

# **River Corridor Closure Contract**

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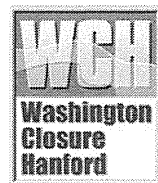
## **Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington**

**Collection of Surface Water, Pore Water, and  
Sediment Samples for Characterization of  
Groundwater Upwelling**

**November 2010**

**Washington Closure Hanford**

Prepared for the U.S. Department of Energy, Richland Operations Office  
Office of Assistant Manager for River Corridor



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# **Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington**

## **Collection of Surface Water, Pore Water, and Sediment Samples for Characterization of Groundwater Upwelling**

**November 2010**

**Authors:**

**L. C. Hulstrom**  
Washington Closure Hanford, LLC

**B. L. Tiller**  
Environmental Assessment Services, LLC

**Contributors:**

Coastal Monitoring Associates, LLC  
Nugent GIS and Environmental Services, LLC



## EXECUTIVE SUMMARY

This report summarizes field sampling activities conducted in support of Washington Closure Hanford's Remedial Investigation of Hanford Site Releases to the Columbia River. The work was conducted from 2008 through 2010 throughout an approximately 64 km (40 mi) section of the Columbia River where contaminated groundwater was known or suspected. The work included preliminary mapping and measurement of Hanford Site contaminants in sediment, pore water, and surface water located in areas where groundwater upwelling were found. This effort included use of the liquid-tip Trident probe and associated river-stage-specific sampling techniques to map offshore and near-shore groundwater upwelling, and when desired, to collect verifiable samples of pore water found 20 to 31 cm (8 to 12-in.) below the riverbed surface. Sediment coring and grab sampling techniques were then used concurrently with the Trident probe to collect sediment, pore water, and surface water to assess the likelihood of potential ecological risk where contaminated groundwater was found entering the river. In total, 972 sample locations were measured.

Groundwater upwelling locations were mapped using conductivity and temperature measured at 685 sample locations. Indicator contaminant levels in the pore water were analyzed in 237 samples and subsequent characterization of multiple Hanford Site contaminants was then conducted in 49 samples of pore water and surface water, and 50 samples of sediment during the spring of 2010. Groundwater mapping results showed upwelling were nonuniformly distributed in each of the eight study areas examined. Groundwater upwelling measured repeatedly at selected sample locations appeared to vary by water depth, by season, and proximity to the shoreline. Indicator compound analysis (hexavalent chromium, strontium-90, tritium, uranium) showed that Hanford Site contaminants above water quality guidelines were found both nearshore and offshore.

The methodology and results obtained provided a basic picture of groundwater upwelling patterns throughout the Hanford Reach and helped to assess the likelihood of ecological risk from Hanford Site releases via groundwater upwelling. Obtaining verifiable pore-water samples under river stage-specified conditions proved to be a viable approach to map and measure off-shore concentrations of Hanford Site contaminants upwelling into the Columbia River.





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## REVISION HISTORY

Revision	Date	Reason for Revision	Revision Initiator
1	11/2010	Text in Section 3.1 was updated to correct a temperature conversion from °C to °F where the reported value is the temperature difference.  Figure 3-39 was corrected to show pore water conductivity rather than hexavalent chromium concentrations which are shown in Figure 3-41.	L. C. Hulstrom
0	07/2010	Initial issuance	NA





## ACRONYMS

AVS	acid volatile sulfide
CRC	Columbia River Component
D4	deactivation, decontamination, decommissioning, and demolition
DI	deionized (water)
DO	dissolved oxygen
DOE	U.S. Department of Energy
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
GPS	global positioning system
HASQARD	Hanford Analytical Services Quality Assurance Requirements Document
HEIS	Hanford Environmental Information System
HGET	Hanford General Employee Training
IWCP	Integration Work Control Program
JHA	job hazard analysis
Kcfs	thousand cubic feet per second
OD	outer diameter
ORP	oxidation reduction potential
PCB	polychlorinated biphenyl
PPE	personal protective equipment
PQL	practical quantitation limit
QA	quality assurance
QC	quality control
RCBRA	River Corridor Baseline Risk Assessment
RCCC	River Corridor Closure Contractor
SAF	sample authorization form
SAI	sampling and analysis instruction
SAP	sampling and analysis plan
SDG	sample delivery group
SEM	simultaneously extracted metals
SVOC	semivolatile organic compound
TPH	total petroleum hydrocarbons
Tri-Parties	U.S. Department of Energy, U.S. Environmental Protection Agency, and Washington State Department of Ecology
VOA	volatile organic analysis
VOC	volatile organic compound
WCH	Washington Closure Hanford



## METRIC CONVERSION CHART

Into Metric Units			Out of Metric Units		
<i>If You Know</i>	<i>Multiply By</i>	<i>To Get</i>	<i>If You Know</i>	<i>Multiply By</i>	<i>To Get</i>
<b>Length</b>			<b>Length</b>		
inches	25.4	millimeters	millimeters	0.039	inches
inches	2.54	centimeters	centimeters	0.394	inches
feet	0.305	meters	meters	3.281	feet
yards	0.914	meters	meters	1.094	yards
miles	1.609	kilometers	kilometers	0.621	miles
<b>Area</b>			<b>Area</b>		
sq. inches	6.452	sq. centimeters	sq. centimeters	0.155	sq. inches
sq. feet	0.093	sq. meters	sq. meters	10.76	sq. feet
sq. yards	0.836	sq. meters	sq. meters	1.196	sq. yards
sq. miles	2.6	sq. kilometers	sq. kilometers	0.4	sq. miles
acres	0.405	hectares	hectares	2.47	acres
<b>Mass (weight)</b>			<b>Mass (weight)</b>		
ounces	28.35	grams	grams	0.035	ounces
pounds	0.454	kilograms	kilograms	2.205	pounds
ton	0.907	metric ton	metric ton	1.102	ton
<b>Volume</b>			<b>Volume</b>		
teaspoons	5	milliliters	milliliters	0.033	fluid ounces
tablespoons	15	milliliters	liters	2.1	pints
fluid ounces	30	milliliters	liters	1.057	quarts
cups	0.24	liters	liters	0.264	gallons
pints	0.47	liters	cubic meters	35.315	cubic feet
quarts	0.95	liters	cubic meters	1.308	cubic yards
gallons	3.8	liters			
cubic feet	0.028	cubic meters			
cubic yards	0.765	cubic meters			
<b>Temperature</b>			<b>Temperature</b>		
Fahrenheit	subtract 32, then multiply by 5/9	Celsius	Celsius	multiply by 9/5, then add 32	Fahrenheit
<b>Radioactivity</b>			<b>Radioactivity</b>		
picocuries	37	millibecquerel	millibecquerels	0.027	picocuries



## 1.0 INTRODUCTION

The primary objective of the remedial investigation upwelling study is to quantify Hanford Site contaminants in river bottom sediments adjacent to locations where contaminated groundwater is upwelling. The results from the study will help to determine whether or not any cleanup actions are needed to address risks to humans or river biota from contaminated sediments at these locations.

An underlying assumption of the study is that separate cleanup actions are underway or will be implemented in the future to address Hanford Site contaminated groundwater plumes such that ambient water quality standards are met.

Eight study areas were established for the upwelling activities: each of the reactor sites (100-B/C, 100-K, 100-N, 100-D, 100-H, and 100-F), the Hanford townsite, and the 300 Area. A multi-phased upwelling investigation design was established in the Work Plan, with the results from each phase progressively informing the plans for the subsequent phase.

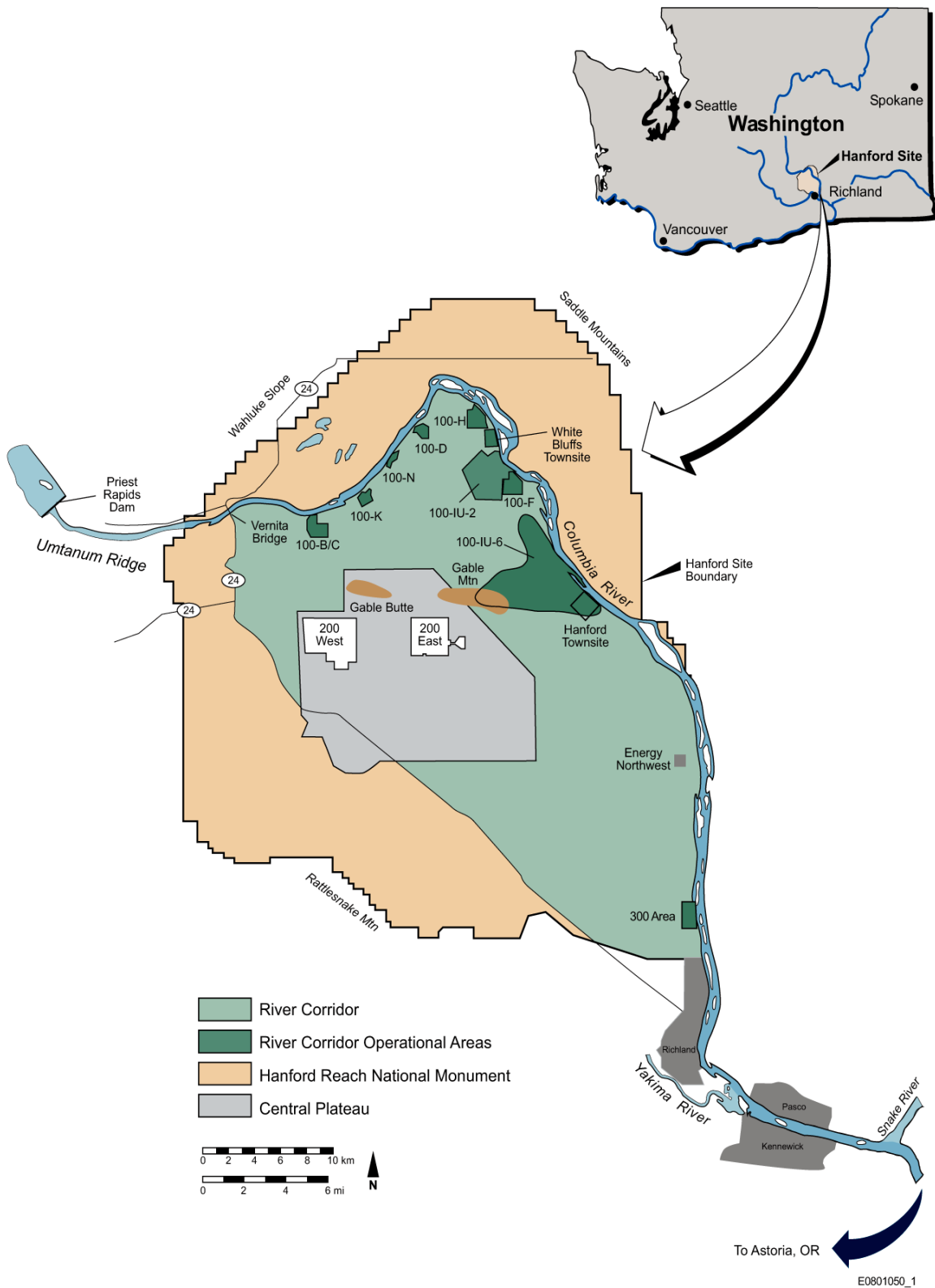
- Verify technology application in Hanford Reach environment (Phase I)
- Identify locations where groundwater is upwelling (Phase II[a])
- Identify locations where contaminated groundwater is upwelling (Phase II[b])
- Characterize sediment, pore water, and surface water at locations where contaminated groundwater is upwelling (Phase III).

### 1.1 PURPOSE

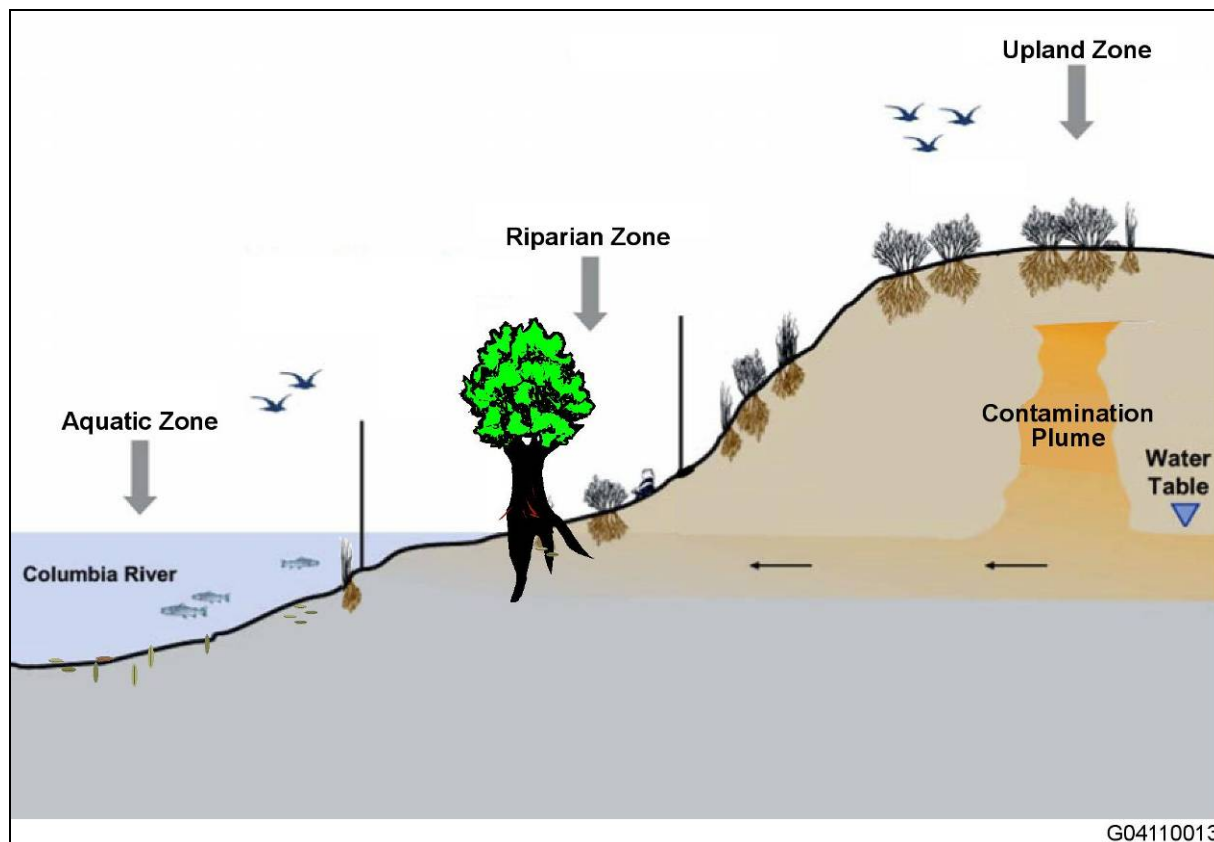
Past waste management and waste disposal practices at the Hanford Site have resulted in the presence of several contaminated groundwater plumes originating from the Central Plateau and the River Corridor operational areas (Figure 1-1). Groundwater beneath the Hanford Site discharges to the Columbia River via springs and sub-aqueous (below the riverbed) groundwater upwelling.

Groundwater provides a means for transporting Hanford Site-related contaminants to the Columbia River. In general, groundwater discharges are considered to be the current dominant pathway for Hanford Site-related contaminants to enter the Columbia River (Figure 1-2). Shoreline springs were documented along the Hanford Reach long before Hanford Site operations began during World War II. During the early 1980s, researchers identified 115 springs along a 66 km (41 mi) portion of the river known as the Hanford Reach (McCormack and Carlile 1984).

Figure 1-1. Hanford Site River Corridor.



**Figure 1-2. Conceptual Model of Hanford Site Releases via Groundwater Upwelling into the Columbia River.**



Within the Columbia River system, large amounts of surface water, sediment, and biota data potentially related to Hanford Site contaminant releases have been collected since the start of operations through various sampling and monitoring programs. Areas upstream, within, and downstream of the Hanford Site boundary have also been investigated per U.S. Department of Energy (DOE) orders. The impacts of Hanford Site releases to the Columbia River are now being formally assessed under *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*.

The *Remedial Investigation Work Plan for Hanford Site Releases to the Columbia River* (DOE/RL-2008-11) was issued in September 2008 to initiate the remedial investigation. This Work Plan established a phased approach to characterize contaminants, assess current risks, and determine whether or not there is a need for any cleanup actions. The scope of the remedial investigation focuses on the impacts of Hanford Site hazardous substance releases to the Columbia River and its users.

Field investigation activities supporting the remedial investigation of Hanford Site releases to the Columbia River were initiated in October 2008. The field investigation was designed to fill the data gaps and characterization needs that were identified as part of the data quality objective scoping process. Media collected as part of the field investigation activities have included island soil, shoreline sediments, river bottom sediments, core sediments, surface water, pore water,

and fish from a 193 km (120 mi) stretch of the Columbia River. Collectively, the Work Plan (DOE/RL-2008-11), the Sampling and Analysis Plan (Appendix A to DOE/RL-2008-11) and the Sampling and Analysis Instructions (WCH-286, as revised) further detail these activities. These reports from this point forward in this report will be referred to as the “Work Plan”, “SAP”, and “SAI”.

## 1.2 SCOPE

Locating and measuring contaminants in upwelling is a method for understanding exposure to the bottom-dwelling, or “benthic” community. However, finding these areas and taking precise measurements in the space between rocks and sediment where the benthic organisms live and fish lay their eggs can be difficult. Conventional methods can be labor-intensive and often impractical in the fast moving waters, deep channels, and large boulders that typify the offshore Columbia River system. Previous techniques used for this type of characterization have only been practical in areas near the Hanford Reach shoreline. Because it has been difficult to sample in the offshore water depths and currents, there has been a data gap with understanding the connection between groundwater and the Columbia River water. One key data gap focus of this field investigation was to further delineate areas where groundwater is upwelling (emerging) into the Columbia River bottom within the Hanford Reach area and determine sediment concentrations at those locations. Pore-water sample results throughout the riverbed areas of the Columbia River adjacent to the Hanford Site were needed to fill data gaps identified in the Work Plan.

### 1.2.1 Hanford Reach Environment

Most of the Columbia River within the United States is impounded by dams. The Hanford Reach is an 82 km (51 mi) stretch of the Columbia River that flows unimpeded between the Priest Rapids Dam to the head of Lake Wallula upstream of McNary Dam. The Hanford Reach is the only free-flowing portion of the river above Bonneville Dam.

The Hanford Reach contains high velocity waters and coarse substrates (rocky riverbed) that make deployment and installation of groundwater monitoring devices used historically along the Columbia River shorelines nearly impossible at the offshore locations. Additionally, the water table and the associated groundwater gradients near the Hanford Site are strongly influenced by river stage fluctuations. As water levels fluctuate, the gradient between the groundwater and river fluctuates. River water moves into the Hanford Site aquifer as the river stage rises (bank storage) and then discharges from the aquifer in the form of shoreline springs and upwelling as the river stage falls. Bank storage of river water also affects the contaminant concentration in groundwater upwelling. Groundwater upwelling discharged immediately following a river stage decline generally consists of river water or a mixture of river water and groundwater. In general, the percentage of groundwater in the upwelling increases and then stabilizes over time following a drop in river stage. At the 300 Area, the river stage is also influenced by the elevation of the McNary Dam pool.

This report contains an assessment of the effects of river stage during sampling events. Measuring the specific conductance of the pore water provides a rather subtle indicator of the extent of bank storage because Hanford Site groundwater has a higher specific conductance than Columbia River water. Typically, surface water conductivity in this region of the



Columbia River is approximately 130 to 145  $\mu\text{S}/\text{cm}$ , whereas groundwater ranges approximately 400 to 600  $\mu\text{S}/\text{cm}$ . Pore water temperatures can also be used as a indication of groundwater by comparing them to surface water temperatures. In this region of the Columbia River, surface water temperatures typically range from approximately 0.5 °C (33 °F) in the winter months to more than 27 °C (80 °F) during the late summer months, whereas groundwater typically stays between 7 °C (45 °F) and 15 °C (60 °F).

### 1.2.2 Previous Shoreline Investigations

Exploratory investigations during the early 1980's identified general shoreline areas where Hanford-related materials were entering the river via ground-water seepage (McCormack and Carlile 1984). Historically, the tools and techniques used for delineating and sampling contaminated aquifers beneath the Hanford Site have been labor-intensive methods deployed along the shoreline. These methods, including vertical drive points, wells, and horizontal pore water devices, are not suited for off-shore, rapid, measurements (e.g., specific conductivity and temperature of pore water) of groundwater upwelling. Divers using syringes to extract small volumes of pore water were able to sample pore water at a few offshore locations during the mid-1990's but the fast moving waters found in many areas of the Hanford Reach limited utility of this approach for large-scale application (Hope and Peterson 1996a, 1996b). A 1:1 mixing dilution model has been used to estimate concentrations that might be found in the off-shore riverbed areas. Tissue concentrations of sentinel organisms, such as the Asiatic clam, have been effective for mapping Hanford Site contamination out to water depths of approximately 2 m (6.5 ft), but fast and deep water conditions limited divers from collecting samples much deeper (Tiller et al., 2004; PNNL-15222). Other devices such as "peepers" have been deployed in soft bottom, slow-moving water bodies throughout the world to obtain small (less than 100 mL) samples of pore water. However, the Hanford Reach contains high velocity waters and coarse substrates (rocky riverbed) that make deployment and installation of these devices nearly impossible.

### 1.2.3 New Field Sampling Techniques Applied to the Hanford Reach

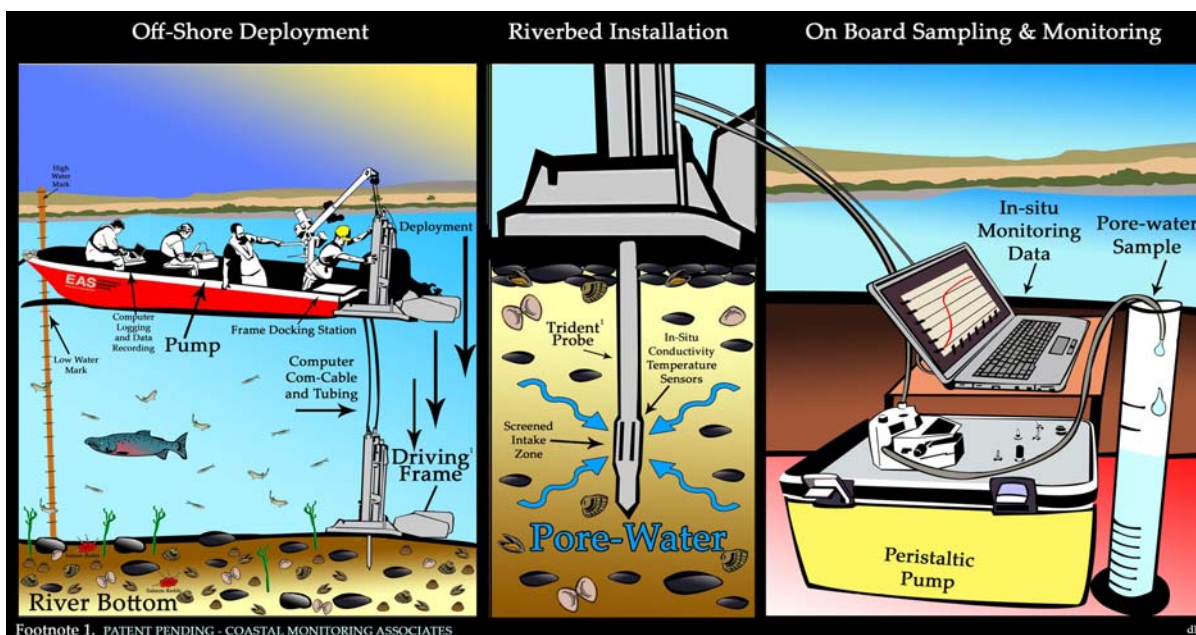
The liquid-tip Trident probe<sup>1</sup> was used to measure key Hanford Reach groundwater upwelling characteristics using a 500-pound frame outfitted with sensors, cameras, and sampling tubes deployed from the research vessel to the bottom of the river (Figure 1-3). The probe was then driven into the riverbed to provide in-situ readings of the pore water characteristics (conductivity and temperature) onboard the research vessel. Pore-water samples could be collected while monitoring the pore water characteristics to verify the samples had not be artificially diluted (i.e., short-circuit) with surface water. The probe, which can be used in most portions of the river, was successfully demonstrated in the first phase of a mapping and characterization project during the fall of 2008.

The liquid-tip Trident probe's pore water conductivity measurements were analyzed using river stage modeling techniques and actual river bathymetry and river flow data to develop river stage-specified sampling guidelines that would help consistently obtain comparable data sets within sites, between sites, and seasons. A further description of these guidelines is provided in Section 2.0.

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<sup>1</sup> Patent pending – Coastal Monitoring Associates.

**Figure 1-3. General Schematic of the Groundwater Mapping and Sampling System.**



This was the first water sample collection campaign for Hanford Site contaminants to date that coordinated sampling events with the river stages. The collection of verifiable pore-water samples during relatively stable and low river discharge conditions proved to be a valuable approach to map and measure concentrations of Hanford Site contaminants in the Columbia River.

## 1.3 PROJECT STRUCTURE

### 1.3.1 Phased Approach

Pore water, sediment, and surface water samples were collected along the river at locations where contaminated groundwater plumes were found to be discharging to the river (DOE/RL-2008-01). Samples were collected from each of the reactor sites (100-B/C, 100-K, 100-N, 100-D, 100-H, and 100-F), the Hanford townsite, and the 300 Area to characterize the plume discharges. Prior to collecting groundwater plume upwelling samples in these areas, a groundwater plume upwelling survey was performed. The purpose of the groundwater plume upwelling survey was to delineate areas of groundwater plume upwelling into the Columbia River for subsequent sampling. Once areas of groundwater plume upwelling were identified, focused pore water, sediment, and surface water sampling locations were identified and provided to the Tri-Parties for review and approval. Upon receiving approval, samples were collected for laboratory analysis. This survey was planned to be completed in three phases:

- Phase I (Technology Demonstration) was a test of the applicability of the proposed Trident probe technology to Hanford Reach conditions.

- Phase II (Groundwater Plume Upwelling Delineation) was divided into two sub-phases (a and b). Phase II(a) focused on delineating eight areas of suspected groundwater plume upwelling. This activity included in-situ pore water measurements of specific conductance and temperature. Phase II(b) included a screening analysis of key Hanford Site indicator contaminants (e.g., hexavalent chromium, strontium-90, uranium, and tritium).
- Phase III (Groundwater Plume Upwelling Characterization) included more extensive characterization of upwelling conditions through pore water, sediment, and surface water sampling at locations selected from review of the Phase II results.

Specific design elements and results for each of the study phases are summarized in the subsections that follow. Supplemental information can be found in Appendices A through L (on CD only).

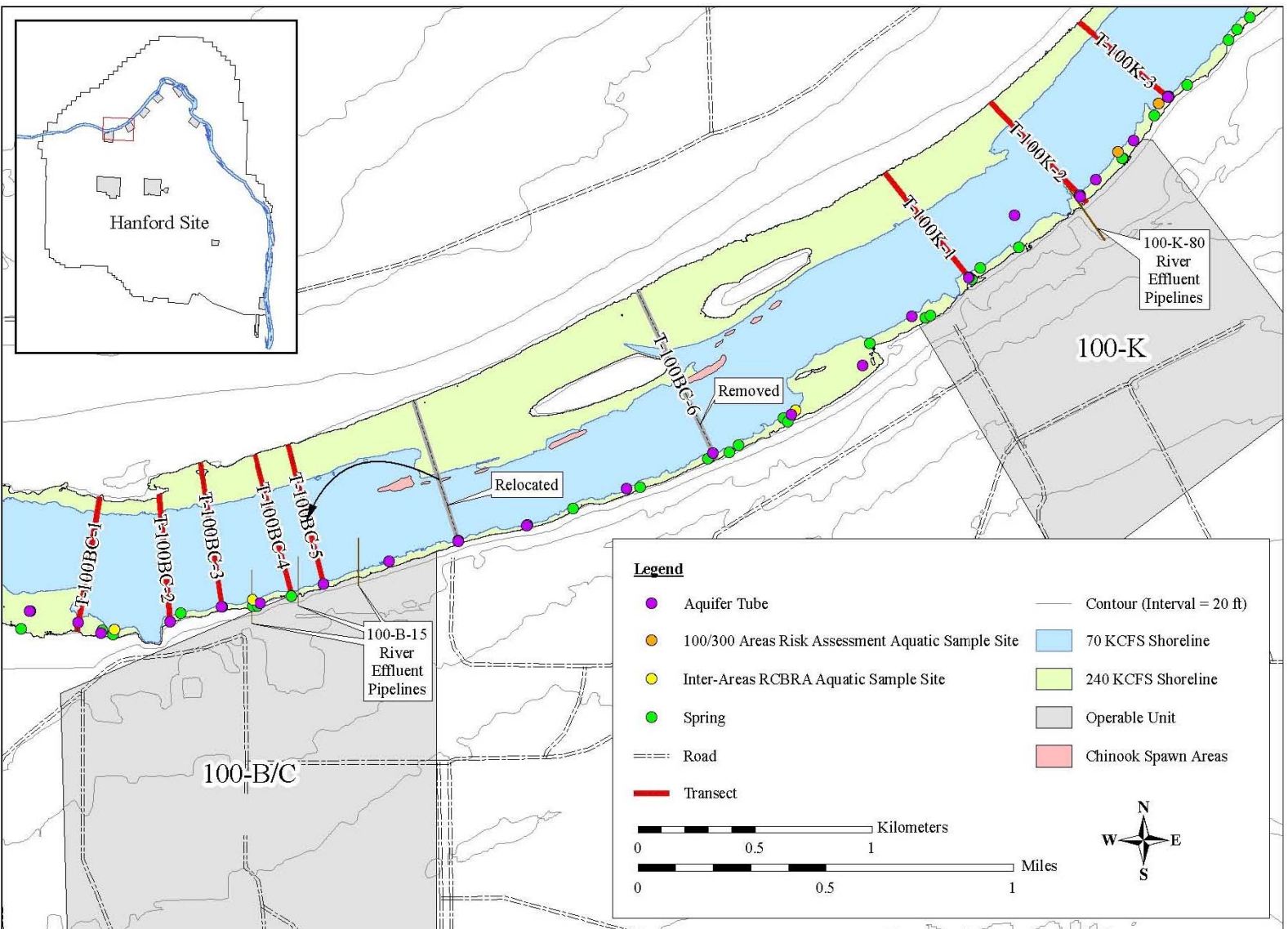
**1.3.1.1 Phase I - Technology Demonstration.** The technology demonstration design was to deploy the Trident Probe in a range of river conditions (e.g., water depths and velocities) and bottom formations (e.g., fine-grained sediments, gravels/cobbles, and cemented formations [e.g., Ringold Upper/Lower Mud]) within the Hanford Reach area. When deployed, the test objective was to verify the ability to draw pore water measurements, in-situ temperature, and conductivity measurements of both surface water and groundwater. This information is provided in Appendix K.

**1.3.1.2 Phase II(a) – Conductivity and Temperature Mapping.** Conductivity is a measure of a material's ability to conduct an electric current. Differences in conductivity between groundwater and river water can be used to identify points where groundwater enters (upwells) into the river. Temperature is another parameter that can be used, especially when river water is cooler than groundwater during the winter months. As such, field teams deployed the Trident probe at selected sample locations and if they were able to penetrate the probe at least 20.3 cm (8-in.) (and generally 30.5 cm [12-in.]) into the riverbed, a series of measurements of the surrounding pore water temperature and conductivity were obtained.

Within each of the eight upwelling study areas, five transects were established based on known Hanford Site groundwater plume contours (DOE/RL-2008-01). Five additional transects were added between reactor areas and south of the 300 Area to provide information outside of known plume areas. All transects started at the Hanford Site near-shore (e.g., reactors areas) and continued across the entire river channel to the far shore (Figure 1-4). Some site-specific adjustment to the planned transect locations were made by the field teams; one case when currents at Coyote Rapids exceeded 3 m/s (10 ft/s), and another case when asymmetrical river channels and the proximity of 100-D Area island prompted field teams to suggest moving the transect upstream a few hundred meters.

The design called for in-situ conductivity and temperature measurements at five points on each transect. In addition, measurements at 5 to 10 judgmental points adjacent to each transect were to be taken to help identify upwelling patterns influenced by preferential flow paths (e.g., river channeling, dredging). Elevated readings from other adjacent areas, bathymetry, presence of sediment accumulation areas, indications from sonar or underwater camera observations, observed changes in geologic formations, and the locations of structures (pipelines, outfalls, and intakes) that may present opportunities for preferential flow were factors that were considered for the selection of judgmental station measurements.

Figure 1-4. Example of Groundwater Mapping (Phase II[a]).



Another objective for the mapping phase was to refine the range of acceptable river conditions to collect field measurements. The work plan identified that favorable conditions would generally be present at sustained flows of 80 to 120 kcfs at Priest Rapids Dam. However, repeated field measurements of in-situ conductivity could be used to verify and refine the range of suitable river stages for Phase II and Phase III activities.

**1.3.1.3 Phase II(b) – Indicator Contaminant Screening.** Collection of pore-water samples at 20 to 30 locations within each of the eight upwelling study areas was planned for Phase II(b). Criteria established to aid selection of sampling locations for indicator contaminant screening (Section 1.4) included areas of high conductivity (>160 µS/cm) from the mapping surveys, spatial distribution of data, and factors such as known or suspected areas of contamination (e.g., close to aquifer tube locations). Final indicator contaminant screening locations and quantities were subject to approval by the DOE, U.S. Environmental Protection Agency (EPA), and Washington State Department of Ecology (Ecology), hereinafter referred to as the Tri-Parties.

Indicator contaminants were established for each of the eight study areas based on known information about existing Hanford Site groundwater plumes (Table 1-1).

**Table 1-1. Summary of Indicator Contaminants by Study Area.**

Study Area	Indicator Contaminants
100-B/C, 100-K, 100-D, 100-H, 100-F	Hexavalent chromium
100-N	Strontium-90, TPH
Hanford townsite	Tritium
300 Area	Uranium, VOC

TPH = total petroleum hydrocarbon  
VOC = volatile organic compound

**1.3.1.4 Phase III – Characterization.** The scope of Phase III built on the Phase II results with collection of pore water, sediment, and surface samples for characterization of a broad list of contaminants. Maps summarizing the results of the pore water screening effort were developed for each of the eight groundwater plume upwelling areas. Images were taken with an underwater camera to document riverbed conditions found at the time of sampling. Phase III locations were selected from a subset of Phase II locations, focusing on those with the greatest pore water concentrations for indicator contaminants. Final sample locations and number of samples for plume upwelling characterization were approved by the Tri-Parties.

## 1.4 SITE SELECTION PROCESS

The overall rationale for selecting the eight study regions is provided in DOE/RL-2008-11. A summary of the site selection process for Phases II(a), II(b), and III is provided below. More site-specific information regarding the sites selected for Phase II(b) and III is provided in Section 3.0.

### 1.4.1 Phase II(a)

Phase II(a) station transect points were located beginning where known wells or aquifer tubes have shown contaminated groundwater plumes intersecting the Hanford Site shoreline (DOE/RL-2008-01) (Figure 1-4). Coordinates for the start and end of each transect were then generated using GIS software. The width of the river at each transect was determined assuming 120 Kcfs steady-state river flows and divided by 5 (five sample locations per transect) to estimate the distance between each point on each transect. A range-finder unit was also used by the field teams to measure the vessel's distance from shore to help locate general transect station locations prior to anchoring and deploying the groundwater upwelling mapping equipment. The first point on any given transect was labeled "A" and each one progressing from the Hanford Site shoreline (right bank) to the opposite shoreline (left bank) was systematically labeled A, B, C, D, or E.

Judgmental points were selected using high-resolution bathymetry and upland digital elevation models of each area, looking for preferential pathways of groundwater to enter the river and considering proximity to Hanford Site contaminated groundwater estimates (DOE/RL-2008-01), and proximity to Phase II(a) sample locations exhibiting signs of groundwater upwelling. Identifying upwelling areas was the result of integrating detailed bathymetry data with existing borehole information. The bathymetry data, used with permission by the Columbia River Inter-Tribal Fish Commission, was the outcome of a multi-agency effort (Anglin et al. 2006). Maps were subsequently prepared to help illustrate and represent patterns of the temperature and conductivity results obtained during Phase II(a).

### 1.4.2 Phase II(b)

An extensive site selection process was developed and used to help guide the selection of the Phase II(b) sample locations, including analysis and synthesis of the following information and data sources:

- Phase II(a) conductivity and temperature patterns
- Areas of suspected or known contamination (DOE/RL-2008-01) of key contaminants
  - Review groundwater contaminant plume estimates
  - Well data
  - Aquifer tube data
- Proximity to known reactor water discharge outfall regions and/or discharge pipelines
- Other available information
  - Hanford Site Beta/Gamma Over Flights (DOE-0335)
  - Hyporheic Zone Investigation Near the 300 Area (PNNL-16805).

Because contaminant concentration sometimes corresponds to geological units encountered along the river shoreline, differences in hyporheic flow interactions in different geologic units were also suspected at off-shore locations. As such, some consideration was given to the likelihood of encountering different geological formations (Hanford, Ringold Unit E, or Ringold Upper/Lower Mud). The considerations included a review of borehole and other available geological data.

Meetings were subsequently set up with the Tri-Parties representatives and the site selection considerations were reviewed. A few additional sites were selected and a few sites were omitted based on input from the Tri-Parties.

### 1.4.3 Phase III

As the number of sample locations was much fewer than previous phases, the site selection process for Phase III became even more important to the success of the project. As stated earlier, the objective of Phase III was different from previous phases; to “characterize multiple contaminants in surface water, pore water, and sediment at a sub-set of Phase II(b) sample locations.” As such, the Phase III site selection process was further expanded to include the following factors:

- Phase II(b) contaminant results
- Phase II(b) pore water conductivity
- Spatial considerations of multiple contaminant plumes
- Relative abundance of sediment
- Elevated conductivity in surface water

A complete description of the contaminant suites according to each of the eight study areas is provided in the Work Plan and the SAI.

Although not primary drivers, both surface water and sediment were target media during Phase III and became part of the decision-making process. Sample locations where surface water readings (conductivity or temperature) were still found to be affected by groundwater upwelling were given special consideration because they represented a site with a realistic exposure pathway to free-swimming fish species. The relative abundance of sediment in the vicinity of each station was estimated based on four general categories (scarce, marginal, moderate, and abundant) as determined by using underwater video records and knowledge of the general hydro-geological setting of the area. Generally, this latter consideration helped assure that at least one Phase III sediment sample in each of the eight study areas would contain a sufficient amount of material for all quality assurance(QA)/QC analyses necessary for each of the analytical suites prescribed. A more detailed summary of each of the Phase II(b) site characteristics used to identify sites proposed for Phase III is provided in Appendix J. This designation also became important when determining the most suitable sediment sampling technique; where areas classified as “scarce” or “marginal” sediment abundance were consistently only suitable for the modified core-barrel mounted to the Trident probe driving frame (Section 2.1.2).





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## 2.0 METHODS

### 2.1 TOOLS AND TECHNIQUES

A variety of tools and techniques were used to effectively and safely perform field sampling activities carried out in support of mapping and characterizing groundwater upwelling. The overall field sampling approach consisted of a 7.6 m (25 ft) vessel with four crew members and equipped with the Trident probe, the probe driving frame, an underwater camera, an onboard computer that monitored in-situ pore water temperature and conductivity, and a peristaltic pump used to retrieve the desired pore-water samples (Figure 1-3). The following sub-sections help describe the various tools and techniques used. See the SAI (WCH-286) for additional sampling method details.

#### 2.1.1 Pore and Surface Water Monitoring and Sample Collection and Handling

Pore water and surface water samples were taken during all phases of the project. The level of detail recorded for each sampling event generally increased according to the phase of the project. Phase II(a) sampling generally included a description of the riverbed and the resulting pore water and surface water conductivity and temperature records. Phase II(b) sampling included all of Phase II(a) records plus results of selected water quality parameters (e.g., DO, ORP, Turbidity), as well as more specific descriptions of the river stage conditions encountered during sampling. Phase II(b) and Phase III also included measuring these water quality parameters from the composite samples submitted for analyses.

Once the Trident probe was found to have penetrated 30.5 cm (12-in.) (acceptable range 20 to 30.5 cm [8 to 12-in.]) into the riverbed, approximately 120 mL of water was purged and discarded. Although the in-situ data was continuously monitored by field team leads to assure pore-water samples were not artificially diluted with surface water (i.e., no short-circuiting with surface water from pumping the pore-water sample too fast or from enhanced connectivity between pore water and surface water due to surface water leaking down into the riverbed along the probe tip), the pore water conductivity and temperature records were documented in the field record log sheet at approximately 50 mL intervals. Once the in-situ pore water conductivity readings had increased from the initial purge level and had generally stabilized, the conductivity and temperature were logged in the computer and samples were collected following the SAI and other details provided in Section 2.1.1.2.

##### 2.1.1.1 Tools Used.

#### Locating Sites

Phase II(a) sites were located using high resolution river bathymetric profiles of each area and identifying significant changes in the slope and elevation of the riverbed using Light Detection and Ranging (LiDAR) bathymetry (+/- 15 cm [6-in.] vertical accuracy in 3 m by 3 m [10 ft by 10 ft] horizontal accuracy). The LiDAR data was used to calculate the maximum change in elevation within a 99 m by 99 m (324 ft by 324 ft) moving window using ArcGIS<sup>2</sup> software. Slope was calculated as the maximum rate of change in a 9 m by 9 m (30 ft by 30 ft)

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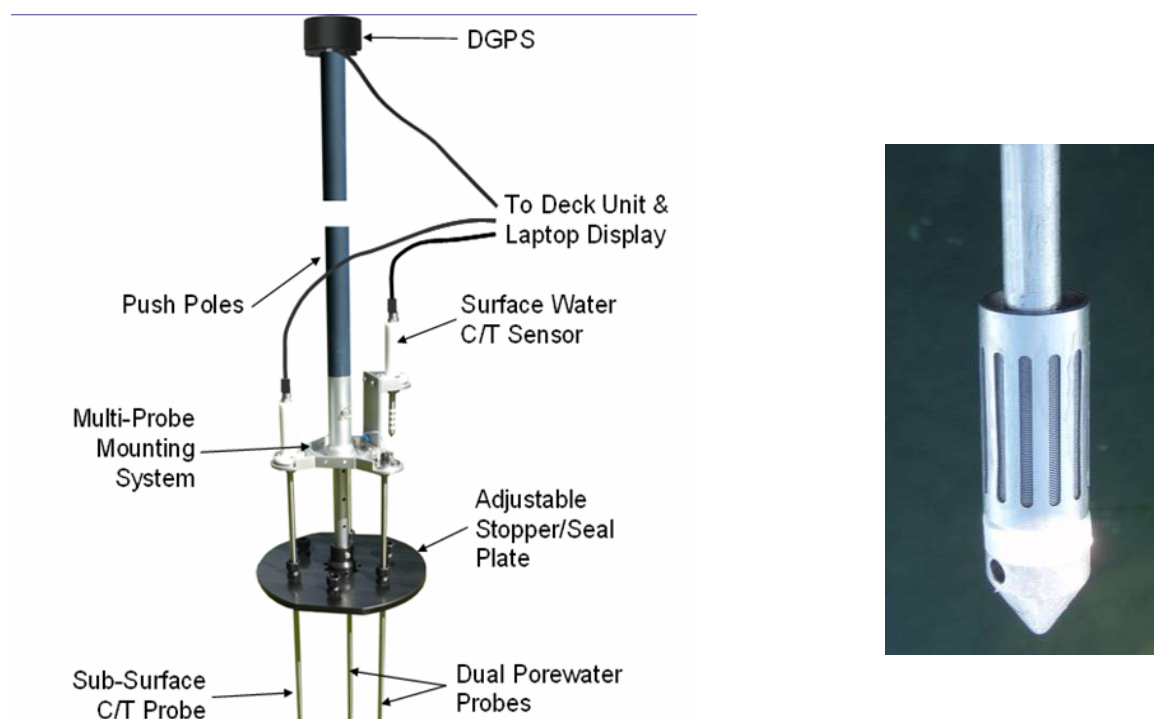
<sup>2</sup> ArcGIS is a registered trademark of ESRI, Redlands, California.

moving window. Riverbed slope, and elevation maps of the entire Hanford Reach were then prepared and transferred onto a lap-top computer that interfaced with the pilot boat's navigation system to show the position of the boat with respect to these riverbed attributes.

### Trident Probe System and Components (Push-Pole, Driving Frame, Pump, GPS)

The primary technology utilized for this project was the Trident probe system (Figure 2-1). The Trident probe is a direct-push or percussion-driven frame-mounted, integrated temperature sensor, conductivity sensor, and pore-water sampler developed to screen sites for areas where groundwater may be discharging to a surface water body (Chadwick et al. 2003). Modifications to the Trident system included incorporation of a shielded measurement and pore water collection area (liquid tip). The liquid tip is displayed in Figure 2-1. This new design allowed for precise in-situ measurement of pore water conductance and temperature with minimal interference from solid particles. Specifications for the Trident probe are provided in Table 2-1. Differences in observed conductivity and/or temperature indicate areas where groundwater discharge may be occurring. The integral pore-water sampler can be used to rapidly confirm the presence of freshwater or other chemical constituents. A GPS receiver (wide area augmentation system enabled) records the location of the Trident probe. The Trident probe software allows for programming and electronic storage of all readings.

**Figure 2-1. Trident Telescoping Pole System With Liquid Tip.**



DGPS = Differentially Corrected Global Positioning System  
C/T = conductivity/temperature

**Table 2-1. Trident Probe Specifications.<sup>a</sup>**

Specifications	Range	Resolution	Depth Rating
Specific conductance	0 to 80 mS/cm (at 25°C)	0.001	150 m
Temperature	0 to 50°C	0.01	150 m

<sup>a</sup> All sampling components manufactured with stainless steel or Teflon.

Various configurations of the Trident probe system were deployed in order to address the variability of the Columbia River bottom and flow conditions. The handheld telescoping pole system (Figure 2-1) and the davit assisted percussion frame system (Figure 2-2) were the two primary Trident systems deployed in order to obtain pore water characteristics and samples. Flow conditions and bottom types were the primary considerations used to determine which system was used. The manually deployed push-pole system was used in shallow areas (<10 m) where river flow velocities were low (< 2 knots), and the bottom sediments were mainly composed of unconsolidated sands and silts. The Trident drive frame system was used in areas where depth, high river velocities and consolidated and/or rocky bottoms were present. The frame system was deployed at the majority of the sample locations due to the presence of rocky bottoms and aggressive river conditions at most station locations. All Phase II and III samples were collected using the drive frame system due to the additional need to be stationary for extended periods of time in order to meet the relatively large (1 to 3 L) sample volume requirements.

**Figure 2-2. Trident Frame Mounted System.**



## Pore Water Survey and Sample Collection

Once the Trident's liquid tip probe was driven 20.3 to 30.5 cm (8 to 12-in.) into the river bottom, data were collected from the conductivity and temperature sensors and the GPS using the TridentTalk<sup>3</sup>. Once the sensor readings had stabilized, the data was recorded by activating the "Log current data" button on the TridentTalk display. The average sensor readings were determined based on a minimum of nine replicate readings over a 60-second period. The real-time data in numeric format was recorded on field sheets and electronically stored on the field computer. During Phase I and II(a), only field measurements of conductance and temperature were made, and no samples were collected. Phase I and II(a) survey data provided information to develop maps of likely groundwater discharge zones. During Phases II(b) and III, samples were collected at selected sample locations that met selection criteria. After initial logging of pore water conductance and temperature, unfiltered and filtered (metals analyses only) pore-water samples were collected with a peristaltic sampling pump. Millipore<sup>4</sup> (Millex-HA Filter, 0.45 µm, mixed cellulose esters, 33 mm, ethylene oxide sterilized) filters were used to obtain the filtered metals pore water and surface water samples. Low flow (approximately 10 mL per minute) sample collection techniques were used to collect pore water. Real time in-situ readings of conductance and temperature were taken and recorded at regular intervals in order to verify a representative pore-water sample had been obtained. The in-situ measurements assured that no short-circuiting (i.e., no artificial infiltration of surface water) was compromising the pore-water sample. If in-situ pore fluid conductance or temperature was observed above 10% of the target value, immediate changes to pump rates were made in order to maintain the target conductance range. After a predetermined sample volume was collected, a conductance measurement of the composite sample was made using a handheld conductance meter to verify target conductance of sample and to document the actual conductance of the composite sample. Figure 1-2 provides a schematic view of the sampling and monitoring process and Figure 2-2 provides an illustration of the driving frame.

## Surface Water Samples

During the pore water collection, a composite surface water sample was also collected using a peristaltic pump from a sample port located 30.5 cm (12-in.) above the sediment bottom. In-situ measurements of river conductance and temperature were also made 30.5 cm (12-in.) above the sediment bottom using the Trident system.

**2.1.1.2 Field Water Quality Measurements.** Water quality data measured using the Trident probe included in-situ pore water conductivity and temperature. Additionally, pore water and surface water samples were analyzed on-site for temperature, conductivity, total dissolved solids (TDS), pH, and oxidation reduction potential (ORP) using a Myron<sup>5</sup> Ultrameter Model 6B water quality analyzer (Ultrameter). The Ultrameter was calibrated with NIST standards prior to the survey, and the calibration was checked on a daily basis. If the calibration was found to be outside controls (10%), then the meter was recalibrated using NIST standards.

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<sup>3</sup> TridentTalk is a trademark of Microsoft Corporation, Redmond, Washington.

<sup>4</sup> Millipore is a trademark of the Millipore Company, Billerica, Massachusetts.  
<http://www.millipore.com/catalogue/item/SLHA033SB>

<sup>5</sup> Myron is a trademark of the Myron L Company, Carlsbad, California

Samples were generally analyzed by pumping water directly from the sampling pump into the measurement cell of the meter. The cell was rinsed three times prior to taking the actual readings.

Specification of the Myron parameters are listed in Table 2-2.

**Table 2-2. Specifications for Myron Ultrameter Model 6B Water Quality Analyzer.**

	Conductivity	Total Dissolved Solids	Resistivity	pH	ORP/Free Chlorine	Temperature
Ranges	0-9,999 $\mu$ S/cm 10-200 mS/cm in 5 autoranges	0-9,999 ppm 10-200 ppt in 5 autoranges	10 K $\Omega$ -30 M $\Omega$	0-14	$\pm$ 999 mV (0.00- 9.99 ppm)	0-71°C (32-160°F)
Resolution	0.01(<100 $\mu$ S) 0.1(<1000 $\mu$ S) 1.0(<10 mS) 0.01(<100 mS) 0.1(<200 mS)	0.01(<100 ppm) 0.1(<1000 ppm) 1.0(<10 ppt) 0.01(<100 ppt) 0.1(<200 ppt)	0.01(<100 K $\Omega$ ) 0.1(<1000 K $\Omega$ ) 0.1(>1 M $\Omega$ )	$\pm$ 0.01 pH	$\pm$ 1 mV 0.01 ppm	0.1°C/F
Accuracy	$\pm$ 1% of reading	$\pm$ 1% of reading	$\pm$ 1% of reading	$\pm$ 0.01 pH <sup>a</sup>	$\pm$ 1 mV $\pm$ 2.5% of reading ppm <sup>b</sup>	$\pm$ 0.1°C
Auto temperature compensation	0-71°C 32-160°F	0-71°C 32-160°F	0-71°C 32-160°F	0-71°C 32-160°F	--	--
Adjustable temperature compensation to 25°C	0-9.99%/°C	0-9.99%/°C	0-9.99%/°C	--	--	--
Conductivity/TDS ratios preprogrammed adjustable conductivity/TDS ratio factor	KCl, 442 <sup>c</sup> , NaCl 0.20-7.99	KCl, 442 <sup>c</sup> , NaCl 0.20-7.99	--	--	--	--

<sup>a</sup>  $\pm$  0.2 pH in presence of radio frequency fields  $\geq$ 3V/m and  $>$ 300mHz.

<sup>b</sup> Assuming water is sanitized by chlorine only at a pH of 6.5-7.5 and a temperature of 25°C.

<sup>c</sup> 442 Natural Water Standard™ Myron L Company.

