Remedial Action Options Report

Kewaunee Marsh Arsenic Contaminated Site

July 2020

BRRTS #02-31-000508

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ACRONYM LIST

cy	Cubic yards
RAOR	Remedial Action Options Report
sf	Square foot
TEC	Threshold Effect Concentration
WDNR	Wisconsin Department of Natural Resources
ZVI	Zero valent iron

Executive Summary

The Kewaunee Marsh Arsenic Contaminated Site (site) includes approximately 15-acres of arsenic-impacted wetland, located within the state-owned C.D. Besadny Fish and Wildlife Area northwest of Kewaunee, Wisconsin. The arsenic contamination (thought to be from a train derailment in the 1940s) was first discovered in 1993. Since then, investigations, treatability studies, remedial evaluations, and interim actions have been completed at the site.

The purpose of this focused Remedial Action Options Report (RAOR) is to evaluate remedial alternatives that can achieve the long-term remedial goals to restore the marsh's ecological and recreational functions, and to minimize arsenic loading to the Kewaunee River. The remedial alternatives evaluated in this RAOR were developed from a set of remedial technologies that were determined to be feasible options for the site.

The technical and economic feasibility of the remedial alternatives are evaluated based on the current understanding of the arsenic impacts at the site. The current site data is sufficient to compare the remedial alternatives. However, several data gaps exist that should be addressed prior to final design, and these are discussed further within this report.

Final site performance standards are anticipated to be developed and selected by Wisconsin Department of Natural Resources (WDNR) following this report. For purposes of this RAOR, two preliminary concentration thresholds in soil/sediment were used for the basis of design and cost. These were soil/sediment with arsenic concentrations greater than 1,000 ppm and soil/sediment with arsenic concentrations greater than 100 ppm.

The remedial alternatives evaluated for the site to address these preliminary concentration thresholds in soil/sediment included the following:

- **Option 1a:** Cap (Arsenic [As] >1,000 ppm)
- **Option 1b:** Cap (As >100 ppm)
- **Option 2a:** In-Situ Stabilization (As >1,000 ppm) + Cap (As >100 ppm)
- **Option 2b:** In-Situ Stabilization + Cap (As >100 ppm)
- **Option 3:** Excavation (As >1,000 ppm) + Cap (As > 100 ppm)
- **Option 4:** Excavation (As >1,000 ppm) + Cap and In-Situ Stabilization (As >100 ppm)
- **Option 5:** Excavation (As >1,000 ppm) + On-site management zone (As >100 ppm)
- **Option 6a:** Excavation (As >1,000 ppm)
- **Option 6b:** Excavation (As >100 ppm)

Each of these alternatives is technically feasible, but there is some degree of variation in their overall implementability and effectiveness. Any excavation alternative will require management and treatment of arsenic-impacted water during construction. This will require that pre-design treatability testing be done, and it may affect overall implementability. Also, any of the in-situ

stabilization alternatives will also require pre-design treatability and pilot testing to optimize the design and determine true effectiveness.

The long-term effectiveness is expected to be best for the Option 6b and least for Option 1a. The relative effectiveness is categorized in Table 1. All of the alternatives, with the exception of Option 6b, will have long-term monitoring requirements, and any of the capping options will require a long-term cap maintenance.

The relative cost of each option is evaluated with a contingency range of -10% to +30%. Without taking the contingency into account, the lowest cost option was Option 1a (~$1.3 Million) and the highest cost option was Option 5 (~$16 Million). Option 5 was evaluated to determine if on-site management of the impacted soil/sediment would be more cost effective than off-site disposal. The cost for off-site disposal for Option 6b was ~$13 Million. Based on this evaluation, the cost for on-site management of impacted soil/sediment does not appear to be beneficial to the project.

Because any future remediation at the site is anticipated to be a department-funded response action, the WDNR will select the remedial action (NR 722.09). Therefore, this focused RAOR does *not* include selection criteria or recommend a remedial action (NR 722.13(2)(e)).

Certifications

Professional Engineer Certification

I, Alia Enright, P.E., hereby certify that I am a registered professional engineer in the State of Wisconsin, registered in accordance with the requirements of ch. A-E 4, Wis. Adm. Code; that this document has been prepared in accordance with the Rules of Professional Conduct in ch. A-E 8, Wis. Adm. Code; and that, to the best of my knowledge, all information contained in this document is correct and the document was prepared in compliance with all applicable requirements in chs. NR 700 to 726, Wis. Adm. Code.

E-47666
Signature and P.E. Number

P.E. Stamp

Certified Hydrogeologist Certification

I, John Rice, P.H., hereby certify that I am a hydrogeologist as that term is defined in s. NR 712.03 (1), Wis. Adm. Code, am registered in accordance with the requirements of ch. GHSS 2, Wis. Adm. Code, or licensed in accordance with the requirements of ch. GHSS 3, Wis. Adm. Code, and that, to the best of my knowledge, all of the information contained in this document is correct and the document was prepared in compliance with all applicable requirements in chs. NR 700 to 726, Wis. Adm. Code.

Signature

July 29, 2020
Date

1.0 Introduction

1.1 Background

The Kewaunee Marsh Arsenic Contaminated Site (site) includes approximately 15-acres of arsenic-impacted wetland, located inside a large meander of the Kewaunee River northwest of Kewaunee, Wisconsin. The site is within the state-owned C.D. Besadny Fish and Wildlife Area (**Figures 1-3**). A historical release of arsenate salts (formerly used as pesticides) from a railcar derailment around the 1940s is thought to be the source of these impacts.

The arsenic contamination was first discovered in 1993. Since then, site investigations, treatability studies, remedial evaluations, and interim actions have been completed by the former potentially responsible party (Fox Valley and Western Railroad, Ltd) and by the Wisconsin Department of Natural Resources (WDNR). The interim actions completed to date include construction of a chain-link fence to enclose the 15-acre site, placement of a 4-acre vegetative cap over the area with significant impacts, and in-situ treatment of approximately 3,000 cubic yards (cy) of the most highly impacted soil/sediment. The fence and cap were constructed in 1996 (STS, 1996) and the in-situ treatment was completed in 2011 (TRC, 2012).

The long-term remedial goals for the site are to restore the marsh's ecological and recreational functions, and to minimize arsenic loading to the Kewaunee River. Remedial action is needed to achieve these long-term remediation goals. Remedial alternatives have been previously evaluated based on the data available at that time (STS, 2004; STS, 2006; RMT, 2010). More data has been collected and the understanding of the site has evolved over time; therefore, this updated, focused Remedial Action Options Report (RAOR) has been prepared for the site.

1.2 Purpose and Scope

The purpose of this focused RAOR is to provide the WDNR with an updated set of remedial action options for the Kewaunee Marsh Arsenic Contaminated Site, which meets the requirements of Wisc. Admin. Code NR 722.13(2) (a)-(d). Because any future remediation at the site is anticipated to be a department-funded response action, the WDNR will finalize the performance standards and select the remedial action (NR 722.09) after issuance of this report. Therefore, this focused RAOR does *not* include selection criteria or recommend a remedial action (NR 722.13(2)(e)).

This focused RAOR includes the following:

- **Section 2:** Current site conditions and status
- **Section 3:** Technology screening to select remedial alternatives
- **Section 4:** Data gap analysis
- **Section 5:** Remedial action options evaluation

2.0 Site Conditions and Regulatory Status

2.1 Site Investigation Summary

Following discovery of the contamination in 1993, a series of investigative work has been completed at the site. Some of the early work was completed by Fox Valley and Western Railroad, Ltd (the former potentially responsible party), but most of the work has been performed by the WDNR. In 2018, the WDNR summarized the historical site investigation activities and results in a comprehensive report titled "Site Investigation Summary and Data Package" (WDNR, 2018). The WDNR's 2018 report can be referred to for details from the site investigations. In general, the investigative work completed to date included the following:

- Stressed Vegetation Mapping
- Potable Well Sampling
- Groundwater Monitoring Well Installation, Slug Testing, and Sampling
- Soil/Sediment Sampling and Permeability Testing
- Slough Flow Monitoring and River Gauging
- Slough and Surface Water (Pond and River) Sampling
- Plant, Insect, and Animal Tissue Sampling

The areas of stressed vegetation and the groundwater monitoring network are shown on **Figure 3**, and the soil/sediment sampling locations are shown on **Figures 4 to 8**. The historical surface water samples from the Kewaunee River, the sloughs, and the constructed ponds[1] are not shown on the figures, but these details can be found in the WDNR's 2018 report.

The site investigation work has found that at least 15 acres of the marsh are impacted with arsenic. Historically a maximum concentration of 68,000 mg/kg was detected in soil/sediment in 1990s. Results from samples collected between 2004 and 2007 found that the highest concentration of arsenic in soil/sediment, surface water, and groundwater at the site were 13,200 mg/kg, 66 mg/L, and 2,840 mg/L, respectively, and that soil/sediment with arsenic concentrations greater than 1,000 mg/kg were likely to be characteristically hazardous based on arsenic toxicity.

The highest concentrations in the marsh soil/sediment and groundwater are adjacent to the former railroad track, near the presumed spill location (source area). High arsenic concentrations are also present in the shallow soil/sediment near the areas of historically stress vegetation. These high concentrations in the shallow soil/sediment are thought to have resulted from overland flow transporting arsenic from the source area. The arsenic concentrations in soil/sediment and groundwater generally decrease as you move vertically downward from the surface and laterally eastward toward the Kewaunee River from the source area, with a few exceptions.

[1] There were approximately 12 small ponds historically constructed in the wetlands of C.D. Besadny Fish and Wildlife Area to attract waterfowl. These ponds were located north of the area of arsenic impacts.

2.2 Interim Action Summary

Several interim actions have been completed at the site to address immediate contact risk and to minimize further transport of arsenic into the marsh from the source area. The interim actions completed to date include construction of a chain-link fence to enclose approximately 15-acres of the site, placement a 4-acre vegetative cap over the areas of stressed vegetations and with the most significant impacts to the shallow soil/sediment, and in-situ treatment of 3,000 cubic yards (cy) of the most highly impacted soil/sediment near the source area. The fence and cap were constructed in 1996 (STS, 1996), and the in-situ treatment was completed in 2011 (TRC, 2012). The locations of the interim remedial measures are shown on **Figures 2 and 3**.

2.2.1 Cap and Fence (1996)

In 1996, STS installed a permeable, vegetative cap over the areas of the marsh with distressed vegetation and installed a fence around 15 acres of the site to prevent direct contact with the arsenic contamination near the surface (STS, 1996). The cap was approximately 1.5-2.5 feet thick, and was constructed from the ground up as follows:

- **Granular Lime:** 30 cy of granular lime were applied across the surface in an effort to remove soluble arsenic as an insoluble precipitate.
- **Polystyrene Sheets:** 5-inch-thick polystyrene sheets were placed over areas devoid of vegetation to provide a supportive base for the cap
- **Geotextile Fabric:** 155,000 sf of woven geotextile was placed over visibly impacted areas to provide a high-strength permeable support for the wood chips
- **Wood Chips:** 2 to 2.5 feet of a yard mulch and wood chip mix was applied across the cap area
- **Vegetation:** Capped area was seeded to establish a vegetative mat.

The chain-link fence remains in place and is effective at limiting human access to the areas of the marsh with arsenic impacts. The permeable cap was not intended to be a long-term remedy, and samples of surface soil/sediments collected in 2004-2006 found that the cap materials are now impacted with arsenic; and therefore, the cap is no longer serving as a direct contact barrier (RMT, 2010). Migration of arsenic into the cap may be the result of arsenic-impacted water moving horizontally from source area and vertically to the surface, plants transporting arsenic from the subsurface water to the cap surface, or to settling of the cap.

2.2.2 In-Situ Remediation (2011)

Groundwater samples collected at the site between 2005 and 2010 found that very high concentrations of dissolved-phase arsenic (up to 2,200 mg/L) were still present near the presumed location of the historical spill. Because arsenic is mobile in the dissolved phase, the highly impacted groundwater was considered to be an on-going source of arsenic to the marsh. In order to minimize further transport of arsenic from this historical source area, an in-situ stabilization remedy was completed as an interim action to reduce the mobility of the arsenic in a defined hot spot area (RMT, 2010).

In October 2011, Orin Technologies, Inc., completed in-situ treatment of approximately 3,000 cy of the most highly impacted soil/sediment. The treatment area extended approximately 70-feet along the trail and 80-feet into the marsh. The in-situ remedy was based on successful bench-scale treatability studies and involved incorporating hydrogen peroxide, granular ferric sulfate, crushed limestone, and bentonite into the soil/sediment. The hydrogen peroxide, granular ferric sulfate, and crushed limestone were designed to stabilize the arsenic so that it was not leachable, and the addition of bentonite was intended to reduce the permeability of the soil/sediment (TRC, 2012). Since the area to be treated was fairly small, the treatment was intended to be both the pilot-scale evaluation of the approach developed in the bench-scale testing and the remediation of the most highly contaminated area.

The initial performance verification testing indicated that arsenic stabilization was achieved throughout the bulk of the hot spot area. However, subsequent sampling showed that elevated concentrations of arsenic were present in the groundwater in the treatment area. A portion of this arsenic was in particulate form and is unlikely to be mobile. It is also possible that that the groundwater in the treatment area returned to anoxic conditions over time, which allowed some of the arsenic to leach from the soil/sediment into the water. A long-term monitoring program was not completed to evaluate the performance of the in-situ stabilization of the hot spot and to optimize the treatment, as needed. In particular, the effect of the bentonite on reducing the permeability has not been evaluated.

2.3 Proposed Performance Standards

On August 21, 2019, the WDNR published a memo title “Development of remedial action performance standards for arsenic cleanup at the Kewaunee Marsh Arsenic Contaminated Site” (WDNR, 2019). In this memo, the WDNR summarized the following:

- Criteria used to support the prior interim actions and evaluations of remedial alternatives.
- Basis for developing final performance standards to achieve the site’s long-term remediation goals, which are to:
  - restore the marsh’s ecological and recreational functions, and
  - minimize arsenic loading to the Kewaunee River.

The memo includes a table titled “Table 1. Summary of the applicable standards and thresholds for development of remedial action performance standards.” The lower threshold of applicable standards for arsenic identified in the memo include:

- **Soil:** 20 mg/kg in soil (site-specific residual contaminant level [RCL] corresponding to 10^{-6} increased cancer risk for adolescent exposure through ingestion), which was referenced for the 1996 interim action
- **Groundwater:** 10 μg/L (NR 140 Enforcement Standard)
- **Surface Water:** 40 μg/L in surface water (human cancer-based risk for marsh determined from WDNR’s Surface Water Quality program).
- **Sediment:** 10 mg/kg in sediment as threshold effect concentration (TEC)

Final performance standards for implementing remediation have not been established for the site, but it is anticipated that the WDNR will select performance standards following issuance of this report.

2.4 Nature and Extent of Contamination

The WDNR's August 21, 2019 memo also provides a detailed evaluation of the nature and extent of arsenic contamination in soil/sediment, groundwater, and surface water at the site. In this evaluation, the distribution of the area-weighted concentration and mass of arsenic in the marsh were estimated using the available data and the following concentration thresholds for arsenic in soil/sediment: 20 mg/kg, 50 mg/kg, 100 mg/kg, 500 mg/kg, and 1,000 mg/kg (WDNR, 2019).

For this Remedial Action Options Report, the WDNR requested that TRC use GIS spatial analysis tools to refine the interpolation of the arsenic isoconcentration contours in soil/sediment for 20 mg/kg, 50 mg/kg, 100 mg/kg, 500 mg/kg, and 1,000 mg/kg using the historical dataset.

TRC completed the GIS spatial analysis using the historical soil/sediment dataset that was compiled by the WDNR and provided to TRC in September 2019. The dataset included soil/sediment samples collected between 1994 and 2010 using a variety of sampling methods from a variety of depths. All soil/sediment data was used, regardless of age and whether the samples were collected before or after the site's interim remedial actions. A detailed summary of the spatial analysis is provided in the TRC Technical Memorandum dated January 20, 2020 (TRC, 2020a), and an overview of the analysis and results are summarized below.

To complete the analysis, the soil/sediment data was first segregated into five depth intervals based on the depth recorded at time of sampling (0'-2', 2'-4', 4'-6', 6'-8'; and >8'). The Natural Neighbor method was then selected from the GIS spatial analysis tools to interpolate soil/sediment isoconcentration contours for the selected arsenic thresholds in each of the five depth intervals. Following interpolation, minor post-processing was performed to align the results with the conceptual site model. This included corrections to create boundary conditions along the railroad to the east, the northern limits of the data set, and the Kewaunee River, and to fill in sparse data for the >8' layer using data from the adjacent layer. The resulting isoconcentration contours from the GIS spatial analysis following post-processing are shown in **Figures 4 to 8**.

The areas and volume of affected soil/sediment for each depth interval are summarized in the tables below. The volume was estimated assuming a 2-foot thickness for each layer, including the > 8' interval. Areas and volumes presented below were then used to develop the opinion of probable costs for the remedial options presented in Section 5.

Depth Interval	Estimated Area (sf) of Soil/Sediment Impacted by Arsenic at Kewaunee Marsh				
	>1,000 ppm	> 500 ppm	> 100 ppm	> 50 ppm	> 20 ppm
0'-2'	119,900	265,100	613,000	744,800	1,015,900
2'-4'	26,000	118,600	321,400	415,800	526,100
4'-6'	23,300	61,200	251,700	330,100	440,000
6'-8'	14,800	22,000	38,500	49,900	110,900
>8'	5,300	10,600	22,600	35,400	152,600

Depth Interval	Estimated Volume (cy) of Soil/Sediment Impacted by Arsenic at Kewaunee Marsh				
	>1,000 ppm	**> 500 ppm**	**> 100 ppm**	**> 50 ppm**	**> 20 ppm**
0’-2’	8,900	19,600	45,400	55,200	75,300
2’-4’	1,900	8,800	23,800	30,800	39,000
4’-6’	1,700	4,500	18,600	24,400	32,600
6’-8’	1,100	1,600	2,900	3,700	8,200
>8’	400	800	1,700	2,600	11,300
Total	**14,000**	**35,300**	**92,400**	**116,700**	**166,400**

3.0 Technology Screening

3.1 Initial Technology Screening

An initial screening of remedial technologies was completed to identify the remedial action options for further evaluation in accordance with Wis. Admin. Code NR § 722.07(2). The remedial technologies evaluated in this initial screening assessment included:

- Excavation (with and without backfill)
- Pump and Treat
- Enhanced Leaching (with Pump and Treat)
- Capping
- Physical Cutoff Wall
- Permeable Reactive Barrier
- Phytoremediation
- In Situ Stabilization (Chemical/Biological)
- In Situ Solidification

The remedial technologies were evaluated and compared in terms of their potential effectiveness, impact to the wetland, and relative cost. The evaluation is summarized in TRC's Memo to the WDNR dated January 20, 2020 (TRC, 2020a). The remedial technologies that were ultimately selected to carry forward as remedial action options included excavation, impermeable cap, permeable reactive barrier, and in-situ stabilization/solidification.

Because in-situ stabilization and capping were previously used as interim measures at the site, further explanation is provided below regarding selection of these technologies.

- **Capping:** The 1996 cap was a permeable vegetative cap that was not designed for long-term use. This cap is no longer effective, most likely because arsenic contaminated water is now incorporated into the pore space of the cap materials. A future engineered cap that is impermeable, designed for long-term stability, and includes features to drain surface water drainage and vent gas is expected to provide long-term protection.
- **In-Situ Stabilization:** The hot spot in-situ stabilization that was completed in 2011 used granular ferric sulfate to immobilize the arsenic and bentonite to reduce soil/sediment permeability. The applied chemistry was successful at immobilizing arsenic in the soil/sediment at the bench scale, but arsenic was still detected in the groundwater at high levels in the hot spot post-treatment. The effectiveness of the bentonite at reducing permeability in the field has not been evaluated. An in-situ stabilization approach that immobilizes arsenic in the field remains a viable alternative, assuming that the appropriate pre-design studies are completed to optimize the design. For purposes of this RAOR, a stabilization approach for previously untreated soil/sediment that relies on anaerobic conditions with bentonite to reduce permeability is carried forward as the basis of design.

This contrasts with the previous in-situ stabilization of the hot spot that relied on maintaining aerobic conditions (i.e., a new in-situ stabilization approach for the untreated soil/sediment is proposed herein).

3.2 Preliminary Concentration Thresholds

As discussed in Section 2.3, final performance standards and selection criteria for the site will be developed by WDNR following this RAOR. However, because concentrations targeted for remediation are needed to compare the remedial alternatives and develop opinions of probable costs, preliminary concentration thresholds were selected for this RAOR. The concentrations thresholds are as follows:

- **Arsenic in Soil/Sediment > 1,000 ppm:** This is inclusive of soil/sediment that is likely to leach arsenic and be characteristically hazardous based on previous bench testing (RMT, 2010).
- **Arsenic in Soil/Sediment > 100 ppm:** This is inclusive of soil over the site-specific RCL corresponding to 10^{-5} increased cancer risk (200 ppm), and accounts for the uncertainty in current extent of impacts identified in Section 3.

3.3 Conceptual Remedial Options

Because of the size and complex nature of the Kewaunee Marsh Arsenic Contaminated Site, the remedial action options were anticipated to incorporate a combination of the selected remedial technologies. Therefore, in advance of this RAOR, TRC completed an interim step to develop conceptual remedial approaches for the WDNR's review and concurrence. Several combinations of options were considered and evaluated based on their relative risk reduction, reliance on engineered controls and aqueous phase treatment, and need for long-term monitoring and maintenance. The conceptual remedial alternatives that were selected to carry forward into the RAOR are summarized in TRC's Memo to the WDNR dated April 13, 2020 (TRC, 2020b). A copy of this memo is provided in **Appendix A** for reference.

The remedial options selected for the RAOR include the following:

- Impermeable Cap (Arsenic [As] >1,000 ppm)
- Impermeable Cap (As >100 ppm)
- In-Situ Stabilization[2] (As >1,000 ppm) + Impermeable Cap (As >100 ppm)
- In-Situ Stabilization[2] (As >100 ppm) + Impermeable Cap (As >100 ppm)
- Excavation (As >1,000 ppm) + Impermeable Cap (As > 100 ppm)
- Excavation (As >1,000 ppm) + Impermeable Cap and In-Situ Stabilization[2] (As >100 ppm)

2 Includes In-Situ Solidification, but is shortened for ease of reading this bullet list.

- Excavation (As >1,000 ppm) + On-site soil/sediment management zone[3] (As >100 ppm)
- Excavation (As >1,000 ppm)
- Excavation (As >100 ppm)

These remedial action options were carried forward in the evaluation of alternatives using the Wis. Admin. Code § NR 722.07(4) criteria that are presented in Section 5.

3 Includes stabilization/solidification of soil/sediment and moving the stabilized materials to area lined with a reactive barrier and covered with an impermeable cap

4.0 Data Gap Analysis

The current understanding of the site, which is summarized in the WDNR's two recent milestone reports (WDNR, 2018; WDNR, 2019) is based on the historical dataset for samples collected from the environmental media at the site; results from prior bench-scale testing and field trials; and observations on the outcomes of the prior interim actions. These items provide enough technical information to select appropriate remedial alternatives to achieve the site's long-term remediation goals. However, data gaps remain, and additional sampling and testing are recommended to finalize the remedial design and establish performance standards for the site.

4.1 Essential Data Gaps

The data gaps identified below are those currently determined to be essential for completing the remedial design and performance standards.

4.1.1 Extent of Arsenic Contaminated Soil/Sediment

The extent of impacted soil/sediment presented in Section 2.4 and **Figures 4 through 8** is based on data collected from several different investigations starting in 1994, which had varying objectives and sampling methods. The soil/sediment data is sparse at depths below 2-feet and the arsenic concentrations are anticipated to change over time[4]. Therefore, a soil/sediment investigation is needed to define the current extent of arsenic impacts for final remedy selection. The results of the investigation will help with the following:

- Reduce uncertainties in the volume and area estimates and improve remedial design
- Reduce uncertainties in the cost estimates for the remedial options
- Confirm if characteristically hazardous soil/sediments remain at the site
- Assist in the determination of site-specific remedial performance standards with consideration of the current exposure risks

A future soil/sediment investigation may use the estimated concentration contours shown in **Figures 4 through 8** as a starting point, and then select sample locations that will confirm and/or refine the concentration boundaries listed below. It may be possible to use field analysis of arsenic to assist in in-field selection of sampling locations for laboratory analysis. There are several field methods that could evaluated prior to the field work.

The horizontal extent of arsenic impacts in the upper 4-feet is needed for all remedial options, and the vertical extent is critical for designing remedies that include excavation or in-situ stabilization. A vertical discretization of 2-feet is recommended for sampling to define the vertical extent of impacts. Sampling to define the following concentration boundaries is recommended, and others may be added as needed.

[4] Decreases in concentration were noted in sediment samples collected from similar areas over time (RMT, 2010; WDNR, 2018).

- Soil/sediment with arsenic concentrations greater 1,000 ppm. This corresponds to the concentration threshold previously determined to be characteristically hazardous for arsenic when not stabilized.
- Soil/sediment with arsenic concentrations greater than the performance standards selected or anticipated for the site (e.g., 100 or 200 mg/kg).
- Soil/sediment with arsenic concentrations greater than the lower threshold of applicable standards (e.g. 20 mg/kg for direct contact risk of 10^{-6} or 10 mg/kg for TEC for sediment).

4.1.2 Evaluation of Previous In-Situ Treatment Area

The area of arsenic impacts that was remediated through in-situ stabilization as part of the 2011 interim action requires testing to evaluate the effectiveness of the prior treatment. This testing is essential to determine if the treated solids have been rendered nonhazardous, and can also be used to see it the addition of bentonite effectively reduced the permeability in the treatment area. The results are critical to remedy selection and final remedial design. For example, if excavation is selected, can the excavated soil/sediment from the previous treatment area be disposed as non-hazardous or will it require further treatment prior to disposal.

4.1.3 Surface Elevations

There is not a map of the current surface elevations for the arsenic contaminated site. The current ground surface elevations are needed to either define volumes of materials for excavation or in-situ treatment, to design the cap, and/or to develop criteria for site restoration after construction. Therefore, prior to finalizing the remedial design, a survey of the current land surface elevation will be needed for the at least the extent of construction.

4.1.4 Pre-Design Studies

A series of bench scale and field scale studies have been completed to test treatability of the arsenic contaminated soil/sediment at Kewaunee Marsh (RMT, 2007; RMT, 2009; RMT, 2010; and RMT, 2011). Treatment options that are expected to be effective based on these previous studies are used as the basis of design for the evaluation of remedial alternatives in Section 5. If in-situ stabilization and/or excavation technologies are part of the selected alternative, additional pre-design studies would be required to finalize the design of the treatment elements of the remedy. These pre-design needs for each remedial option are identified in Section 5, but generally include the following:

- **Water Treatment:** Treatment of arsenic-impacted water from dewatering excavated soil/sediment or from dewatering open excavation areas is needed to be able to discharge the water on-site or to the Kewaunee River. There are several potential ways to remove arsenic from the discharge water during the remediation process when solids will be moved. These include column treatments using zero valent iron (ZVI) or an arsenic-specific ion exchange resin, or adsorption/precipitation using iron or aluminum salts in treatment tanks. A study is needed to determine appropriate methods for the marsh water and to provide the input data for the system design.

