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HERRINGTON LAKE CORRECTIVE ACTION PLAN: PHASE I TECHNICAL MEMORANDUM AND PHASE II PLAN

MERCER COUNTY, KENTUCKY

Prepared For: Kentucky Utilities Company for Submittal to: Kentucky Division of Water

Agreed Order No. DOW - 17001

RAMBOLL

Prepared by: Ramboll

DRAFT HERRINGTON LAKE CORRECTIVE ACTION PLAN PHASE I TECHNICAL MEMORANDUM AND PHASE II PLAN

MERCER COUNTY, KENTUCKY

Revision	**1**
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ACRONYMS AND ABBREVIATIONS

°C	degrees Celsius
µg/D	micrograms per day
µg/L	micrograms per liter
µm	micron or micrometer
AsIII or As3+	arsenate
AsV or As5+	arsenite
AT	averaging time
bw	body weight
bws	below water surface
Cabinet	Kentucky Energy and Environment Cabinet
CAP	corrective action plan
CCR	coal combustion residuals
CF	conversion factor
CI	Curds Inlet
cm	centimeter
CPUE	catch per unit effort
CSF	cancer slope factor
Dix Dam	Dix River hydroelectric dam
DO	dissolved oxygen
DR	Dix River
dw	dry weight
ED	exposure duration
EF	exposure frequency
ERA	ecological risk assessment
ESB	environmental services branch
ESV	ecological screening value
FD	field duplicate
FI	fractional intake
FSP	field sampling plan
g	grams
GIS	geographic information system
GPS	global positioning system
GWRAP	groundwater remedial action plan
HHRA	human-health risk assessment
HQ	HQ inlet
hr	hour
IDs	identification numbers
INF	ingestion rate of fish
IRM	interim remedial measure
KAR	Kentucky Administrative Record
KDFW	Kentucky Department of Fish and Wildlife Resources
KDOW	Kentucky Division of Water

kg	kilograms
KU	Kentucky Utilities Company
LHL	lower Herrington lake
LSU	Louisiana State University
MCL	maximum contaminant level
MDS	multiparameter display system
MeHg	methylmercury
mg/kg	milligram per kilogram
mg/L	milligram per liter
MHL	middle Herrington lake
mm	millimeters
mS/cm	micro Siemens per centimeter
MS/MSD	matrix spike/matrix spike duplicate
MSL	mean sea level
MW	megawatt
NELAP	National Environmental Laboratory Accreditation Program
NOV	notice of violation
pH	potential of hydrogen or acidity
Plant	E.W. Brown Generating Station
QA/QC	quality assurance/quality control
QAPP	quality assurance project plan
QBI	Quality Bioresources Incorporated
R4	USEPA Region 4
RBC	risk based concentration
RSL	regional screening level
RSV	refined screening value
SDG	sample data group
SOP	standard operating procedure
TOC	total organic carbon
USEPA	United States Environmental Protection Agency
WBFC	whole body fish concentration
WQC	water quality criteria
WQS	water quality standards
WW	wet weight
YOY	young-of-the-year
YSI	Yellow Springs Instruments

EXECUTIVE SUMMARY

This Phase I Technical Memorandum and Phase II Field Sampling Plan (hereafter referred to as the *Phase I Technical Memorandum*) is provided to the Kentucky Energy and Environment Cabinet (Cabinet) in accordance with the Corrective Action Plan (CAP) for Herrington Lake that was submitted to the Cabinet in August 2017. The Phase I sampling effort described in this report was implemented during the period of October through December 2017 and included field sampling locations in the lower and middle Herrington Lake regions, as well as Dix River (Figure ES-1).

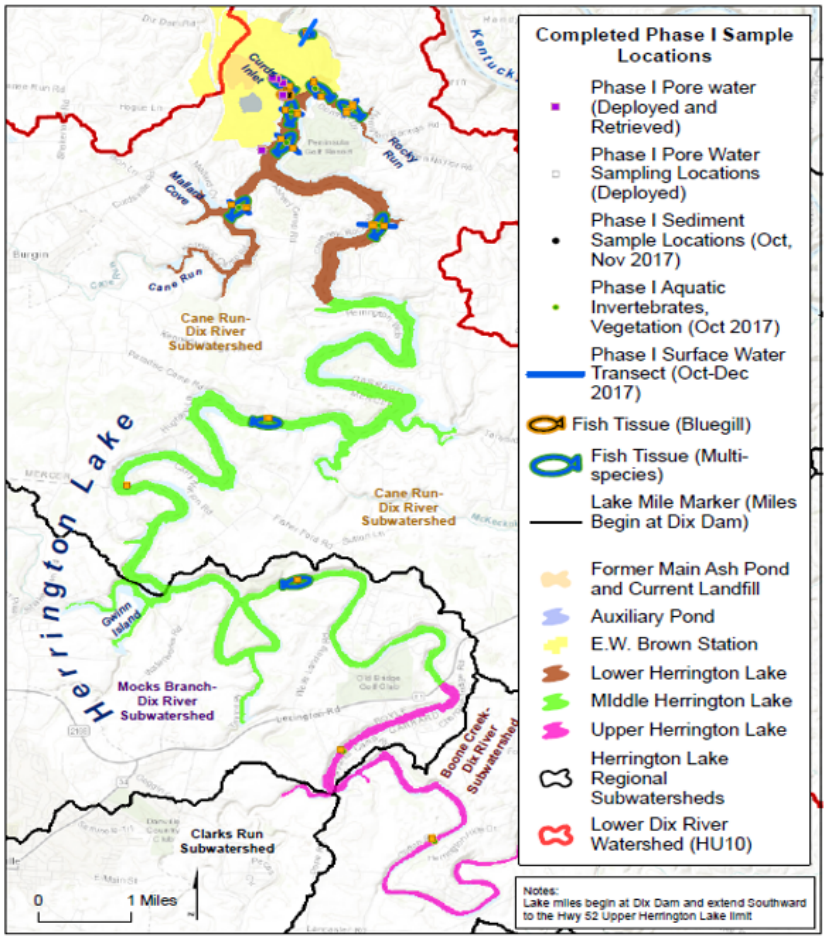


Figure ES-1: Herrington Lake Phase I Sample Collection Overview

The Phase I effort included collection of approximately 200 samples in the following environmental media: multiple species of fish, surface water (during both lake stratification and lake overturn conditions), sediment pore water, sediment, aquatic vegetation, and aquatic invertebrates. The fish species sampled in the lake were bluegill, bass, and catfish. The fish species sampled from Dix River, downstream from the Dix dam were brown trout, spotted sucker, northern hogsucker, and green sunfish.

The samples were submitted for laboratory for analyses in accordance with the CAP and Herrington Lake Quality Assurance Project Plan, and were analyzed for:

- total and speciated selenium
- total and speciated arsenic
- total and methylated mercury
- additional metals: cadmium, boron, lead, zinc iron, and magnesium
- sulfate, dissolved oxygen, lipids, moisture content, solids, and total organic carbon

The Phase I Technical Memorandum documents the Phase I field sampling effort and results of the analytical testing. Sampling results are presented in comparison with Kentucky Water Quality Standards and other risk-based criteria as a basis to understand potential data gaps from Phase I sampling to guide the Phase II sampling effort.

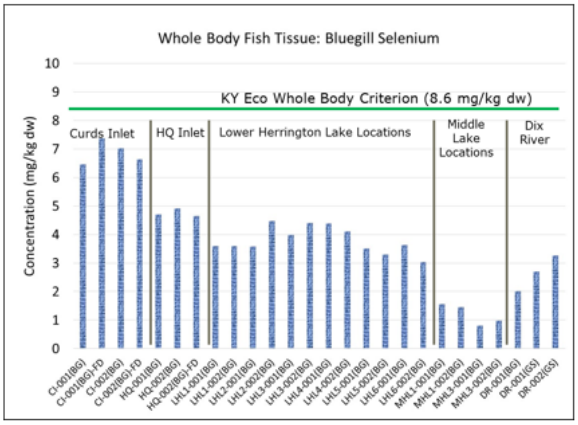
Key Findings for Phase I Fish Tissues

Fish tissue sampling was conducted to evaluate metals concentrations in whole body, filet and ovary tissues. More than 160 individual fish were collected and these comprised more than 60 fish composite samples, as indicated in Exhibit ES-1 (right). Based on an evaluation of the Phase I data set, there is sufficient fish tissue data to support the following conclusions:

- The Phase I fish tissue concentrations (whole body and ovaries) are less than the Kentucky whole body dry weight fish tissue standard for selenium and the ovary tissue standard for selenium (Figures ES-2 and ES-3).

Exhibit ES-1: Total Number of Fish and Samples Collected During Phase I Sampling

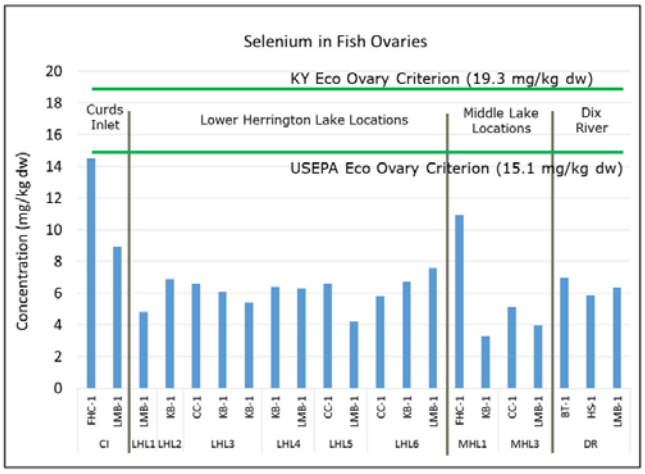
Species	Number of Fish Collected	Total Number of Samples
Bluegill	74	21
Green sunfish	7	2
Largemouth bass	30	12
Channel catfish	21	12
Kentucky (Spotted) bass	17	6
Flathead catfish	8	6
Spotted sucker	2	1
Northern hogsucker	2	1
Brown trout	1	1
Total:	162	62
Pan fish:	81	23
Larger fish:	81	39



Bluegill (BG), Green Sunfish (GS), Dry Weight (DW), Curds Inlet (CI), HQ Inlet (HQ), Lower Herrington Lake (LHL), Middle Herrington Lake (MHL), Dix River (DR), milligrams per kilogram (mg/kg), dry weight (DW)

Dry weight, consistent with Kentucky standard
Observations
- Below standard
- Highest in Curds Inlet, with gradient away from Curds Inlet
- Field duplicates show similar results (Curds Inlet)
- Lowest in MHL locations

Figure ES-2: Selenium in Whole-Body Fish-tissue Bluegill and Green Sunfish (Dry Weight)



Flathead Catfish (FHC), Largemouth Bass (LMB), Kentucky Bass (KB), Channel Catfish (CC), Brown Trout (BT), Northern Hogsucker (HS), Curds Inlet (CI), Lower Herrington Lake (LHL), Middle Herrington Lake (MHL), Dix River (DR), milligrams per kilogram (mg/kg), dry weight (DW)

Dry weight, consistent with Kentucky ecological standard

Figure ES-3: Selenium in Larger Fish Ovaries Larger Fish (Dry Weight)

- A bluegill "split" sample from the Phase I investigation was sent to the Cabinet for selenium tissue analysis, and the whole body tissue analytical results were consistent with those from the Phase I analyses.
- The concentrations of selenium in fish fillets from samples collected as part of the Phase I sampling program are less than human health risk-based ingestion values for selenium.
- The Phase I fish tissue concentrations are also below the screening level benchmarks identified from scientific literature (where available) for arsenic, cadmium, boron, lead, and zinc for ecological receptors (based on whole body concentrations) and human health receptors (based on fillet concentrations).

- The concentrations of methyl mercury in fish tissue fillet and whole body samples (the most dominant form of mercury) are below risk-based screening levels for most of the fish samples, with some exceedances observed in areas of the lake away from Curds Inlet.
- Arsenic speciation in fish fillet tissues demonstrated that inorganic arsenic (the form of arsenic that is potentially toxic to humans) is not present in fish fillets or is present in fish fillets at concentrations lower than the human health standard for arsenic ingestion in fish tissues.
- Two data gaps were identified for the fish dataset that will guide Phase II fish sampling.
    - Additional sampling of fish is warranted for selenium because the Phase I results showed lower concentrations in October 2017 than those reported for samples collected by the Cabinet in May of 2016. Therefore, targeted collection of fish and analysis of selenium only is proposed for Phase II study.
    - The results of a young of the year (YOY) study of fish in Curds Inlet conducted in 2016 became publically available during the implementation of the Phase I field program. A YOY study was not conducted in the Phase I sampling. To further assess the findings reported by the 2016 study, a YOY study is proposed for Phase II at multiple locations in Herrington Lake, including Curds Inlet and at locations away from Curds Inlet.

Key Findings for Phase I Surface Water Sampling

Phase I water sampling was conducted during lake thermal stratification and during lake overturn. Forty surface water samples were collected from various water depths for the two sampling events. Based on a review of these data, there is sufficient information for surface water (stratification and overturn) to support the following conclusions:

- Selenium concentrations in surface water are below the Kentucky water quality standards for stratified lake sampling and overturn sampling. The only exception is that sampling within the innermost portions of Curds Inlet during overturn detected selenium at a concentration equal to the Kentucky standard.
- Detected concentrations of arsenic, cadmium, lead, and zinc are below the Kentucky water quality standards and USEPA screening levels. Detected concentrations of boron are below risk-based screening concentrations (Kentucky does not have water quality criteria for boron).
- Detected concentrations of methyl mercury in water samples are below risk-based screening levels.
- Total and dissolved mercury in stratified lake surface water from Curds Inlet at concentrations that exceeded the Kentucky and USEPA ecological and human health standards. The lake overturn water sampling total and dissolved mercury concentrations did not exceed either Kentucky or USEPA risk based standards. The lowest risk-based standard for ecological and human health are based on a value for water protective of fish tissue bioaccumulation and ingestion. Due to the transient nature of the elevated mercury concentration in Curds Inlet, additional sampling of mercury in surface water is planned for Phase II.

Key Findings for Phase I Sediment Pore Water and Sediment Sampling

Phase I sampling included 16 pore water samples and approximately 30 sediment samples. There is sufficient information for sediment pore water and sediment to support the following conclusions:

- The concentrations for sediment samples indicate that selenium and arsenic are elevated at Curds Inlet transect CI-3A, the thalweg sample in the central part of Curds Inlet. Other locations within Curds Inlet further from the lake are also elevated for selenium and arsenic. Therefore, Phase II sampling will include additional characterization around Transect CI-3.

- The highest cadmium concentration in sediment was observed at location CI-1, which is an area within Curds Inlet that is now well characterized. No additional characterization is needed based on these data.
- Sediment pore water concentrations were lower than the Kentucky water quality standards, which provides a conservative comparison because the water quality standards protect fish and other aquatic wildlife, not all of which inhabit pore water. However, some of the pore water sampling devices from the Phase I sampling effort could not be recovered, including the sampler at CI-3A.
- Based on the results from the Phase I sampling program, sediment and pore water sampling is proposed for Phase II in Curds Inlet to further characterize conditions around CI-3A. The Phase II sediment and pore water sampling will include the same inorganic constituents as analyzed in the Phase I (i.e., selenium, arsenic, mercury, cadmium, boron, lead, magnesium, and iron). Sediment pore water samples for Phase II will also include analysis for speciated selenium and arsenic.

Key Findings for Phase I Aquatic Vegetation and Aquatic Invertebrate Samples

Aquatic vegetation and aquatic invertebrates were each sampled at 12 locations. Based on a review of these data, there is sufficient information for aquatic vegetation and aquatic invertebrates to support the following conclusions:

- There are no specific criteria for comparison to these data. Concentrations of the chemicals evaluated showed comparable results across the sampled locations.
- Characterization of aquatic vegetation and invertebrates is sufficient and no additional data collection is warranted in the Phase II sampling program.