-- = not available

ORP = oxidation reduction potential

TDS = total dissolved solids

## Dissolved Oxygen

Pore water and surface water samples were analyzed on-site for dissolved oxygen (DO) using a YSI ProODO<sup>6</sup> optical dissolved oxygen meter. The DO meter was calibrated using zero and saturated solutions following the manufacturer's recommended procedure. Calibrations were checked on a daily basis (when in use), and the meters were recalibrated if they were found to

<sup>6</sup> YSI ProODO is a trademark of YSI Inc., Yellow Springs, Ohio.

be out of calibration. Samples were generally analyzed by sub-sampling an aliquot of the composite chemistry sample in a small jar as soon as possible following collection.

### **2.1.1.3 Other Field Parameters Measured.**

#### **Photograph Record**

An underwater camera (Aqua-Vu Explorer 5<sup>7</sup>) mounted on the trident driving frame provided photographic evidence of the probe's penetration and a qualitative evaluation of the bottom condition and type. The camera also assisted field crews to avoid placement of the driving frame on top of large boulders and submerged cables. The photo records are provided in Appendix L (see attached CD).

#### **Water Depths**

Water depths were measured using a Vexilar<sup>8</sup> model LPS-1 hand-held acoustic depth sounder. The sounder measures depths to a resolution of 3 cm (0.1 ft). Measurements were taken by holding the head of the meter just below the surface and triggering the switch. At least three measurements were taken to make sure that a consistent reading was obtained. The final reading of a consistent series was recorded. A river staff gauge (Figure 2-3) was installed in most reactor areas to allow field teams to monitor river levels during sampling events. Staff gauges were set along the "green line" (low water mark) and used as a field screening tool during Phase IIb and III sampling events. See Section 2.2.3 for additional information of river stage guidelines for sampling.

#### **Substrate Condition**

Substrate conditions varied from unconsolidated sand, silts, gravel and cobble (Figures 2-4 through 2-6) to consolidated river bottom areas composed of hardpan and possibly outcrops of the Ringold Formation. Areas of fine silts and sands were located in areas shielded from high river flow velocities and conducive to depositional sedimentation. These areas included the intake structures and near-shore areas with low flow velocities or back currents. Some areas of deposition were covered with various submerged vegetation species. Sediment deposition was also observed in cobble and gravel areas at depth, usually within 15.2 cm (6-in.) of the sediment water interface.

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<sup>7</sup> Aqua-Vu Explorer 5 is a trademark of Outdoors Insight, Inc., Crosslake, Minnesota.

<sup>8</sup> Vexilar is a copyright of Vexilar, Inc., Minneapolis, Minnesota.

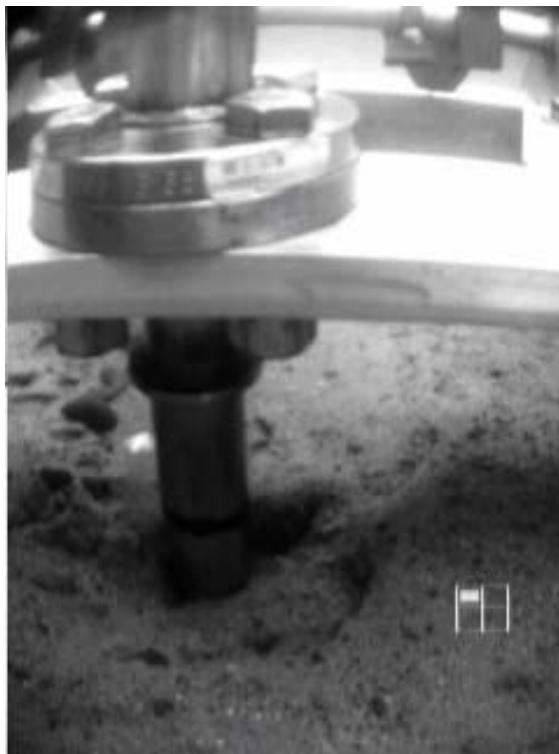
**Figure 2-3. River Stage Station.**



**Figure 2-4. Cobble Substrate.**



**Figure 2-5. Fine Grain Sediments.**



**Figure 2-6. Rocky Riverbeds of the Columbia River.**

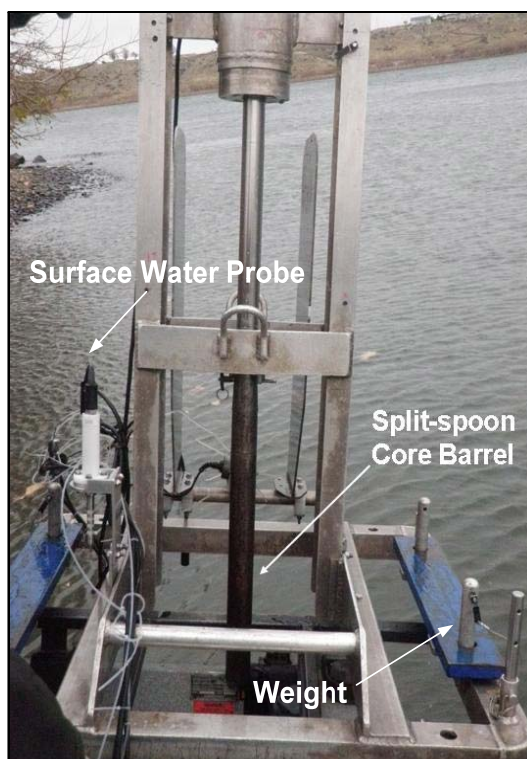




### 2.1.2 Sediment Sample Collection and Handling

Sediment samples were collected concurrently with pore and surface water samples during Phase III of the project. A complete description of sediment sample collection procedures used during the Phase III sample collection events is given in the SAI. Sediment sampling using a modified Van Veen power-grab technique was the preferred sampling approach and was used in previous sediment collection efforts (WCH-352). Upon surveying and photographing the riverbeds at a number of the groundwater upwelling sites, it became evident that a backup sampling method was desirable. A traditional sampling technique (the split-spoon) using the off-shore Trident driving frame allowed sediment collection at the off-shore groundwater upwelling sample locations that contained large cobble (Figure 2-7). An initial assessment of the suitability of both techniques tested at several test sites is provided in Appendix B. A combination of split-spoon (a core-barrel that splits into two halves) sampling and power-grab sampling techniques was eventually used.

**Figure 2-7. Split-Spoon Core Barrel.**



The best sediment deposit within approximately two boat-lengths of the pre-determined sample location was identified for sampling. Collection of a sediment sample using the power-grab system was attempted up to three times. If the unit did not produce sediment, the split-spoon sampler was deployed up to five times. In some instances, the power-grab unit was not attempted due to river condition and only the split-spoon was attempted. No sediment was collected at several Phase III sample locations. A summary of the sampling success for each system is provided below.

**2.1.2.1 Core Barrel.** Both 5.1 cm (2-in.) and 7.6 cm (3-in.) diameter core barrels were used pending field-based judgment of the field supervisors; the narrow diameter barrel was typically more effective in substrates consisting of large cobbles and boulders, whereas the larger-diameter barrel was better in small substrate sizes.

### Sample Handling

Sediment samples were brought on board; the split-spoon was opened, and the contents were photographed. The total length of the sample was measured, and the consolidated substrate length of the sample was measured and recorded. Only the top 10.2 cm (4-in.) of sediment material was used for the chemical and radiological analyses and the remaining material was placed back into the river. If SVOA was needed at any given site, the field team would immediately take a sub-sample from the top 10.2 cm (4-in.) of the consolidated substrate before homogenizing the material for the remaining analyses. Detailed characteristics (total sample depth, consolidated depth, color, odor, percent silt, percent sand, percent 0.1 to 1 cm particles, and mass of each sediment sample) were recorded in the field log-book and are summarized in Appendix I.

**2.1.2.2 Power Grab.** A modified Van-Veen power-grab system was used to collect sediment during Phase III sampling event (Figure 2-8). An air-line supplied pneumatic system attached to a tank of air was kept in each vessel and used to operate the jaws of the power grab system once lowered to the riverbed. An acceptable sample was collected if upon retrieval, the jaws of the power grab were closed and some of the contents were less than 1 cm (0.4-in.) diameter.

**Figure 2-8. Power Grab System.**



## Sample Handling

If the jaws of the power grab system were closed upon retrieval, the window of the sampler was opened to see if substrate was present and to provide an initial assessment of the quality of the sample. The depth of the substrate was then measured and recorded. The contents were then emptied into a plastic-lined container and photographed. Material less than 1 cm (0.4-in.) diameter was separated from the larger materials by hand using pre-cleaned nitrile gloves and a pre-cleaned stainless steel spoon. The material retained was then mixed using the steel spoon for at least 30 seconds, or until the material was a uniform color and a relatively even mixture of particle sizes.

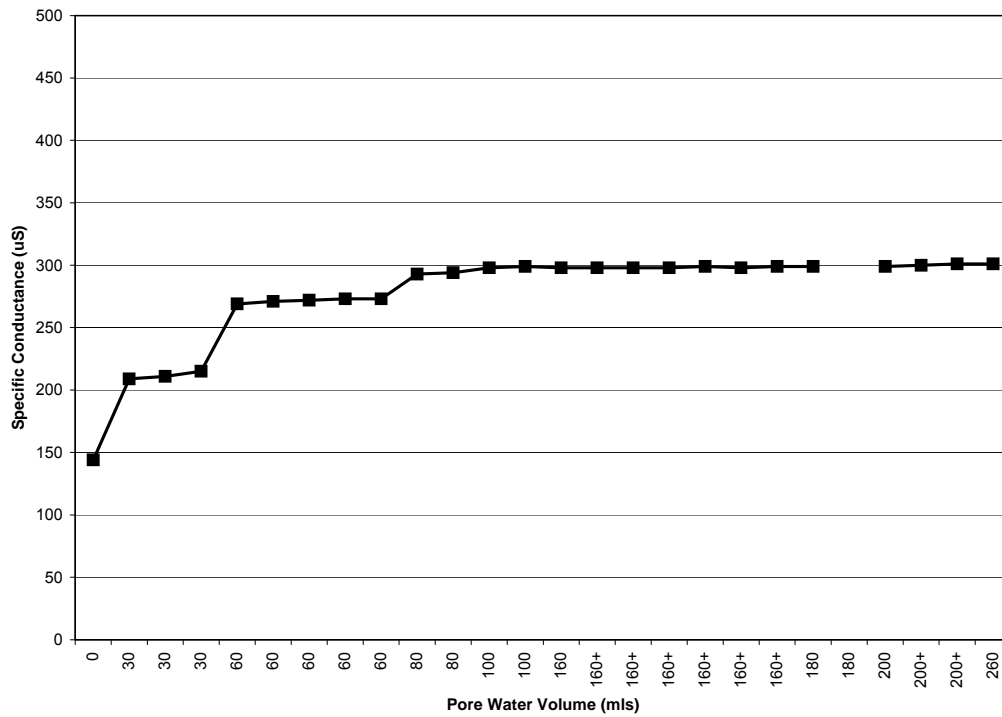
## 2.2 PORE-WATER SAMPLE COLLECTION GUIDELINES

A number of sample collection guidelines were developed and implemented to minimize variation of the results associated with river stage fluctuations and to help verify that samples of pore water were not artificially diluted with surface water as a result of over-pumping (mining out) significant quantities of pore water from a shallow point in the riverbed. These guidelines were also key to obtaining data that were relatively comparable to one another, across space and over time. Sample results were flagged with project unique qualifiers when the guidelines were not met. This was the first large-scale study that applied river stage-specified sampling guidelines to characterize Hanford Site releases via shallow groundwater upwellings.

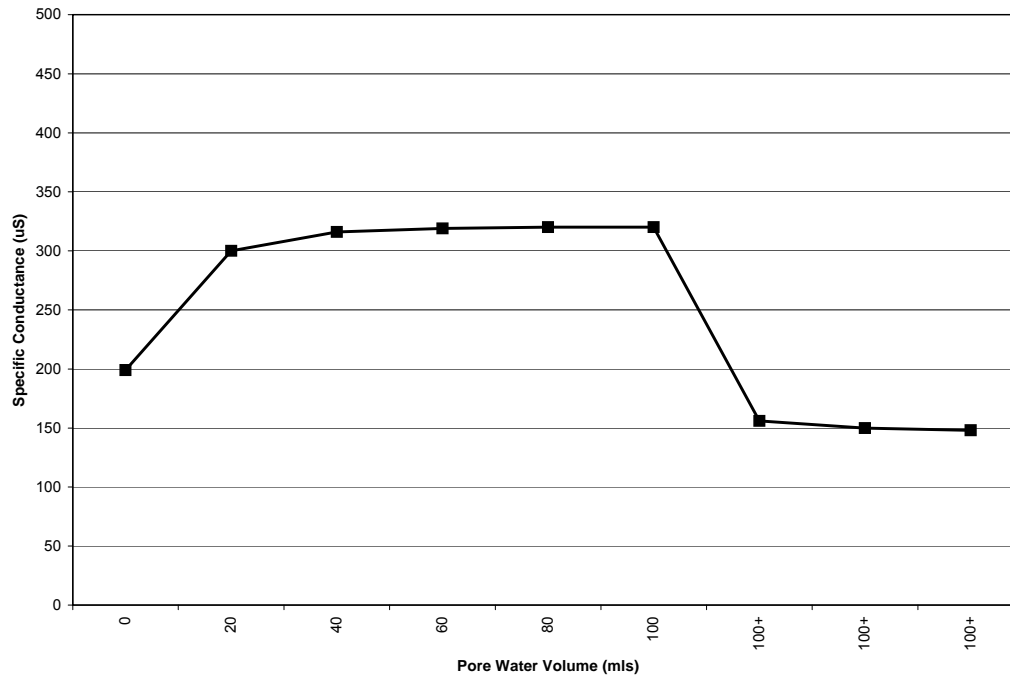
### 2.2.1 Short Circuit with Surface Water

In order to verify the accuracy of the modified Trident probe (liquid-tip design) several verification pore-water samples were collected during the survey and analyzed on-site with the handheld Myron Ultrameter water quality meter. Regression analysis ( $R_2 = 0.94$ ) of the Trident liquid-tip sensor and Myron Ultrameter indicated that the Trident liquid-tip sensor was highly predictive of the true pore water conductivity (see Appendix K, Figure K-25). The verification samples were used to determine the required purge volume needed to obtain stable, representative pore water measurements with the new probe design and to verify that short circuiting due to the infiltration of surface water was not occurring. Figure 2-9 indicates that a stable signal was achieved after 100 mL of water was purged from the probe reservoir of the liquid tip. Generally speaking, stable signals were maintained when pumping rates were kept at or below 10 mL per minute, but varied considerably (from less than 10 mL per minute up to 300 mL per minute) depending on substrate type and discharge rate of the groundwater upwelling at the sampling location. Figure 2-10 reveals the effect of excessive pumping and related siltation in the liquid tip reservoir during initial testing in Phase I. Modifications to the liquid tip reservoir, low flow sampling and constant in-situ monitoring during all sampling events of Phase II and III proved effective in avoiding any type of short circuiting during sample collection. In order to verify representative pore water, samples were collected and conductance and temperature readings were monitored constantly and recorded at 100 mL intervals. The in-situ monitoring of conductance and temperature during sampling provided a reliable and verifiable method for the collection of pore water.

**Figure 2-9. No Short-Circuiting With Surface Water (Station 2A-E).**



**Figure 2-10. Short-Circuit with Surface Water (Station 2A-C in Silty Sand Substrate).**



## 2.2.2 Consistency of Groundwater Signals

Measuring the specific conductance of the pore water (containing a mixture of groundwater and surface water) provided an indicator of the extent of bank storage because Hanford Site groundwater has a higher specific conductance than Columbia River water. As such, a number of pore water measurements were taken repeatedly from several sample locations and used to help characterize river levels that did not appear to substantially alter the conductivity of the pore water. This way, sampling during times when river stages had little effect on the groundwater signal would provide a more consistent and comparable measure of the concentrations of Hanford contaminants found throughout the study areas. This approach also provided an opportunity to monitor changes at these stations over time.

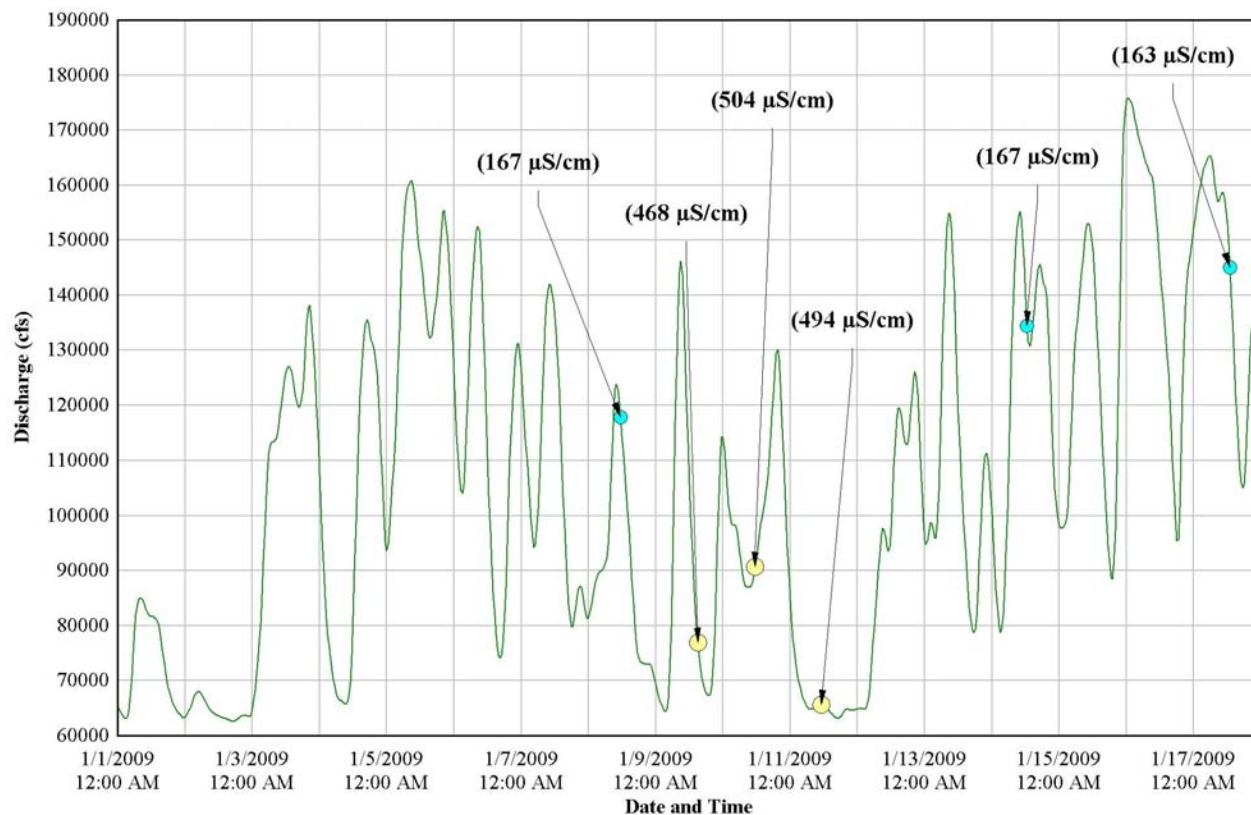
Groundwater upwelling measurements taken during Phase II(a) were avoided when river flows exceeded approximately 160 Kcfs. The upper discharge limit in the SAP was 120 Kcfs but was modified during Phase II(a) based on field sample results that showed groundwater influences (conductivity > 140uS/cm) were still detected during these higher (120 to 160 Kcfs) river discharge periods. During this time a number of measurements were made to help define stable groundwater signals at each area to develop river stage-specified sampling guidelines for Phase II(b) and III sampling (i.e., when samples were collected for chemical and radiological contaminant measurements). Additional summaries of the river stage assessments are provided in Section 3.0 and Appendix A.

Additionally, a rather straight-forward guideline was used by field teams to determine whether to collect the samples during Phase II(b) and III sample. The pore water conductivity measured during the current sampling event was compared to previous conductivity records taken there when low and stable river level existed. Sample guidelines were to collect the sample if the current pore water conductivity reading was at least 90% of the value previously measured there. Additional details of these guidelines are summarized in Section 3.0.

## 2.2.3 River Stage

A great deal of research on the Hanford Site has shown the important role the Columbia River's stage (river level) has on groundwater discharge patterns and contaminant concentrations. The sampling and analysis plan guidelines also prescribed the pore water sampling events to take place during relatively low flow periods (80 to 120 Kcfs). This requirement prompted the need to establish field sampling guidelines that would help the field crews identify when relatively stable groundwater conditions existed at the work sites each day. The resulting guidelines were then used to help field teams avoid sampling, or helped qualify sample results that were collected during Phase II(b) and Phase III sampling when relatively high river stages may have been suppressing or diluting the groundwater upwelling with surface water. Figure 2-11 provides an illustration of the influence of river stage on suppression of the groundwater water signals.

**Figure 2-11. Suppression of Groundwater Upwelling Signals.**



Groundwater upwelling measurements were not taken when river discharge rates exceeded 160 Kcfs (160,000 cubic feet per second) at Priest Rapids dam during Phase II(a) sampling. This upper limit was determined based on the finding that groundwater influences were consistently detected at river discharge levels up to 160 Kcfs at a number of riverbed sample locations.

River level gauges were installed at 100-B/C, 100-N, 100-D, 100-H, the White Bluffs town site, the Hanford townsite, and the 300 Areas. The low water mark (a.k.a. the “green line”) was located by field teams and a 4 m (13 ft)-long pipe was driven approximately 0.9 m (3 ft) into soft substrate until stable. A wooden platform was then fitted around the base of the post to prevent the post from sinking into the mud. River levels were subsequently measured at 10 cm (4-in.) intervals where 0 m (0 ft) demarked the green line (approximately 40 Kcfs flows). River level gauges were measured regularly during sampling events to help crews evaluate the river conditions (Figure 2-4). A general depiction of daily average river flows encountered during each phase of the project is further described in Section 3.0 and Appendix G.

A summary of the field sampling guidelines developed based on findings of the river stage evaluation (see Appendix A), is provided below:

- Collect samples when the river levels have been less than or equal to 0.9 m (3 ft) above the low water mark for at least 1 to 2 hours prior to sampling. (NOTE: In some areas it was

found that river levels should be less than approximately 0.8 m [2.6 ft] above the low water level [i.e., steady flows of approximately 70 Kcfs or less] have been present for at least 1 hour).

- Intermittently perform pore water conductivity checks at selected sample locations near work site to check for signs of significant dilution from bank recharge and/or surface water pressure.
- Collect samples if pore water conductivity reading is at least 90% of the conductivity measurements previously reported there during Phase II(a) or Phase II(b) sampling (under favorable conductivity measuring conditions, low and steady flows).
- Monitor river level before and after each sampling event.





### 3.0 RESULTS AND DISCUSSION

#### 3.1 PHASE II(A) MAPPING GROUNDWATER UPWELLING LOCATIONS

Phase II(a) field sampling activities were fully executed during the periods extending from December 2008 through March 2009 and July 2009 through January 2010. The bulk of Phase II(a) sampling was completed during the first period (December 2008 through March 2009) but was halted in March 2009 to avoid the periods when river discharge rates were commonly in excess of approximately 160 Kcfs. Additional sampling during the second period (July 2009 through January 2010) was carried out once the river levels had dropped during the late summer, and also to complete sampling at a limited number of stations located in known salmon spawning areas. Although Phase II(a) sampling efforts during this second period extended through January 2010, the Phase II(a) sampling was largely completed by mid-August 2010 prior to the commencement of Phase II(b), with only six additional stations sampled after that time. A total of 685 different sample locations were measured in support of Phase II(a) objectives (mapping groundwater upwelling). Appendix C provides the summary tables containing the field records and water quality results obtained during Phase II(a). The site-specific summary maps provided in Appendix D illustrate groundwater upwelling patterns (using conductivity and temperature) and the station identifications that were used to map groundwater upwelling during Phase II(a). A general summary of the sample results and data collected is provided below.

##### 3.1.1 Data Collected

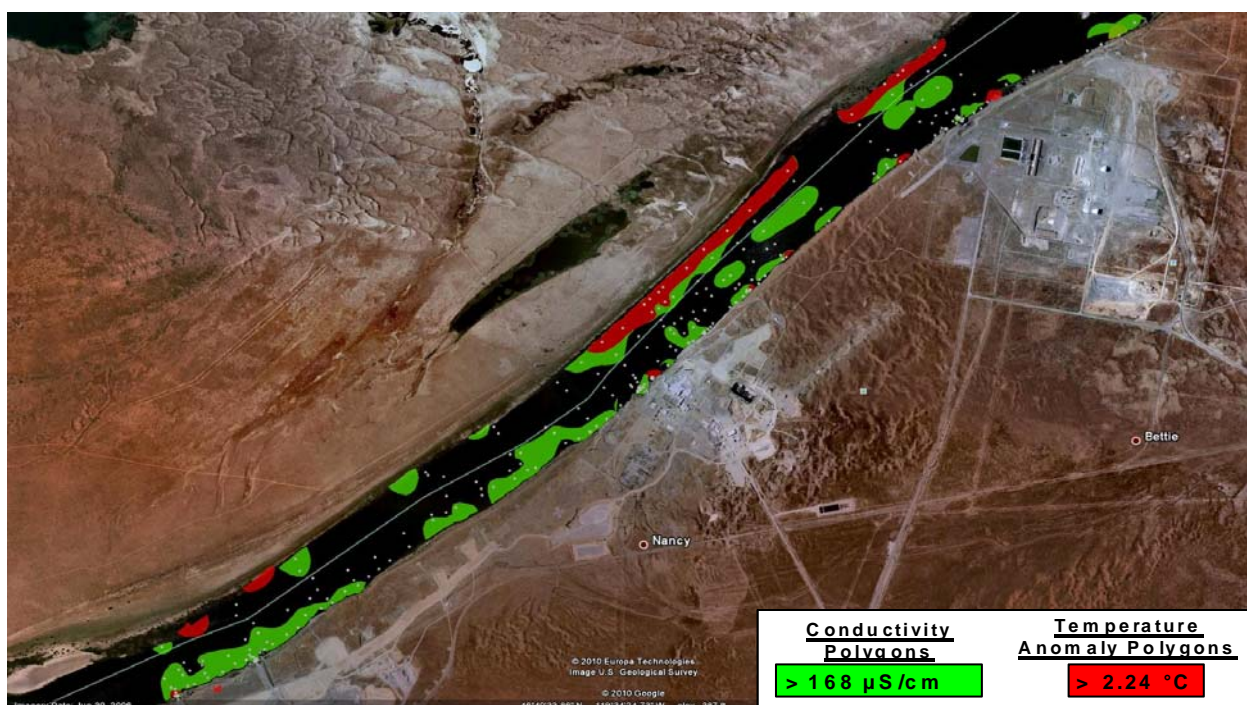
Table 3-1 summarizes the number of sample locations successfully measured in support of mapping groundwater upwelling in the Columbia River and resulting maximum pore water temperature anomalies (January through March 2009), and maximum pore water conductivity recorded during Phase II(a). A complete summary of temperature, conductivity, and associated metadata recorded at the 685 Phase II(a) sample locations is given in Appendix C.

**Table 3-1. Summary of Phase II(a) Sample Locations and Maximum Conductivity ( $\mu\text{S}/\text{cm}$ ) and Temperature ( $^{\circ}\text{C}$ ) by Study Area.**

Study Area	Number of Transect Sample Locations	Number of Judgmental Sample Locations	Total Number of Sample Locations	Maximum Pore Water Conductivity ( $\mu\text{S}/\text{cm}$ )	Maximum Pore Water Temperature Anomaly ( $^{\circ}\text{C}$ ) (January Through March 2009)
100-B/C	27	65	92	388	7.8
100-K	30	60	90	533	7.7
100-N	30	67	97	1058	6.9
100-D	25	52	77	975	7.5
100-H	30	61	91	1535	3.5
100-F	25	39	64	858	2.7
Hanford townsite	25	55	80	648	4.4
300-Area	30	64	94	1090	10.4
Totals	222	463	685	--	--

Groundwater upwelling were found in all eight study regions examined. The site-specific summary maps provided in Appendix D illustrate groundwater upwelling patterns (using conductivity and temperature) mapped during Phase II(a). Figure 3-1 represents the dynamic nature of groundwater upwelling into the Columbia River. This figure is a representative example from the 100 Areas (between 100-K and 100-D) illustrating the presence of groundwater upwelling (elevated pore water conductivity and temperature) along both shorelines and extending outward, in some cases, to the center of the Columbia River. The 100-B/C, 100-F, 100-H, Hanford townsite, and 300 Area regions mapped elicited similar patterns (Appendix D). Some of the upwelling areas along the left shoreline (Franklin and Grant Counties) were proximal to the Saddle Mountain ponds and known run-off from agricultural sources (ponds on left side of the Columbia River). Shallow groundwater movement from the Saddle Mountain ponds to the river is expected. However, some of the left-shore upwelling areas did not correspond to known agricultural run-off areas.

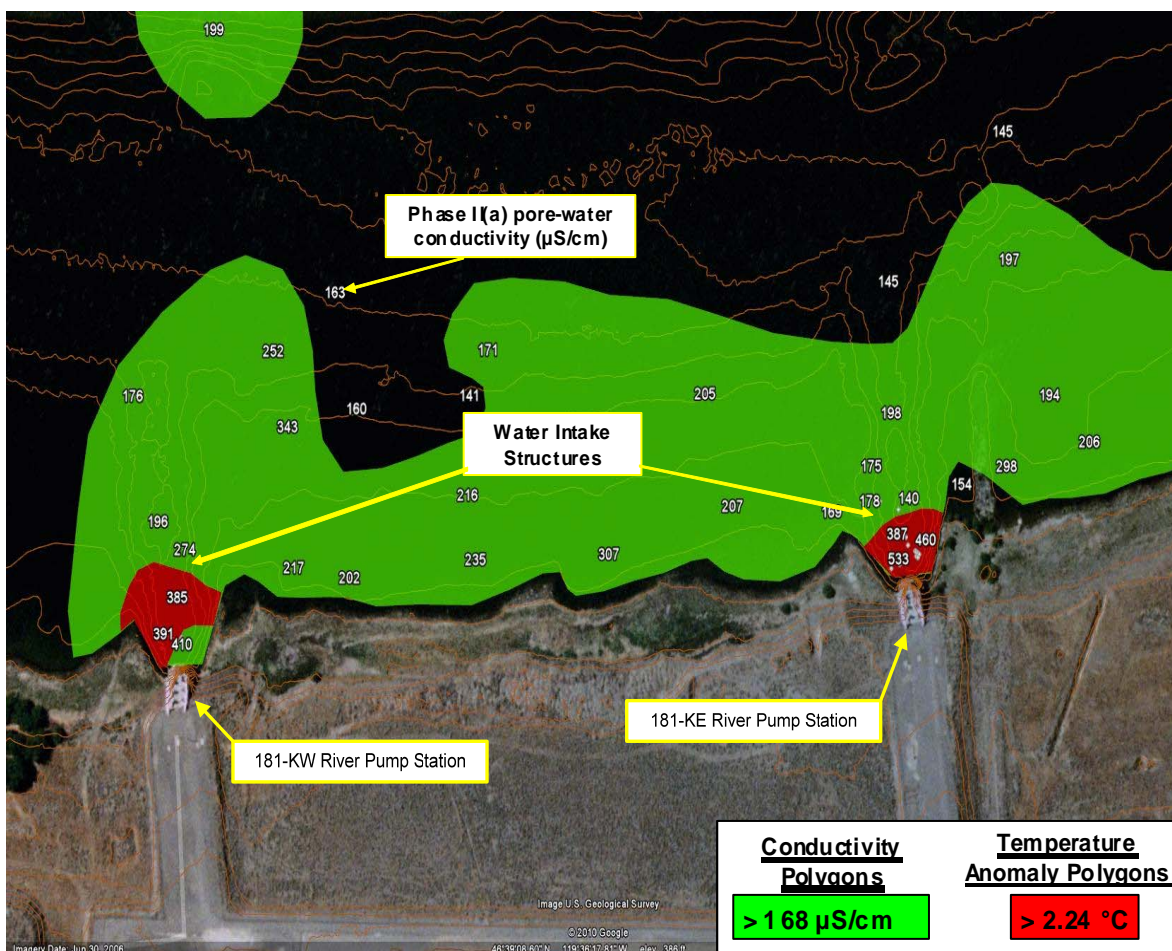
**Figure 3-1. Nonuniform Groundwater Upwelling Patterns.**



Relatively high temperature anomalies (approximately 5° to 12°C [9 to 22°F]) measured during the winter period (pore water temps minus surface water temps) were useful to locate specific regions that exhibited signs of relatively high groundwater discharge (Figure 3-1). The elevated pore water temperature results correlated well with the conductivity patterns and helped identify relatively high groundwater discharge areas (i.e., large temperature anomalies).

Reactor water intake structures (in water 4.6 to 9 m [15 to 30 ft] deep) were consistently found to exhibit relatively high conductivity and temperature anomalies, suggesting a preferential pathway for groundwater releases into the river (Figure 3-2). This pattern was seen at 100-B/C, 100-K (East and West), 100-N, and 100-D Areas. Riverbeds in front of the Hanford Site reactor water intake structures were modified as part of Hanford Site start-up operations and consisted of creating deep channels (6 m to 9 m [20 ft to 30 ft] deep below the low-water mark) and steep sloped banks.

**Figure 3-2. High Groundwater Discharge Areas Near 100-K Water Intake Structures.**



Pore water conductivity measurements recorded at some sample locations were higher than measurements reported from near-shore wells or aquifer tubes (Table 3-1; DOE/RL-2008-66). These sample locations exhibited distinct signs of groundwater upwelling as seen by high temperature anomalies. It has been conjectured by some individuals that the abundance of fine-grained sediments at these sample locations may have been regulating groundwater discharge rates and/or playing a role in the potentiation of dissolved solids in the porewater. It should also be noted that low conductivity was seen at a number of sites where sediment was

present but groundwater upwelling were not apparent (i.e., low temperature anomaly and/or low conductivity), further supporting the premise of the existence of complex groundwater interactions with fine-grained riverbed substrates.

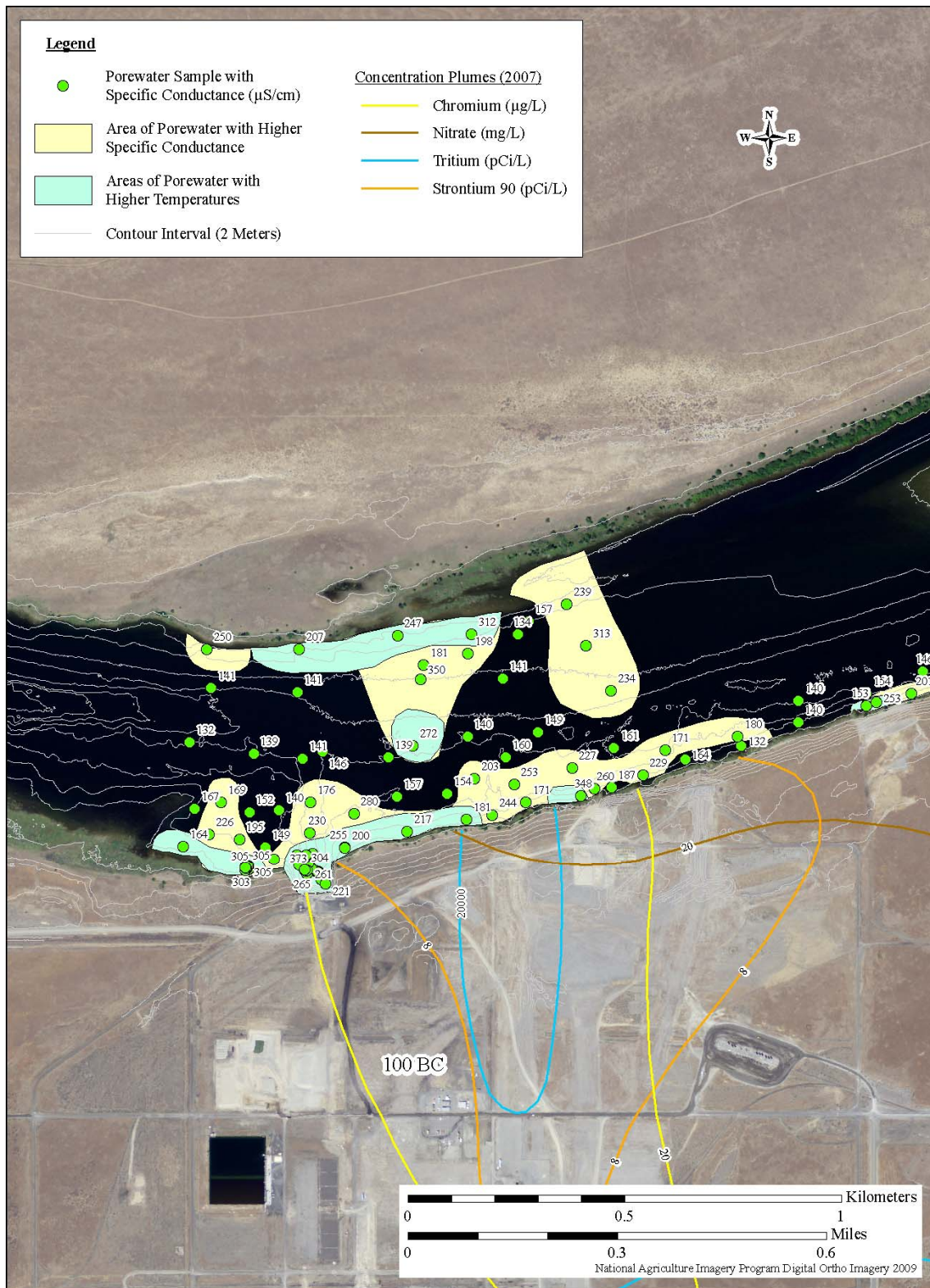
Conductivity measurements 0.9 m (3 ft) above the riverbed were found to be elevated above reference surface water values (approximately 140  $\mu\text{S}/\text{cm}$ ) at a number of sample locations, particularly in areas where river flow was low and where high temperature anomalies were found which suggested relatively high groundwater discharge rates. This finding played a key role in the selection of sample locations for follow-up sampling as surface water sampling was identified for Phase III of the project. Elevated conductivity in the surface water readings verified that characteristics at some sites had created a viable exposure pathway to free-swimming fishes from potentially contaminated groundwater entering the river via upwelling. The reactor water intake structures and some slow-moving backwater channels of the river were most commonly found exhibiting these characteristics.

A brief description of Phase II(a) specific information is given in each of the eight general areas below. Appendices C and D provides complete data summary table and site-specific maps of each of the study areas.

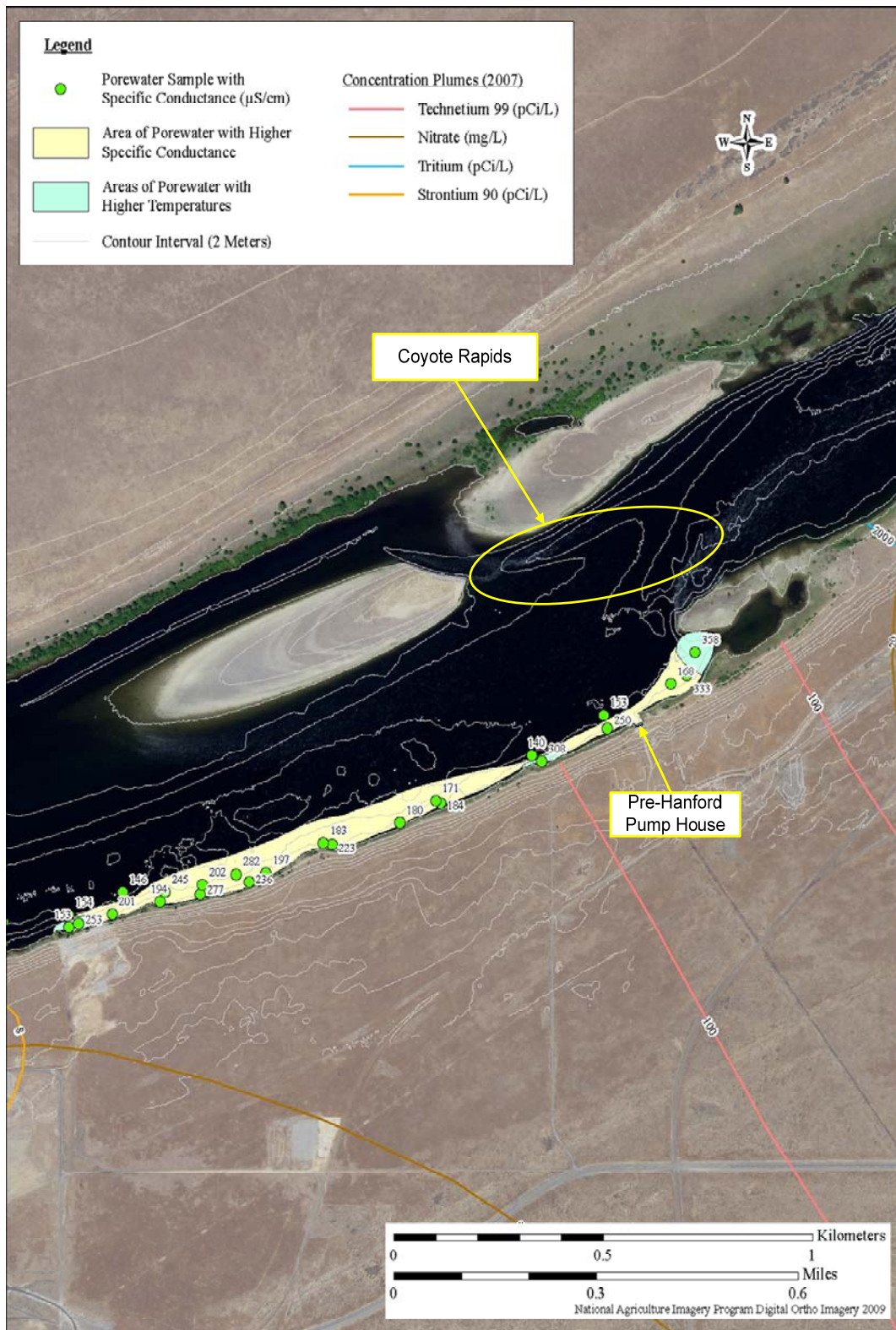
**3.1.1.1 100-B/C Area.** Figures 3-3 through 3-4 illustrate the groundwater upwelling patterns (using pore water conductivity and temperature anomalies) near the 100-B/C Area during Phase II(a). A total of 92 sample locations were sampled along approximately a 3.2 km (2 mi) stretch of the river. River velocities in excess of 3 m/s (10 ft/s) were encountered near Coyote Rapids and limited the field team's off-shore mapping efforts. Although high temperature anomalies were limited to the 100-B/C water intake structure and near a pre-Hanford pump house (Figures 3-3 and 3-4), groundwater upwelling (as indicated by elevated pore water conductivity) were found along a rather extensive region (approximately 3.2 km [2 mi]) of the Hanford Site shoreline, illustrating the diffuse nature of the hyporheic flow throughout this area. Out of 92 Phase II(a) sample locations sampled in the 100-B/C Area, the maximum pore water conductivity was 388  $\mu\text{S}/\text{cm}$  and maximum temperature anomaly was 7.8°C (14.0°F). The maximum pore water conductivity was measured in the water intake structure for the 100-B/C Reactors in silty sand substrate, with an associated temperature anomaly of 2.23°C (4.0°F). The maximum temperature anomaly was measured on February 15, 2009 near the center of the river, in roughly 7 m (22 ft) of water, in small and medium cobble substrate (in the small aqua zone surrounded by yellow) (Figures 3-3 and 3-4), with an associated conductivity of 272  $\mu\text{S}/\text{cm}$ .

**3.1.1.2 100-K Area.** Figures 3-5 and 3-6 illustrate groundwater upwelling patterns (using pore water conductivity and temperature anomalies) mapped near the 100-K Area during Phase II(a). A total of 90 sample locations were sampled along approximately 3.2 km (2 mi) stretch of the Columbia River. Most of the large temperature anomalies in the 100-K Area were near the left shore while conductivity values exceeding 168  $\mu\text{S}/\text{cm}$  were common near both shores. Both K East and K West water intake structures contained distinctly high temperature anomalies (in addition to high pore water conductivity readings) and highlight the association of the intake structure with preferential groundwater flow pathways. Groundwater upwelling were nonuniformly distributed but persisted throughout much of this stretch of the River. Out of 90 Phase II(a) sample locations sampled, the maximum conductivity was 533  $\mu\text{S}/\text{cm}$  and maximum temperature anomaly was 7.7°C (13.9°F). The maximum conductivity was measured near the K Reactor intake (upstream of the outfall pipe noted on Figures 3-5 and 3-6) in silty sand

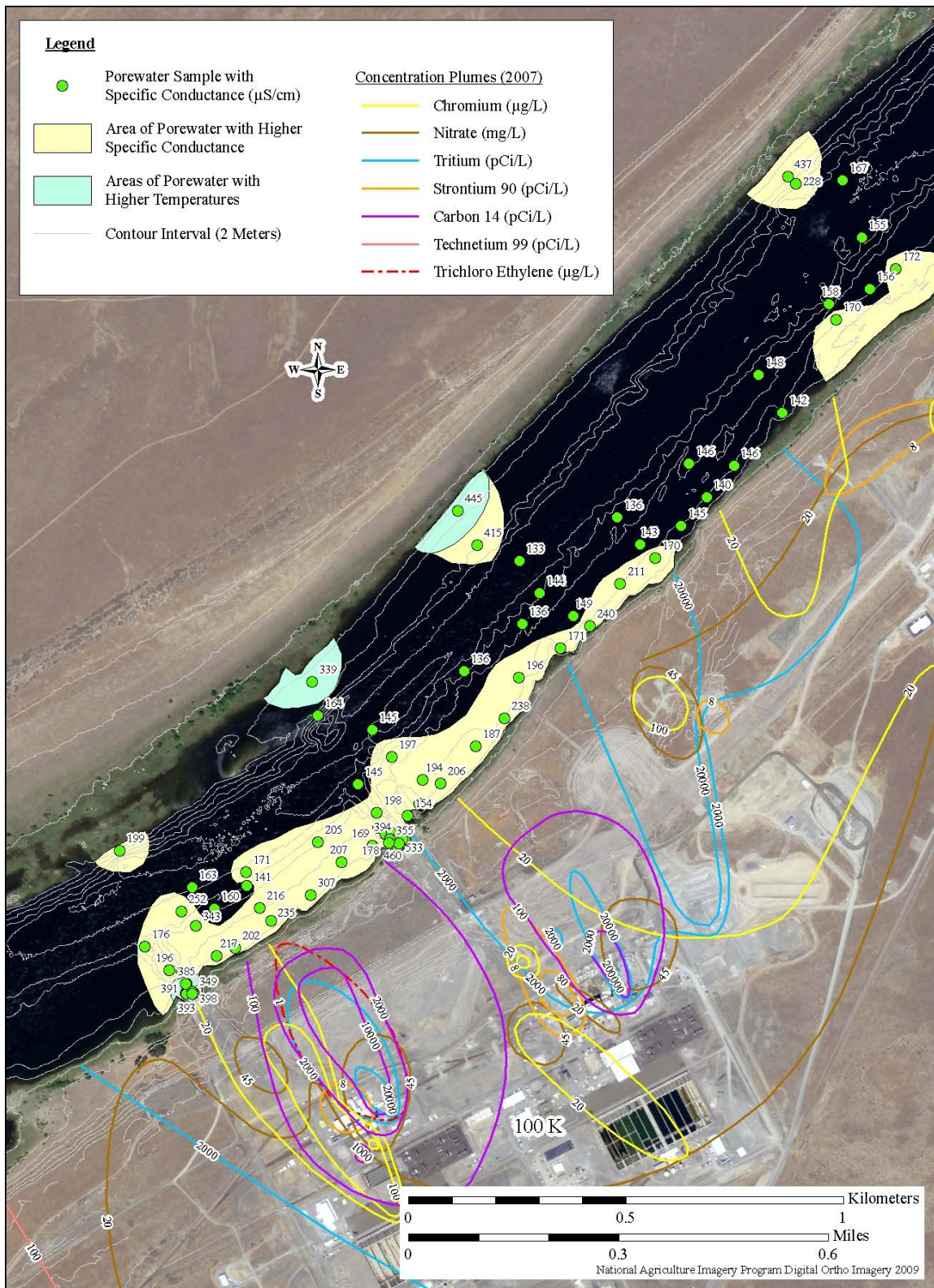
**Figure 3-3. Pore Water Conductivity ( $\mu\text{S}/\text{cm}$ ) and Temperature Anomaly Patterns Measured During Phase II(a) Near the 100-B/C Area (Sheet 1 of 2).**



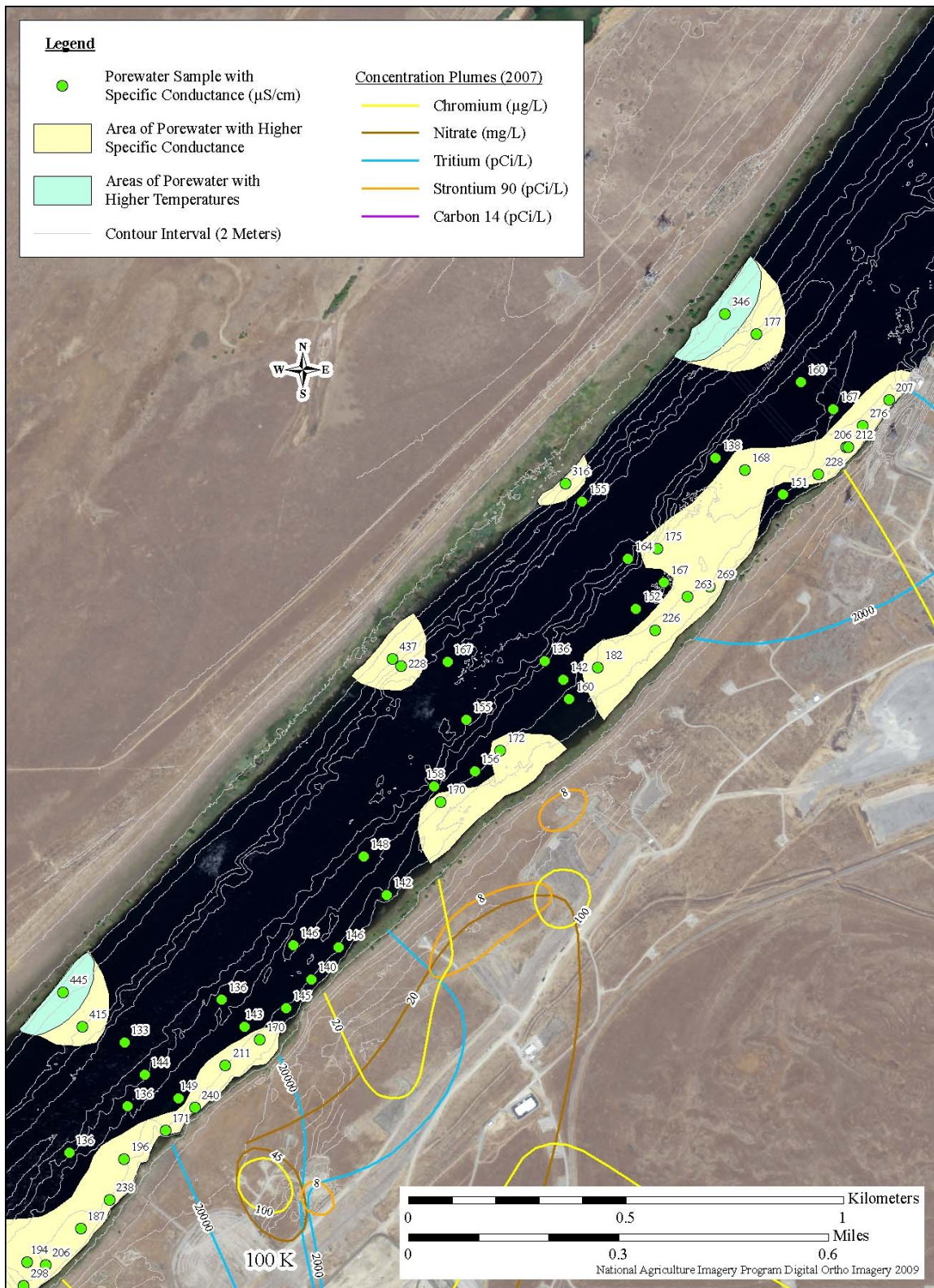
**Figure 3-4. Pore Water Conductivity ( $\mu\text{S}/\text{cm}$ ) and Temperature Anomaly Patterns Measured During Phase II(a) Near the 100-B/C Area (Sheet 2 of 2).**



**Figure 3-5. Pore Water Conductivity ( $\mu\text{S}/\text{cm}$ ) and Temperature Anomaly Patterns Measured During Phase II(a) Near the 100-K Area (Sheet 1 of 2).**



**Figure 3-6. Pore Water Conductivity ( $\mu\text{S}/\text{cm}$ ) and Temperature Anomaly Patterns Measured During Phase II(a) Near the 100-K Area (Sheet 2 of 2).**





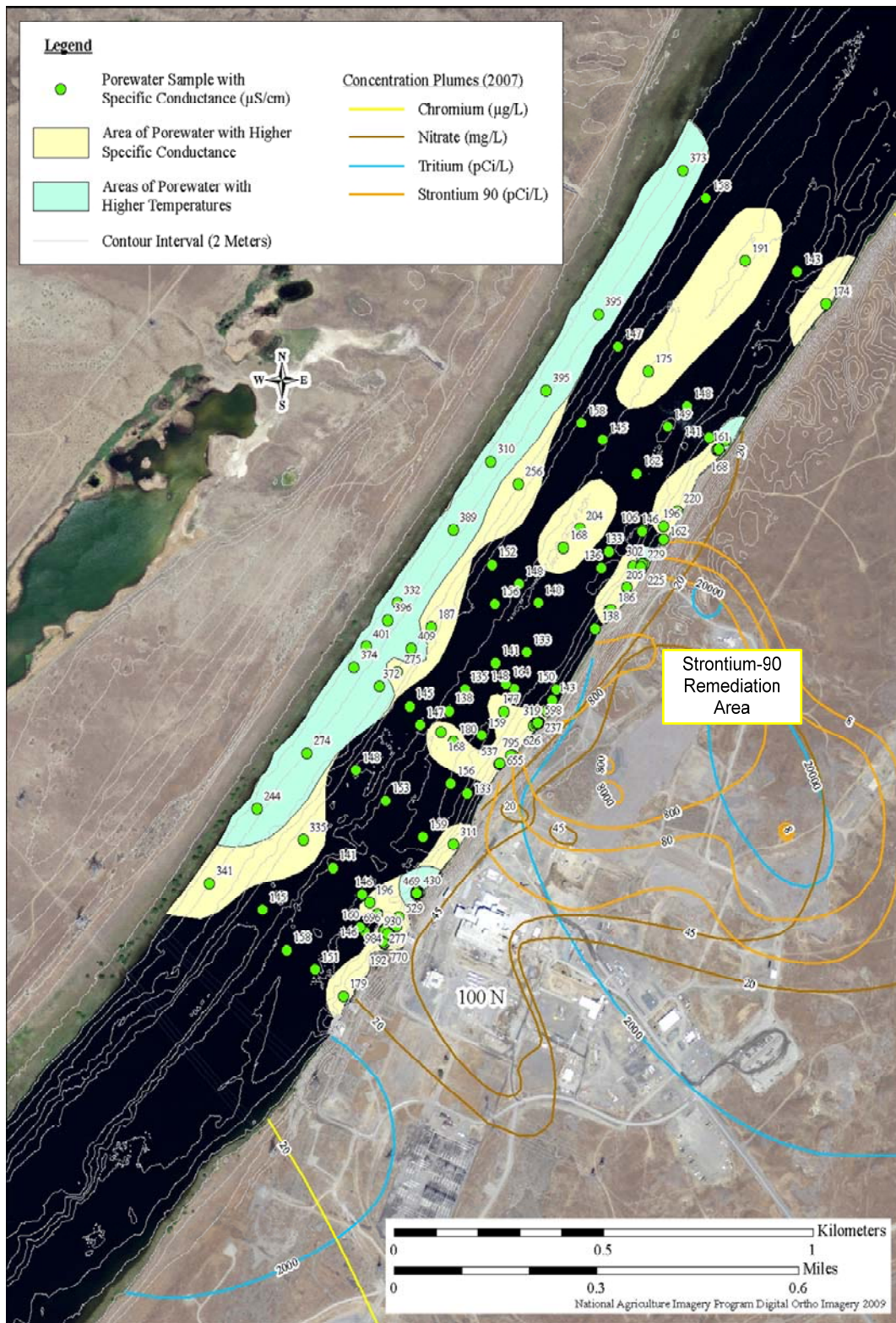
substrate with an associated temperature anomaly of 1.57°C (2.8°F). The maximum temperature anomaly was measured near the left shore (the middle of the three northern aqua zones) with an associated conductivity of 445 µS/cm in medium/large cobble substrate (Figures 3-5 and 3-6).