- **Disposal Stabilization:** Treatment of characteristically hazardous arsenic impacted soil/sediment is likely needed so that it can be disposed as non-hazardous waste. The results from the 2007 and 2010 bench scale work identified treatment chemistries that can render the soil/sediment non-hazardous for arsenic. A field or bench study is needed to optimize the final specified design

- **In-situ stabilization:** An in-situ stabilization pilot scale study is needed to demonstrate that the organic reducing agent-ferrous sulfate treatment will work on a larger scale. Bench scale studies showed that the concept could work using sodium lactate-ferrous sulfate and soil/sediment samples having arsenic around 1,000 mg/kg As to reduce concentration in groundwater. Bench-scale studies are needed to select the most cost-effective organic reducing agent (lactate versus emulsified vegetable oil) and optimize dose. A field-scale pilot test is needed to demonstrate that the approach will work on a larger scale basis and to optimize the treatment approach. The proposed methods of stabilization are expected to be effective as long as the treated soil/sediments remain anoxic, which is expected in the current marsh setting and high-water level conditions. However, as records show Lake Michigan water level can fluctuate significantly and there is no guarantee the entire contaminated area can remain anoxic. In addition, the root zone of wetland vegetation can change the anoxic condition.

4.2 Other Non-Essential Data Gap Questions

Evidence of arsenic transport has been observed at the site during previous investigation and sampling events. While not essential to remedial design, it would be very helpful to have a better understanding of arsenic transport mechanisms at the site to reduce uncertainties in long-term performance and timeframe for the remedial options. Further field studies could be implemented as funding and time permit to answer one of more of the key questions related to water movement, arsenic movement, and arsenic transformations at the site.

- Is there a true decrease in arsenic concentration over time for soil/sediment samples collected from similar areas?

- What specific mechanism(s) (e.g., surface runoff, vertical advection flux, diffusion, plant transport, overland migration) contributed to the recontamination of the permeable cap and to movement of arsenic at the site?

- Do arsenic concentrations in the emergent plant material allow the material to be harvested and disposed separately from the rest of the soil/sediment at the site?

- How are the redox conditions affected as the surface water and groundwater levels fluctuate temporally and spatially?

- How do the changing Lake Michigan water levels influence water flow and arsenic flux to the Kewaunee River from the marsh?

5.0 Remedial Action Options

The evaluation of the remedial action options selected for Kewaunee Marsh Arsenic Contaminated Site is presented below. A summary of the elements that are common or used in some combination for each of the alternatives is presented in Section 5.2. Following this summary is the detailed evaluation that applies the technical and economic feasibility criteria set forth in Wis. Admin. Code NR § 722.07(4).

- The **technical feasibility criteria** include long-term effectiveness, short-term effects, implementability, time frame, and consideration of continuing obligations.
- The **economic feasibility** are opinions of probable cost for each option, which account for pre-design and bench testing, direct and indirect capital costs, and long-term monitoring, operation and maintenance (O&M). The estimates are derived using the design basis set forth for each option and are presented as a range of probable costs. These costs and basis of designs are intended to be used for comparison of remedial options and are not intended for final budgeting or design. The detailed cost estimating sheets used to derive the opinions of probable costs are included in **Appendix B**.

The relative effectiveness and opinion of probable costs are also summarized in **Table 1**. The remedial options evaluated in this section include the following:

- **Option 1a:** Impermeable Cap (As >1,000 ppm)
- **Option 1b:** Impermeable Cap (As >100 ppm)
- **Option 2a:** In-Situ Stabilization (As >1,000 ppm) + Impermeable Cap (As >100 ppm)
- **Option 2b:** In-Situ Stabilization (As >100 ppm) + Impermeable Cap (As >100 ppm)
- **Option 3:** Excavation (As >1,000 ppm) + Impermeable Cap (As >100 ppm)
- **Option 4:** Excavation (As >1,000 ppm) + Impermeable Cap + In-Situ Stabilization (As >100 ppm)
- **Option 5:** Excavation (As >1,000 ppm) + On-Site Management Zone (As >100 ppm)
- **Option 6a:** Excavation (As >1,000 ppm)
- **Option 6b:** Excavation (As >100 ppm)

5.1 Remediation Areas and Volumes

As discussed in Section 4, the current extent of the arsenic-impacted soil/sediment remains a data gap that should be addressed prior to final design. For purposes of this remedial options evaluation, the opinions of probable costs are based on the estimated surface area and volumes presented in Section 2.4 and shown on **Figures 4 through 8**. The remediation targets are segregated into soil/sediments with arsenic concentrations greater than 1,000 ppm and soil/sediments with arsenic concentrations greater than 100 ppm (see Section 3.2).

- The areas to be capped are based on the extent of impacts shown on **Figure 4**:
  - **>1,000 ppm:** 120,000 sf
  - **>100 ppm:** 613,000 sf
- The volumes of soil/sediment for in-situ stabilization and/or excavation include the extent of impacts shown for each depth interval in **Figures 4 through 8**.
  - **>1,000 ppm:** 14,000 cy(see footnote 5)
  - **>100 ppm:** 92,000 cy

5.2 Remedial Elements and Considerations

The following design elements are included in one or more of the remedial alternatives. This section provides a conceptual description of the key design elements. These concepts are not intended for final design, but provide a reasonable approach to serve as the basis of costs for comparison of the options. The detailed assumptions used to develop the costs are included in **Appendix B**.

5.2.1 Cap

The cap will cover the portions of the site where surficial (0 to 4-foot interval) arsenic concentrations exceed the selected option-specific concentration threshold. The proposed cap is designed to be impermeable to prevent direct contact and hydraulic connection with the underlying soil/sediments and pore water, while still promoting ecological and recreational use of the marsh.

For the cap to be effective it must be designed for this complex setting. A variety of design options could be assumed, but for purposes of this report an engineered multi-layered soil/sediment cap that can vent gas and remain effective in submerged conditions is assumed as the basis of design. The conceptual cap design includes five layers (in order from bottom to top):

- a base layer of gas-permeable bedding with an average thickness of 1-foot,
- a geotextile support layer,
- an impermeable geomembrane layer, such as a 60-mil textured HDPE geomembrane, which can be factory welded to minimize the number of welds needed in the field,
- a 1-foot thick fill layer to prevent hydraulic lift of the cap,
- and an upper layer of approximately 6 inches of topsoil or organic material with seed.

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[5] The volumes assume maximum depth of 10 feet. The depth of impacts may be greater near the source area, but the total additional volume is expected to be minimal and have incidental effect on probable cost.

The gas-permeable base layer will be graded using a 1 percent slope to support passive gas venting from below the cap and surface water drainage on top of the cap. Passive vents will be constructed at the peaks of the cap to allow for gas venting from the gas-permeable layer to the atmosphere. In addition to the data gaps presented in Section 4, a geotechnical evaluation is recommended to assess the stability of the final cap design.

Construction methods used to install the cap will need to consider the water levels at the site at the time of construction. If water levels remain high, the use of diversion structures (e.g. aqua dams, porta dams, or sheetpiling) may be needed to complete installation. Those construction methods would add additional cost to the project, which is covered by the by the contingency in estimated costs in **Appendix B**.

For some alternatives, remaining arsenic-contaminated areas (i.e. soil/sediment with arsenic concentrations between 100 and 1,000 ppm) will be capped with the multi-layered cap described above. For other alternatives, all soil/sediment with arsenic concentrations exceeding 100 ppm is planned to be removed from the site, and/or portions of the site will be backfilled with clean fill and restored without a cap.

5.2.2 Stabilization/Solidification

The stabilization/solidification treatment involves mixing impacted soil/sediment in-situ with a solidification agent to reduce soil/sediment permeability and with a reducing agent to reduce the solubility of the arsenic (which becomes less soluble in strongly reduced environments). Both the stabilization and solidification are intended to reduce the mobility of the arsenic in the groundwater and surface water and the mass flux of arsenic to the Kewaunee River. The proposed solidification agent would be bentonite and the proposed reducing agent would be a sodium lactate-ferrous sulfate mixture. Other reducing agents (e.g. emulsified vegetable oil) could also be used. Final amendment types and mix ratios would be determined based on proposed pre-design studies discussed in Section 4. This treatment is designed to treat the soil/sediment that was not previously treated with ferric sulfate and bentonite.[6]

5.2.3 Excavation and Disposal

Excavation and disposal involve excavating soil/sediment and disposing at an off-site licensed disposal facility. The extent of the excavation will be defined based on the option-specific concentration threshold selected. The excavation areas will be divided into multiple cells, with the goal of reducing the amount of dewatering required during the excavation of each area. Slurry walls will be installed to depths of approximately 10 feet below ground surface as dividers between the excavation cells. During excavation, a wedge of soil/sediment will be left in place along the slurry wall to stabilize and buttress the wall.

The excavated soil/sediment will be dewatered on-site and the standing water that accumulates in the excavation cells will be pumped prior to backfilling the area. The water collected from both soil/sediment dewatering and pumping the excavation areas will be treated on-site using a media

[6] For purposes of this report, the volume of previously treated material is included in the cost estimate for full scale remediation.

such as ZVI or an arsenic-specific ion-exchange resin prior to discharging on-site. The goal of the on-site water treatment will be to meet permit criteria for surface water discharge.

All excavated soil/sediment will be hauled by truck for off-site disposal as non-hazardous waste at a licensed facility. The soil/sediment with arsenic concentrations exceeding 1,000 ppm will be treated on-site using ZVI, or similar treatment additive, in order to reduce leaching potential of the arsenic and render it non-hazardous prior to off-site disposal. Based on previous testing, the soil/sediments with arsenic concentrations less than 1,000 ppm will be able to be disposed as non-hazardous solid waste without further on-site treatment. Soil/sediment with arsenic concentrations detected exceeding 2,000 mg/kg prior to 2010 was previously treated and are assumed to be non-hazardous.[6]

5.2.3.1 Backfill

For purposes of developing costs in this RAOR, the post-remediation management assumes that the excavation areas will be backfilled. The options for backfill material include imported clean fill and/or residual arsenic-impacted soil/sediment. The assumed backfill material is provided for each excavation alternative. The slurry wall and wedge of supporting soil/sediment used to sub-divide the excavation areas may either be excavated during the backfill process or left in place.

5.2.3.2 No Backfill

Although backfill with clean materials is used as the basis of cost for most of the excavation options, it may be possible to leave a ponded area post-remediation rather than backfilling with clean materials. The ponded water would require long-term monitoring and management to ensure it meets surface water performance standards, but it may be easier to manage and treat the aqueous phase in the pond instead of developing a contingency to manage the backfill if it becomes contaminated because of residual aqueous phase impacts. The choice to backfill with clean materials or leave ponded water can be further evaluated during remedial design.

5.2.4 On-Site Management Zone

In Option 5, an engineered on-site soil/sediment management zone is created to reduce the footprint of the area with residual arsenic-impacted soil/sediment. The on-site management zone will be constructed within the hole of the excavation of the soil/sediment with arsenic concentrations exceeding 1,000 ppm. The base and sides of the on-site management zone will be lined with a permeable reactive barrier, such as ZVI. The soil/sediment with arsenic concentrations between 100 and 1,000 ppm will then be relocated into the lined management zone and capped. The management zone will result in a mounded area. Imported backfill will be used to restore the areas that once contained soil/sediment with arsenic between 100 and 1,000 ppm. The addition of the permeable reactive barrier to line the management zone is intended to treat arsenic-impacted water as it flows through the barrier, which will minimize the potential to contaminate the clean backfill placed at the site.

5.3 Option 1a – Cap >1,000 ppm Area

5.3.1 Description

Cap the portions of the site where surficial arsenic concentrations exceed 1,000 ppm. Maintain the fence around the site.

5.3.2 Technical and Economic Feasibility

Long-Term Effectiveness

Capping the areas where surficial arsenic concentrations exceed 1,000 ppm will be protective against the direct contact pathway in these specific areas but will not remove or treat the contamination. Maintenance of the fence will be critical to prevent direct contact risk with the residual impacts outside the capped area, and protectiveness could be compromised if there is a break or breach to the fence.

Given that all impacted soil/sediment will be left in place and a large portion of the impacted soil/sediment will remain uncapped, there would likely still be a significant risk of off-site migration and impacts to water quality at the site. Recontamination of the cap materials from surface flow coming off the uncapped areas is possible, but it is unlikely because the capped area would be upgradient of the residual arsenic impacts.

Short-Term Effects

Changing local elevations and adding an impermeable cap will change wetland hydrology, the nature of the plant community, and wetland functions. The wetland impact will be proportional to the size of the cap. This option is least disruptive to the marsh environment given the small area and shallow depth of disturbance for cap construction. It is expected that fencing and erosion control will effectively prevent public health exposure and migration of impacted soil/sediments during the cap construction.

Implementability

This option would be implemented easily relative to other options given the small area of the proposed cap, easy access to the cap area based on its location, and fewer materials required for construction. It is anticipated that crane mats would be used to support construction equipment in the marsh and that the trail would be used as a haul road to bring in equipment and materials. No treatment of water is needed to construct this option.

Time Frame

Protection against the direct contact pathway for areas exceeding 1,000 ppm arsenic will be achieved upon completion of the cap. Achievement of numeric remedial goals for soil/sediment is not expected to occur, and long-term protection will rely on the continuing obligations identified below.

Continuing Obligations and Long-Term Monitoring

The cap and fence will require annual inspections and ongoing care and maintenance as needed, such as filling, revegetation, and fence repairs. Results of annual sampling, inspection, and maintenance will be summarized in an annual report. It is assumed that this care will be needed indefinitely (a duration of 30 years is used in the present worth calculations to estimate the opinion of probable cost over this indefinite period).

Post-remediation monitoring will also be needed. The specific performance monitoring plan will be developed during the remedial design, and will include a contingency plan for situation where the monitoring results find that the performance standards are not met. For purposes of this RAOR, the long-term monitoring is assumed include a network of groundwater monitoring wells sampled up to four times a year during the same duration as the long-term care. Samples will be analyzed for arsenic to monitor long-term concentration trends and seasonal and hydrological influences. Costs to implement a contingency plan are not included.

Opinion of Probable Cost

The total estimated cost to implement this remedial action option is $1,140,000 to $1,640,000. Refer to Appendix B - Opinion of Probable Cost Tables for cost estimate details and assumptions.

5.4 Option 1b – Cap >100 ppm Area

5.4.1 Description

Cap portions of the site where surficial arsenic concentrations exceed 100 ppm.

5.4.2 Technical and Economic Feasibility

Long-Term Effectiveness

Capping the areas where surficial arsenic concentrations exceed 100 ppm will be protective against the direct contact pathway but will not remove or treat the contamination. Given that all impacted soil/sediment would be left in place, there would likely still be a continued flux of arsenic to the river. However, because the impermeable cap will limit infiltration within the capped area, the total flux is expected to be reduced compared to Option 1a. Maintenance of the fence may be needed to address the residual impacts; however, future assessment of the arsenic contaminated area could allow for removal of all, or a portion of the fence.

Short-Term Effects

Changing local elevations and adding an impermeable cap will change wetland hydrology, the nature of the plant community, and wetland functions. The wetland impact will be proportional to the size of the cap. Therefore, wetland impact will be greater for this option than for Option 1a due to the increased cap extent. This option is more disruptive to the natural environment than Option 1a because of the larger area of the cap, but it is less disruptive compared to options involving subsurface treatment or excavation. It is expected that erosion control and construction fencing will effectively prevent public health exposure and migration of impacted soil/sediments during the cap construction.

Implementability

This option would be implemented easily relative to most other options, but would take a longer time than Option 1a due to the larger cap area and may have more challenges where the cap area approaches the river. It is anticipated that crane mats would be used to support construction equipment in the marsh and that the trail would be used as a haul road to bring in equipment and materials. The contractor may also elect to do portions of the work from the water if there is better access compared to overland. No treatment of water is needed to construct this option.

Time Frame

Protection against the direct contact pathway will be achieved upon completion of the cap. Achievement of numeric remedial goals for soil/sediment is not expected to occur, and long-term protection will rely on the continuing obligations identified below.

Continuing Obligations and Long-Term Monitoring

The fence and cap will require annual inspections and ongoing care and maintenance as needed, such as filling and revegetation. Results of annual sampling, inspection, and maintenance will be summarized in an annual report. It is assumed that this care will be needed indefinitely (a duration of 30 years is used in the present worth calculations to estimate the opinion of probable cost over this indefinite period).

Post-remediation monitoring will also be needed. The specific performance monitoring plan will be developed during the remedial design, and will include a contingency plan for situation where the monitoring results find that the performance standards are not met. For purposes of this RAOR, the long-term monitoring is assumed include a network of groundwater monitoring wells sampled up to four times a year during the same duration as the long-term care. Samples will be analyzed for arsenic to monitor long-term concentration trends and seasonal and hydrological influences. Costs to implement a contingency plan are not included.

Opinion of Probable Cost

The total estimated cost to implement this remedial action option is $3,680,000 to $5,310,000. Refer to Appendix B - Opinion of Probable Cost Tables for cost estimate details and assumptions.

5.5 Option 2a – In-Situ Stabilization/Solidification of >1,000 ppm Area + Cap >100 ppm Area

5.5.1 Description

Treat soil/sediment with in-situ stabilization/solidification where arsenic concentrations exceed 1,000 ppm.[7] Install a cap over the portions of the site where surficial arsenic concentrations exceed 100 ppm.

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[7] The soil/sediment in the hot spot area that was previously treated in-situ is included in the cost. However, this material may be excluded in the final design depending on results of additional sampling.

5.5.2 Technical and Economic Feasibility

Long-Term Effectiveness

Capping the areas where surficial arsenic concentrations exceed 100 ppm will be protective against the direct contact pathway. In-situ treatment will not reduce the overall contaminant mass on-site, but the stabilization and solidification of the soil/sediment with arsenic concentrations exceeding 1,000 ppm[7] is expected to prevent the mobilization of arsenic into groundwater in the area of treatment. Therefore, this option will improve to water quality and lessen the potential for recontamination of the cap and the arsenic flux to the Kewaunee River as compared to Option 1b. (Note, although it is unlikely that arsenic would remobilize from the stabilized soil/sediment, it is possible if anoxic conditions are not maintained because of the marsh's complex geochemistry and/or changing water levels). Maintenance of the fence may be needed to address the residual impacts; however, future assessment of the arsenic contaminated area could allow for removal of all, or a portion of the fence.

Short-Term Effects

Mixing to stabilize/solidify soil/sediment and adding an impermeable cap will change wetland hydrology, the nature of the plant community, and wetland functions. The wetland impact will predominantly be proportional to the size of the cap. However, the wetland impact will be slightly greater for this option than for Option 1b due to the addition of deeper stabilization/solidification work. It is expected that erosion control and construction fencing will effectively prevent public health exposure and migration of impacted soil/sediments during capping and in-situ mixing.

Implementability

It is anticipated that crane mats would be used to support construction equipment in the marsh and that the trail would be used as a haul road to bring in equipment and materials. Implementation of the stabilization/solidification treatment is more complicated than capping alone but can be done in-situ with standard construction equipment at the proposed depths, as demonstrated by previous in-situ remediation in the hot spot area. No treatment of water is needed to construct this option.

Time Frame

Protection against the direct contact pathway will be achieved upon completion of the cap. The cap is expected to remain protective of the direct contact pathway indefinitely if it is properly maintained. Stabilization/solidification is expected to reduce off-site migration of arsenic upon completion of the in-situ mixing, and is intended to be effective indefinitely if anoxic conditions can be maintained. Achievement of numeric remedial goals for soil/sediment is not expected to occur, and long-term protection will rely on the continuing obligations identified below.

Continuing Obligations and Long-Term Monitoring

The fence and cap will require annual inspections and ongoing care and maintenance as needed, such as filling and revegetation. Results of annual sampling, inspection, and maintenance will be summarized in an annual report. It is assumed that this care will be needed indefinitely (a duration of 30 years is used in the present worth calculations to estimate the opinion of probable cost over this indefinite period).

Post-remediation monitoring will also be needed. The specific performance monitoring plan will be developed during the remedial design, and will include a contingency plan for situation where the monitoring results find that the performance standards are not met. For purposes of this RAOR, the long-term monitoring is assumed include a network of groundwater monitoring wells sampled up to four times a year during the same duration as the long-term care. Samples will be analyzed for arsenic to monitor long-term concentration trends and seasonal and hydrological influences. Costs to implement a contingency plan are not included.

Opinion of Probable Cost

The total estimated cost to implement this remedial action option is $4,410,000 to $6,380,000. Refer to Appendix B - Opinion of Probable Cost Tables for cost estimate details and assumptions.

5.6 Option 2b – In-Situ Stabilization/Solidification of >100 ppm Area + Cap >100 ppm Area

5.6.1 Description

Treat soil/sediment with in-situ stabilization/solidification where arsenic concentrations exceed 100 ppm.[7] Install a cap over the portions of the site where surficial arsenic concentrations exceed 100 ppm.

5.6.2 Technical and Economic Feasibility

Long-Term Effectiveness

Capping the areas where surficial arsenic concentrations exceed 100 ppm will be protective against the direct contact pathway. In-situ treatment will not reduce the overall contaminant mass on-site, but the stabilization and solidification of the soil/sediment with arsenic concentrations exceeding 100 ppm[7] is expected to prevent the mobilization of arsenic into groundwater in the area of treatment. Therefore, this option will improve to water quality and lessen the potential for recontamination of the cap and the arsenic flux to the Kewaunee River as compared to Option 2a. (Note, although it is unlikely that arsenic would remobilize from the stabilized soil/sediment, it is possible if anoxic conditions are not maintained because of the marsh's complex geochemistry and/or changing water levels). Maintenance of the fence may be needed to address the residual impacts; however, future assessment of the arsenic contaminated area could allow for removal of all, or a portion of the fence.

Short-Term Effects

Mixing to stabilize/solidify soil/sediment and adding an impermeable cap will change wetland hydrology, the nature of the plant community, and wetland functions. The wetland impact will predominantly be proportional to the size of the cap. However, the wetland impact will be slightly greater for this option than for Option 2a due to the larger extents of deeper stabilization/solidification work.

It is expected that erosion control and construction fencing will effectively prevent public health exposure and migration of impacted soil/sediments during capping and in-situ mixing.

Implementability

It is anticipated that crane mats would be used to support construction equipment in the marsh and that the trail would be used as a haul road to bring in equipment and materials. Implementation of the stabilization/solidification treatment is more complicated than capping alone, but can be done on site at the proposed depths, as demonstrated by previous blending used for remediation in the hot spot area. Implementation of this option will require more effort than that of Option 2a given the larger treatment area for stabilization/solidification. No treatment of water is needed to construct this option.

Time Frame

Protection against the direct contact pathway will be achieved upon completion of the cap. The cap is expected to remain protective of the direct contact pathway indefinitely if it is properly maintained. Stabilization/solidification is expected to reduce off-site migration of arsenic upon completion of the in-situ mixing, and is intended to be effective indefinitely if anoxic conditions can be maintained. Achievement of numeric remedial goals for soil/sediment is not expected to occur, and long-term protection will rely on the continuing obligations identified below.

Continuing Obligations and Long-Term Monitoring

The fence and cap will require annual inspections and ongoing care and maintenance as needed, such as filling and revegetation. Results of annual sampling, inspection, and maintenance will be summarized in an annual report. The timeframe to maintain the cap may be lessened if the stabilization/solidification remains effective. It is assumed that this care will be needed for a long, but not indefinite time (a duration of 30 years is used in the present worth calculations to estimate the opinion of probable cost over this indefinite period).

Post-remediation monitoring will also be needed. The specific performance monitoring plan will be developed during the remedial design, and will include a contingency plan for situation where the monitoring results find that the performance standards are not met. For purposes of this RAOR, the long-term monitoring is assumed include a network of groundwater monitoring wells sampled up to four times a year during the same duration as the long-term care. Samples will be analyzed for arsenic to monitor long-term concentration trends and seasonal and hydrological influences. Costs to implement a contingency plan are not included.

Opinion of Probable Cost

The total estimated cost to implement this remedial action option is $9,000,000 to $13,000,000. Refer to Appendix B - Opinion of Probable Cost Tables for cost estimate details and assumptions.

5.7 Option 3 – Excavation of >1,000 ppm Area + Cap >100 ppm Area

5.7.1 Description

Excavate soil/sediment where arsenic concentrations exceed 1,000 ppm. Treat soil/sediment on-site prior to disposal in order to render material non-hazardous. Dewater excavated soil/sediment and standing water that accumulates in the excavation; treat water on site prior to discharging. Grade a portion of the residual soil/sediment with arsenic concentrations of 100 to 1,000 ppm into the excavation area to create a level base for the cap. Install a cap over the areas of the site where surficial arsenic concentrations exceed 100 ppm.[8]

5.7.2 Technical and Economic Feasibility

Long-Term Effectiveness

Capping the areas where surficial arsenic concentrations exceed 100 ppm will be protective against the direct contact pathway. The excavation of soil/sediment with arsenic concentrations exceeding 1,000 ppm will reduce the total contaminant mass on-site; however, the residual soil/sediment with arsenic concentrations less than 1,000 ppm is expected to result in some continued off-site migration of arsenic to the river. Because soil/sediment with arsenic exceeding 1,000 ppm will be removed, the potential for recontamination of the cap and the arsenic flux to the Kewaunee River is expected to be less than Option 2a. Maintenance of the fence may be needed to address the residual impacts; however, future assessment of the arsenic contaminated area could allow for removal of all, or a portion of the fence.

Short-Term Effects

Excavation and adding an impermeable cap will change wetland hydrology, the nature of the plant community, and wetland functions. The wetland impact will predominantly be proportional to the size of the cap. However, the wetland impact will be slightly less for this option than for Option 2a due to the regrading of native soil/sediment rather than mixing soil/sediment with stabilization/solidification amendments. It is expected that erosion control and construction fencing will effectively prevent public health exposure to impacted soil/sediments during capping and excavation.

Implementability

It is anticipated that crane mats would be used to support construction equipment in the marsh and that the trail would be used as a haul road to bring in equipment and materials. Excavation and capping are implementable at the site for the expected excavation depths and capped area. Treatment of the excavated soil/sediment to render it non-hazardous would require additional pre-design testing and materials and equipment during construction. Treatment of the water from dewatering will require additional pre-design studies and mobilization of on-site treatment equipment. Permits and testing would be required for surface discharge of treated water.