Proposed Phase II Sampling

The Phase II sampling program is to designed to fill data gaps identified from the evaluation of Phase I sampling data. The Phase II Study Area will include portions of the Herrington Lake Study Area, with particular focus on Curds Inlet and other areas and embayments adjacent to, or near, the E.W. Brown Generating Station. The Phase II field program is focused on the following elements (illustrated in Figure ES-2):

- **Young of the Year (YOY) Fish Assessment**: A YOY fish study will be conducted. The study will target bass species at locations in Curds Inlet and other locations in Herrington Lake. YOY bass collections will be conducted in 6 areas that provide opportunity to measure a gradient of potential differences away from Curds Inlet, if such a gradient exists. Two YOY areas are planned for Curds Inlet and 4 additional areas are planned as indicated on Figure ES-2.

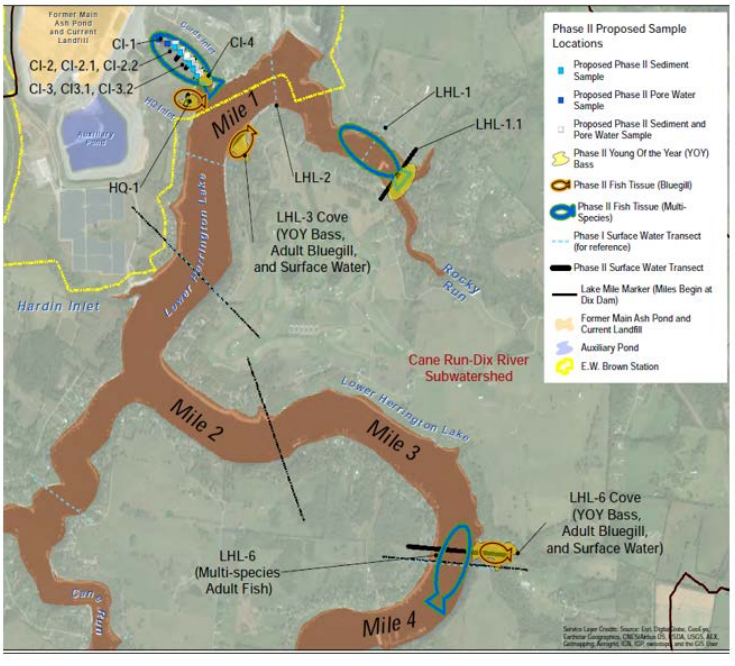


Figure ES-2. Phase II Sampling Plan Overview

- **Whole body fish tissue collection**: Collection of whole body adult and YOY fish samples will build on Phase I results to provide additional characterization of selenium levels in whole body fish, focused on Curds Inlet and other lake areas. Fish sampling for Phase II will be:
  - 12 YOY composite fish samples, each comprised of 10 individual fish (for a total of 120 fish)
  - 11 bluegill, bass, and catfish samples, each comprised of 2 to 5 individual fish (for a total of 22 to 55 fish)
  - Approximately 10% of the whole body fish sample freeze dry aliquots will also be submitted to the Kentucky Environmental Services Branch for split sample analysis as part of the quality assurance program.
- **Surface Water Samples**: Surface water samples will be collected concurrent with YOY fish collection at each of the 6 locations. This information will provide insight into chemicals in the environment relative to water quality standards. Water profiles will be performed to determine lake thermal stratification and the stratified water samples will be sampled. Phase II water samples will be analyzed for total and dissolved metals, mercury, and methyl mercury.
- **Sediment Pore Water and Sediment**: Sediment pore water and sediment samples are planned for Curds Inlet only. These will allow more focused characterization around the location CI-3A where the highest concentrations of selenium and arsenic were observed. Transect CI-3 will be resampled to confirm the Phase I analytical results. Four new transects will be added near CI-3. Thirteen pore water samples and 18 sediment samples are planned for Phase II sampling. In situ pore water samplers will be deployed at locations along the new transects and at former transects where pore water was not collected (at the mouth of Curds Inlet) and where samplers deployed in Phase I could not be retrieved in the interior of Curds Inlet. Phase II sediment pore water samples will be analyzed for total and dissolved metals, mercury, and methyl mercury, and speciated selenium and arsenic. Phase II sediment samples will be analyzed for metals, mercury, and methyl mercury.

The Phase II field program will be implemented during one or more events in the summer of 2018 (June) scheduled to take into account water levels, water temperatures, and fish spawning. The sampling plan and analytical methods identified for the sample media will ensure that data are of sufficient quality and quantity to be used for the human health and ecological risk assessments that will be performed for the Study Area. Samples will be collected in accordance with the approved Quality Assurance Project Plan and Standard Operating Procedures.

1. INTRODUCTION

This *Phase I Technical Memorandum and Phase II Field Sampling Plan* (hereafter referred to as the *Phase I Technical Memorandum*) is provided to the Kentucky Energy and Environment Cabinet (Cabinet) in accordance with the August 2017 *Corrective Action Plan (CAP) for Herrington Lake* (Ramboll 2017a). The CAP for Herrington Lake was developed and submitted to the Cabinet as part of efforts to resolve the January 11, 2017 Notice of Violation (NOV) received by Kentucky Utilities Company (KU) due to detections of selenium in whole-body fish-tissue from Herrington Lake at concentrations above Kentucky's water quality standard for protection of aquatic life. To resolve the NOV, KU entered into an Agreed Order with the Cabinet on January 30, 2017 that required an investigation of sediment and surface water in Herrington Lake. Specifically, the Agreed Order directs KU to develop and submit for review and approval:

> *"A plan for (1) the further investigation of sediments, surface water quality and biological receptors in Herrington Lake, including an appropriate assessment of human-health and ecological risks, (2) an assessment of the sources of selenium impacts, and (3) a consideration of remedial actions, if necessary, to supplement the Groundwater Remedial Action Plan (GWRAP), and a schedule for implementation of such plan for selenium impacts found to be from the E.W. Brown Station."*

It is noted that while the Agreed Order focuses on selenium impacts, the CAP was designed to also address other constituents of potential interest typically present in coal combustion residuals (CCR), including arsenic, mercury, cadmium, boron, lead, zinc, magnesium, iron, as well as other parameters needed to better understand the aquatic system (like sulfate, total organic carbon, and hardness). The CAP for Herrington Lake was approved by the Cabinet in March 2018.

1.1 Study Area Location and History

The E.W. Brown Generating Station (plant) is on the east edge of Mercer County, approximately 3.8 miles northeast of the city of Burgin (Figure 1-1). The plant is located on the west side of the Herrington Lake portion of the Dix River next to a hydroelectric dam (Dix Dam) built by KU in the 1920s. A coal-fired generating plant (currently consisting of three units) has operated at the site since the 1950s, and more recently a combustion turbine generating plant (consisting of seven combustion turbine units that can be fueled by either fuel oil or natural gas) was added to the plant to meet peak demands. In 2016, KU commenced operation of a 10 megawatt (MW) universal solar facility comprised of more than 44,000 solar panels on a 50-acre tract at the plant site. A site layout map is provided in Figure 1-2.

The plant has generated and disposed of CCR since the 1950s. Historically, CCR consisted primarily of bottom ash and fly ash generated from coal combustion. Beginning in 2009, gypsum began to be produced a scrubber installed to remove sulfur dioxide from the plant's air emissions. Ash was sluiced to the Main Ash Pond, or Main Pond, located directly south of the generating station. As the Main Pond filled, it was expanded twice, in 1973 and 1989, and at time of closure covered approximately 114 acres. In 2008, a second pond (referred to as the Auxiliary Pond, or "Aux Pond") was constructed as a temporary settling pond until the Main Pond could be expanded again. In late 2008, the Main Pond was taken out of service, and the sluicing operation was switched to the Auxiliary Pond. Much of the Main Pond was covered with soil in 2011 in preparation for construction of a landfill over the closed pond. Construction of a special waste landfill over the top of the Main Pond was permitted in 2015 and completed in 2016, and this landfill is currently receiving CCR (including bottom ash, fly ash and gypsum) generated by the plant. Construction of the landfill atop the Main Ash Pond also served to cap the former pond.

Beginning in 2015, KU initiated additional remediation activities to address elevated levels of certain metals in on-site groundwater believed to be associated with CCR disposal in the Main Ash Pond. This

work is being conducted in accordance with the GWRAP approved by the Cabinet in October 2015 (AMEC 2015, KYDWM 2015). These remedial actions are underway.

As a condition of the issuance of an operating permit for the new CCR landfill, KU was required to (1) develop a closure plan for the Main Pond; and (2) develop a remedial action plan to define specific methods to be used to abate groundwater contamination from the facility and prevent further groundwater contamination. The *Main Ash Pond Closure Plan* (AMEC, 2014) was submitted by KU in 2014. This plan describes the final capping of the Main Pond in connection with the construction of the new CCR landfill over the Main Pond. In addition, as described in the GWRAP, KU has initiated significant remedial actions (referred to as interim remedial measures, or IRMs) that are designed to mitigate the release of constituents of interest into groundwater and limit the migration of impacted groundwater from on-site sources. It is expected that these interim remedial actions are helping to control further migration of constituents of interest, including selenium, from the plant site to Herrington Lake, mostly by preventing surface water infiltration and recharge of groundwater in target areas.

The IRMs implemented at the site during the period of 2014 through 2016 are summarized in Table 1-1; the performance of these IRMs is being monitored by KU in accordance with the GWRAP, and they are expected to become part of the permanent remedial action for the site, as recognized by the Agreed Order. In order to evaluate the performance of the IRMs, the GWRAP, Agreed Order and solid waste permits require KU to conduct ongoing monitoring of groundwater and springs in the vicinity of Herrington Lake. The results of this monitoring are reported semiannually to the Cabinet. KU is also monitoring changes to conditions in the Main Pond as a result of the IRMs and construction of the new overlying CCR landfill. Spring data was submitted to the Division of Waste Management in *Groundwater Compliance Monitoring Reports* to support the GWRAP. Groundwater monitoring well data has been posted to a public website, as required by the *Disposal of Coal Combustion Residuals from Electric Utilities final rule*. Kentucky Pollution Discharge Elimination System (KPDES) outfall data was submitted to the Division of Water in monthly *Discharge Monitoring Reports (DMR)*.

1.2 Phase I Technical Memorandum Overview and Organization

This Phase I Technical Memorandum contains the full Phase I field results, discusses the data gaps that are the basis of the proposed Phase II sampling program, and provides the proposed Phase II Field Sampling Plan (FSP). This Phase I Technical Memorandum (including the Phase II FSP) is submitted in partial fulfilment of obligations under the Agreed Order. The preliminary results for the Phase I investigation were presented to the Cabinet on March 16, 2018 during a meeting between the Cabinet and representatives of KU. As agreed upon during the March 16, 2018 meeting, the proposed Phase II portion of this Phase I Technical Memorandum was submitted to the Cabinet in draft on April 10, 2018 to facilitate the review of the proposed Phase II field efforts.

The remainder of the Phase I Technical Memorandum is organized as follows:

- Section 2 provides a description of Phase I sampling locations and sampling methods.
- Section 3 provides a summary of the field sample collection results.
- Section 4 discusses the field quality assurance and quality control procedures.
- Section 5 provides summarizes analytical results and discusses the Phase I results for the chemicals of interest.
- Section 6 provides the proposed Phase II Field Sampling Plan (FSP)

This Phase I Technical Memorandum also provides a series of supporting appendices, as follows:

- Appendix A provides Geographic coordinates for all sampling locations.
- Appendix B provides photo logs for all media sampled.
- Appendix C provides a summary of the surface water profiling results transcribed from the field data sheets (Appendix C1) and figures summarizing fish field-weight and field-length by species (Appendix C2).
- Appendix D provides the field data sheets.
- Appendix E provides complete laboratory reports, including the sample chain of custody records and information supporting Level II and Level IV validation information.
- Appendix F provides the third-party Level II and Level IV validation report.

As stated in the CAP, the goal of Phase I is to characterize environmental chemical constituents, particularly metals, in Lower Herrington Lake (LHL), with emphasis on selenium and arsenic in regions near the plant, including Curds Inlet, HQ Inlet, and Dix Dam (Ramboll 2017a). Phase I sampling effort was therefore most extensive within Curds Inlet nearest the plant to help provide a spatial gradient of any potential plant-related contributions of metals concentrations. The Phase I field effort also included multi-media sampling from the downgradient Dix River (DR) to measure and compare the river and lake metals levels. To provide a comparison to any non-plant-related contributions and to establish relevant background contaminant levels, fish-only sampling was completed at two middle Herrington Lake (MHL) locations, MHL1 and MHL3. Phase I also included analytical testing for arsenic (total and speciated), mercury (organic and elemental), cadmium, boron, lead, zinc, magnesium, iron and additional analytes including sulfate, total organic carbon (TOC), hardness, and speciated selenium and arsenic (analyzed to investigate bioavailability within the aquatic environment).

The sampling program design and analytical methods were chosen to ensure sufficient data quality and quantity for use in the Human Health Risk Assessment and Ecological Risk Assessment (HHRA and ERA) (as described in Sections 3 and 4 of the CAP).

To minimize any potential disruption from sample collection activities to spring fish migration or spawning patterns, or to invertebrate breeding periods, and to ensure optimal plant and aquatic invertebrate productivity, all sampling was completed during lake stratification and overturn conditions.

2. PHASE I FIELD SAMPLING LOCATIONS AND METHODS

As specified in the CAP, the Phase I field sampling effort targeted sample collection areas described as LHL and MHL, as identified in Figure 2-1 and Table 2-1. Section 3 of this report provides a detailed summary of the actual samples collected for each medium and discusses the sample results.

The LHL Phase I sampling targeted areas including Rocky Run Embayment, the main channel of the lake at the dam and upstream and downstream from Curds Inlet, HQ Inlet, and Hardin Inlet for the following sampling media: fish, surface water, sediment pore water, sediment, aquatic vegetation, and aquatic invertebrates (Table 2-1, Figure 2-1A, Figure 2-2B). The sampling areas for MHL were focused on fish collection only for the Phase I field effort (Figure 2-2C).

The Phase I sampling was conducted as identified in the CAP and associated Quality Assurance Project Plan (QAPP) and Standard Operating Procedures (SOPs) (Ramboll 2017a, b, c, d, e, f). The Phase I field effort was implemented in 2017 as follow:

- October 1–17: stratification surface water sampling, biological tissue collection (fish, aquatic vegetation, and aquatic invertebrates), sediment collection, and in situ sediment pore water placement.
- November 1–4: extraction of in situ sediment pore water samplers. In addition, with lower water levels compared to October allowing access, an additional sediment sample was collected from the deep thalweg sample at the mouth of Curds Inlet.
- December 10–14: lake overturn surface water sampling.

Sample information for the Phase I field effort was recorded using a Trimble® Yuma Global Positioning System (GPS) Tablet to collect GIS coordinates. Coordinates are provided in Appendix A. Samples were photographed and photo logs are provided in Appendix B, as follows:

- Appendix B1 and B2 provide photos of fish sampling methods and fish samples, respectively.
- Appendix B3 provides photographs of lake profiling and surface water collection.
- Appendix B4 provides sediment pore water collection efforts and samples.
- Appendix B5 provides photographs of sediment sample collection.
- Appendix B6 provides photographs of the aquatic vegetation and aquatic invertebrate samples.

The Phase I sample collection followed the SOPs, including use of field data sheets. Surface water field data were summarized from the collection of field data sheets into a summary table provided in Appendix C. The individual field data sheets are provided in Appendix D, as follows:

- Appendices D1 and D2 provide Fishing Methods and Field-Catch Data Sheets and fish sample data sheets, respectively.
- Appendix D3 provides the lake profile and surface water data sheets.
- Appendix D4 and D4 provide the data sheets for aquatic vegetation and aquatic invertebrates, respectively.

The remainder of this section discusses:

- Fish sampling methods (Section 2.1).
- Surface water sampling methods (Section 2.2).
- Sediment pore water collection methods (Section 2.3).