**3.1.1.3 100-N Area.** Figure 3-7 illustrates groundwater upwelling patterns (using pore water conductivity and temperature anomalies) mapped near the 100-N Area during Phase II(a). Three nonuniform groundwater upwelling areas were identified near 100-N; one near the 100-N water intake structure, one immediately in front of the active strontium remediation area, and one near the down-river end of the 100-N strontium remediation area (Figure 3-7). Out of 97 Phase II(a) sites, the maximum conductivity was 1,058 µS/cm and maximum temperature anomaly was 6.9°C (12.4°F). The maximum conductivity occurred on January 14, 2009 near the N Reactor intake in silty sand substrate with an associated temperature anomaly of 1.34°C (2.4°F). The maximum temperature anomaly occurred on March 3, 2009 in cobble/gravel substrate near the left shore roughly 0.4 km (0.25 mi) downstream of the large upland pond seen in Figure 3-7. As in the 100-K Area, most of the temperature anomalies in the 100-N Area were near the left shore, while conductivity values exceeding 168 µS/cm were common near both shores.

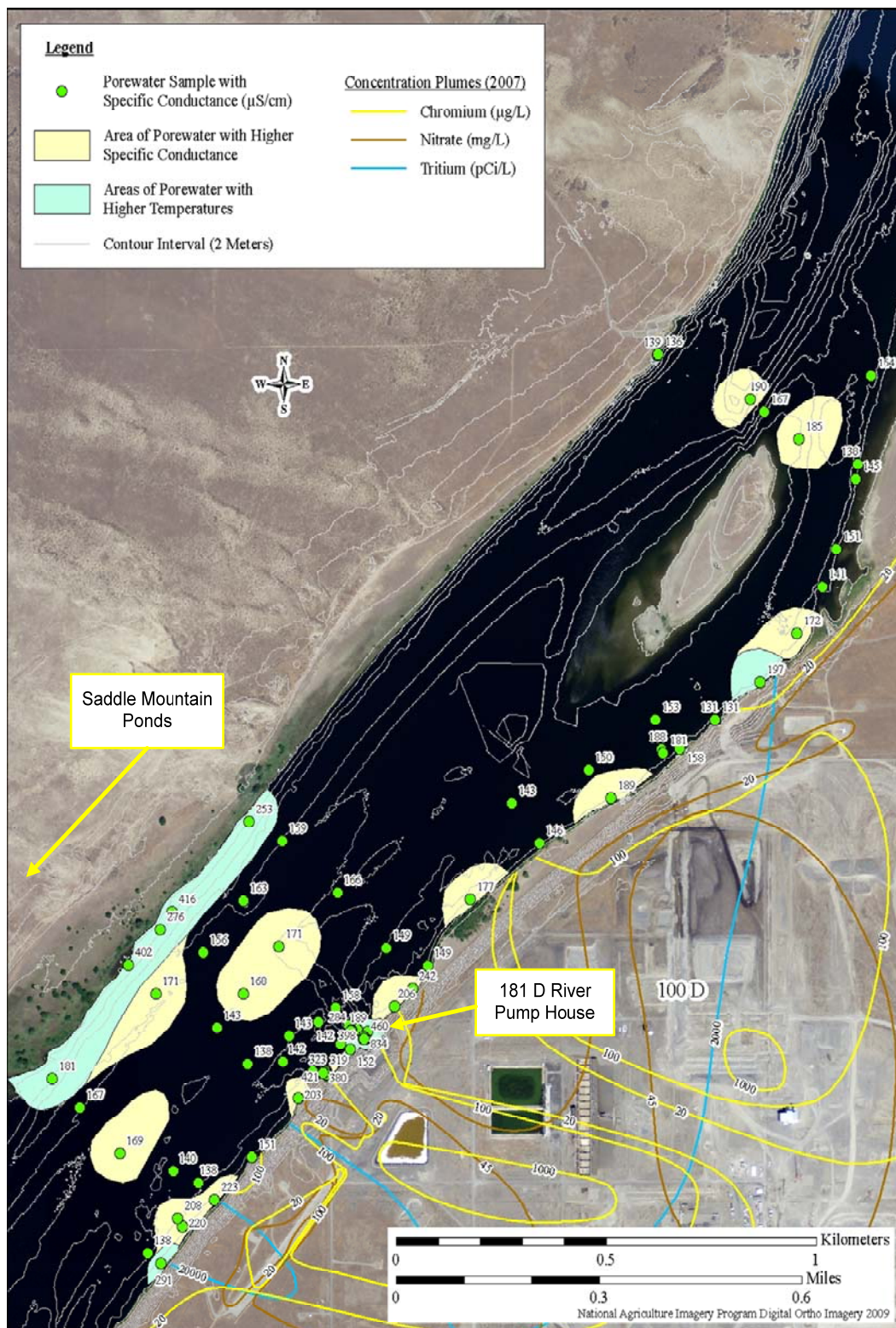
**3.1.1.4 100-D Area.** Figure 3-8 illustrates the Phase II(a) groundwater upwelling patterns near the 100-D Area (using pore water conductivity and temperature anomalies). The most prominent groundwater upwelling area appeared along the left shoreline region directly across the river from 100-D and just down-gradient of the Saddle Mountain ponds (Figure 3-8). A relatively small upwelling was found near the center of the river with no distinct temperature anomaly (i.e., relatively low discharge), and several areas were found beginning approximately 0.4 km (0.25 mi) upstream of the water intake structure and extending downstream approximately 1.3 km (0.8 mi). Upwellings were noted near the lee-ward end of the 100-D Island and between the Hanford Site shorelines and the island, a major salmon spawning area (Figure 3-8). Out of 77 Phase II(a) sample locations measured, the maximum conductivity was 975 µS/cm and maximum temperature anomaly was 7.5°C (13.5°F). The highest conductivity occurred on January 10, 2009 with an associated temperature anomaly of 2.38°C (4.3°F) in silty sand substrate in the inlet for the D Reactor intake structure (181D River Pump House) (near the right edge of the middle aqua zone on the right shore in Figure 3-8). Another cluster of high pore water conductivity values (around approximately 700 uS/cm) with coinciding high temperature anomalies was found just off the left shore near the base of the White Bluffs escarpment (sample locations not shown in this figure; see sample locations T100D5J2, T100D5J3, and T100D5J5 in Appendix D and in Figure 3-33).

**3.1.1.5 100-H Area.** Figures 3-9 and 3-10 illustrate groundwater upwelling patterns (using pore water conductivity and temperature anomalies) near the 100-H Area during Phase II(a). A prominent upwelling was found near the upriver tip of Locke Island where elevated chromium levels (at least 20 µg/L) had been reported during 2007 (DOE/RL-2008-01). Another upwelling site was located further off-shore and in the active river channel. A third upwelling area parallel with the two previous areas described, was found in the old river channel against the dry walls of the White Bluffs. These patterns were noteworthy because unlike the other prominent groundwater upwelling areas mapped along the left shorelines, this site was outside of the known agricultural water runoff areas (e.g., Figure 3-7). The elevation difference between the Hanford Site shoreline and the two river channels was about 4.6 m (15 ft), making it plausible that groundwater upwelling along the base of the White Bluffs escarpment (left shore) may have

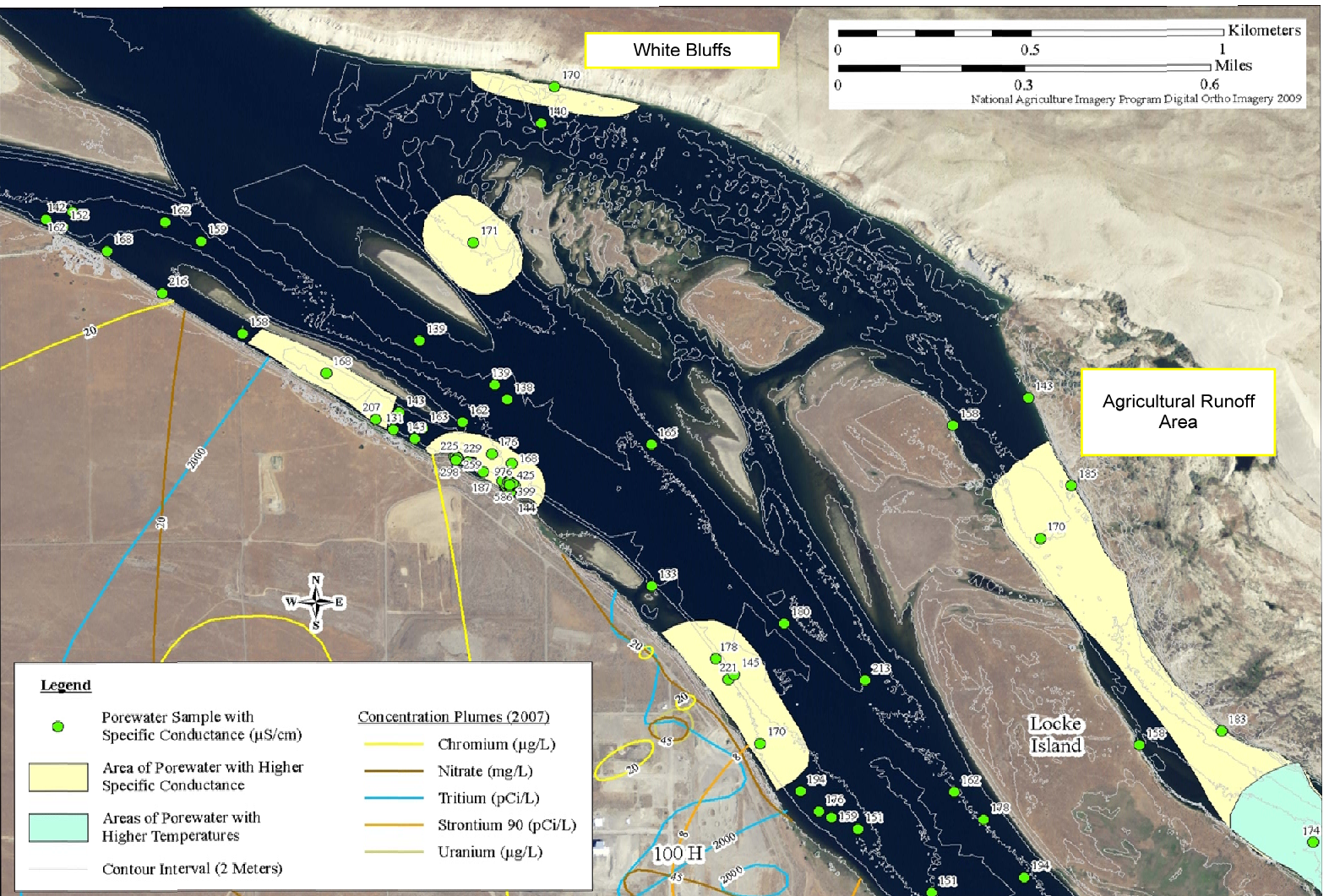
**Figure 3-7. Pore Water Conductivity ( $\mu\text{S}/\text{cm}$ ) and Temperature Anomaly Patterns Measured During Phase II(a) Near the 100-N Area.**



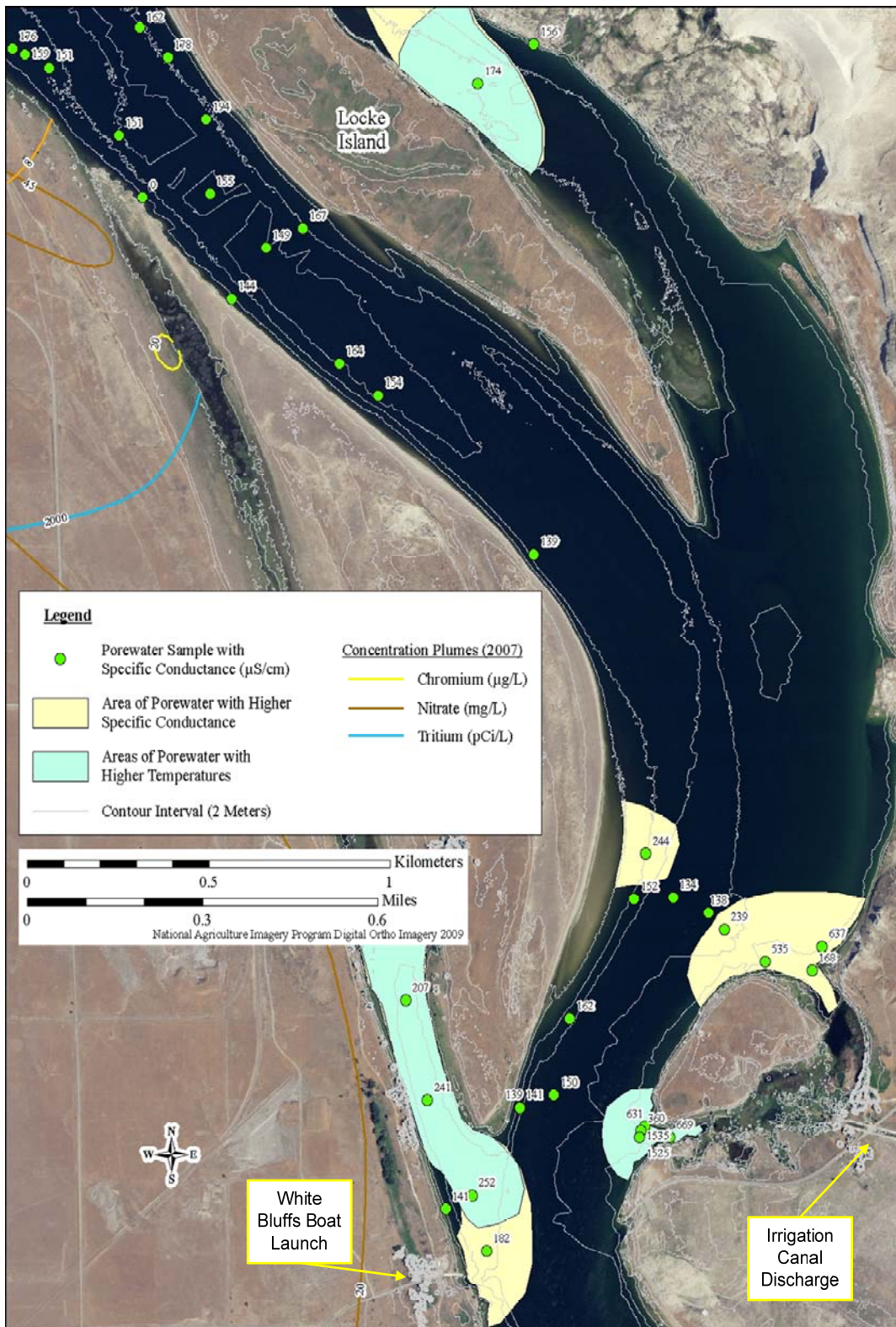
**Figure 3-8. Pore Water Conductivity ( $\mu\text{S}/\text{cm}$ ) and Temperature Anomaly Patterns Measured During Phase II(a) Near the 100-D Area.**



**Figure 3-9. Pore Water Conductivity ( $\mu\text{S}/\text{cm}$ ) and Temperature Anomaly Patterns Measured During Phase III(a) Near the 100-H Area (Sheet 1 of 2).**



**Figure 3-10. Pore Water Conductivity ( $\mu\text{S}/\text{cm}$ ) and Temperature Anomaly Patterns Measured During Phase II(a) Near the 100-H Area (Sheet 2 of 2).**



originated from the Hanford Site groundwater sources carrying chromium, largely from the 100-D Area. Another prominent groundwater upwelling was noted further downriver immediately in front of an active agricultural run-off area and between Locke Island and the left bank (Figure 3-9). Groundwater upwelling were observed throughout the White Bluffs Town Site slough and in front of two agricultural water run-off areas along the left shoreline (Figure 3-10).

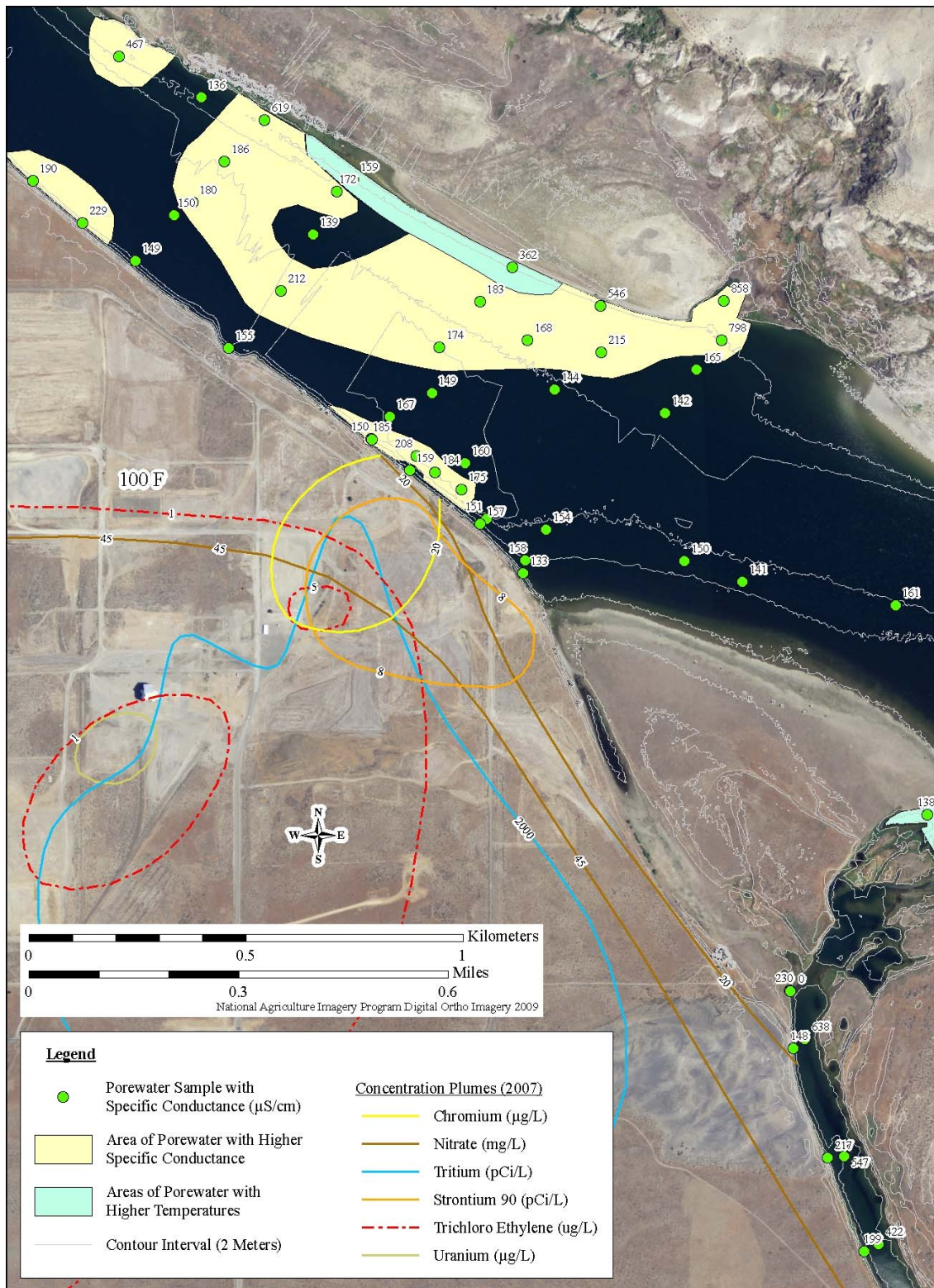
Out of 91 Phase II(a) sample locations completed, the maximum conductivity was 1,535  $\mu\text{S}/\text{cm}$  and the maximum temperature anomaly was 3.5°C (6.3°F). The maximum conductivity occurred on January 23, 2009 with an associated temperature anomaly of 2.26°C (4.1°F) in sandy silt substrate on the eastern shore near the mouth of an inlet roughly 1.6 km (1 mi) downstream of Locke Island (Figure 3-10, left bank). The maximum temperature anomaly occurred on March 16, 2009 with an associated conductivity of 207  $\mu\text{S}/\text{cm}$  in sediment/sand substrate near the western shore (right bank), well inside an inlet roughly 1.3 km (0.8 mi) downstream of Locke Island.

**3.1.1.6 100-F Area.** Figures 3-11 and 3-12 illustrates groundwater upwelling patterns (using pore water conductivity and temperature anomalies) mapped near the 100-F Area during Phase II(a). The most prominent groundwater upwelling patterns were found along the left shoreline directly across the river from the 100-F Area. Relatively high temperature anomaly patterns coincided with the prominence of high conductivity values in this region. One small groundwater upwelling region was observed immediately adjacent to the 100-F Area where chromium (at least 20  $\mu\text{g}/\text{L}$ ) in well water had been reported (Figure 3-11). There were no elevated temperature anomalies near the 100-F Area, suggesting relatively low discharge rates. Groundwater upwelling areas were also observed in the 100-F slough area and near the beginning of the 100-F island complex (Figure 3-12).

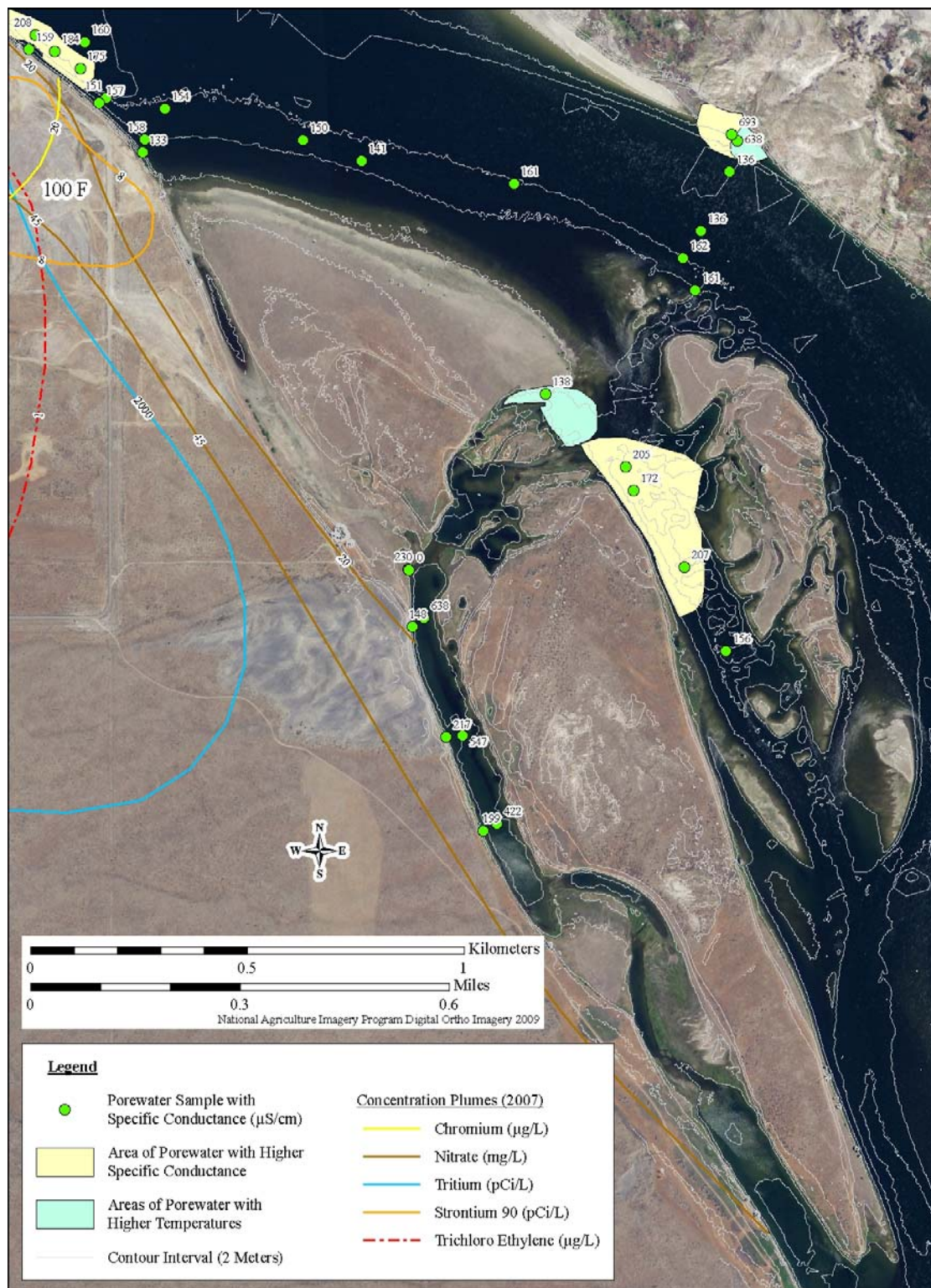
Out of 64 Phase II(a) sample locations completed, the maximum conductivity was 858  $\mu\text{S}/\text{cm}$  and maximum temperature anomaly was 2.7°C (4.9°F). The maximum conductivity occurred on January 24, 2009 with an associated temperature anomaly of 1.84°C (3.3°F) in sandy silt substrate in an inlet on the left shore near the base of a landslide off the White Bluffs (on the downriver edge of the largest green polygon area in Figure 3-11). The maximum temperature anomaly occurred on March 16, 2009 in cobble substrate with an associated conductivity of 159  $\mu\text{S}/\text{cm}$  near the left shore.

**3.1.1.7 Hanford Townsite Area.** Eighty sample locations were completed throughout approximately 20.9 km (13 mi) of the river between the Hanford townsite and Energy Northwest (Figures 3-13 through 3-16). Groundwater upwelling were detected offshore in waters as deep as approximately 10.9 m (36 ft). Pore water conductivity indicated the presence of groundwater beginning at the Hanford townsite slough (Figure 3-13) down to Energy Northwest (Figure 3-16). Out of 80 Phase II(a) sample locations completed, the maximum conductivity was 684  $\mu\text{S}/\text{cm}$  and maximum temperature anomaly was 4.4°C (7.9°F). The maximum conductivity occurred on January 12, 2009 with an associated temperature anomaly of 2.16°C (3.9°F) in silty/cobble substrate roughly 2.6 km (1.6 mi) upstream of Savage Island. The maximum temperature anomaly occurred on February 22, 2009 in gravel/sediment/sand substrate with an associated conductivity of 589  $\mu\text{S}/\text{cm}$  near the Hanford Site shore across roughly the mid-length of Savage Island. There were relatively few (n=3) areas along the Hanford shorelines where elevated temperature anomaly patterns were distinctly observed (Figures 3-13 through 3-16).

**Figure 3-11. Pore Water Conductivity ( $\mu\text{S}/\text{cm}$ ) and Temperature Anomaly Patterns Measured During Phase II(a) Near the 100-F Area (Sheet 1 of 2).**

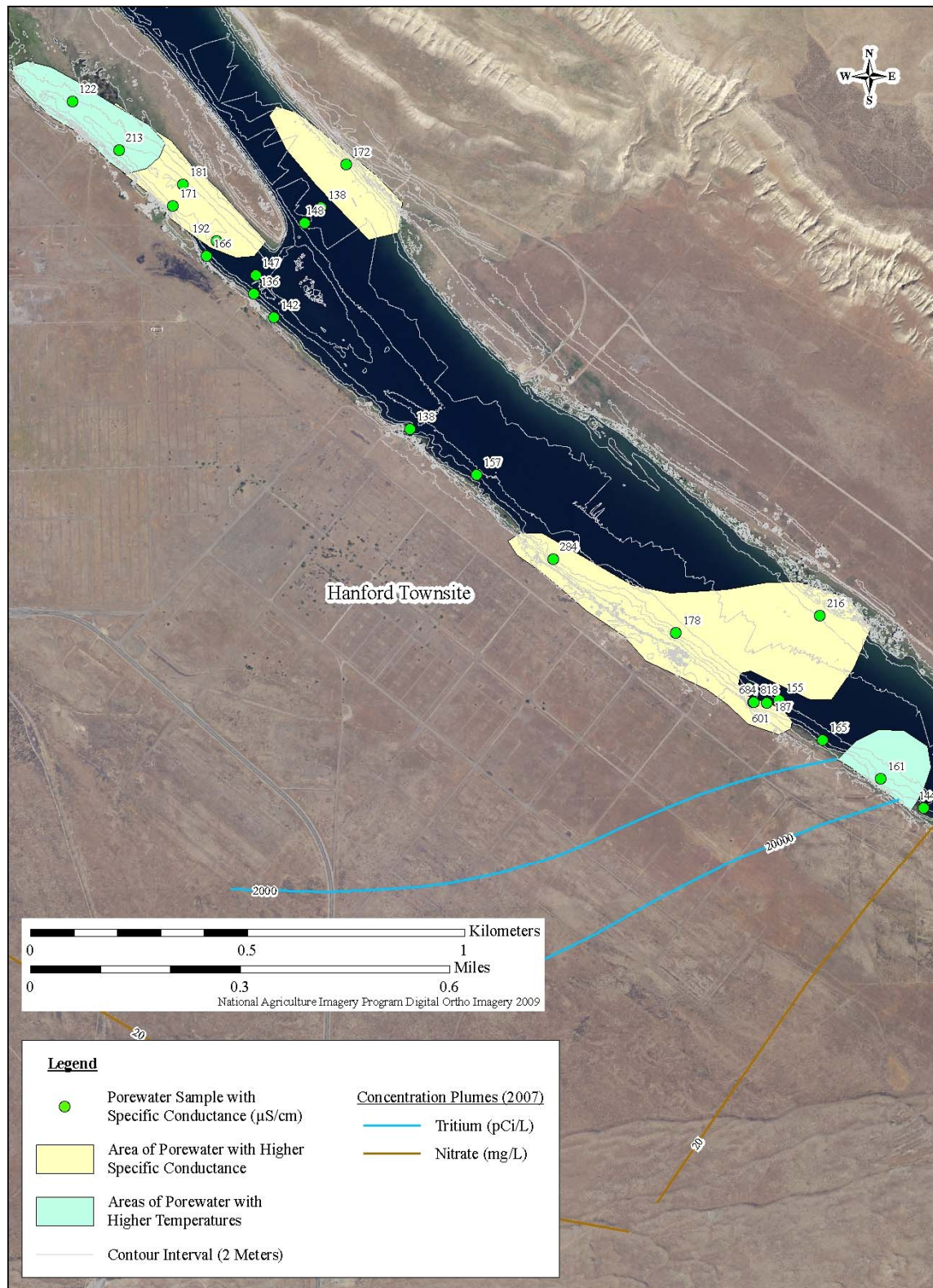


**Figure 3-12. Pore Water Conductivity ( $\mu\text{S}/\text{cm}$ ) and Temperature Anomaly Patterns Measured During Phase II(a) Near the 100-F Area (Sheet 2 of 2).**

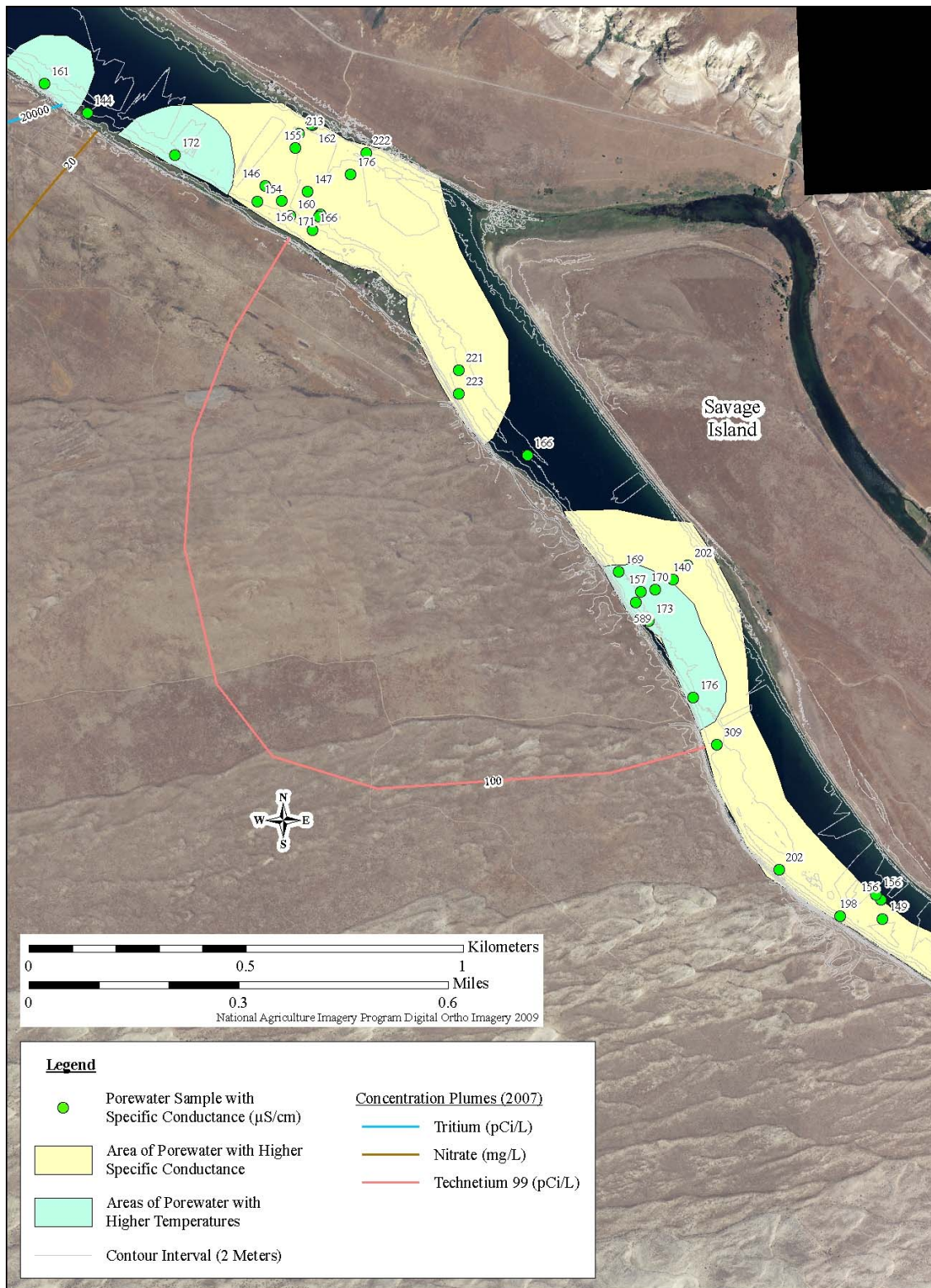




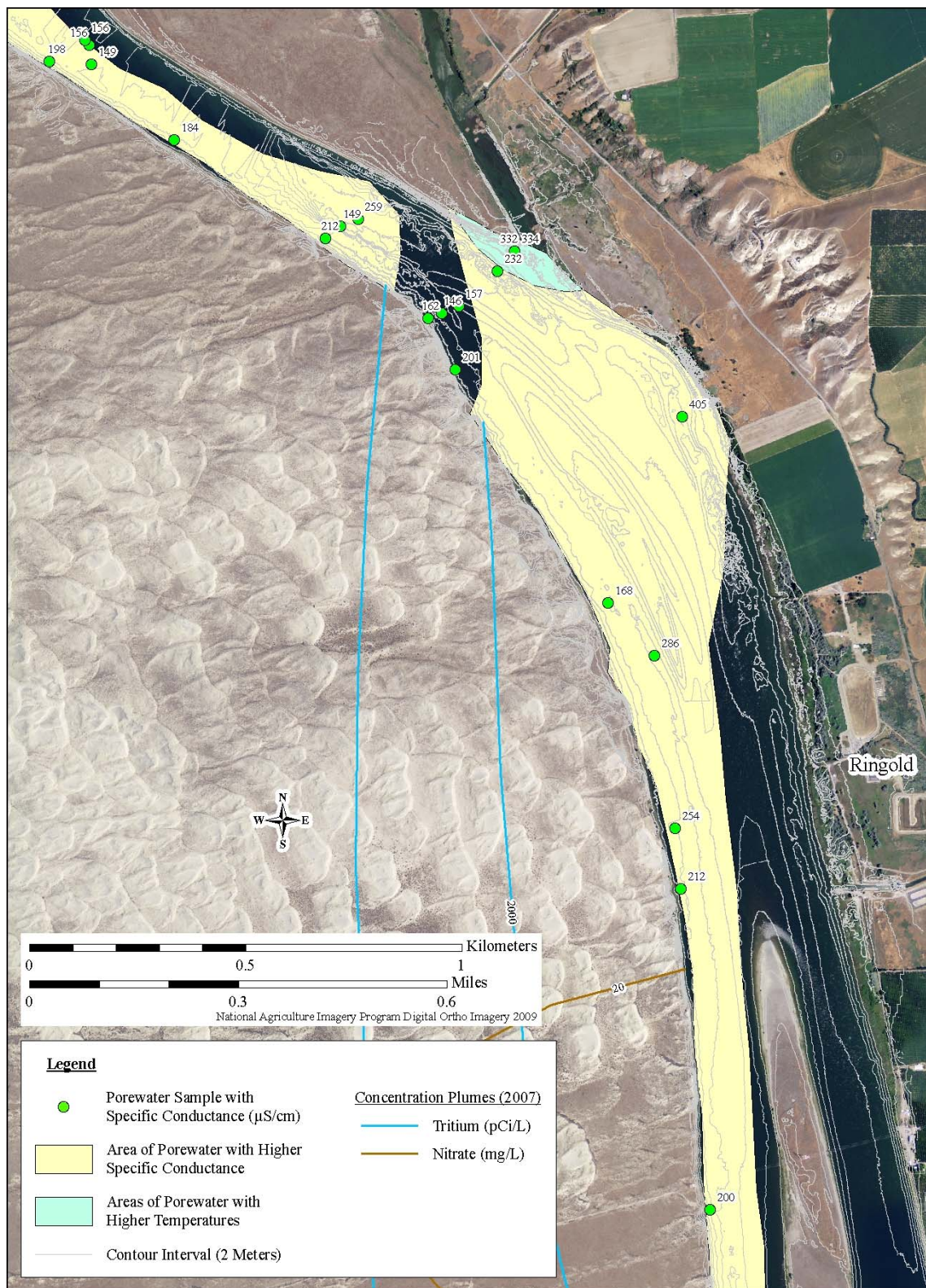
**Figure 3-13. Pore Water Conductivity ( $\mu\text{S}/\text{cm}$ ) and Temperature Anomaly Patterns Measured During Phase II(a) Near the Hanford Townsite Area (Sheet 1 of 4).**



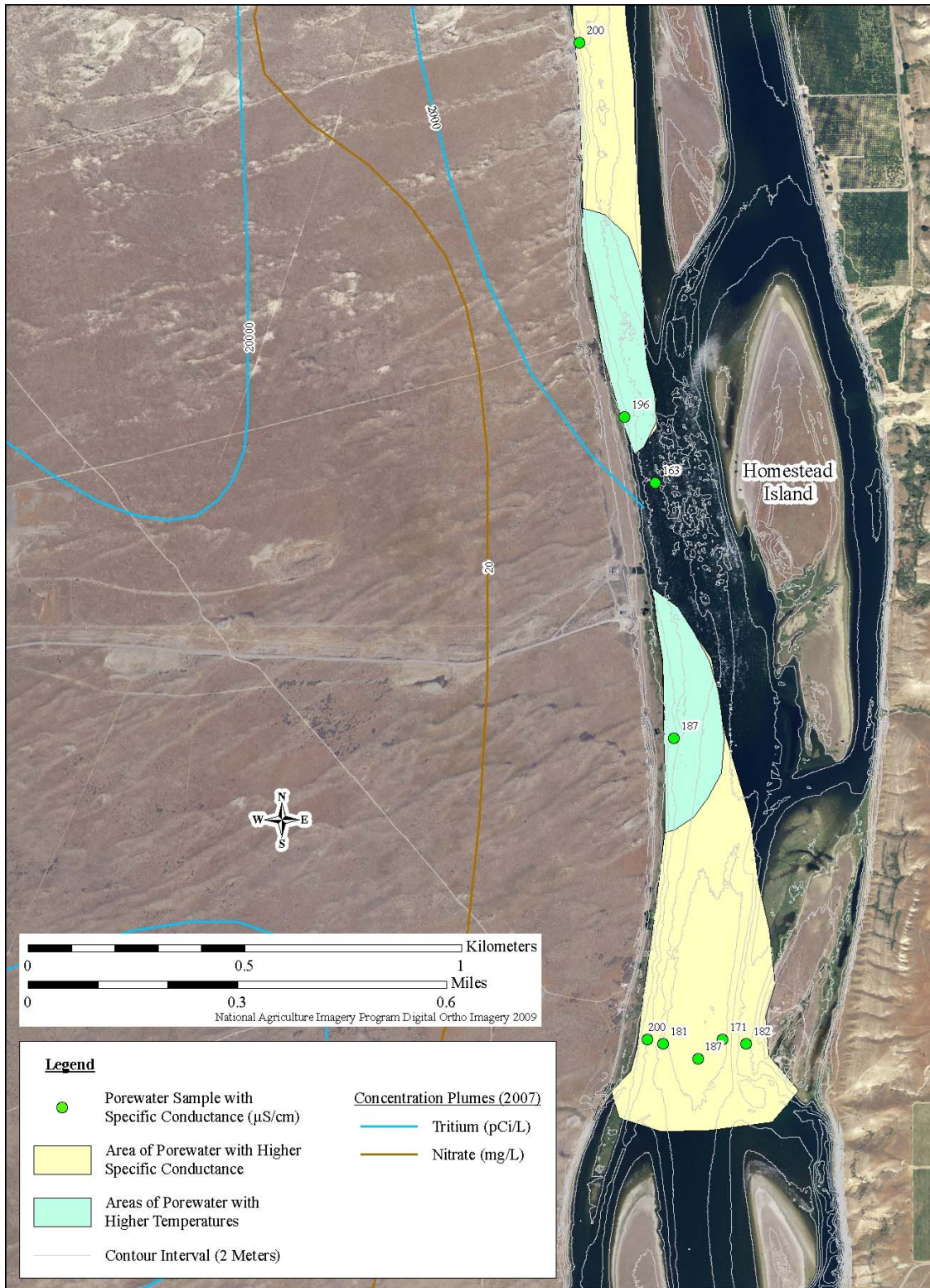
**Figure 3-14. Pore Water Conductivity ( $\mu\text{S}/\text{cm}$ ) and Temperature Anomaly Patterns Measured During Phase II(a) Near the Hanford Townsite Area (Sheet 2 of 4).**



**Figure 3-15. Pore Water Conductivity ( $\mu\text{S}/\text{cm}$ ) and Temperature Anomaly Patterns Measured During Phase II(a) Near the Hanford Townsite Area (Sheet 3 of 4).**



**Figure 3-16. Pore Water Conductivity ( $\mu\text{S}/\text{cm}$ ) and Temperature Anomaly Patterns Measured During Phase II(a) Near the Hanford Townsite Area (Sheet 4 of 4).**



**3.1.1.8 300 Area.** A total of 94 sample locations were sampled along a 4.8 km (3 mi) section of the river in the vicinity of the 300 Area during Phase II(a). Figures 3-17 and 3-18 illustrate the Phase II(a) groundwater upwelling patterns using pore water conductivity and temperature anomalies near the 300 Area. Generally, groundwater upwelling were most notable along both shorelines and extended about 0.4 km (0.25 mi) into the river. Out of 94 Phase II(a) sample locations completed, the maximum conductivity was 1,090  $\mu\text{S}/\text{cm}$  and maximum temperature anomaly was 10.4°C (18.7°F). The maximum conductivity occurred on January 20, 2009 with an associated temperature anomaly of 8.22°C (14.8°F) in silt/sand substrate near the eastern shore along a residential area (Figure 3-18).

### 3.1.2 River Stages Encountered During Phase II(a)

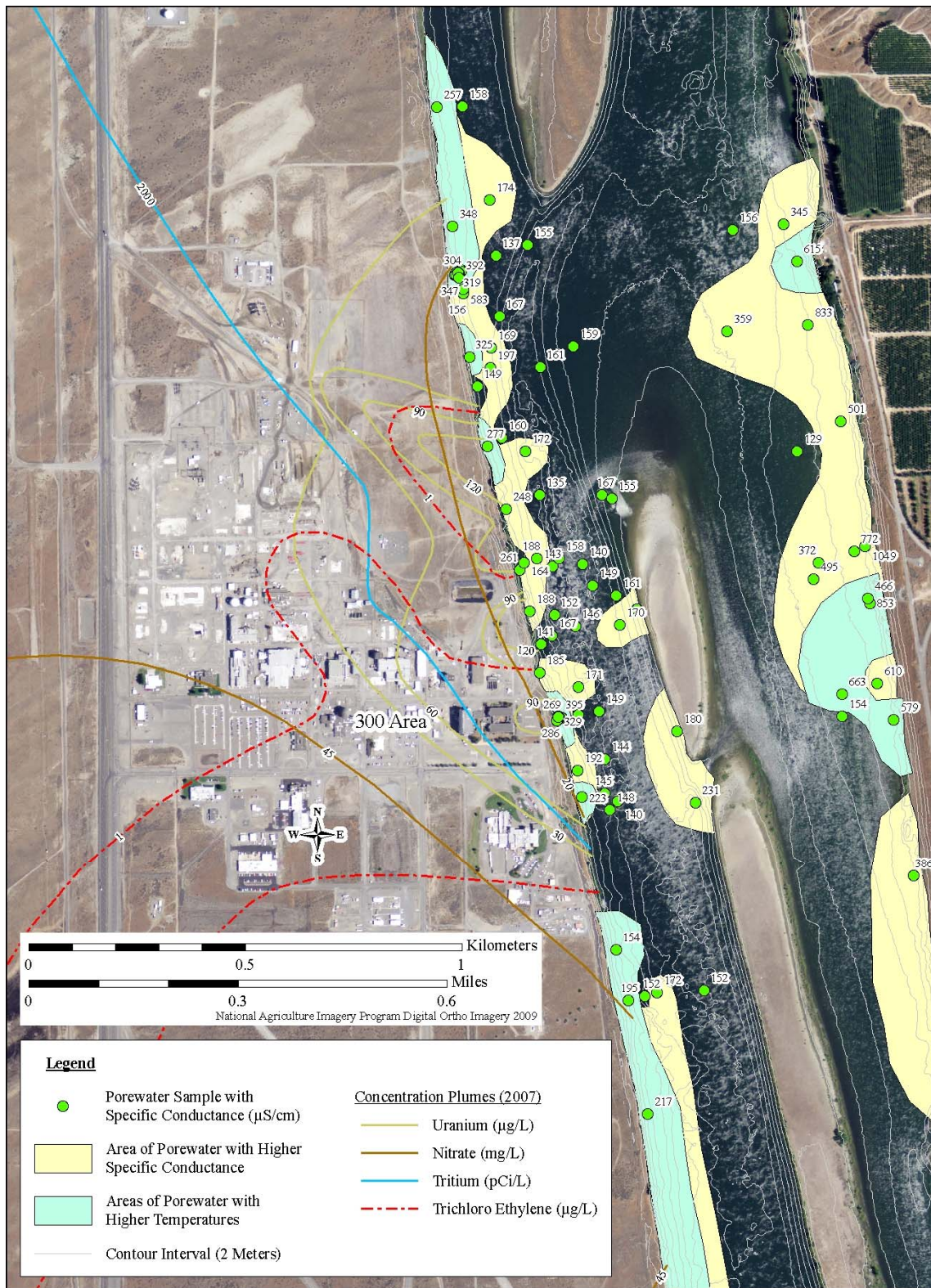
A number of sample locations were measured in Phase II(a) under more variable water conditions, and mapping groundwater upwelling during Phase II(a) was least restrictive of all three phases of the project (Figure 3-19). River stage fluctuations during Phase II(a) were the most variable of the entire study. Groundwater upwelling measurements were not taken when river flows exceeded approximately 160 Kcfs during Phase II(a), and primarily occurred when flows were less than 120 Kcfs. This 160 Kcfs upper limit was determined based on more than 50 data points collected during Phase II(a) that showed groundwater influences (elevated conductivity above the surface water levels) were still detectable (values greater than 160  $\mu\text{S}/\text{cm}$ ) with the Trident probe technique. More details regarding the river stages encountered at each study area during Phases II(b) and III are provided in these respective results sections of the report. River stages encountered during each sample are also summarized in the master data summary sheets (Appendix C, E, and F). The development of field QC guidelines used to describe quality of the sample results is provided in Appendix A.