8 For purposes of this report, the capped area is assumed to be the same as for Option 2b (613,000 sf).

Time Frame

The reduction in contaminant mass will be achieved as soon as excavation is complete. Protection against the direct contact pathway will be achieved upon completion of the cap. Achievement of numeric remedial goals for soil/sediment is not expected to occur, and long-term protection will rely on the continuing obligations identified below.

Continuing Obligations and Long-Term Monitoring

The fence and cap will require annual inspections and ongoing care and maintenance as needed, such as filling and revegetation. Results of annual sampling, inspection, and maintenance will be summarized in an annual report. It is assumed that this care will be needed indefinitely (a duration of 30 years is used in the present worth calculations to estimate the opinion of probable cost over this indefinite period).

Post-remediation monitoring will also be needed. The specific performance monitoring plan will be developed during the remedial design, and will include a contingency plan for situation where the monitoring results find that the performance standards are not met. For purposes of this RAOR, the long-term monitoring is assumed include a network of groundwater monitoring wells sampled up to four times a year during the same duration as the long-term care. Samples will be analyzed for arsenic to monitor long-term concentration trends and seasonal and hydrological influences. Costs to implement a contingency plan are not included.

Opinion of Probable Cost

The total estimated cost to implement this remedial action option is $6,780,000 to $9,800,000. Refer to Appendix B - Opinion of Probable Cost Tables for cost estimate details and assumptions.

5.8 Option 4 – Excavation of >1,000 ppm Area, Stabilization/Solidification + Cap of 100-1,000 ppm Area

5.8.1 Description

Excavate soil/sediment where arsenic concentrations exceed 1,000 ppm. Treat soil/sediment on-site prior to disposal in order to render material non-hazardous. Dewater excavated soil/sediment and standing water that accumulates in the excavation; treat water on site prior to discharging. Grade a portion of the soil/sediment with arsenic concentrations of 100 to 1,000 ppm into the excavated area to create a level base for the cap. Treat all residual soil/sediment with arsenic concentrations greater than 100 ppm with in-situ stabilization/solidification. Install a cap over the area of stabilized soil/sediment where surficial arsenic concentrations exceed 100 ppm.[8]

5.8.2 Technical and Economic Feasibility

Long-Term Effectiveness

Capping the areas where surficial arsenic concentrations exceed 100 ppm will be protective against the direct contact pathway. The excavation and off-site disposal of soil/sediment with arsenic concentrations exceeding 1,000 ppm will reduce total contaminant mass on-site. Stabilization/solidification of the 100 to 1,000 ppm impacted soil/sediments is expected to prevent the mobilization of arsenic into groundwater and therefore reduce water quality impacts and off-site migration. Because soil/sediment with arsenic exceeding 1,000 will be removed, and the soil/sediment with arsenic between 100 and 1,000 ppm will be stabilized, the potential for recontamination of the cap and the arsenic flux to the Kewaunee River is expected to be less than Option 2b or Option 3. (Note, although it is unlikely that arsenic would remobilize from the stabilized soil/sediment, it is possible if anoxic conditions are not maintained because of the marsh's complex geochemistry and/or changing water levels). Maintenance of the fence may be needed to address the residual impacts; however, future assessment of the arsenic contaminated area could allow for removal of all, or a portion of the fence.

Short-Term Effects

Excavation, mixing to stabilize/solidify soil/sediment, and adding an impermeable cap will change wetland hydrology, the nature of the plant community, and wetland functions. The wetland impact will predominantly be proportional to the size of the cap. However, the wetland impact will be slightly greater for this option than for Option 3 due to the stabilization/solidification work. It is expected that erosion control and construction fencing will effectively prevent public health exposure to impacted soil/sediments during in-situ mixing, excavation, and capping.

Implementability

It is anticipated that crane mats would be used to support construction equipment in the marsh and that the trail would be used as a haul road to bring in equipment and materials. Excavation and capping are implementable at the site for the expected excavation depths and capped area. The stabilization/solidification treatment can be implemented on site at the proposed depths, as demonstrated by previous in-situ remediation in the hot spot area. Treatment of the excavated soil/sediment to render it non-hazardous would require additional pre-design testing and materials and equipment during construction. Treatment of the water from dewatering will require additional pre-design studies and mobilization of on-site treatment equipment. Permits and testing would be required for surface discharge of treated water.

Time Frame

The reduction in contaminant mass will be achieved as soon as excavation is complete. Protection against the direct contact pathway will be achieved upon completion of the cap. Achievement of numeric remedial goals for soil/sediment is not expected to occur, and long-term protection will rely on the continuing obligations identified below.

Continuing Obligations and Long-Term Monitoring

The fence and cap will require annual inspections and ongoing care and maintenance as needed, such as filling and revegetation. Results of annual sampling, inspection, and maintenance will be summarized in an annual report. The timeframe to maintain the cap may be lessened if the stabilization/solidification remains effective. It is assumed that this care will be needed for a long, but not indefinite time (a duration of 30 years is used in the present worth calculations to estimate the opinion of probable cost over this indefinite period).

Post-remediation monitoring will also be needed. The specific performance monitoring plan will be developed during the remedial design, and will include a contingency plan for situation where the monitoring results find that the performance standards are not met. For purposes of this RAOR, the long-term monitoring is assumed include a network of groundwater monitoring wells sampled up to four times a year during the same duration as the long-term care. Samples will be analyzed for arsenic to monitor long-term concentration trends and seasonal and hydrological influences. Costs to implement a contingency plan are not included.

Opinion of Probable Cost

The total estimated cost to implement this remedial action option is $10,490,000 to $15,150,000. Refer to Appendix B - Opinion of Probable Cost Tables for cost estimate details and assumptions.

5.9 Option 5 – Excavation of >1,000 ppm Area, Stabilization/Solidification of 100-1,000 ppm, and On-Site Management Zone with Reactive Barrier and Cap

5.9.1 Description

Excavate soil/sediment where arsenic concentrations exceed 1,000 ppm and dispose off-site. Treat soil/sediment on-site prior to disposal in order to render material non-hazardous. Dewater excavated soil/sediment and standing water that accumulates in the excavation; treat water on site prior to discharging. Create an on-site management zone within the excavation area for the reuse of stabilized soil/sediment with arsenic concentrations of 100 to 1,000 ppm. Treat residual soil/sediment with in-situ stabilization/solidification where arsenic concentrations exceed 100 ppm. Line the base and sides of the on-site management zone with a permeable reactive barrier (e.g., ZVI), then fill the area with the stabilized/solidified soil/sediments, resulting in a mound at the surface. Stabilized/solidified soil/sediments will not require dewatering. Install a cap over the on-site management zone. Use imported backfill to fill the excavation area outside the on-site management zone, allowing restoration of wetland function in the backfilled area.

5.9.2 Technical Feasibility

Long-Term Effectiveness

This option is more protective of groundwater and off-site impacts than Option 4, where the 100 to 1,000 ppm soil/sediments remain stabilized/solidified in place without the supplemental control from a reactive barrier.

Capping the on-site management zone will be protective against the direct contact pathway. The excavation of soil/sediment with arsenic concentrations exceeding 1,000 ppm will reduce total contaminant mass on-site, and stabilization/solidification of the 100 to 1,000 ppm impacted soil/sediments is expected to limit arsenic mobility and reduce off-site migration. Placement of the 100 to 1,000 ppm soil/sediments in the on-site management zone will further reduce the potential for impacts to water quality and off-site migration of arsenic in the residual soil/sediment as compared to Option 4. Note, although it is unlikely that arsenic would remobilize from the stabilized soil/sediment, it is possible if anoxic conditions are not maintained because of the marsh's complex geochemistry and/or changing water levels. If remobilization occurs, the ZVI line will limit migration of arsenic from the on-site management zone. Maintenance of the fence may be needed to address the residual impacts; however, future assessment of the arsenic contaminated area could allow for removal of all, or a portion of the fence.

Wetland restoration will be possible in the areas outside the soil/sediment management zone that received clean backfill.

Short-Term Effects

Excavation in the area with arsenic exceeding 1,000 ppm and stabilization/solidification, capping, and a permeable reactive barrier in the area with arsenic exceeding 100 ppm will change wetland hydrology, the nature of the plant community, and wetland functions. In the short-term, the impacts are expected to be similarly disruptive to the wetland as compared to Option 4. However, because wetland restoration will be possible in the areas that receive clean backfill, the overall impact to the wetland is improved from Option 4. It is expected that erosion control and construction fencing will effectively prevent public health exposure to impacted soil/sediments during in-situ mixing, excavation, and capping.

Implementability

It is anticipated that crane mats would be used to support construction equipment in the marsh and that the trail would be used as a haul road to bring in equipment and materials. Excavation, installation of a permeable reactive barrier, and capping are implementable at the site for the expected excavation depths and lined/capped areas. The stabilization/solidification treatment can be implemented on site at the proposed depths, as demonstrated by previous blending used for remediation in the hot spot area. Treatment of the excavated soil/sediment to render it non-hazardous would require additional pre-design testing and materials and equipment during construction. Treatment of the water from dewatering will require additional pre-design studies and mobilization of on-site treatment equipment. Permits and testing would be required for surface discharge of treated water, and permits and/or approvals would be required for the on-site management zone.

Time Frame

The reduction in contaminant mass will be achieved as soon as excavation is complete. Protection against the direct contact pathway will be achieved upon backfilling with clean material outside the on-site management zone and upon completion of the cap within the on-site management zone. Achievement of numeric remedial goals for soil/sediment is not expected to occur within the on-site management zone; however, achievement of numeric remedial goals in water and soil/sediment is likely within a short time-frame (less than 5 years) in areas outside of the on-site management zone.

Continuing Obligations and Long-Term Monitoring

The fence and cap in the on-site management zone will require annual inspections and ongoing care and maintenance as needed, such as filling and revegetation. Results of annual sampling, inspection, and maintenance will be summarized in an annual report. The timeframe to maintain the cap may be lessened if the stabilization/solidification remains effective. It is assumed that this care will be needed for a long, but not indefinite time (a duration of 30 years is used in the present worth calculations to estimate the opinion of probable cost over this indefinite period).

Post-remediation monitoring will also be needed. The specific performance monitoring plan will be developed during the remedial design, and will include a contingency plan for situation where the monitoring results find that the performance standards are not met. For purposes of this RAOR, the long-term monitoring is assumed include a network of groundwater monitoring wells sampled up to four times a year during the same duration as the long-term care. Samples will be analyzed for arsenic to monitor long-term concentration trends and seasonal and hydrological influences. Costs to implement a contingency plan are not included.

Opinion of Probable Cost

The total estimated cost to implement this remedial action option is $14,620,000 to $21,120,000. Refer to Appendix B - Opinion of Probable Cost Tables for cost estimate details and assumptions.

5.10 Option 6a – Excavation and Backfill of >1,000 ppm Area

5.10.1 Description

Excavate soil/sediment where arsenic concentrations exceed 1,000 ppm and dispose off-site. Treat soil/sediment on-site prior to disposal in order to render material non-hazardous. Dewater excavated soil/sediment and standing water that accumulates in the excavation; treat water on site prior to discharging. Backfill excavation with imported fill. Maintain the fence around the site.

5.10.2 Technical and Economic Feasibility

Long-Term Effectiveness

The excavation of soil/sediment with arsenic concentrations exceeding 1,000 ppm will reduce total contaminant mass on-site. However, the residual soil/sediment with arsenic concentrations less than 1,000 ppm is expected to result in continued off-site migration of arsenic to the river. In addition, recontamination of the backfill is likely as arsenic-impacted water from the surrounding soil/sediment infiltrates into the backfill area.

Direct contact risk will remain for the uncapped areas. Maintenance of the fence will be critical to prevent direct contact risk with the residual impacts outside the capped area, and protectiveness could be compromised if there is a break or breach to the fence.

Wetland restoration will be possible in the excavation area after it is backfilled with clean material. However, recontamination of this restored area is possible because of the residual impacts that will remain uncontrolled at the site.

Short-Term Effects

Excavation and backfilling will temporarily change the wetland hydrology, the nature of the plant community, and wetland functions. This option involves similar short-term impacts to the wetland as compared to Option 1a. However, because wetland restoration will be possible in the areas that received clean backfill, the overall impact to the wetland is improved from Option 1a. It is expected that erosion control and construction fencing will effectively prevent public health exposure to impacted soil/sediments during excavation.

Implementability

It is anticipated that crane mats would be used to support construction equipment in the marsh and that the trail would be used as a haul road to bring in equipment and materials. Excavation is implementable at the site for the expected excavation depths. Treatment of the excavated soil/sediment to render it non-hazardous would require additional pre-design testing and materials and equipment during construction. Treatment of the water from dewatering will require additional pre-design studies and mobilization of on-site treatment equipment. Permits and testing would be required for surface discharge of treated water.

Time Frame

Protection against the direct contact pathway will be achieved in the excavation area as soon as it is backfilled with clean material; however, recontamination of the clean backfill material may to occur over time. Achievement of numeric remedial goals for soil/sediment is not expected to occur, and long-term protection will rely on the continuing obligations identified below.

Continuing Obligations and Long-Term Monitoring

The fence will require annual inspections and ongoing care. Results of annual sampling, inspection, and maintenance will be summarized in an annual report. The timeframe to maintain the cap may be lessened if the stabilization/solidification remains effective. It is assumed that this care will be required indefinitely (a duration of 30 years is used in the present worth calculations to estimate the opinion of probable cost over this indefinite period).

Post-remediation monitoring will also be needed. The specific performance monitoring plan will be developed during the remedial design, and will include a contingency plan for situation where the monitoring results find that the performance standards are not met (e.g. contamination of clean backfill from residual impacts). For purposes of this RAOR, the long-term monitoring is assumed include a network of groundwater monitoring wells sampled up to four times a year during the same duration as the long-term care. Samples will be analyzed for arsenic to monitor long-term concentration trends and seasonal and hydrological influences. Costs to implement a contingency plan are not included.

Opinion of Probable Cost

The total estimated cost to implement this remedial action option is $2,730,000 to $3,940,000. Refer to Appendix B - Opinion of Probable Cost Tables for cost estimate details and assumptions.

5.11 Option 6b – Excavation and Backfill of >100 ppm Area

5.11.1 Description

Excavate soil/sediment where arsenic concentrations exceed 100 ppm and dispose off-site. Treat soil/sediment exceeding 1,000 ppm on-site prior to disposal in order to render material non-hazardous. Dewater excavated soil/sediment and standing water that accumulates in the excavation of areas exceeding 1,000 ppm; treat water on site prior to discharging. Backfill excavation with imported fill. Potentially able to remove the fence; however, a final decision will be made after reevaluation of the arsenic contaminated area.

5.11.2 Technical and Economic Feasibility

Long-Term Effectiveness

The excavation of soil/sediment with arsenic concentrations exceeding 100 ppm will reduce total contaminant mass on-site and achieve numeric remedial goals for soil/sediment as well as significantly reduce the potential for impacts to water quality and off-site migration. Direct contact protection will be achieved by backfilling the excavation with clean fill material. Maintenance of some portion of the fence may be needed to address the residual impacts; however, future assessment of arsenic contaminated area is likely to find that all, or a portion of the fence is no longer needed.

Wetland restoration will be possible in the excavation area after it is backfilled with clean material. Recontamination of the backfill is unlikely because of the low residual mass of arsenic following the excavation.

Short-Term Effects

Excavation and backfilling will temporarily change the wetland hydrology, the nature of the plant community, and wetland functions. This option involves similar short-term impacts to the wetland as compared to Option 2.b and 5. However, because wetland restoration will be possible in the areas that received clean backfill, the overall impact to the wetland is improved from these previous options. It is expected that erosion control and construction fencing will effectively prevent public health exposure to impacted soil/sediments during excavation.

Implementability

It is anticipated that crane mats would be used to support construction equipment in the marsh and that the trail would be used as a haul road to bring in equipment and materials. Excavation is implementable at the site for the expected excavation depths; however, the excavation near the river will special consideration to construction methods and phasing. Treatment of the excavated soil/sediment greater than 1,000 ppm to render it non-hazardous would require additional pre-design testing and materials and equipment during construction. Treatment of the water from dewatering will require additional pre-design studies and mobilization of on-site treatment equipment. Permits and testing would be required for surface discharge of treated water.

Time Frame

Protection against the direct contact pathway and achievement of numeric remedial goals for soil/sediment is expected to within a reasonable time frame after the excavation is backfilled.

Continuing Obligations and Long-Term Monitoring

No long-term care or inspections are required for this option; however, short period of post-remediation performance monitoring is required, and the fence may be required during this time. Five years of monitoring are used in the present worth calculations for the opinion of probable cost, after which it is assumed monitoring will show that the site can enter the WDNR Case Closure process.

The specific performance monitoring plan will be developed during the remedial design, and it will include a contingency plan for situation where the monitoring results find that the performance standards are not met. For purposes of this RAOR, the long-term monitoring is assumed include a network of groundwater monitoring wells sampled up to four times a year for 5 years. Samples will be analyzed for arsenic to monitor long-term concentration trends and seasonal and hydrological influences. Costs to implement a contingency plan are not included.

Opinion of Probable Cost

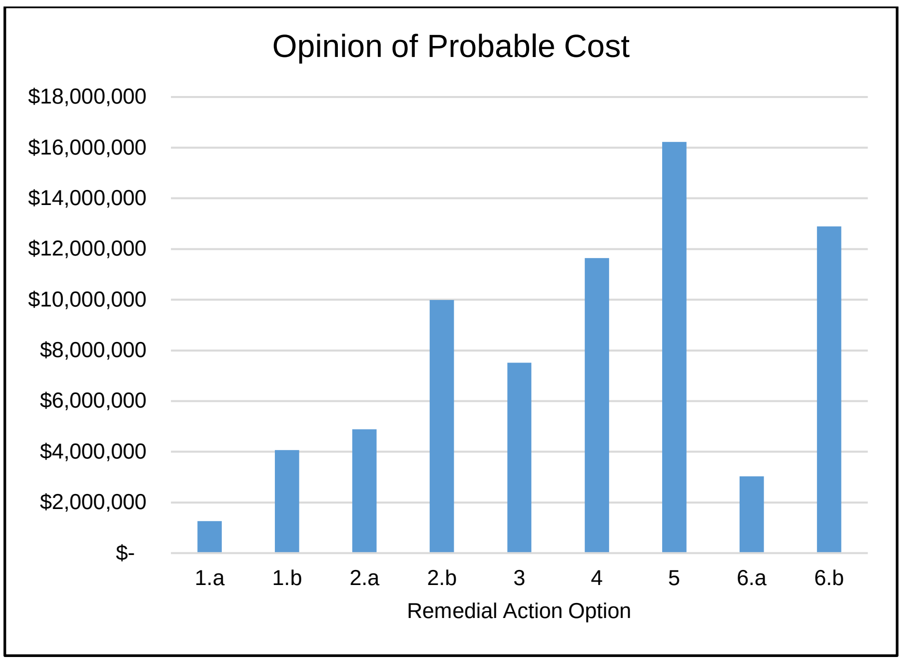
The total estimated cost to implement this remedial action option is $11,620,000 to $16,780,000. Refer to Appendix B - Opinion of Probable Cost Tables for cost estimate details and assumptions.

5.12 Economic Feasibility Comparison

The following graph summarizes the total estimated cost to implement each of the remedial action options. It is intended to provide a comparison of economic feasibility between remedial options. The costs plotted on the graph are the estimated costs without contingency. The final estimated range of costs for each option were provided in the preceding sections and include a contingency range of -10% to +30%. These costs are intended to be used for comparison of remedial options and are not intended for final budgeting or design.

The lowest cost option was Option 1a (~$1.3 Million) and the highest cost option was Option 5 (~$16 Million). Option 5 was evaluated to determine if on-site management of the impacted soil/sediment would be more cost effective than off-site disposal. The cost for off-site disposal for Option 6b was ~$13 Million. Based on this evaluation, the cost for on-site management of impacted soil/sediment does not appear to be beneficial to the project.

Option	Cost
1a	$1,263,000
1b	$4,085,000
2a	$4,905,000
2b	$9,999,000
3	$7,535,000
4	$11,653,000
5	$16,247,000
6a	$3,031,000
6b	$12,906,000



6.0 References

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WDNR. 2018. Site investigation summary and data package. Kewaunee Marsh Arsenic Spill Site, Kewaunee, WI. 02-31-000508. November 5, 2018.

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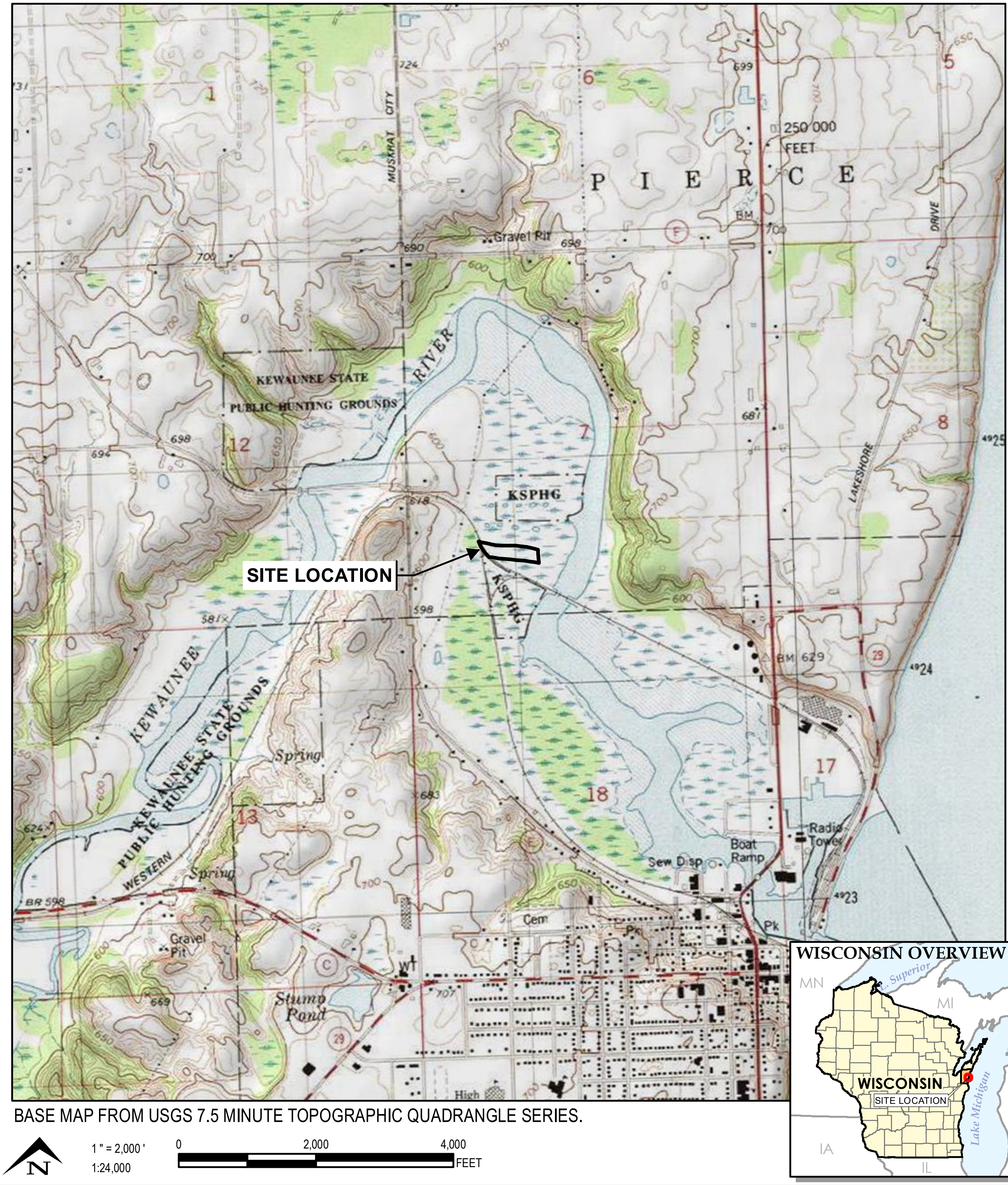
Table 1: Summary of Remedial Alternatives
WDNR - Kewaunee Marsh, Kewaunee, Wisconsin

Remedial Option			Arsenic Concentration Threshold Managed	Remedial Technology (with area or volume treated)				Summary Technical and Economic Feasibility				
#	Group	Brief Description		Cap	Stabilization/ Solidification[(1)]	Excavation+ Disposal[(1)]	On-Site Management Zone	Aqueous Phase Treatment During Construction (Y/N)	Long-Term Effectiveness (Risk Reduction)	O&M	Long-Term Monitoring	Opinion of Probable Cost (-10% to 30% range)
1.a	Cap Only	Cap soil/sediment > 1,000 ppm in upper 4' with impermeable engineered cover.	> 1,000 ppm	120,000 sq ft				N	- Direct contact (As > 1,000 ppm) - Water quality (probably minor reduction) - Off-site migration (probably minor reduction)	Cap of > 1,000 ppm Only and Fence	Indefinitely	$1,140,000 to $1,640,000
1.b		Cap soil/sediment > 100 ppm in upper 4' with impermeable engineered cover.	> 100 ppm	613,000 sq ft				N	- Direct contact (As > 100 ppm) - Water quality (better than Option 1.a) - Off-site migration (better than Option 1.a)	Cap and Fence	Indefinitely	$3,680,000 to $5,310,000
2.a	Stabilization/ Solidification + Cap	Stabilize soil/sediment > 1,000 ppm in-situ with bioreductant to reduce solubility of arsenic and add in bentonite to reduce permeability. Cap soil/sediment > 100 ppm in upper 4' with impermeable engineered cover.	> 100 ppm	613,000 sq ft	14,000 cy			N	- Direct contact (As > 100 ppm) - Water quality (better than Option 1.b) - Off-site migration (better than Option 1.b)	Cap and Fence	Long-Term	$4,410,000 to $6,380,000
2.b		Stabilize soil/sediment > 100 ppm in-situ with bioreductant to reduce solubility of arsenic and add in bentonite to reduce permeability. Cap soil/sediment > 100 ppm in upper 4' with impermeable engineered cover.	> 100 ppm	613,000 sq ft	92,000 cy			N	- Direct contact (As > 100 ppm) - Water quality (better than Option 2.a) - Off-site migration (better than Option 2.a)	Cap and Fence	Long-Term	$9,000,000 to $13,000,000
3	Excavation + Cap	Excavate soil/sediment >1,000 ppm. Treat excavated soil/sediment to render it non-hazardous and transport and dispose off-site at a licensed facility. Grade portion of the residual soil/sediment (i.e. soil/sediment with arsenic 100-1,000 ppm in upper 10') into the open excavation areas. Cap all soil/sediment > 100 ppm in upper 4' with impermeable engineered cover.	> 100 ppm	613,000 sq ft		14,000 cy		Y	- Direct contact (As > 100 ppm) - Water quality (better than Option 2.a) - Off-site migration (better than Option 2.a)	Cap and Fence	Indefinitely	$6,780,000 to $9,800,000
4	Excavation + Stabilization/ Solidification + Cap	Excavate soil/sediment >1,000 ppm. Treat excavated soil/sediment to render it non-hazardous and transport and dispose off-site at a licensed facility. Grade a portion of residual soil/sediment (i.e. soil/sediment with arsenic 100-1,000 ppm) into the open excavation. Stabilize all soil/sediment >100 ppm in-situ with bioreductant to reduce solubility of arsenic and add in bentonite to reduce permeability. Cap soil/sediment > 100 ppm in upper 4' with impermeable engineered cover.	> 100 ppm	613,000 sq ft	78,000 cy	14,000 cy		Y	- Direct contact (As > 100 ppm) - Water quality (better than Option 2.b or 3) - Off-site migration (better than Option 2.b or 3)	Cap and Fence	Long-Term	$10,490,000 to $15,150,000
5	Excavation + Stabilization/ Solidification + PRB Liner + Cap	Excavate soil/sediment >1,000 ppm. Treat excavated soil/sediment to render it non-hazardous and transport and dispose off-site at a licensed facility. Create an on-site management zone in a portion of the excavation area by lining it with ZVI. Move all residual soil/sediment (i.e. soil/sediment with arsenic 100-1,000 ppm in upper 10') into the ZVI-lined on-site management zone. Stabilize relocated soil/sediment in the on-site management zone in-situ with bioreductant to reduce solubility of arsenic and add in bentonite to reduce permeability. Cap on-site management zone with impermeable engineered cover. Backfill remaining areas.	> 100 ppm	See On-Site Management Zone	78,000 cy	14,000 cy; Import 78,000 cy of Clean Backfill	120,000 sq ft ZVI Liner + Cap	Y	- Direct contact (As > 100 ppm) - Water quality (better than Option 4) - Off-site migration (better than Option 4)	Cap (On-Site Management Zone Only) and Fence	Long-Term	$14,620,000 to $21,120,000
6.a	Excavation + Backfill	Excavate soil/sediment > 1,000 ppm. Treat excavated soil/sediment to render it non-hazardous and transport and dispose off-site at a licensed facility. Backfill excavation area with imported clean fill.	> 1,000 ppm			14,000 cy		Y	- Direct contact (As > 1,000 ppm) - Water quality (probably minor reduction) - Off-site migration (probably minor reduction)	Fence	Indefinitely	$2,730,000 to $3,940,000
6.b		Excavate soil/sediment > 100 ppm. Treat excavated soil/sediment >1,000 ppm to render it non-hazardous. Transport and dispose all soil/sediment off-site at a licensed facility. Backfill excavation area with imported clean fill.	> 100 ppm			92,000 cy		Y	- Direct contact (As > 100 ppm) - Off-site migration (best option) - Water Quality (best option)	Fence (possibly)	None (Short-Term Only)	$11,620,000 to $16,780,000

Notes:
[(1)] The volumes assume maximum depth of 10 feet. The depth of impacts may be greater near the source area, but the total additional volume is expected to be minimal and have incidental effect on probable cost.
See Appendix B for detailed cost estimating sheets and list of assumptions for what is included in each cost.
Grey Scale is relative ranking of effectiveness
Least Effective
Most Effective



BASE MAP FROM USGS 7.5 MINUTE TOPOGRAPHIC QUADRANGLE SERIES.