- Sediment collection methods (Section 2.4).
- Aquatic vegetation sampling methods (Section 2.5).
- Aquatic invertebrate sampling methods (Section 2.6).

2.1 Fish Sampling Locations and Methods

Phase I biological tissue sampling included fish-tissue collection in accordance with the Kentucky Department of Water (KDOW) fish collection protocols, as applicable for the Herrington Lake study area habitats (KDOW 2014; Ramboll 2017c). Fish samples were collected from the LHL and MHL as indicated in Figures 2-2A, 2-2B, and 2-2C. The Phase I fish sampling targeted the following fish trophic levels:

1. A small home range, lower trophic level predator/prey fish, the bluegill (*Lepomis macrochirus*); in Dix River downstream from the dam where bluegill were not present, green sunfish (*Lepomis cyanellus*) were collected.
2. An upper trophic level predator - largemouth bass (*Micropterus salmoides*) and spotted bass (*Micropterus punctulatus*) (also known as Kentucky bass) were collected from the lake. One brown trout (*Salmo trutta*) was also collected from the Dix River below Dix Dam.
3. A bottom scavenger/ bottom dwelling ambush predator - channel catfish (*Ictalurus punctatus*) and flathead catfish (*Pylodictis olivaris*) were target species from the lake. Northern hogsucker and spotted sucker were collected from Dix River downstream from the dam where catfish were not present.

The fish were collected via electroshocking, overnight gill nets, opportunistically within the epilimnion (for largemouth bass, bluegill, and catfish) and the metalimnion (catfish only). Samples were collected within the specified 1.5 total days fishing effort per sampling region. Largemouth bass were the target species of bass but Kentucky bass were collected when largemouth bass were not available. The spotted (Kentucky) bass, native to the Mississippi River Basin, is often mistaken for the largemouth bass, but is generally smaller, with a slightly smaller mouth including a circular tooth patch on its tongue. The identification of fish collected as either largemouth bass or Kentucky bass was made by the field team at the time of sampling. Fisheries biologists conducting the field work were also tasked with making observations of physical deformities (if any) as they handled and photographed fish. Deformities were not observed.

Although significant effort was made to maintain target-species consistency throughout the Phase I study area, local environmental factors including habitat-type variability (e.g. above vs. below Dix Dam), steep near-shore bathymetry (not ideal habitat for bluegill or largemouth bass), and sample region size (e.g. small HQ Inlet) decreased daily catch-per-unit-effort (CPUE) and increased catch-species variability. The collected fish were grouped by location and species and then grouped into composite whole-body samples of 2–5 fish per sample, where sufficient fish numbers were collected.

Sample weights and sizes were field-measured and wherever possible, non-target fish were released into the lake at the time of sampling. Fish within a composite sample measured a minimum of 75% of the length of the longest individual. The fish samples were photographed and wrapped in aluminum foil (dull side against the sample) and placed into plastic bags. The bags were labelled with project name, sample identification number (ID), species, location, and date-time. The wrapped, bagged, and labeled fish samples were placed in the freezer and freezer temperatures were checked at the beginning and end of every field-sampling day to ensure that the samples remained frozen.

Fish ovary samples were collected from bass and catfish by the fisheries biologists in the field, as specified in the CAP.

2.2 Surface Water Sampling Locations and Methods

2.2.1 Lake Thermal Stratification and Overturn Sampling Approach

The CAP specified both stratified and overturn sampling during the Phase I program. Thermal stratification of a lake refers to a change in the temperature at different water depths resulting from seasonal changes in water's density with temperature. Stratification occurs because water density is a function of temperature, where water is most dense at 4 degrees Celsius. The Phase I sampling for Herrington Lake targeted up to three layers of stratification, the epilimnion (upper layer), metalimnion (middle layer), and hypolimnion (deepest layer), where stratification was documented. Some areas of the lake that were more shallow did not show stratification so only a single sample was collected from mid-depth within the water column. Lake overturn occurs when the water temperatures within the lake are similar and lake mixing can occur due to strong winds. Lake overturn for Herrington Lake occurred in December, as such, the overturn sampling occurred in December.

Knowledge of the Herrington lake stratification and overturn conditions was obtained using water profiling, as described in the Surface Water SOP (Ramboll 2017d). Water profiles were collected using an YSI® 650 Multiparameter Display System (MDS) water monitor with an Yellow Springs Instruments® (YSI®) 6920 V2 Sonde with 200 feet of field cable. This was done prior to collecting a target surface water sample(s) at multiple surface water sampling transects throughout lower Herrington Lake so that a general understanding of lake stratification or overturn was available to identify the sample depth intervals for sampling. The YSI® 650 MDS water quality monitor arrived lab-calibrated onsite and underwent daily calibration before sampling. Recorded water quality and lake profile parameters included water depth in feet below water surface (bws), turbidity (Secchi depth in feet) (Cialdi and Secchi, 1865), water temperature (in °C or degrees Celsius), dissolved oxygen (DO), specific conductivity (in millisiemens per centimeter, mS/cm) and acidity (pH). These parameters, considered together with time-of-year, helped determine the lake stratification profile(s) for each sampled transect. The surface water samples were co-located with the thalweg sediment samples. The surface water profiling indicated that, with the exception of one sampling transect CI-4 (CI indicates Curds Inlet) (water depth = 75–90 feet bws), located near the mouth of Curds Inlet, a single depth interval was deemed adequate during both stratification and overturn, for the shallower well-mixed locations within Curds Inlet, HQ Inlet, and Hardin Inlet, and the Dix River. Surface water sampling from shallow, downstream Dix River targeted a single mid-depth sample along this transect, since the shallow river water also appeared to be well-mixed, likely due to its close proximity to and flow from the dam.

2.2.2 Surface Water Sampling Methods

Surface water samples were collected using grab sampling methodology and a Van Dorn-type horizontal water sampler, as identified in the SOP (Ramboll 2017d). The sampler was lowered to the desired depth and then sent the messenger weight down the tethered line to trigger the caps on the end of the cylindrical sampler to close, sealing in the water at depth. Water samples were collected from the approximate middle of each of the surface water transects. Each sample was placed on ice, in a cooler to await shipment to the laboratory. With the exception of the matrix spike/matrix spike duplicate (MS/MSD) field samples, which require triple the volume of a standard parent sample, the Van Dorn provided sufficient volume to fill all of the laboratory containers with one grab sample.

Phase I surface water sampling thus included two events; one during stratification (October), and one during overturn (December). Comparing stratification to overturn results provides evidence to examine the possible influence of Herrington Lake seasonal cycling on the possible environmental cycling of selenium.

For the deeper sample transects (deeper than 70 feet bws) surface water sampling during stratification included one sample from each of the existing stratified lake layers, the sunlight zone (epilimnion), the

mid-depth zone (metalimnion aka thermocline), and from the deep-water zone (hypolimnion) to a maximum depth of approximately 100 feet bws. Overturn surface-water sampling included the collection of a single water sample from 25 feet bws. For the shallow inlet sampling locations having water depth of less than 25 feet bws, the single winter sample was collected from mid-depth in the water column.

With the exception of the single surface water sample collected from the Dix River, sampling was completed sequentially from downstream to upstream starting with location LHL-1 (Rocky Run Embayment), LHL-2 (Dix Dam), and proceeding into Curds Inlet, and then up the main lake through the open-water sampling locations of LHL-3, LHL-4, LHL-5, and LHL-6 (SW sampling locations displayed in Figures 3-1A, B). Surface water samples were field-filtered for dissolved metals. Samples were field filtered using a 0.45 micron (µm) filter on the end of the tubing, pouring the filtered water directly from the filter into the sample containers.

2.3 Sediment Pore Water Sampling Locations and Methods

Phase I sediment pore water sampling targeted Curds Inlet, HQ Inlet, and Hardin Inlet to collect samples for selenium and arsenic speciation. Pore water samples were collected via the use of duration-deployed passive sampling devices (hereafter referred to as peepers). The 5 and 10 milliliter diffusion chambers were filled with deionized water and capped with a 0.45 µm semipermeable latex mesh membrane, allowing constituents to diffuse into the chambers, providing time-averaged, estimate of the metals concentration in sediment pore water. Before deployment, the casing was rinsed by soaking in deionized water.

The Phase I pore water sampling locations were determined along transects and actual sample placement was based on the presence of sediment deposits identified by divers at the time of sampling. The peepers were buried horizontally within the upper 6-inch sediment interval of sediment. Phase I pore water locations are identified in Figures 2-1B. Wherever soft sediment was available, including at some thalweg locations, the divers hand-pressed the peepers into the sediment. The peepers then were connected to leader lines attached to small bright-orange buoys suspended underwater approximately 2–3 feet above the peeper. A GPS unit confirmed the sample geographic coordinates for each deployed peeper recorded.

The peepers were left in place to equilibrate for 3 weeks. The sampling devices were retrieved by divers. Sampling devices were removed from the sediments and rinsed gently with lake water upon retrieval. They were transported to the KU laboratory where pore water was extracted from the devices using syringes. The extraction and filling of the sample containers was done in anaerobic argon bags.

2.4 Sediment Sampling Locations and Methods

Sediment samples were collected from each transect identified in Figures 2-1A and 2-1B. Sediment samples were collected by divers just before the deployment of sediment pore water devices. The sediment pore water devices were placed as close to the sediment sample location as possible. The sediment sampling effort targeted depositional areas, and were collected from the inlets as follows:

- Location A: subaqueous, close to the deepest point in the channel (thalweg),
- Location B: subaqueous, at a depth below winter pool (approximately 725 feet above mean sea level [msl]; and,
- Location C: a location above winter pool elevation and below summer pool elevation (approximately 740 feet above msl).

Sediment sampling locations targeted the 0–6 inch interval of depositional sediment having consistent geochemical composition. Professional divers collected several grab samples from each location to ensure sufficient sediment volume for the relevant laboratory analyses. The individual samples were

mixed until observed to be homogeneous and then placed into glass sampling containers. Sediment lithology (texture, color, etc.) was recorded and photographed (Appendix B3).

2.5 Aquatic Vegetation Sampling Locations and Methods

Direct measurement of the aquatic vegetation selenium concentrations provides valuable site-specific data for use in an ERA, since selenium food web cycling (dietary input for bluegill and other small fishes) typically contributes more to its bioaccumulation in fish compared to uptake directly from surface water or sediment. Aquatic vegetation sampling preferentially consisted of periphyton and macrophytes. Aquatic plant material was collected using nets or gloved hands. Samples were placed directly in to holding containers, then on ice, in a cooler, until sufficient sample mass was achieved at each sampling location. If larger submerged or emergent aquatic vegetation was located within a target area, a sample was collected from that area and this would be included as part of a composite aquatic vegetation sample. The field sampling teams made conscious efforts to minimize any sampling-related disturbance to the aquatic habitat. To meet sample-volume requirements, individual plants were identified generally (e.g., periphyton, submerged aquatic vegetation), and then composited. Samples were rinsed, patted dry, and sample weight was measured and recorded. The samples were then wrapped in aluminum foil (dull side against the sample), and placed into a small, plastic zip-top bag with labels. The bag labels included project name, sample identification, sample date, and time, and the analyses requested. Samples were then placed in one of the two portable laboratory freezers to await shipment to the laboratory for analysis. The aquatic vegetation sample locations are displayed in Figures 2-1A and 2-1B.

2.6 Aquatic Invertebrates Sampling Locations and Methods

The Phase I Aquatic invertebrate sample locations were co-located with the surface water transects within lower Herrington Lake (Figures 2-1A and Figure 2-B). Aquatic invertebrate sample methods included fine-mesh hand netting, limited trap deployment (for crayfish in Curds Inlet and HQ inlet), and opportunistic hand-catch methods throughout each lake-section. Conscious effort was made to minimize any sampling-related disturbance to the aquatic habitat. The invertebrate samples were placed directly into lake water-filled Ziploc bags, then in a cooler having moderately cool temperature with limited direct exposure to the cold ice (to avoid early mortality before the end of the 24-hour (hr) depuration period), until sufficient sample mass was achieved at each sampling location. The individual invertebrates were then keyed, and field-identified to the lowest practical taxonomic level. Sample weight was then measured and recorded. After the 24-hr depuration period, the live-invertebrates were then wrapped in aluminum foil (dull side against the sample), and placed into a small, plastic zip-top bag. The bags were labelled with project name, sample identification, sample date, and time, and the analyses requested. Samples were then placed in one of the two portable laboratory freezers to await shipment to the laboratory for analysis.

3. FIELD SAMPLE COLLECTION RESULTS

The Phase I field program included the collection of more than 200 samples (counting quality assurance samples) from 18 sampling locations, including 15 Phase I sampling locations and three previously sampled locations 'CurdsNB', 'Curds1', and 'Curds2'. The number of samples collected is identified on Tables 3-1A and Table 3-1B for fish and other media, respectively. The remainder of this section discusses the collection results for each medium, including a discussion of the field parameters collected.

3.1 Fish Collection Results

Three trophic levels of fish were collected from each station, as identified on Table 3-1A (small home range forage fish, predatory fish, and bottom dwellers). Table 3-1A identifies the species collected at each location and the number of individual fish that were included in each fish composite sample. For example, as indicated in Table 3-1A, two bluegill composite samples were collected from Curds Inlet. The first bluegill composite sample was comprised of 4 individual fish and the second bluegill sample was comprised of 3 individual fish. Collectively, the October 2017 Phase I field sampling of lower and middle Herrington Lake included the collection of approximately 160 individual fish, combined for more than 50 composite fish samples (consisting of 2–5 fish per sample), and 10 single-fish samples (catfish, bass, and trout), for a total of more than 60 fish samples from the various species combined. Field-observations and recorded photographs for the collected fish revealed no observable physical deformities or evidence of parasites. Photographs of the fish samples are provided in Appendix A2. A summary of the weight and length of fish collected is provided in Appendix C1. Fish field data sheets are provided in Appendix D1. The following is a brief description of field sampling results for each of the fish tropic levels sampled.

- Lake Forage Fish Collection: Bluegills had the highest catch rate among the target fish species and almost all of the bluegills were caught using electroshocking. Approximately 80 bluegill and green sunfish were collected during the October 2017 Phase I fish sampling effort. The bluegill and green sunfish weights ranged from approximately 25–120 grams (g) (approximately 0.7–4 ounces), (Appendix C1 and Appendix D1).
- Lake Predatory Fish Collection: Approximately 50 bass were collected, including 30 largemouth bass and 17 spotted (Kentucky) bass. Bass weights ranged from 250–1550 g (approximately 0.5–3.5 pounds), and lengths ranged from 285–470 millimeters (mm) (approximately 11–18.5 inches) (Appendix C1 and Appendix D1).
- Lake Bottom Dwellers: Channel catfish (*Ictalurus punctatus*) and flathead Catfish (*Pylodictis olivaris*) were the bottom dwelling fish collected from the lake. Approximately 30 catfish were collected. The weights ranged from 550–8910 g, (approximately 1–19 pounds), lengths ranged from 415–865 mm (approximately 16–34 inches).
- Dix River below the Dam Collection: The fish collected from the Dix River below the dam were brown trout, northern hogsucker, spotted sucker, and green sunfish.
- Fish Ovary Sampling Results: Fish ovary samples were collected from multiple bass and catfish, and from a brown trout, and a northern hogsucker. A total of approximately 20 ovary samples were collected.

3.2 Surface Water Collection and Field Water Quality Parameters

Approximately 40 Phase I surface water samples were collected from the 14 surface water transects, including stratified and overturn samples (Table 3-1B). For each transect, if the surface water profile indicated lake stratification, then one sample was collected from each of the 2 to 3 stratified layers.

Sampling density was greatest within Curds Inlet, where approximately 15 of the samples collected. Each of the open-water water transects (LHL-2–LHL-6) were from each of the three stratified layers and again at 25 feet below the water surface during the overturn sampling. Each water sample included one field-filtered and one non-filtered set of containers, each constituting a unique sample ID. Two equipment blanks were also collected using distilled water poured into and then from the surface water collection device (Van Dorn, 1957).