### 3.1.3 Data Reduction for Phase II(b) Site Selections

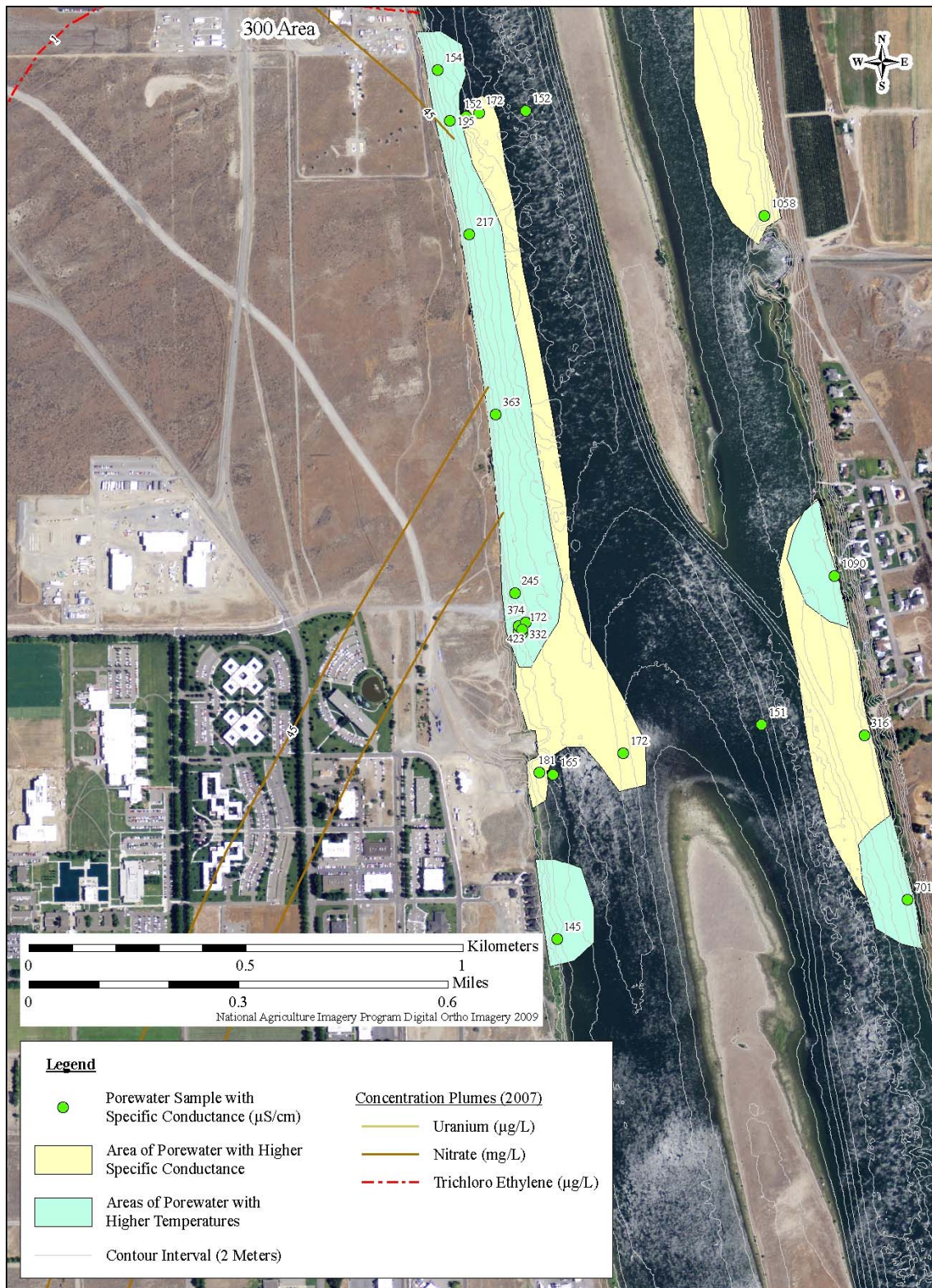
Because of the differing ranges in conductivity between surface water and pore water in the Phase II(a) sample locations, sample locations having pore water conductivity values greater than 95% of the surface water conductivity data (i.e., greater than 168  $\mu\text{S}/\text{cm}$ ), were considered to be potentially influenced by groundwater and were further considered (retained) during the Phase II(b) station selection process. A second tier screening of Phase II(a) temperatures was used for all samples that were excluded during the first tier conductivity screening. Sites rejected during first tier screening that were found to have temperature anomalies greater than 95% of all anomaly measurements (i.e., greater than 2.24°C [4.0°F]) were considered to be potentially influenced by groundwater and were retained for the Phase II(b) station selection process. Temperature anomalies were defined as the degree by which pore water temperature exceeded the reference temperature (the lowest surface water temperature on any given day within a sampled area). The following steps outline the initial screening criteria:

1. Calculate the surface water conductivity reference envelope:  
(SWCRE = SW Average Cond + 2 SD = 168  $\mu\text{S}/\text{cm}$ )
2. Define nondischarge station population subsurface conductivity <168  $\mu\text{S}/\text{cm}$

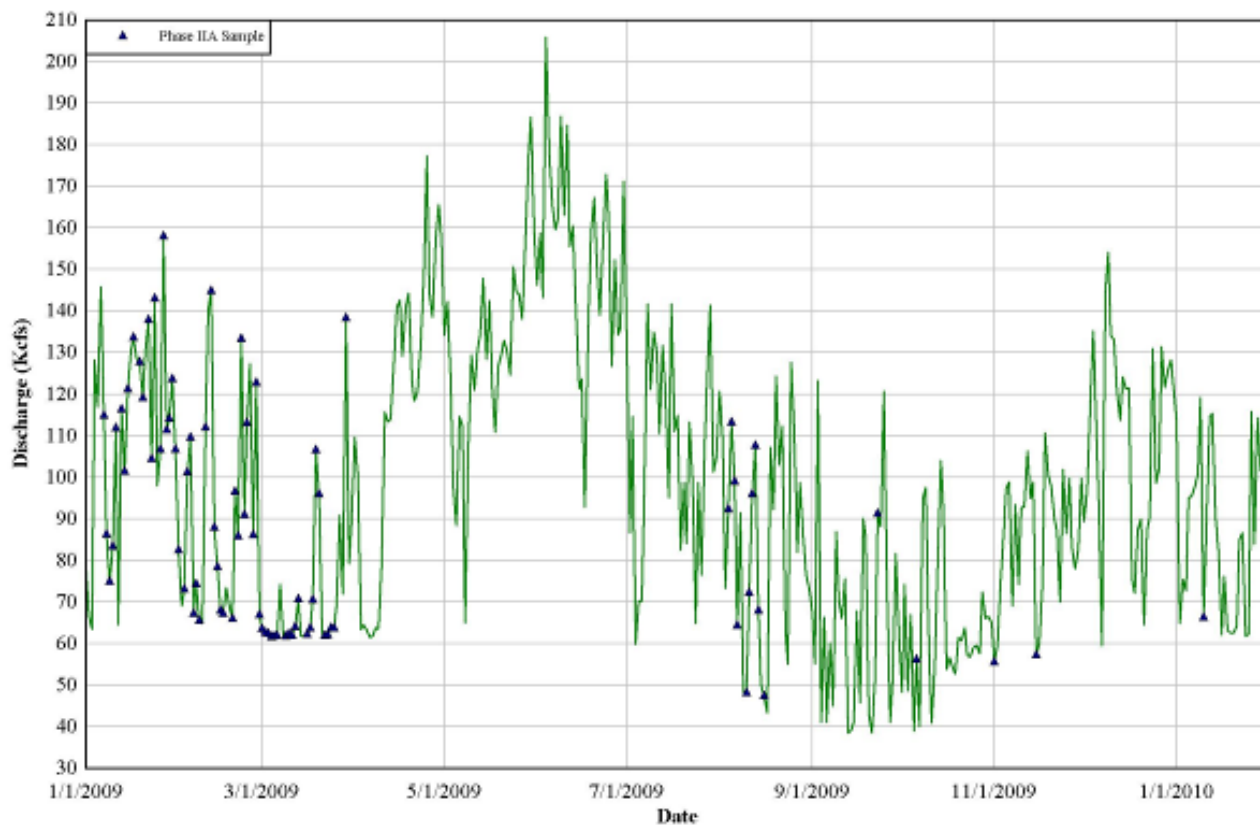
**Figure 3-17. Pore Water Conductivity ( $\mu\text{S}/\text{cm}$ ) and Temperature Anomaly Patterns Measured During Phase II(a) Near the 300 Area (Sheet 1 of 2).**



**Figure 3-18. Pore Water Conductivity ( $\mu\text{S}/\text{cm}$ ) and Temperature Anomaly Patterns Measured During Phase II(a) Near the 300 Area (Sheet 2 of 2).**



**Figure 3-19. Overview of Daily River Flows Encountered During Phase II(a) Sampling Events.**



3. Calculate the station temperature anomaly:  
(TA = Subsurface Station Temp – Area Daily Reference Surface Water Temp)
4. Identify nondischarge station population temperature anomaly envelope (NDTAE):  
(NDTAE = Avg. of Nondischarge Station Temp Anomalies + 2 SD = 2.24°C)

Temperature anomalies of sites selected for Phase II(b) indicator contaminant screening were often less than 2°C (3.6°F) but ranged as high as 10.37°C (18.7°F). Conductivity in surface water was usually less than 200 µS/cm and in most pore water was greater than 200 µS/cm with maximum values of more than 1,000 µS/cm at four sites (Table 3-2).



**Table 3-2. Frequency of Conductivity Values and Temperature Anomalies of Phase II(b) Sample Locations Selected from Phase II(a) Data Collected During January through March 2009.**

Conductivity ( $\mu\text{S}/\text{cm}$ )	100 - 200	200 - 400	400 - 600	600 - 800	800 - 1,000	+1,000
Surface water (30.5 cm [12-in.] above bottom)	208	2	0	0	0	0
Pore water (20.3 to 30.5 cm [8 to 12-in.] below riverbed)	66	111	12	15	3	4
Temperature ( $^{\circ}\text{C}$ )	0 - 2	2 - 4	4 - 6	6 - 8	8 - 10	10 - 12
Temperature anomalies ( $^{\circ}\text{C}$ )	137	53	12	7	1	1

### 3.2 PHASE II(B) SCREENING INDICATOR CONTAMINANTS AT KNOWN UPWELLINGS

Phase II(b) sampling began in late August 2009 and continued through February 2010. The Phase II(b) sampling was largely completed prior to commencement of Phase III in early January 2010, with only 4 stations sampled after this time. A total of 233 sample locations were successfully sampled for analyses of selected water quality parameters (conductivity, temperature, DO, pH, ORP, and TDS) as well as the indicator contaminants prescribed in the SAI (Table 1-1). Appendix E provides complete summaries of the Phase II(b) water quality sample results and illustrates the complementing indicator contaminant levels reported throughout each of the eight study areas. Temperature anomalies (differences between groundwater upwelling and surface water) were not useful during Phase II(b) because the difference was not as distinct during the summer months, when pore water temperatures were the nearly same as surface water temperature or slightly cooler than the surface water.

#### 3.2.1 Data Collected

The following sections include maps showing specific site locations to be sampled in Phase II(b) and a brief discussion of maximum values in each area sampled (Table 3-3).

**Table 3-3. Summary of Phase II(b) Sample Locations and Maximum Conductivity ( $\mu\text{S}/\text{cm}$ ) by Study Area.**

Study Area	Dates Performed	Total Number of Stations	Maximum Pore Water Conductivity ( $\mu\text{S}/\text{cm}$ )
100-B/C	August – September 2009	29	474
100-K	September – November 2009	32	490
100-N	October – November 2009	30	874
100-D	October 2009	30	934
100-H	September – November 2009	30	1,230
100-F	July and November 2009	19	1,038
Hanford Town Site (HTS)	November 2009 – January 2010	29	726
300 Area	August – September 2009	34	1,148
Total		233	

**3.2.1.1 100-B/C Area.** Thirty Phase II(b) sample locations were sampled during August and September 2009 to collect pore water for hexavalent chromium analyses (Figure 3-20). All but three sample locations (J100BC5, T100BC4A, and J100BC2) were sampled during relatively low and stable river levels.

Elevated conductivity readings were observed at nearly all 29 of the 30 sites measured, suggesting the presence of groundwater throughout most of the 100-B/C riverbed area sampled (Figure 3-21). Only one station, J100BC18, did not exhibit a conductivity value indicative of groundwater. The 100-B/C reactor water intake structure consistently produced some of the highest conductivities recorded throughout the 100-B/C Area (315 to 474  $\mu\text{S}/\text{cm}$ ). Higher levels were observed at three sample locations located in the center of the river during Phase II(a) (Figures 3-5 through 3-7).

Seventeen of 29 (57%) pore water hexavalent chromium sample results were reported above the practical quantitation limit (PQL) of 3.7  $\mu\text{g}/\text{L}$  (Figure 3-22). Fourteen of 17 pore-water sample results > PQL exceeded EPA ambient water quality criteria (10  $\mu\text{g}/\text{L}$ ) (results ranged between 15 and 112  $\mu\text{g}/\text{L}$ ). Four of the five highest hexavalent chromium pore water concentrations (range 56 to 112  $\mu\text{g}/\text{L}$ ) were collected from offshore locations, including the deepest channel of river near the 100-B/C. The hexavalent chromium results generally corresponded to the groundwater plume estimates (DOE/RL-2008-01), but one sample location (J100BC47) located nearly 0.6 km (0.37 mi) downstream of known groundwater plume and proximal to an active remediation site (Appendix G). This site also contained a significant temperature anomaly value during the Phase II(a) mapping effort (Appendix D).

Phase II(b) pore water conductivity values were generally higher than Phase II(a) results obtained during January through March 2009, and supported the premise that low- and stable river levels were important factors to consider during the Phase II(b) and III sampling events (Section 3.2.2 and Appendix G). However, higher conductivity levels observed at all three mid-river sample locations during Phase II(a) compared to Phase (b) may indicate changes in the groundwater upwelling patterns as seasons and hydraulic gradients change.

High pore water conductivity values indicated the presence of groundwater, but high conductivity was not linearly consistent with the level of hexavalent chromium contaminated groundwater present near 100-B/C. For example, a 91  $\mu\text{g}/\text{L}$  concentration of hexavalent chromium was found where conductivity was only 160  $\mu\text{S}/\text{cm}$ , a conductivity value just marginally higher than surface water (approximately 140  $\mu\text{S}/\text{cm}$ ). The hexavalent chromium pore water patterns seen at 100-B/C suggested a nonuniform pattern of contaminated pore water may exist.

**3.2.1.2 100-K Area.** Thirty-two sites were selected for hexavalent chromium analyses in Phase II(b) near 100-K Area (Figure 3-23). Pore-water samples were collected near 100-K between September and November 2009 during periods when river flows ranged between approximately 40 Kcfs to approximately 70 Kcfs (see Section 3.2.2 for additional river stage details).

Figure 3-20. Phase II(b) Sample Locations Selected Near the 100-B/C Area.

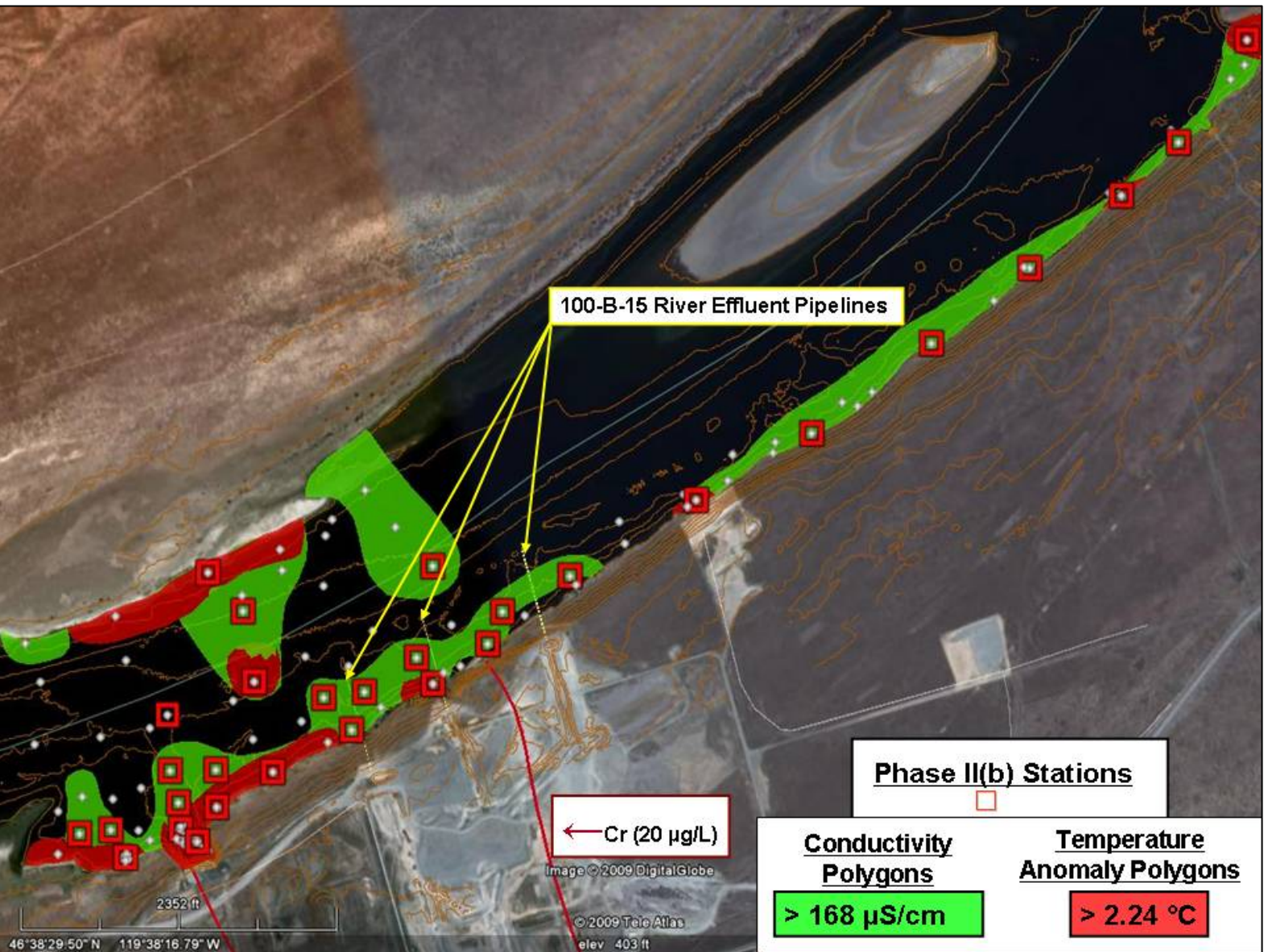


Figure 3-21. Pore Water Conductivity ( $\mu\text{S}/\text{cm}$ ) Measured During Phase II(b) Near the 100-B/C Area.

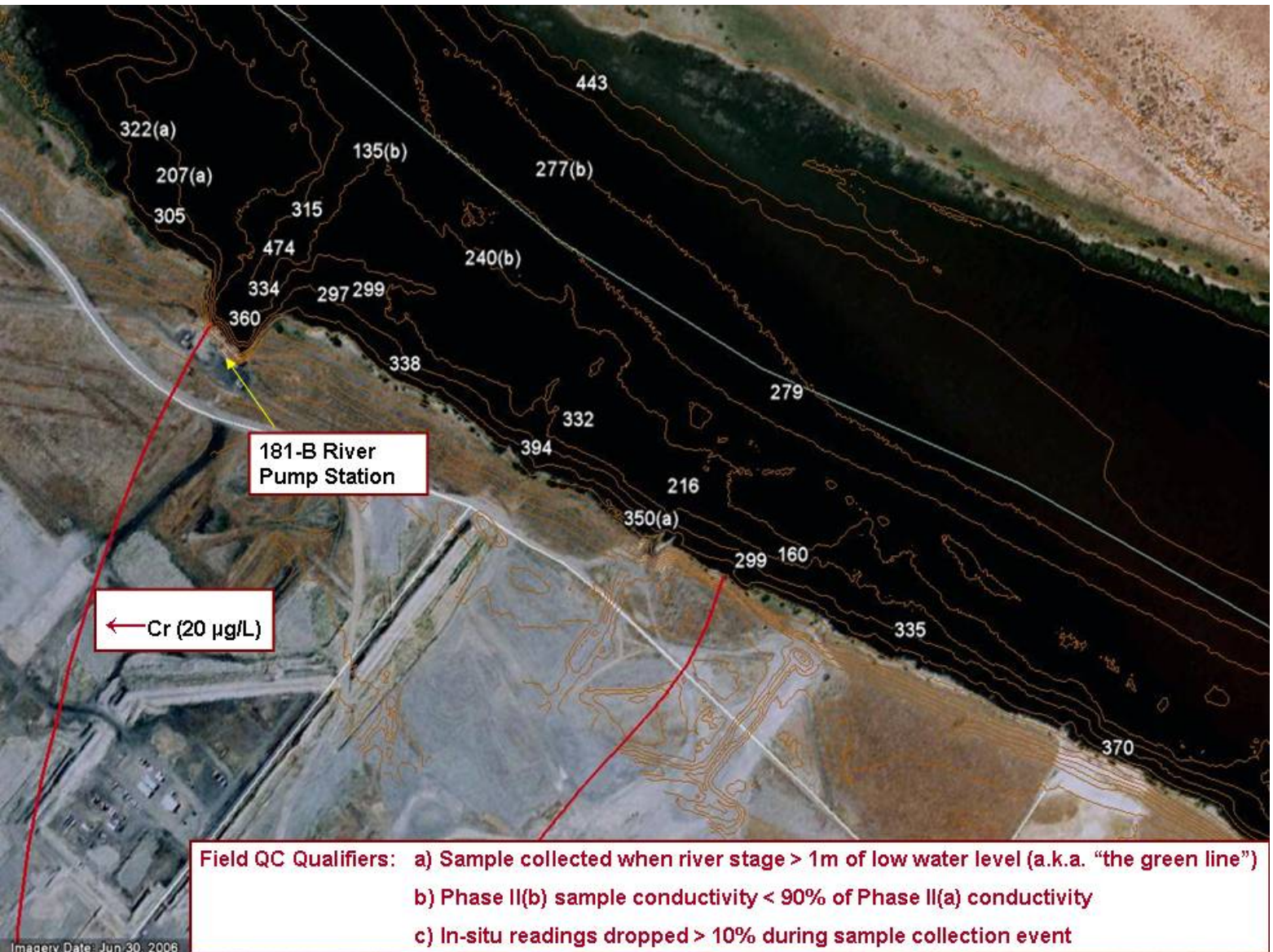


Figure 3-22. Pore Water Hexavalent Chromium ( $\mu\text{g/L}$ ) Levels Measured During Phase II(b) Near the 100-B/C Area.

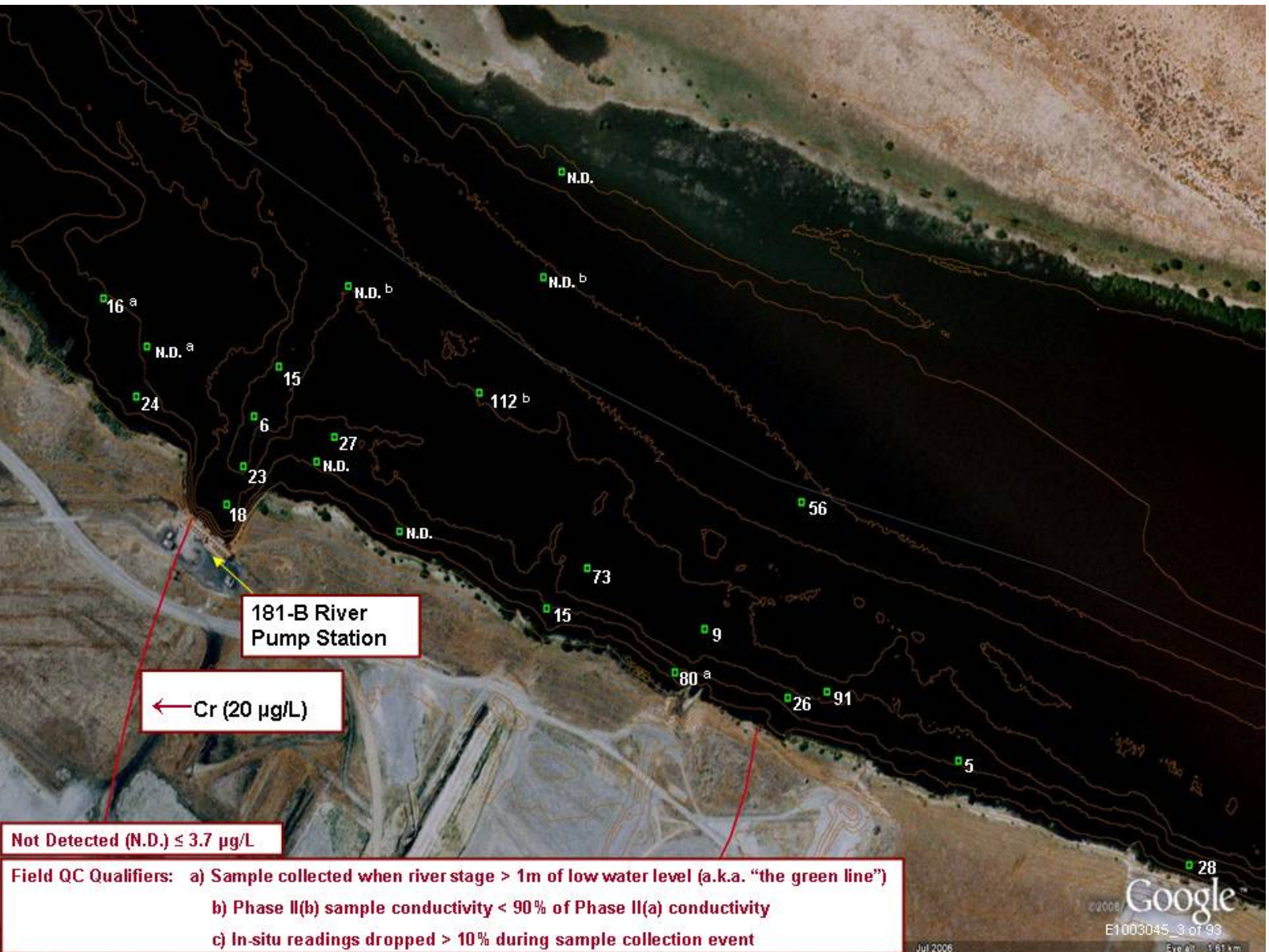
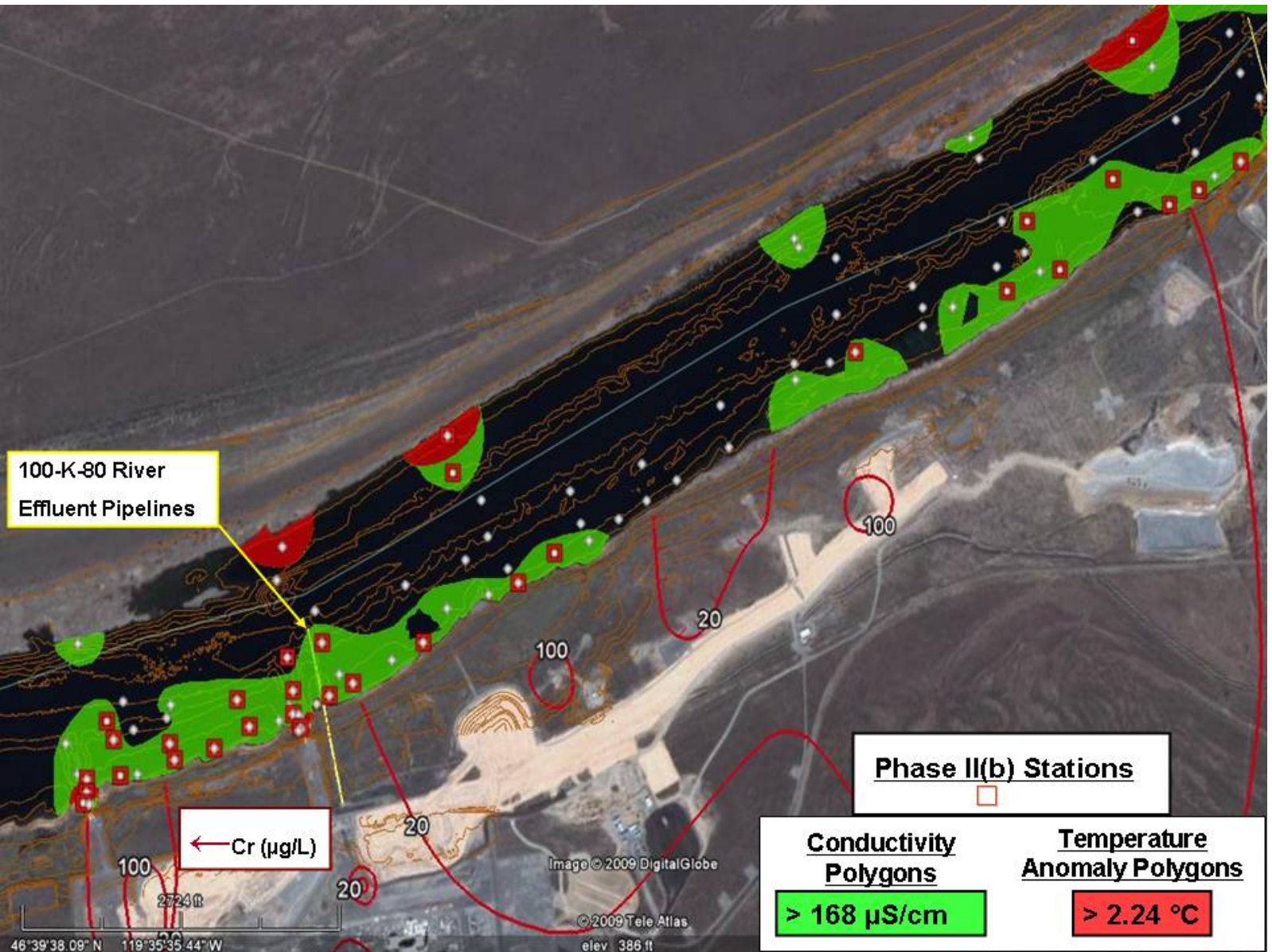


Figure 3-23. Phase II(b) Sample Locations Selected Near the 100-K Area.



Pore water conductivity levels measured near 100-K Area during Phase II(b) were generally higher than the values measured at these sites during Phase II(a) (Figures 3-24 and 3-25). Although some pore water conductivity variation was apparent throughout the 100-K Area, the presence of groundwater was detected at all 32 pore-water sample locations. Both intake structures (K East and K West water intake structures) showed a consistent pattern of elevated conductivity as compared to other stations measured (Figures 3-24 and 3-25). In general, the pore water conductivity decreased as distance from the shoreline increased.

Twelve of 32 (38%) pore water hexavalent chromium sample results were reported above the PQL of 3.7 ug/L near the 100-K Area (Figures 3-26 and 3-27). Nine of 12 pore-water sample results reported above the PQL were at or above an ambient water quality criteria (10 µg/L) (results ranged between 10 and 44 µg/L). Of those nine results, three were collected near shore and six were collected in offshore locations. The highest hexavalent chromium result reported near 100-K during Phase II(b) was collected furthest off-shore at a depth of approximately 6.4 m (21 ft) below the low water mark (Figures 3-26, 3-27, and Appendix E).

**3.2.1.3 100-N Area.** Thirty sample locations were selected for strontium analysis in Phase II(b). Out of these 30 sample locations, 10 were also sampled for total petroleum hydrocarbons (TPH) (Figure 3-28). All samples were obtained during late-October and early November 2009 when seasonal average river flows ranged between approximately 40 through 70 Kcfs (i.e., less than 0.9 m [3 ft] height). However, daily river level fluctuations were approximately 60 Kcfs (approximately 60 Kcfs to 120 Kcfs) during this time and was noteworthy because the river cycles may have potentially affected the sample results by adding more bank-recharge surface water (Appendix G). Nine samples were taken when conductivity was less than 90% of the Phase II(a) values and two of those sites (N Intake D, and T100N1B) were collected when river levels were likely suppressing the groundwater signal (see sites with both qualifiers a and b in Figure 3-29).

Conductivity results measured during Phase II(b) near 100-N were generally higher during the fall 2009 period as compared to the Phase II(a) results obtained during January through March 2009 (Figure 3-29). All but one of the 30 Phase II(b) sample locations yielded conductivity values that indicated the presence of groundwater (i.e., >approximately 160 Kcfs). Some of the highest conductivity values (range 559 to 776 µS/cm) were observed immediately adjacent to the 100-N water intake structure. High pore water conductivity (range 381 to 874 µS/cm) was also observed immediately adjacent to the historical shoreline area known to have elevated levels of strontium-90. Groundwater upwelling were prominent in all sample locations located along the left shoreline (Figure 3-29). Although still indicative of a groundwater upwelling, the lowest pore water conductivity values measured near 100-N during Phase II(b) were obtained near the center of the river channel.

Figure 3-24. Pore Water Conductivity ( $\mu\text{S}/\text{cm}$ ) Measured During Phase II(b) Near the 100-K Area (Sheet 1 of 2).

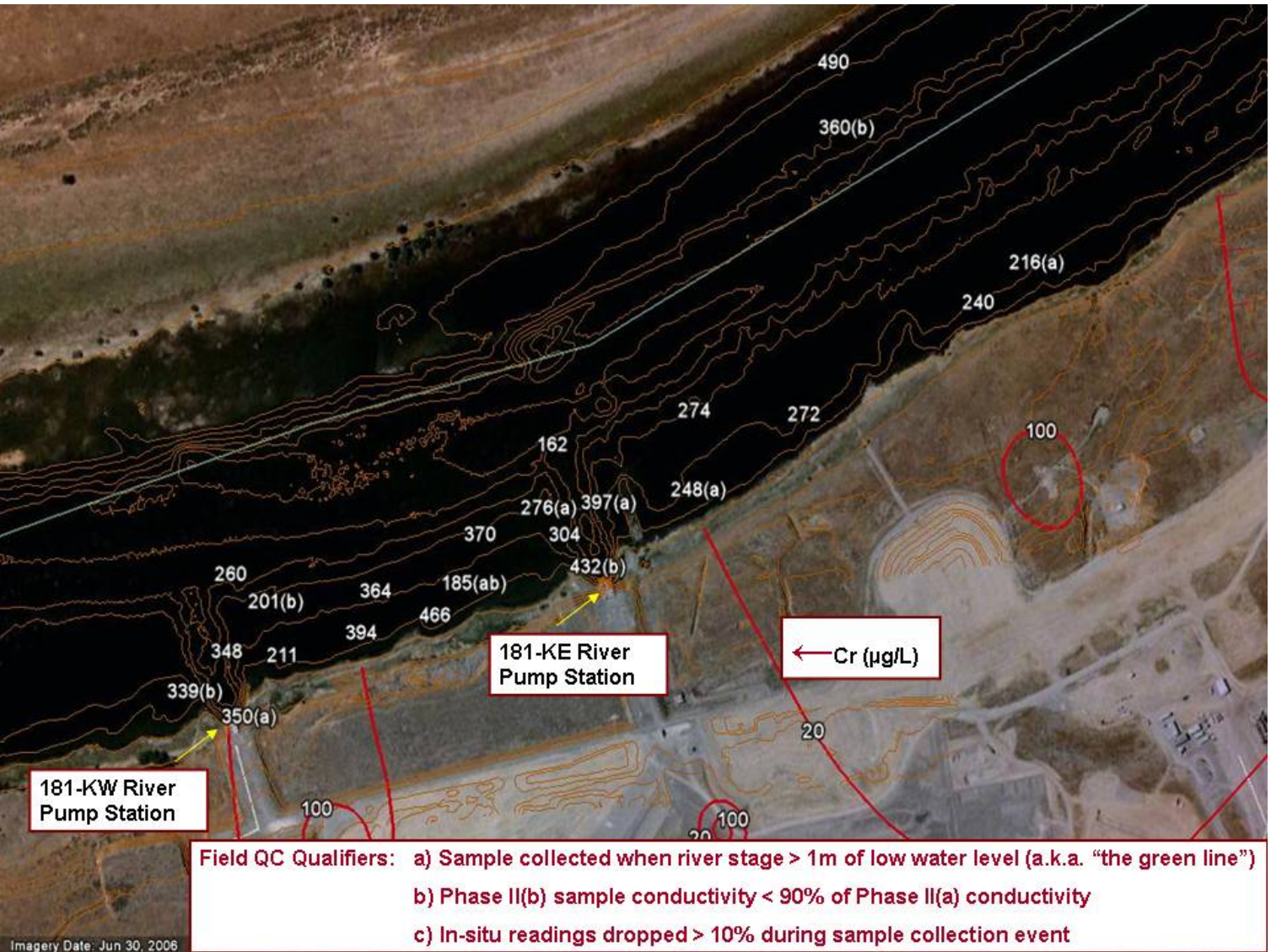




Figure 3-25. Pore Water Conductivity ( $\mu\text{S}/\text{cm}$ ) Measured During Phase II(b) Near the 100-K Area (Sheet 2 of 2).

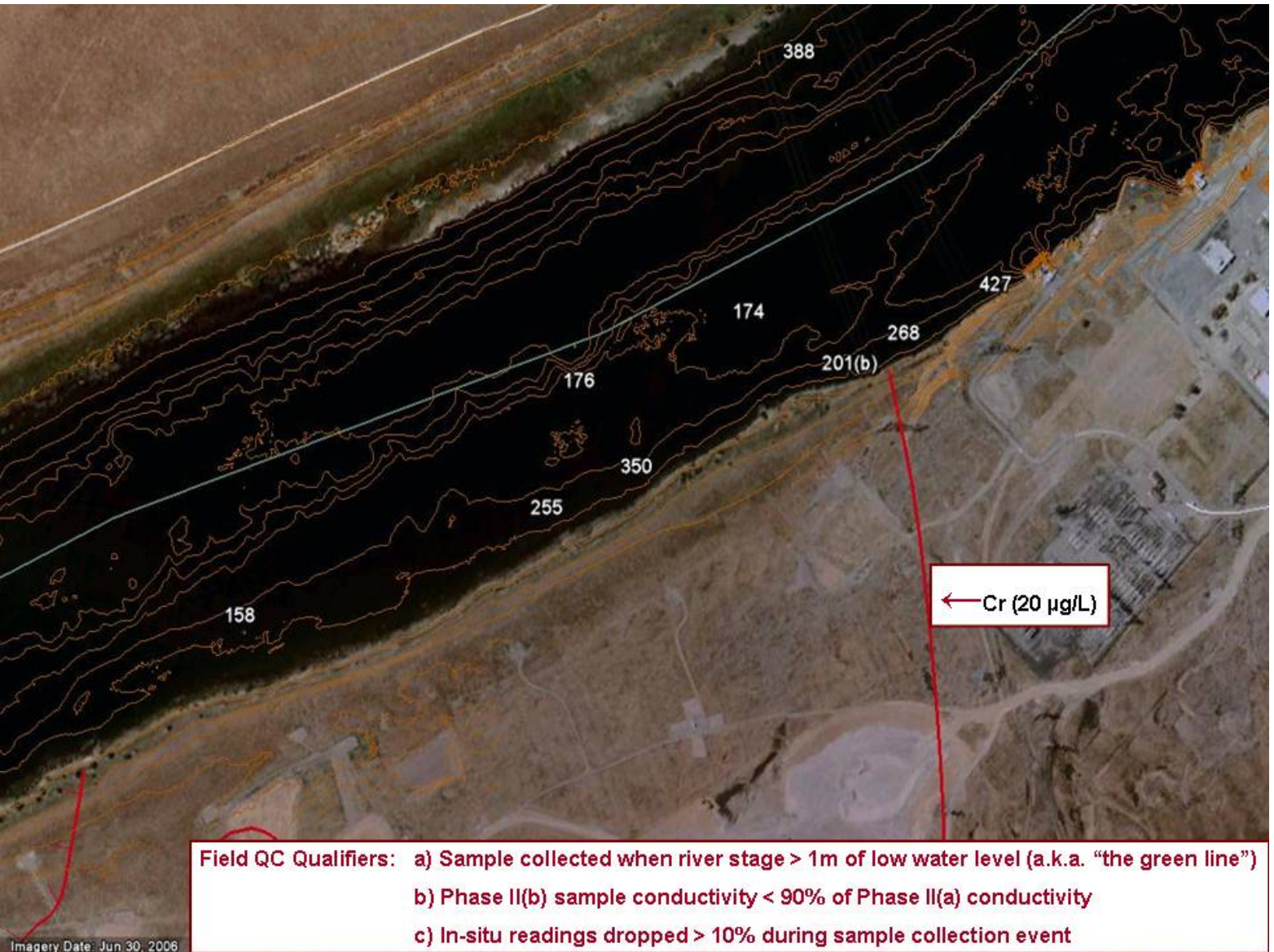


Figure 3-26. Pore Water Hexavalent Chromium ( $\mu\text{g/L}$ ) Levels Measured During Phase II(b) Near the 100-K Area (Sheet 1 of 2).

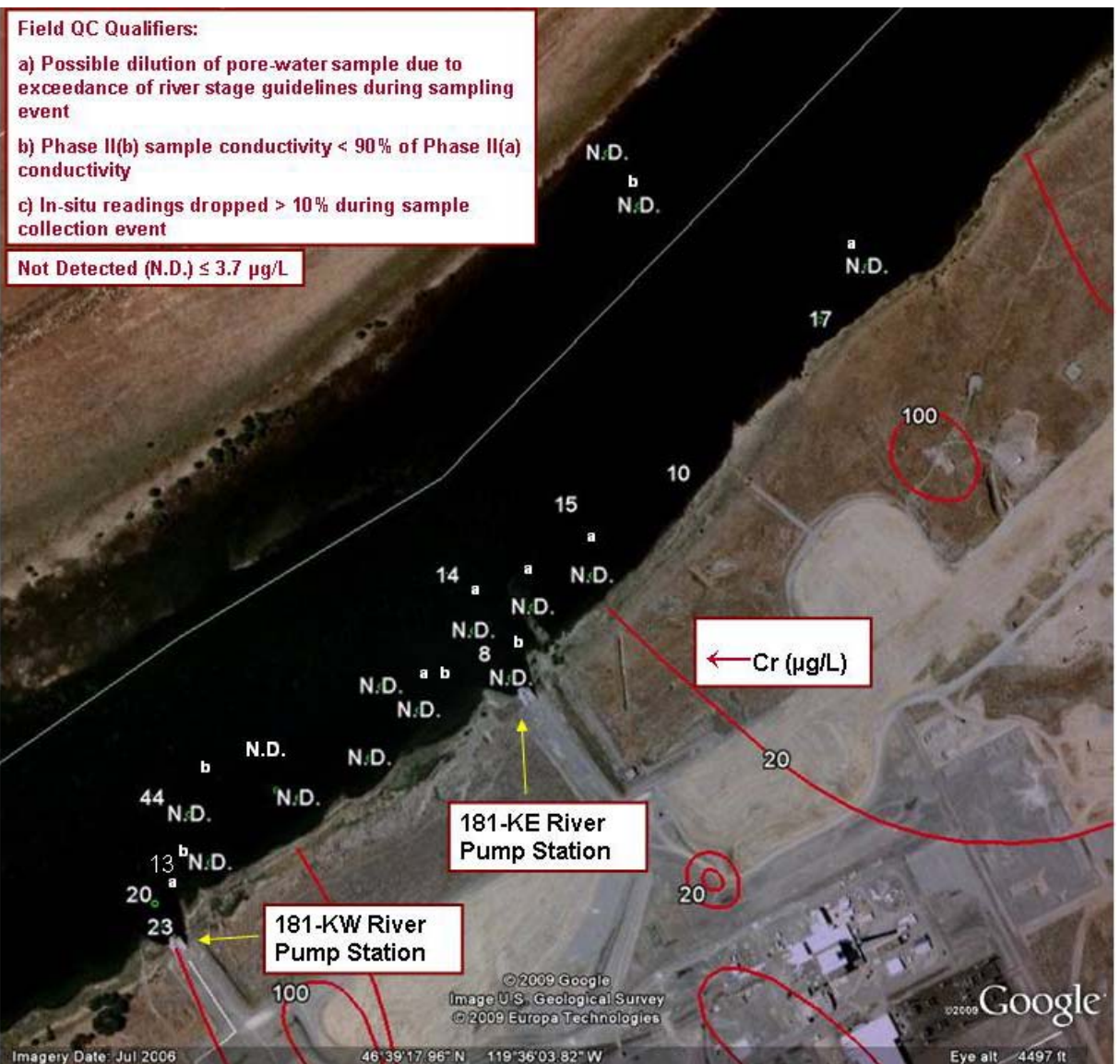


Figure 3-27. Pore Water Hexavalent Chromium ( $\mu\text{g/L}$ ) Levels Measured During Phase II(b) Near the 100-K Area (Sheet 2 of 2).

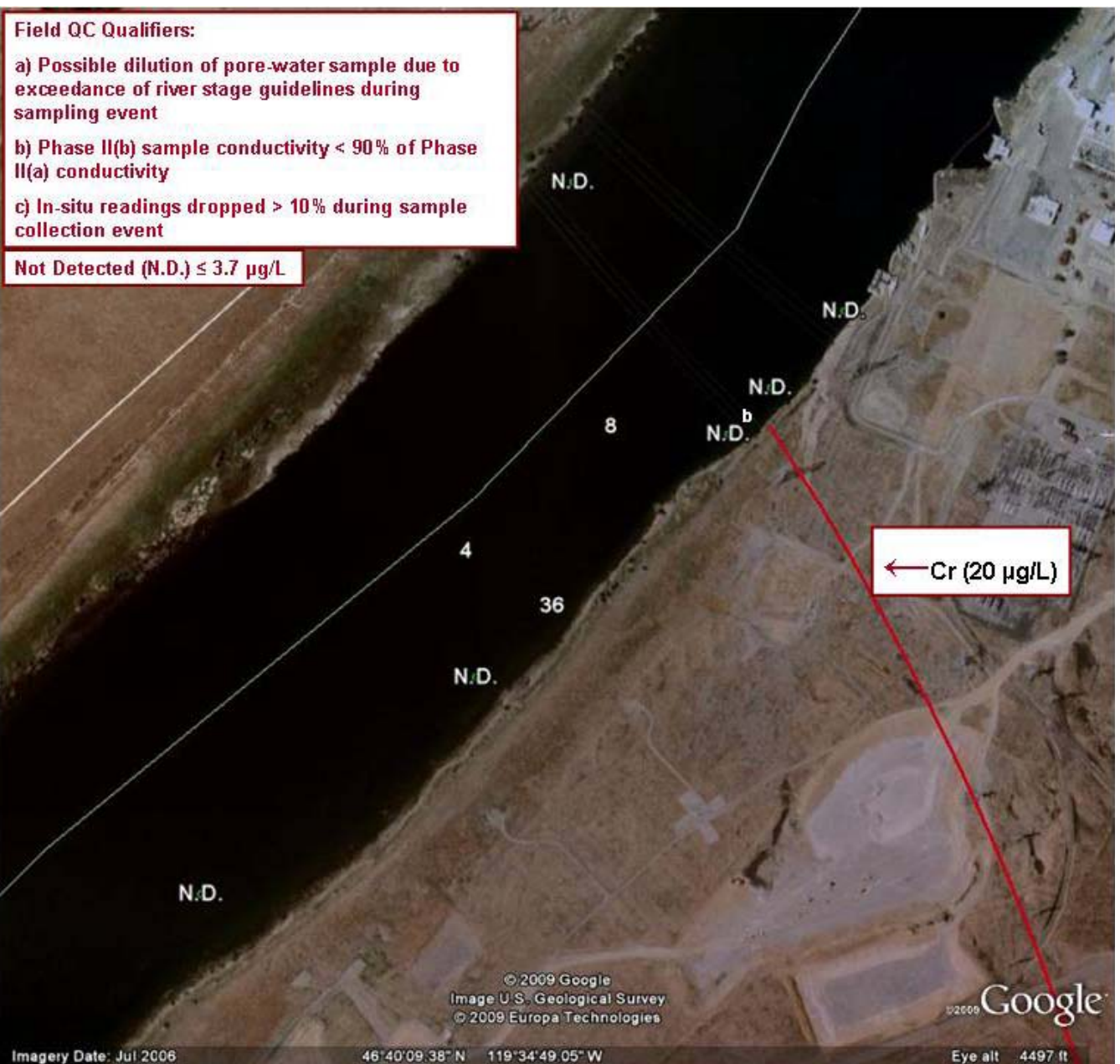


Figure 3-28. Phase II(b) Sample Locations Selected Near the 100-N Area.