1 " = 2,000 '
1:24,000

0 2,000 4,000 FEET

N

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Madison, WI 53717
Phone: 608.826.3600

TRC - GIS

PROJECT:

WDNR
KEWAUNEE MARSH ARSENIC CONTAMINATED SITE
BRRTS #02-31-000508

TITLE:

SITE LOCATOR MAP

DRAWN BY:	R. SUEMNICHT
CHECKED BY:	L. AUNER
APPROVED BY:	A. SELLWOOD
DATE:	JULY 2020
PROJ. NO.:	344583.0002
FILE:	344583-RAOR-001slm.mxd

FIGURE 1

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LEGEND

1996 CAPPED AREA

CHAIN LINK FENCE

2011 IN SITU TREATMENT AREA

NOTES

1. BASE MAP IMAGERY FROM GOOGLE EARTH PRO & PARTNERS, OCTOBER 2013..
2. MAP PROJECTION AND GRID COORDINATES ARE NAD83 STATE PLANE WISCONSIN CENTRAL, US SURVEY FEET.

0 1,000 2,000 Feet

1 " = 1,000 '

1:12,000

PROJECT:

WDNR
KEWAUNEE MARSH ARSENIC CONTAMINATED SITE
BRRTS #02-31-000508

TITLE:

SITE LOCATION

DRAWN BY:	R. SUEMNICHT	PROJ. NO.:	344583.0002
CHECKED BY:	L. AUNER	FIGURE 2	
APPROVED BY:	A. SELLWOOD		
DATE:	JULY 2020		

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FILE NO.: 344583-RAOR-002.mxd

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Coordinate System: NAD 1983 StatePlane Wisconsin Central FIPS 4802 Feet (Foot US)
Map Rotation: 0

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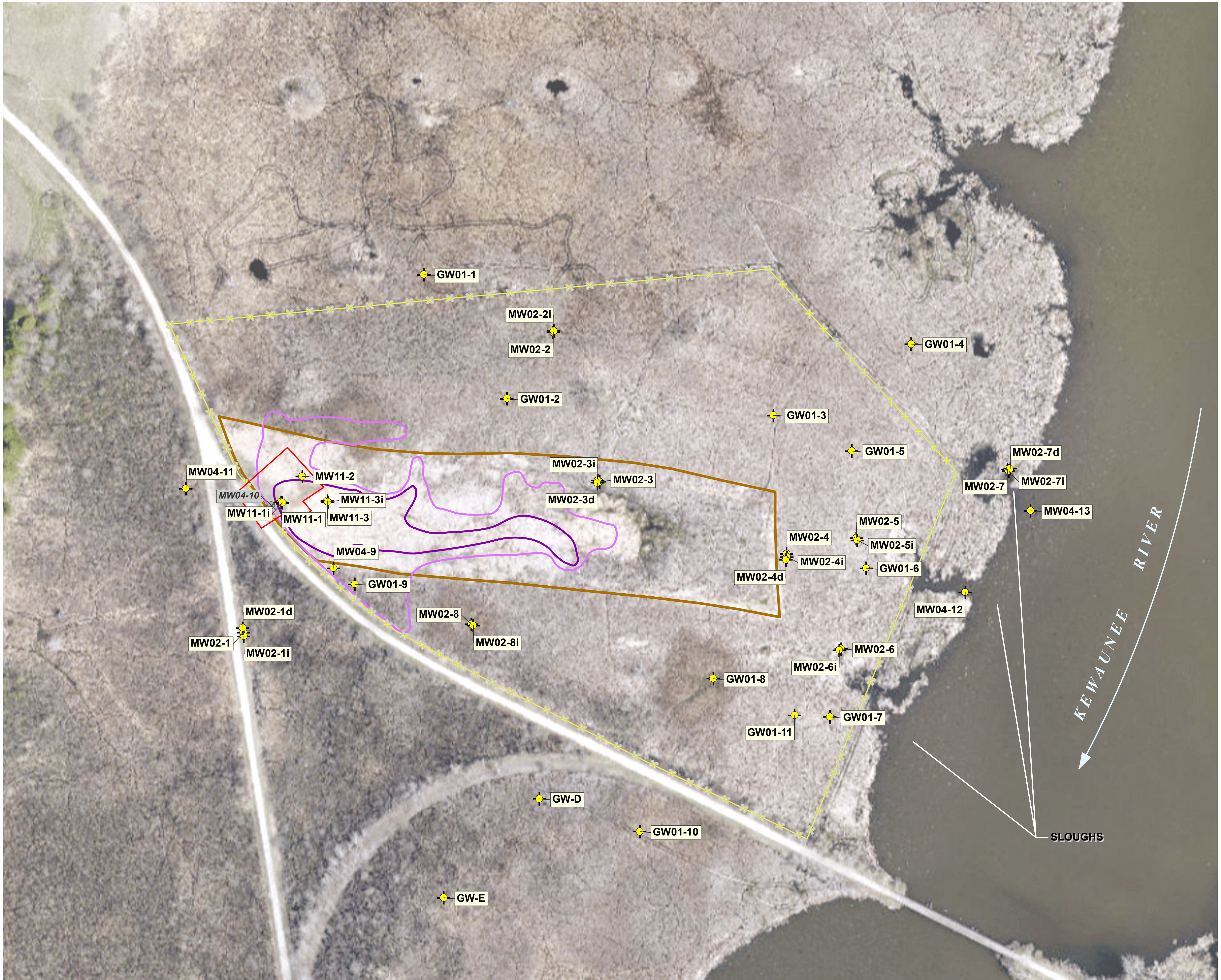
TRC - GIS



LEGEND

- CHAIN LINK FENCE
- 1996 CAPPED AREA
- 1993 HISTORICAL STRESSED VEGETATION
- 1993 HISTORICAL VERY STRESSED VEGETATION
- 2011 IN SITU TREATMENT AREA
- MONITORING WELL
- ABANDONED WELL

NOTES

1. BASE MAP IMAGERY FROM KEWAUNEE COUNTY, 2019.
2. MAP PROJECTION AND GRID COORDINATES ARE NAD83 STATE PLANE WISCONSIN CENTRAL, US SURVEY FEET.

N

0 150 300 Feet

1 " = 150 '
1:1,800

PROJECT:
WDNR
KEWAUNEE MARSH ARSENIC CONTAMINATED SITE
BRRTS #02-31-000508

TITLE:
MONITORING WELL NETWORK

DRAWN BY:	R. SUEMNICHT	PROJ. NO.:	344583.0002
CHECKED BY:	L. AUNER		**FIGURE 3**
APPROVED BY:	A. SELLWOOD		
DATE:	JULY 2020		

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FILE NO.: 344583-RAOR-003.mxd

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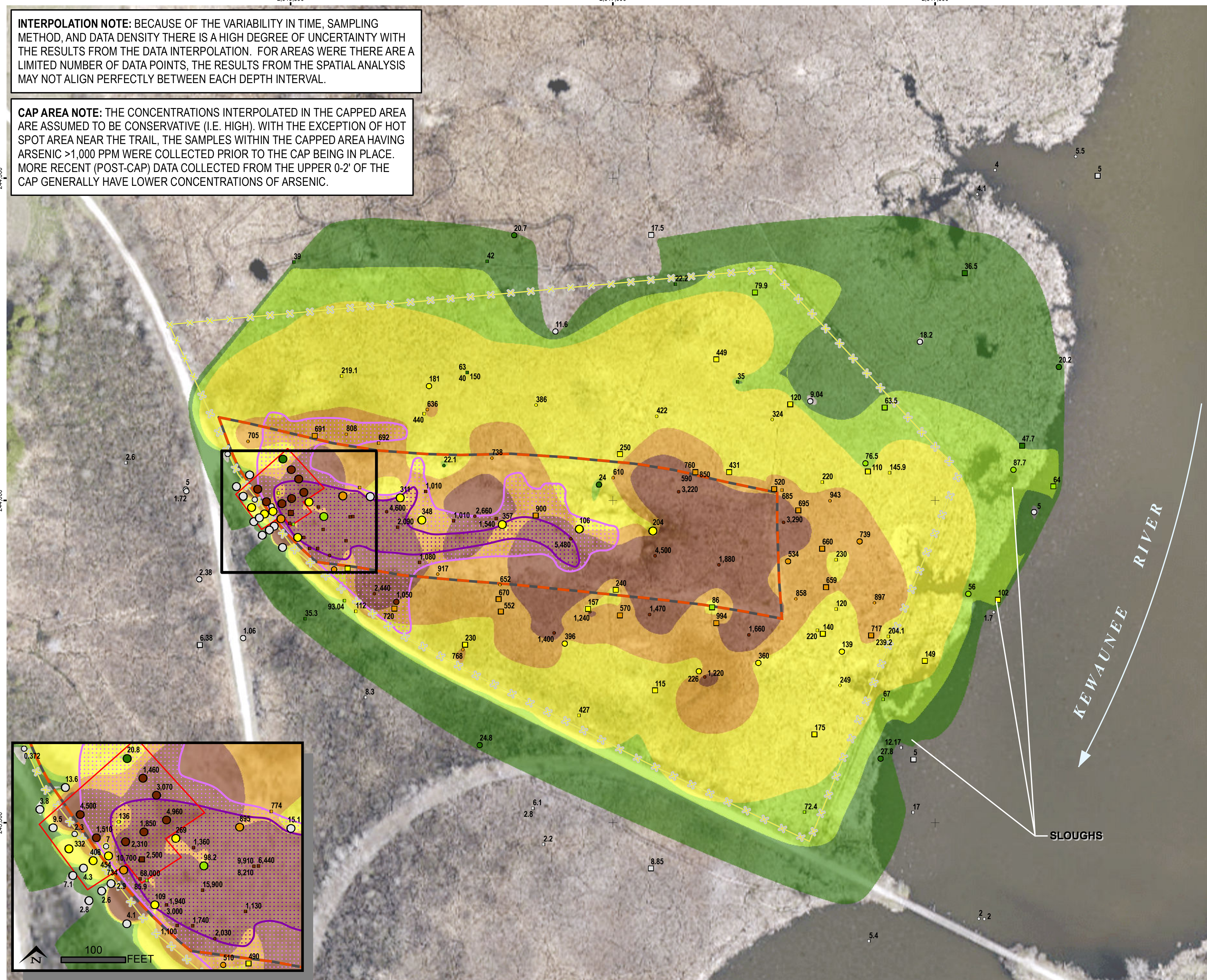
INTERPOLATION NOTE: BECAUSE OF THE VARIABILITY IN TIME, SAMPLING METHOD, AND DATA DENSITY THERE IS A HIGH DEGREE OF UNCERTAINTY WITH THE RESULTS FROM THE DATA INTERPOLATION. FOR AREAS WERE THERE ARE A LIMITED NUMBER OF DATA POINTS, THE RESULTS FROM THE SPATIAL ANALYSIS MAY NOT ALIGN PERFECTLY BETWEEN EACH DEPTH INTERVAL.

CAP AREA NOTE: THE CONCENTRATIONS INTERPOLATED IN THE CAPPED AREA ARE ASSUMED TO BE CONSERVATIVE (I.E. HIGH). WITH THE EXCEPTION OF HOT SPOT AREA NEAR THE TRAIL, THE SAMPLES WITHIN THE CAPPED AREA HAVING ARSENIC >1,000 PPM WERE COLLECTED PRIOR TO THE CAP BEING IN PLACE. MORE RECENT (POST-CAP) DATA COLLECTED FROM THE UPPER 0-2' OF THE CAP GENERALLY HAVE LOWER CONCENTRATIONS OF ARSENIC.



LEGEND

- FENCE
- 1996 CAPPED AREA
- 1993 HISTORICAL STRESSED VEGETATION
- 1993 HISTORICAL VERY STRESSED VEGETATION
- 2011 IN SITU TREATMENT AREA

ARSENIC CONCENTRATION (ppm) - NOTE 4

- <20
- 20 - <50
- 50 - <100
- 100 - <500
- 500 - <1,000
- >1,000

GRAB SYMBOL SIZE BASED ON DATE RANGE

- PRE-2000 SAMPLE
- 2000-2008 SAMPLE
- POST-2008 SAMPLE

CORE SYMBOL SIZE BASED ON DATE RANGE

- PRE-2000 SAMPLE
- 2000-2008 SAMPLE
- POST-2008 SAMPLE

NOTES

1. BASE MAP IMAGERY FROM KEWAUNEE COUNTY, 2019.
2. MAP PROJECTION AND GRID COORDINATES ARE NAD83 STATE PLANE WISCONSIN CENTRAL, US SURVEY FEET.
3. SOIL/SEDIMENT SAMPLES COLLECTED DURING VARIOUS SAMPLING EVENTS BETWEEN 1994 AND 2010. THE COMPILED DATA WAS PROVIDED BY WDNR TO TRC IN SEPTEMBER 2019.
4. COLORS FOR ARSENIC CONCENTRATIONS APPLY TO THE SAMPLE POINTS AND THE RESULTS FROM THE GIS SPATIAL ANALYSIS. THE NATURAL NEIGHBOR METHOD WAS USED IN GIS TO INTERPOLATE ARSENIC CONCENTRATIONS IN SEDIMENT AT THE SITE, AND POST-PROCESSING WAS COMPLETED TO ADJUST SOME OF THE BOUNDARIES TO FIT THE CONCEPTUAL SITE MODEL. SEE JAN. 2020 MEMO FOR ADDITIONAL DETAILS.

0 150 300 Feet

1 " = 150 '

1:1,800

N

PROJECT:

WDNR
KEWAUNEE MARSH ARSENIC CONTAMINATED SITE
BRRTS #02-31-000508

TITLE:

SOIL/SEDIMENT ARSENIC CONCENTRATIONS 0-2' INTERVAL

DRAWN BY:	R. SUEMNICHT	PROJ NO.:	344583.0002
CHECKED BY:	L. AUNER		
APPROVED BY:	A. SELLWOOD	**FIGURE 4**	
DATE:	JULY 2020		

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FILE NO.: 344583-RAOR-004.mxd

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Coordinate System: NAD 1983 StatePlane Wisconsin Central FIPS 4802 Feet (Foot US)
Map Rotation: 0

Plot Date: 7/27/2020, 10:06:27 AM by RSUEMNICHT -- LAYOUT: ANSI B(11"x17")
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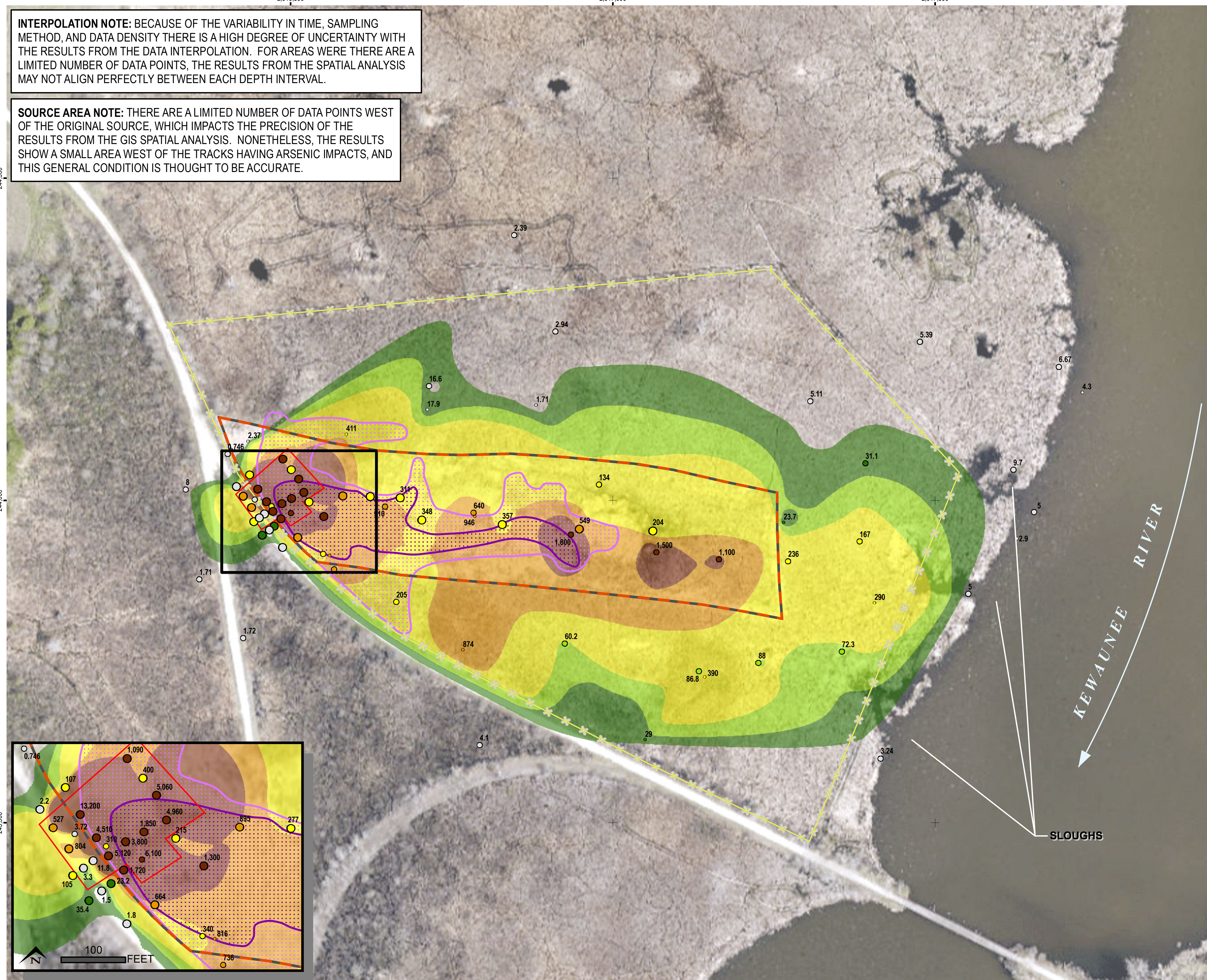

LEGEND

- FENCE
- 1996 CAPPED AREA
- 1993 HISTORICAL STRESSED VEGETATION
- 1993 HISTORICAL VERY STRESSED VEGETATION
- 2011 IN SITU TREATMENT AREA

ARSENIC CONCENTRATION (ppm) - NOTE 4

- <20
- 20 - <50
- 100 - <500
- 500 - <1,000
- >1,000

SYMBOL SIZE BASED ON DATE RANGE

- PRE-2000 SAMPLE
- 2000-2008 SAMPLE
- POST-2008 SAMPLE

NOTES

1. BASE MAP IMAGERY FROM KEWAUNEE COUNTY, 2019.
2. MAP PROJECTION AND GRID COORDINATES ARE NAD83 STATE PLANE WISCONSIN CENTRAL, US SURVEY FEET.
3. SOIL/SEDIMENT SAMPLES COLLECTED DURING VARIOUS SAMPLING EVENTS BETWEEN 1994 AND 2010. THE COMPILED DATA WAS PROVIDED BY WDNR TO TRC IN SEPTEMBER 2019.
4. COLORS FOR ARSENIC CONCENTRATIONS APPLY TO THE SAMPLE POINTS AND THE RESULTS FROM THE GIS SPATIAL ANALYSIS. THE NATURAL NEIGHBOR METHOD WAS USED IN GIS TO INTERPOLATE ARSENIC CONCENTRATIONS IN SEDIMENT AT THE SITE, AND POST-PROCESSING WAS COMPLETED TO ADJUST SOME OF THE BOUNDARIES TO FIT THE CONCEPTUAL SITE MODEL. SEE JAN. 2020 MEMO FOR ADDITIONAL DETAILS.

0 150 300 Feet
1 " = 150 '
1:1,800

PROJECT:
WDNR
KEWAUNEE MARSH ARSENIC CONTAMINATED SITE
BRRTS #02-31-000508

TITLE:
SOIL/SEDIMENT ARSENIC CONCENTRATIONS 2-4' INTERVAL

DRAWN BY:	R. SUEMNICHT	PROJ NO.:	344583.0002
CHECKED BY:	L. AUNER		
APPROVED BY:	A. SELLWOOD		**FIGURE 5**
DATE:	JULY 2020		

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FILE NO.: 344583-RAOR-005.mxd

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Map Rotation: 0

Plot Date: 7/27/2020, 10:07:30 AM by RSUEMNICHT -- LAYOUT: ANSI B(11"x17")
Path: S:\1-PROJECTS\WI_DNR\KewauneeMarsh\2019_344583\344583-RAOR-005.mxd

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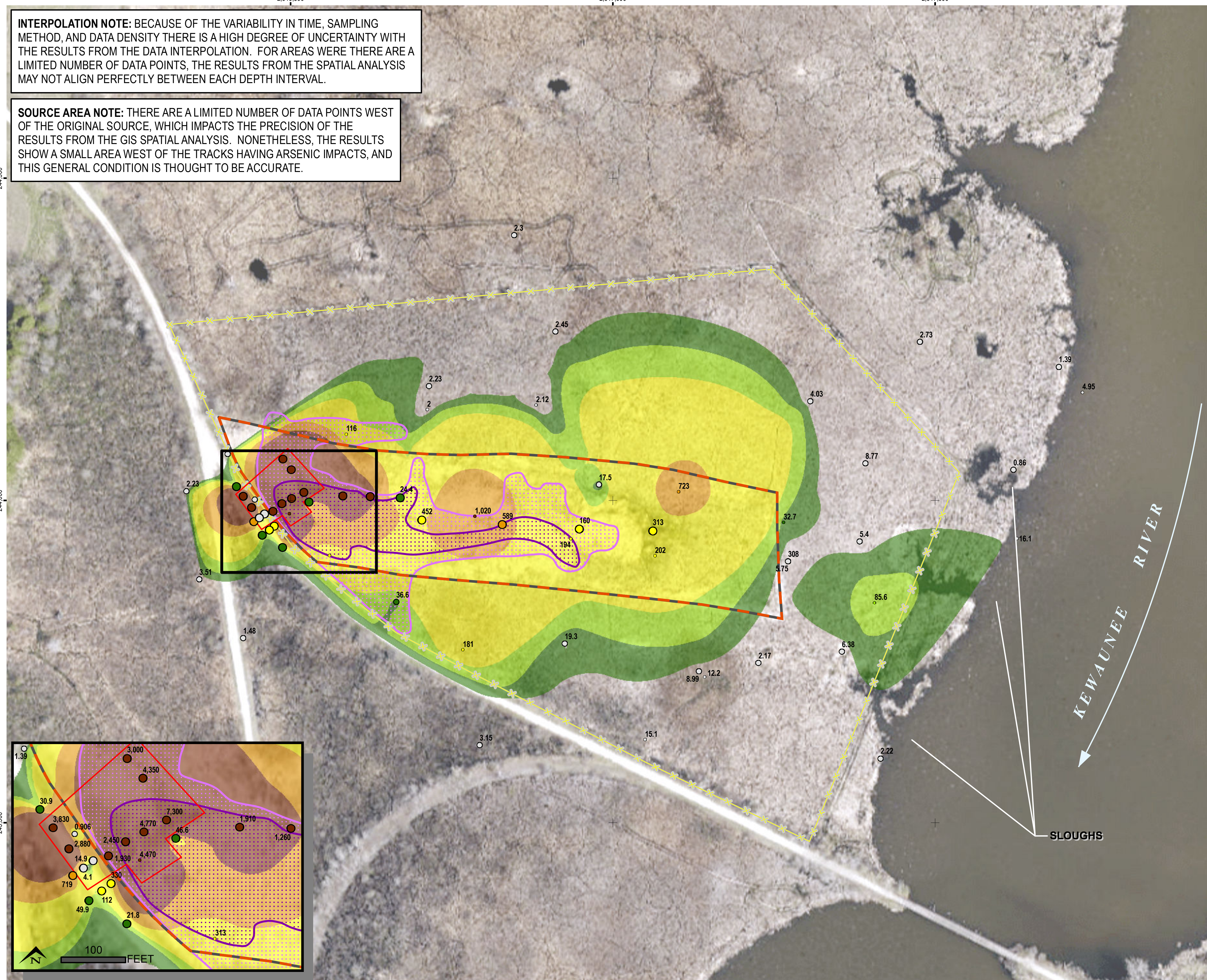
INTERPOLATION NOTE: BECAUSE OF THE VARIABILITY IN TIME, SAMPLING METHOD, AND DATA DENSITY THERE IS A HIGH DEGREE OF UNCERTAINTY WITH THE RESULTS FROM THE DATA INTERPOLATION. FOR AREAS WERE THERE ARE A LIMITED NUMBER OF DATA POINTS, THE RESULTS FROM THE SPATIAL ANALYSIS MAY NOT ALIGN PERFECTLY BETWEEN EACH DEPTH INTERVAL.