Stratification sampling involved collection of water profiles. The water profile information collected in field data sheets was transcribed to provide a summary of field measures, as indicated in Appendix C2. Examples of lake stratification and lake overturn profiles based on temperature and dissolved oxygen are provided in Figures 3-1A and 3-1B, respectively. The deep open-water (LHL-2–LHL-6) summer surface water profiles differed significantly from overturn conditions recorded at the same locations (Figure 3-1A and Figure 3-1B). During the October 2017 sampling effort, the recorded surface water profiles for the deep open-water sampling transects exhibited summer lake stratification zones as follows:

- Epilimnion - the 0 to 30 foot water depth sunlight-zone, characterized by significantly higher DO concentrations.
- Metalimnion - the thermocline within the 70 to 90 foot depth interval, characterized by a significant decrease in water temperature and DO levels, and a clear partition from the deeper, colder water beneath it.
- Hypolimnion – deeper than 100 feet, characterized by a significantly lower, but more stable, water temperature and DO levels.

The surface-water profiling indicated that the shallow inlets were well-mixed and only required one surface water sample during each of the stratification and overturn sampling efforts. There were two locations where two sample depth intervals were appropriate for sampling. The first was Curds Inlet location CI-4, located at the mouth of Curds Inlet. This location had a water depth range of 75–90 feet. The second was sample location LHL-1, located in Rocky Run Embayment, with a water depth range of 75–110 feet. Both locations displayed limited-stratification, so two water samples were collected from these locations; one from 20 feet deep, and one from 70 feet deep (Appendix C2).

October stratification water quality parameters are provided in Appendix C1, with a summary as follows:

- Temperatures ranged from 9.5–22.5°C, with the coldest stratification water recorded at LHL-2 (Dix Dam, greater than 100 feet bws) as would be expected given the very deep water (290 feet bws) at the Dam.
- pH ranged from 7.2–8.6, with the highest pH values recorded at LHL-2 (Dix Dam).
- DO ranged from 0.67–5.65 milligram per liter (mg/L) during stratified sampling.
- Secchi depth ranged from 5–8 feet.

December overturn water quality parameters are also provided in Appendix C1, summarized as follows:

- Temperatures ranged from 12.3–13.51 °C, with the lowest temperatures recorded at LHL-2 (Dix Dam at a depth greater than 150 feet bws).
- pH ranged from 7.6–8, with the highest pH values seen in location CI-3 (Central/Lower Curds Inlet).
- DO ranged from 1.68–7.03 mg/L from LHL-2 (Dix Dam, 150 feet bws) and CI-3 (Central/Lower Curds Inlet) respectively.

- Secchi disc depth ranged from 3–9 feet (Secchi depth) with minimum and maximums recorded at CI-1(3 feet bws) and from locations HQ Inlet, LHL-2 (Dix Dam), and LHL-3, (9 feet bws) respectively.

3.3 Sediment Pore Water and Sediment Collection

A total of 23 peepers were deployed at 20 targeted locations within Curds Inlet, HQ Inlet, and Hardin Inlet (Table 3-1B). Sixteen of the peepers were successfully retrieved and processed from locations identified in Figure 2-2B. Peepers were not retrieved from CI-1A, CI-1B, CI-2B, CI-3A, and CI-3B. Sediment samples were collected from 34 locations, including the deepest sample from Curds Inlet (i.e., the CI-4 thalweg location, CI-4A). Twenty-nine of the sediment sampling locations were analyzed for metals and grain-size and five locations (that were also sampled before Phase I) were grain-size only.

3.4 Aquatic Vegetation and Aquatic Invertebrate Collection Results

Aquatic vegetation samples consisting of plants and algae were collected from the pre-defined sampling regions located within lower Herrington Lake. Twelve locations were sampled (with duplicates, yielding 13 vegetation samples and 14 invertebrate samples). The vegetation and invertebrate sampling regions extended approximately 50 meters to each side of the relevant surface water transect along both shores but also out from shore, from structures that included protruding rocks, plastic dock structures or floats, or submerged logs. Aquatic vegetation and invertebrate sampling density was highest within Curds Inlet where samples from four transect locations were collected, one sample location at Curds Inlet sampling locations, CI-1, CI-2, CI-3, and CI-4 transects. The vegetation samples were collected from just below the water surface or from epi-benthic locations such as submerged rocks or secured logs sitting on the lake bottom or vegetation samples were collected by divers during the sediment sampling effort. The aquatic invertebrate species primarily consisted of benthic (bottom-dwelling) invertebrates, including crayfish, and larval-stage flies including mayflies, damselflies, stoneflies, and dobsonflies. For some samples, crayfish contributed to the majority of the sample weight, whereas the larval-stage fly species contributed to the sample species diversity. Aquatic vegetation and invertebrate photographs are provided in Appendices B5. Field data sheets are provided in Appendix D4.

3.5 Sample Collection Deviations from the CAP

The primary deviation from the CAP was the incomplete retrieval of the peepers. As illustrated (as pink squares) in Figure 2-1B, peepers from 5 locations could not be recovered (CI-1A, CI-1B, CI-2B, CI-3A, and CI-3B). The water level of the lake was lower at the time of pore water sampler retrieval (November) than when placed (October). This difference was the change from summer pool to winter pool. As the water level dropped, debris in Curds Inlet moved along the sediment surface. Some of the debris displaced samplers or markers. Therefore, not all samplers could be found.

In addition, some of the membranes of the peepers were torn upon retrieval, limiting the volume to perform the analyses for some of the analyses. A priority of analyses was identified so that the selenium and arsenic speciation samples were collected from all samples. The analyses most likely to be omitted (if any) were sulfate and dissolved organic carbon. The analytical methods for each pore water sample are discussed further in Section 5 of this report.

4. QAQC PROCEDURES AND LABORATORY METHODS

The Phase I field effort was implemented in accordance with the Herrington Lake QAPP and SOPs (Ramboll 2017a, b, c, d, e, f). This section is organized as follows:

- Section 4.1 describes sample identification, records, handling, custody, and transport
- Section 4.2 identifies the analytical laboratory used for sample analyses and identifies the laboratory methods analyzed for the samples from Herrington Lake
- Section 4.3 Laboratory Handling and Processing Methods for Fish
- Section 4.4 summaries the laboratory analytical reports and identifies the reports provided as an appendix to this Phase I Technical Memorandum
- Section 4.5 describes the Phase 1 bluegill split sample submitted to and analyzed by KDOW
- Section 4.6 describes the third-party data validation approach and conclusions

4.1 Sample Identification, Records, Handling, Custody, and Transport

Sample designation, quality assurance and quality control (QA/QC), and handling, and sample nomenclature was used in a manner consistent with that identified in the Herrington Lake SOPs. Each sample has a unique sample identification. Sample identification for surface water includes notation of water depth. The sample identification numbers were entered onto the sample labels, field forms, chain-of-custody forms, logbooks, and other records documenting sampling activities.

Surface water, sediment, and sediment pore water samples were placed in the specified laboratory containers, capped, labelled, placed in plastic bags, and stored in coolers on ice for shipment to the analytical laboratories. Biological tissue samples were wrapped in aluminum foil, placed into plastic bags, and stored in coolers on wet or dry ice (or in a freezer, if available) until shipment. Samples were shipped to the ALS Kelso Washington laboratory under chain of custody seal.

4.2 Analytical Laboratory and Laboratory Methods

The ALS Kelso Washington laboratory performed the chemical analyses for the Phase I samples. The Phase I fish, surface water, pore water, sediment, aquatic vegetation, and aquatic invertebrates were analyzed for constituents as identified in Tables 4-1A and 4-1B.

QA/QC samples collected during the investigation included field blind duplicate samples and equipment blanks. Field duplicates were collected at a frequency of one in every 10 primary samples and were analyzed for the same suite of parameters as the primary sample. In addition, MS/MSD procedures were included as a laboratory control measure. MS/MSD field samples were collected at a frequency of one per 20 samples. Samples, including paired for blind duplicate samples from the Phase I program are identified in Table 4-1C.

Equipment blank samples were collected to assess the effectiveness of decontamination procedures. Equipment blank samples are obtained by pouring deionized water over or through the decontaminated sampling equipment and then collecting and submitting for analysis.

4.3 Laboratory Handling and Processing Methods for Fish

The fish preparation was conducted in the ALS Kelso Washington laboratory environment to ensure consistency in the handling of all fish samples. The fish were and processing in accordance with the standard operating procedures for preparation and homogenization of fish-tissue samples (KDOW 2017, Ramboll 2017c). The only exception to this was the field collection of ovary samples. Those were

collected in the field by qualified fisheries biologists to ensure that adequate sample volume and species collection were available for the targeted ovary samples.

As described in the CAP, each composite fish sample was analyzed for fillet tissue and remains so that the fish data were applicable for both future human health and ecological risk assessments. The specific collection approaches are described here for each of the fish types.

4.3.1 Laboratory Preparation: Bluegill and Green Sunfish Fillet/Remains Preparation

The Phase I laboratory preparation analytical methods reflected the consideration of both the bluegill and green sunfish as pan fish for human exposure. For practical preparation reasons, and to preserve what little flesh is available for consumption, humans typically either fillet the pan fish or descale it, gut it, and cook it whole. For this reason, the laboratory prepared the sunfish by removing the head, tail, guts and scales, which was considered the “remains” sample. The remaining portion of the fish was considered the “fillet” sample.

4.3.2 Laboratory Preparation: Bass, Catfish, Trout, and Sucker Fillet/Remains Preparation

Like the sunfish, all bass, catfish and suckers were also considered as pan fish for human exposure. Therefore, the laboratory prepared these fish by first removing the right fillet with skin on and the belly flap, consistent with KDOW (2017). Scales on the fillet were removed for the bass and suckers. The remaining portion of the fish, including the scales, was considered the “remains” sample.

4.3.3 Laboratory Freeze-Dry Methods for Fish-Tissue

The ALS Kelso Washington laboratory performed the freeze-dry processing (i.e., lyophilization) as part of fish tissue preparation per the QAPP and SOP (Ramboll 2017a, c). Some of the Herrington Lake fish samples were large and took a week or longer to reach appropriate freeze dry criteria. To expedite the freeze-dry preparation of fish tissue for analyses, a portion of the larger fish tissue samples were sent from the ALS Kelso Washington laboratory to Quality Bioresources, Inc. (QBI) in Seguin, Texas, on dry ice and under appropriate chain-of-custody. QBI offers lyophilization services for the medical device, diagnostic industries, and industrial applications and was approved for lyophilization services for this project.

Upon arrival at QBI, fish tissue samples were thawed to room temperature while remaining in the labelled glass jars that were shipped from the ALS Kelso Washington laboratory . On March 2, 2018, QBI prepared the samples to be placed into the freeze dryer. The Ramboll field team leader for the Herrington Lake effort was present on-site in Texas to observe the process and ensure the Herrington Lake fish processing SOP was followed (Ramboll 2017c, KDOW 2017). No deviations from the pre-determined protocol were noted; the process appeared to be well organized and executed. Freeze dry information from QBI (dates, weights and percentage of water removed) is presented in Table 4-2.

QBI personnel recorded the weight of each aluminum tray (tare weight) before transferring the contents of the glass jar(s) to the tray. Samples were placed in the trays in a single, thin layer to promote thorough freeze-drying. In some cases, more than one tray was required for a given sample. Each tray was labelled with the laboratory sample ID and weighed (pre-lyophilization gross weight) following sample transfer. When all samples were processed, trays were placed inside the lyophilizer to freeze dry. Freeze-drying continued until March 6. Each tray was removed and weighed (post-lyophilization gross weight). The percent of water removed during freeze-drying was calculated by subtracting the post-lyophilization gross weight from the pre-lyophilization gross weight and converting to a percentage. The freeze dry process was considered complete for all samples with a percentage of water removal of 70% or greater (Table 4-2). All other samples were placed back in the lyophilizer for an additional six days (until March 12). The remaining samples were then weighed (post-lyophilization gross weight) and percentage of water removed recalculated. Water removed during the additional six days of freeze-

drying was very minimal, resulting in an increase of only up to 0.38%. Therefore, the remaining samples were considered freeze-dried to the maximum extent practical.

4.4 Phase 1 Bluegill Split Samples Submitted to and Analyzed by KDOW

The Cabinet requested that a spilt sample from the ALS Kelso Washington laboratory be sent to the Kentucky Environmental Services Branch (ESB) for analysis. A bluegill sample from Curds Inlet was selected for this split sample. The sample was shipped to the Kentucky Environmental Services Branch, 100 Sower Blvd. Frankfort, KY 40601, on March 7, 2018. The analytical results for the fish samples collected as part of the Phase I CAP are discussed in Section 5. Analytical reports from the Kentucky ESB were sent to Ramboll on March 23, 2013.

The selenium concentrations measured in the KDOW split sample were similar to the concentrations measured for the other portions of the sample, as indicated below.

Bluegill from Curds Inlet	Whole body selenium concentration (mg/kg, dry weight)
CAP Phase I Result	6.46
CAP Phase I Result (duplicate)	7.38
Kentucky ESB Split Sample	7.69

The calculations of whole-body fish tissue estimates for the Kentucky ESB samples and lab results from ESB samples are provided in Appendix E.

4.5 Laboratory Analytical Reports

Laboratory analytical reports, including chain of custody forms, are provided in Appendix F. Appendix F is divided into sample data groups and Level II or Level IV data validation packages, as follows:

- Appendix F1: Fish Laboratory Analytical Report (Sample Data Group (SDG) K1712347), Level IV.
- Appendix F2: Fish Laboratory Analytical Report (SDG K1712350), Level IV.
- Appendix F3: Fish Laboratory Analytical Report (SDG K1712468), Level II.
- Appendix F4: Fish Laboratory Analytical Report (SDG K1712469), Level II.
- Appendix F5: Fish Laboratory Analytical Report (SDG K1712471), Level II.
- Appendix F6: Fish Laboratory Analytical Report (SDG K1712474), Level IV.
- Appendix F7: Fish Laboratory Analytical Report (SDG K1712476), Level II.
- Appendix F8: Fish Laboratory Analytical Report (SDG K1712477), Level II.
- Appendix F9: Fish Laboratory Analytical Report (SDG K1712479), Level II.
- Appendix F10: Surface Water Laboratory Analytical Report (SDG K1711263), Level IV.
- Appendix F11: Surface Water Laboratory Analytical Report (SDG K1711264), Level II.
- Appendix F12: Surface Water Laboratory Analytical Report (SDG K1713449), Level II.
- Appendix F13: Sediment Laboratory Analytical Report (SDG K1711369), Level II.
- Appendix F14: Sediment Laboratory Analytical Report (SDG K1711372), Level IV.
- Appendix F15: Sediment Laboratory Analytical Report (SDG K1711619), Level II.

- Appendix F16: Sediment Laboratory Analytical Report (SDG K1712054), Level II.
- Appendix F17: Sediment Laboratory Analytical Report (SDG K1712090), Level II.
- Appendix F18: Pore Water Laboratory Analytical Report (SDG K1712055), Level IV.
- Appendix F19: Pore Water Laboratory Analytical Report (SDG K1712059), Level II.
- Appendix F20: Aquatic Plant and Invertebrate Laboratory Analytical Report (SDG K1712478), Level II/IV.

4.6 Third Party Data Validation

A third-party data validation was performed by Validata, LLC in accordance with the United States Environmental Protection Agency (USEPA) National Functional Guidelines for Inorganic Data Review (USEPA 2010, 2014), as was specified in the Herrington Lake CAP and QAPP. The third-party data validator received 20 SDGs that were the focus of data validation efforts. A 100% Level II data validation following USEPA protocols was conducted for all SDGs. A Level IV data validation was performed for 20% of the samples. The data validation was performed as an independent effort to evaluate and assign data assessment qualifiers for assistance in data interpretation. The validation demonstrated that the Herrington Lake samples analyzed by the ALS Kelso Washington laboratory met the USEPA National Functional Guidelines and are considered valid data for use for site evaluation and risk assessment purposes. The data validation report is provided in Appendix G.