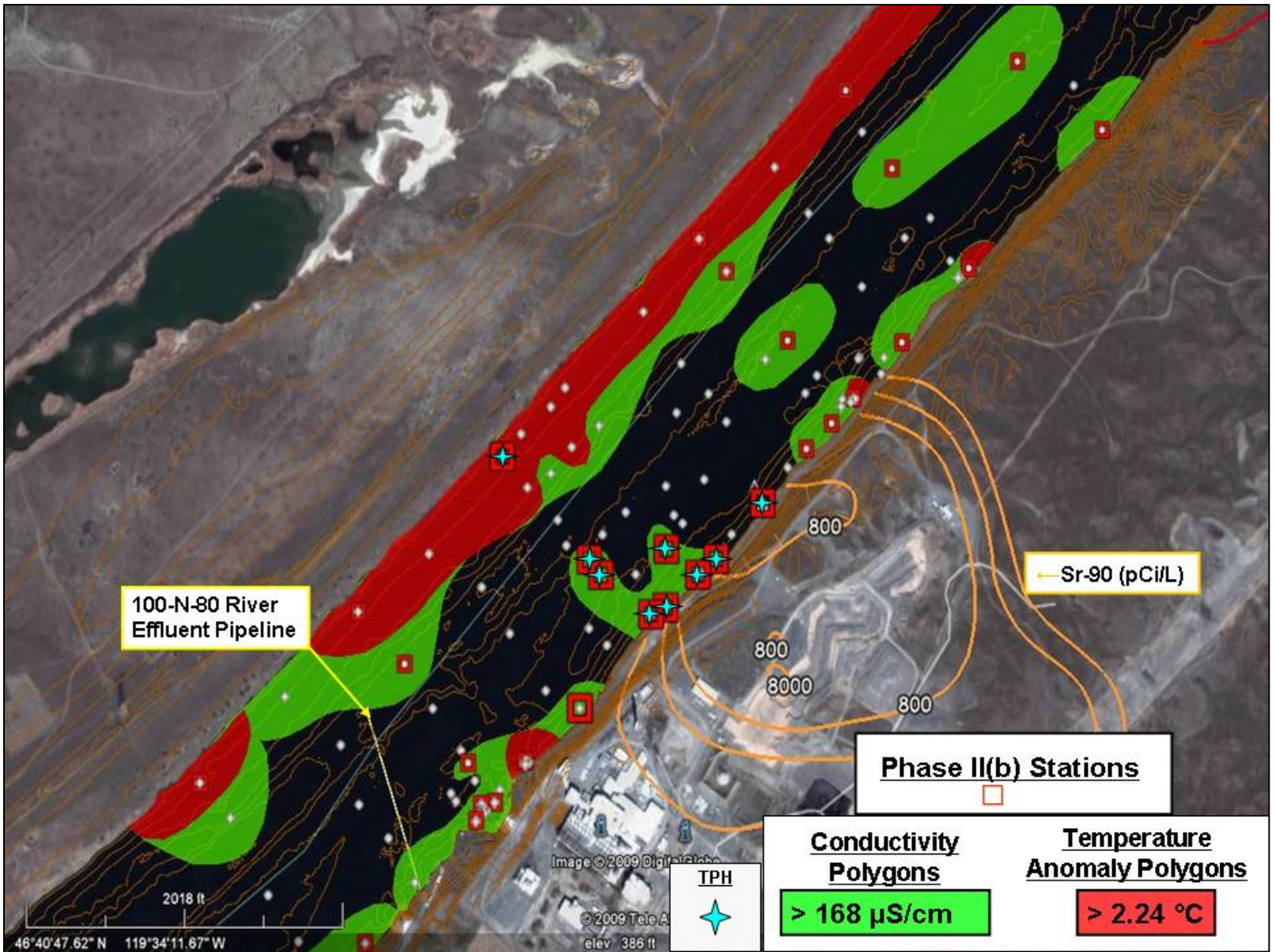
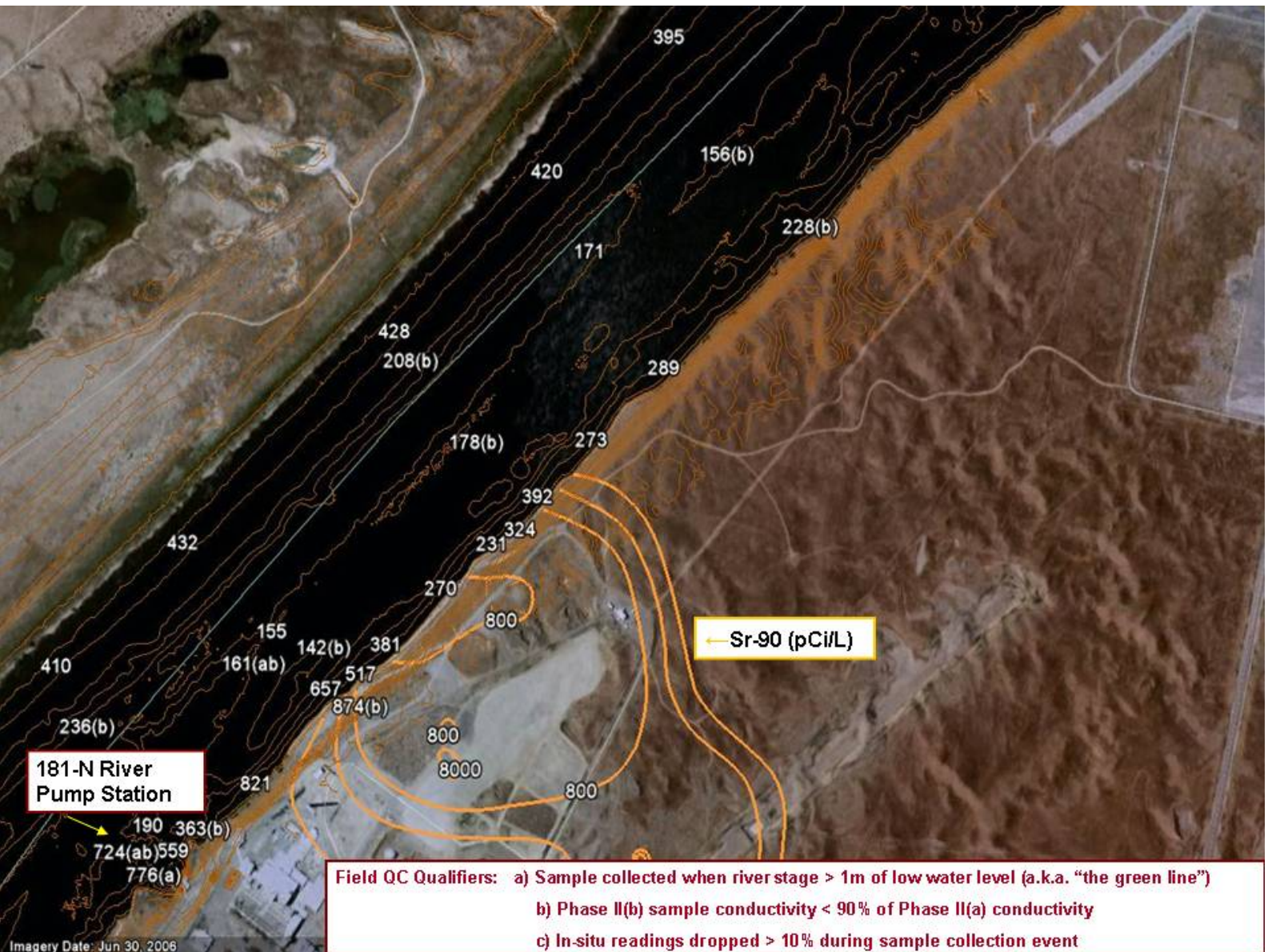


Figure 3-29. Pore Water Conductivity ( $\mu\text{S}/\text{cm}$ ) Measured During Phase II(b) Near the 100-N Area.



Five of 30 (17%) pore water strontium-90 sample results were reported above the average minimum detectable activity (MDA = 3.25 pCi/L) (Figure 3-29). All five of these sample results exceeded the 8 pCi/L drinking water standard and were collected near the right shoreline in shallow water less than approximately 1.5 m (5 ft) below the low water level (green line). Strontium-90 concentrations ranged from 10.7 to 72.3 pCi/L. Two of the five elevated strontium-90 results were collected from sample locations located upriver of the groundwater plume contours (Figure 3-30). One of these sample results (17.3 pCi/L) was located in front of a small outfall structure (Figure 3-29). It should be noted that the highest strontium-90 concentration (72.3 pCi/L) was measured at a station where field crews targeted a specific region of the riverbed where the Ringold geological formation appeared to interface with the upper Hanford formation and as such was assigned the station name "T100N5Ring" (Appendix G). None of the 10 locations measured for TPH in pore water were reported above the analytical detection limit in either the diesel or motor oil ranges. The minimum lab reporting limits were 100 and 300 ug/L, respectively.

**3.2.1.4 100-D Area.** Thirty sites were selected for pore water hexavalent chromium analysis in Phase II(b). Of these 30 sites, 3 were selected for additional analyses for anions, nitrate, and metals (ICP) (Figure 3-31). All samples were obtained during October 2009 when seasonal average river flows ranged between approximately 40 to 70 Kcfs (i.e., less than 0.9 m [3 ft] height). However, daily river levels fluctuations were approximately 60 Kcfs (approximately 60 Kcfs to 120 Kcfs) during this time and was noteworthy because the river cycles may have potentially affected the sample results by adding more bank-recharge surface water (Appendix G). None of the samples were collected when river levels exceeded 0.9 m (3 ft); however, 11 samples were taken when river levels were near the upper limits (>0.7 m [2.2 ft] above the low water mark). However, conductivity measured at all Phase II(b) sample locations were within 90% of the Phase II(a) values (see sites with both qualifiers a and b in Figures 3-32 and 3-33).

Conductivity measurements made at all of the Phase II(b) sample locations near 100-D Area indicated the presence of groundwater at all sample locations (Figures 3-32 and 3-33). Generally the lowest conductivity (i.e., weakest groundwater signals) was found near the center of the river. The highest conductivity measured was found immediately adjacent to the 100-D water intake structure (see 934  $\mu\text{S}/\text{cm}$  on Figure 3-32). Another high conductivity area was observed across the river (left bank) downstream of 100-D and at the base of the White Bluffs (Figure 3-33). These areas also showed a large temperature anomaly during Phase II(a) suggesting relatively high discharge rates. It should be noted that a groundwater signal (262  $\mu\text{S}/\text{cm}$ ) was also found in the deep channel of this section of the river at approximately 13.7 m (45 ft) deep (from the low-water level).

Fifteen of 30 (50%) pore water hexavalent chromium sample results were reported above the PQL of 3.7  $\mu\text{g}/\text{L}$  (Figure 3-34). Sample results ranged between 10 and 331  $\mu\text{g}/\text{L}$ . Eleven of 15 pore-water sample results > PQL equaled or exceeded an ambient water quality criteria of 10  $\mu\text{g}/\text{L}$ . The two highest hexavalent chromium pore water concentrations (112 and 331  $\mu\text{g}/\text{L}$ ) were collected in two separate regions in <0.9 m (3 ft) water depths below the low water mark. Two of three samples collected in front of the 100-D Area water intake structure just downriver from the 331  $\mu\text{g}/\text{L}$  station had exceptionally high conductivity values and exceptionally low ORP values. The second highest hexavalent chromium pore water concentration (112  $\mu\text{g}/\text{L}$ ) was located about 9.7 m (32 ft) off-shore of an area where the groundwater plume estimates show that hexavalent chromium concentrations of 100  $\mu\text{g}/\text{L}$  had been found in the wells (Figure 3-34).

Figure 3-30. Pore Water Strontium-90 (pCi/L) Levels Measured During Phase II(b) Near the 100-N Area.

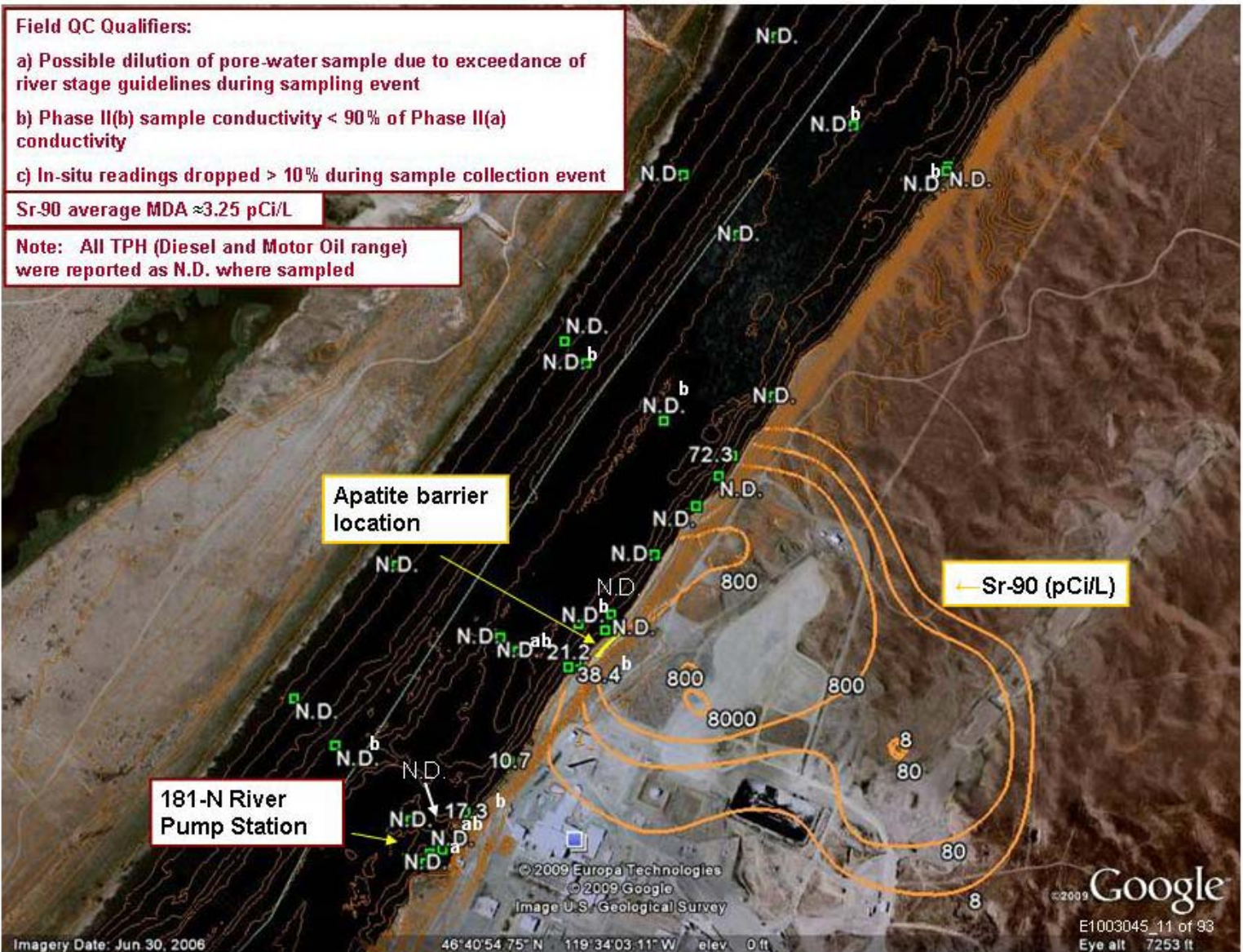


Figure 3-31. Phase II(b) Sample Locations Selected Near the 100-D Area.

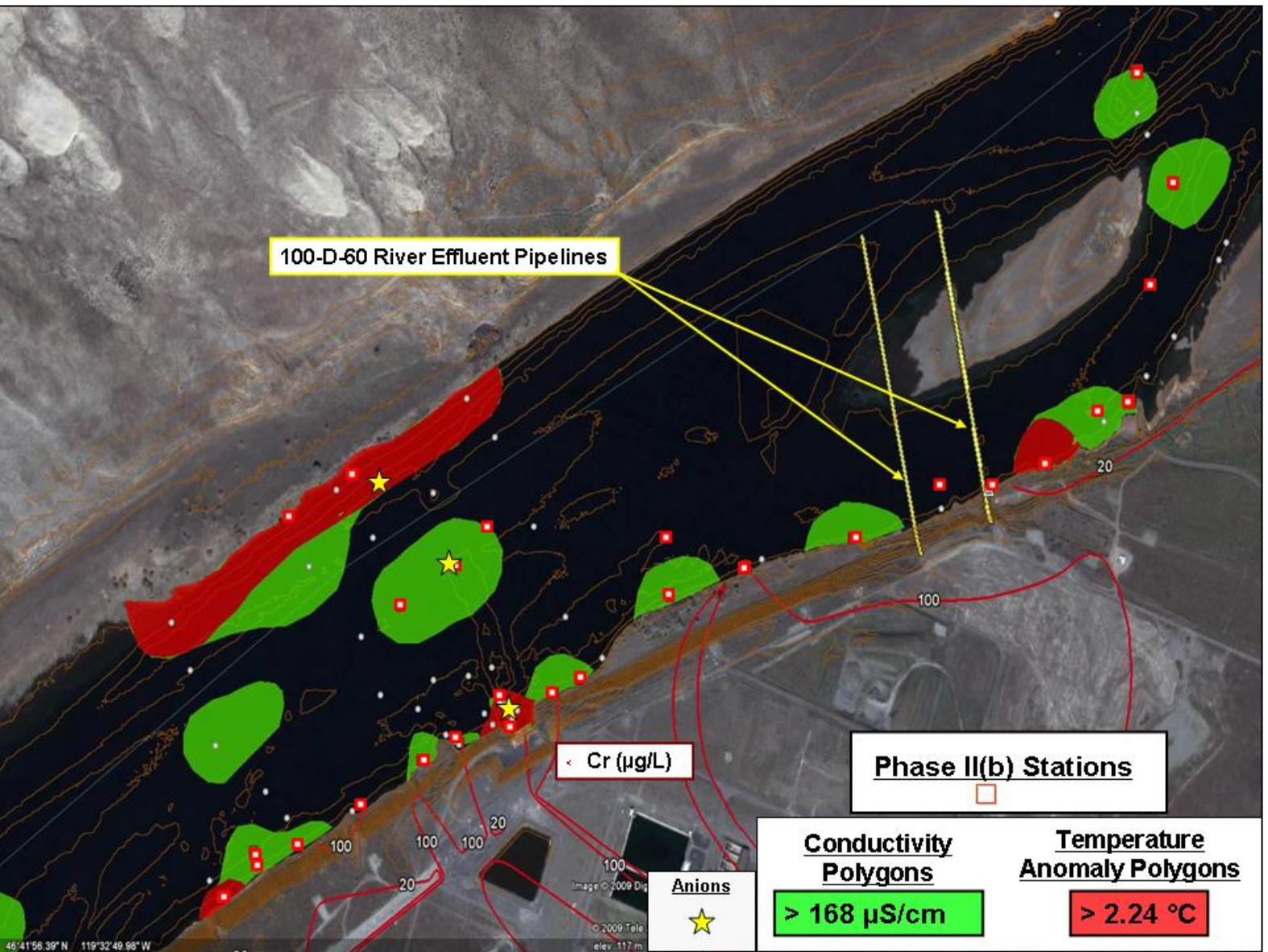




Figure 3-32. Pore Water Conductivity ( $\mu\text{S}/\text{cm}$ ) Measured During Phase II(b) Near the 100-D Area (Sheet 1 of 2).

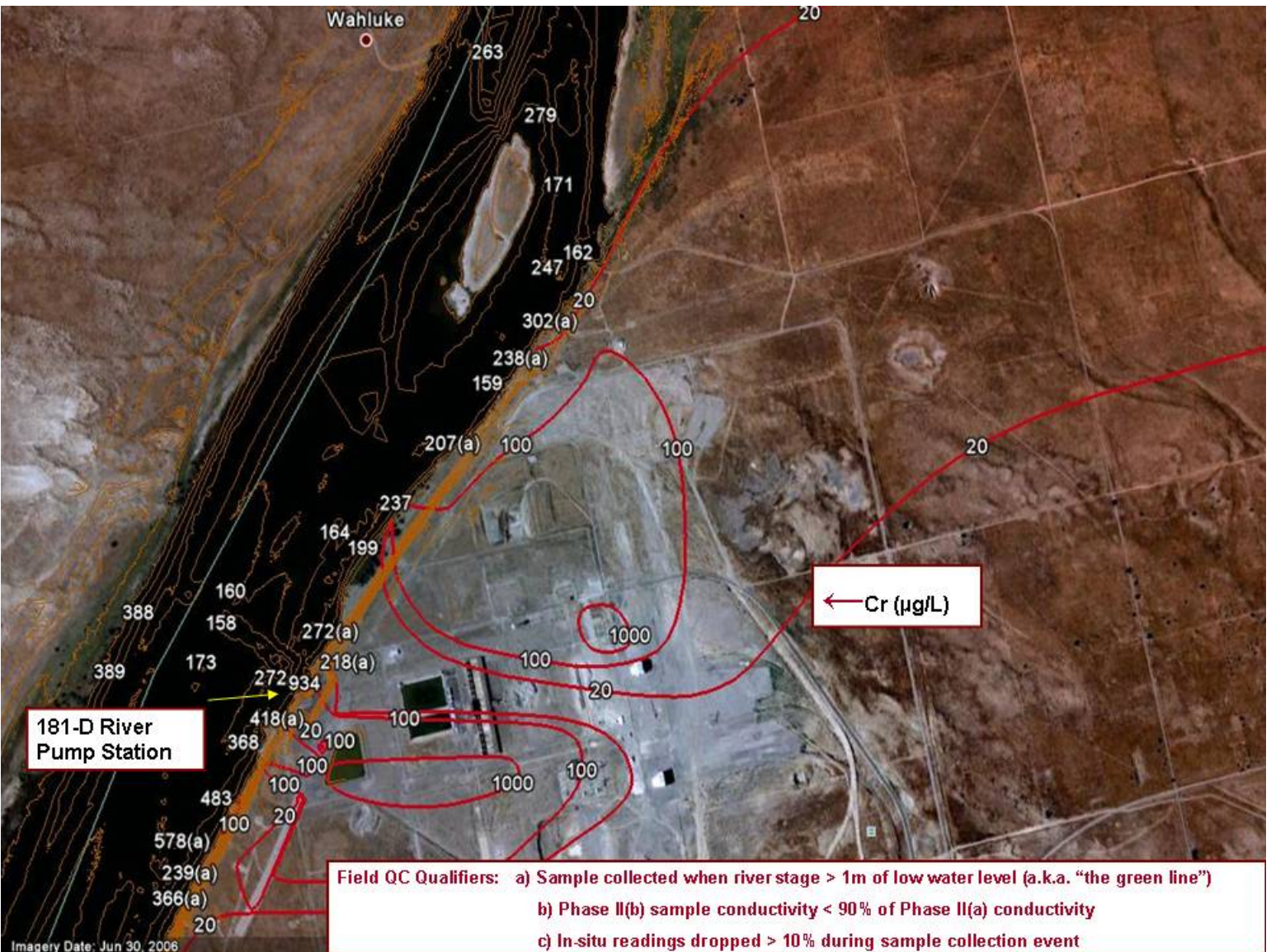


Figure 3-33. Pore Water Conductivity ( $\mu\text{S}/\text{cm}$ ) Measured During Phase II(b) Near the 100-D Area (Sheet 2 of 2).

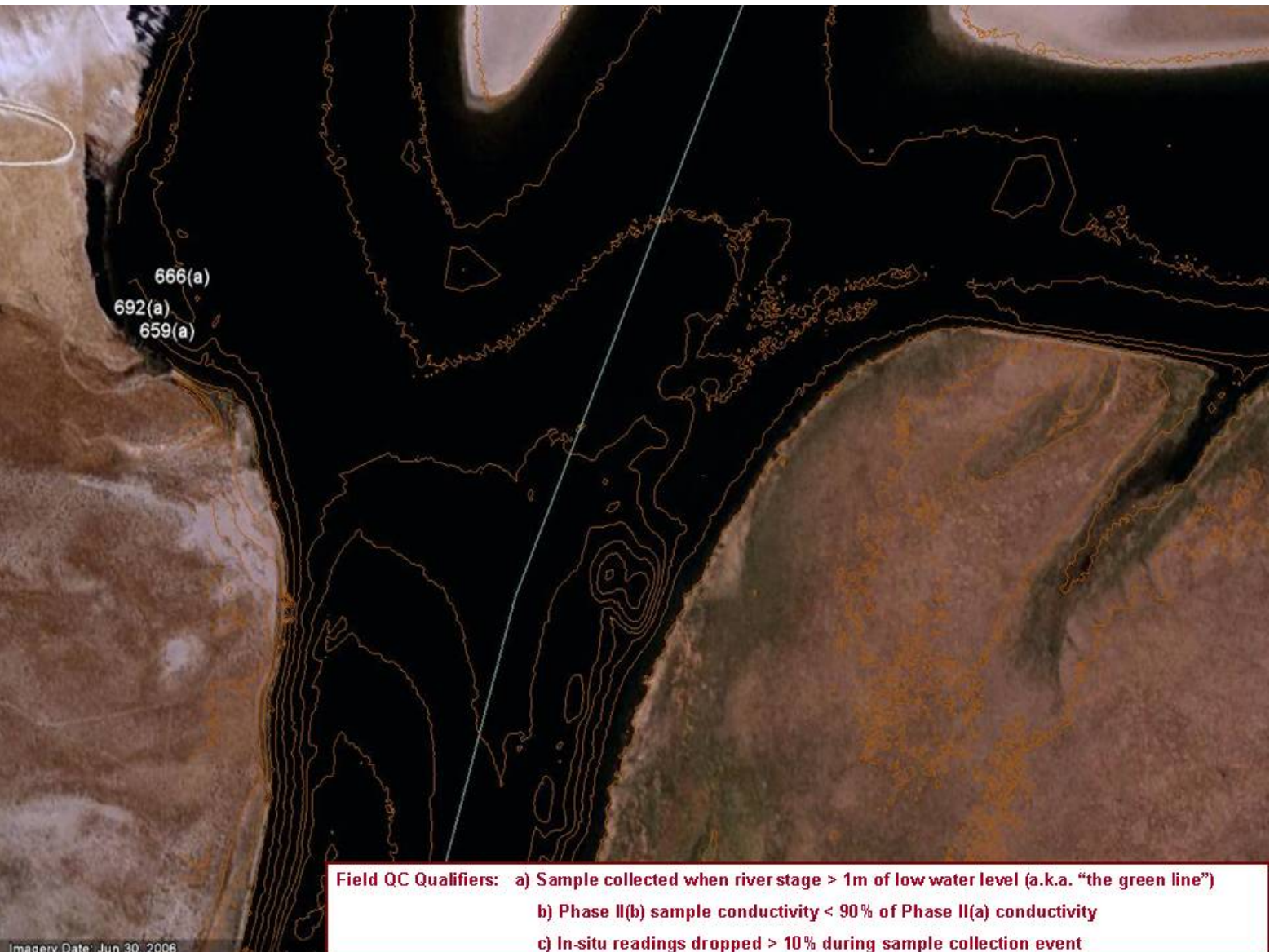
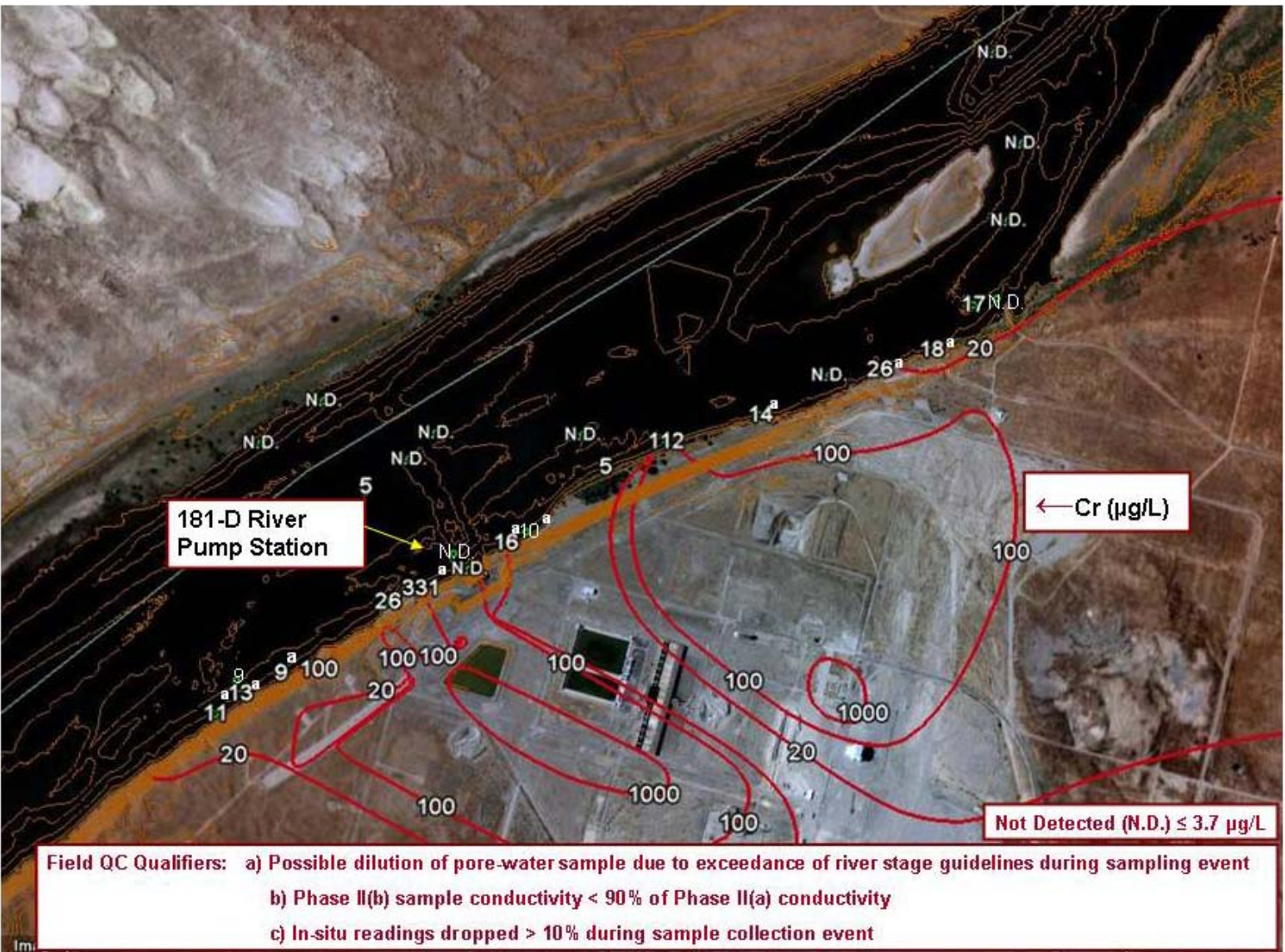


Figure 3-34. Pore Water Hexavalent Chromium ( $\mu\text{g/L}$ ) Levels Measured During Phase II(b) Near the 100-D Area.



One sample result (5 µg/L), just slightly above the PQL, was reported from the center of the river in an area where elevated groundwater upwelling patterns had been seen during both Phase II(a) and II(b) (Figure 3-34). No detectable levels of hexavalent chromium were reported from the samples along the left shoreline, despite the prominent groundwater upwelling.

Ion analysis was performed on one cross-river transect in the 100-D Area (Table 3-4). The purpose of the analysis was to provide an initial screening of groundwater signature to determine if the discharge zones on the Hanford side of the river had a similar signature to the discharge zones on the opposite shore which would suggest that groundwater from the Hanford side might potentially be discharging on both sides. Three sample locations were targeted including 100D3J5 on the opposite shore, J100D5 in mid-river, and station D-A on the Hanford side. The limited number of sample locations and the limited suite of ions that were analyzed precluded full development of piper diagrams; however an initial screening of the results was carried out by simply comparing the TDS normalized ion concentrations across the transect. The results are shown in Figure 3-35 for cations and Figure 3-36 for anions. Results indicate that station D-A on the Hanford side was distinctive from station 100D3J5 on the opposite shore. The opposite shore station generally had distinctively higher normalized concentrations of the cations sodium, magnesium, potassium and aluminum and the anions chloride, fluoride and nitrate. For example, the sodium to calcium ratio in the 100D3J5 sample was over 10 times higher than in the D-A sample on a meq/L basis). These initial screening results suggest that the discharge zones are controlled by distinctive sources on opposite sides of the river.

**3.2.1.5 100-H Area.** Thirty Phase II(b) sample locations were selected near the 100-H Area (Figure 3-37). One station included strontium analyses per input from the Tri-Parties. Phase II(b) sample locations near the 100-H Area were sampled between September, October, and early November. River flows encountered during the sampling events ranged between 40 Kcfs and 80 Kcfs, with daily fluctuations ranging up near 120 Kcfs. Daily fluctuation of nearly 60 Kcfs was noteworthy because the river cycles may have potentially affected the sample results by adding more surface water from bank-recharge (Appendix G). None of the samples were collected when river levels exceeded 0.9 m (3 ft); however, nine samples were taken when river levels were near the upper limits (>0.7 ft [2.3 ft] above the low water mark). Conductivity measured at five Phase II(b) sample locations were less than 90% of the Phase II(a) values. One station was sampled when the water was near the upper river stage boundary and did not attain 90% of the conductivity measured during Phase II(a) (see station with both qualifiers a and b in Figure 3-37).

**Table 3-4. Results from the Ion Analysis at Three Stations in the 100-D Area. (2 Pages)**

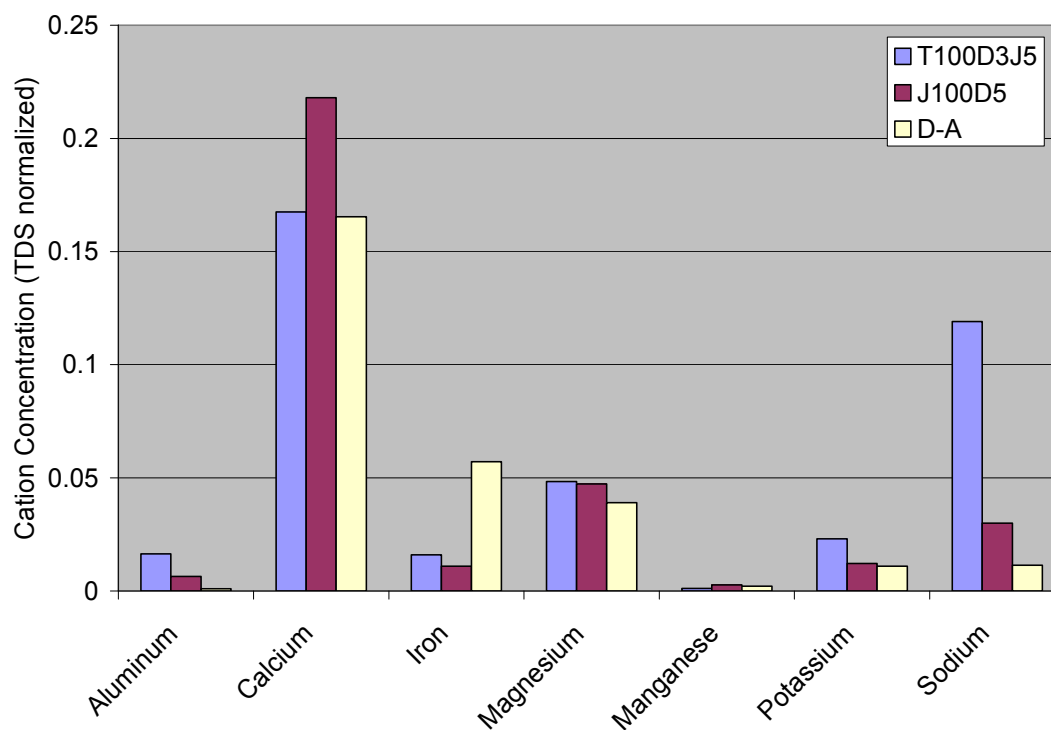
Station	T100D3J5		J100D5		J100D5		D-A	
Sample Number	J19369		J19C98		J19C99		J19370	
Location	Left Bank		Mid Channel		Mid Channel Duplicate		Right Bank	
Aluminum	4.4	NL	0.887		0.45		0.65	L
Antimony	0.0031	U	0.006	U	0.006	U	0.0031	U
Arsenic	0.0062	B	0.01	U	0.01	U	0.0066	B
Barium	0.00058	UM	0.048		0.0448		0.57	
Beryllium	0.00047	U	0.002	U	0.002	U	0.00047	U

**Table 3-4. Results from the Ion Analysis at Three Stations in the 100-D Area. (2 Pages)**

Station	T100D3J5		J100D5		J100D5		D-A	
Boron	0.024		0.0336		0.0874		0.06	
Cadmium	0.00045	U	0.000773	B	0.000778	B	0.00073	B
Calcium	45		22.7		22.6		110	
Chromium	0.0072		0.00244		0.0062		0.0014	B
Cobalt	0.0026	B	0.000832	B	0.000863	B	0.0015	B
Copper	0.013		0.0131		0.0143		0.003	B
Iron	4.3		1.23		1.05		38	
Lead	0.0098		0.0221		0.023		0.0026	U
Magnesium	13		4.96		4.87		26	
Manganese	0.3		0.286		0.286		1.4	
Nickel	0.0066	B	0.04	U	0.00496	B	0.0024	B
Potassium	6.2		1.3	B	1.23	B	7.3	
Selenium	0.0049	U	0.01	U	0.01	U	0.0049	U
Silver	0.00093	U	0.002	U	0.002	U	0.00093	U
Sodium	32	L	3.09		3.15		7.6	L
Vanadium	0.024		0.00366	B	0.00285	B	0.0027	B
Zinc	0.04		0.0385		0.0393		0.039	
Uranium	0.0077		0.2	U	0.2	U	0.00028	B
Bromide	0.11	U	0.25	U	0.25	U	0.11	U
Chloride	9.5		1.14		1.2		2.1	B
Fluoride	0.38	B	0.25	U	0.25	U	0.17	B
Nitrate as N	0.78		1.05		1.05		0.042	U
Nitrite as N	0.049	U	0.25	U	0.25	U	0.049	U
Phosphate as P, Ortho	0.19	U	0.25	U	0.25	U	0.19	U
Sulfate	34		10.5		10.1		0.51	B
Nitrate/nitrite as N			0.09		0.09			

- B = Organics: Method blank contamination. The associated method blank contains the target analyte at a reportable level  
 Inorganics: Estimated result. Result is less than the RL, but greater than the MCL  
 L = serial dilution of a digestate in the analytical batch indicates that physical and chemical interferences are present  
 M = Inorganics: sample duplicate precision not met  
 N = all (excepts GCMS): MS/MSD or LCS recovery is outside control limits  
 GC/MS Only: Presumptive evidence of compound based on mass spectral library search (TIC)  
 U = nondetect

**Figure 3-35. TDS-Normalized Cation Distribution in Samples Collected at Three Sample Locations in the 100-D Area.**



**Figure 3-36. TDS-Normalized Anions Distribution in Samples Collected at Three Sample Locations in the 100-D Area.**

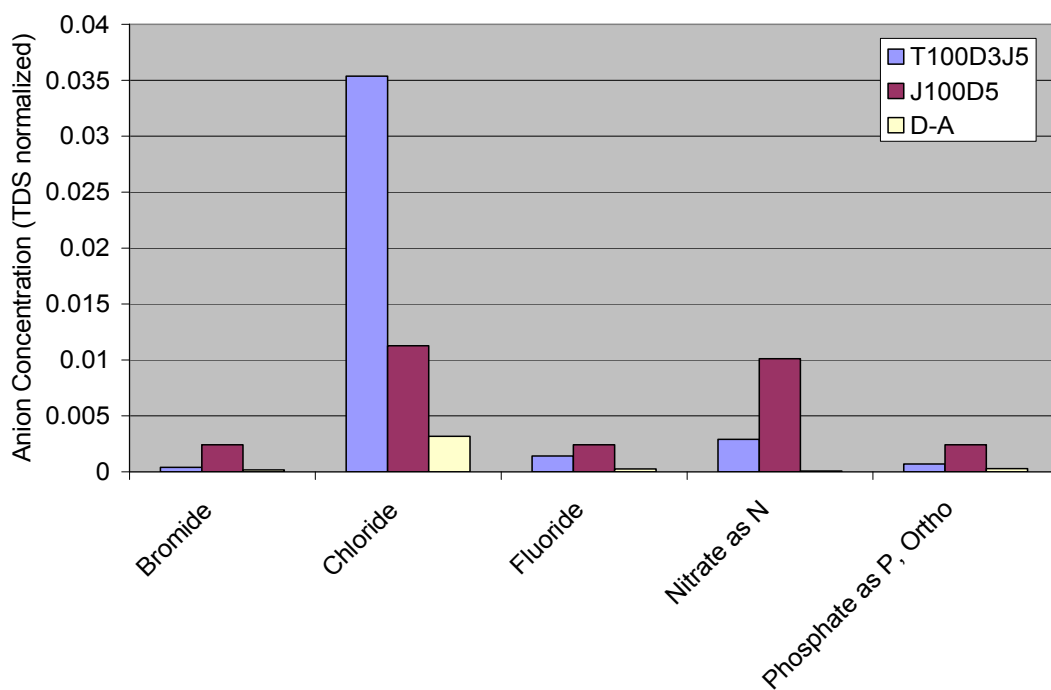
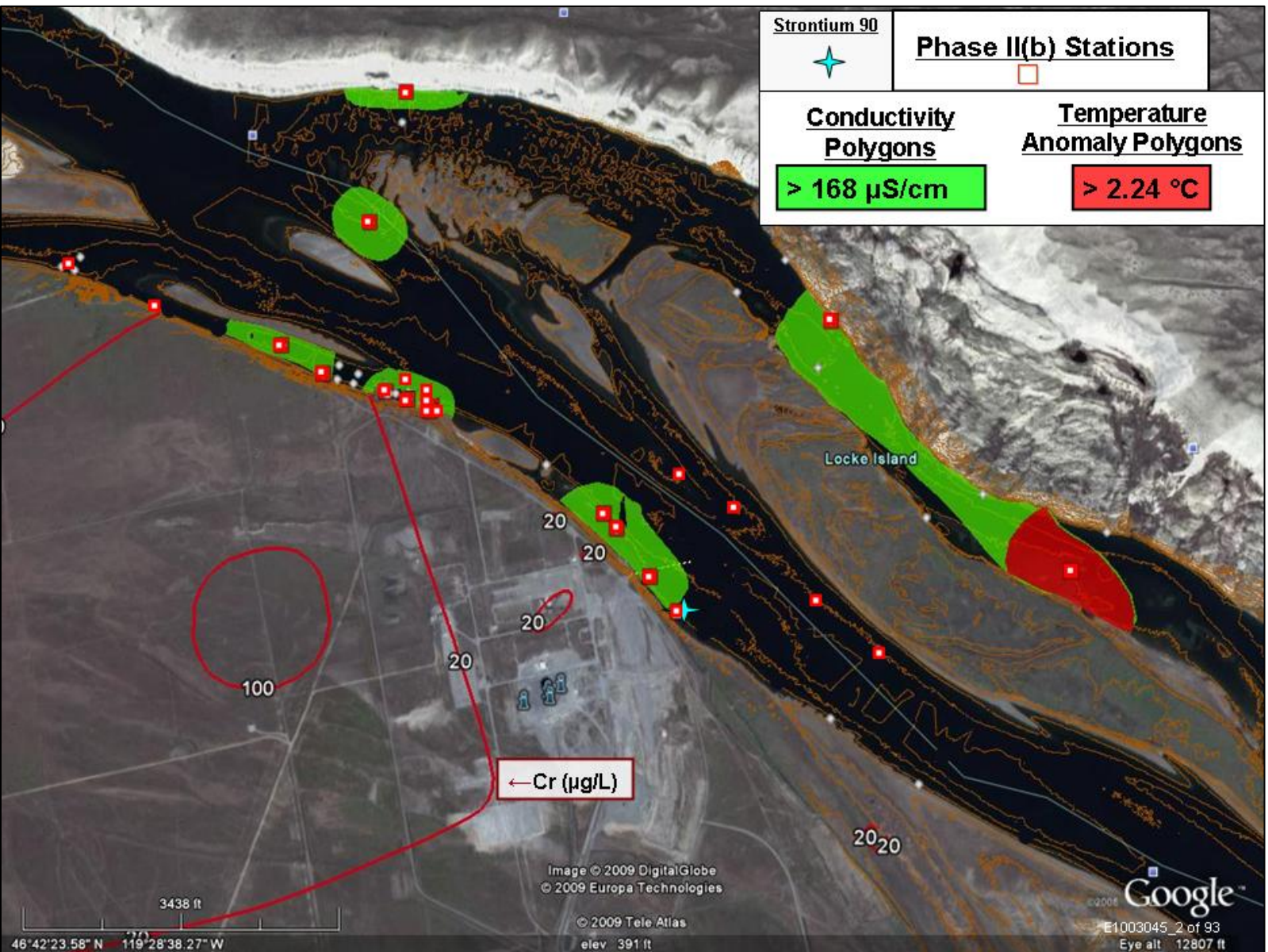


Figure 3-37. Phase II(b) Sample Locations Selected Near the 100-H Area.



Pore water conductivity measured during Phase II(b) near 100-H showed the presence of groundwater at all 30 sample locations (Figures 3-38 and 3-39). Pore water conductivity values ranged from 154  $\mu\text{S}/\text{cm}$  up to 1,230  $\mu\text{S}/\text{cm}$ . The third highest conductivity (950  $\mu\text{S}/\text{cm}$ ) was measured approximately 50.2 m (165 ft) off-shore in an area about 4.6 m (15 ft) deep near 100-H that may have been used as the 100-H water intake system, though no structure exists there today. The highest conductivity (1,230  $\mu\text{S}/\text{cm}$ ) was measured along the left shorelines where the agricultural run-off has been causing bank erosion for several years (Figure 3-38 and 3-39). Groundwater upwelling were observed during Phase II(a) and II(b) near the center of the river. Groundwater upwelling was notable in the White Bluffs town site slough as well, including the second highest conductivity in the 100-H Area (1137  $\mu\text{S}/\text{cm}$ ; Figure 3-39).

Seventeen of 30 (57%) pore water hexavalent chromium sample results were reported above PQL of 3.7  $\mu\text{g}/\text{L}$  (Figures 3-40 and 3-41). Some hexavalent chromium concentrations were found mid channel and near the opposite shoreline (left bank), where an old river channel was located. Fifteen of 17 pore-water sample results > PQL exceed ambient water quality criteria (10  $\mu\text{g}/\text{L}$ ) (results ranged between 12 and 46  $\mu\text{g}/\text{L}$ ). Three locations downriver near the White Bluffs town site boat launch had detections (31, 31a, 46  $\mu\text{g}/\text{L}$ ) (Figure 3-41).

One station measured for strontium-90 reported a value of 6.78 pCi/L, which was comparable to the predicted groundwater plume concentration (8 pCi/L) in that area.

**3.2.1.6 100-F Area.** Although 21 station were planned, only 19 sample locations were successfully sampled for hexavalent chromium analysis in Phase II(b) near 100-F (Figure 3-42). Two sample locations (J100F17 and J100F19) were attempted, but crews were unable to safely anchor in unstable river flow conditions (both are located in mid channel positions). The first sample in the 100-F slough area was collected during late July 2009 when high flows (approximately 100 Kcfs) allowed crews to float a pontoon equipped with the Trident-probe into the back-water regions of the slough. The remaining 18 sample locations were sampled during November 2009 when river flows ranged between 60 Kcfs and 80 Kcfs, but daily river level fluctuations ranged as high as approximately 160 Kcfs, which is nearly 1.9 m (6 ft) change in the water levels. Daily fluctuation of nearly 60 Kcfs was noteworthy because the river cycles may have potentially affected the sample results by adding more surface water from bank-recharge (Appendix G). None of the samples were collected when river levels exceeded 0.9 m (3 ft); however, one sample was taken when river levels were near the upper limits (>0.7 m [2.3 ft] above the low water mark). Three samples were taken when conductivity was less than 90% of the Phase II(a) values (see sample locations with qualifiers a or b in Figure 3-43).

Groundwater upwelling were most prominent along the left shoreline and marginally present immediately in front of the 100-F Area. A relatively strong groundwater upwelling was found in the 100-F slough (693  $\mu\text{S}/\text{cm}$ ). The two highest conductivity values (972 and 1,038  $\mu\text{S}/\text{cm}$ ) were measured along the left shoreline and corresponded to prominent agricultural run-off areas (Figure 3-43). One station was located in a known salmon spawning redd area and was the only station that did not indicate the presence of groundwater upwelling (140  $\mu\text{S}/\text{cm}$ ).

Only 1 of 19 pore-water sample hexavalent chromium results was reported above the PQL of 3.7  $\mu\text{g}/\text{L}$  (Figure 3-44). The value reported was 8  $\mu\text{g}/\text{L}$  (less than the ambient water quality criteria [10  $\mu\text{g}/\text{L}$ ]). A field duplicate sample taken at this same location had a "U" reported.



Figure 3-38. Pore Water Conductivity ( $\mu\text{S}/\text{cm}$ ) Measured During Phase II(b) Near the 100-H Area (Sheet 1 of 2).

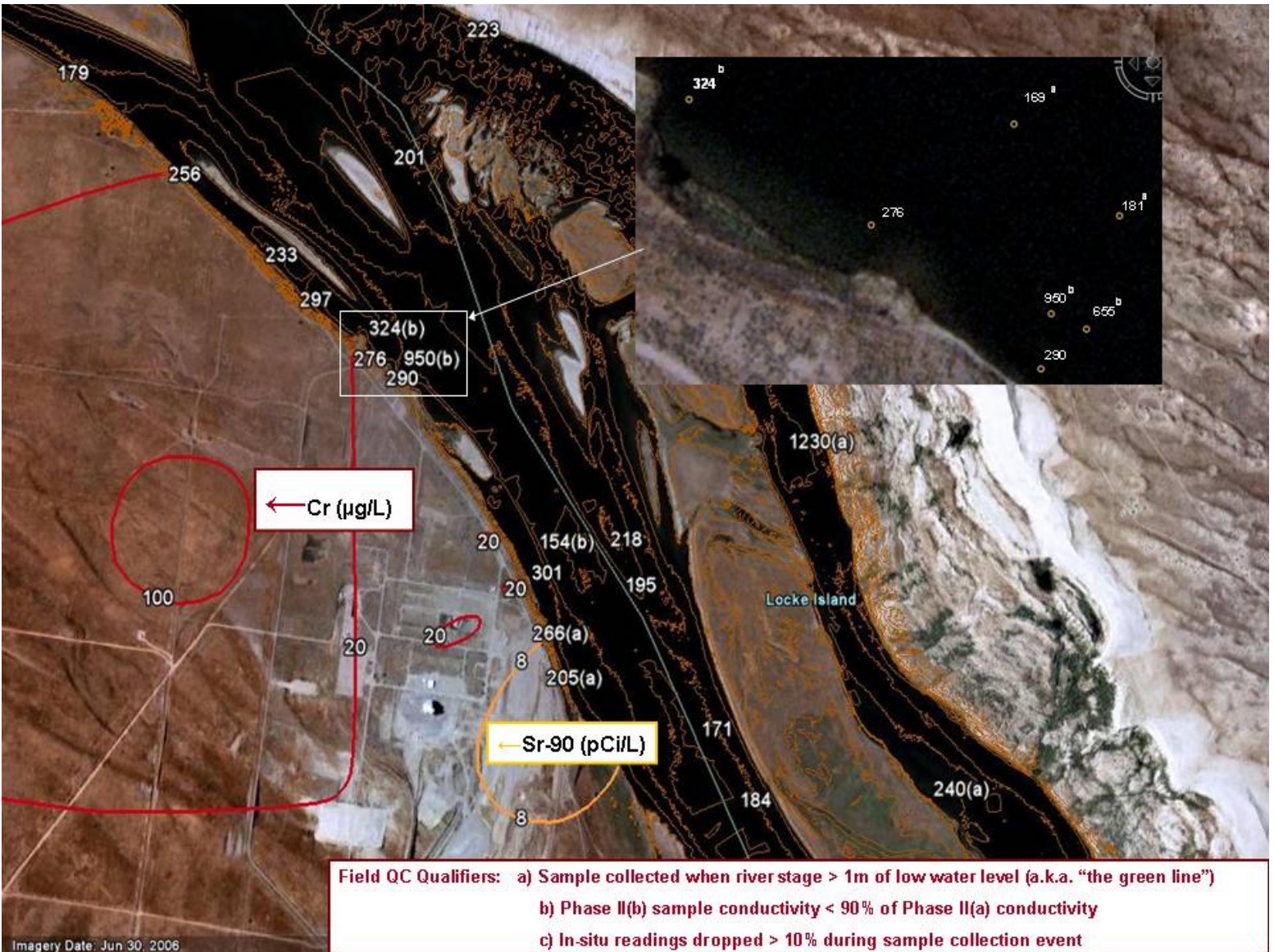


Figure 3-39. Pore Water Conductivity ( $\mu\text{S}/\text{cm}$ ) Measured During Phase II(b) Near the 100-H Area (Sheet 2 of 2).

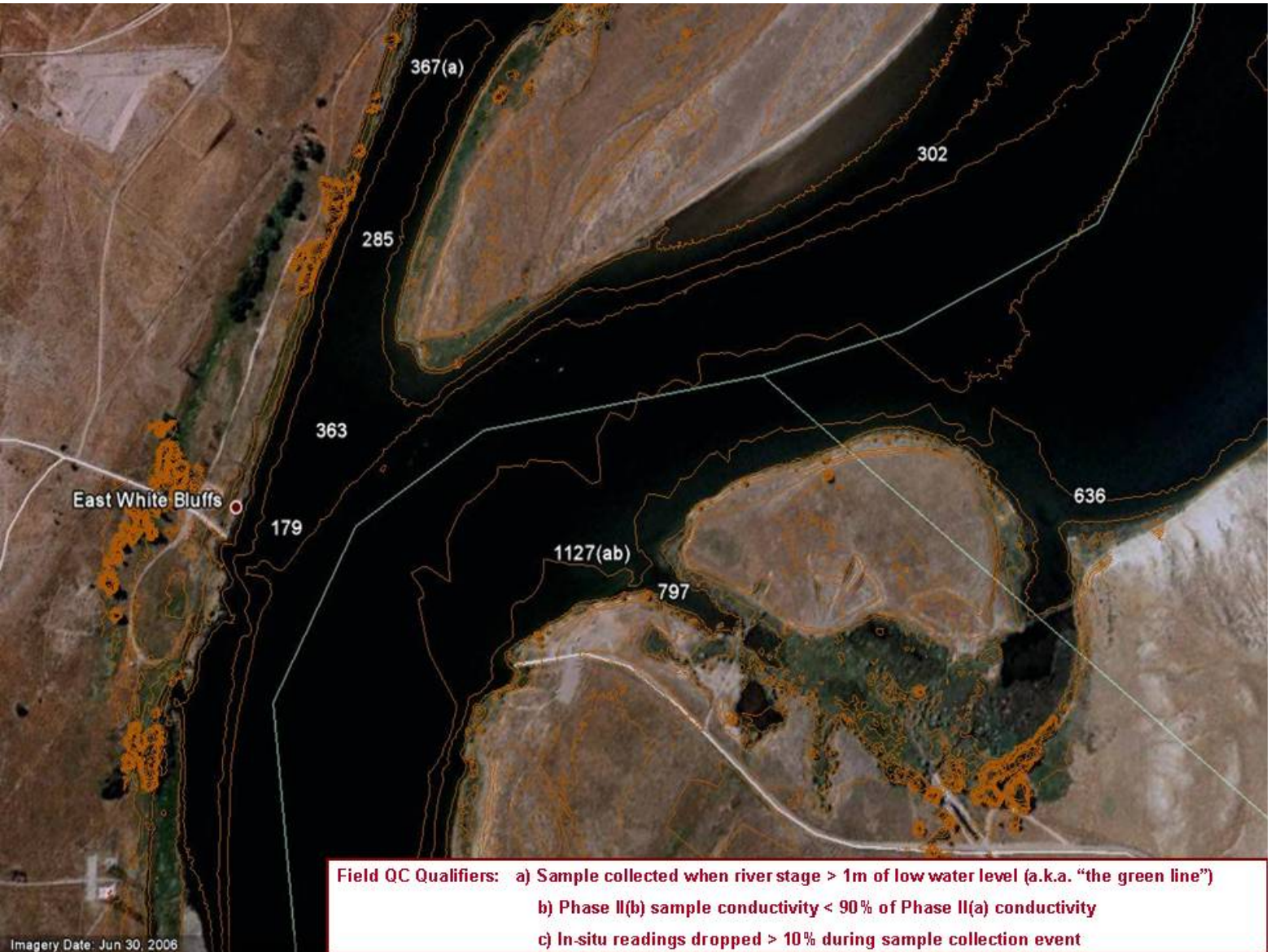


Figure 3-40. Pore Water Hexavalent Chromium ( $\mu\text{g/L}$ ) Levels Measured During Phase II(b) Near the 100-H Area (Sheet 1 of 2).