SOURCE AREA NOTE: THERE ARE A LIMITED NUMBER OF DATA POINTS WEST OF THE ORIGINAL SOURCE, WHICH IMPACTS THE PRECISION OF THE RESULTS FROM THE GIS SPATIAL ANALYSIS. NONETHELESS, THE RESULTS SHOW A SMALL AREA WEST OF THE TRACKS HAVING ARSENIC IMPACTS, AND THIS GENERAL CONDITION IS THOUGHT TO BE ACCURATE.



LEGEND

- FENCE
- 1996 CAPPED AREA
- 1993 HISTORICAL STRESSED VEGETATION
- 1993 HISTORICAL VERY STRESSED VEGETATION
- 2011 IN SITU TREATMENT AREA

ARSENIC CONCENTRATION (ppm) - NOTE 4

- <20
- 20 - <50
- 100 - <500
- 500 - <1,000
- >1,000

SYMBOL SIZE BASED ON DATE RANGE

- PRE-2000 SAMPLE
- 2000-2008 SAMPLE
- POST-2008 SAMPLE

NOTES

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3. SOIL/SEDIMENT SAMPLES COLLECTED DURING VARIOUS SAMPLING EVENTS BETWEEN 1994 AND 2010. THE COMPILED DATA WAS PROVIDED BY WDNR TO TRC IN SEPTEMBER 2019.
4. COLORS FOR ARSENIC CONCENTRATIONS APPLY TO THE SAMPLE POINTS AND THE RESULTS FROM THE GIS SPATIAL ANALYSIS. THE NATURAL NEIGHBOR METHOD WAS USED IN GIS TO INTERPOLATE ARSENIC CONCENTRATIONS IN SEDIMENT AT THE SITE, AND POST-PROCESSING WAS COMPLETED TO ADJUST SOME OF THE BOUNDARIES TO FIT THE CONCEPTUAL SITE MODEL. SEE JAN. 2020 MEMO FOR ADDITIONAL DETAILS.

0 150 300 Feet

1 " = 150 '

1:1,800

N

PROJECT:

WDNR
KEWAUNEE MARSH ARSENIC CONTAMINATED SITE
BRRTS #02-31-000508

TITLE:

SOIL/SEDIMENT ARSENIC CONCENTRATIONS 4-6' INTERVAL

DRAWN BY:	R. SUEMNICHT	PROJ NO.:	344583.0002
CHECKED BY:	L. AUNER		
APPROVED BY:	A. SELLWOOD		**FIGURE 6**
DATE:	JULY 2020		

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FILE NO.: 344583-RAOR-006.mxd

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Coordinate System: NAD 1983 StatePlane Wisconsin Central FIPS 4802 Feet (Foot US)
Map Rotation: 0

Plot Date: 7/27/2020, 10:08:24 AM by RSUEMNICHT -- LAYOUT: ANSI B(11"x17")
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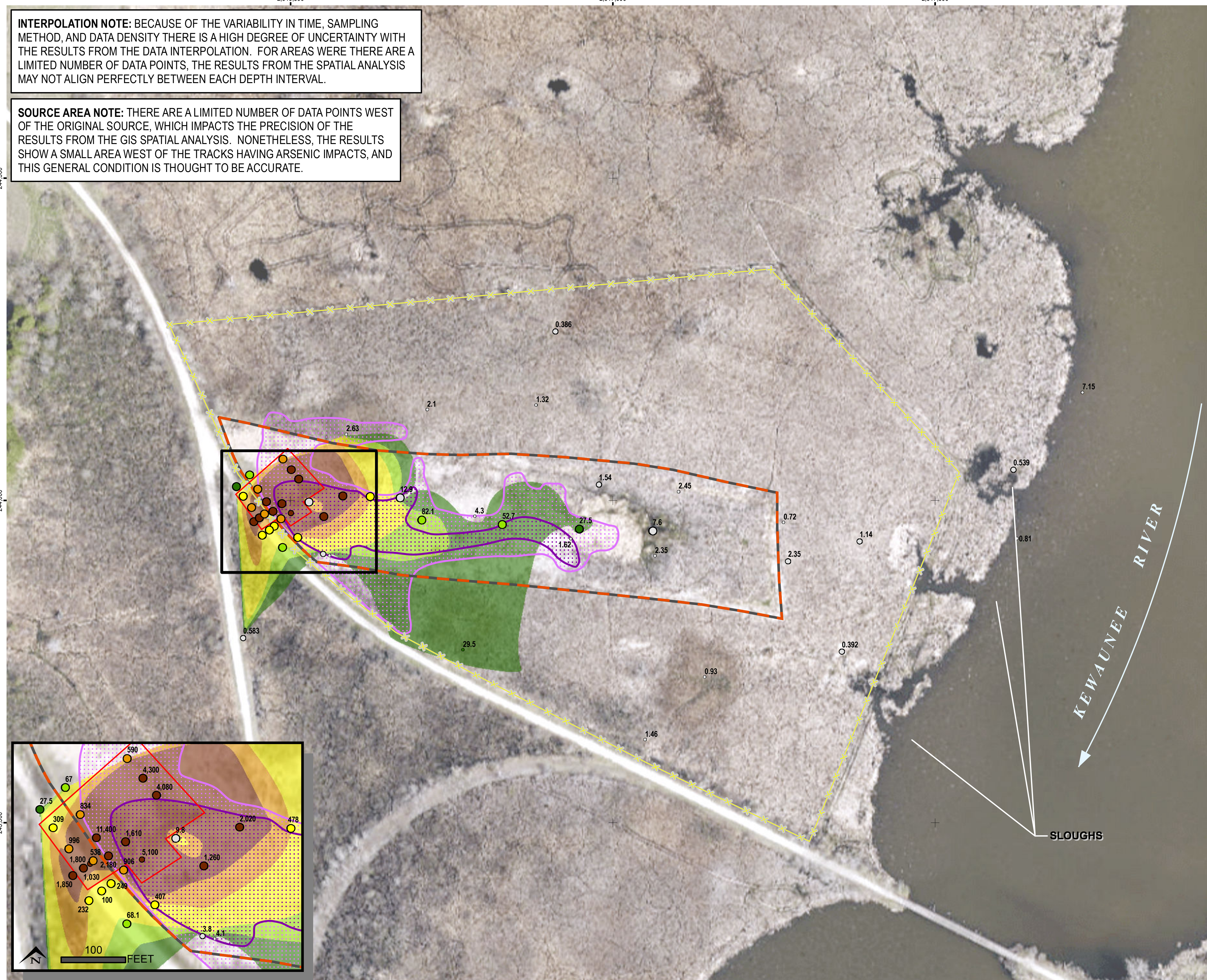
INTERPOLATION NOTE: BECAUSE OF THE VARIABILITY IN TIME, SAMPLING METHOD, AND DATA DENSITY THERE IS A HIGH DEGREE OF UNCERTAINTY WITH THE RESULTS FROM THE DATA INTERPOLATION. FOR AREAS WERE THERE ARE A LIMITED NUMBER OF DATA POINTS, THE RESULTS FROM THE SPATIAL ANALYSIS MAY NOT ALIGN PERFECTLY BETWEEN EACH DEPTH INTERVAL.

SOURCE AREA NOTE: THERE ARE A LIMITED NUMBER OF DATA POINTS WEST OF THE ORIGINAL SOURCE, WHICH IMPACTS THE PRECISION OF THE RESULTS FROM THE GIS SPATIAL ANALYSIS. NONETHELESS, THE RESULTS SHOW A SMALL AREA WEST OF THE TRACKS HAVING ARSENIC IMPACTS, AND THIS GENERAL CONDITION IS THOUGHT TO BE ACCURATE.



LEGEND

- FENCE
- 1996 CAPPED AREA
- 1993 HISTORICAL STRESSED VEGETATION
- 1993 HISTORICAL VERY STRESSED VEGETATION
- 2011 IN SITU TREATMENT AREA

ARSENIC CONCENTRATION (ppm) - NOTE 4

- <20
- 20 - <50
- 50 - <100
- 100 - <500
- 500 - <1,000
- >1,000

SYMBOL SIZE BASED ON DATE RANGE

- PRE-2000 SAMPLE
- 2000-2008 SAMPLE
- POST-2008 SAMPLE

NOTES

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0 150 300 Feet

1 " = 150 '

1:1,800

N

PROJECT:

WDNR
KEWAUNEE MARSH ARSENIC CONTAMINATED SITE
BRRTS #02-31-000508

TITLE:

SOIL/SEDIMENT ARSENIC CONCENTRATIONS 6-8' INTERVAL

DRAWN BY:	R. SUEMNICHT	PROJ NO.:	344583.0002
CHECKED BY:	L. AUNER		
APPROVED BY:	A. SELLWOOD	**FIGURE 7**	
DATE:	JULY 2020		

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FILE NO.: 344583-RAOR-007.mxd

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Coordinate System: NAD 1983 StatePlane Wisconsin Central FIPS 4802 Feet (Foot US)
Map Rotation: 0

Plot Date: 7/27/2020, 10:09:23 AM by RSUEMNICHT -- LAYOUT: ANSI B(11"x17")
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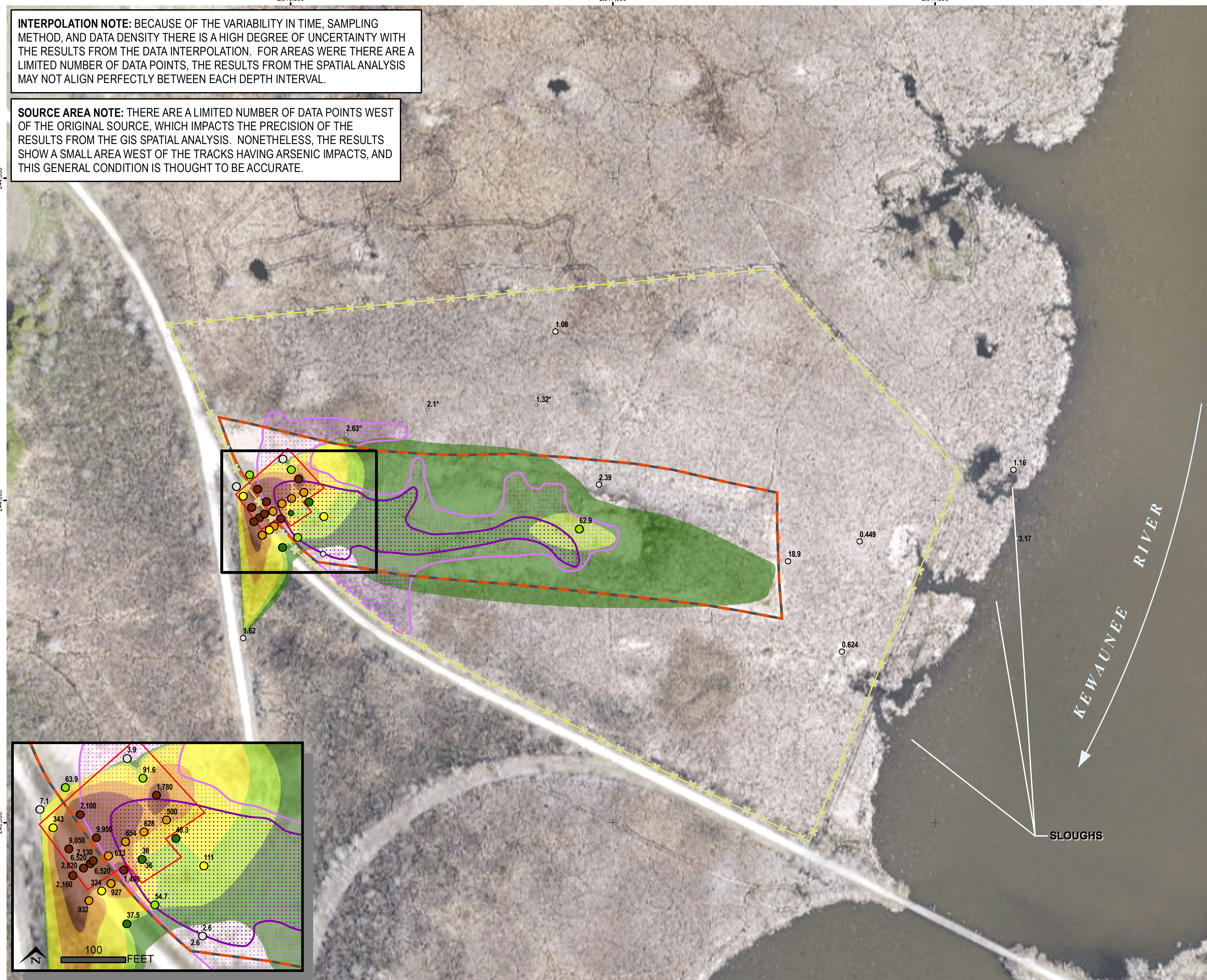
INTERPOLATION NOTE: BECAUSE OF THE VARIABILITY IN TIME, SAMPLING METHOD, AND DATA DENSITY THERE IS A HIGH DEGREE OF UNCERTAINTY WITH THE RESULTS FROM THE DATA INTERPOLATION. FOR AREAS WERE THERE ARE A LIMITED NUMBER OF DATA POINTS, THE RESULTS FROM THE SPATIAL ANALYSIS MAY NOT ALIGN PERFECTLY BETWEEN EACH DEPTH INTERVAL.

SOURCE AREA NOTE: THERE ARE A LIMITED NUMBER OF DATA POINTS WEST OF THE ORIGINAL SOURCE, WHICH IMPACTS THE PRECISION OF THE RESULTS FROM THE GIS SPATIAL ANALYSIS. NONETHELESS, THE RESULTS SHOW A SMALL AREA WEST OF THE TRACKS HAVING ARSENIC IMPACTS, AND THIS GENERAL CONDITION IS THOUGHT TO BE ACCURATE.



LEGEND

FENCE

1996 CAPPED AREA

1993 HISTORICAL STRESSED VEGETATION

1993 HISTORICAL VERY STRESSED VEGETATION

2011 IN SITU TREATMENT AREA

ARSENIC CONCENTRATION (ppm) - NOTE 4 AND 5

- <20
- 20 - <50
- 50 - <100
- 100 - <500
- 500 - <1,000
- >1,000

SYMBOL SIZE BASED ON DATE RANGE

- PRE-2000 SAMPLE
- 2000-2008 SAMPLE
- POST-2008 SAMPLE

NOTES

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4. COLORS FOR ARSENIC CONCENTRATIONS APPLY TO THE SAMPLE POINTS AND THE RESULTS FROM THE GIS SPATIAL ANALYSIS. THE NATURAL NEIGHBOR METHOD WAS USED IN GIS TO INTERPOLATE ARSENIC CONCENTRATIONS IN SEDIMENT AT THE SITE, AND POST-PROCESSING WAS COMPLETED TO ADJUST SOME OF THE BOUNDARIES TO FIT THE CONCEPTUAL SITE MODEL. SEE JAN. 2020 MEMO FOR ADDITIONAL DETAILS.
5. THE DATA WITH A * NEXT TO IT IS FROM AN ADJACENT DEPTH INTERVAL (6-8') AND WAS ADDED TO HELP CONSTRAIN BOUNDARIES OF THE MODEL.

0 150 300 Feet

1 " = 150 '

1:1,800

N

PROJECT:

WDNR
KEWAUNEE MARSH ARSENIC CONTAMINATED SITE
BRRTS #02-31-000508

TITLE:

SOIL/SEDIMENT ARSENIC CONCENTRATIONS 8+' INTERVAL

DRAWN BY:	R. SUEMNICHT	PROJ NO.:	344583.0002
CHECKED BY:	L. AUNER		
APPROVED BY:	A. SELLWOOD		**FIGURE 8**
DATE:	JULY 2020		

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FILE NO.: 344583-RAOR-008.mxd

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Coordinate System: NAD 1983 StatePlane Wisconsin Central FIPS 4802 Feet (Foot US)
Map Rotation: 0

Plot Date: 7/27/2020, 10:10:07 AM by RSUEMNICHT -- LAYOUT: ANSI B(11"x17")
Path: S:\1-PROJECTS\WI_DNR\KewauneeMarsh\2019_344583\344583-RAOR-008.mxd

Appendix A: April 13, 2020 Memo - Conceptual Remedial Alternatives

TRC
708 Heartland Trl.
Suite 3000
Madison, WI 53717

Main 608.826.3600
Fax 608.826.3941

Technical Memorandum

To:	Xiaochun Zhang Wisconsin Department of Natural Resources (WDNR)
From:	Alia Enright, Alyssa Sellwood, John Rice, and Robert Stanforth
Subject:	Kewaunee Marsh Arsenic Contaminated Site, BRRTS #02-31-000508 Conceptual Remedial Alternatives for WDNR Review
Date:	April 13, 2020
Project No.:	344583.0000 Phase 000002

The Kewaunee Marsh Arsenic Contaminated Site is located inside a large meander of the Kewaunee River northwest of Kewaunee, Wisconsin within the state-owned C.D. Besadny Fish and Wildlife Area (site). Approximately 15-acres of the marsh are impacted with arsenic, and a historical release of arsenate salts (formerly used as pesticides) from a railcar derailment around the 1940s is thought to be the source of these impacts.

The former potentially responsible party (Fox Valley and Western Railroad, Ltd) initiated investigative activities in 1994 and placed a vegetative cap over the area with most significant impacts as an interim action. The WDNR has since completed additional site investigation activities and an interim remedial action (in-situ treatment of the spill or source area). In August 2019, WDNR retained TRC to complete a focused remedial options evaluation and Remedial Action Options Report (RAOR) for the site.

In advance of the RAOR, TRC provided WDNR with a technologies screening memo to summarize the available remedial technologies (see TRC Technical Memorandum dated January 20, 2020). Because of the size and complex nature of the site, the remedial alternatives evaluated in the RAOR are anticipated to use a combination of technologies. WDNR responded on February 4, 2020 with a recommendation that TRC evaluate up to five viable options for remedial action at the site, and that TRC retain the following technologies for use in the remedial alternatives: excavation, capping, pump and treat, in-situ physical stabilization/solidification, and a permeable reactive barrier. TRC then developed five conceptual remedial alternatives using these technologies, as summarized in a February 24, 2020 TRC memo.

WDNR provided TRC with written comments to the proposed remedial concepts on March 18, 2020, and with additional feedback in a March 23, 2020 conference call. The primary outcomes from this feedback were as follows:

- In the future, WDNR anticipates setting 200 ppm as the target clean-up level for arsenic in sediment at the site, which equates to a 10^{-5} direct contact risk. For this stage of the evaluation, WDNR requested TRC to proceed as follows:
  - Do not update the GIS interpolation to include a 200 ppm contour interval. This evaluation is not worthwhile given the age and distribution of the available data.
  - Use 100 ppm (a contour interval included in the current GIS interpolation) as a proxy for the anticipated target clean-up level in the current remedial options evaluation.
- Remove pump and treat from the remedial options because this technology is not feasible for this setting.
- Include in situ stabilization / solidification as a primary remedial alternative, with the understanding that (1) large-scale in situ treatment may differ from the in situ treatment previously completed in the hot spot area; and (2) field studies would be needed to optimize the design for this alternative prior to full-scale implementation.

This memo summarizes remedial alternatives that TRC has developed based on this discussion. A description of the four proposed alternatives is provided below, and a matrix detailing the controls, risk reduction, and long-term monitoring and operations and maintenance for each alternative is summarized in Table 1.

If WDNR agrees with these conceptual remedial approaches, then TRC will proceed to the focused RAOR where the alternatives will be evaluated in further detail, and cost estimates will be provided to facilitate remedy selection for the site.

Conceptual Remedial Alternatives

1. Capping

- Install a cap over the portions of the site where surficial arsenic concentrations exceed a) 1,000 ppm or b) 100 ppm. Construct cap with a low-permeable material, such as; clay, bentonite, high-density polyethylene (HDPE), or other impermeable materials.

2. Capping + In-Situ Stabilization/Solidification

- Mix sediment where arsenic concentrations exceed a) 1,000 ppm or b) 100 ppm with bentonite or other materials to reduce sediment permeability and with an organic reducing agent to reduce the solubility of the arsenic.
- Install a cap over the portions of the site where surficial arsenic concentrations exceed 100 ppm. Construct cap with a low-permeable material, such as; clay, bentonite, HDPE, or other impermeable materials.

3. Capping + In-Situ Stabilization/Solidification + Excavation (>1,000 ppm)[1]

- Excavate sediment with arsenic impacts exceeding 1,000 ppm.
  - Dewater sediment and treat[2] the water prior to discharge on-site.
  - Haul excavated/dewatered material to a regulated off-site disposal facility.
  - Dewater open excavation area and treat[2] water prior to discharge on-site.
- Mix sediment where arsenic concentrations exceed 100 ppm with bentonite or other materials to reduce sediment permeability and with an organic reducing agent to reduce the solubility of the arsenic.
- The sediment with arsenic concentrations greater than 100 ppm, but less than 1,000 ppm will be managed on-site. For Option 3a the sediments will be stabilized, graded, and capped in situ within the extent of the 100 ppm concentration boundary. For Option 3b, the sediments will be moved to a controlled-engineered management zone and backfill will be used to restore the grade where needed.
  - Option 3a:
    - Grade stabilized sediment into areas where sediment with arsenic concentrations greater than 1,000 ppm was excavated and removed. (This is done to limit need for addition backfill).
    - Install a cap over the sediment where surficial arsenic concentrations exceed 100 ppm. Construct cap with a low-permeable material, such as; clay, bentonite, HDPE, or other impermeable materials.
  - Option 3b:
    - Create an engineered area for on-site management of the stabilized sediment with arsenic concentrations > 100 ppm. (This is done to improve control over the direct contact and off-site migration risks from the residual impacts).
    - Create on-site management area within the deeper excavation areas near the rail line. Line the defined area with a reactive barrier material[3], such as zero valent iron (ZVI).
    - Move stabilized sediment to fill-in the management zone that is lined with reactive barrier.

---

[1] Option 3 in TRC's February 24, 2020 memo included a concept where open water was left in the area of excavation and the water was made safe with long-term pump and treat. Because pump and treat is no longer being considered, TRC recommends the open water concept be removed from this alternative. It is uncertain if open water that is treated by chemistry alone (i.e. without hydraulic controls) would achieve the surface water criteria for arsenic, and if so, it would still require frequent long-term monitoring to ensure that the arsenic concentrations in the ponded water stayed below the surface water criteria.

[2] The design to treat water decanted from excavated material or excavations would require bench testing prior to full scale design and implementation.

[3] The concept of a traditional vertical permeable reactive barrier (PRB) is not included, but rather is used as the liner of the sides and base of the controlled engineered area for on-site management of sediment. A traditional vertical flow-through PRB would be subject to fluctuating oxic/anoxic conditions at this site, which would limit its effectiveness.

- o Install a cap over the sediment within the management zone (i.e. sediment with arsenic concentrations exceed 100 ppm.) Construct cap with a low-permeable material, such as; clay, bentonite, HDPE, or other impermeable materials.
- o Import backfill to restore grade where needed.

4. Excavation + Off-Site Disposal + Backfill (or Cap for Option 4b)

- Excavate sediment with arsenic impacts exceeding 1,000 ppm (Options 4a and 4b) or 100 ppm (Option 4c).
  - – Dewater sediment and treat[2] the water prior to discharge on-site.
  - – Haul excavated/dewatered material to a regulated off-site disposal facility.
  - – Dewater excavations and treat[2] water prior to discharge on-site.
- Import backfill soils to replace excavated sediment (Options 4a and 4c).
- For Option 4b, construct a cap to address the direct contact risk for the residual sediment with arsenic greater than 100 ppm. For this option, rather than backfilling the open excavation areas with imported fill, the residual sediment having arsenic concentrations greater than 100 ppm would be graded into the open excavation areas, and the “imported backfill” would be the low-permeability material used to construct and build up the cap to address the direct contact risk from the residual sediment. A small amount of additional backfill may be needed in some areas. The low-permeability cap material would be placed over all sediment with arsenic concentrations that exceed 100 ppm. (This is similar to Option 3a, but does not include in situ stabilization/solidification of the sediment.)