5. ANALYTICAL RESULTS AND DISCUSSION

This section reports the analytical results for fish, surface water, sediment pore water, sediment, aquatic vegetation, and aquatic invertebrates. The analytical results are provided in detail with full lab reports. In addition, data summaries are provided for each medium. Finally, the analytical results are discussed and key findings are presented in terms of potential data gaps to inform the Phase II Field Sampling Plan provided in Section 6.

5.1 Analytical Results Summaries by Media

Analytical results for each medium on a sample-by-sample basis are provided as follows:

- Table 5-1A: Bluegill and Green Sunfish Analytical Results (Fillet/Remains, Wet and Dry Weight)
- Table 5-1B: Bluegill and Green Sunfish Calculated Whole-body Results (Dry Weight, Selenium)
- Table 5-1C: Bluegill and Green Sunfish Calculated Whole-body Results (Wet-weight, Inorganics)
- Table 5-1D: Bass, Catfish, Trout, and Sucker Analytical Results and Calculated Whole-body Results (Dry Weight, Selenium)
- Table 5-1E: Bass, Catfish, Trout, and Sucker Analytical Results and Calculated Whole-body Results (Wet-weight, Inorganics)
- Table 5-1F: Bass and Catfish Ovary Analytical Results (Wet and Dry Weight, Selenium)
- Table 5-2: Surface Water Analytical Results
- Table 5-3: Sediment Pore Water Analytical Results
- Table 5-4: Sediment Analytical Results
- Table 5-5: Aquatic Vegetation Analytical Results (Wet and Dry Weight)
- Table 5-6: Aquatic Invertebrate Analytical Results (Wet and Dry Weight)

As indicated in the CAP, fish samples were divided into fillet and remains so that the data are usable for both human health and ecological risk assessments. The KDOW selenium fish-tissue standard is expressed as whole-body dry-weight. Therefore, data for selenium is provided in dry weight. Risk assessments typically use wet weight results, and therefore, wet weight results are also provided.

5.1.1 Whole-Body Fish-Tissue Calculation

The fish tissue data presented in Tables 5-1A through 5-1C provides fillet, remains, and ovary samples (as applicable) for the fish samples. The calculation used to develop whole body fish tissue concentrations by combining measurements for fillet, remains, and ovary tissues was described in the Fish SOP (Ramboll 2017c). The following equations were used to estimate the whole-body fish-tissue concentrations (WBFC) discussed further later in Section 5.

The general WBFC in mg/kg equation is:

$$WBFC = ([W_F / W_{WB}] * C_F) + ([W_R / W_{WB}] * C_R)$$

Where:

C_F = Constituent concentration in fish fillet composite sample (mg/kg)

C_R = Constituent concentration in remains composite sample (mg/kg)

W_{wb} = Weight of the whole fish body (kg)

W_R = Weight of the remains (g), where remains indicate the rest of the fish carcass that was not part of the specifically analyzed organs

W_F = Weight of the fillets (g)

WBFC Equation for Bluegill and Green Sunfish

For the bluegill and green sunfish, the fillets were extracted together as one mass because these are small fish. Ovaries were not extracted from either of the sunfish species. This variation of the general WBFC Equation applied to the bluegill and green sunfish analytical results, as follows. The weight of the whole fish body is equal to the weight of the paired-fillet and the remains as follows:

$$WBFC = ([W_F/ (W_F + W_R)] * C_F) + ([W_R/ (W_F + W_R)] * C_R)$$

WBFC Equation for Basses, Catfishes, Trout, and Suckers

For the larger fish where ovary samples were not collected, the fillets were laboratory-removed and, for practical reasons related to the fillet drying process, lab analysis included one of the two fillets only. The whole-body calculation for these fish uses a fillet estimate that is twice the weight of the single fillet plus the weight of the remains, as follows.

$$WBFC = ([W_F/ (2*W_F + W_R)] * C_F) + ([W_R/ (2*W_F + W_R)] * C_R)$$

WBFC Equation for Basses, Catfishes, Trout, and Suckers – With Ovary Data

To estimate WBFC for the basses, catfishes, trout and suckers where there was ovary data, the weight of the whole fish body equals twice the weight of the single filet, plus the weight of the remains, plus the weight of the field-extracted ovaries as follows:

$$WBFC = ([W^F/ (2*W_F + W_R + W_O)] * C_F) + ([W_R/ (2*W_F + W_R + W_O)] * C_R)$$

Where:

W_O = Weight of the ovaries (g)

5.2 Risk-Based Screening Levels Used for Consideration of Results

Consistent with the approach presented in the CAP, risk-based screening levels were assembled to provide one basis for evaluating the Phase I sampling results. These risk-based screening levels are not intended as a risk assessment and risk assessment conclusions are not provided in this Phase I Memorandum. Risk assessment and remedy evaluation will occur at a future time in accordance with the Agreed Order. Rather, these risk-based screening levels allow for a preliminary understanding of the potential significance of concentrations detected in the Phase I samples, and focus on potential data gaps that may need to be filled in Phase II sampling in order to have sufficient data to support the ecological and human health risk assessments and the remedy evaluation. The ecological and human health risk-based screening levels assembled for this data evaluation are provided on Tables 5-7A and 5-7B, respectively.

5.2.1 Screening Levels for Surface Water and Pore Water

Surface water and pore water screening levels include:

- Kentucky Water Quality Criteria identified in Table 1. of the Kentucky Surface water standards 401 Kentucky Administrative Record (KAR) 10:031 Section 6 (KAR, 2018) including:
  - Ecological acute and chronic water quality criteria.
  - Human health standards for drinking water and consumption of fish.
- USEAP Freshwater Ambient Water Quality Criteria for Selenium (2016).

- USEPA Region 4 Ecological Screening Values, acute and chronic criteria (USEPA R4, 2018). Wildlife screening values are also considered for surface water, where available.
- USEPA regional screening levels (RSLs) (USEPA 2018) for human health for drinking water are used for consideration of the surface water. Pore water concentrations are not relevant for human health.

5.2.2 Screening Levels for Sediments

Sediment screening levels include:

Ecological:

- USEPA Region 4 Ecological Screening Values (ESVs) and Refined Screening Values (RSVs) (USEPA R4, 2018).

No representative screening levels were identified for boron. Boron concentrations in sediment were evaluated through comparison with typical background ranges for boron in sediment provided in (Mason and Dragun 1996). No data are available for Kentucky. Background for Georgia, Washington, Illinois, Kansas, Nebraska, Michigan, Utah, and New Mexico demonstrate that naturally occurring background boron ranges are 10–700 mg/kg (averaging approximately 40 mg/kg).

Human Health:

- USEPA RSLs (USEPA 2018) for human health for exposure to residential soil derived assuming:
  - Exposure to soil 350 days per year for 30 years and based on an excess cancer risk of 1 in one million or $1x10^{-6}$ or a non-cancer hazard quotient of 1.
  - This is a highly protective basis for screening and would be expected to be much higher than exposure individuals might have to sediments. More representative exposure assumptions for sediment contact will be developed in the human health risk assessment.

5.2.3 Ecological Risk-based Screening Levels for Fish

Ecological risk-based screening levels for fish include:

- Kentucky Water quality criteria. 401 KAR 10:031 (KAR, 2018) including:
  - Whole-body fish tissue for selenium
  - Ovary tissue for selenium
- The USEPA selenium ovary tissue level is also considered (USEPA 2016)
- Scientific literature, such as Dillon et al. 2010, Beckvar et al. 2005, and additional fish whole-body residue values from Jarvinen and Ankley 1999 (Table .

5.2.4 Fish-tissue Human-health Consumption Advisories

There are no fish consumption advisories specific to Herrington Lake, but it is subject to a Kentucky-statewide advisory for mercury in fish species, as follows:

- Predatory fishes (largemouth bass, spotted (Kentucky) bass, and flathead catfish) - women of childbearing age and children 6 years and younger 6 meals per year, all others 1 meal per month.
- Bottom feeders (channel catfish, northern hogsucker, and spotted sucker) and pan fish (bluegill and green sunfish) - women of childbearing age and children 6 years and younger 1 meal per month, all other consumers should eat no more than 1 meal per week (Kentucky Department of Fish and Wildlife Resources [KDFW] 2014).

5.2.5 Human Health Risk-based Concentrations for Fish Ingestion

Risk based concentrations (RBCs) protective of human receptors consuming fish tissue were derived as described below, with screening levels summarized in Table 5-7B. The RBCs for fish tissue were derived assuming an adult consumes 52 fish meals per year from the lake and that the fish meal size is eight ounces. The number of meals assumed here likely overestimates exposure for many anglers, but is used for screening purposes and is consistent with the consumption rate used to develop the Kentucky statewide mercury advisory for pan fish (KDFW 2014).

RBCs for fish tissue were derived using the following algorithm provided in USEPA (1989, 2018) and are shown in Table 5-7B:

RBC = (BW * AT * Target Risk) – (INf * FI * EF * ED * CF * (cooking/trimming loss) * (CSF or 1/RFD))

Where:

RBC = Chronic daily intake in milligrams per kilogram per day (mg/kg-day) calculated with the exposure terms shown here (USEPA 1989):

BW = Body weigh in kg. Adult body weight of 80 kg used here (USEPA 2018)

AT = Averaging time of 25,550 days (365 days x 70 years) used here for cancer and 365 days x exposure duration used for noncancer (USEPA 2018).

Target risk = Cancer: 1 $x10^{-6}$ used for the inorganic arsenic RBC noncancer: Hazard index of 1 used for all others (USEPA 1989).

INf = Ingestion rate of fish. Assumed to be 52 meals per year, which is the upper end of meals in the Kentucky advisory for mercury in fish. This is equivalent to 32.2 g/day.

FI = Fractional intake, which represents the fraction taken from this resource. Assumed to be 100% here or an FI of 1.0.

EF = Exposure frequency and 365 days per year are used for fish consumption (USEPA 1989, 2018).

ED = Exposure duration and 26 years was used for adults (USEPA 2018).

CF = Conversion factor or 0.001 mg–g.

Cooking loss = No cooking loss was assumed here.

CSF or 1/RfD = Cancer slope factor (CSF) or reference dose (RfD) for noncancer is a chemical specific value taken from the USEPA RSL table (USEPA 2018).

Fish tissue concentrations are considered in wet weight consistent with human health risk assessment guidance (USEPA 1989, 2018). Site-specific fish consumption rates will be further refined as part of the human health risk assessment.

For methyl mercury, the guideline of 0.3 mg/kg (300 µg/kg) in fish tissue identified within Table 1 of 401 KAR 10:031 was used to screen fish tissue data. The screening value used for lead in fish tissue is based on an advisory for lead in sport fish developed by the Ohio Cooperative Fish Tissue Monitoring Program Sport Fish Tissue Consumption Advisory Program (Ohio 2010); Ohio (2010) identifies a lead concentration in fish tissue of 0.375 mg/kg wet weight (ww) or 375 µg/kg derived based on a 1 meal / week fish and also on the USFDA Provisional Tolerable Daily Intake concentration of 6.0 micrograms per day (µg/day) for lead (USFDA 2017).

5.3 Analytical Results on a Metal-Specific Basis

Analytical results are evaluated across media for each constituent to provide insight into spatial trends and to identify potential data gaps to be addressed in Phase II of the CAP. The analytical data are provided in detail in Tables 5-1A though 5-6. Data summaries showing the range of detected values for each medium, the frequency of detection, and the range of detection limits for each medium are provided in Tables 5-8A through 5-13, as follows:

- Table 5-8A-1: Bluegill and Green Sunfish Tissue Results Summary (Whole-body, Wet and Dry Weight).
- Table 5-8A-2: Bluegill and Green Sunfish Tissue Results Summary (Filet, Wet and Dry Weight).
- Table 5-8B-1: Bass Tissue Results Summary (Whole-body, Wet and Dry Weight).
- Table 5-8B-2: Bass Tissue Results Summary (Fillet, Wet and Dry Weight).
- Table 5-8C-1: Catfish Tissue Results Summary (Whole-body, Wet and Dry Weight).
- Table 5-8C-2: Catfish Tissue Results Summary (Fillet, Wet and Dry Weight).
- Table 5-8D-1: Trout and Sucker Tissue Results Summary (Whole-body, Wet and Dry Weight).
- Table 5-8D-2: Trout and Sucker Tissue Results Summary (Fillet, Wet and Dry Weight).
- Table 5-9: Surface Water: Stratification Results Summary.
- Table 5-10: Surface Water: Overturn Results Summary.
- Table 5-11: Sediment Results Summary.
- Table 5-12: Sediment Pore Water Results Summary.
- Table 5-13: Aquatic Vegetation Results Summary.
- Table 5-14: Aquatic Invertebrate Results Summary.

The remainder of this section reports the analytical results, as follows:

- Section 5.3.1: Selenium.
- Section 5.3.2: Arsenic.
- Section 5.3.3: Mercury and Methyl Mercury.
- Section 5.3.4: Cadmium.
- Section 5.3.5: Boron.
- Section 5.3.6: Lead.
- Section 5.3.7: Other Constituents.
- Section 5.3.8: Key Findings to Inform Phase II Sampling.

5.3.1 Selenium

The results for the selenium analysis are presented for each medium in Figures 5-1A though 5-1J, as follows:

- Figure 5-1A: Selenium in Whole-Body Fish-tissue: Bluegill and Green Sunfish (Dry Weight).
- Figure 5-1B: Selenium in Larger Fish Ovaries: Larger Fish (Dry Weight).
- Figure 5-1C: Selenium in Whole-Body Fish-tissue: Larger Fish (Dry Weight).

- Figure 5-1D: Selenium in Fillet Tissue: Bluegill and Green Sunfish (Wet Weight).
- Figure 5-1E: Selenium in Fillet Tissue: Larger fish (Wet Weight).
- Figure 5-1F: Selenium in KDOW 2016 Fish Study Fish-tissue.
- Figure 5-1G: Selenium in Surface Water (Stratified and Overturn).
- Figure 5-1H: Selenium in Sediment Pore Water.
- Figure 5-1I: Selenium in Sediment.
- Figure 5-1J: Selenium in Vegetation and Invertebrates.

The results for each medium are briefly discussed.

5.3.1.1 Selenium in Fish-Tissue

The Phase I data for selenium in fish tissues are presented in a series of graphics provided in Figures 5-1A though 5-1E. As shown on these figures, the concentrations are generally higher in Curds Inlet, and the lowest levels are detected in MHL samples.

- Whole-body bluegill selenium levels for all Phase I whole-body fish samples range from 0.81–7.38 mg/kg dry weight (dw), with concentrations exhibiting a downward gradient related to distance from Curds Inlet (Figure 5-1A); these concentrations are below the KDOW fish-tissue standard (8.6 mg/kg dw). Average selenium concentration of the collected bluegill and green sunfish is 3.85 mg/kg dw.
- Selenium in ovary tissues is illustrated in Figure 5-1B. As indicated in Figure 5-1B, ovary tissue selenium levels for the Phase I fish samples range 3.3–14.5 mg/kg dw, which is below the KDOW ovary standard (19.3 mg/kg dw) and the USEPA ovary standard (15.1 mg/kg dw). The lower levels are from a female spotted (Kentucky) bass from MHL1 and a female largemouth bass from MHL3 (3.3 and 3.95 mg/kg dw respectively).
- The selenium concentrations for whole-body bass, catfish, trout, and sucker fish samples are also below the KDOW whole body fish-tissue standard (Figure 5-1C).
- The selenium concentrations in fish fillet tissue are presented in Figure 5-1D for bluegill and sunfish and Figure 5-1E for larger fish (bass, catfish, trout, and sucker). The selenium concentrations for the Phase I filet tissue samples are below the RBC level (13 mg/kg ww).