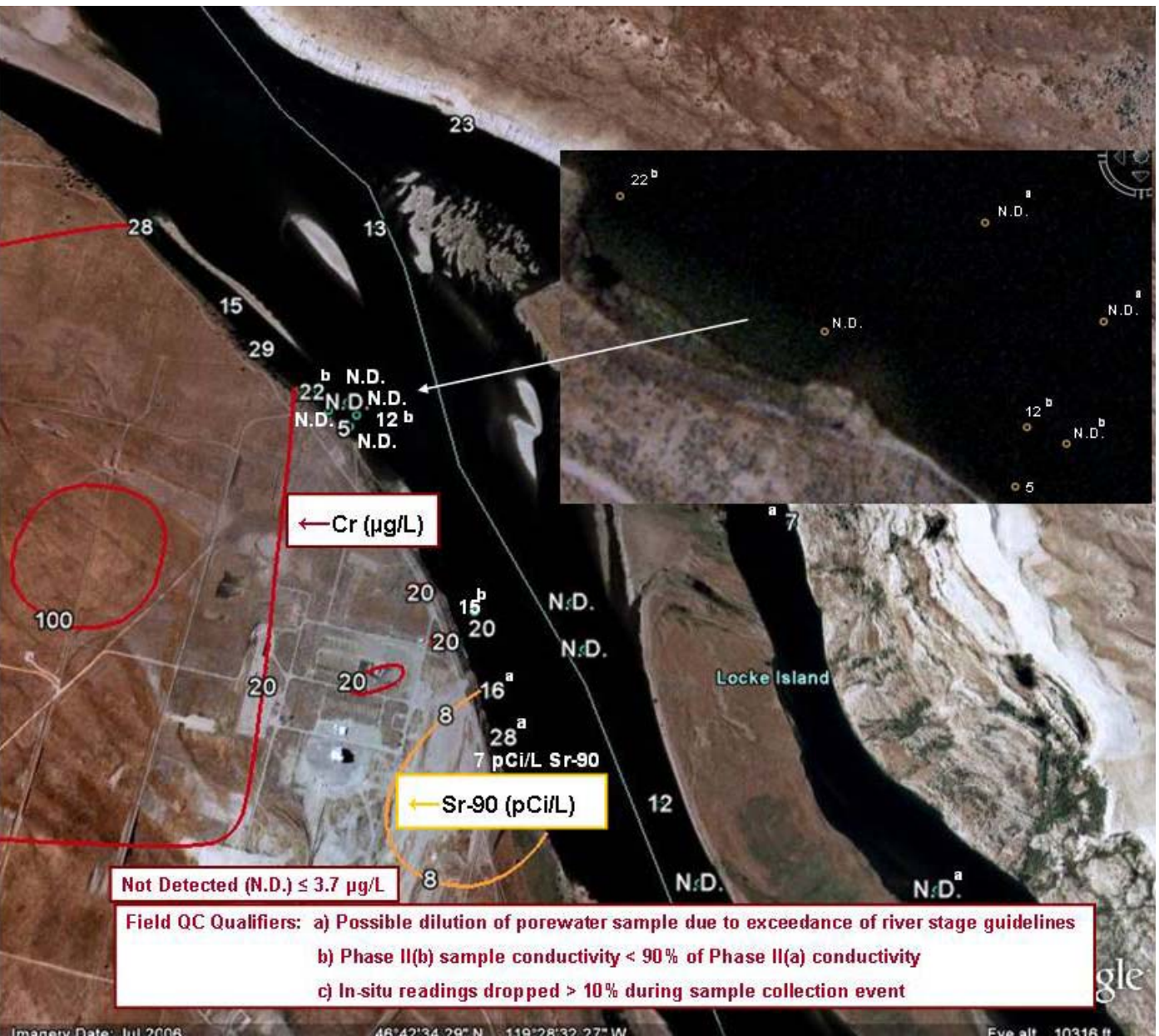


Figure 3-41. Pore Water Hexavalent Chromium ( $\mu\text{g/L}$ ) Levels Measured During Phase II(b) Near the 100-H Area (Sheet 2 of 2).



Figure 3-42. Phase II(b) Sample Locations Selected Near the 100-F Area.

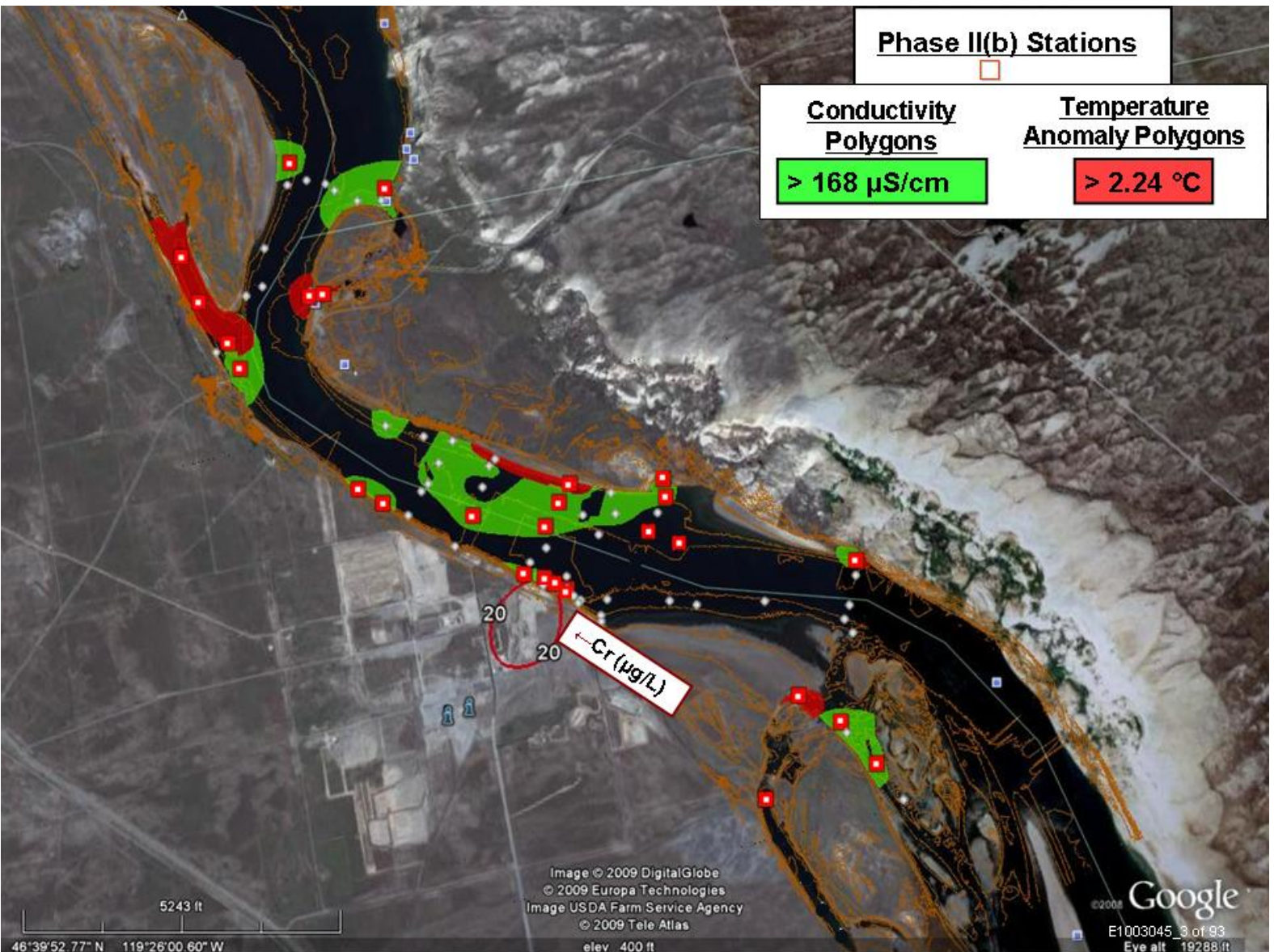


Figure 3-43. Pore Water Conductivity ( $\mu\text{S}/\text{cm}$ ) Measured During Phase II(b) Near the 100-F Area.

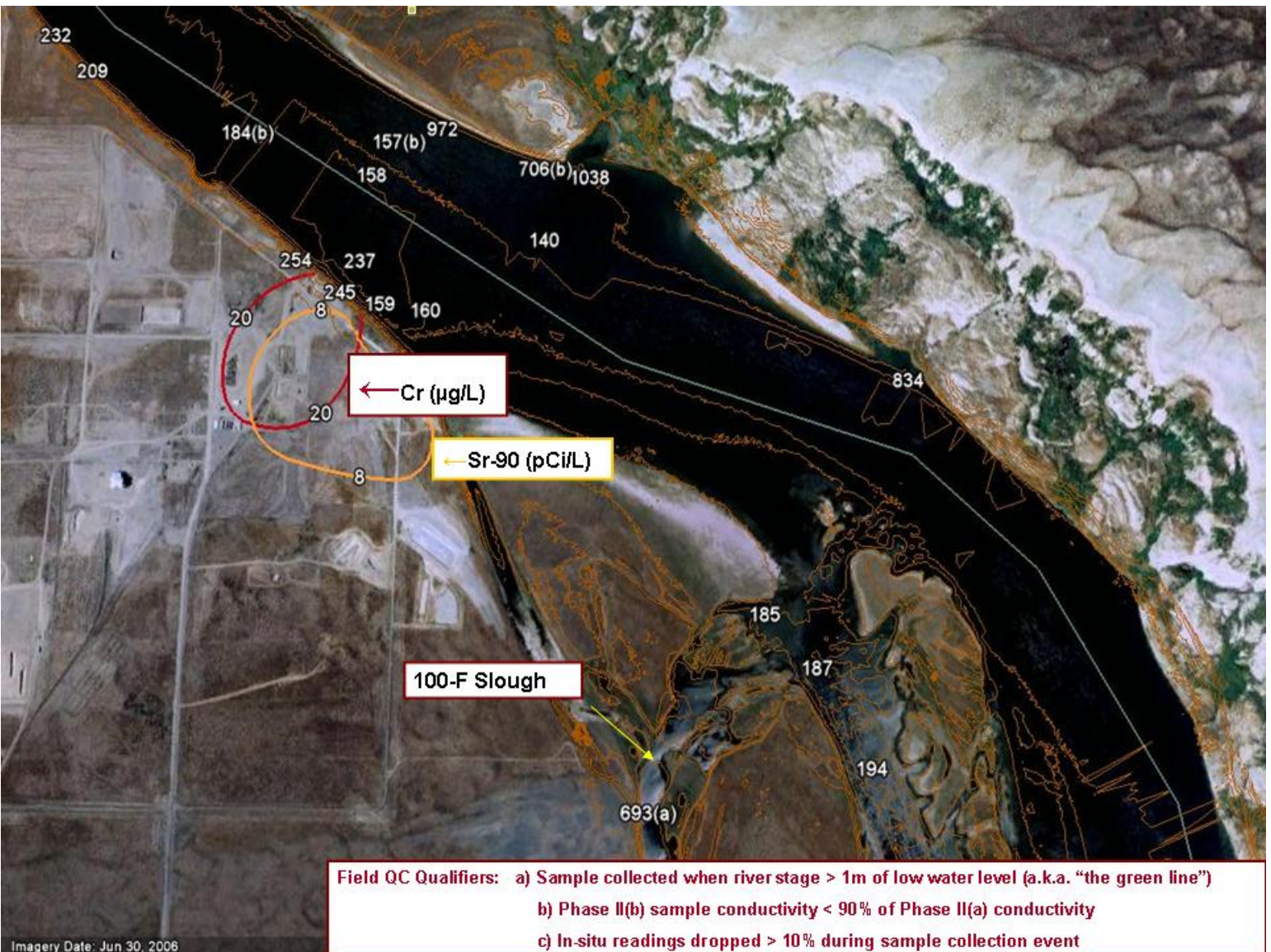
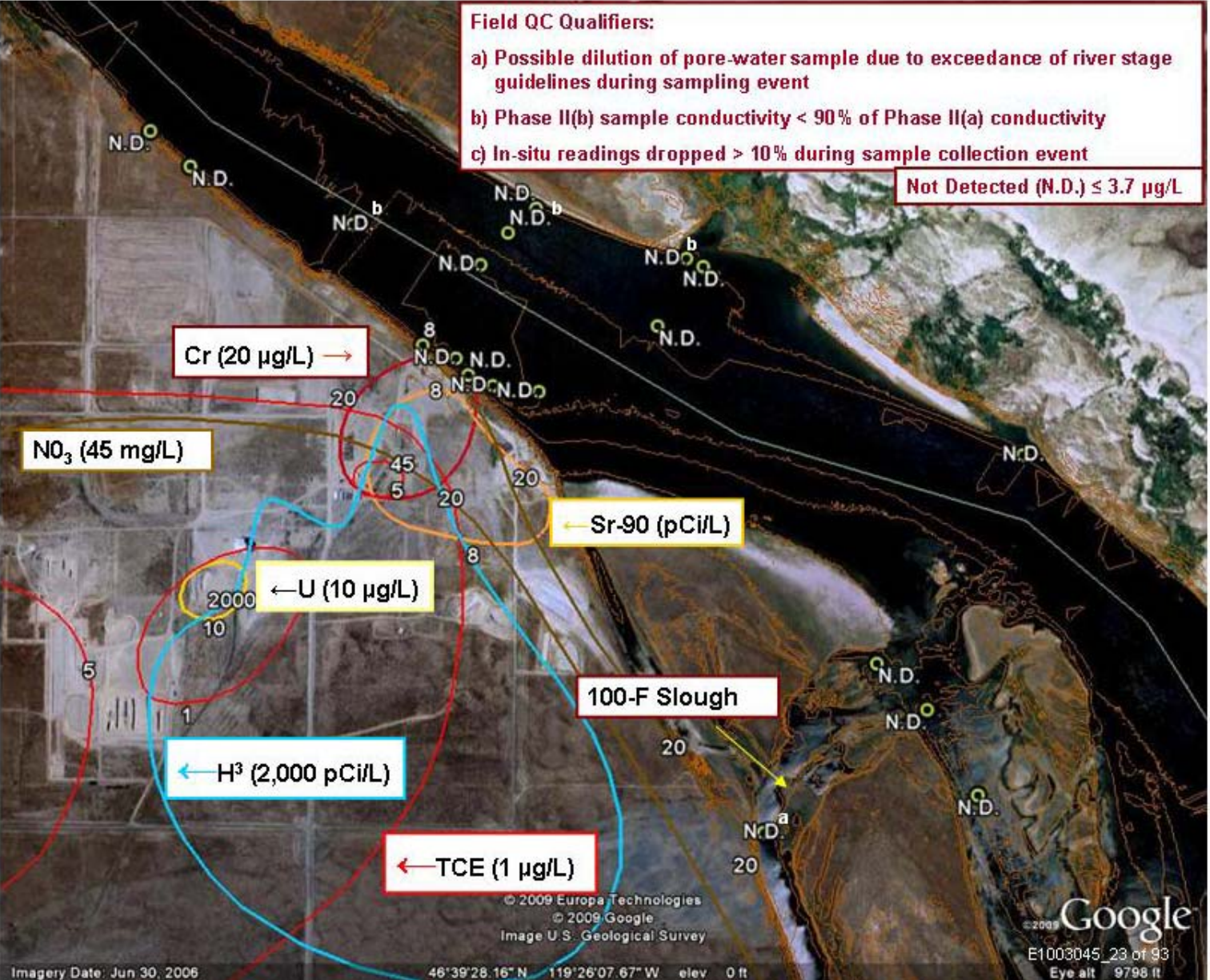


Figure 3-44. Pore Water Hexavalent Chromium ( $\mu\text{g/L}$ ) Levels Measured During Phase II(b) Near the 100-F Area.



**3.2.1.7 Hanford Townsite Area.** Twenty-nine of 31 sample locations were sampled for tritium analysis during Phase II(b) (Figure 3-45). Two sample locations (JHTS13 and JHTS46) were attempted, but crews were unable to safely anchor in unstable river flow conditions (both sample locations were located in mid channel positions).

Phase II(b) samples near the Hanford townsite were collected in November through December 2009 and early January 2010 under a wide range of river levels. Twenty-four of the 29 sample locations were sampled when relatively high river stages may have been suppressing the groundwater signals. Twenty-three of the 29 sample locations were sampled when river levels ranged between 0.9 and 3 m (3 and 10 ft) above the low-water mark (river flows approximately 120 Kcfs to 140 Kcfs). Further, 6 of those 24 sample locations were sampled when pore water conductivity was less than 90% of the conductivity value measured there during Phase II(a) (see qualifiers a and b in Figures 3-46 through 3-49; also see Appendix G). The Phase II(b) data obtained near the Hanford townsite area are thus qualified to denote limited comparability of the indicator contaminant results within this Phase and to other datasets obtained during Phase III within this area.

All Phase II(b) sample locations indicated the presence of groundwater in the pore-water samples near the Hanford townsite, though the maximum value (726  $\mu\text{S}/\text{cm}$ ) was not as high as maximum values obtained from the other study areas (Figures 3-46 through 3-49). Groundwater upwelling were detected off-shore in waters as deep as approximately 11 m (36 ft). Pore water conductivity indicated the presence of groundwater beginning at the Hanford town site slough (Figure 3-46) and down to near Energy Northwest (Figure 3-49). The maximum conductivity (642  $\mu\text{S}/\text{cm}$ ) along the right shore (Hanford Site side of the river) was located in an area historically monitored due to the presence of elevated tritium found in the shoreline springs (Figure 3-46).

Seven of 29 (24%) pore water tritium sample results were reported above the average minimum detectable activity (MDA = 310 pCi/L) (Figures 3-50 through 3-53). Two of these exceed the 20,000 pCi/L EPA drinking water standard (Figure 3-51; PNNL 18427). Values of the seven reported above the MDA ranged from 675 to 64,600 pCi/L. The two highest reported values (31,500 and 64,600 pCi/L) were found near an aquifer tube, which was reported to have had 35,000 pCi/L in recent years (Figure 3-51). Of the seven results with detectable tritium, four samples were collected in less than 1.8 m (6 ft) of water and three were collected further offshore (Appendix G).

**3.2.1.8 300 Area.** Thirty-four sample locations were sampled for total uranium during Phase II(b) near the 300 Area. Out of these 30 sample locations, 11 were sampled for volatile organic compounds (VOC) (Figure 3-54). Phase II(b) sampling near the 300 Area started in late August and continued through September 2009. River conditions encountered were near optimum, with flows less than 80 Kcfs and river levels less than 0.9 m (3 ft) above the low-water level.



Figure 3-45. Phase II(b) Sample Locations Selected Near the Hanford Townsite Area.

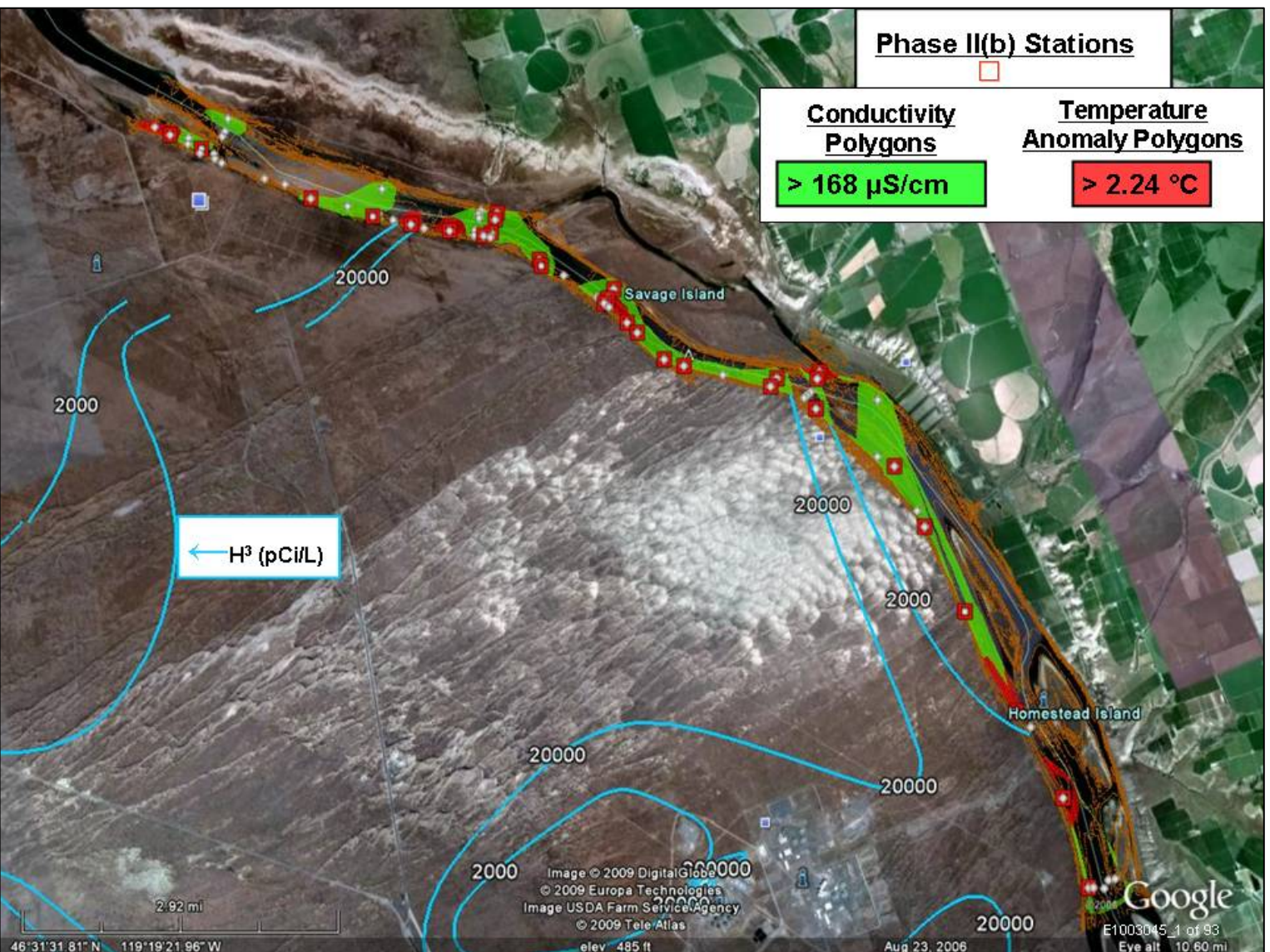


Figure 3-46. Pore Water Conductivity ( $\mu\text{S}/\text{cm}$ ) Measured During Phase II(b) Near the Hanford Townsite Area (Sheet 1 of 4).

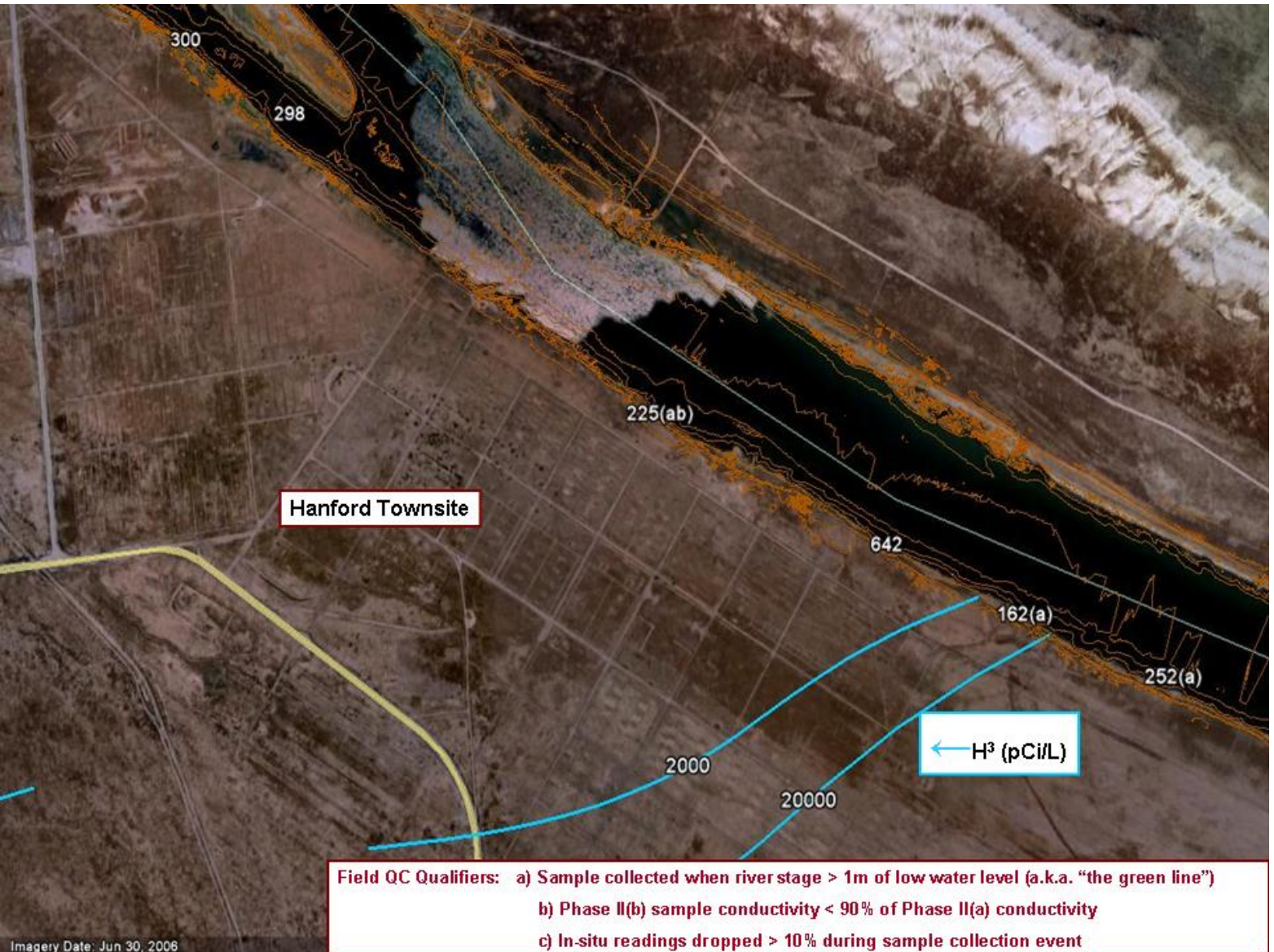


Figure 3-47. Pore Water Conductivity ( $\mu\text{S}/\text{cm}$ ) Measured During Phase II(b) Near the Hanford Townsite Area (Sheet 2 of 4).

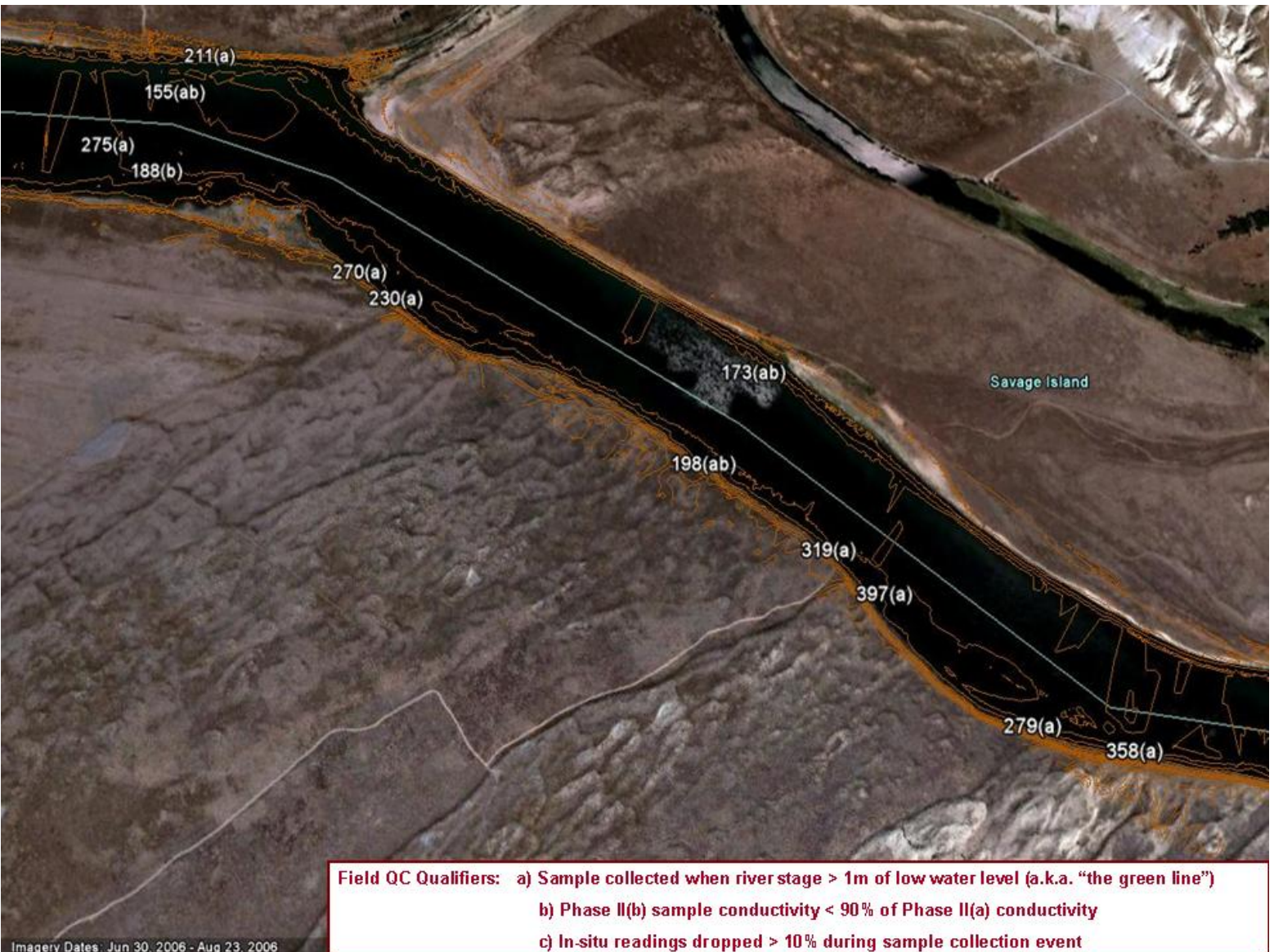


Figure 3-48. Pore Water Conductivity ( $\mu\text{S}/\text{cm}$ ) Measured During Phase II(b) Near the Hanford Townsite Area (Sheet 3 of 4).

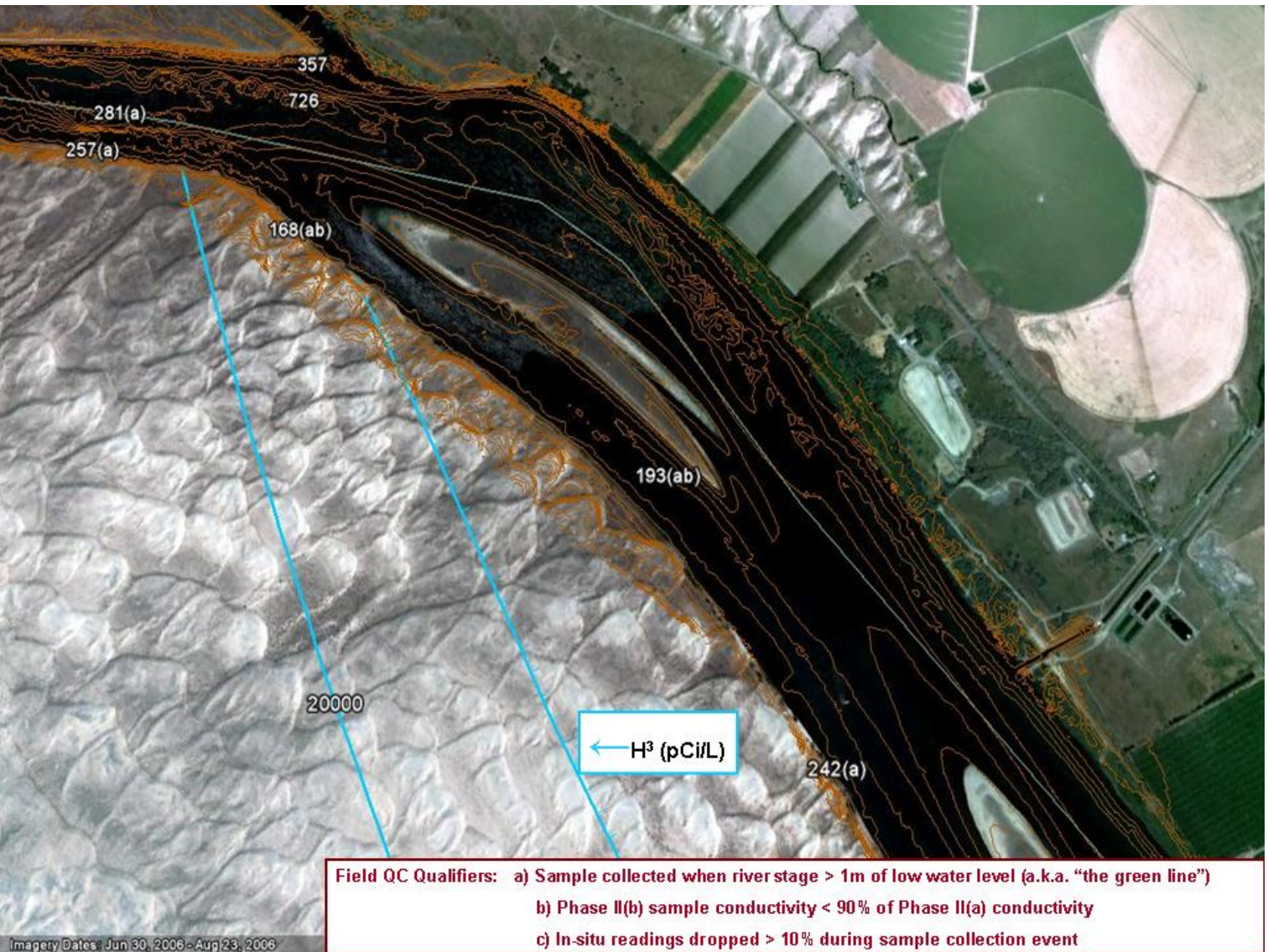


Figure 3-49. Pore Water Conductivity ( $\mu\text{S}/\text{cm}$ ) Measured During Phase II(b) Near the Hanford Townsite Area (Sheet 4 of 4).

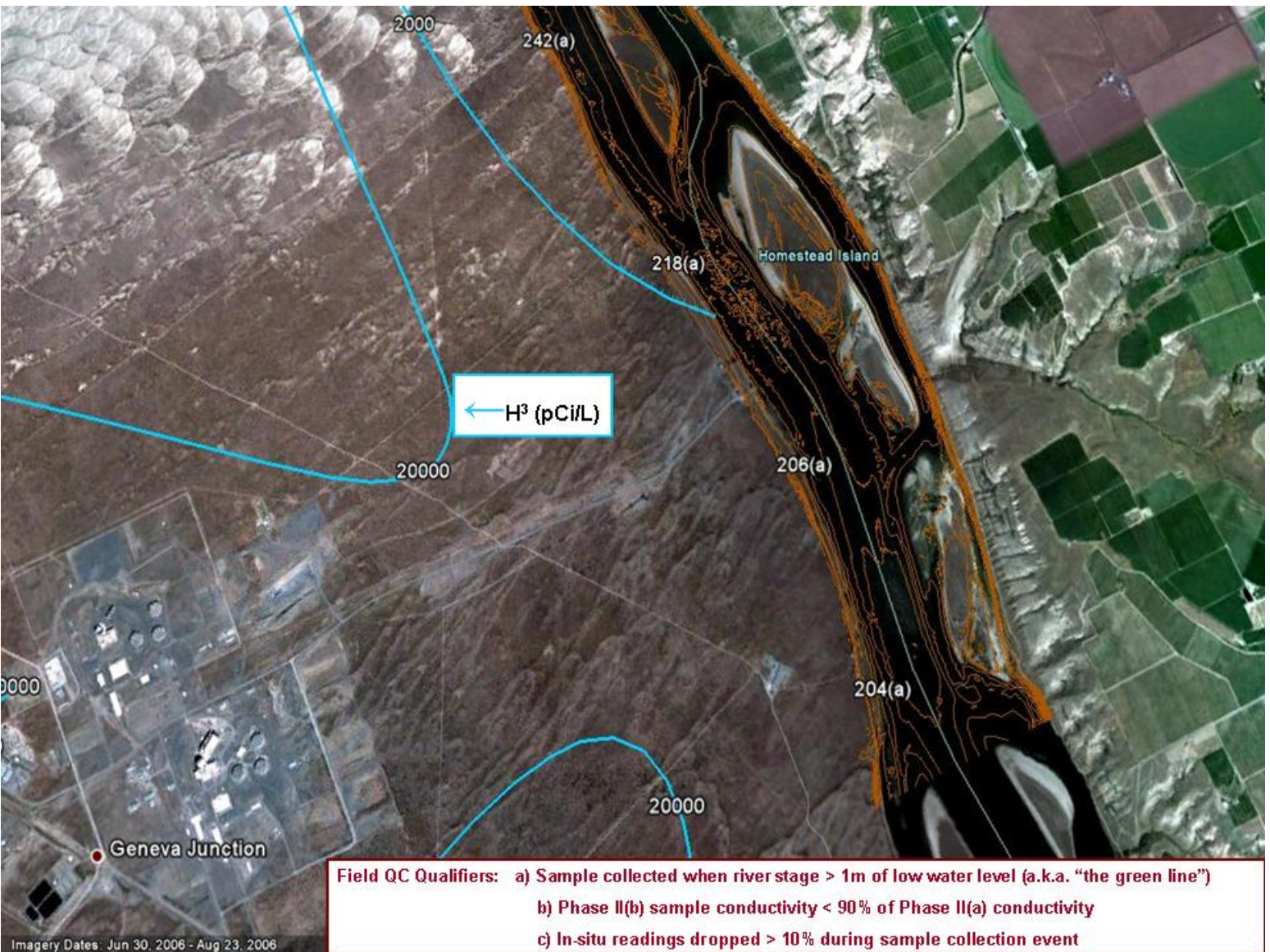


Figure 3-50. Pore Water Tritium (pCi/L) levels Measured During Phase II(b) Near the Hanford Townsite Area (Sheet 1 of 4).

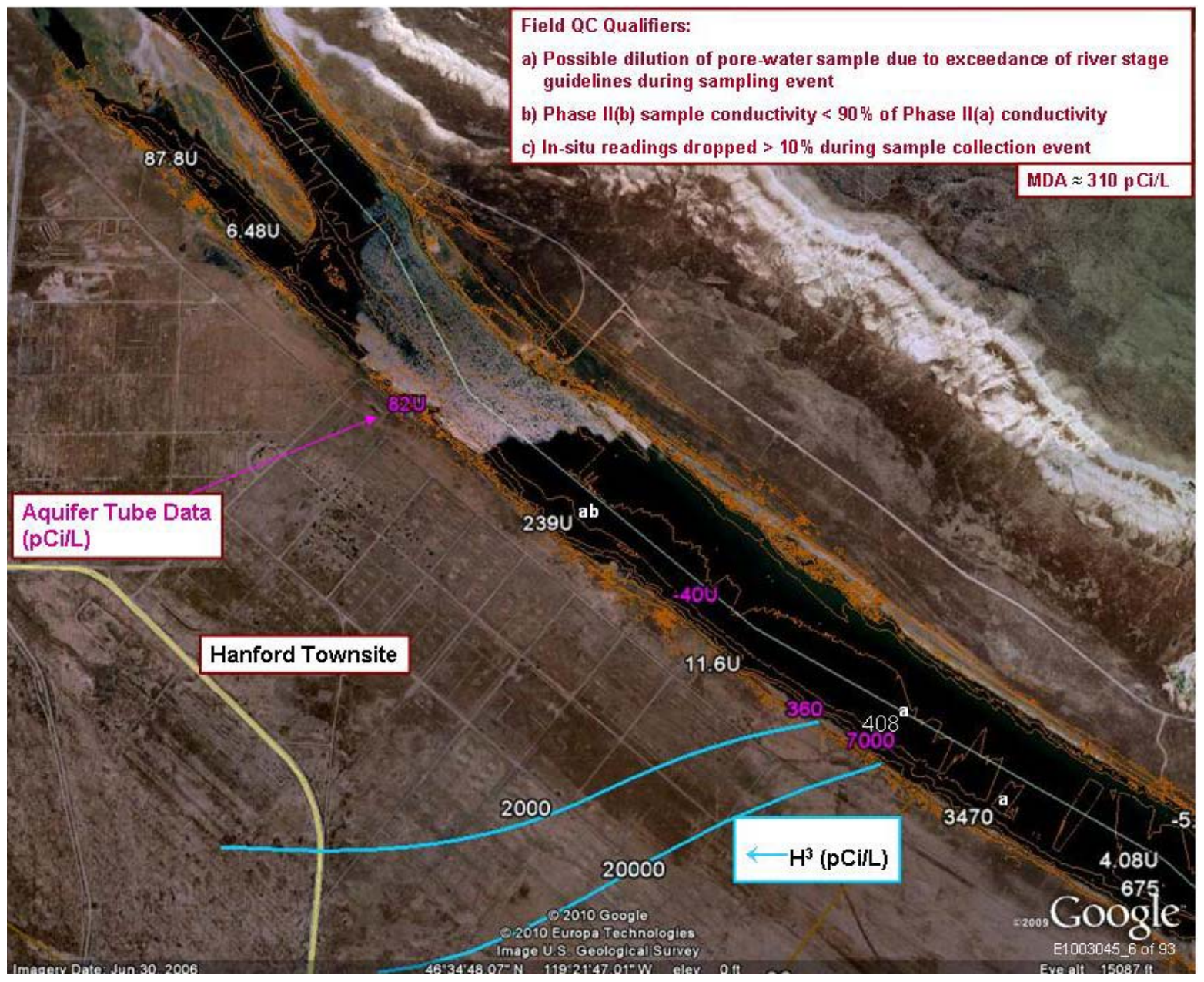


Figure 3-51. Pore Water Tritium (pCi/L) Levels Measured During Phase II(b) Near the Hanford Townsite Area (Sheet 2 of 4).

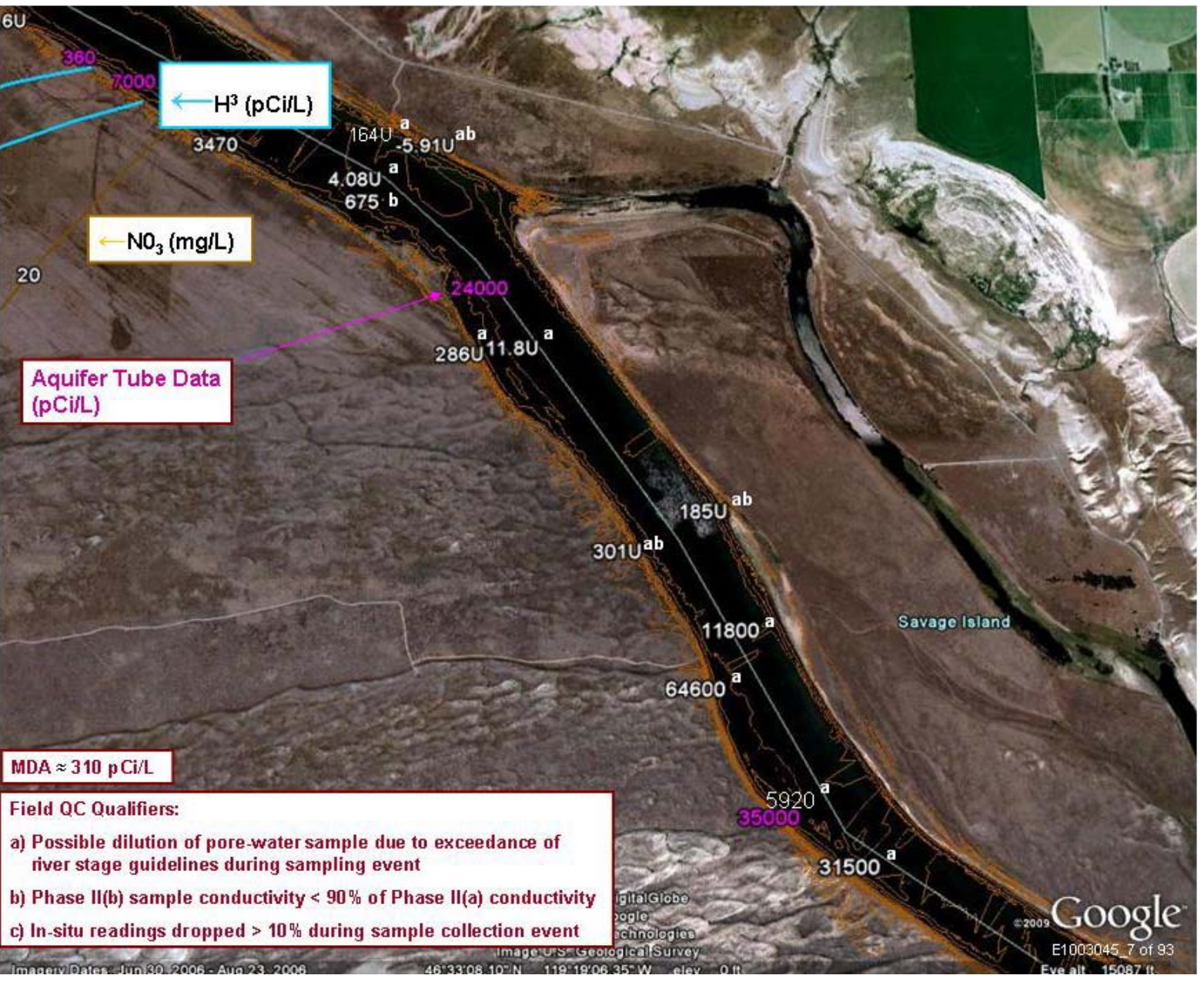


Figure 3-52. Pore Water Tritium (pCi/L) Levels Measured During Phase II(b) Near the Hanford Townsite Area (Sheet 3 of 4).

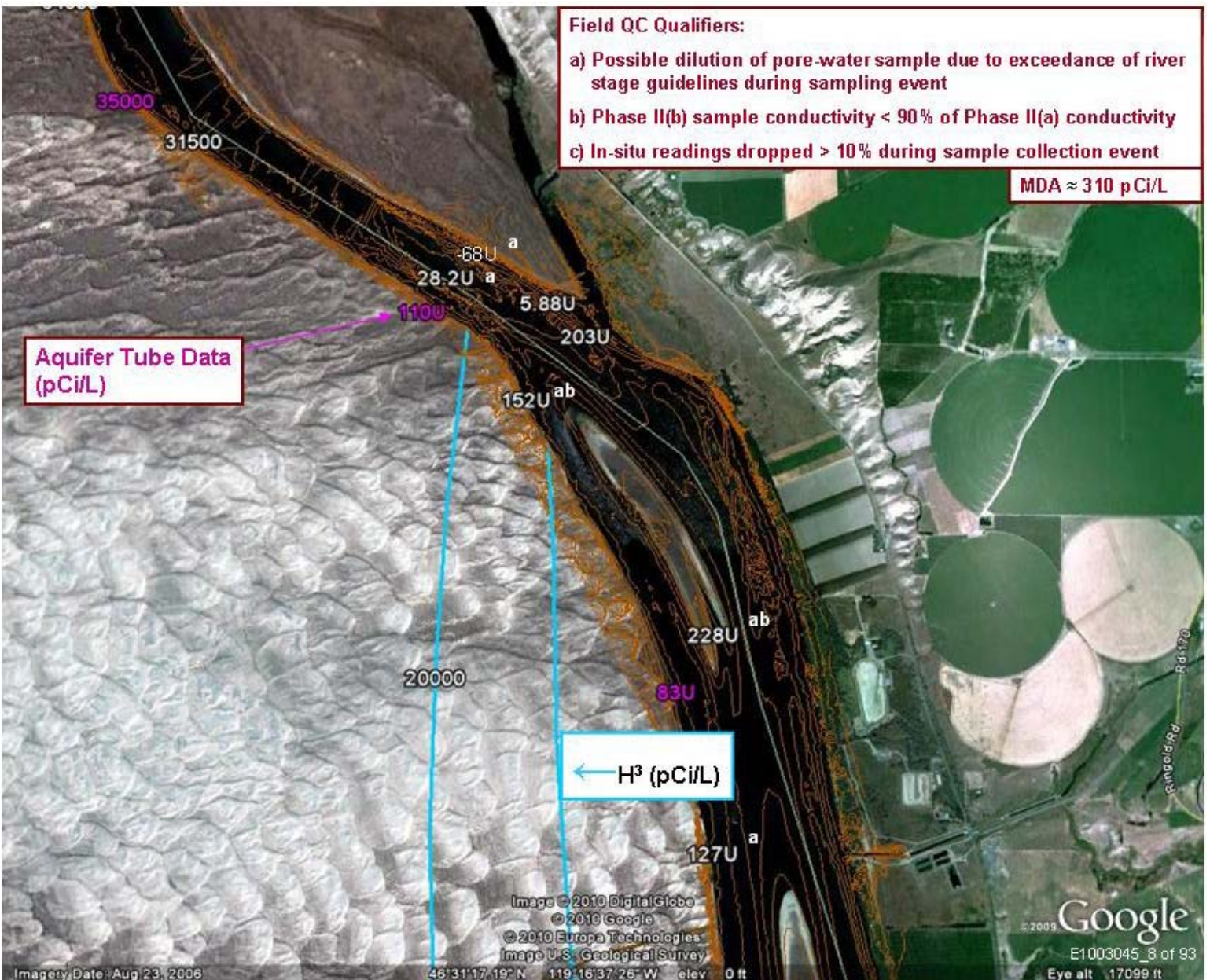




Figure 3-53. Pore Water Tritium (pCi/L) Levels Measured During Phase II(b) Near the Hanford Townsite Area (Sheet 4 of 4).