Table 1. Summary of Remedial Alternatives (April 13, 2020 Memo)

	Option	Remedial Technology and Concentration Threshold (ppm): Cap		Stabilization/ Solidification		Excavation+ Disposal		Backfill		Reactive Barrier*	Summary of OM&M and Expected Risk Reduction: Control	Aqueous Phase Treatment	Risk Reduction	Risk Remaining	Monitoring Post-Remediation	O&M
		1000	100	1000	100	1000	100	1000	100	100						
1a	Cap Only										-Low-permeable cover	NA	-Direct contact (As > 1,000 ppm)	-Direct contact (100 ppm < As < 1,000 ppm) -Off-site migration -Water quality -Cap recontamination from vertical migration	Yes Indefinitely	Cap maintenance
1b											-Low-permeable cover	NA	-Direct contact (As > 100 ppm)	-Off-site migration -Water quality -Cap recontamination from vertical migration	Yes Indefinitely	Cap maintenance
2a	Cap + Stabilization/ Solidification										-Low-permeable cover -Reduced hydraulic conductivity and As solubility in sediment	NA	-Direct contact (As > 100 ppm) -Reduce off-site migration	-Off-site migration *(but better than Option 1)* -Water quality *(but better than Option 1)* -Cap recontamination *(but better than Option 1)*	Yes Long Time	Cap maintenance
2b											-Low-permeable cover -Reduced hydraulic conductivity and As solubility in sediment	NA	-Direct contact (As > 100 ppm) -Reduce off-site migration (greater reduction than Option 2a)	-Off-site migration *(but better than Option 2a)* -Water quality *(but better than Option 2a)* -Cap recontamination *(but better than Option 2a)*	Yes Long Time	Cap maintenance
3a	Cap + Stabilization/ Solidification + Excavation							(1)			-Low-permeable cover -Reduced hydraulic conductivity and As solubility in sediment -Source removal	Treat water from excavated sediment and excavation area	-Direct contact (As > 100 ppm) -Reduce off-site migration (greater reduction than Option 2b)	-Off-site migration *(but better than Option 2b)* -Water quality *(but better than Option 2b)* -Cap recontamination *(but better than Option 2b)*	Yes Long Time	Cap maintenance
3b*								(2)			-On-Site Sediment Mgt Area* -Source removal	Treat water from excavated sediment and excavation area	-Direct contact (As > 100 ppm) -Reduce off-site migration (greater reduction than Option 3a)	-Off-site migration *(but better than Option 3a)* -Water quality *(but better than Option 3a)* -Potential contamination of imported backfill	Yes Long Time	Cap maintenance
4a	Excavation + Backfill *(+ Cap)*										-Source removal	Treat water from excavated sediment and excavation area	-Direct contact (As > 1,000 ppm)	-Direct contact (100 ppm < As <1,000 ppm) -Off-site migration (but better than Option 1a) -Water quality (but better than Option 1a) -Recontamination of imported backfill	Yes Indefinitely	None
4b								(3)			-Low-permeable cover -Source removal	Treat water from excavated sediment and excavation area	-Direct contact (As < 100 ppm)	-Off-site migration *(but better than Option 1b)* -Water quality *(but better than Option 1b)* -Recontamination of imported backfill/cap	Yes Indefinitely	Cap maintenance
4c											-Source removal	Treat water from excavated sediment and excavation area	-Direct contact (As < 100 ppm) -Off-site migration -Water Quality	-Some water quality for 20 ppm < As < 100 ppm	Yes Short Time	None

Notes:

* Prepare an area for on-site management of contaminated sediment. The sediment will be stabilized/solidified and then placed in engineered area that is lined with a reactive barrier (e.g. ZVI) and capped with a low permeability material (e.g. clay).

(1) Stabilized sediment to be graded into excavation areas before capping, so no imported backfill needed.

(2) Stabilized sediment moved to an area engineered for on-site management, so some imported backfill needed in excavation areas.

(3) Residual sediment graded into excavated areas before capping to minimize imported backfill needed.

Appendix B: Opinion of Probable Cost Tables

Remedial Alternative Option 1.a
Capping (1,000 ppm)
Opinion of Probable Cost
WDNR - Kewaunee Marsh, Kewaunee, Wisconsin
Project No. 344583.0000

	Item	Unit	Unit Cost	Qty.	Total
Pre-Design and Bench Testing Cost					
1	Additional Investigation	LS	$35,000	1	$35,000
2	Treatability Testing	LS	-	0	$0
3	Field Pilot Study	LS	-	0	$0
	SUBTOTAL OF PRE-DESIGN AND BENCH TESTING				$35,000
Direct Capital Cost					
4	Mob/Demobilization	LS	$30,000	1	$30,000
5	Site Preparations/Temporary Controls	LS	$84,000	1	$84,000
6	Crane Mats	Load	$2,500	10	$25,000
7	Capping (>1,000 ppm)				
a	Gas Permeable Bedding Layer	CY	$19.00	4,000	$76,000
b	Geotextile	SF	$0.40	120,000	$48,000
c	Geomembrane	SF	$0.85	120,000	$102,000
d	Fill Layer	CY	$15.00	4,000	$60,000
e	Topsoil and Seed	SF	$1.50	120,000	$180,000
8	Monitoring Well Installation	Well	$2,500	15	$37,500
9	Fence Replacement	LS	$12,000	1	$12,000
	SUBTOTAL OF DIRECT CAPITAL COST				$655,000
	20% CONTINGENCY				$131,000
	SUBTOTAL + CONTINGENCY OF DIRECT CAPITAL COST				$786,000
Indirect Cost					
10	Remedial Design	LS	$20,000	1	$20,000
11	Geotechnical Design	LS	$20,000	1	$20,000
12	Contracting/Permitting	LS	$10,000	1	$10,000
13	Construction Oversight	%	10%	Direct Capital	$78,600
14	Reporting	LS	$20,000	1	$20,000
15	Project Management/Administration	%	2%	Direct Capital	$15,700
	SUBTOTAL OF INDIRECT CAPITAL COST				$165,000
Long-Term Cost					
16	Sampling - Labor	HR	$100	25	$2,500
17	Field Equipment and Expenses	Event	$1,500	1	$1,500
18	Lab	Event	$1,000	1	$1,000
19	Reporting	LS	$5,000	1	$5,000
20	Project Management/Administration	LS	$3,000	1	$3,000
21	Long-Term Maintenance - Cap	LS	$5,000	1	$5,000
	SUBTOTAL OF ANNUAL LONG-TERM COST				$18,000
PRESENT WORTH - LONG-TERM COST		30	years @	5%	$277,000
	OPTION 1.A — TOTAL COST				**$1,263,000**
				+ 30%	**$1,640,000**
				- 10%	**$1,140,000**

Notes:

1. Costs determined from experience and estimates from other similar projects.
2. Interest rate 5%; the balance of an 8% interest rate less a 3% inflation rate, based on EPA approach for remedial cost estimating.
3. All costs are based on preliminary concepts. They are intended for remedial option comparison and not for final budgeting.

Created by: A. Enright
QC by: L. Auner
QA by: K. Vater/A. Sellwood

Assumptions
Remedial Alternative Option 1.a
Capping (1,000 ppm)

1. Estimate to delineate 1,000 ppm arsenic extents at the site.
2. No treatability testing required for this remedial option.
3. No field pilot study required for this remedial option.
4. Estimate based on previous TRC projects.
5. Temporary controls include erosion control, silt fencing, import stone for material storage areas, fuel tanks, and temporary fencing. Unit cost from 2010 Kewaunee Marsh Opinion of Probable cost, adjusted to 2020 costs using RSM cost index conversion.
6. Crane mats will be used to construct temporary roadways across the site to provide access for heavy machinery. Unit costs are typical costs for a load of 18 crane mats. Costs assume crane mat dimensions of 4 ft by 18 ft are laid three side-by-side to form temporary roadways, resulting in about 100 feet of temporary roadway per load of crane mats.
7. Cap to cover areas where surficial (0- to 4-foot direct contact zone) arsenic exceeds 1,000 ppm.
    a. Gas permeable bedding layer constructed of granular fill to cover entire extents of capped area. This layer will be graded to support passive gas venting and surface water drainage, with an average 1-foot thickness. A 1% slope will be required to sufficiently vent gas. Cap design includes constructed vents at peaks of the cap for gas venting to prevent cap failure. Unit cost is based on similar Wisconsin projects and includes providing, placing, and compacting gravel fill.
    b. Geotextile layer to cover entire extents of capped area. Unit costs from Clean Air and Water Systems.
    c. 60-mil Textured HDPE Geomembrane to cover entire extents of capped area. Unit costs from Clean Air and Water Systems.
    d. 1-foot fill layer to cover entire extents of capped area to prevent hydraulic lift of cap layers. Unit cost is based on similar Wisconsin projects and includes providing, placing, and compacting general fill.
    e. 6-inch topsoil layer with seeding to cover entire extents of capped area. Unit cost from 2010 Kewaunee Marsh Opinion of Probable cost, adjusted to 2020 costs using RSM cost index conversion.
8. Installation of NR 141-compliant monitoring wells. Unit costs based on Geoprobe® driller bids for similar Wisconsin projects.
9. Fence replacement needed for section removed to access site during construction. Unit cost from 2010 Kewaunee Marsh Opinion of Probable cost, adjusted to 2020 costs using RSM cost index conversion.
10. Typical based on similar Wisconsin projects.
11. The geotechnical design cost is required to evaluate stability and geometry of items to be constructed on the marsh.
12. Typical for construction.
13. Typical for construction oversight.
14. Typical for construction oversight. Includes Remedial Action Completion Report & Cap Maintenance Plan.
15. Typical for construction oversight.
16. Annual sampling at 15 groundwater monitoring wells and 3 surface water sampling locations.
17. Monitoring wells sampled using low flow techniques. Estimate based on equipment costs for similar Wisconsin projects.
18. 18 water samples for each annual event analyzed for arsenic by method 6010.
19. Typical for annual groundwater monitoring reporting.
20. Typical based on similar Wisconsin projects.
21. Typical annual long-term maintenance costs for a cap.

Remedial Alternative Option 1.b
Capping (100 ppm)
Opinion of Probable Cost
WDNR - Kewaunee Marsh, Kewaunee, Wisconsin
Project No. 344583.0000

	Item	Unit	Unit Cost	Qty.	Total
Pre-Design and Bench Testing Cost					
1	Additional Investigation	LS	$50,000	1	$50,000
2	Treatability Testing	LS	-	0	$0
3	Field Pilot Study	LS	-	0	$0
	SUBTOTAL OF PRE-DESIGN AND BENCH TESTING				$50,000
Direct Capital Cost					
4	Mob/Demobilization	LS	$30,000	1	$30,000
5	Site Preparations/Temporary Controls	LS	$84,000	1	$84,000
6	Crane Mats	Load	$2,500	20	$50,000
7	Capping (>100 ppm)				
a	Gas Permeable Bedding Layer	CY	$19.00	23,000	$437,000
b	Geotextile	SF	$0.40	613,000	$245,200
c	Geomembrane	SF	$0.85	613,000	$521,100
d	Fill Layer	CY	$15.00	23,000	$345,000
e	Topsoil and Seed	SF	$1.50	613,000	$919,500
8	Monitoring Well Installation	Well	$2,500	15	$37,500
9	Fence Replacement	LS	$12,000	1	$12,000
	SUBTOTAL OF DIRECT CAPITAL COST				$2,682,000
	20% CONTINGENCY				$537,000
	SUBTOTAL + CONTINGENCY OF DIRECT CAPITAL COST				$3,219,000
Indirect Cost					
10	Remedial Design	LS	$25,000	1	$25,000
11	Geotechnical Design	LS	$20,000	1	$20,000
12	Contracting/Permitting	LS	$10,000	1	$10,000
13	Construction Oversight	%	10%	Direct Capital	$321,900
14	Reporting	LS	$20,000	1	$20,000
15	Project Management/Administration	%	2%	Direct Capital	$64,400
	SUBTOTAL OF INDIRECT CAPITAL COST				$462,000
Long-Term Cost					
16	Sampling - Labor	HR	$100	25	$2,500
17	Field Equipment and Expenses	Event	$1,500	1	$1,500
18	Lab	Event	$1,000	1	$1,000
19	Reporting	LS	$5,000	1	$5,000
20	Project Management/Administration	LS	$3,000	1	$3,000
21	Long-Term Maintenance - Cap	LS	$10,000	1	$10,000
	SUBTOTAL OF ANNUAL LONG-TERM COST				$23,000
PRESENT WORTH - LONG-TERM COST		30	years @	5%	$354,000
	OPTION 1.B — TOTAL COST				**$4,085,000**
				+ 30%	**$5,310,000**
				- 10%	**$3,680,000**

Notes:
1. Costs determined from experience and estimates from other similar projects.
2. Interest rate 5%; the balance of an 8% interest rate less a 3% inflation rate, based on EPA approach for remedial cost estimating.
3. All costs are based on preliminary concepts. They are intended for remedial option comparison and not for final budgeting.

Created by: A. Enright
QC by: L. Auner
QA by: K. Vater/A. Sellwood

Assumptions
Remedial Alternative Option 1.b
Capping (100 ppm)

1. Estimate to delineate 100 ppm arsenic extents at the site.
2. No treatability testing required for this remedial option.
3. No field pilot study required for this remedial option.
4. Estimate based on previous TRC projects.
5. Temporary controls include erosion control, silt fencing, import stone for material storage areas, fuel tanks, and temporary fencing. Unit cost from 2010 Kewaunee Marsh Opinion of Probable cost, adjusted to 2020 costs using RSM cost index conversion.
6. Crane mats will be used to construct temporary roadways across the site to provide access for heavy machinery. Unit costs are typical costs for a load of 18 crane mats. Costs assume crane mat dimensions of 4 ft by 18 ft are laid three side-by-side to form temporary roadways, resulting in about 100 feet of temporary roadway per load of crane mats.
7. Cap to cover areas where surficial (0- to 4-foot direct contact zone) arsenic exceeds 100 ppm.
    a. Gas permeable bedding layer constructed of granular fill to cover entire extents of capped area. This layer will be graded to support passive gas venting and surface water drainage, with an average 1-foot thickness. A 1% slope will be required to sufficiently vent gas. Cap design includes constructed vents at peaks of the cap for gas venting to prevent cap failure. Unit cost is based on similar Wisconsin projects and includes providing, placing, and compacting gravel fill.
    b. Geotextile layer to cover entire extents of capped area. Unit costs from Clean Air and Water Systems.
    c. 60-mil Textured HDPE Geomembrane to cover entire extents of capped area. Unit costs from Clean Air and Water Systems.
    d. 1-foot fill layer to cover entire extents of capped area to prevent hydraulic lift of cap layers. Unit cost is based on similar Wisconsin projects and includes providing, placing, and compacting general fill.
    e. 6-inch topsoil layer with seeding to cover entire extents of capped area. Unit cost from 2010 Kewaunee Marsh Opinion of Probable cost, adjusted to 2020 costs using RSM cost index conversion.
8. Installation of NR 141-compliant monitoring wells. Unit costs based on Geoprobe® driller bids for similar Wisconsin projects.
9. Fence replacement needed for section removed to access site during construction. Unit cost from 2010 Kewaunee Marsh Opinion of Probable cost, adjusted to 2020 costs using RSM cost index conversion.
10. Typical based on similar Wisconsin projects.
11. The geotechnical design cost is required to evaluate stability and geometry of items to be constructed on the marsh.
12. Typical for construction.
13. Typical for construction oversight.
14. Typical for construction oversight. Includes Remedial Action Completion Report & Cap Maintenance Plan.
15. Typical for construction oversight.
16. Annual sampling at 15 groundwater monitoring wells and 3 surface water sampling locations.
17. Monitoring wells sampled using low flow techniques. Estimate based on equipment costs for similar Wisconsin projects.
18. 18 water samples for each annual event analyzed for arsenic by method 6010.
19. Typical for annual groundwater monitoring reporting.
20. Typical based on similar Wisconsin projects.
21. Typical annual long-term maintenance costs for a cap.

Remedial Alternative Option 2.a
In-Situ Stabilization/Solidification (1,000 ppm) + Capping (100 ppm)
Opinion of Probable Cost
WDNR - Kewaunee Marsh, Kewaunee, Wisconsin
Project No. 344583.0000

	Item	Unit	Unit Cost	Qty.	Total
Pre-Design and Bench Testing Cost					
1	Additional Investigation	LS	$50,000	1	$50,000
2	Treatability Testing	LS	$5,000	1	$5,000
3	Field Pilot Study	LS	$50,000	1	$50,000
	SUBTOTAL OF PRE-DESIGN AND BENCH TESTING				$105,000
Direct Capital Cost					
4	Mob/Demobilization	LS	$40,000	1	$40,000
5	Site Preparations/Temporary Controls	LS	$84,000	1	$84,000
6	Crane Mats	Load	$2,500	20	$50,000
7	In-Situ Stabilization/Solidification (>1,000 ppm)				
a	Stabilization Additive - ABC-Olé	lb	$0.90	378,000	$341,000
b	Stabilization Additive - Ferrous Sulfate	lb	$1.40	3,780	$5,300
c	Solidification Additives	Ton	$275	700	$192,500
d	Mixing	CY	$5.00	14,000	$70,000
e	Confirmation Sampling	Sample	$15.00	30	$450
	IN-SITU STABILIZATION/SOLIDIFICATION SUBTOTAL				$610,000
8	Capping (>100 ppm)				
a	Gas Permeable Bedding Layer	CY	$19.00	23,000	$437,000
b	Geotextile	SF	$0.40	613,000	$245,200
c	Geomembrane	SF	$0.85	613,000	$521,100
d	Fill Layer	CY	$15.00	23,000	$345,000
e	Topsoil and Seed	SF	$1.50	613,000	$919,500
	CAPPING SUBTOTAL				$2,468,000
9	Monitoring Well Installation	Well	$2,500	15	$37,500
10	Fence Replacement	LS	$12,000	1	$12,000
	SUBTOTAL OF DIRECT CAPITAL COST				$3,302,000
	20% CONTINGENCY				$660,000
	SUBTOTAL + CONTINGENCY OF DIRECT CAPITAL COST				$3,962,000
Indirect Cost					
11	Remedial Design	LS	$25,000	1	$25,000
12	Geotechnical Design	LS	$20,000	1	$20,000
13	Contracting/Permitting	LS	$20,000	1	$20,000
14	Construction Oversight	%	10%	Direct Capital	$396,200
15	Reporting	LS	$20,000	1	$20,000
16	Project Management/Administration	%	2%	Direct Capital	$79,200
	SUBTOTAL OF INDIRECT CAPITAL COST				$561,000
Long-Term Cost					
17	Sampling - Labor	HR	$100	25	$2,500
18	Field Equipment and Expenses	Event	$1,500	1	$1,500
19	Lab	Event	$1,000	1	$1,000
20	Reporting	LS	$5,000	1	$5,000
21	Project Management/Administration	LS	$3,000	1	$3,000
22	Long-Term Maintenance - Cap	LS	$5,000	1	$5,000
	SUBTOTAL OF ANNUAL LONG-TERM COST				$18,000
PRESENT WORTH - LONG-TERM COST		30	years @	5%	$277,000
	OPTION 2.A — TOTAL COST				**$4,905,000**
				+ 30%	**$6,380,000**
				- 10%	**$4,410,000**

Notes:
1. Costs determined from experience and estimates from other similar projects.
2. Interest rate 5%; the balance of an 8% interest rate less a 3% inflation rate, based on EPA approach for remedial cost estimating.
3. All costs are based on preliminary concepts. They are intended for remedial option comparison and not for final budgeting.

Created by: A. Enright
QC by: L. Auner
QA by: K. Vater/A. Sellwood

Assumptions
Remedial Alternative Option 2.a
In-Situ Stabilization/Solidification (1,000 ppm) + Capping (100 ppm)

1. Estimate to delineate 100 ppm arsenic extents at the site.
2. Treatability study includes a $5,000 bench scale study for stabilization/solidification methods.
3. Field pilot study for stabilization/solidification amendments; costs based on previous work performed at the site.
4. Estimate based on previous TRC projects.
5. Temporary controls include erosion control, silt fencing, import stone for material storage areas, fuel tanks, and temporary fencing. Unit cost from 2010 Kewaunee Marsh Opinion of Probable cost, adjusted to 2020 costs using RSM cost index conversion.
6. Crane mats will be used to construct temporary roadways across the site to provide access for heavy machinery. Unit costs are typical costs for a load of 18 crane mats. Costs assume crane mat dimensions of 4 ft by 18 ft are laid three side-by-side to form temporary roadways, resulting in about 100 feet of temporary roadway per load of crane mats.
7. Includes in-situ mixing of amendments with soil/sediment from all depth intervals sampled to date with arsenic concentrations exceeding 1,000 ppm.
    a. For estimating purposes, used a dose of 1 pound of ABC-Olé per cubic foot of soil. Unit costs provided by supplier bid.
    b. For estimating purposes, used a dose of 1 pound of ferrous sulfate per every 100 lbs of ABC-Olé. Unit costs provided by supplier bid.
    c. Bentonite solidification amendment to be mixed at about 5% by volume of soil/sediment.
    d. Includes in-situ mixing of amendments with soil/sediment from all depth intervals sampled to date with arsenic concentrations exceeding 1,000 ppm. Unit cost estimates based on previous TRC projects.
    e. Samples analyzed for arsenic by method 6010.
8. Cap to cover areas where surficial (0- to 4-foot direct contact zone) arsenic exceeds 100 ppm.
    a. Gas permeable bedding layer constructed of granular fill to cover entire extents of capped area. This layer will be graded to support passive gas venting and surface water drainage, with an average 1-foot thickness. A 1% slope will be required to sufficiently vent gas. Cap design includes constructed vents at peaks of the cap for gas venting to prevent cap failure. Unit cost is based on similar Wisconsin projects and includes providing, placing, and compacting gravel fill.
    b. Geotextile layer to cover entire extents of capped area. Unit costs from Clean Air and Water Systems.
    c. 60-mil Textured HDPE Geomembrane to cover entire extents of capped area. Unit costs from Clean Air and Water Systems.
    d. 1-foot fill layer to cover entire extents of capped area to prevent hydraulic lift of cap layers. Unit cost is based on similar Wisconsin projects and includes providing, placing, and compacting general fill.
    e. 6-inch topsoil layer with seeding to cover entire extents of capped area. Unit cost from 2010 Kewaunee Marsh Opinion of Probable cost, adjusted to 2020 costs using RSM cost index conversion.
9. Installation of NR 141-compliant monitoring wells. Unit costs based on Geoprobe® driller bids for similar Wisconsin projects.
10. Fence replacement needed for section removed to access site during construction. Unit cost from 2010 Kewaunee Marsh Opinion of Probable cost, adjusted to 2020 costs using RSM cost index conversion.
11. Typical.
12. The geotechnical design cost is required to evaluate stability and geometry of items to be constructed on the marsh.
13. Typical for construction.
14. Typical for construction.
15. Typical for construction.
16. Typical for construction.
17. Annual sampling at 15 groundwater monitoring wells and 3 surface water sampling locations.
18. Monitoring wells sampled using low flow techniques. Estimate based on equipment costs for similar Wisconsin projects.
19. 18 water samples for each annual event analyzed for arsenic by method 6010.
20. Typical for annual groundwater monitoring reporting.
21. Typical based on similar Wisconsin projects.
22. Typical annual long-term maintenance costs for a cap.

Remedial Alternative Option 2.b
In-Situ Stabilization/Solidification (100 ppm) + Capping (100 ppm)
Opinion of Probable Cost
WDNR - Kewaunee Marsh, Kewaunee, Wisconsin
Project No. 344583.0000

	Item	Unit	Unit Cost	Qty.	Total
Pre-Design and Bench Testing Cost					
1	Additional Investigation	LS	$50,000	1	$50,000
2	Treatability Testing	LS	$5,000	1	$5,000
3	Field Pilot Study	LS	$50,000	1	$50,000
	SUBTOTAL OF PRE-DESIGN AND BENCH TESTING				$105,000
Direct Capital Cost					
4	Mob/Demobilization	LS	$40,000	1	$40,000
5	Site Preparations/Temporary Controls	LS	$84,000	1	$84,000
6	Crane Mats	Load	$2,500	20	$50,000
7	In-Situ Stabilization/Solidification (>100 ppm)				
a	Stabilization Additive - ABC-Olé	lb	$0.90	2,862,000	$2,576,000
b	Stabilization Additive - Ferrous Sulfate	lb	$1.40	28,620	$40,100
c	Solidification Additives	Ton	$275	4,600	$1,265,000
d	Mixing	CY	$5.00	92,000	$460,000
e	Confirmation Sampling	Sample	$15.00	80	$1,200
	IN-SITU STABILIZATION/SOLIDIFICATION SUBTOTAL				$4,343,000
8	Capping (>100 ppm)				
a	Gas Permeable Bedding Layer	CY	$19.00	23,000	$437,000
b	Geotextile	SF	$0.40	613,000	$245,200
c	Geomembrane	SF	$0.85	613,000	$521,100
d	Fill Layer	CY	$15.00	23,000	$345,000
e	Topsoil and Seed	SF	$1.50	613,000	$919,500
	CAPPING SUBTOTAL				$2,468,000
9	Monitoring Well Installation	Well	$2,500	15	$37,500
10	Fence Replacement	LS	$12,000	1	$12,000
	SUBTOTAL OF DIRECT CAPITAL COST				$7,035,000
	20% CONTINGENCY				$1,407,000
	SUBTOTAL + CONTINGENCY OF DIRECT CAPITAL COST				$8,442,000
Indirect Cost					
11	Remedial Design	LS	$25,000	1	$25,000
12	Geotechnical Design	LS	$20,000	1	$20,000
13	Contracting/Permitting	LS	$20,000	1	$20,000
14	Construction Oversight	%	10%	Direct Capital	$844,200
15	Reporting	LS	$20,000	1	$20,000
16	Project Management/Administration	%	2%	Direct Capital	$168,800
	SUBTOTAL OF INDIRECT CAPITAL COST				$1,098,000
Long-Term Cost					
17	Sampling - Labor	HR	$100	25	$2,500
18	Field Equipment and Expenses	Event	$1,500	1	$1,500
19	Lab	Event	$1,000	1	$1,000
20	Reporting	LS	$5,000	1	$5,000
21	Project Management/Administration	LS	$3,000	1	$3,000
22	Long-Term Maintenance - Cap	LS	$10,000	1	$10,000
	SUBTOTAL OF ANNUAL LONG-TERM COST				$23,000
PRESENT WORTH - LONG-TERM COST		30	years @	5%	$354,000
	OPTION 2.B — TOTAL COST				**$9,999,000**
				+ 30%	**$13,000,000**
				- 10%	**$9,000,000**

Notes:

1. Costs determined from experience and estimates from other similar projects.
2. Interest rate 5%; the balance of an 8% interest rate less a 3% inflation rate, based on EPA approach for remedial cost estimating.
3. All costs are based on preliminary concepts. They are intended for remedial option comparison and not for final budgeting.