The Phase I fish tissue data were compared to fish-tissue samples collected from Herrington Lake in May 2016 by the KDOW from locations near Dix Dam and from Rocky Run embayment. Fish fillet tissues were collected from five bluegill, seven largemouth bass, and one spotted (Kentucky) bass near Dix Dam (KDOW 2016). The 2016 KDOW fish tissue results are presented in Figure 5-1F. The whole-body selenium results for bluegill ranged 9.7–11.5 mg/kg dw; for the spotted (Kentucky) bass the single reported result was 10.7 mg/kg dw; and for largemouth bass, results ranged 4.9–11.7 mg/kg dw. These concentrations exceed the KDOW whole-body dry-weight standard (8.6 mg/kg dw). The whole-body fish tissue results from the KDOW May 2016 study are higher than those observed in the Phase I investigation. This variability represents an uncertainty that potentially warrants further consideration in the Phase II investigation.

The KDOW study also included largemouth bass ovary samples collected from the residential cove, and from at Dix Dam (Figure 5-1F). Selenium was detected in the fish ovary sample collected from near the dam at a concentration of 7.93 mg/kg. Selenium was detected in ovary samples from the residential cove at concentrations of 11 and 11.3 mg/kg. None of the ovary samples analyzed by KDOW exceed the ovary standard (19.3 mg/kg, dw). The ovary tissue results from the KDOW sampling are similar to

those observed in the Phase I study. As such, further study of fish ovaries is not warranted in the Phase II investigation.

Fish tissue samples were also collected as part of a young of the year (YOY) study in June of 2016 (Downstream Strategies 2016). The selenium fish tissue results from that study ranged from 5.9-8.5 mg/kg, dw, which are similar to those observed in the Phase I investigation results for fish tissues. The YOY study was conducted only in Curds Inlet, without a Herrington Lake reference area. A more comprehensive young of the year study is proposed for the Phase II investigation.

5.3.1.2 Selenium in Surface Water

Total and dissolved surface water selenium levels collected during Phase I stratification and overturn are presented in Figure 5-1G. The concentrations exhibit a downward selenium gradient related to distance from the inner portions of Curds Inlet. Total surface water selenium levels collected during stratification range 0.2–2.1 micrograms per liter (µg/L) from Rocky Run (LHL-1 at 60 feet bws), and upper Curds Inlet (CI-1). Surface water total selenium levels collected from Curds Inlet locations CI-1, CI-2, and CI-3 exceed the recommended USEPA Lake (Lentic) 30-day average criterion of 0.0015 mg/L (1.5 µg/L), but were below the Kentucky chronic criterion of 0.005 mg/L (5.0 µg/L). Sampling during the overturn detected total selenium concentrations in the surface water ranging from 0.003-0.0052 mg/L with the highest level reported in upper Curds Inlet (CI-1) and the lowest from sampling location LHL-6. The overturn sample collected at CI-1 (0.0052 mg/L), was slightly higher than the Kentucky Eco Chronic Water Quality Standard (WQS) (0.005 mg/L). The overturn sample results for selenium at CI-1 and CI-2 exceed those seen in the stratified sampling event. This is likely due to greater mixing of lake water during the lake overturn sampling.

The Phase I surface water samples collected during stratification were lower than the Kentucky human-health water quality standard for selenium (0.17 mg/L) and the USEPA Maximum Contaminant Level (MCL) for selenium (0.050 mg/L).

5.3.1.3 Selenium in Sediment Pore Water

The concentrations for selenium in pore water are illustrated in Figure 5-1H. Detected concentrations of selenium in pore water range 0.002–0.005 mg/L with the lowest and highest levels from locations HI1C and CURDSNB, respectively. These detected concentrations (including speciated selenium) are below the Kentucky Eco Chronic WQS of 0.005 mg/L. The use of human-health WQS criteria is not relevant to evaluate pore water.

As discussed in Section 3, not all in situ pore water samplers deployed could be recovered. This may represent a data gap, particularly at CI-3A where the highest selenium was detected in sediment. Additional pore water sampling in Curds Inlet, particularly near CI-3A is proposed for the Phase II investigation.

5.3.1.4 Selenium in Sediment

The selenium concentrations for sediment are presented in Figure 5-1I. Detected concentrations of selenium in the sediment range 0.4–32.8 mg/kg with minimum and maximum recorded from locations LHL-6B and CI-3A, respectively. The highest concentration of selenium at Transect CI-3A is the thalweg sample within the central portion of Curds Inlet. Detected concentrations in sediment exceed the 2018 USEPA R4 ESV (0.72 mg/kg) and the USEPA R4 RSV (2.9 mg/kg). Exceedances of the ESVs and RSVs will be evaluated further in the site-specific ecological risk assessment. The selenium levels in Phase I sediment concentrations are below the USEPA RSL for exposure to residential soil exposure to soil concentrations (390 mg/kg).

5.3.1.5 Selenium in Aquatic Vegetation and Invertebrates

The selenium concentrations in vegetation and invertebrates are provided in Figure 5-1J. There is no apparent pattern of high concentration contribution in Curds Inlet or a concentration gradient away from Curds Inlet. There are no USEPA or KDOW standards for aquatic invertebrate or aquatic vegetation tissues.

5.3.1.6 Key Findings for Selenium in Phase I Sampling

The key findings for selenium are:

- Additional fish tissue sampling for selenium may be warranted because the Phase I findings are lower than those reported by KDOW for sampling in May 2016 at the Dix Dam.
- A young of the year fish study for Curds Inlet and areas away from Curds Inlet would fill a data gap for understanding young of the year fish conditions.
- Additional surface water sampling for selenium would be beneficial in areas where young of the year fish sampling is planned.
- Additional delineation in sediment pore water and sediment in Curds Inlet may be warranted, particularly around CI-3A where the highest selenium concentrations were detected. Although there are exceedances of the ESV and RSV outside of Curds Inlet, the available information outside of Curds Inlet is considered sufficient to perform the risk assessment and remedy evaluation.
- There are no patterns of selenium in aquatic vegetation or aquatic invertebrates. Therefore, no additional sampling of these media for further delineation of selenium is considered necessary for the Phase II investigation.

5.3.2 Arsenic

The results for arsenic analysis are presented for each of the media in Figures 5-2A though 5-2F, as listed below.

- Figure 5-2A: Arsenic in Fish-tissue Whole-Body Arsenic (Wet Weight).
- Figure 5-2B: Arsenic in Fish-tissue Fillet: Inorganic Arsenic.
- Figure 5-2C: Arsenic in Surface Water (Stratified and Overturn).
- Figure 5-2D: Arsenic in Sediment Pore Water.
- Figure 5-2E: Arsenic in Sediment.
- Figure 5-2F: Arsenic in Vegetation and Invertebrates.

The results for each medium are briefly discussed.

5.3.2.1 Arsenic in Fish-Tissue

Data for total arsenic in whole-body fish tissues (in wet weight) are presented in Figure 5-2A for bluegill, green sunfish, bass, catfish, catfish, trout, and suckers. The detected total arsenic results in whole-body fish tissues are less than the fish screening levels for adult and early life stage fish, as indicated in scientific literature (e.g., Jarvinen and Ankley 1999).

The fish tissues were analyzed for arsenic speciation via Method 1632A to assess the relative amount of inorganic arsenic present in the tissues, which is most relevant for understanding human health exposures (Schoof and Yager 2007). Inorganic arsenic data for fish fillet tissues are presented in Figure 5-2B based on the sum of arsenate (AsIII or As3+) and arsenite (AsV or As5+). Inorganic arsenic data

for fish fillet tissues are presented in Figure 5-2B measured directly via Method 1632A; (note that Method 1632 had lower detection limits than those for arsenate and arsenite). Specifically:

- The data in Figure 5-2B indicates that inorganic arsenic (from Method 1632A) was detected at low concentrations in three bluegill, two from Curds Inlet and one from HQ Inlet. As seen in Figure 5-2B, the inorganic arsenic is detected in the bluegill duplicate sample but not the parent sample. Inorganic arsenic from Method 1632A was not detected in larger fish (bass, catfish, trout, and suckers).
- The data presented in Figure 5-2B indicates that inorganic arsenic is rarely detected and when detected, it is below the risk based threshold for ingestion of fish.

Human health RBCs for inorganic arsenic are provided in Figures 5-2B. Fish tissue data were compared with the RBC for inorganic arsenic of 0.005 mg/kg ww which was derived assuming 52 meals per year for an adult and with a risk target of 10^{-6}. Data were also evaluated relative to a screening level of 0.068 mg/kg ww for total arsenic concentrations. The total arsenic screening level was derived assuming 6.8% inorganic arsenic in freshwater fish consistent with findings from data summarized in Schoof and Yager (2007). As indicated in Figure 5-2B no fish tissue concentrations are greater than the human health RBCs.

5.3.2.2 Arsenic in Surface Water

Total and dissolved surface water arsenic levels collected during Phase I stratification and overturn are presented in Figure 5-2C. Stratification total arsenic detected concentrations in the surface water range 0.00092-0.00265 mg/L with minimum and maximum recorded from locations LHL-1 (60 feet bws) and (CI-4, mouth of Curds Inlet) respectively. Overturn total arsenic detected concentrations in the surface water range 0.00095-0.000558 mg/L with minimum and maximum recorded from locations LHL-6 and CI-1 2 respectively. Arsenic concentrations in surface water samples collected during both stratification and overturn sampling efforts are below the Kentucky Human-Health WQS (0.01 mg/L) and the Kentucky Eco Chronic WQS (0.15 mg/L).

5.3.2.3 Arsenic in Sediment Pore water

The dissolved arsenic concentrations in sediment pore water are presented in Figure 5-2D. Arsenic, where analyzed by two methods, provided similar results (EPA 200.8 and Method 1632A), as presented in Figure 5-2D. Detected concentrations of total dissolved arsenic in the pore water range 0.000515–0.123 mg/L with minimum and maximum recorded from locations CI-2C and CURDS2A respectively. Detected concentrations of dissolved AsIII in the pore water range 0.0000322–0.0716 mg/L with minimum and maximum recorded from locations CURDS1 and CURDS2A respectively. Detected concentrations of dissolved AsV in the pore water range 0.000475–0.040 mg/L with minimum and maximum recorded from locations HI1C and CURDS2B respectively. Dissolved arsenic and arsenic species arsenite (AsIII or As3+) and arsenate (AsV or As5+) concentrations are below ecological risk-based screening levels.

5.3.2.4 Arsenic in Sediment

The arsenic concentrations for sediment are presented in Figure 5-2E. Detected concentrations of arsenic in the sediment range from 1.73–448 mg/kg with minimum and maximum reported for locations LHL-6B and CI-3A respectively. CI-3A, the thalweg sample, also had the highest selenium sediment concentration. Arsenic concentrations in sediment in Curds Inlet and elsewhere in the lake exceed ecological screening values of 9.8 mg/kg. Sediment concentrations for samples from Curds Inlet and HQ Inlet exceed the RSV of 33 mg/kg. For human-health, the USEPA RSL of for residential soil (0.7 mg/kg) is not relevant for sediment, and is also below typical soil background concentrations. Many

sampling locations exceeded this RSL with no spatial pattern except that the concentrations are highest in Curds Inlet.

5.3.2.5 Arsenic in Aquatic Invertebrates and Vegetation

The arsenic concentrations for sediment are presented in Figure 5-2F. For arsenic in aquatic invertebrates and vegetation, there was no pattern of high concentration in Curds Inlet. There are no USEPA or KDOW standards for aquatic invertebrate or aquatic vegetation tissues.

5.3.2.6 Key Findings for Arsenic in Phase I Sampling

The key findings for arsenic are:

- Fish tissue concentrations of arsenic are sufficiently characterized from Phase I sampling to perform the risk assessments and remedy evaluations. No data gaps are identified that warrant Phase II sampling for arsenic in fish tissues.
- Surface water concentrations of arsenic are sufficiently characterized from Phase I sampling to perform the risk assessments and remedy evaluations. No data gaps are identified from water sampling that would require Phase II sampling for arsenic in water. However, based on data gaps identified for arsenic in sediment, some additional water sampling may also be considered beneficial in the Phase II investigation.
- Additional delineation in sediment pore water and sediment in Curds Inlet may be warranted, particularly around CI-3A where the highest arsenic (and selenium) detections were detected.
- There are no patterns of arsenic in aquatic vegetation or aquatic invertebrates that identify a data gap related to arsenic in these biological tissues. Therefore, no additional sampling of aquatic vegetation or aquatic invertebrates for further delineation of arsenic is considered necessary.

5.3.3 Mercury and Methyl Mercury

Phase I data for mercury and methyl mercury sampling is presented for each medium in Figures 5-3A though 5-3F, as listed below. The results for each medium are briefly discussed.

- Figure 5-3A: Methyl mercury in Fish-tissue Whole-Body (Wet Weight).
- Figure 5-3B: Methyl mercury in Fish-tissue Fillet: Larger fish (Wet Weight).
- Figure 5-3C: Methyl mercury in Surface Water (Stratified and Overturn).
- Figure 5-3D: Dissolved Total Mercury and Dissolved methyl mercury in Sediment Pore Water.
- Figure 5-3E: Total Mercury in Surface Water (Stratified and Overturn).
- Figure 5-3F: Total Mercury in Surface Water (Stratified and Overturn) Low Concentrations.
- Figure 5-3G: Total Mercury and methyl mercury in Sediment.
- Figure 5-3H: Total Mercury and methyl mercury in Vegetation and Invertebrates.

5.3.3.1 Methyl Mercury in Fish-Tissue

Methyl mercury in fish tissues (wet weight) are presented in Figures 5-3A and 5-3B for whole-body fish and fish fillets, respectively. The methyl mercury concentrations for bluegill and most of the bass, catfish, trout, and sucker are less than ecological screening levels (Beckvar et al. 2005 and Dillion et al. 2010). The methyl mercury concentrations for two catfish samples and one bass sample exceed the lower of the two ecological screening levels. The catfish samples exceeding the lower benchmark were from LHL4 and MHL1. The bass sample with a concentration exceeding the lower benchmark was from

LHL6. The Curds Inlet samples and Dix River (below the dam) were lower than both ecological benchmarks.

The fish fillet concentrations relative to the USEPA and Kentucky human-health criterion (300 µg/kg) were similar to that described for whole-body fish tissues. Specifically, the methyl mercury concentrations for bluegill and most of the bass, catfish, trout, and sucker are less than human health RCB. The fillet tissues with methyl mercury concentrations exceeding the RBC were catfish from LHL4 and MHL3.

5.3.3.2 Mercury and Methyl Mercury in Surface Water and Sediment Pore Water

Total methyl mercury concentrations in surface water from stratification and overturn sampling are presented in Figure 5-3C. Mercury and methyl mercury results for pore water are provided on Figure 5-3D. Total methyl mercury concentrations in surface water from stratification and overturn sampling are presented in Figure 5-3E, with greater resolution of lower detected concentrations presented in Figure 5-3F. The data provide conflicting results for the multiple sampling types, as follows:

- The total and dissolved mercury concentrations in overturn water samples do not exceed Kentucky ecological or human health criteria. As indicated on Figure 5-3C, the detected concentrations of methyl mercury in stratified lake samples and overturn samples are less than the Kentucky and USEPA R4 water quality criteria, including the lowest of the criteria for ingestion of fish by wildlife (0.000028 mg/L) and human health (0.000051 mg/L).
- The detected pore water concentrations illustrated on Figure 5-3D are less than the chronic Kentucky Eco WQS (0.00077 mg/L) for total mercury and the chronic USEPA R4 aquatic life screening value for total methyl mercury (0.0000028 mg/L). The screening level for ingestion of fish for wildlife and human health are not appropriate for pore water. In fact, dissolved total mercury was not detected in 15 of the pore water samples (including field duplicates) and dissolved methyl mercury was not detected in Curds Inlet but in Hardin Inlet only.
- However, the total and dissolved mercury concentrations in the stratified surface water samples from Curds Inlet did exceed Kentucky ecological and human health criteria, as presented in Figures 5-3E and 5-3F. The elevated mercury seen during stratified sampling but not during overturn sampling indicates a transient condition in the inner portion of Curds Inlet. These samples could reflect particulate matter and influence from algae in the water sample. Also, it is noted that the Kentucky human health water quality standard for mercury is for fish consumption and the USEPA R4 screening level for wildlife is also for fish consumption. As discussed previously, mercury concentrations in fish tissues from Curds Inlet are below ecological risk-based screening levels and the USEPA and Kentucky human health fish ingestion standards.
- Collectively, this information indicates that additional characterization of mercury in surface water from Curds Inlet may be warranted for the Phase II investigation.