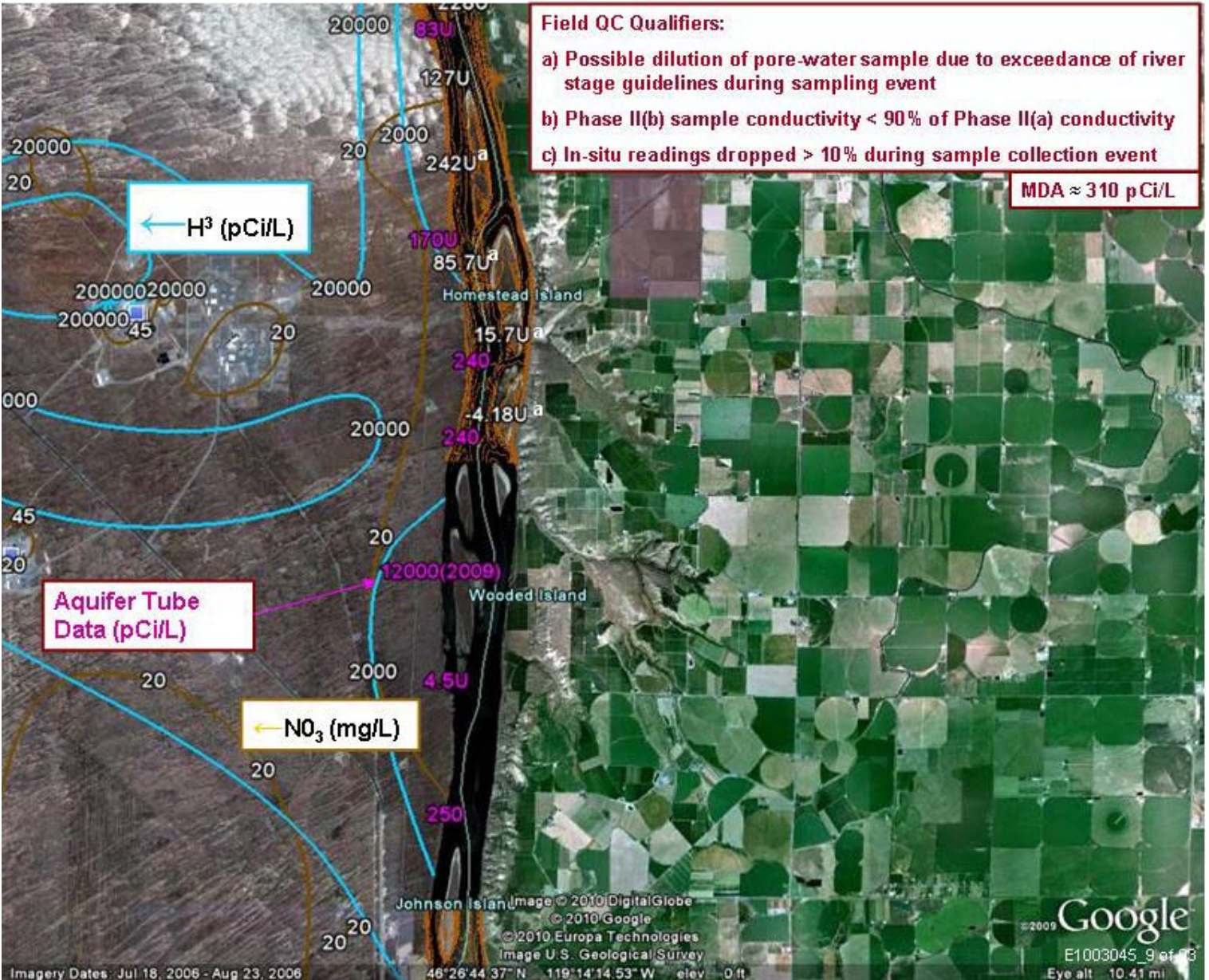
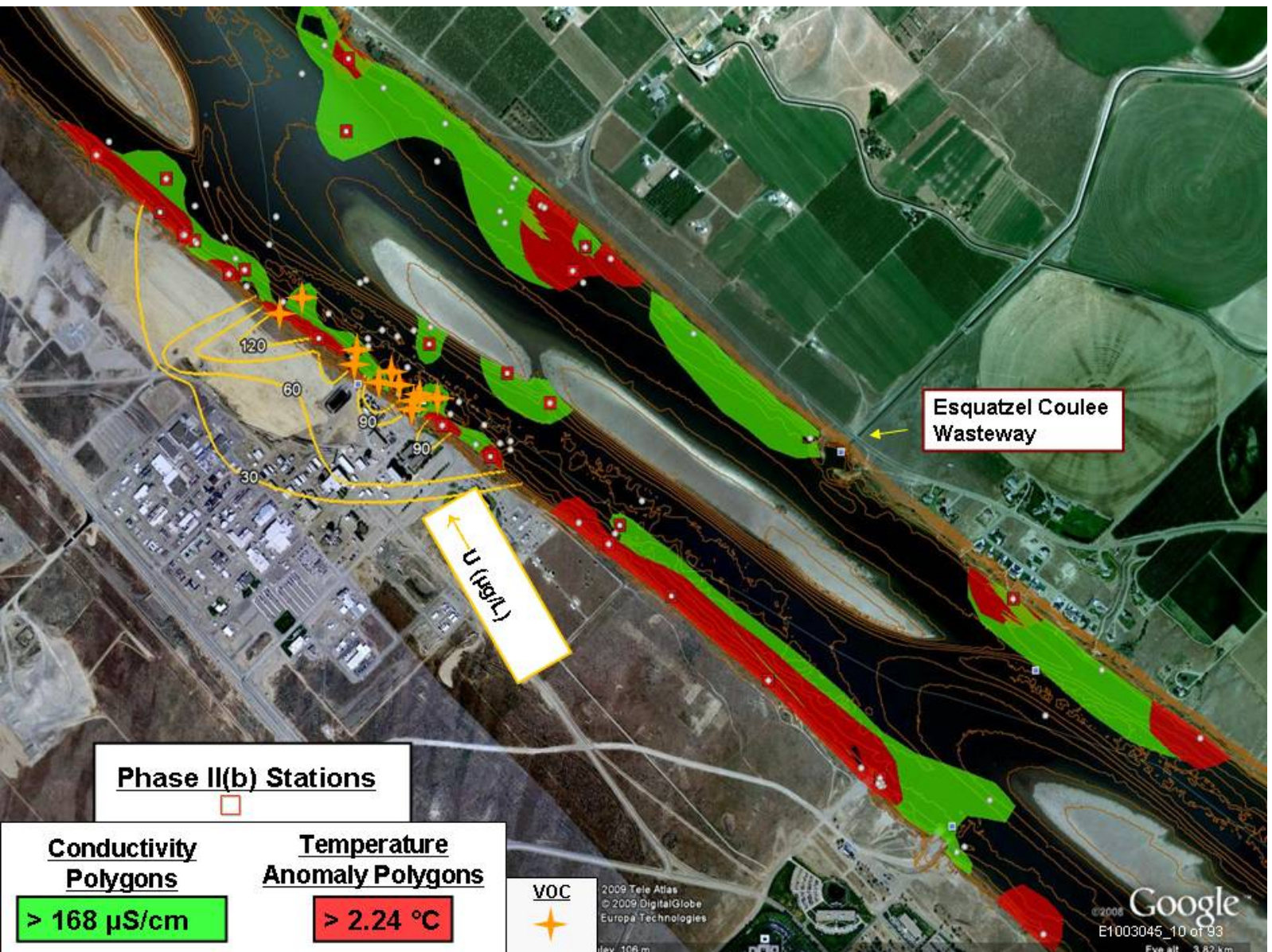


Figure 3-54. Phase II(b) Sample Locations Selected Near the 300 Area.



Pore water conductivity showed the presence of groundwater at all but one of the 300 Area sample locations sampled during Phase II(b) (Figure 3-55). Pore water conductivity ranged between approximately 150  $\mu\text{S}/\text{cm}$  up to 1,148  $\mu\text{S}/\text{cm}$ . The highest conductivity measurement was found approximately 10 m (33 ft) offshore of a historically monitored shoreline spring (Figure 3-55). Two of the five highest conductivity readings taken during Phase II(b) near the 300 Area (715  $\mu\text{S}/\text{cm}$  and 927  $\mu\text{S}/\text{cm}$ ) were located just off-shore of areas where relatively high uranium levels had been reported in the near-shore wells (Figure 3-55). Conductivity levels appeared to decrease the further off-shore the sample locations were located. Prominent upwelling patterns were again observed along the left shoreline (Franklin County shore) (Figure 3-56).

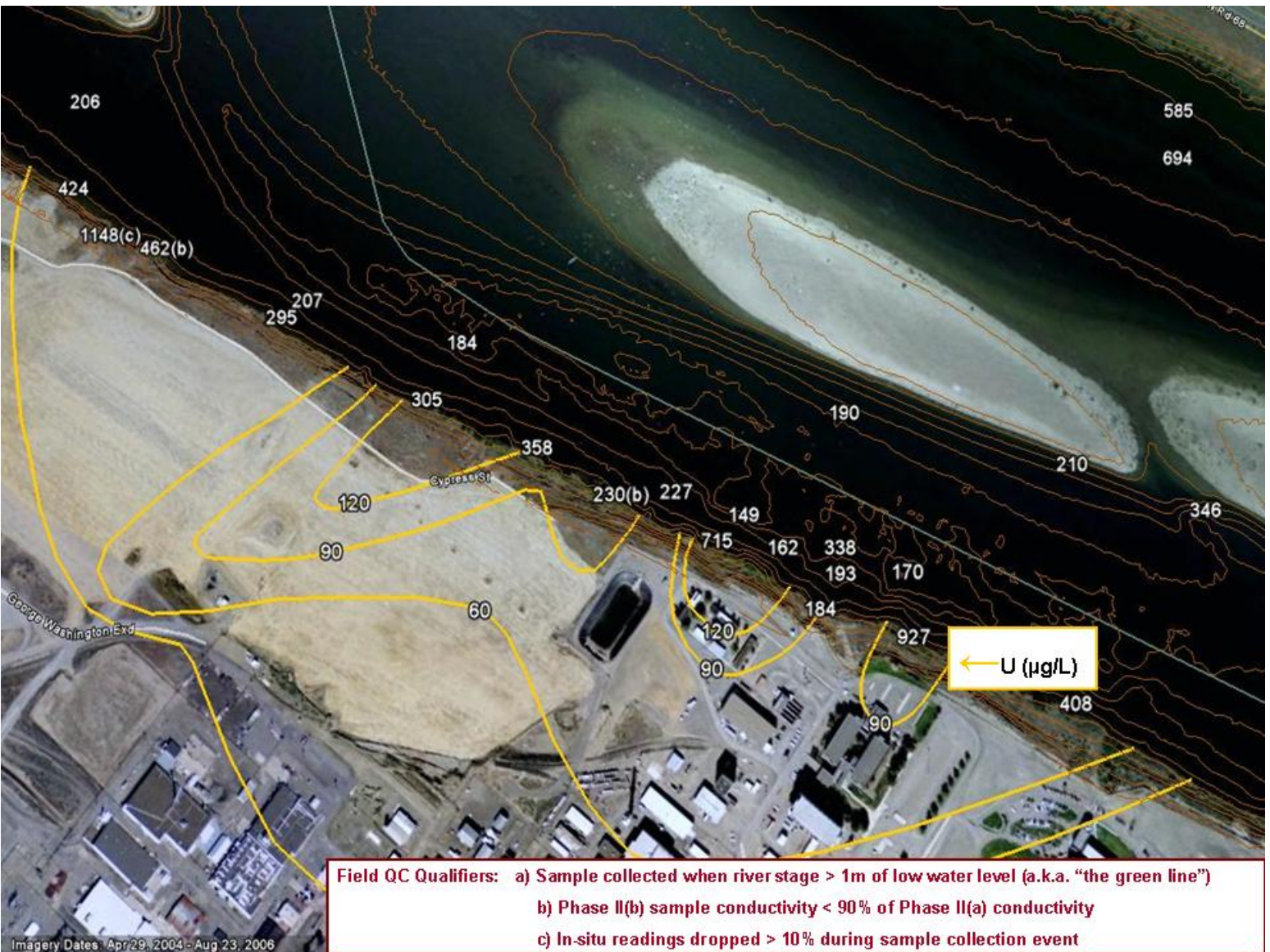
Uranium levels in 34 of 34 (100%) pore water total uranium sample results were reported above analytical detection limit (D.L. = 0.008  $\mu\text{g}/\text{L}$ ) (Figure 3-57). Only 2 of 11 pore water volatile organic compound results (VOC) were reported to be nominally above the analytical detection limit (suspected lab contaminant). Total uranium levels ranged between 34 and 113  $\mu\text{g}/\text{L}$ . Seven of 34 pore-water sample results exceeded the drinking water criteria of 30  $\mu\text{g}/\text{L}$  were located adjacent to the 300 Area. One sample result (see T3005J5 in Appendix G) was collected near the left bank and contained nearly 27  $\mu\text{g}/\text{L}$  (Figure 3-58). Phase II(b) uranium results generally conformed to isopleths generated from Hanford Site well data. A few exceptions were found near the upriver boundary of the 30  $\mu\text{g}/\text{L}$  uranium plume; this effort reported approximately 49  $\mu\text{g}/\text{L}$ , 76  $\mu\text{g}/\text{L}$ , and 113  $\mu\text{g}/\text{L}$ . Near the lower boundary of the 90  $\mu\text{g}/\text{L}$  uranium plume, this effort reported 107  $\mu\text{g}/\text{L}$ . All seven sample locations exceeding the 30  $\mu\text{g}/\text{L}$  total uranium threshold were located within approximately 50.2 m (165 ft) from the Hanford Site shoreline in water depths ranging from <1 m (<3 ft) to approximately 6 m (20 ft) deep. High pore water conductivity values generally corresponded to elevated uranium results.

### 3.2.2 Phase II(b) River Stages Encountered

Field sampling guidelines used during Phase II(b) helped minimize the influence of river fluctuations and bank recharge so that results could be compared with one another. The Phase II(b) pore water sampling guidelines instituted include:

- Performing in-situ monitoring while collecting samples to assure conductivity does not fall more than 10% during sampling.
- Avoid collecting pore-water samples when:
  - River levels are  $\geq 0.9$  m (3 ft) above the low water mark
  - 1 to 2 hours immediately following a significant decrease in river stage
- Checking nearby field selected sample locations intermittently during sampling events to document fluctuating groundwater signals and help assure that pore-water sample results are comparable to one another in terms of the percent dilution of surface water or bank recharge water. This information is paired with measurements taken from the nearby field gauge.
- Recording river height (staff gauge readings) before and after each sample.

Figure 3-55. Pore Water Conductivity ( $\mu\text{S}/\text{cm}$ ) Measured During Phase II(b) Near the 300 Area (Sheet 1 of 2).



**Figure 3-56. Pore Water Conductivity ( $\mu\text{S}/\text{cm}$ ) Measured During Phase II(b) Near the 300 Area (Sheet 2 of 2).**

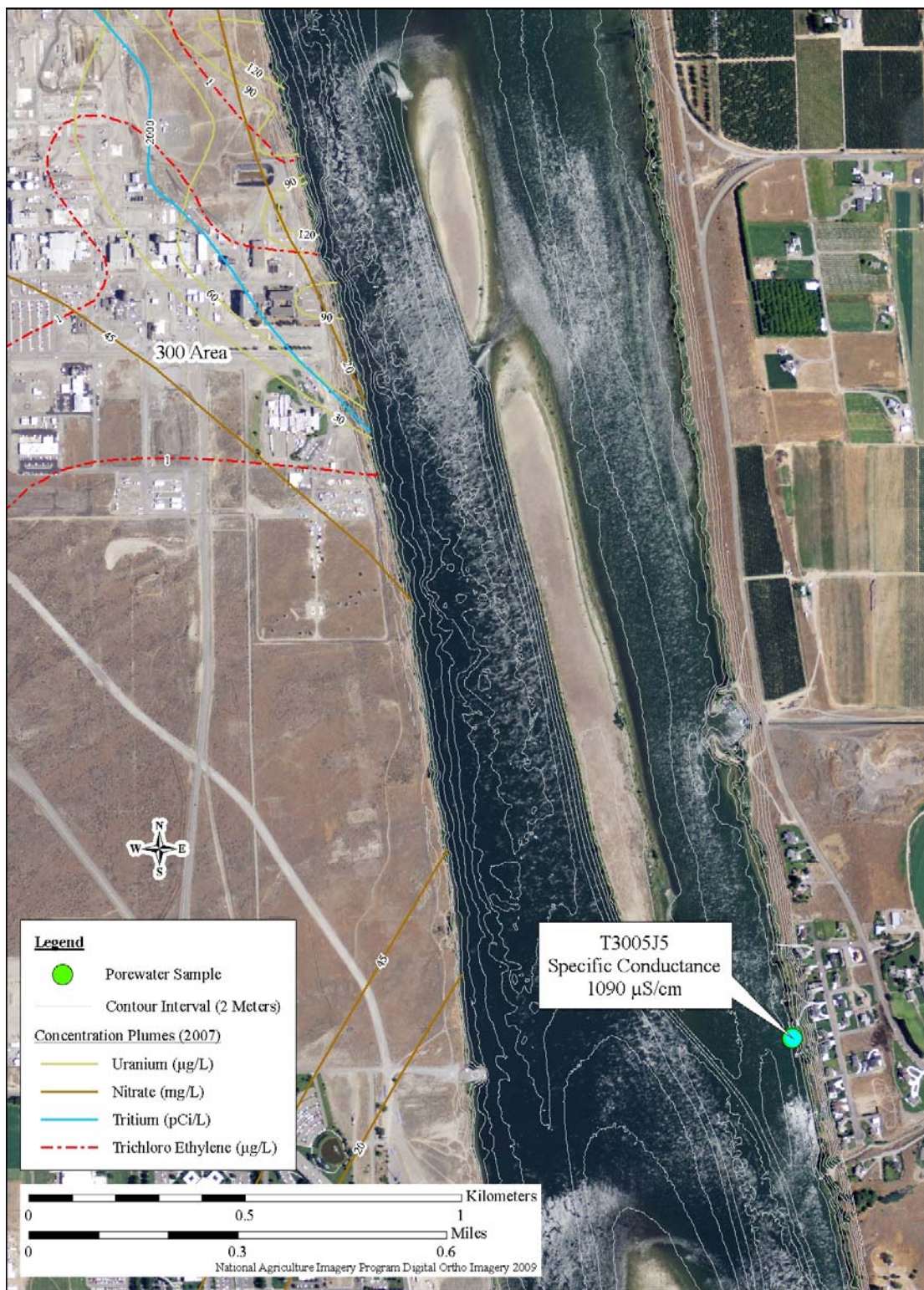
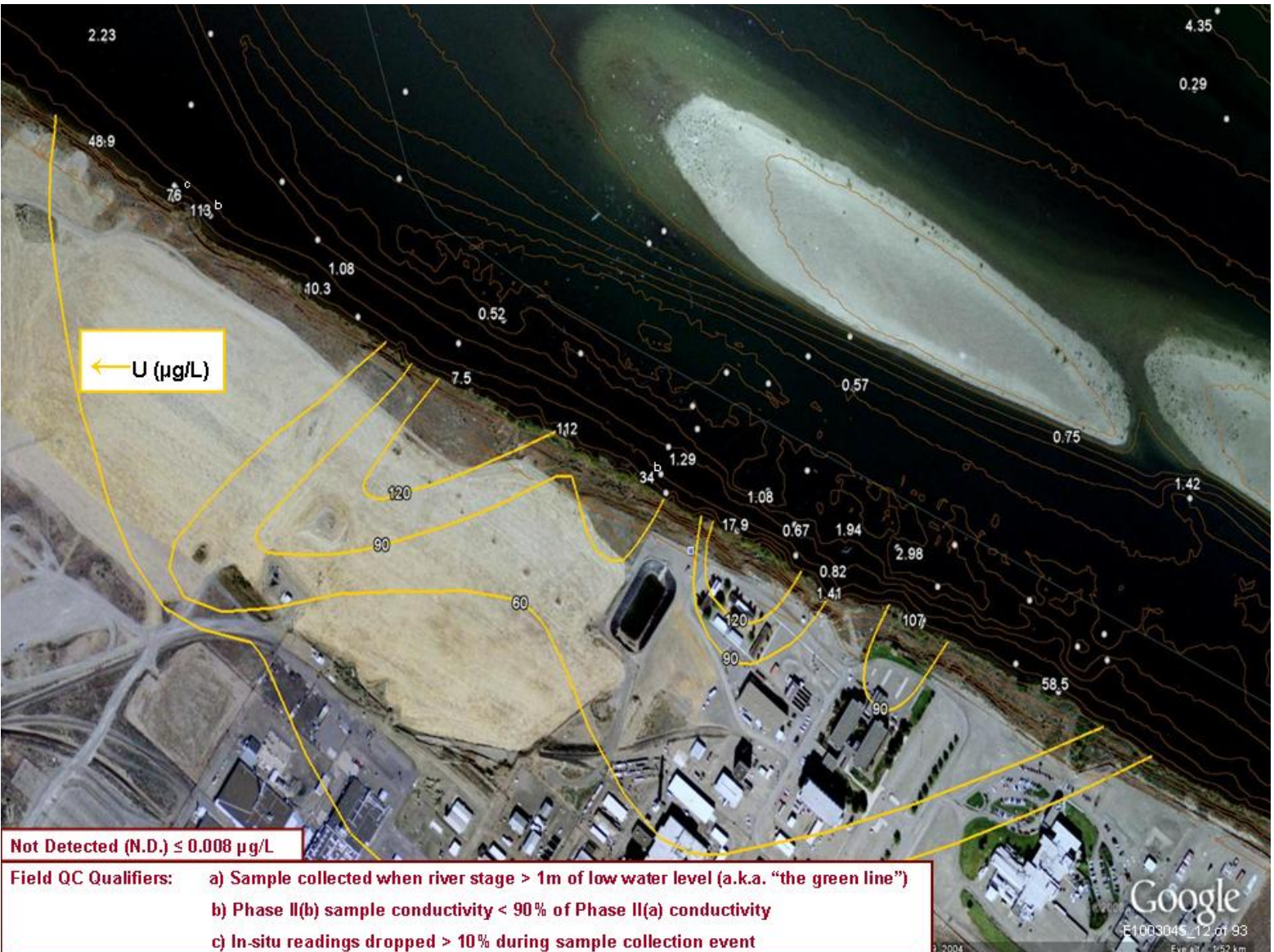
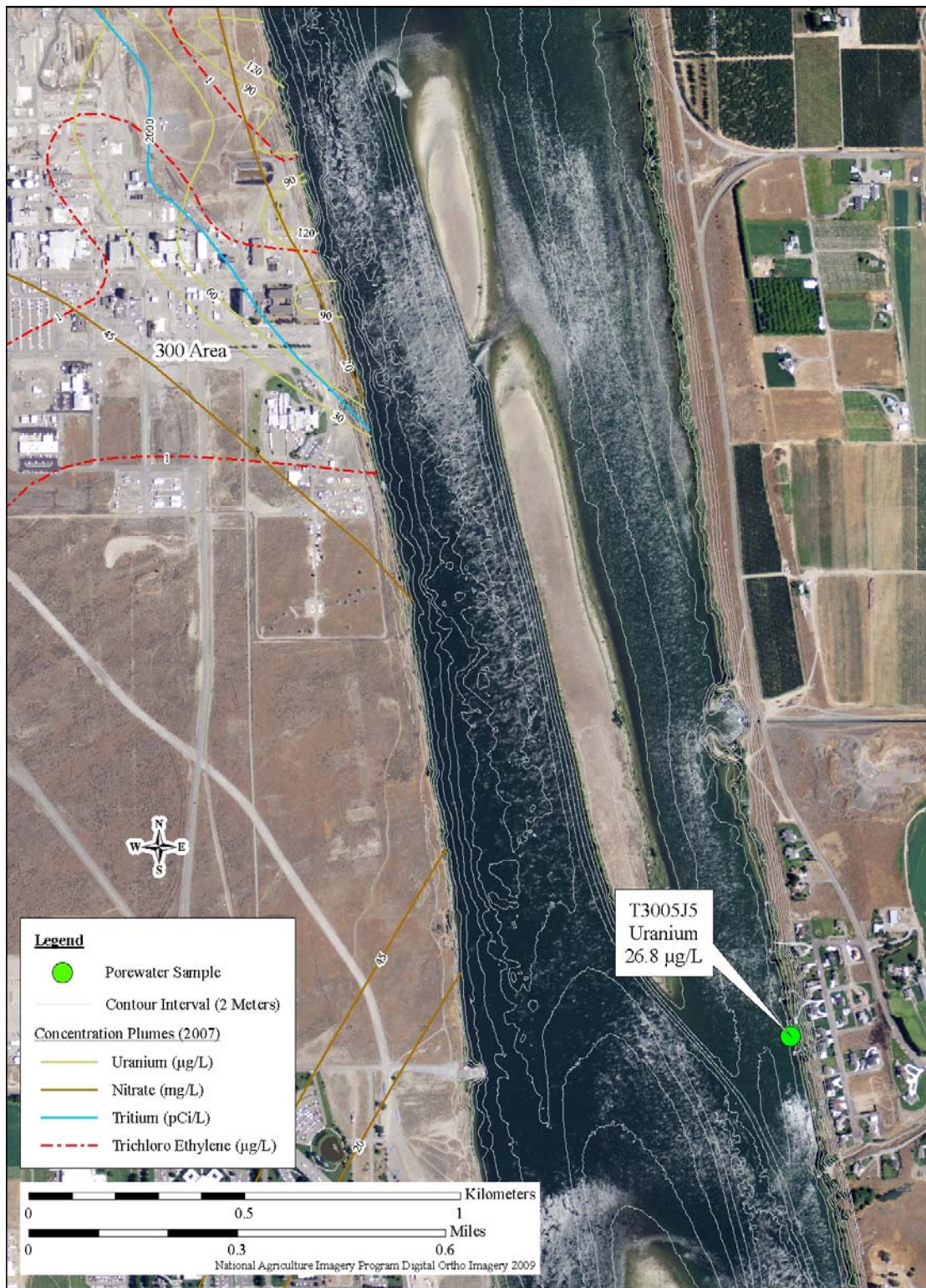


Figure 3-57. Pore Water Uranium ( $\mu\text{g/L}$ ) Levels Measured During Phase II(b) Near the 300 Area (Sheet 1 of 2).



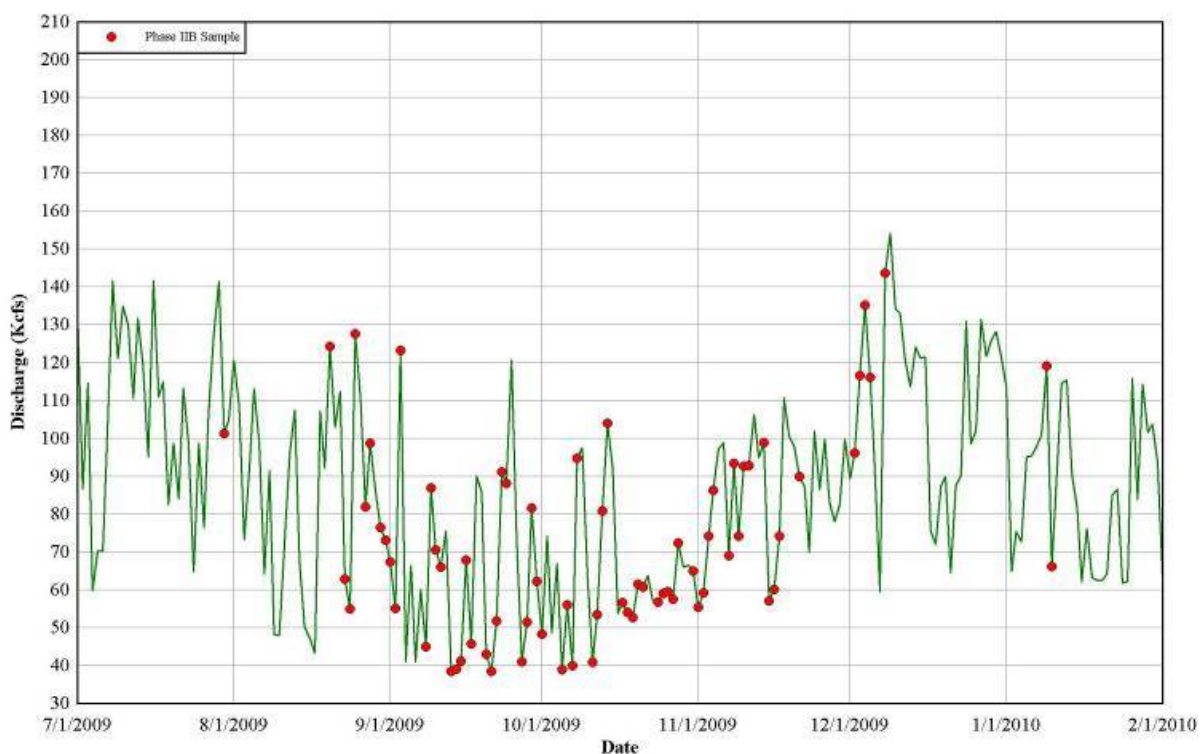
**Figure 3-58. Pore Water Uranium ( $\mu\text{g/L}$ ) Levels Measured During Phase II(b) Near the 300 Area (Sheet 2 of 2).**



- Search for micro-sites (approximately two boat lengths from Phase II[a] station coordinates) for pore water conductivity values that are within 10% of the highest value obtained during Phase II(a) mapping efforts.

Figure 3-59 provides a general depiction of the daily average river flows encountered on days when Phase II(b) sampling took place. Although site-specific discussion of river stages encountered were provided in the discussion of results for each study area, this figure helps depict the general river conditions encountered. Appendix G also provides a similar set of illustrations that describe the hourly flow conditions encountered during Phase II(b).

**Figure 3-59. Overview of Daily River Flows Encountered During Phase II(B) Sampling Events.**



### 3.2.3 Data Reduction for Phase III Site Selection

As the number of sample locations was much fewer than previous phases, the site-selection process for Phase III became even more important to the success of the project. As stated earlier, the objective of Phase III was different from previous phases; to “characterize multiple contaminants in surface water, pore water, and sediment at a sub-set of Phase II(b) sample locations.” As such, the Phase III site selection process was further expanded to include the following factors:

- Phase II(b) contaminant results
- Phase II(b) pore water conductivity



- Spatial considerations of multiple contaminant plumes
- Relative abundance of sediment
- Elevated conductivity in surface water.

Both pore water and sediment were target media during Phase III and became part of the decision-making process. Sample locations where surface water readings (conductivity or temperature) were still found to be affected by groundwater upwelling were given special consideration because they represented a site with a realistic exposure pathway to free-swimming fish species. The relative abundance of sediment in the vicinity of each station was estimated based on four general categories (scarce, marginal, moderate, and abundant) using underwater video records and knowledge of the general hydro-geological setting of the area. Generally this latter consideration helped assure that at least one Phase III sediment sample in each of the eight study areas would contain a sufficient amount of material for all QA/QC analyses necessary for each of the analytical suites prescribed. More detailed summary of each of the Phase II(b) site characteristics used to identify sites proposed for Phase III is provided in Appendix J. This designation also became important when determining the most suitable sediment sampling technique; where areas classified as “scarce” or “marginal” sediment abundance were consistently only suitable for the modified core-barrel mounted to the Trident probe driving frame (Section 2.0).

### **3.3 PHASE III (CHARACTERIZATION OF PORE WATER, SURFACE WATER, AND SEDIMENT IN STUDY AREAS**

Once Phase III sites were identified (Section 3.2.3), field teams commenced sampling efforts to include the collection of co-located samples of pore water, sediment, and surface water for more complete characterization of the contaminant levels found in each of these media types. Much larger volumes of water were needed during Phase III sampling to accommodate the analytical laboratory sample volume requirements for the more complete analyses and on a daily basis, fewer sites were completed by each field team.

#### **3.3.1 Overall Sampling Summary**

Phase III sampling commenced in January 2010 and continued through February 2010. A total of 49 sample locations were sampled, and attempts were made to collect all three media at all of these sites. Additionally, one sediment sample was taken at a station (T100N3A) near the 100-N apatite barrier, but no pore water/surface water samples were taken. The rationale behind this single sediment sample was that although the apatite barrier was reducing strontium-90 pore water levels, sediment found could still contain elevated levels of the strontium-90. Table 3-5 provides a summary of the Phase III sampling success for each media. More detailed sampling summaries are provided in each section below. Appendix F provides a detailed summary of water quality parameters measured during Phase III. Appendix H provides graphical illustrations of the Phase III conductivity results for each area. Appendix I provides a detailed summary of the sediment sample field records and photo logs of the sediment samples.

**Table 3-5. Overall Summary of Phase III Sampling Success by Media Type and Study Area.**

Study Area	Pore Water	Surface Water	Sediment
100 B/C	9	9	9
100 K	6	6	5
100 N	5	5	6
100 D	6	6	5
100 H	6	6	5
100 F	2	2	2
HTS	5	5	5
300 A	8	8	8
<b>Total</b>	<b>47</b>	<b>47</b>	<b>45</b>

**3.3.1.1 Pore and Surface water Sampling Summary.** Table 3-6 summarizes the Phase III pore-water samples that were collected from each of the eight study areas. Two additional sites were attempted; one near 100-B/C Area (J100BC21) and one near the 300 Area (J30040), but were abandoned due to low pore water conductivity measurements measured during Phase III. In general, groundwater signals measured were comparable to Phase II(b); however, 11 Phase III sample locations failed to yield conductivity values similar to Phase II(b) when sampled. Seven of the 11 sample locations were sampled when river levels were high enough to be possibly suppressing the groundwater signal. Surface water conductivity measurements were relatively stable (approximately 140 to 155  $\mu\text{S}/\text{cm}$ ) across all regions during the entire Phase III sampling period. However, surface water conductivity was found to be elevated (30.5 cm [12-in.] above the riverbed) near some of the prominent groundwater upwelling sites (where river flows were very low) (see summary tables in Appendix F). The following section summarizes the pore water and surface water sampling success and provides a comparison of the pore water conductivity results to the previous sampling events.

**Table 3-6. Summary of Phase III Sample Locations and Maximum Conductivity ( $\mu\text{S}/\text{cm}$ ) by Study Area.**

Study Area	Dates Performed	Number of Transect Stations	Number of Judgmental Stations	Total Number of Stations	Maximum Pore Water Conductivity ( $\mu\text{S}/\text{cm}$ )
100-B/C	January – February 2010	3	6	9	344
100-K	January – February 2010	3	3	6	483
100-N	February 2010	3	2	5	895
100-D	February 2010	3	3	6	560
100-H	January – February 2010	2	4	6	343
100-F	February 2010	1	1	2	212
Hanford Town Site	February 2010	0	5	5	417
300 Area	January – February 2010	1	7	8	1,026
<b>Total</b>		<b>16</b>	<b>31</b>	<b>47</b>	

As stated earlier a large range of analyses were performed on surface water and pore water samples taken during Phase III. The discussions of analytical results that follow focus on only the indicator contaminants from Phase II(b) for comparison purposes. The remaining analytical results will be presented in a different document.

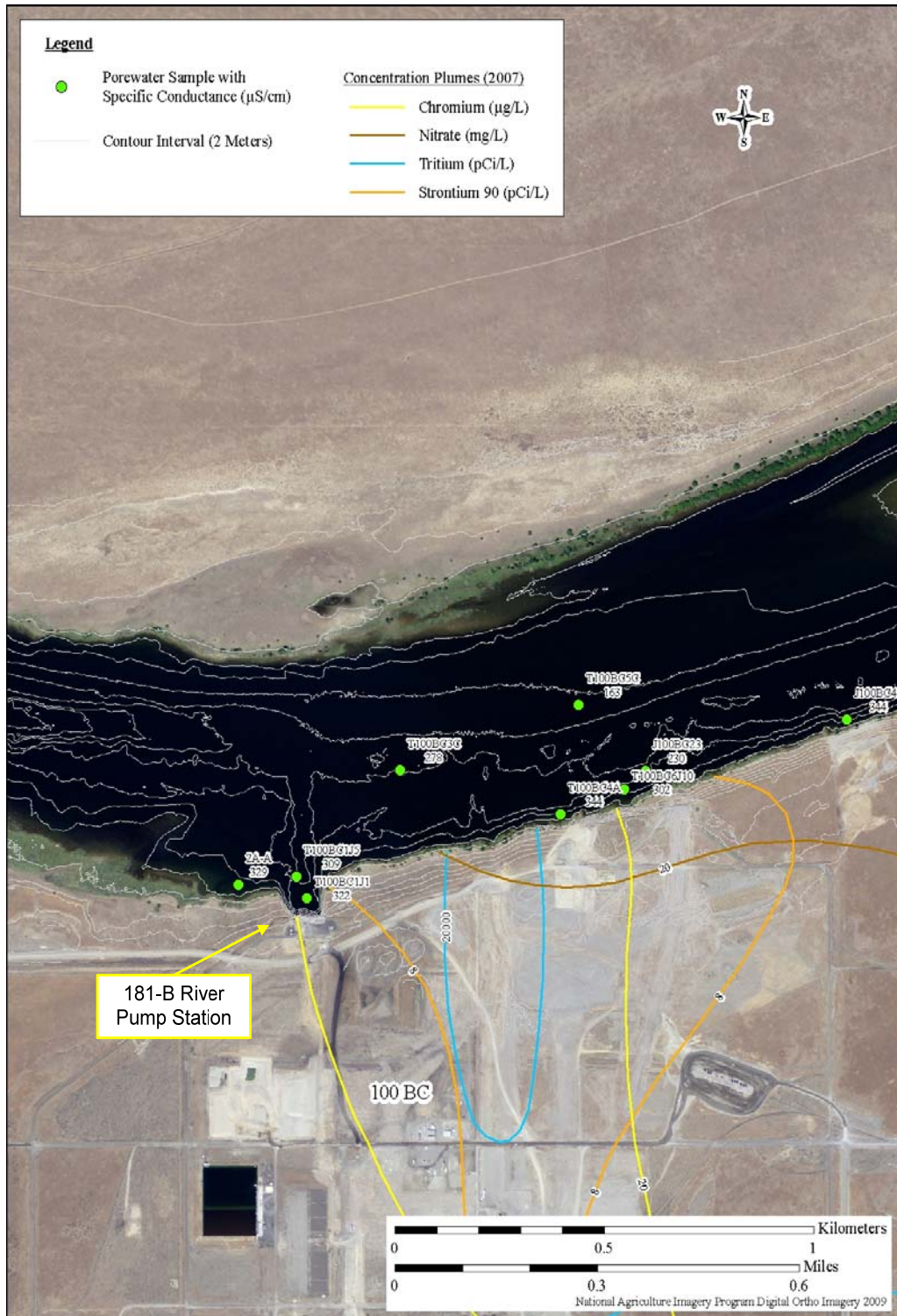
**3.3.1.1.1 100-B/C Area.** A total of 10 sample locations were selected for Phase III sampling near 100-B/C; six primary sites and four secondary sites (to be collected after other regions primary sites had been collected) (see maps in Appendix H). Pore water and surface water samples were collected at nine of the ten 100-B/C sites. One site (J100BC21) was not sampled because a groundwater signal greater than 160  $\mu\text{S}/\text{cm}$  could not be found. Samples were collected between January 15 and February 28, 2010. Pore water conductivity values ranged between 163  $\mu\text{S}/\text{cm}$  and 344  $\mu\text{S}/\text{cm}$  (Figure 3-60). Site J100BC47 yielded the maximum pore water conductivity (344  $\mu\text{S}/\text{cm}$ ) value during Phase III near the 100-B/C Area. This site was found to have 28  $\mu\text{g}/\text{L}$  of hexavalent chromium during Phase II(b) and was located just off-shore of an active remediation site (Appendices H and F). Three sample locations near 100-B/C were sampled when river levels were potentially suppressing or diluting the pore-water sample, three sample locations were sampled when pore water conductivity was less than 90% of the Phase II(b) value, and two of those sample locations were sampled when both of river stage guidelines were not met (Appendix F). Pore water conductivity dropped more than 10% on one sample near 100-B/C (T100BC6J10), but the final conductivity value obtained during Phase III was similar to that obtained during Phase II(b).

Laboratory results for hexavalent chromium and total uranium in surface water were all at non-detect levels during Phase III. Only one detection of strontium-90 at 0.6 pCi/L was seen in surface water at station T100BC3C. Pore water sample results for hexavalent chromium ranged from 5 to 46  $\mu\text{g}/\text{L}$ . At station T100BC3C where the result was 112  $\mu\text{g}/\text{L}$  during Phase II(b) a detection of only 22  $\mu\text{g}/\text{L}$  was observed. The same observation was generally true at other stations within the 100 B/C area where Phase III results were lower than Phase II(b). Seasonal affects or differences in discharge flow conditions from the Priest Rapids Dam may have played a role. Strontium-90 was detected once in pore water at station T100BC4A at a concentration of 6.1 pCi/L. Tritium was also detected over a range of 1,400 to 12,100 pCi/L with the maximum found at station T100BC4A.

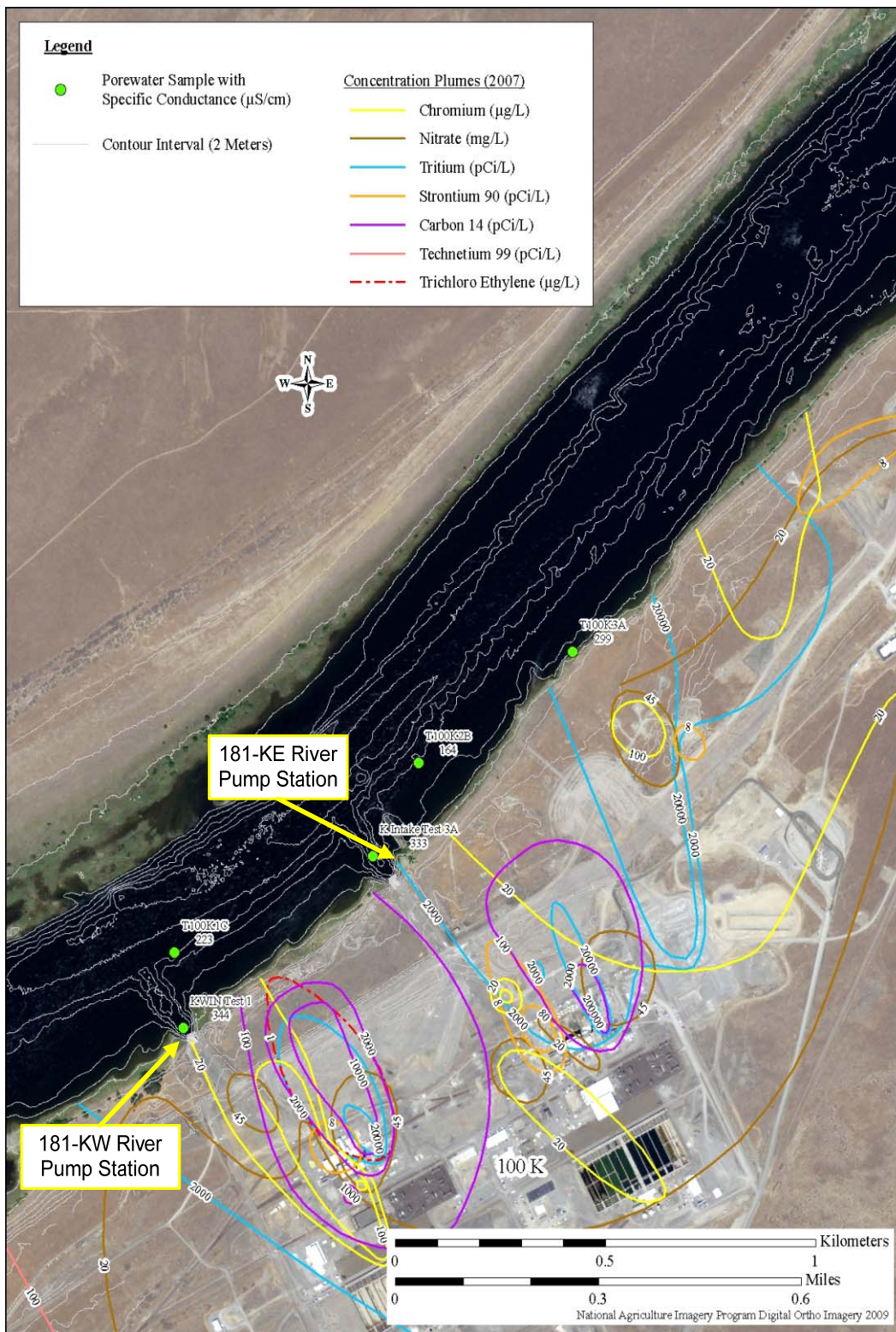
**3.3.1.1.2 100-K Area.** A total of six sample locations were selected for Phase III sampling near 100-K; five primary sites and one secondary site (to be collected after other regions primary sites had been collected) (see maps in Appendix H). Pore water and surface water samples were collected at all six sites. The Phase III samples were collected near 100-K between January 22, and February 28, 2010. Pore water conductivity values ranged between 164  $\mu\text{S}/\text{cm}$  and 482  $\mu\text{S}/\text{cm}$  (Figures 3-61 and 3-62). Site J100K24 yielded the maximum pore water conductivity (482  $\mu\text{S}/\text{cm}$ ) value during Phase III near the 100-K Area. This site was found to have 36  $\mu\text{g}/\text{L}$  of hexavalent chromium during Phase II(b) with 350  $\mu\text{S}/\text{cm}$  pore water conductivity value (Appendices F and H). All six sample locations near 100-K were sampled when river levels were potentially suppressing or diluting the pore-water sample and one of those sample locations (T100K2B) was sampled when both of river stage guidelines were not met (Appendix F).

Laboratory results for hexavalent chromium, total uranium, and strontium-90 in surface water were all at non-detect levels during Phase III. Pore water sample results for hexavalent chromium ranged from 18 to 56  $\mu\text{g}/\text{L}$ . At stations T100K3A and T100K24 the results were

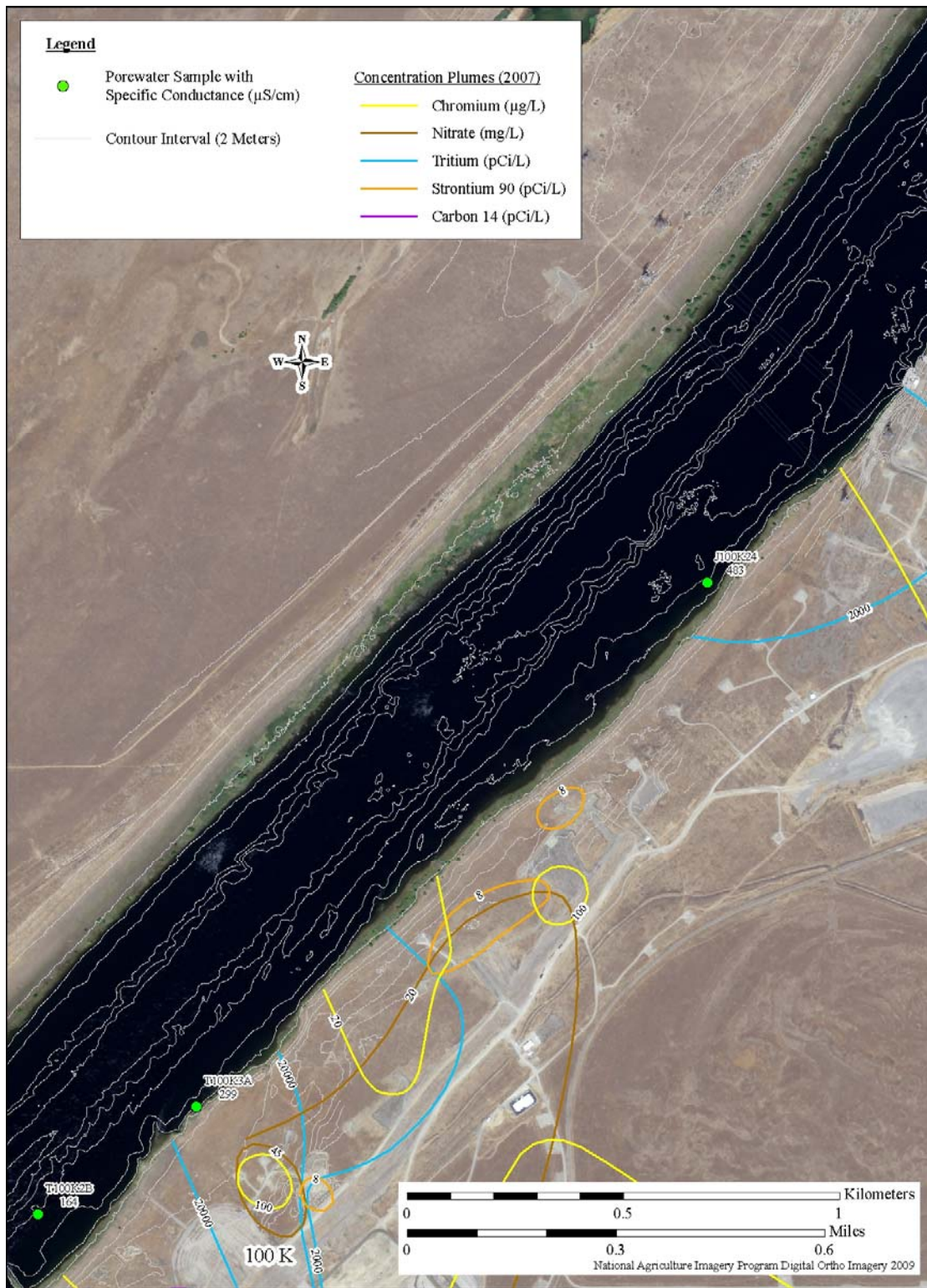
**Figure 3-60. Phase III Sample Locations Selected Near the 100-B/C Area and Pore Water Conductivity Measurements.**



**Figure 3-61. Phase III Sample Locations Selected Near the 100-K Area and Pore Water Conductivity Measurements (Sheet 1 of 2).**



**Figure 3-62. Phase III Sample Locations Selected Near the 100-K Area and Pore Water Conductivity Measurements (Sheet 2 of 2).**



56 and 55 ug/L respectively, an increase from Phase II(b) where values of 17 and 36 ug/L were seen. At the four other stations measured the concentrations during Phase III were less than Phase II(b). Tritium was also detected in pore water ranging from 658 to 6,500 pCi/L with the maximum found at station T100K3A. Both total uranium and strontium-90 were not detected in pore water in the 100K Area.

**3.3.1.1.3 100-N Area.** A total of five sample locations were selected for Phase III sampling near 100-N and one additional site (T100N3A) was selected for a sediment-only sample under the premise that strontium may be largely absent in pore water but still potentially present in sediment there; (see maps in Appendix H). Pore water and surface water samples were collected at all five sites. The Phase III samples were collected near 100-N between February 6, and February 8, 2010. Pore water conductivity values ranged between 359 and 895  $\mu\text{S/cm}$  (Figure 3-63). Site T100N1A yielded the maximum pore water conductivity (895  $\mu\text{S/cm}$ ) value during Phase III near the 100-N Area. This site was found to have 21 pCi/L of strontium-90 during Phase II(b) with a similar pore water conductivity value (Appendices F and H). All sample locations were sampled near 100-N within the river stage guidelines (Appendix F).

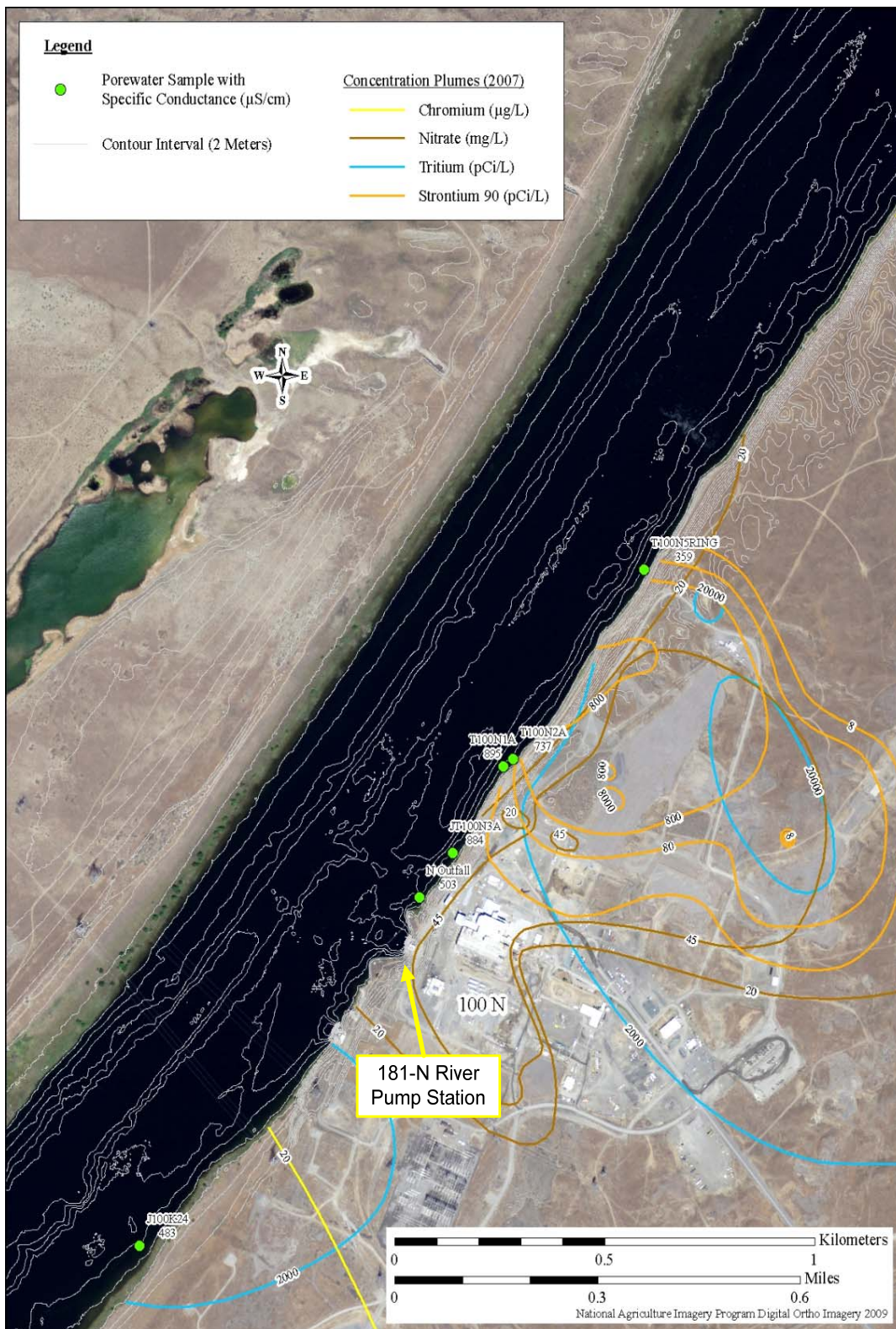
Laboratory results for hexavalent chromium, total uranium, and strontium-90 in surface water were all at non-detect levels during Phase III. Pore water sample results for hexavalent chromium were all non-detects, with the exception of one detection of 26 ug/L at station T100N1A. Strontium-90 ranged from 8 to 55 pCi/L with the maximum found at the N Outfall station. Tritium was also detected over a range of 1,100 to 12,000 pCi/L with the maximum found at station T100N5Ring.

