on the demonstrated COC control at the Site. Alternative 3 scored lower than 2 and 2-a since it provides a lower degree of COCs control and would be less likely acceptable to the community. Alternative 4 scored lower than Alternative 2 and 2-a because this alternative is expected to result in the complete demolition of the reopened park and restriction of Village Harbor use during the one to two years of remedy implementation and would increase the mobility of CKD and CKD-impacted groundwater during construction. Alternative 4-a was scored lower than Alternative 4 because this alternative will result in similar impacts to the reopened park for an estimated two to three years, increase of CKD mobility during construction would occur over a longer overall duration than Alternative 4, and partially obstruct the view of Little Traverse Bay from the community as a result of raised final ground surfaces. Both Alternatives 4 and 4-a do not provide for greater environmental benefit than Alternatives 2 and 2-a and discharge dewatering water to Little Traverse Bay justifying lower community acceptance.

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