Created by: A. Enright
QC by: L. Auner
QA by: K. Vater/A. Sellwood

Assumptions
Remedial Alternative Option 2.b
In-Situ Stabilization/Solidification (100 ppm) + Capping (100 ppm)

1. Estimate to delineate 100 ppm arsenic extents at the site.
2. Treatability study includes a $5,000 bench scale study for stabilization/solidification methods.
3. Field pilot study for stabilization/solidification amendments; costs based on previous work performed at the site.
4. Estimate based on previous TRC projects.
5. Temporary controls include erosion control, silt fencing, import stone for material storage areas, fuel tanks, and temporary fencing. Unit cost from 2010 Kewaunee Marsh Opinion of Probable cost, adjusted to 2020 costs using RSM cost index conversion.
6. Crane mats will be used to construct temporary roadways across the site to provide access for heavy machinery. Unit costs are typical costs for a load of 18 crane mats. Costs assume crane mat dimensions of 4 ft by 18 ft are laid three side-by-side to form temporary roadways, resulting in about 100 feet of temporary roadway per load of crane mats.
7. Includes in-situ mixing of amendments with soil/sediment from all depth intervals sampled to date with arsenic concentrations exceeding 100 ppm.
    a. For estimating purposes, used a dose of 1 pound of ABC-Olé per cubic foot of soil. Unit costs provided by supplier bid.
    b. For estimating purposes, used a dose of 1 pound of ferrous sulfate per every 100 lbs of ABC-Olé. Unit costs provided by supplier bid.
    c. Bentonite solidification amendment to be mixed at about 5% by volume of soil/sediment.
    d. Includes in-situ mixing of amendments with soil/sediment from all depth intervals sampled to date with arsenic concentrations exceeding 100 ppm. Unit cost estimates based on previous TRC projects.
    e. Samples analyzed for arsenic by method 6010.
8. Cap to cover areas where surficial (0- to 4-foot direct contact zone) arsenic exceeds 100 ppm.
    a. Gas permeable bedding layer constructed of granular fill to cover entire extents of capped area. This layer will be graded to support passive gas venting and surface water drainage, with an average 1-foot thickness. A 1% slope will be required to sufficiently vent gas. Cap design includes constructed vents at peaks of the cap for gas venting to prevent cap failure. Unit cost is based on similar Wisconsin projects and includes providing, placing, and compacting gravel fill.
    b. Geotextile layer to cover entire extents of capped area. Unit costs from Clean Air and Water Systems.
    c. 60-mil Textured HDPE Geomembrane to cover entire extents of capped area. Unit costs from Clean Air and Water Systems.
    d. 1-foot fill layer to cover entire extents of capped area to prevent hydraulic lift of cap layers. Unit cost is based on similar Wisconsin projects and includes providing, placing, and compacting general fill.
    e. 6-inch topsoil layer with seeding to cover entire extents of capped area. Unit cost from 2010 Kewaunee Marsh Opinion of Probable cost, adjusted to 2020 costs using RSM cost index conversion.
9. Installation of NR 141-compliant monitoring wells. Unit costs based on Geoprobe® driller bids for similar Wisconsin projects.
10. Fence replacement needed for section removed to access site during construction. Unit cost from 2010 Kewaunee Marsh Opinion of Probable cost, adjusted to 2020 costs using RSM cost index conversion.
11. Typical.
12. The geotechnical design cost is required to evaluate stability and geometry of items to be constructed on the marsh.
13. Typical for construction.
14. Typical for construction.
15. Typical for construction.
16. Typical for construction.
17. Annual sampling at 15 groundwater monitoring wells and 3 surface water sampling locations.
18. Monitoring wells sampled using low flow techniques. Estimate based on equipment costs for similar Wisconsin projects.
19. 18 water samples for each annual event analyzed for arsenic by method 6010.
20. Typical for annual groundwater monitoring reporting.
21. Typical based on similar Wisconsin projects.
22. Typical annual long-term maintenance costs for a cap.

Remedial Alternative Option 3
Excavation + Off-Site Disposal (1,000 ppm) + Backfill + Capping (100 ppm)
Opinion of Probable Cost
WDNR - Kewaunee Marsh, Kewaunee, Wisconsin
Project No. 344583.0000

	Item	Unit	Unit Cost	Qty.	Total
Pre-Design and Bench Testing Cost					
1	Additional Investigation	LS	$50,000	1	$50,000
2	Treatability Testing	LS	$10,000	1	$10,000
3	Field Pilot Study	LS	$50,000	1	$50,000
	SUBTOTAL OF PRE-DESIGN AND BENCH TESTING				$110,000
Direct Capital Cost					
4	Mob/Demobilization	LS	$40,000	1	$40,000
5	Site Preparations/Temporary Controls	LS	$84,000	1	$84,000
6	Crane Mats	Load	$2,500	20	$50,000
7	Excavation (>1,000 ppm)				
a	Waste Characterization	LS	$2,000	1	$2,000
b	Slurry Walls	SF	$15.00	30,000	$450,000
c	Excavation	CY	$5.50	14,000	$77,000
d	Treatment to Non-Hazardous Levels	Ton	$5.00	14,000	$70,000
e	Contaminated Soil/Sediment Transport (Non-Haz)	Ton	$14.63	18,200	$266,200
f	Contaminated Soil/Sediment Disposal (Non-Haz)	Ton	$37.30	18,200	$678,900
g	Confirmation Sampling	Sample	$15.00	30	$450
h	Dewatering System	LS	$20,000	1	$20,000
i	Water Treatment	Ton	$10.00	7,000	$70,000
j	Backfill	CY	$13.00	1,500	$19,500
	EXCAVATION SUBTOTAL				$1,655,000
8	Soil/Sediment Relocation (select 100 ppm - 1,000 ppm)				
a	Excavation	CY	$5.50	78,000	$429,000
b	Soil/Sediment Relocation	CY	$5.50	78,000	$429,000
	ON-SITE MANAGEMENT SUBTOTAL				$858,000
9	Capping (>100 ppm)				
a	Gas Permeable Bedding Layer	CY	$19.00	23,000	$437,000
b	Geotextile	SF	$0.40	613,000	$245,200
c	Geomembrane	SF	$0.85	613,000	$521,100
d	Fill Layer	CY	$15.00	23,000	$345,000
e	Topsoil and Seed	SF	$1.50	613,000	$919,500
	CAPPING SUBTOTAL				$2,468,000
10	Monitoring Well Installation	Well	$2,500	15	$37,500
11	Fence Replacement	LS	$12,000	1	$12,000
	SUBTOTAL OF DIRECT CAPITAL COST				$5,205,000
	20% CONTINGENCY				$1,041,000
	SUBTOTAL + CONTINGENCY OF DIRECT CAPITAL COST				$6,246,000

Remedial Alternative Option 3
Excavation + Off-Site Disposal (1,000 ppm) + Backfill + Capping (100 ppm)
Opinion of Probable Cost
WDNR - Kewaunee Marsh, Kewaunee, Wisconsin
Project No. 344583.0000 Ph. 00002

	Item	Unit	Unit Cost	Qty.	Total
Indirect Cost					
12	Remedial Design	LS	$20,000	1	$20,000
13	Geotechnical Design	LS	$20,000	1	$20,000
14	Contracting/Permitting	LS	$15,000	1	$15,000
15	Construction Oversight	%	10%	Direct Capital	$624,600
16	Reporting	LS	$20,000	1	$20,000
17	Project Management/Administration	%	2%	Direct Capital	$124,900
				SUBTOTAL OF INDIRECT CAPITAL COST	$825,000
Long-Term Cost					
18	Sampling - Labor	HR	$100	25	$2,500
19	Field Equipment and Expenses	Event	$1,500	1	$1,500
20	Lab	Event	$1,000	1	$1,000
21	Reporting	LS	$5,000	1	$5,000
22	Project Management/Administration	LS	$3,000	1	$3,000
23	Long-Term Maintenance - Cap	LS	$10,000	1	$10,000
				SUBTOTAL OF ANNUAL LONG-TERM COST	$23,000
PRESENT WORTH - LONG-TERM COST		30	years @	5%	$354,000
				OPTION 3 — TOTAL COST	**$7,535,000**
				+ 30%	**$9,800,000**
				- 10%	**$6,780,000**

Notes:

1. Costs determined from experience and estimates from other similar projects.
2. Interest rate 5%; the balance of an 8% interest rate less a 3% inflation rate, based on EPA approach for remedial cost estimating.
3. All costs are based on preliminary concepts. They are intended for remedial option comparison and not for final budgeting.

Created by: A. Enright
QC by: L. Auner
QA by: K. Vater/A. Sellwood

Assumptions
Remedial Alternative Option 3
Excavation + Off-Site Disposal (1,000 ppm) + Backfill + Cap (100 ppm)

1. Estimate to delineate 1,000 ppm arsenic extents at the site.
2. Treatability study includes a $5,000 bench scale study of discharge water treatment methods and a $5,000 bench scale study for treatment of excavated materials prior to off-site disposal as non-hazardous.
3. Field pilot study includes a $25,000 discharge water treatment methods study and a $25,000 excavated materials treatment study. Costs based on previous work performed at the site.
4. Estimate based on previous TRC projects.
5. Temporary controls include erosion control, silt fencing, import stone for material storage areas, fuel tanks, and temporary fencing. Unit cost from 2010 Kewaunee Marsh Opinion of Probable cost, adjusted to 2020 costs using RSM cost index conversion.
6. Crane mats will be used to construct temporary roadways across the site to provide access for heavy machinery. Unit costs are typical costs for a load of 18 crane mats. Costs assume crane mat dimensions of 4 ft by 18 ft are laid three side-by-side to form temporary roadways, resulting in about 100 feet of temporary roadway per load of crane mats.
7. Includes excavation and off-site disposal of soil/sediment from all depth intervals sampled to date with arsenic concentrations exceeding 1,000 ppm.
    a. Estimate based on previous TRC projects.
    b. Slurry wall barriers are required to divide excavation areas into workable portions (estimated to extend around the perimeter of the current 1,000 ppm extents and to account for the interior division walls, with barriers to extend 10 ft deep) to minimize the generation of standing water requiring treatment. Unit costs are based on previous projects.
    c. Includes soil/sediment from all depth intervals sampled to date with arsenic concentrations exceeding 1,000 ppm. Unit costs from similar Wisconsin projects.
    d. Excavated soil/sediment with concentrations exceeding 1,000 ppm will require on-site treatment prior to transport to reduce arsenic concentrations to non-hazardous levels. This will be achieved through mixing with an amendment such as zero valent iron (ZVI). Based on previous testing, an appropriate dose is approximately 0.5% ZVI by volume. At $1,000/ton for ZVI, this gives a treatment cost of $5/ton of soil/sediment to be treated, based on similar projects in Wisconsin. Use 1 ton/CY conversion factor for organic soil/sediment.
    e. Use 1.3 ton/CY conversion factor for organic soil/sediment mixed with 10% drying amendment. Unit costs from similar Wisconsin projects. Includes non-hazardous waste transport, freight charge, and fuel surcharge.
    f. Use 1.3 ton/CY conversion factor for organic soil/sediment mixed with 10% drying amendment. Unit costs from similar Wisconsin projects. Includes non-hazardous waste disposal costs and Wisconsin landfill tax costs.
    g. Samples analyzed for arsenic by method 6010.
    h. Treatment system to consist of frac tanks for water collection/mixing, a sand filter, bag filters, pumps, and a collection tank for testing prior to discharge. Estimate based on previous TRC projects.
    i. Includes treatment of liquids from soil/sediment dewatering and pumping accumulated water from within open excavation area. Assumes a discharge permit will be obtained to discharge treated water to wetland/river. Volume of water to be treated assumes excavated wetland soil/sediments are saturated with a porosity of 30% and that water accumulation in excavation is approximately equivalent to water generated from soil/sediment dewatering. A 1% dose of ZVI by weight of water to be treated is for cost estimating purposes. At $1,000/ton for ZVI, this gives a treatment cost of $10/ton of soil/sediment to be treated, based on similar projects in Wisconsin.
    j. Minimal backfill required to facilitate final grading. Unit costs from similar Wisconsin projects.
8. Includes excavation and on-site management of soil/sediment from all depth intervals sampled to date with arsenic concentrations ranging from 100 ppm to 1,000 ppm.
    a. Includes soil/sediment from all depth intervals sampled to date with arsenic concentrations between 100 ppm to 1,000 ppm. Unit costs from similar Wisconsin projects.
    b. Transport of stabilized/solidified soil/sediment across the site into an on-site management area. Includes soil/sediment from all depth intervals sampled to date with arsenic concentrations between 100 ppm to 1,000 ppm. Unit costs from similar Wisconsin projects

9. A cap will be installed over areas where surficial (0- to 4-foot direct contact zone) arsenic exceeds 100 ppm.
    a. Gas permeable bedding layer constructed of granular fill to cover entire extents of capped area. This layer will be graded to support passive gas venting and surface water drainage, with an average 1-foot thickness. A 1% slope will be required to sufficiently vent gas. Cap design includes constructed vents at peaks of the cap for gas venting to prevent cap failure. Unit cost is based on similar Wisconsin projects and includes providing, placing, and compacting gravel fill.
    b. Geotextile layer to cover entire extents of capped area. Unit costs from Clean Air and Water Systems.
    c. 60-mil Textured HDPE Geomembrane to cover entire extents of capped area. Unit costs from Clean Air and Water Systems.
    d. 1-foot fill layer to cover entire extents of capped area to prevent hydraulic lift of cap layers. Unit cost is based on similar Wisconsin projects and includes providing, placing, and compacting general fill.
    e. 6-inch topsoil layer with seeding to cover entire extents of capped area. Unit cost from 2010 Kewaunee Marsh Opinion of Probable cost, adjusted to 2020 costs using RSM cost index conversion.
10. Installation of NR 141-compliant monitoring wells. Unit costs based on Geoprobe® driller bids for similar Wisconsin projects.
11. Fence replacement needed for section removed to access site during construction. Unit cost from 2010 Kewaunee Marsh Opinion of Probable cost, adjusted to 2020 costs using RSM cost index conversion.
12. Typical.
13. The geotechnical design cost is required to evaluate stability and geometry of items to be constructed on the marsh.
14. Typical for construction.
15. Typical for construction.
16. Typical for construction.
17. Typical for construction.
18. Annual sampling at 15 groundwater monitoring wells and 3 surface water sampling locations.
19. Monitoring wells sampled using low flow techniques. Estimate based on equipment costs for similar Wisconsin projects.
20. 18 water samples for each annual event analyzed for arsenic by method 6010.
21. Typical for annual groundwater monitoring reporting.
22. Typical based on similar Wisconsin projects.
23. Typical annual long-term maintenance costs for a cap.

Remedial Alternative Option 4
Excavation (1,000 ppm) + In-Situ Stabilization/Solidification (100 ppm) + Capping (100 ppm)
Opinion of Probable Cost
WDNR - Kewaunee Marsh, Kewaunee, Wisconsin
Project No. 344583.0000

	Item	Unit	Unit Cost	Qty.	Total
Pre-Design and Bench Testing Cost					
1	Additional Investigation	LS	$50,000	1	$50,000
2	Treatability Testing	LS	$15,000	1	$15,000
3	Field Pilot Study	LS	$75,000	1	$75,000
	SUBTOTAL OF PRE-DESIGN AND BENCH TESTING				$140,000
Direct Capital Cost					
4	Mob/Demobilization	LS	$60,000	1	$60,000
5	Site Preparations/Temporary Controls	LS	$84,000	1	$84,000
6	Crane Mats	Load	$2,500	20	$50,000
7	Excavation (>1,000 ppm)				
a	Waste Characterization	LS	$2,000	1	$2,000
b	Slurry Walls	SF	$15.00	30,000	$450,000
c	Excavation	CY	$5.50	14,000	$77,000
d	Treatment to Non-Hazardous Levels	Ton	$5.00	14,000	$70,000
e	Contaminated Soil/Sediment Transport (Non-Haz)	Ton	$14.63	18,200	$266,200
f	Contaminated Soil/Sediment Disposal (Non-Haz)	Ton	$37.30	18,200	$678,900
g	Confirmation Sampling	Sample	$15.00	30	$450
h	Dewatering System	LS	$20,000	1	$20,000
i	Water Treatment	Ton	$10.00	7,000	$70,000
	EXCAVATION SUBTOTAL				$1,635,000
8	In-Situ Stabilization/Solidification (100 ppm - 1,000 ppm)				
a	Stabilization Additive - ABC-Olé	lb	$0.90	2,484,000	$2,236,000
b	Stabilization Additive - Ferrous Sulfate	lb	$1.40	24,840	$34,800
c	Solidification Additives	Ton	$275	3,900	$1,072,500
d	Mixing	CY	$5.00	78,000	$390,000
e	Confirmation Sampling	Sample	$15.00	50	$750
	IN-SITU STABILIZATION/SOLIDIFICATION SUBTOTAL				$3,735,000
9	Soil/Sediment Relocation (select 100 ppm - 1,000 ppm)				
a	Excavation	CY	$5.50	14,000	$77,000
b	Soil/Sediment Relocation	CY	$5.50	14,000	$77,000
	ON-SITE MANAGEMENT SUBTOTAL				$154,000
10	Capping (>100 ppm)				
a	Gas Permeable Bedding Layer	CY	$19.00	23,000	$437,000
b	Geotextile	SF	$0.40	613,000	$245,200
c	Geomembrane	SF	$0.85	613,000	$521,100
d	Fill Layer	CY	$15.00	23,000	$345,000
e	Topsoil and Seed	SF	$1.50	613,000	$919,500
	CAPPING SUBTOTAL				$2,468,000
11	Monitoring Well Installation	Well	$2,500	15	$37,500
12	Fence Replacement	LS	$12,000	1	$12,000
	SUBTOTAL OF DIRECT CAPITAL COST				$8,236,000
	20% CONTINGENCY				$1,647,000
	SUBTOTAL + CONTINGENCY OF DIRECT CAPITAL COST				$9,883,000

Remedial Alternative Option 4
Excavation (1,000 ppm) + In-Situ Stabilization/Solidification (100 ppm) + Capping (100 ppm)
Opinion of Probable Cost
WDNR - Kewaunee Marsh, Kewaunee, Wisconsin
Project No. 344583.0000 Ph. 00002

	Item	Unit	Unit Cost	Qty.	Total
Indirect Cost					
13	Remedial Design	LS	$30,000	1	$30,000
14	Geotechnical Design	LS	$20,000	1	$20,000
15	Contracting/Permitting	LS	$20,000	1	$20,000
16	Construction Oversight	%	10%	Direct Capital	$988,300
17	Reporting	LS	$20,000	1	$20,000
18	Project Management/Administration	%	2%	Direct Capital	$197,700
	SUBTOTAL OF INDIRECT CAPITAL COST				$1,276,000
Long-Term Cost					
19	Sampling - Labor	HR	$100	25	$2,500
20	Field Equipment and Expenses	Event	$1,500	1	$1,500
21	Lab	Event	$1,000	1	$1,000
22	Reporting	LS	$5,000	1	$5,000
23	Project Management/Administration	LS	$3,000	1	$3,000
24	Long-Term Maintenance - Cap	LS	$10,000	1	$10,000
	SUBTOTAL OF ANNUAL LONG-TERM COST				$23,000
PRESENT WORTH - LONG-TERM COST		30	years @	5%	$354,000
	OPTION 4 — TOTAL COST				**$11,653,000**
				+ 30%	**$15,150,000**
				- 10%	**$10,490,000**

Notes:

1. Costs determined from experience and estimates from other similar projects.
2. Interest rate 5%; the balance of an 8% interest rate less a 3% inflation rate, based on EPA approach for remedial cost estimating.
3. All costs are based on preliminary concepts. They are intended for remedial option comparison and not for final budgeting.

Created by: A. Enright
QC by: L. Auner
QA by: K. Vater/A. Sellwood

Assumptions
Remedial Alternative Option 4
Excavation (1,000 ppm) + In-Situ Stabilization/Solidification (100 ppm) + Capping (100 ppm)

1. Estimate to delineate 100 ppm arsenic extents at the site.
2. Treatability study includes a $5,000 bench scale study for stabilization/solidification methods, a $5,000 bench scale study of discharge water treatment methods, and a $5,000 bench scale study for treatment of excavated materials prior to off-site disposal as non-hazardous.
3. Field pilot study includes a $25,000 stabilization/solidification amendments study, a $25,000 discharge water treatment methods study, and a $25,000 excavated materials treatment study. Costs based on previous work performed at the site.
4. Estimate based on previous TRC projects.
5. Temporary controls include erosion control, silt fencing, import stone for material storage areas, fuel tanks, and temporary fencing. Unit cost from 2010 Kewaunee Marsh Opinion of Probable cost, adjusted to 2020 costs using RSM cost index conversion.
6. Crane mats will be used to construct temporary roadways across the site to provide access for heavy machinery. Unit costs are typical costs for a load of 18 crane mats. Costs assume crane mat dimensions of 4 ft by 18 ft are laid three side-by-side to form temporary roadways, resulting in about 100 feet of temporary roadway per load of crane mats.
7. Includes excavation and off-site disposal of soil/sediment from all depth intervals sampled to date with arsenic concentrations exceeding 1,000 ppm.
    a. Estimate based on previous TRC projects.
    b. Slurry wall barriers are required to divide excavation areas into workable portions (estimated to extend around the perimeter of the current 1,000 ppm extents and to account for the interior division walls, with barriers to extend 10 ft deep) to minimize the generation of standing water requiring treatment. Unit costs are based on previous projects.
    c. Includes soil/sediment from all depth intervals sampled to date with arsenic concentrations exceeding 1,000 ppm. Unit costs from similar Wisconsin projects.
    d. Excavated soil/sediment with concentrations exceeding 1,000 ppm will require on-site treatment prior to transport to reduce arsenic concentrations to non-hazardous levels. This will be achieved through mixing with an amendment such as ZVI. Based on previous testing, an appropriate dose is approximately 0.5% ZVI by volume. At $1,000/ton for ZVI, this gives a treatment cost of $5/ton of soil/sediment to be treated, based on similar projects in Wisconsin. Use 1 ton/CY conversion factor for organic soil/sediment.
    e. Use 1.3 ton/CY conversion factor for organic soil/sediment mixed with 10% drying amendment. Unit costs from similar Wisconsin projects. Includes non-hazardous waste transport, freight charge, and fuel surcharge.
    f. Use 1.3 ton/CY conversion factor for organic soil/sediment mixed with 10% drying amendment. Unit costs from similar Wisconsin projects. Includes non-hazardous waste disposal costs and Wisconsin landfill tax costs.
    g. Samples analyzed for arsenic by method 6010.
    h. Treatment system to consist of frac tanks for water collection/mixing, a sand filter, bag filters, pumps, and a collection tank for testing prior to discharge. Estimate based on previous TRC projects.
    i. Includes treatment of liquids from soil/sediment dewatering and pumping accumulated water from within open excavation area. Assumes a discharge permit will be obtained to discharge treated water to wetland/river. Volume of water to be treated assumes excavated wetland soil/sediments are saturated with a porosity of 30% and that water accumulation in excavation is approximately equivalent to water generated from soil/sediment dewatering. A 1% dose of ZVI by weight of water to be treated is for cost estimating purposes. At $1,000/ton for ZVI, this gives a treatment cost of $10/ton of soil/sediment to be treated, based on similar projects in Wisconsin.
8. Includes in-situ stabilization/solidification of soil/sediment from all depth intervals sampled to date with arsenic concentrations ranging from 100 ppm to 1,000 ppm.
    a. For estimating purposes, used a dose of 1 pound of ABC-Olé per cubic foot of soil. Unit costs provided by supplier bid.
    b. For estimating purposes, used a dose of 1 pound of ferrous sulfate per every 100 lbs of ABC-Olé. Unit costs provided by supplier bid.
    c. Bentonite solidification amendment to be mixed at about 5% by volume of soil/sediment.

d. Includes in-situ mixing of amendments with soil/sediment from all depth intervals sampled to date with arsenic concentrations between 100 ppm to 1,000 ppm. Unit cost estimates based on previous TRC projects.
e. Samples analyzed for arsenic by method 6010.

9. Includes relocation of stabilized/solidified soil/sediment with arsenic concentrations ranging from 100 ppm to 1,000 ppm from its current location into the excavation left by removal of the 1,000 ppm exceedance area.
   a. Volume of soil/sediment equal to 1,000 ppm exceedance soil/sediment excavated and disposed off-site. Unit costs from similar Wisconsin projects.
   b. Transport and placement of stabilized/solidified soil/sediment across the site into open excavation. Unit costs from similar Wisconsin projects
10. A cap will be installed over areas where surficial (0- to 4-foot direct contact zone) arsenic exceeds 100 ppm.
   a. Gas permeable bedding layer constructed of granular fill to cover entire extents of capped area. This layer will be graded to support passive gas venting and surface water drainage, with an average 1-foot thickness. A 1% slope will be required to sufficiently vent gas. Cap design includes constructed vents at peaks of the cap for gas venting to prevent cap failure. Unit cost is based on similar Wisconsin projects and includes providing, placing, and compacting gravel fill.
   b. Geotextile layer to cover entire extents of capped area. Unit costs from Clean Air and Water Systems.
   c. 60-mil Textured HDPE Geomembrane to cover entire extents of capped area. Unit costs from Clean Air and Water Systems.
   d. 1-foot fill layer to cover entire extents of capped area to prevent hydraulic lift of cap layers. Unit cost is based on similar Wisconsin projects and includes providing, placing, and compacting general fill.
   e. 6-inch topsoil layer with seeding to cover entire extents of capped area. Unit cost from 2010 Kewaunee Marsh Opinion of Probable cost, adjusted to 2020 costs using RSM cost index conversion.
11. Installation of NR 141-compliant monitoring wells. Unit costs based on Geoprobe® driller bids for similar Wisconsin projects.
12. Fence replacement needed for section removed to access site during construction. Unit cost from 2010 Kewaunee Marsh Opinion of Probable cost, adjusted to 2020 costs using RSM cost index conversion.
13. Typical.
14. The geotechnical design cost is required to evaluate stability and geometry of items to be constructed on the marsh.
15. Typical for construction.
16. Typical for construction.
17. Typical for construction.
18. Typical for construction.
19. Annual sampling at 15 groundwater monitoring wells and 3 surface water sampling locations.
20. Monitoring wells sampled using low flow techniques. Estimate based on equipment costs for similar Wisconsin projects.
21. 18 water samples for each annual event analyzed for arsenic by method 6010.
22. Typical for annual groundwater monitoring reporting.
23. Typical based on similar Wisconsin projects.
24. Typical annual long-term maintenance costs for a cap.