**3.3.1.1.4 100-D Area.** A total of six sample locations were selected for Phase III sampling near 100-D; (see maps in Appendix H). Pore water and surface water samples were collected at all six sites. The Phase III samples were collected near 100-D between February 5 and February 14, 2010. Pore water conductivity values ranged between 213  $\mu\text{S/cm}$  and 560  $\mu\text{S/cm}$  (Figure 3-64). Site T100D1A yielded the maximum pore water conductivity (560  $\mu\text{S/cm}$ ) value during Phase III near the 100-D Area. This site was found to have 9  $\mu\text{g/L}$  of hexavalent chromium in the pore water during Phase II(b) with a similar pore water conductivity value as Phase III (Appendices F and H). Three sample locations near 100-D were sampled when river levels were potentially suppressing or diluting the pore-water sample, and one of those sample locations (J100D9) was sampled when both of the key river stage guidelines were not met (Appendix F).

Laboratory results for hexavalent chromium, total uranium, and strontium-90 in surface water were all at non-detect levels during Phase III. Pore water sample results for hexavalent chromium ranged from 9 to 640 ug/L with the maximum value found at station T100D3A where a high of 331 ug/L was found during Phase II(b). A single detection of strontium-90 at 1.5 pCi/L was reported at station J100D9. Tritium was also detected over a range of 353 to 14,100 pCi/L with the maximum found at station T100D1A.

**3.3.1.1.5 100-H Area.** A total of six sample locations were selected for Phase III sampling near 100-H; (see maps in Appendix H). Pore water and surface water samples were collected at all six sites. The Phase III samples were collected near 100-H from January 24 through

**Figure 3-63. Phase III Sample Locations Selected Near the 100-N Area and Pore Water Conductivity Measurements.**





February 27, 2010. Pore water conductivity values ranged between 184 and 343  $\mu\text{S}/\text{cm}$  (Figures 3-65 and 3-66). Site T100H1A yielded the maximum pore water conductivity (343  $\mu\text{S}/\text{cm}$ ) value during Phase III near the 100-H Area. This site was found to have 29  $\mu\text{g}/\text{L}$  of hexavalent chromium in the pore water during Phase II(b) with a similar pore water conductivity value as Phase III (Appendices F and H). Two sample locations were sampled when river levels were potentially suppressing or diluting the pore-water sample (J100H43 and J100H44); however, pore water conductivity values similar to Phase II(b) were attained at these two sites when Phase III samples were collected.

Laboratory results for hexavalent chromium, total uranium, and strontium-90 in surface water were all at non-detect levels during Phase III. Pore water sample results for hexavalent chromium ranged from 7 to 50  $\mu\text{g}/\text{L}$ , with the maximum value found at station T100H1A. Strontium-90 in pore water were all non-detects with the exception of one detection at 6  $\text{pCi}/\text{L}$  found at station J100H44. Tritium was also detected over a range of 454 to 1,250  $\text{pCi}/\text{L}$  with the maximum found at station T100H1A.

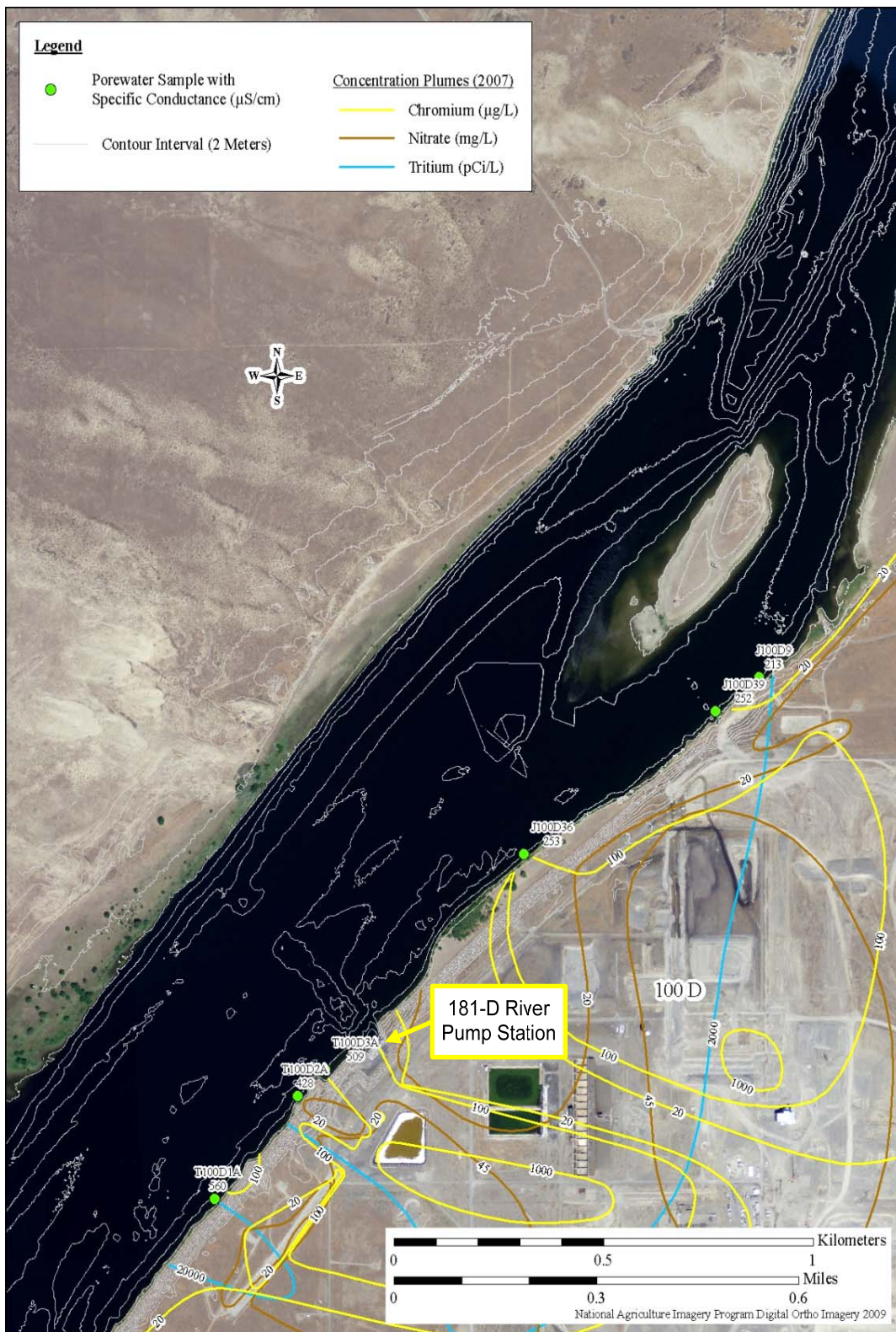
**3.3.1.1.6 100-F Area.** A total of two sample locations were selected for Phase III sampling near 100-F; (see maps in Appendix H). Pore water and surface water samples were collected at both sites. The Phase III samples were collected near 100-F on February 12, 2010. Pore water conductivity values were both 212  $\mu\text{S}/\text{cm}$  (Figure 3-67). Both sites were sampled when river levels were potentially suppressing or diluting the pore-water sample and Phase III pore water conductivity values were less than 90% of the Phase II(b) conductivity values.

Laboratory results for hexavalent chromium, total uranium, and strontium-90 in surface water were all at non-detect levels during Phase III. Hexavalent chromium was found at 20  $\mu\text{g}/\text{L}$  at station T100F2A. Minor detections of strontium-90 ranging were 1.5 to 2.3  $\text{pCi}/\text{L}$  were also noted. Tritium was not detected.

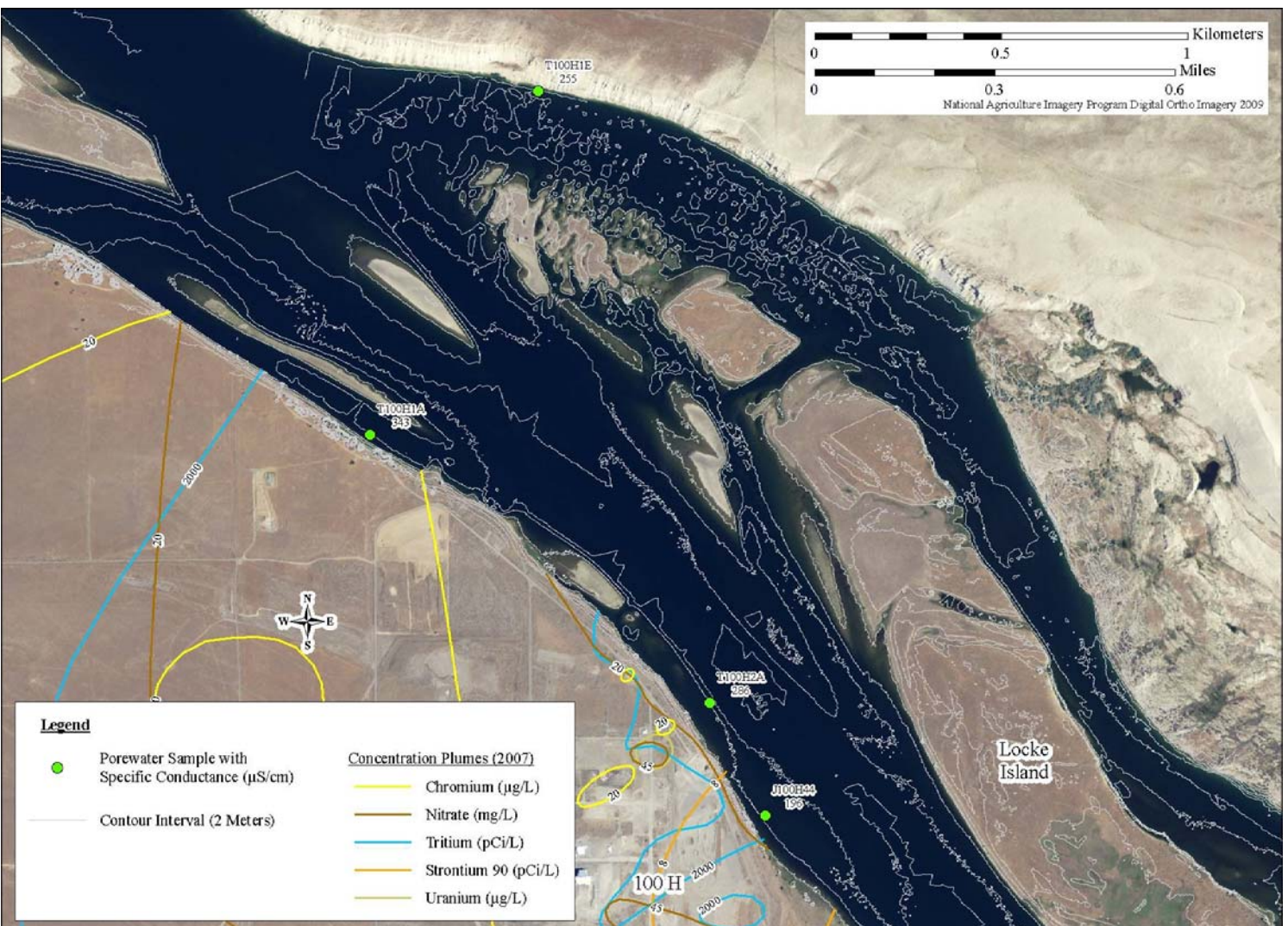
**3.3.1.1.7 Hanford Townsite Area.** A total of five sample locations were selected for Phase III sampling near Hanford townsite (see maps in Appendix H). Pore water and surface water samples were collected at all five sites. The Phase III samples were collected near the Hanford townsite from February 15 through February 26, 2010. Pore water conductivity values ranged between 208  $\mu\text{S}/\text{cm}$  and 417  $\mu\text{S}/\text{cm}$  (Figures 3-68 and 3-69). Station JHTS33 yielded the maximum pore water conductivity (417  $\mu\text{S}/\text{cm}$ ) value during Phase III near the Hanford townsite. This station was found to have 64,600  $\text{pCi}/\text{L}$  of tritium in the pore water during Phase II(b) with a similar pore water conductivity value as Phase III (Appendices H and F). Two sample locations near the Hanford townsite were sampled when river levels were potentially suppressing or diluting the pore-water sample, two sample locations were sampled when pore water conductivity was less than 90% of the Phase II(b) value, and one of those sample locations (JHTS9) was sampled when both of river stage guidelines were not met (Appendix F).

Hexavalent chromium, total uranium, and strontium-90 were not analyzed for during Phase III in the HTS Area. Tritium was found in surface water at concentrations ranging from 255 to 989  $\text{pCi}/\text{L}$ . Pore water sample results for hexavalent chromium ranged from 13 to 21  $\mu\text{g}/\text{L}$  at 4 locations along the right bank opposite Savage Island. This was unexpected since there are no known chromium plumes reported in this area. Tritium was also detected over a range of 675 to 65,200  $\text{pCi}/\text{L}$  with the maximum found at station JHTS33. These tritium detections were consistent with measurements obtained during Phase II(b).

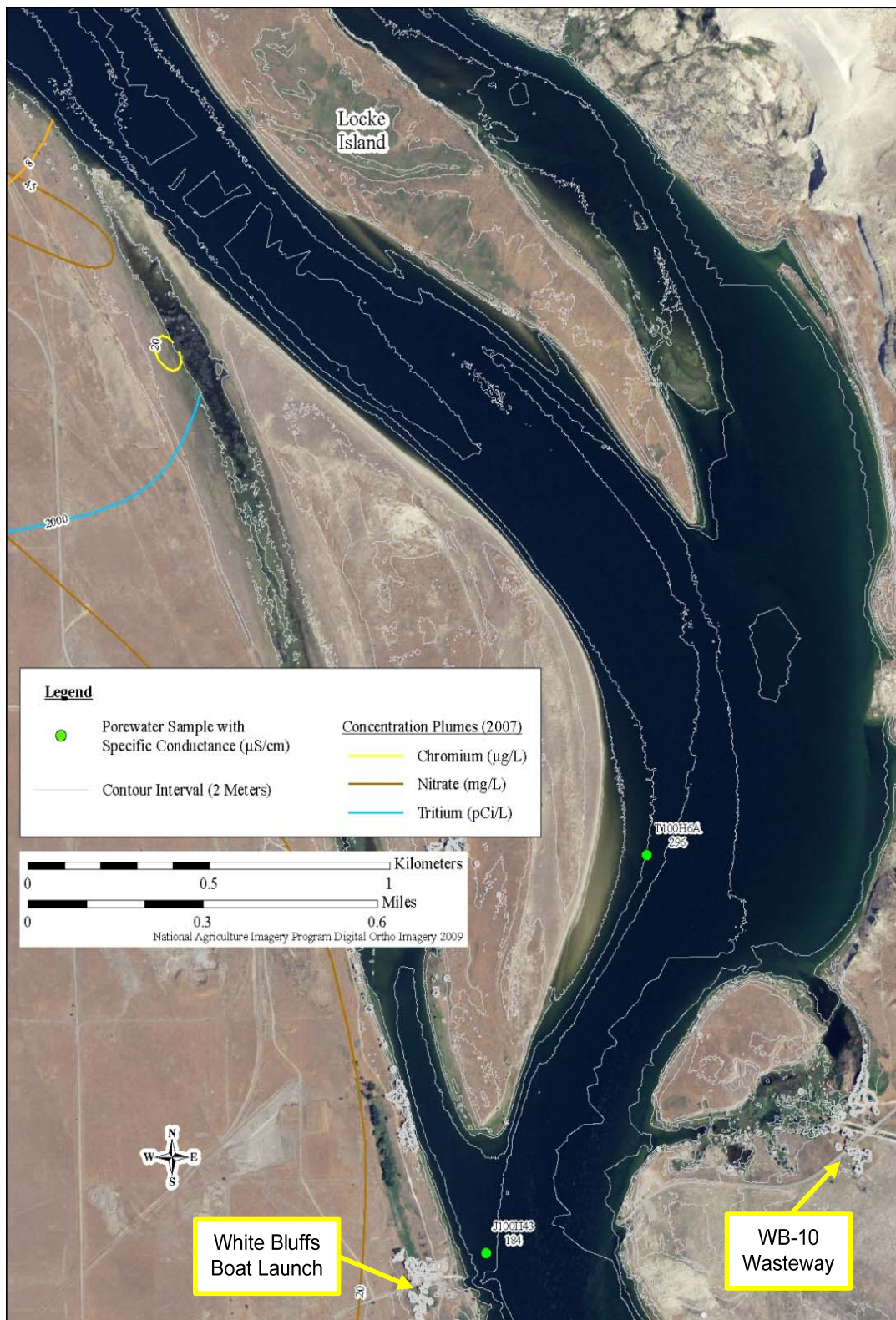
**Figure 3-64. Phase III Sample Locations Selected Near the 100-D Area and Pore Water Conductivity Measurements.**



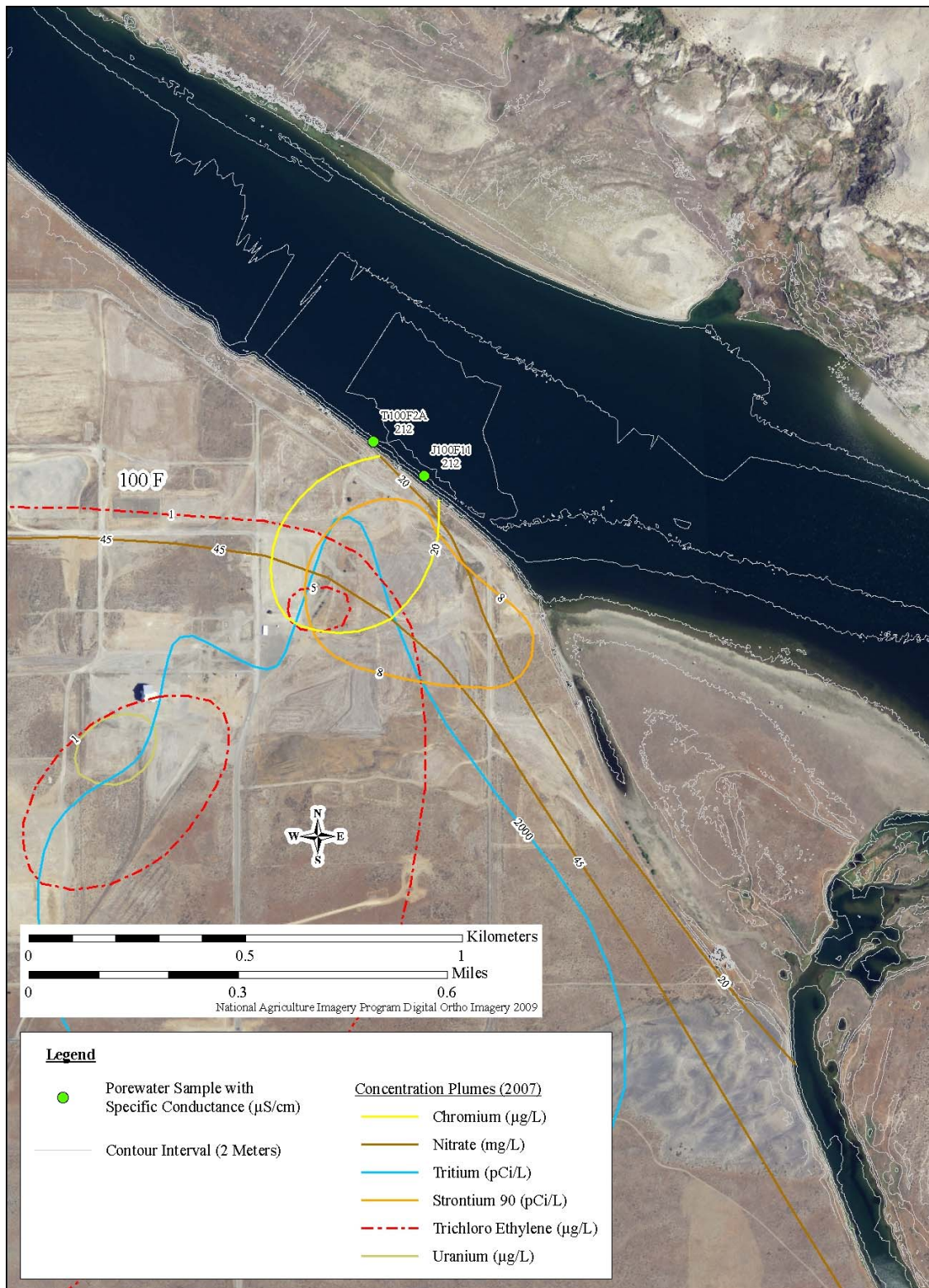
**Figure 3-65. Phase III Sample Locations Selected Near the 100-H Area and Pore Water Conductivity Measurements (Sheet 1 of 2).**



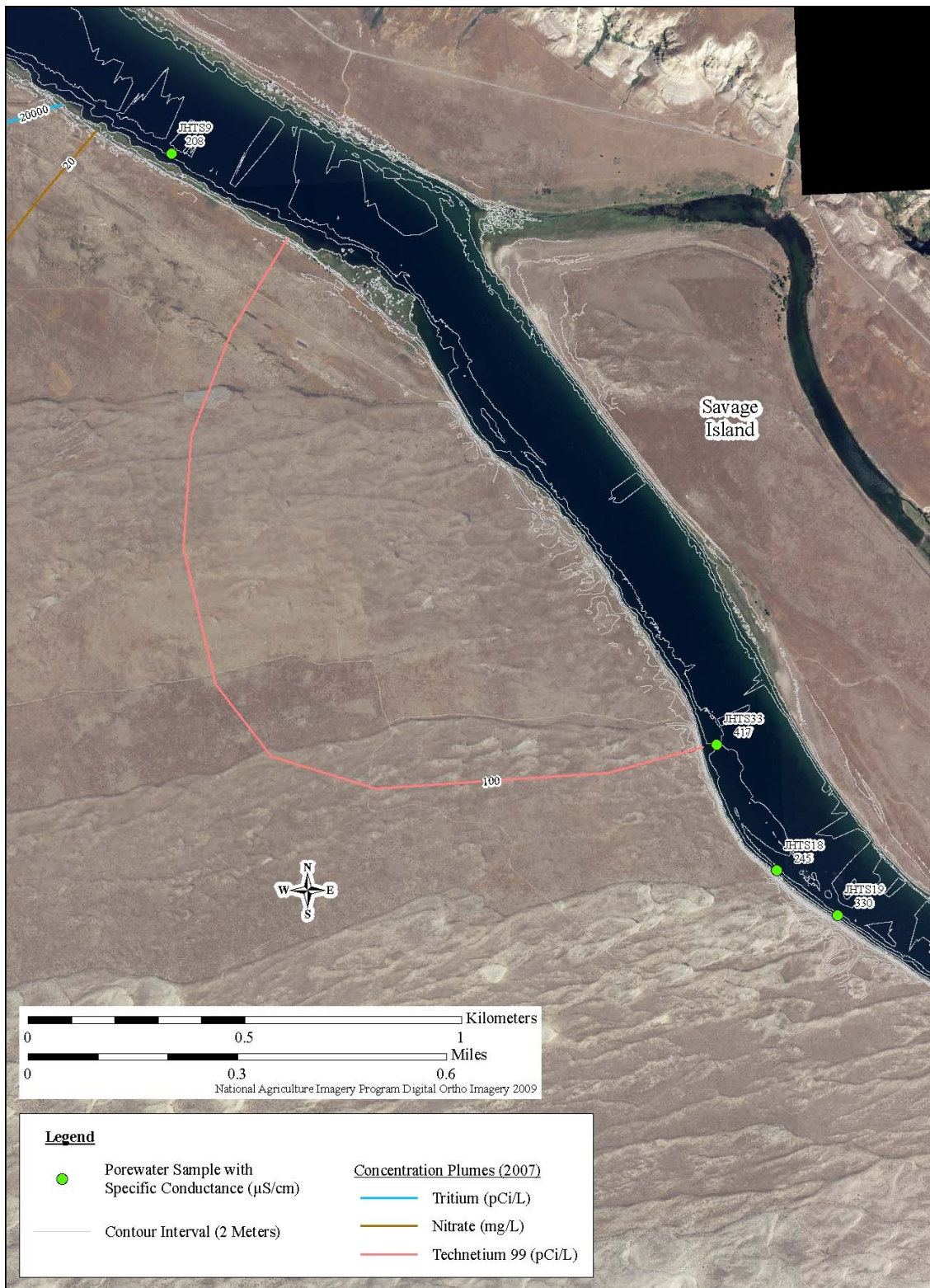
**Figure 3-66. Phase III Sample Locations Selected Near the 100-H Area and Pore Water Conductivity Measurements (Sheet 2 of 2).**



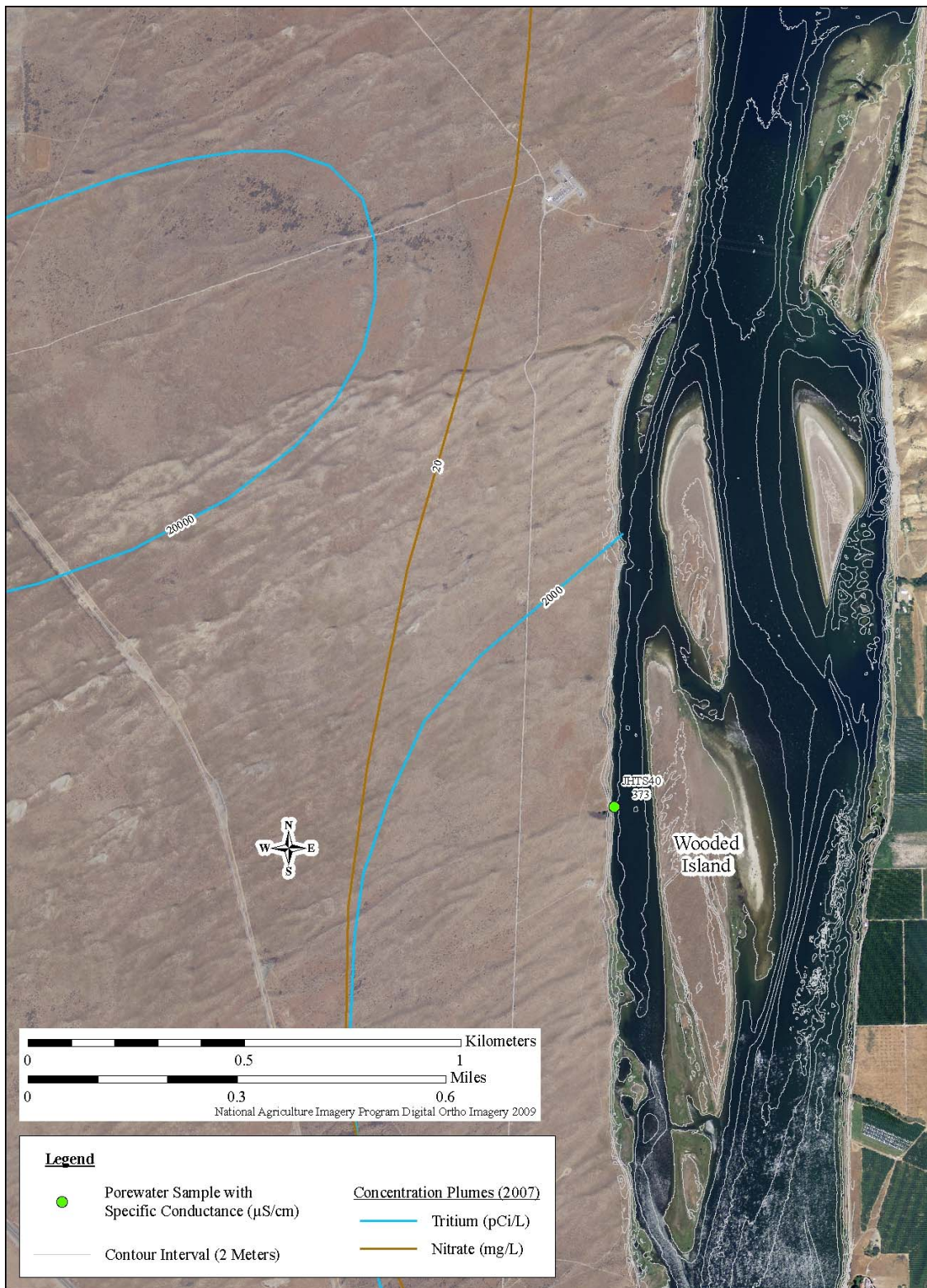
**Figure 3-67. Phase III Sample Locations Selected Near the 100-F Area and Pore Water Conductivity Measurements.**



**Figure 3-68. Phase III Sample Locations Selected Near the Hanford Townsite Area and Pore Water Conductivity Measurements (Sheet 1 of 2).**



**Figure 3-69. Phase III Sample Locations Selected Near the Hanford Townsite Area and Pore Water Conductivity Measurements (Sheet 2 of 2).**



**3.3.1.1.8 300 Area.** A total of nine sample locations were selected for Phase III sampling near Hanford townsite (see maps in Appendix H). The Phase III samples were collected near the 300 Area from January 11 through February 26, 2010. Pore water and surface water samples were collected at eight of the nine sites. One site (J30040) was not sampled because a pore water signal greater than 160  $\mu\text{S}/\text{cm}$  could not be found. Pore water conductivity values ranged between 304 and 1026  $\mu\text{S}/\text{cm}$  (Figures 3-70 and 3-71). Station T3005J5 yielded the maximum pore water conductivity (1026  $\mu\text{S}/\text{cm}$ ) value during Phase III and was located across the river from the 300 Area. This station was found to have approximately 27  $\mu\text{g}/\text{L}$  of uranium in the pore water during Phase II(b) with a similar pore water conductivity value as Phase III (Appendices H and F). No sample locations near the 300 Area were sampled when river levels were potentially suppressing or diluting the pore-water sample, but two sample locations were sampled when pore water conductivity was less than 90% of the Phase II(b) value (sample locations J30013 and J30016) (Appendix F).

Hexavalent chromium and total uranium were not detected in surface water, and strontium-90 and tritium were not analyzed for during Phase III in the 300 Area. Two minor detections of hexavalent chromium at 4 and 6  $\mu\text{g}/\text{L}$  were reported in pore water during Phase III. Total uranium detections were reported from a number of locations during Phase III over a range of 5 to 197  $\mu\text{g}/\text{L}$ . These reported values are consistent with concentrations reported during Phase II(b), which are also consistent with the known plumes in this area. Tritium was also detected over a range of 1,760 to 6,720  $\text{pCi}/\text{L}$  with the maximum found at station T3001J3.

**3.3.1.2 Sediment Sampling Summary.** Phase III sediment sampling commenced in January 2010 and continued through February 2010 in concert with the pore water and surface water sampling. A total of 44 samples were successfully collected from target stations. Additional details of the sediment sampling are summarized below. Appendix I provides a detailed summary of the sediment sample field records and photograph logs of the sediment samples.

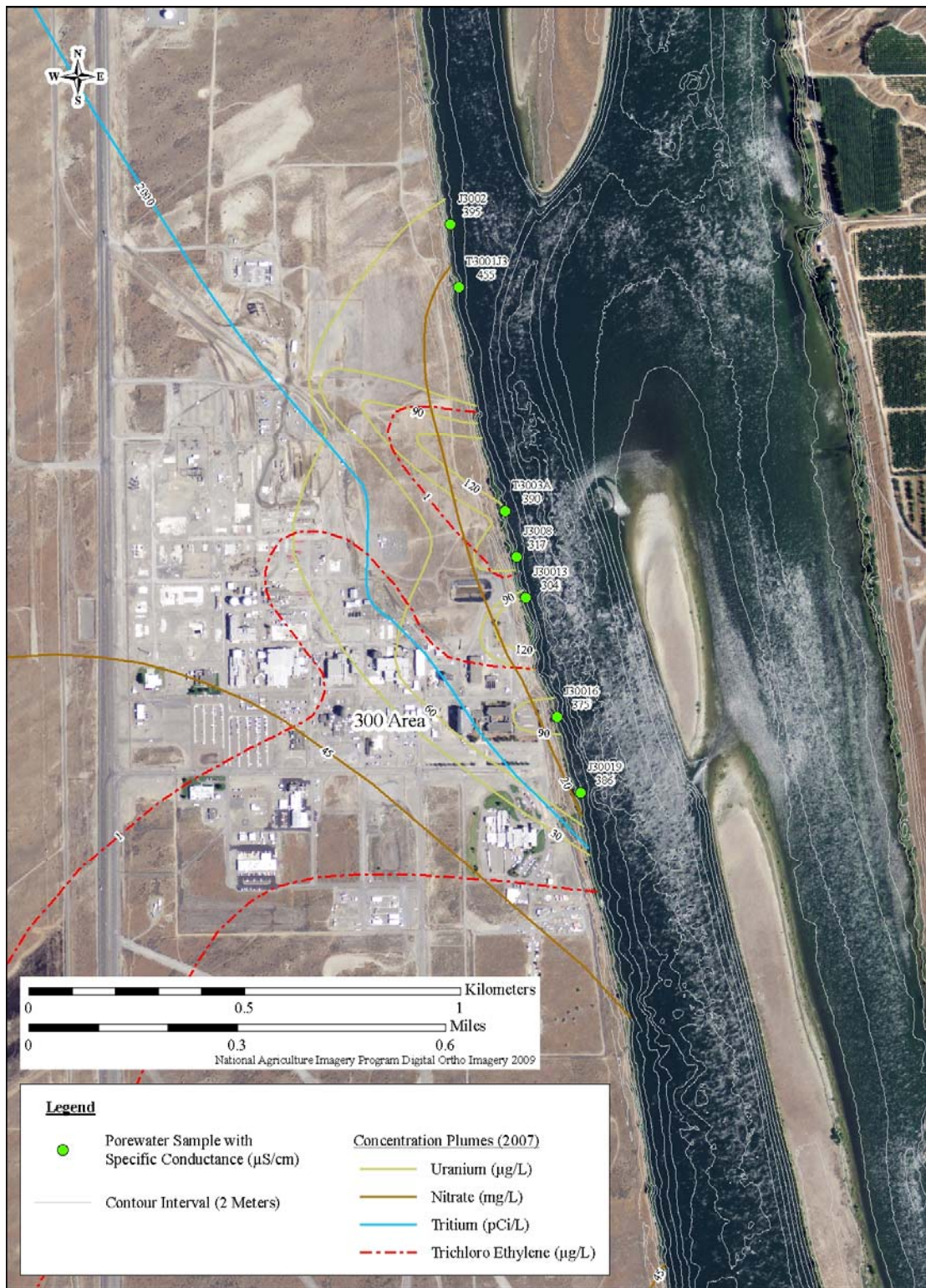
During sampling there were several stations (T100BC5C, T100BC6J10, and T100K2B) where insufficient sediment volumes were obtained. While most analyses could be performed this resulted in no sample material available to send to the laboratory for the acid volatile sulfides (AVS) and simultaneously extracted metals (SEM) analyses. At a number of other locations (stations T100D1A, JHTS40, J30013, and J30019) the initial radiological screening of samples indicated the presence of strontium-90, tritium, or uranium at levels exceeding background. This prevented sending these samples to the laboratory that performed the AVS/SEM analysis since they could not accept any samples above background levels.

**3.3.1.2.1 Core Barrel System.** The core barrel system successfully collected sediment 33 of 38 attempts (approximately 87% efficiency). There were three sites where core-barrel sampling was attempted but did not yield sediment: T100K1C; J100D36; and T100H2A (see Phase III maps in Section 3.3.1). Sites where sediment samples were obtained using the core barrel system are summarized in Table 3-7.

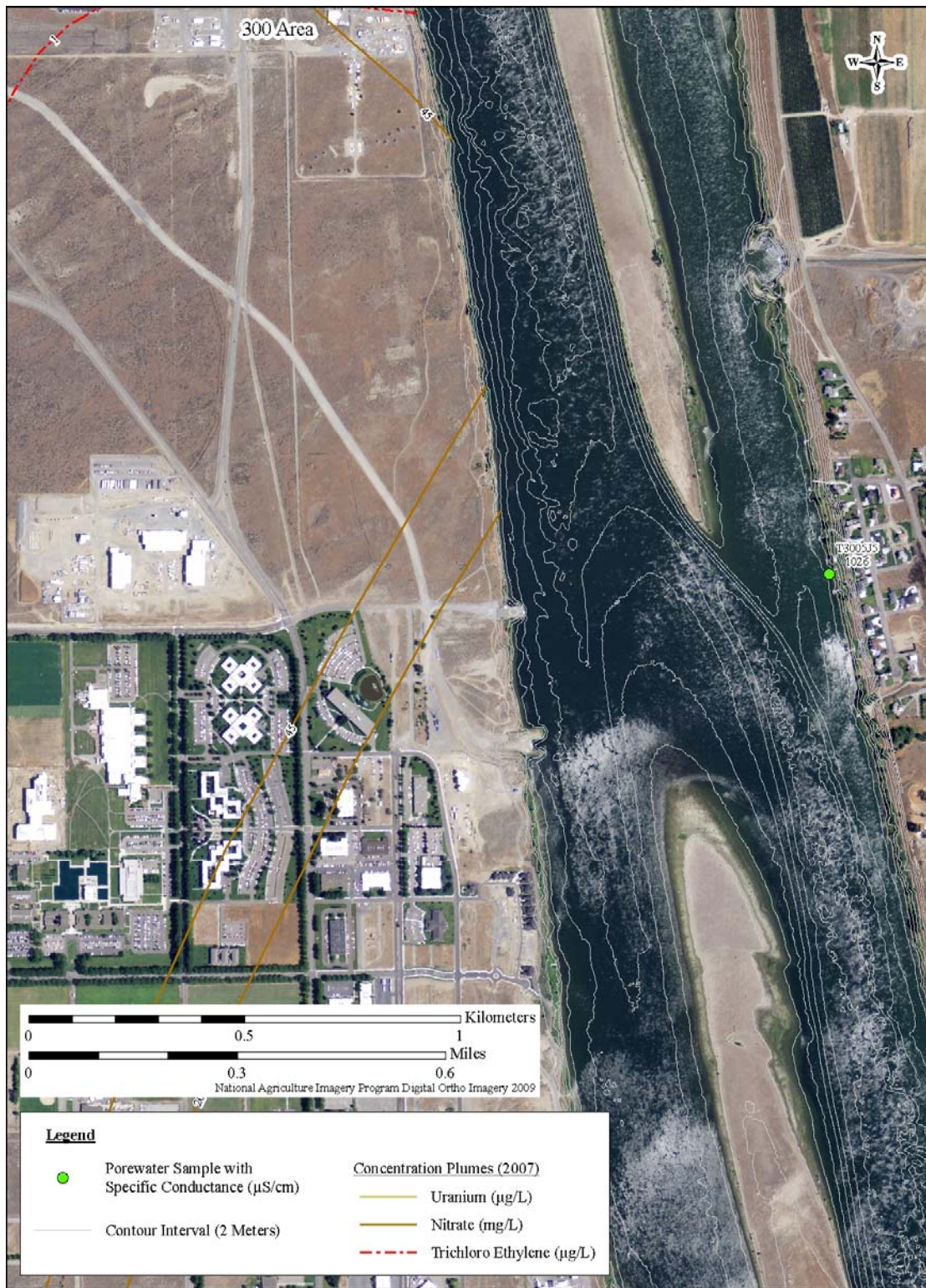
**Power Grab System.** During Phase III, the power grab system was deployed 25 times and successfully collected sediment on 11 of those occasions. The substrate at successful sites consisted almost entirely of sediment. Sites where abundant sediment was found and the power-grab system was used to obtain the sediment are summarized in



**Figure 3-70. Phase III Sample Locations Selected Near the 300 Area and Pore Water Conductivity Measurements (Sheet 1 of 2).**



**Figure 3-71. Phase III Sampling Locations Selected Near the 300 Area and Pore Water Conductivity Measurements (Sheet 2 of 2).**



**Table 3-7. Summary of Phase III Sites Where the Core Barrel System was Used to Collect Sediment.**

Study Area	Sample Location Identification
100-B/C	J100BC23, J100BC47, T100BC4A, T100BC6J10, T100BC5C, T100BC3C
100-K	T100K2B, T100K3A, J100K24
100-N	T100N1A, T100N2A, T100N3A, JT100N3A, T100N5RING
100-D	T100D1A, T100D2A, J100D39, J100D9
100-H	T100H1A, J100H43, J100H44, T100H6A
100-F	J100F11, T100F2A
Hanford townsite	JHTS18, JHTS19, JHTS33, JHTS9, JHTS40
300 Area	T3003A, J30016, J3008, J30019, J30013

Table 3-8. These samples were typically also used for QA/QC sample collection as more sediment material was available at these sites.

**3.3.1.2.2 Analytical Results.** Sediment samples obtained during Phase III sampling underwent a broad suite of analyses as defined in the Work Plan and SAP (DOE/RL-2008-11). The following discussions focus on only the indicator contaminants utilized during Phase II(b). The remaining analytical results will be presented in a different document.

Hexavalent chromium was detected in bulk sediment at concentrations ranging from 0.2 to 4.7 mg/kg with the highest concentration found in the 100D Area at station T100D3A. Uranium was detected in two sediment samples at the 300 Area but the results were qualified as “B” which indicates that the reported value was less than the method reporting limit. Strontium-90 was detected at both the 100K and 100N Areas within a range of 0.4 to 1.1 mg/kg. Tritium was detected only once in sediment at a value of 11.3 mg/kg from the HTS Area station JHTS33.

This information is a small subset of all of the samples collected during the remedial investigation of Hanford Site releases to the Columbia River. In particular it is worth noting that hexavalent chromium was detected in sediment samples at numerous locations, including sites along the left bank within the Hanford Reach and at several sites in the Snake, Walla Walla, and Yakima rivers. Further discussion of these samples can be found in WCH-352 and the subsequent risk assessments that are being prepared to support the remedial investigation.

### 3.3.2 Phase III River Stages Encountered

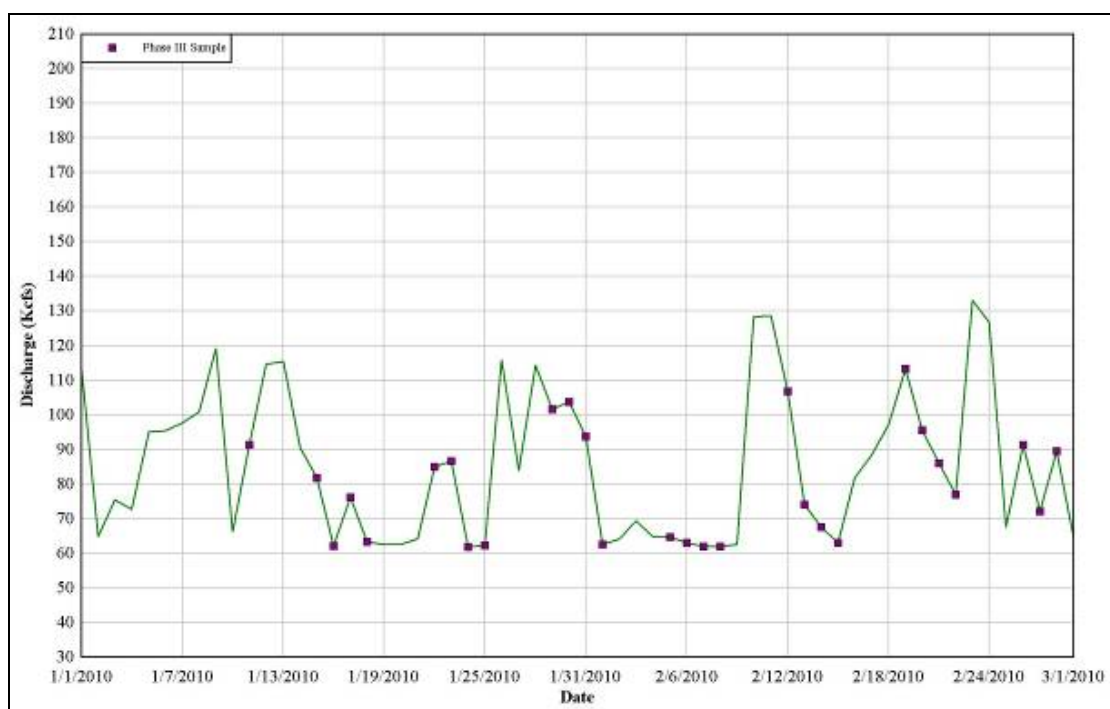
River stage guidelines established during Phase II(b) were used during Phase III sampling events also. A general depiction of the daily average river flows encountered on days when Phase III samples were collected is given in Figure 3-72. River stage qualifiers are also listed in Appendix F master summary data tables. Generally, river stages were less variable during Phase III as compared to Phase II(b) (see Figure 3-58). During Phase III, a total of 18 sample locations were sampled when river levels were potentially suppressing or diluting the pore-water sample. Eleven sample locations were sampled when pore water conductivity was less than

90% of the Phase II(b) value, and most importantly, a total of seven sample locations were sampled when both of river stage guidelines were not met (see Appendix F for details).

**Table 3-8. Summary of Phase III Sites Where the Power Grab System was Used to Collect Sediment.**

Study Area	Station Identification
100-B/C	T100BC1J1, T100BC1J5, 2A-A
100-K	KWIN Test 1, K Intake Test 3A
100-N	N Outfall
100-D	T100D3A
100-H	T100H1E
300 Area	T3005J5, T3001J3, J3002

**Figure 3-72. Overview of Daily River Discharge (Kcfs) at Priest Rapids Dam During Phase III.**



### 3.4 DEVIATIONS FROM THE SAP

Deviations from the field sampling plan were sometimes necessary for safety, technical, or logistical reasons. Although groundwater upwelling mapping and sampling efforts required in the SAP were largely adhered to, a few activities were modified. A number of these (e.g., not being able to collect Phase II(b) samples due to excessive water currents) are described in other sections of the text specific to the study area and phase of the work. A few general deviations from the SAP are noted below:

- The SAP identified river discharges between 80 and 120 Kcfs as acceptable levels during sampling. Groundwater mapping efforts (Phase II[a]) were allowed to take place when river discharges ranged up to approximately 160 Kcfs. Information gathered during the study indicated that groundwater upwellings could still be detected in most regions when flows were as high as 160 Kcfs.
- Many of the Phase III sediment samples were collected using a stainless steel split spoon core barrel device fitted to the Trident probe driving frame. The SAP called for a power-grab sampling technique, however, the rocky riverbed characteristic of most sample locations limited the success of power grab techniques to recover enough sediment for analyses. Appendix B provides more discussion on this subject.
- The SAP specified that at least one location on each transect line in a study area would be included as a Phase III sample station. Results from Phase II(b) sampling and discussions with the Tri-Parties ultimately guided the final selection of the Phase III sample locations. Section 1.4 and Appendix J provide more details on this process.



## 4.0 GENERAL CONCLUSIONS

This report summarizes the field work associated with one of the components of the remedial investigation of Hanford Site releases to the Columbia River. The focus of this component was to delineate areas where contaminated groundwater is upwelling (emerging) into the Columbia River bottom within the Hanford Reach area and to determine concentrations of radionuclides, trace metals, and organic compounds in sediment, pore water, and surface water at those locations. The sample results will be added to other results from samples collected during the RI to develop a conceptual site model of contaminant distribution throughout the section of the Columbia River that comprises the RI study area. Results will be utilized in both ecological and human health risk assessments to determine the risk to users of the Columbia River attributable to releases from Hanford Site operations.

Development and application of the Trident Probe and its associated equipment and other tools resulted in a technique to successfully and safely measure pore water conductivity and temperature in the environment of the Columbia River. Use of these parameters was effective in determining areas where upwelling was occurring. A phased approach, coupled with use of the sampling equipment associated with the Probe, proved to be a cost effective means of gathering necessary analytical data to determine where contaminated groundwater was entering the river. Subsequent sampling of sediments at these locations, with the assistance of a modification to the Trident Probe, proved to be a valuable approach to retrieval of sufficient sample material to complete the required analyses.

Inherent to the development and application of the equipment during the project was the establishment of quality controls to minimize impacts due to changing river stages and possible introduction of river water into the pore water samples. Use of these controls throughout the project reduced uncertainty associated with data comparability.

Application of these techniques and quality controls in the field at each of the eight study areas resulted in the development of an enhanced understanding of how groundwater upwelling is occurring throughout the Hanford Reach. Contributing factors such as river bathymetry, river depth, groundwater hydraulic gradients, varying river bottom substrates and geologic formations, and proximity to known agricultural water drainages all play a role in developing a conceptual model of how groundwater contamination from the Hanford Site may be impacting the Columbia River.

Over the duration of the work there were a number of unique observations that became apparent. These included:

- Identification of hexavalent chromium in pore water at locations in the river adjacent to the 100 B/C area where previously unknown
- Confirmation of the presence of groundwater emanating from the right bank (Hanford shoreline) as well as from the left bank and the middle of the river channel
- Presence of preferential pathways for groundwater upwelling into the river, as demonstrated at several of the reactor water intake structures and deep water channels, and subtle movement of these pathways with changing conditions

- Presence of areas of high volume discharges as seen in some areas where surface water measurements one foot above the river bed were exhibiting influences from the upwelling groundwater and high temperature differences between the porewater and surface water
- Variability of the groundwater discharge with fluctuations in daily river levels (i.e., bank recharge) as well as seasonal variations (fall versus spring) with impacts on conductivity as well as contaminant concentrations
- Impacts on pore water conductivity due to the presence of varying types and amounts of substrates (e.g, cobbles versus sands)
- Extended mapping of groundwater plume contours into the river with respect to contaminants such as hexavalent chromium, strontium-90, uranium, and tritium via the presence of these contaminants in pore water
- Identification of hexavalent chromium in pore water at locations within the Hanford Townsite study area where previously unknown
- Importance of applying quality controls during measurements to assure consistency across lateral as well as temporal extents
- Use of river staff gauges in the field to monitor daily fluctuations in river levels by field crews from nearby sampling stations
- Presence of hexavalent chromium in pore water at locations with corresponding concentrations in bulk sediment samples and implications for possible sediment transport
- Use of underwater photography to distinguish features not readily available from the surface, such as changes in lithology or the presence of disturbed areas
- Need for “hardened” equipment that is suitable for use in high volume currents and rocky riverbeds
- Need for experienced river boat captains and field teams familiar with the conditions found in the Columbia River in order to safely perform the work

Combining the data obtained from the groundwater upwelling studies with the additional data (sediment, surface water, soils, and fish) gathered during the RI (as reported in WCH-352) is an ongoing task being performed as part of the development of the ecological and human health risk assessments that will be completed for the Columbia River.



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