5.3.3.3 Mercury and methyl mercury in Sediment

Concentrations of mercury and methyl mercury in sediment are presented in Figure 5-3G. Detected concentrations of mercury in the sediment range 0.004–0.143 mg/kg with minimum and maximum reported for locations LHL-6B and CI-4A respectively. Total mercury concentrations are less than the ecological screening level (0.18 mg/kg) and the USEPA R4 ESV for mercury for wildlife (0.017 mg/kg). The total mercury sediment concentrations are below the human-health USEPA (2018) residential soil RSL for inorganic mercury (23 mg/kg), and below the RSL for methyl mercury (8 mg/kg).

Detected concentrations of methyl mercury in the sediment range 0.00004–0.00174 mg/kg with minimum and maximum reported for locations LHL-5B and LHL-6C respectively. The USEPA R4

screening levels were updated in 2018 and include a methyl mercury ESV and RSV of 0.00045 mg/kg and 0.0045 mg/kg, respectively. There are no exceedances of the methyl mercury ESV in Curds Inlet, as methyl mercury was not detected in most of the Curds Inlet samples. All of the detected concentrations for methyl mercury are less than the RSV. The wildlife ESV and RSV are related to the wildlife ingestion of fish. The methyl mercury in fish are discussed in Section 5.3.3.1.

5.3.3.4 Mercury and Methyl mercury in Aquatic Vegetation and Invertebrates

Total and methyl mercury concentrations in aquatic vegetation and invertebrates are presented in Figure 5-3H. Methyl mercury was not detected in most of vegetation samples. The Phase I data do not indicate any data gaps that warrant further investigation.

5.3.3.5 Key Findings for Mercury and Methyl Mercury in Phase I Sampling

The key findings for mercury and methyl mercury are:

- Fish tissue concentrations of methyl mercury (the dominant form of mercury in fish) are sufficiently characterized from Phase I sampling to support the assessment of potential human health and ecological risks and remedy evaluations. No data gaps are identified that warrant Phase II sampling for mercury in fish tissues.
- Surface water concentrations in Curds Inlet indicate additional sampling of mercury in surface water is warranted in the Phase II investigation to evaluate the transient nature of the elevated detections seen in Phase I results.
- Sediment concentrations of mercury and methyl mercury are sufficiently characterized from Phase I sampling of sediment pore water, sediment, aquatic vegetation, and aquatic invertebrates to perform the risk assessments and remedy evaluations. No data gaps are identified that warrant Phase II sampling for mercury or methyl mercury in these media.

5.3.4 Cadmium

The results for the cadmium analysis are presented for each medium, as indicated in Figures 5-4A though 5-4F, as listed below.

- Figure 5-4A: Cadmium in Fish-tissue Whole-Body (Wet Weight).
- Figure 5-4B: Cadmium in Fish-tissue Fillet (Wet Weight).
- Figure 5-4C: Cadmium in Surface Water (Stratified and Overturn).
- Figure 5-4D: Cadmium in Sediment Pore Water and Sediment.
- Figure 5-4E: Cadmium in Vegetation and Invertebrates.

The results for each medium are briefly discussed.

5.3.4.1 Cadmium in Fish-Tissue and Surface Water

The cadmium concentrations in whole-body fish samples, fillet fish samples, and surface water are below the below the ecological and human health Kentucky criteria and risk-based criteria. The cadmium in whole-body fish tissues showed the highest concentrations in Curds Inlet, with concentrations exhibiting a decrease with distance from the inner portion of Curds Inlet (Figure 5-4A). The pattern is less apparent for fish fillet concentrations (Figure 5-4B). The pattern of cadmium concentrations in surface water for stratified samples and overturn is similar to that described for selenium, where overturn concentrations at the inner portion of Curds Inlet were higher than seen during the stratification sampling. Regardless, the cadmium concentrations during both events are below the KY human health and ecological criteria (Figure 5-4C).

5.3.4.2 Cadmium in Sediment Pore Water and Sediment

Cadmium concentrations in sediment pore water are below the Kentucky ecological criteria. Sediment concentrations (Figure 5-4D) are below human health criteria at all locations and below ecological RSVs at all locations except CI-1A. Some of the sediment concentrations exceed the ecological ESV (the lower of the two ecological criteria). Notably, the location CI-3A where the maximum selenium and arsenic were seen in sediment has a cadmium concentration slightly exceeding the ecological ESV.

5.3.4.3 Cadmium in Aquatic Vegetation and Invertebrates

Cadmium concentrations in the aquatic vegetation and aquatic invertebrates are presented in Figure 5-4E. Concentrations for both vegetation and invertebrates demonstrate a pattern of higher concentrations in Curds Inlet relative to other areas, with the highest concentration of cadmium seen at location CI-3.

5.3.4.4 Key Findings for Cadmium in Phase I Sampling

The key findings for cadmium are:

- Cadmium is sufficiently characterized from Phase I sampling of surface water, sediment pore water, sediment, aquatic vegetation, and aquatic invertebrates to perform the risk assessments and remedy evaluations.

5.3.5 Additional Metals (Boron, Lead, and Zinc)

Phase I data for boron, lead, and zinc are presented in each of the media, as indicated in Figures 5-5A though 5-7F, as listed below. The results for each medium are briefly discussed.

- Figure 5-5A: Boron in Fish-tissue Whole-Body (Wet Weight)
- Figure 5-5B: Boron in Fish Fillet Tissue (Wet Weight)
- Figure 5-5C: Boron in Surface Water (Stratified and Overturn)
- Figure 5-5D: Boron in Sediment
- Figure 5-5E: Boron in Vegetation and Invertebrates

- Figure 5-6A: Lead in Fish-tissue Whole-body (Wet Weight)
- Figure 5-6B: Lead in Fish Fillet Tissue (Wet Weight)
- Figure 5-6C: Lead in Surface Water (Overturn)
- Figure 5-6D: Lead in Sediment
- Figure 5-6E: Lead in Vegetation and invertebrates

- Figure 5-7A: Zinc in Fish-tissue Whole-body (Wet Weight)
- Figure 5-7B: Zinc in Fish Fillet Tissue (Wet Weight)
- Figure 5-7C: Zinc in Surface Water (Overturn)
- Figure 5-7D: Zinc in Pore Water
- Figure 5-7E: Zinc in Sediment
- Figure 5-7F: Zinc in Vegetation and invertebrates

5.3.5.1 Boron, Lead, and Zinc Results

The detected concentrations of boron, lead, and zinc are below Kentucky and USEPA ecological and human health criteria and risk-based screening levels, where such criteria exist. An exception to this is for boron and zinc in sediment, where the lower of the ecological screening levels are exceeded by some concentrations detected in Curds Inlet, as follows:

- Detected concentrations of boron in the sediment range 2.95–72.3 mg/kg with minimum and maximum recorded from locations CI-4B and CI-1A respectively (Figure 5-5D, Table 5-11). Three locations have concentrations greater than the average of average background concentrations of boron in sediments of 40 mg/kg, CI-1A, CI-4A and HQ-1A (HQ indicates HQ Inlet), but all concentrations detected in sediment are below the average of the maximum values of boron in background sediments identified in Mason and Dragun (1966). Boron concentrations were well below the screening level for residential soil of 16,000 mg/kg.
- Detected concentrations of zinc in the sediment range 10.9–245 mg/kg with minimum and maximum recorded from locations LHL-6B and CI-1A respectively (Figure 5-7E, Table 5-11). The concentration at CI-1A (245 mg/kg) and some other Curds Inlet detections exceed the lower USEPA R4 ESV (121 mg/kg) but all of the detected concentrations in sediment are less than the USEPA R4 RSV (459 mg/kg) and well below the USEPA RSL of 23,000 mg/kg for residential soil (USEPA 2018).

5.3.5.2 Key Findings for Boron, Lead, and Zinc in Phase I Sampling

The key finding for boron, lead, and zinc is that Phase I sampling of surface water, sediment pore water, sediment, aquatic vegetation, and aquatic invertebrates was adequate to perform the risk assessments and remedy evaluations.

5.3.6 Additional Metals (Magnesium and Iron)

Magnesium and iron were also sampled in surface water, sediment pore water, sediment, aquatic vegetation, and aquatic invertebrates. The data for these metals are provided in the Section 5 tables (results are not graphically presented). The data are also adequate to perform the risk assessments and remedy evaluations.

5.4 Key Findings from Phase I Investigation for Each Medium

A discussion of results on a chemical-specific basis is provided in Section 5.3. This section summarizes results by media to inform the Phase II investigation plan provided in Section 6.

5.4.1 Key Findings for Fish

This section discusses the Phase I fish-tissue results relative to other recent Herrington Lake fish studies, and to KDOW and USEPA water quality standards and consumption advisories. It is important to note that there are no fish consumption advisories specific to Herrington Lake but it is subject to a Kentucky-statewide advisory for mercury in fish (KDOW 2017).

The Phase I analytical results for fish provided sufficient data to support the following conclusions:

- The concentration of selenium in fish tissues (whole-body and ovaries) collected as part of the Phase I sampling program are below the KDOW whole-body dry weight fish-tissue standard for selenium and the KDOW ovary standard (Figures 5-1A, 5-1B, and 5-1C).
- The concentration of selenium in fish fillets from samples collected as part of the Phase I sampling program are less than human-health risk-based ingestion values for selenium (Figures 5-1D and 5-1E).

- The KDOW fish-tissue values exceeded the KDOW standard for whole-body fish for sampling conducted in May 2016; the ovary results for 2016 did not exceed the ovary standard (Figure 5-1F).
- The fish-tissues analyses from the Young-Of-the-Year (YOY) study conducted in June 2016 (i.e., small fish) showed similar concentration to those measured in the Phase I sampling program.
- Fish tissues for chemicals other than selenium is adequately characterized with Phase I sampling.
    - Fish-tissue concentrations for Phase I sampling are also below the screening level benchmarks identified from scientific literature for arsenic, cadmium, boron, lead, and zinc for both ecological receptors and human-health, where they exist.
    - Arsenic speciation in fish-tissues demonstrated that inorganic arsenic (the form of arsenic that is potentially toxic to humans) is not present or was present at concentrations much lower than the human-health standard for arsenic ingestion in fish-tissues.
    - Methylmercury (MeHg, the dominant form of mercury in fish-tissues) was detected less than risk-based screening-levels in Curds Inlet but there were some areas outside of Curds Inlet where some limited exceedances of risk-based screening levels were seen.

5.4.2 Key Findings for Surface Water

This section discusses the Phase I analytical results for surface water including relevant KDOW and USEPA surface water quality standards. It is important to note that KDOW deleted its acute water column criterion for selenium from its water quality standards in 2016 on the basis that the prior standard of 20 µg/L was not supported by underlying scientific data. That regulatory action was reviewed and accepted by USEPA Region 4 (USEPA 2017). There is sufficient information for surface water (stratification and overturn) to support the following conclusions:

- Selenium concentrations in surface water are below the KDOW water quality standards for stratified lake sampling and overturn sampling, with the possible exception of CI-1 during overturn, where selenium was detected at a concentration equal to the KDOW standard.
- Detected concentrations are below the KDOW water quality standards for arsenic, methyl mercury, cadmium, lead, and zinc. These results are sufficient to perform the risk assessment and consider remedy evaluations. No additional analyses are needed for these chemicals in surface water.
- Because Kentucky does not have water quality criteria for boron, the Phase I sampling results for boron were compared to drinking water standards for human-health and a Canadian ecological screening value. The stratified boron water results are less than both screening values. The overturn sample results slightly exceed the Canadian ecological screening value at the CI-1 and CI-2 locations in the interior Curds Inlet locations. These results are sufficient to perform the risk assessment and consider remedy evaluations. No additional boron is needed for surface water.
- Total and dissolved mercury in surface water was detected at elevated concentrations in the stratified sampling but not the overturn. The lowest criterion for human-health is based on a value for water protective of fish-tissue bioaccumulation and ingestion. Due to the transient nature of the elevated mercury concentration in Curds Inlet, some additional sampling of mercury is planned for Phase II.

5.4.3 Key Findings for Sediment and Sediment Pore Water

There is sufficient information for sediment pore water and sediment to support the following conclusions:

- Results indicate that selenium and arsenic are elevated at Curds Inlet transect CI-3A, the thalweg sample. Other locations within Curds Inlet further from the lake are also elevated for selenium and

arsenic. Therefore, Phase II sampling will include additional characterization around Transect CI-3, primarily for selenium and arsenic but the same set of chemicals for sediment will be analyzed in Phase II as was conducted in Phase I.

- Cadmium in sediment is most elevated at location CI-1, which is an area within Curds Inlet that is now well characterized. So no additional characterization is needed based on this detection.
- Most constituents in sediment pore water were detected at concentrations lower than the KDOW water quality standards, which is a conservative comparison because the water quality standards protect fish and other aquatic wildlife, not all of which inhabit pore water. However, some of the pore water devices from the Phase I sampling effort could not be recovered, including the sampler at CI-3A. Therefore, The Phase II field sampling plan proposes pore water sampling in Curds Inlet to further characterize conditions around CI-3A and to obtain pore water where devices could not be recovered from Phase I sampling.

5.4.4 Key Findings for Aquatic Invertebrates and Vegetation

There is sufficient information for aquatic vegetation and aquatic invertebrates to support the following conclusions:

- The results aquatic vegetation and invertebrates are sufficient to conduct the risk assessment and consider remedy evaluations. There are no specific criteria for comparison to these data. Concentrations of the chemicals evaluated show comparable results around the lake locations sampled.
- No additional aquatic vegetation and invertebrates are planned for Phase II sampling.

6. PHASE II PROPOSED FIELD SAMPLING PLAN

The Phase II FSP is designed to fill data gaps identified from the evaluation of the Phase I sampling data. This section identifies the Phase II sample locations, media planned for Phase II sample collection, the analytical methods for each medium, and the collection methods that will be used for Phase II. The Phase II sampling locations are shown in Figures 6-1A and 6-1B. Phase I proposed sample collection, with analytical methods is summarized on Tables 6-1 and 6-2, respectively.

The Phase II Study Area will include portions of the Herrington Lake Study Area, with particular focus on Curds Inlet and other areas and embayments adjacent to, or near, the E.W. Brown Generating Station. The Phase II field program is focused on the following elements:

- YOY Fish Assessment: A YOY bass study will be conducted at locations in Curds Inlet and other locations proximal to the E.W. Brown Generating Station. YOY bass collections will be conducted in areas that provide opportunity to measure a gradient of potential differences away from Curds Inlet, if such a gradient exists. The YOY assessment is discussed further in Section 6.1.1 (Figure 6-1A and 6-1B).
- Whole-body fish tissue collection: Collection of whole-body adult and YOY fish samples will build on Phase I results to provide additional characterization of selenium levels in whole-body fish, focused on Curds Inlet and other lake areas located in relative proximity to E.W. Brown Generating Station (Figure 6-1A and 6-1B).
- Water Samples: Water samples will be provided in locations concurrent with YOY fish collection (Figure 6-1A and 6-1B). This information will provide insight into chemicals in the environment relative to water quality standards.
- Sediment Pore Water and Sediment: The sediment pore water and sediment samples are planned for Curds Inlet only. These will allow more focused characterization around the location CI-3A where highest concentrations of selenium and arsenic were observed. Transect CI-3 will be resampled to confirm the Phase I analytical results. Four new transects will be added near CI-3 (Figure 6-1B). In situ pore water samplers will be deployed at locations along the new transects and at former transects where pore water was not collected (CI-4) or where samplers deployed in Phase I could not be retrieved (e.g., CI-3A, CI-1A, CI-1B, CI-2B) (Figure 6-1B).