Remedial Alternative Option 5
Excavation (1,000 ppm) + In-Situ Stabilization/Solidification (100 ppm) + PRB Liner (100 ppm) + Capping (100 ppm)
Opinion of Probable Cost
WDNR - Kewaunee Marsh, Kewaunee, Wisconsin
Project No. 344583.0000

	Item	Unit	Unit Cost	Qty.	Total
Pre-Design and Bench Testing Cost					
1	Additional Investigation	LS	$50,000	1	$50,000
2	Treatability Testing	LS	$15,000	1	$15,000
3	Field Pilot Study	LS	$75,000	1	$75,000
	SUBTOTAL OF PRE-DESIGN AND BENCH TESTING				$140,000
Direct Capital Cost					
4	Mob/Demobilization	LS	$60,000	1	$60,000
5	Site Preparations/Temporary Controls	LS	$84,000	1	$84,000
6	Crane Mats	Load	$2,500	20	$50,000
7	Excavation (>1,000 ppm)				
a	Waste Characterization	LS	$2,000	1	$2,000
b	Slurry Walls	SF	$15.00	30,000	$450,000
c	Excavation	CY	$5.50	14,000	$77,000
d	Treatment to Non-Hazardous Levels	Ton	$5.00	14,000	$70,000
e	Contaminated Soil/Sediment Transport (Non-Haz)	Ton	$14.63	18,200	$266,200
f	Contaminated Soil/Sediment Disposal (Non-Haz)	Ton	$37.30	18,200	$678,900
g	Confirmation Sampling	Sample	$15.00	30	$450
h	Dewatering System	LS	$20,000	1	$20,000
i	Water Treatment	Ton	$10.00	7,000	$70,000
	EXCAVATION SUBTOTAL				$1,635,000
8	In-Situ Stabilization/Solidification (100 ppm - 1,000 ppm)				
a	Stabilization Additive - ABC-Olé	lb	$0.90	2,484,000	$2,236,000
b	Stabilization Additive - Ferrous Sulfate	lb	$1.40	24,840	$34,800
b	Solidification Additives	Ton	$275	3,900	$1,072,500
c	Mixing	CY	$5.00	78,000	$390,000
d	Confirmation Sampling	Sample	$15.00	50	$750
	IN-SITU STABILIZATION/SOLIDIFICATION SUBTOTAL				$3,735,000
9	On-Site Management (100 ppm - 1,000 ppm)				
a	Permeable Reactive Barrier Liner	CY	$680	5,400	$3,672,000
b	Excavation	CY	$5.50	78,000	$429,000
c	Soil/Sediment Relocation	CY	$5.50	78,000	$429,000
	ON-SITE MANAGEMENT SUBTOTAL				$4,530,000
10	Backfill	CY	$13	78,000	$1,014,000
11	Capping (Relocated Soil/Sediments 100 ppm - 1,000 ppm)				
a	Gas Permeable Bedding Layer	CY	$19.00	4,000	$76,000
b	Geotextile	SF	$0.40	120,000	$48,000
c	Geomembrane	SF	$0.85	120,000	$102,000
d	Fill Layer	CY	$15.00	4,000	$60,000
e	Topsoil and Seed	SF	$1.50	120,000	$180,000
	CAPPING SUBTOTAL				$466,000
12	Monitoring Well Installation	Well	$2,500	15	$37,500
13	Fence Replacement	LS	$12,000	1	$12,000
	SUBTOTAL OF DIRECT CAPITAL COST				$11,624,000
	20% CONTINGENCY				$2,325,000
	SUBTOTAL + CONTINGENCY OF DIRECT CAPITAL COST				$13,949,000

Remedial Alternative Option 5

Excavation (1,000 ppm) + In-Situ Stabilization/Solidification (100 ppm) + PRB Liner (100 ppm) + Capping (100 ppm)

Opinion of Probable Cost

WDNR - Kewaunee Marsh, Kewaunee, Wisconsin

Project No. 344583.0000 Ph. 00002

	Item	Unit	Unit Cost	Qty.	Total
Indirect Cost					
14	Remedial Design	LS	$40,000	1	$40,000
15	Geotechnical Design	LS	$20,000	1	$20,000
16	Contracting/Permitting	LS	$50,000	1	$50,000
17	Construction Oversight	%	10%	Direct Capital	$1,394,900
18	Reporting	LS	$20,000	1	$20,000
19	Project Management/Administration	%	2%	Direct Capital	$279,000
				SUBTOTAL OF INDIRECT CAPITAL COST	$1,804,000
Long-Term Cost					
20	Sampling - Labor	HR	$100	25	$2,500
21	Field Equipment and Expenses	Event	$1,500	1	$1,500
22	Lab	Event	$1,000	1	$1,000
23	Reporting	LS	$5,000	1	$5,000
24	Project Management/Administration	LS	$3,000	1	$3,000
25	Long-Term Maintenance - Cap	LS	$10,000	1	$10,000
				SUBTOTAL OF ANNUAL LONG-TERM COST	$23,000
PRESENT WORTH - LONG-TERM COST		30	years @	5%	$354,000
				OPTION 5 — TOTAL COST	**$16,247,000**
				+ 30%	**$21,120,000**
				- 10%	**$14,620,000**

Notes:

1. Costs determined from experience and estimates from other similar projects.
2. Interest rate 5%; the balance of an 8% interest rate less a 3% inflation rate, based on EPA approach for remedial cost estimating.
3. All costs are based on preliminary concepts. They are intended for remedial option comparison and not for final budgeting.

Created by: A. Enright
QC by: L. Auner
QA by: K. Vater/A. Sellwood

Assumptions
Remedial Alternative Option 5
Excavation (1,000 ppm) + In-Situ Stabilization/Solidification (100 ppm) +
PRB Liner (100 ppm) + Capping (100 ppm)

1. Estimate to delineate 100 ppm arsenic extents at the site.
2. Treatability study includes a $5,000 bench scale study for stabilization/solidification methods, a $5,000 bench scale study of discharge water treatment methods, and a $5,000 bench scale study for treatment of excavated materials prior to off-site disposal as non-hazardous.
3. Field pilot study includes a $25,000 stabilization/solidification amendments study, a $25,000 discharge water treatment methods study, and a $25,000 excavated materials treatment study. Costs based on previous work performed at the site.
4. Estimate based on previous TRC projects.
5. Temporary controls include erosion control, silt fencing, import stone for material storage areas, fuel tanks, and temporary fencing. Unit cost from 2010 Kewaunee Marsh Opinion of Probable cost, adjusted to 2020 costs using RSM cost index conversion.
6. Crane mats will be used to construct temporary roadways across the site to provide access for heavy machinery. Unit costs are typical costs for a load of 18 crane mats. Costs assume crane mat dimensions of 4 ft by 18 ft are laid three side-by-side to form temporary roadways, resulting in about 100 feet of temporary roadway per load of crane mats.
7. Includes excavation and off-site disposal of soil/sediment from all depth intervals sampled to date with arsenic concentrations exceeding 1,000 ppm.
   a. Estimate based on previous TRC projects.
   b. Slurry wall barriers are required to divide excavation areas into workable portions (estimated to extend around the perimeter of the current 1,000 ppm extents and to account for the interior division walls, with barriers to extend 10 ft deep) to minimize the generation of standing water requiring treatment. Unit costs are based on previous projects.
   c. Includes soil/sediment from all depth intervals sampled to date with arsenic concentrations exceeding 1,000 ppm. Unit costs from similar Wisconsin projects.
   d. Excavated soil/sediment with concentrations exceeding 1,000 ppm will require on-site treatment prior to transport to reduce arsenic concentrations to non-hazardous levels. This will be achieved through mixing with an amendment such as ZVI. Based on previous testing, an appropriate dose is approximately 0.5% ZVI by volume. At $1,000/ton for ZVI, this gives a treatment cost of $5/ton of soil/sediment to be treated, based on similar projects in Wisconsin. Use 1 ton/CY conversion factor for organic soil/sediment.
   e. Use 1.3 ton/CY conversion factor for organic soil/sediment mixed with 10% drying amendment. Unit costs from similar Wisconsin projects. Includes non-hazardous waste transport, freight charge, and fuel surcharge.
   f. Use 1.3 ton/CY conversion factor for organic soil/sediment mixed with 10% drying amendment. Unit costs from similar Wisconsin projects. Includes non-hazardous waste disposal costs and Wisconsin landfill tax costs.
   g. Samples analyzed for arsenic by method 6010.
   h. Treatment system to consist of frac tanks for water collection/mixing, a sand filter, bag filters, pumps, and a collection tank for testing prior to discharge. Estimate based on previous TRC projects.
   i. Includes treatment of liquids from soil/sediment dewatering and pumping accumulated water from within open excavation area. Assumes a discharge permit will be obtained to discharge treated water to wetland/river. Volume of water to be treated assumes excavated wetland soil/sediments are saturated with a porosity of 30% and that water accumulation in excavation is approximately equivalent to water generated from soil/sediment dewatering. A 1% dose of ZVI by weight of water to be treated is for cost estimating purposes. At $1,000/ton for ZVI, this gives a treatment cost of $10/ton of soil/sediment to be treated, based on similar projects in Wisconsin.
8. Includes in-situ stabilization/solidification of soil/sediment from all depth intervals sampled to date with arsenic concentrations ranging from 100 ppm to 1,000 ppm.
   a. For estimating purposes, used a dose of 1 pound of ABC-Olé per cubic foot of soil. Unit costs provided by supplier bid.
   b. For estimating purposes, used a dose of 1 pound of ferrous sulfate per every 100 lbs of ABC-Olé. Unit costs provided by supplier bid.
   c. Bentonite solidification amendment to be mixed at about 5% by volume of soil/sediment.

d. Includes in-situ mixing of amendments with soil/sediment from all depth intervals sampled to date with arsenic concentrations between 100 ppm to 1,000 ppm. Unit cost estimates based on previous TRC projects.
e. Samples analyzed for arsenic by method 6010.

9. Includes on-site management of stabilized/solidified soil/sediment from all depth intervals sampled to date with arsenic concentrations ranging from 100 ppm to 1,000 ppm.
   a. A permeable reactive barrier (PRB) will be used to line the sides and base of the area where excavated and solidified/stabilized soil/sediments will be relocated for on-site management. The on-site management zone is expected to cover approximately the same area as the current extents of surficial arsenic exceeding 1,000 ppm with a thickness of approximately 1 foot. Unit cost from previous TRC project includes installation labor and material costs for zero valent iron mixed with imported sand fill. There is no future replacement cost included for this PRB, as contaminant flux is expected to be limited due to the stabilization/solidification of soil/sediments placed within the on-site management zone.
   b. Includes soil/sediment from all depth intervals sampled to date with arsenic concentrations between 100 ppm to 1,000 ppm. Unit costs from similar Wisconsin projects.
   c. Transport of stabilized/solidified soil/sediment across the site into an on-site management zone. Includes soil/sediment from all depth intervals sampled to date with arsenic concentrations between 100 ppm to 1,000 ppm. Unit costs from similar Wisconsin projects
10. Backfill all areas relocated into the on-site management zone, which includes all depth intervals sampled to date with arsenic concentrations between 100 to 1,000 ppm. Unit costs from similar Wisconsin projects
11. A cap will be installed over the area where excavated and solidified/stabilized soil/sediments will be relocated for on-site management. The on-site management zone is expected to cover approximately the same area as the current extents of surficial arsenic exceeding 1,000 ppm.
   a. Gas permeable bedding layer constructed of granular fill to cover entire extents of capped area. This layer will be graded to support passive gas venting and surface water drainage, with an average 6-inch thickness. A 1% slope will be required to sufficiently vent gas. Cap design includes constructed vents at peaks of the cap for gas venting to prevent cap failure. Unit cost is based on similar Wisconsin projects and includes providing, placing, and compacting gravel fill.
   b. Geotextile layer to cover entire extents of capped area. Unit costs from Clean Air and Water Systems.
   c. 60-mil Textured HDPE Geomembrane to cover entire extents of capped area. Unit costs from Clean Air and Water Systems.
   d. 1-foot fill layer to cover entire extents of capped area to prevent hydraulic lift of cap layers. Unit cost is based on similar Wisconsin projects and includes providing, placing, and compacting general fill.
   e. 6-inch topsoil layer with seeding to cover entire extents of capped area. Unit cost from 2010 Kewaunee Marsh Opinion of Probable cost, adjusted to 2020 costs using RSM cost index conversion.
12. Installation of NR 141-compliant monitoring wells. Unit costs based on Geoprobe® driller bids for similar Wisconsin projects.
13. Fence replacement needed for section removed to access site during construction. Unit cost from 2010 Kewaunee Marsh Opinion of Probable cost, adjusted to 2020 costs using RSM cost index conversion.
14. Typical.
15. The geotechnical design cost is required to evaluate stability and geometry of items to be constructed on the marsh.
16. Typical for construction.
17. Typical for construction.
18. Typical for construction.
19. Typical for construction.
20. Annual sampling at 15 groundwater monitoring wells and 3 surface water sampling locations.
21. Monitoring wells sampled using low flow techniques. Estimate based on equipment costs for similar Wisconsin projects.
22. 18 water samples for each annual event analyzed for arsenic by method 6010.
23. Typical for annual groundwater monitoring reporting.
24. Typical based on similar Wisconsin projects.
25. Typical annual long-term maintenance costs for a cap.

Remedial Alternative Option 6.a
Excavation + Off-Site Disposal (1,000 ppm) + Backfill (1,000 ppm)
Opinion of Probable Cost
WDNR - Kewaunee Marsh, Kewaunee, Wisconsin
Project No. 344583.0000

	Item	Unit	Unit Cost	Qty.	Total
Pre-Design and Bench Testing Cost					
1	Additional Investigation	LS	$35,000	1	$35,000
2	Treatability Testing	LS	$10,000	1	$10,000
3	Field Pilot Study	LS	$50,000	1	$50,000
				SUBTOTAL OF PRE-DESIGN AND BENCH TESTING	$95,000
Direct Capital Cost					
4	Mob/Demobilization	LS	$40,000	1	$40,000
5	Site Preparations/Temporary Controls	LS	$84,000	1	$84,000
6	Crane Mats	Load	$2,500	10	$25,000
7	Excavation (>1,000 ppm)				
a	Waste Characterization	LS	$2,000	1	$2,000
b	Slurry Walls	SF	$15.00	30,000	$450,000
c	Excavation	CY	$5.50	14,000	$77,000
d	Treatment to Non-Hazardous Levels	Ton	$5.00	14,000	$70,000
e	Contaminated Soil/Sediment Transport (Non-Haz)	Ton	$14.63	18,000	$263,300
f	Contaminated Soil/Sediment Disposal (Non-Haz)	Ton	$37.30	18,000	$671,400
g	Confirmation Sampling	Sample	$15.00	30	$450
h	Dewatering System	LS	$20,000	1	$20,000
i	Water Treatment	Ton	$10.00	7,000	$70,000
j	Backfill	CY	$13.00	14,000	$182,000
				EXCAVATION SUBTOTAL	$1,807,000
8	Monitoring Well Installation	Well	$2,500	15	$37,500
9	Fence Replacement	LS	$12,000	1	$12,000
				SUBTOTAL OF DIRECT CAPITAL COST	$2,006,000
				20% CONTINGENCY	$401,000
				SUBTOTAL + CONTINGENCY OF DIRECT CAPITAL COST	$2,407,000
Indirect Cost					
10	Remedial Design	LS	$10,000	1	$10,000
11	Contracting/Permitting	LS	$10,000	1	$10,000
12	Construction Oversight	%	10%	Direct Capital	$240,700
13	Reporting	LS	$20,000	1	$20,000
14	Project Management/Administration	%	2%	Direct Capital	$48,100
				SUBTOTAL OF INDIRECT CAPITAL COST	$329,000
Long-Term Cost					
15	Sampling - Labor	HR	$100	25	$2,500
16	Field Equipment and Expenses	Event	$1,500	1	$1,500
17	Lab	Event	$1,000	1	$1,000
18	Reporting	LS	$5,000	1	$5,000
19	Project Management/Administration	LS	$3,000	1	$3,000
				SUBTOTAL OF ANNUAL LONG-TERM COST	$13,000
PRESENT WORTH - LONG-TERM COST		30	years @	5%	$200,000
				OPTION 6.A — TOTAL COST	**$3,031,000**
				+ 30%	**$3,940,000**
				- 10%	**$2,730,000**

Notes:
1. Costs determined from experience and estimates from other similar projects.
2. Interest rate 5%; the balance of an 8% interest rate less a 3% inflation rate, based on EPA approach for remedial cost estimating.
3. All costs are based on preliminary concepts. They are intended for remedial option comparison and not for final budgeting.

Created by: A. Enright
QC by: L. Auner
QA by: K. Vater/A. Sellwood

Assumptions
Remedial Alternative Option 6.a
Excavation + Off-Site Disposal (1,000 ppm) + Backfill (1,000 ppm)

1. Estimate to delineate 1,000 ppm arsenic extents at the site.
2. Treatability study includes a $5,000 bench scale study of discharge water treatment methods and a $5,000 bench scale study for treatment of excavated materials prior to off-site disposal as non-hazardous.
3. Field pilot study includes a $25,000 discharge water treatment methods study and a $25,000 excavated materials treatment study. Costs based on previous work performed at the site.
4. Estimate based on previous TRC projects.
5. Temporary controls include erosion control, silt fencing, import stone for material storage areas, fuel tanks, and temporary fencing. Unit cost from 2010 Kewaunee Marsh Opinion of Probable cost, adjusted to 2020 costs using RSM cost index conversion.
6. Crane mats will be used to construct temporary roadways across the site to provide access for heavy machinery. Unit costs are typical costs for a load of 18 crane mats. Costs assume crane mat dimensions of 4 ft by 18 ft are laid three side-by-side to form temporary roadways, resulting in about 100 feet of temporary roadway per load of crane mats.
7. Includes excavation and off-site disposal of soil/sediment from all depth intervals sampled to date with arsenic concentrations exceeding 1,000 ppm.
    a. Estimate based on previous TRC projects.
    b. Slurry wall barriers are required to divide excavation areas into workable portions (estimated to extend around the perimeter of the current 1,000 ppm extents and to account for the interior division walls, with barriers to extend 10 ft deep) to minimize the generation of standing water requiring treatment. Unit costs are based on previous projects.
    c. Includes soil/sediment from all depth intervals sampled to date with arsenic concentrations exceeding 1,000 ppm. Unit costs from similar Wisconsin projects.
    d. Excavated soil/sediment with concentrations exceeding 1,000 ppm will require on-site treatment prior to transport to reduce arsenic concentrations to non-hazardous levels. This will be achieved through mixing with an amendment such as ZVI. Based on previous testing, an appropriate dose is approximately 0.5% ZVI by volume. At $1,000/ton for ZVI, this gives a treatment cost of $5/ton of soil/sediment to be treated, based on similar projects in Wisconsin. Use 1 ton/CY conversion factor for organic soil/sediment.
    e. Use 1.3 ton/CY conversion factor for organic soil/sediment mixed with 10% drying amendment. Unit costs from similar Wisconsin projects. Includes non-hazardous waste transport, freight charge, and fuel surcharge.
    f. Use 1.3 ton/CY conversion factor for organic soil/sediment mixed with 10% drying amendment. Unit costs from similar Wisconsin projects. Includes non-hazardous waste disposal costs and Wisconsin landfill tax costs.
    g. Samples analyzed for arsenic by method 6010.
    h. Treatment system to consist of frac tanks for water collection/mixing, a sand filter, bag filters, pumps, and a collection tank for testing prior to discharge. Estimate based on previous TRC projects.
    i. Includes treatment of liquids from soil/sediment dewatering and pumping accumulated water from within open excavation area. Assumes a discharge permit will be obtained to discharge treated water to wetland/river. Volume of water to be treated assumes excavated wetland soil/sediments are saturated with a porosity of 30% and that water accumulation in excavation is approximately equivalent to water generated from soil/sediment dewatering. A 1% dose of ZVI by weight of water to be treated is for cost estimating purposes. At $1,000/ton for ZVI, this gives a treatment cost of $10/ton of soil/sediment to be treated, based on similar projects in Wisconsin.
    j. Backfill all areas excavated, which includes all depth intervals sampled to date with arsenic concentrations exceeding 1,000 ppm. Unit costs from similar Wisconsin projects.
8. Installation of NR 141-compliant monitoring wells. Unit costs based on Geoprobe® driller bids for similar Wisconsin projects.
9. Fence replacement needed for section removed to access site during construction. Unit cost from 2010 Kewaunee Marsh Opinion of Probable cost, adjusted to 2020 costs using RSM cost index conversion.
10. Typical.
11. Typical for construction.
12. Typical for construction.

13. Typical for construction.
14. Typical for construction.
15. Annual sampling at 15 groundwater monitoring wells and 3 surface water sampling locations.
16. Monitoring wells sampled using low flow techniques. Estimate based on equipment costs for similar Wisconsin projects.
17. 18 water samples for each annual event analyzed for arsenic by method 6010.
18. Typical for annual groundwater monitoring reporting.
19. Typical based on similar Wisconsin projects.

Remedial Alternative Option 6.b
Excavation + Off-Site Disposal (100 ppm) + Backfill (100 ppm)
Opinion of Probable Cost
WDNR - Kewaunee Marsh, Kewaunee, Wisconsin
Project No. 344583.0000

	Item	Unit	Unit Cost	Qty.	Total
Pre-Design and Bench Testing Cost					
1	Additional Investigation	LS	$50,000	1	$50,000
2	Treatability Testing	LS	$10,000	1	$10,000
3	Field Pilot Study	LS	$50,000	1	$50,000
				SUBTOTAL OF PRE-DESIGN AND BENCH TESTING	$110,000
Direct Capital Cost					
4	Mob/Demobilization	LS	$40,000	1	$40,000
5	Site Preparations/Temporary Controls	LS	$84,000	1	$84,000
6	Crane Mats	Load	$2,500	20	$50,000
7	Excavation (>100 ppm)				
a	Waste Characterization	LS	$2,000	1	$2,000
b	Slurry Walls	SF	$15.00	50,000	$750,000
c	Excavation	CY	$5.50	92,000	$506,000
d	Treatment to Non-Hazardous Levels	Ton	$5.00	14,000	$70,000
e	Contaminated Soil/Sediment Transport (Non-Haz)	Ton	$14.63	119,600	$1,749,200
f	Contaminated Soil/Sediment Disposal (Non-Haz)	Ton	$37.30	119,600	$4,461,100
g	Confirmation Sampling	Sample	$15.00	80	$1,200
h	Dewatering System	LS	$20,000	1	$20,000
i	Water Treatment	Ton	$10.00	47,000	$470,000
j	Backfill	CY	$13.00	92,000	$1,196,000
				EXCAVATION SUBTOTAL	$9,226,000
8	Monitoring Well Installation	Well	$2,500	15	$37,500
9	Fence Replacement	LS	$12,000	1	$12,000
				SUBTOTAL OF DIRECT CAPITAL COST	$9,450,000
				20% CONTINGENCY	$1,890,000
				SUBTOTAL + CONTINGENCY OF DIRECT CAPITAL COST	$11,340,000
Indirect Cost					
10	Remedial Design	LS	$10,000	1	$10,000
11	Contracting/Permitting	LS	$10,000	1	$10,000
12	Construction Oversight	%	10%	Direct Capital	$1,134,000
13	Reporting	LS	$20,000	1	$20,000
14	Project Management/Administration	%	2%	Direct Capital	$226,800
				SUBTOTAL OF INDIRECT CAPITAL COST	$1,401,000
Long-Term Cost					
15	Sampling - Labor	HR	$100	25	$2,500
16	Field Equipment and Expenses	Event	$1,500	1	$1,500
17	Lab	Event	$500	1	$500
18	Reporting	LS	$5,000	1	$5,000
19	Project Management/Administration	LS	$3,000	1	$3,000
				SUBTOTAL OF ANNUAL LONG-TERM COST	$12,500
PRESENT WORTH - LONG-TERM COST		5	years @	5%	$55,000
				OPTION 6.B — TOTAL COST	**$12,906,000**
				+ 30%	**$16,780,000**
				- 10%	**$11,620,000**

Notes:
1. Costs determined from experience and estimates from other similar projects.
2. Interest rate 5%; the balance of an 8% interest rate less a 3% inflation rate, based on EPA approach for remedial cost estimating.
3. All costs are based on preliminary concepts. They are intended for remedial option comparison and not for final budgeting.

Created by: A. Enright
QC by: L. Auner
QA by: K. Vater/A. Sellwood

Assumptions
Remedial Alternative Option 6.b
Excavation + Off-Site Disposal (100 ppm) + Backfill (100 ppm)

1. Estimate to delineate 100 ppm arsenic extents at the site.
2. Treatability study includes a $5,000 bench scale study of discharge water treatment methods and a $5,000 bench scale study for treatment of excavated materials prior to off-site disposal as non-hazardous.
3. Field pilot study includes a $25,000 discharge water treatment methods study and a $25,000 excavated materials treatment study. Costs based on previous work performed at the site.
4. Estimate based on previous TRC projects.
5. Temporary controls include erosion control, silt fencing, import stone for material storage areas, fuel tanks, and temporary fencing. Unit cost from 2010 Kewaunee Marsh Opinion of Probable cost, adjusted to 2020 costs using RSM cost index conversion.
6. Crane mats will be used to construct temporary roadways across the site to provide access for heavy machinery. Unit costs are typical costs for a load of 18 crane mats. Costs assume crane mat dimensions of 4 ft by 18 ft are laid three side-by-side to form temporary roadways, resulting in about 100 feet of temporary roadway per load of crane mats.
7. Includes excavation and off-site disposal of soil/sediment from all depth intervals sampled to date with arsenic concentrations exceeding 100 ppm.
    a. Estimate based on previous TRC projects.
    b. Slurry wall barriers are required to divide excavation areas into workable portions (estimated to extend around the perimeter of the current 100 ppm extents and to account for the interior division walls, with barriers to extend 10 ft deep) to minimize the generation of standing water requiring treatment. Unit costs are based on previous projects.
    c. Includes soil/sediment from all depth intervals sampled to date with arsenic concentrations exceeding 100 ppm. Unit costs from similar Wisconsin projects.
    d. Excavated soil/sediment with concentrations exceeding 1,000 ppm will require on-site treatment prior to transport to reduce arsenic concentrations to non-hazardous levels. This will be achieved through mixing with an amendment such as ZVI. Based on previous testing, an appropriate dose is approximately 0.5% ZVI by volume. At $1,000/ton for ZVI, this gives a treatment cost of $5/ton of soil/sediment to be treated, based on similar projects in Wisconsin. Use 1 ton/CY conversion factor for organic soil/sediment.
    e. Use 1.3 ton/CY conversion factor for organic soil/sediment mixed with 10% drying amendment. Unit costs from similar Wisconsin projects. Includes non-hazardous waste transport, freight charge, and fuel surcharge.
    f. Use 1.3 ton/CY conversion factor for organic soil/sediment mixed with 10% drying amendment. Unit costs from similar Wisconsin projects. Includes non-hazardous waste disposal costs and Wisconsin landfill tax costs.
    g. Samples analyzed for arsenic by method 6010.
    h. Treatment system to consist of frac tanks for water collection/mixing, a sand filter, bag filters, pumps, and a collection tank for testing prior to discharge. Estimate based on previous TRC projects.
    i. Includes treatment of liquids from soil/sediment dewatering and pumping accumulated water from within open excavation area. Assumes a discharge permit will be obtained to discharge treated water to wetland/river. Volume of water to be treated assumes excavated wetland soil/sediments are saturated with a porosity of 30% and that water accumulation in excavation is approximately equivalent to water generated from soil/sediment dewatering. A 1% dose of ZVI by weight of water to be treated is for cost estimating purposes. At $1,000/ton for ZVI, this gives a treatment cost of $10/ton of soil/sediment to be treated, based on similar projects in Wisconsin.
    j. Backfill all areas excavated, which includes all depth intervals sampled to date with arsenic concentrations exceeding 100 ppm. Unit costs from similar Wisconsin projects.
8. Installation of NR 141-compliant monitoring wells. Unit costs based on Geoprobe® driller bids for similar Wisconsin projects.
9. Fence replacement needed for section removed to access site during construction. Unit cost from 2010 Kewaunee Marsh Opinion of Probable cost, adjusted to 2020 costs using RSM cost index conversion.
10. Typical.
11. Typical for construction.
12. Typical for construction.

13. Typical for construction.
14. Typical for construction.
15. Annual sampling at 15 groundwater monitoring wells and 3 surface water sampling locations.
16. Monitoring wells sampled using low flow techniques. Estimate based on equipment costs for similar Wisconsin projects.
17. 18 water samples for each annual event analyzed for arsenic by method 6010.
18. Typical for annual groundwater monitoring reporting.
19. Typical based on similar Wisconsin projects.