The Phase II field program will be implemented during one event in the summer of 2018 in June at a timeframe where water temperatures are appropriate for bass spawning, to correspond to the timing of the 2016 YOY study. The sampling plan and analytical methods identified for the sample media will ensure that data are of sufficient quality and quantity to be used for the human health and ecological risk assessments that will be performed for the Study Area. Samples will be collected in accordance with the approved QAPP and SOPs (Ramboll 2017b,c,d,e,f). A new SOP will be developed and submitted to the Cabinet for the YOY study. A QAPP Addendum will be prepared to explain the YOY laboratory analyses that will be used. Those documents will be provided to the Cabinet for review under separate cover from the *Phase I Technical Memorandum*.

6.1.1 Assessment of YOY Bass

The assessment of YOY bass will be conducted via methods consistent with the 2016 study of YOY in Curds Inlet (Downstream Strategies 2016, Lemly 2017, 2018). The 2016 study locations for Curds Inlet are presented on Slide 27 of the March 16 presentation materials. The researchers collected 500 YOY fish from three locations within Curds Inlet and composited them into a single sample for Curds Inlet. The Phase II field program shows two distinct locations for YOY fish (Figure 6-1B). These locations align with the 2016 YOY locations with separation that may allow an understanding of gradient, if any, within

Curds Inlet. If possible, two separate YOY samples will be collected for assessment of deformities. A single sample will be collected if sufficient numbers of YOY bass are not found. As listed in Table 6-1 and illustrated in Figures 6-1A and 6-1B, the YOY bass will be collected from the following six sampling areas:

1. Curds Inlet (near the middle portion of Curds Inlet)
2. Curds Inlet (near the mouth of the inlet with the lake, near CI-4)
3. HQ Inlet
4. LHL3 Cove located across from Curds Inlet
5. LHL1 Rocky Run
6. LHL6 Cove

The Curds Inlet locations may be combined into a single sample, if sufficient numbers of fish cannot be collected. The sample collection method planned for Phase II is consistent with the 2016 collection methods. In order to achieve statistical significance, the target sample number of YOY bass is 500 individuals within a size range of 2–5 centimeters (cm) (approximately 1–2 ½ inches) total length. Fish seining will be the primary collection method, but minnow traps may also be used. Because electrofishing has the potential to cause physical effects to small fishes similar to the deformities being assessed in this study, electrofishing will only be employed if the preferred methods are not effective. In addition, electroshocking will only be used to collect fish greater than 4 cm (approximately 2 inches) in length, as potential electroshock burns (if any) will be more easily discernible on the larger size fish. Also, the larger fish may be more effective at avoiding the seine nets, so electroshocking may allow capture of some fish that would otherwise evade capture. YOY bass collected by electrofishing methods will be composited separately from the fish collected by netting or minnow trap methods. Multiple fish collection efforts may be conducted over the bass spawning season, if needed.

YOY bass collected for deformities assessment will be preserved in denatured alcohol upon capture and handling. The following deformities will be assessed: Spinal curvature (kyphosis, lordosis, and scoliosis);

- Craniofacial defects (including mouth, jaw, and gill cover);
- Fin irregularities (missing, misshaped, vestigial);
- Eye abnormalities (including lens cataracts and exophthalmos); and
- Edema (fluid accumulation).

The preserved specimens will be assessed for deformities by Richard Lockwood (Ramboll, Nashville TN Aquatic Toxicity Lab). Photographs of all fish will be taken, with a ruler for scale of the fish size. A third party quality assurance deformities evaluation will be conducted on 25% of all fish with no deformities and on 100% of fish with deformities by Dr. John Hawke (Department of Pathobiological Sciences, Aquatic Diagnostic Laboratory, Louisiana State University School of Veterinary Medicine (LSU)). More detailed information about the Ramboll Aquatic Toxicology Lab and the LSU Department of Pathobiological Sciences will be submitted as part of the QAPP Addendum that will be submitted concurrent with the *Phase I Technical Memorandum*.

6.1.2 YOY and Adult Fish Tissue Collection and Analysis

YOY and adult fish tissue collection will be conducted summarized on Table 2-1 and briefly described as follows:

- YOY bass fish composite samples will be collected for analysis of whole-body selenium concentrations at each of the YOY fish sampling stations for a total of 12 YOY fish samples.

- Adult fish will be collected for the locations identified in Figures 6-1A and 6-1B as was conducted for the Phase I effort:
- Adult whole-body fish from three target fish species including a small home range prey fish (bluegill), an upper trophic level predator (largemouth bass), and a bottom feeder (catfish). Proposed fish collection areas are:
    - Curds Inlet (bluegill, bass, catfish)
    - HQ Inlet (bluegill only)
    - LHL3 Cove located across from Curds Inlet (bluegill only)
    - LHL1 Rocky Run (bluegill, bass, catfish)
    - LHL6 Cove (bluegill from the cove, bass and catfish from LHL6)

Proposed number of YOY and adult composite fish samples:

- The YOY composite fish sample for laboratory chemical analysis will consist of samples collected from each of the six separate YOY collection locations. Two YOY fish composite samples will be collected from each location, which is consistent with the number of samples collected per species in the Phase I sampling program. The YOY fish samples will be comprised of 10 fish per composite sample, if sufficient numbers of fish are collected. A total of 12 YOY fish composite samples will reflect up to 120 individual YOY fish, if sufficient numbers of YOY fish are collected. The individual fish collected for the composite samples will be randomly collected from the YOY fish collected as part of the YOY assessment (i.e., the selection of fish for tissue residue analysis will be a random grab of up to 10 YOY fish from among the fish collected via the effort described in Section 6.1.1).
- Adult bluegill, bass, and catfish will be collected from each location as indicated in bullets above. Adult fish samples will be comprised of 2 to 5 fish per composite sample.
- Ten percent of the YOY and adult fish samples will be sent to the Kentucky ESB for split sample analysis. Aliquots of homogenized freeze dried fish will be sent to ESB directly from the analytical laboratory performing Phase II analyses.

YOY captured as described in Section 6.1.1 and retained for whole-body tissue residue analysis will not be preserved as stated for YOY assessment. They will be placed on ice and frozen, as described for adult fish. Multiple fish will be combined into a single composite sample, photographed, wrapped in foil, and shipped as described for adult fish.

Adult-fish will be collected via electro-fishing, gill netting, or the use of multi-hook lines, large minnow traps, or standard hook and line, as necessary, as described in the Herrington Lake Fish SOP (Ramboll 2017c), which follows the KDOW Fish Collection SOP (2014). During collection, target fish will be placed into temporary holding containers until sampling for the area is completed. Effort will be made to minimize disturbance to the aquatic habitat while sampling. Non-target fish collected incidentally and not retained for tissue analysis will be immediately released back into the sample environment. Fish samples collected during Phase II sampling, including young-of-year sampling will photographed with a digital camera including a ruler next to the fish for scale. The whole-body fish samples will be wrapped in aluminum foil (dull side against the sample) and placed into a plastic zip-top bag. The bag will be labelled with project name, sample identification, sample date/time, and the analyses requested. Samples will be placed immediately on wet or dry ice (or refrigerated or frozen, if available). The samples will be kept cool or frozen in a cooler until transported to a freezer for long-term storage. Samples will be processed and analyzed as conducted in the Phase I program, in accordance with the

standard operating procedures for preparation and homogenization of fish tissue samples (Ramboll 2017c, KDOW 2017). Frozen fish samples will be shipped via appropriate chain-of-custody procedures on dry ice to the laboratory.

6.1.3 Surface Water Collection

Water profiles will be taken during Phase II sampling to evaluate stratification conditions so that samples can be collected from each layer present at the time of sampling. Surface water samples will be collected at locations identified in Figure 6-1B. A summary of surface water samples is provided on Table 6-1 and the analytical methods for surface water are provided on Table 6-2.

Phase I lake profiles indicated that the shallow inlet locations in middle Curds Inlet and HQ Inlet are well-mixed and that one surface water sample, collected from mid-depth, is considered adequate in these inlets. Surface water profiles collected during Phase I suggest that Locations CI-4, LHL-1, and LHL-2 will require one water sample for each of the (up to) three LHL summer-phase thermal-stratification layers, estimated as described but actual field collection will be based on profiles collected at the time of Phase II sample collection (i.e., profiles will be conducted in the Phase II program to guide Phase II collection efforts):

- Epilimnion - the 0 to 30 foot bws sunlight-zone, characterized by significantly higher DO concentrations that would support fish life.
- Metalimnion - the thermocline within the 50 to 90 foot bws interval characterized by a significant decrease in water temperature and DO levels, and clear partitioning from the deeper, colder water beneath it.
- Hypolimnion - the greater than 100 feet bws interval characterized by a significantly lower, but more stable, water temperature and DO levels, and clear partitioning from the metalimnion.

Therefore, it is estimated that for Phase II, a total of thirteen surface water samples are proposed from seven locations within LHL as follows:

- One from each of two shallow Curds Inlet locations CI-2.2 and CI-3.1, and two from the deeper CI-4 locations,
- One from shallow HQ Inlet, two from deeper LHL-1 (Rocky Run), and three from deep LHL-3 and LHL-6 locations.

Surface water samples will be collected from the approximate center of each of surface water transect, following the Phase I Surface Water SOP (Ramboll 2017d). Lake profiling at each SW sample location will also record water temperature, pH, dissolved oxygen, specific conductivity (using a multi meter), and turbidity (using a Secchi disc). Each SW sample will include both field-filtered (0.45 µm filter) and non-filtered samples to measure both total and dissolved constituents, as identified in Table 6-2. The samples will be placed in the specified laboratory containers, capped, labelled, placed in plastic bags, and stored in coolers, on ice, for shipment to the analytical laboratories. Under appropriate chain-of-custody procedures, each sample will be shipped via overnight or expedited courier to the identified laboratory.

6.1.4 Sediment Pore Water and Sediment Collection

Sediment pore water and sediment samples will be collected in accordance with the Herrington Lake Sediment Pore Water and Sediment SOP (Ramboll 2017e) for locations identified in Figure 6-1B, Table 6-1, and Table 6-2.

The deployment of sediment pore water samplers (peepers) is proposed within Curds Inlet in the thalweg and below winter pool depths, as briefly described below:

- New transects: CI-2.1, CI-2.2, CI-3.1, and CI-3.2.
- Previous locations not sampled: CI-4A and CI-4B.
- Previous locations where Phase I samplers were not retrieved (CI-1A, CI-1B, CI-2B, CI-3A, and CI-3B).
- Multiple samplers will be deployed where quality assurance samples will be collected. Multiple samplers may also be deployed to ensure collection. The inability to retrieve samplers from Phase I efforts was due to the dislodging of sampler markers and potential movement of samplers as lake water was lowered from summer to winter pool. This change is not anticipated for Phase II as it is proposed that sampling occur in June. Peepers deployed in June will be retrieved in July after 3 weeks of equilibration. Phase I samplers that were not retrieved may be found during the deployment of Phase II samplers. If found intact, those devices from the Phase I deployment will be processed for samples and may be used in placed new Phase II samplers.

Wherever practical, the peepers will be co-located with the collected sediment samples but final deployment locations will be determined at time of deployment by the field team leader. The retrieved pore water samples will be placed in the specified laboratory containers, capped, labelled, placed in plastic bags, and stored in coolers, on ice, for shipment to the analytical laboratories. Using appropriate chain-of-custody procedures, samples will be shipped via overnight or expedited courier to the identified laboratory (or laboratories). Peeper deployment duration is three weeks for measuring metals.

Sediment samples are proposed for Curds Inlet, as shown in Figure 1-4B and briefly described below:

- Phase I transect locations to resample: CI-3 and CI-4
- New transect locations: CI-2.1, CI-2.2, CI-3.1, and CI-3.2

To the extent practical, the sediment sample locations will include one sample collected from the each of the following:

- Location A: subaqueous, close to the deepest point in the channel (thalweg).
- Location B: Near west (depositional) shoreline, subaqueous, below the water winter lake level of 720 feet.
- Location C: Between summer and winter pool.

For practicality, the final sampling locations will be determined in the field based on field conditions and at the discretion of the field team leader. Based on Phase I experience, the deep rocky substrates of Curds Inlet pose practical challenges to collect sediment from specific locations. Phase II sediment sampling will target depositional areas, wherever practical, to provide a conservative characterization of sediment quality.

Sediment samples will be collected following the methodology in the Phase I CAP (Ramboll 2017a) and Phase II SOP (Appendix A). Sediment samples will be placed in the specified laboratory containers, capped, labelled, placed in plastic bags, and stored in coolers, on ice, for shipment to the analytical laboratories. Under appropriate chain-of-custody procedures, samples will be shipped via overnight or expedited courier to the identified laboratory (or laboratories).

6.1.5 Field Quality Assurance/Quality Control Procedures

Field QA/QC samples collected during the proposed investigation include field duplicate samples and equipment blanks, consistent with the Phase II QAPP (Ramboll 2017b) and the QAPP Addendum for YOY sampling. Field duplicate (FD) samples will be labelled and packaged in the same manner as primary samples but with “FD” appended to the sample ID. Field duplicates will be collected at a frequency of

one in every 10 primary samples and will be analyzed for the same suite of parameters as the primary sample. Equipment blanks will be collected once per field event, if necessary. In addition, MS/MSD procedures are used as a laboratory control measure, and while not defined as field QA/QC samples, they do require additional sample volume. MS/MSD procedures are performed on field samples at a frequency of one per 20 samples, as was identified in the QAPP (Ramboll 2017b).

6.1.6 Sample Designation

To maintain consistency, a unique sample identification convention will be developed and will be followed while implementing this Phase II FSP. The sample IDs will be entered onto the sample labels, field forms, chain-of-custody forms, logbooks, and other records documenting sampling activities.

6.2 Phase II Laboratory Methods and Data Validation

The analytical laboratory, methods, and data validation procedures are described below.

6.2.1 Analytical Laboratory, Laboratory Preparation, and Analytical Methods

Samples will be sent to a National Environmental Laboratory Accreditation Program (NELAP) laboratory for analysis. The ALS Kelso Washington laboratory will be used again.

Phase II samples will be analyzed for selenium and other constituents using the USEPA Method 200.8 for water and sediment and Method 6010/6020 for solids, as indicated in Table 6-2, as was done for the Phase I collection effort. A difference in the sampling program between Phase I and Phase II is that only whole body fish will be analyzed and the samples will only be analyzed for selenium.

6.2.2 Chemistry Data Validation

Data generated during performance of the fieldwork will undergo two levels of review and validation: one at the laboratory and a second review after the data are received by Ramboll. Ramboll and a designated independent data validation contractor will perform the second data validation review. Data will be validated at 100% level with Level II validation and 20% of the samples validated at Level IV, as was conducted for Phase I. The same third party validator will be used (Validate LLC).

6.3 Phase II Reporting Schedule

An implementation schedule for completing the characterization and analyses identified in this Phase II FSP is dependent upon the timing of Cabinet approval of the plan. An early June 2018 Phase II start time is proposed so that the YOY study can be conducted at the same time as the past YOY study. It is anticipated that the field effort will be approximately 2 to 3 weeks for the YOY fish, adult fish, surface water, sediment pore water, and sediment. Retrieval of sediment pore water will occur 3 weeks after deployment. Laboratory analyses will take 6 to 8 weeks (given the time required to freeze dry the fish samples). Data validation will require 3 additional weeks. Reporting will be provided within 3 months of receipt of final validated data

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