A Conceptual Site Model for Nature and Extent of Contamination in a Riparian-Near Shore Area -
12410

Donna Morgans*, John Lowe**, Chris McCarthy**, and Alaa Aly***

*CHPRC and FLUOR Government Services, Richland, Washington 99354
**CH2M HILL, Richland, Washington 99354
***CHPRC and INTERA Incorporated, Richland, Washington 99354

ABSTRACT

The 100-K decision area is located along the Columbia River and includes source Operable Units (OUs), a groundwater OU, and the adjacent surface water, saturated sediment and aquatic biota. A conceptual site model (CSM) has been developed to evaluate concentrations of non-radiological substances and radionuclides detected in soil, water and sediments in a riparian near-shore area along the Columbia River. The CSM is used to determine if potential transport pathways exist to these media from Hanford Site sources by incorporating information from the physical system, surface hydrology, subsurface hydrogeology, analytical results, and ecological evaluation into the model. Six contaminants of ecological concern, mostly metals and non-radiological inorganics, have been identified in riparian and near-shore media. With few exceptions (notably chromium and hexavalent chromium), there are ambient sources for these constituents in soil, sediment and water that are unrelated to the Hanford Site. While the CSM documented analytical and biological conditions, this paper presents results focused on analytical measurements to document the potential for these contaminants to be related to a release from the Hanford Site.

INTRODUCTION

The 100-K decision area is situated between the 100-BC Area and 100-N Area and borders the Columbia River. Topography changes are greatest in the vicinity of the river. Away from the river, the 100-K decision area is characterized by low relief and gentle slopes. The operational area within the perimeter fence has been disturbed and graded extensively by human activity since reactor construction began in the 1950s through present-day waste site remedial activities [1], [2].

The entire River Corridor, which includes the 100-K decision area, has been divided in three environmental zones for purposes of investigation [3], [4] the upland, riparian and near-shore aquatic zones. With the exception of one area of remediated waste sites (includes the 116-K-2 trench) that extends 1.5 km northeast from the perimeter fence, the upland area outside of the fence is relatively undisturbed. Spatial data provided by the Ecological Monitoring and Compliance program shows that vegetation to the east, south and west of the perimeter fence consists primarily of three vegetation types: Sandberg’s bluegrass-cheatgrass, gray rabbitbrush/Sandberg’s bluegrass-cheatgrass, and small patches of big sagebrush/Sandberg’s bluegrass-cheatgrass. Wildlife species observed in this area also are described by [2].

The riparian environment adjacent to the 100-K Area extends in a strip along the Columbia River to the north and slightly west of the facility. The strip varies in width from a narrow zone (50 to 75 meters) lying north of the eastern end of the 100-K Area to a wider zone (150 to 200 meters) at the westernmost portion of the facility near the river [2].
Remediation of waste sites in the 100-K decision area has been ongoing since 2002 [1] based on an interim action Record of Decision (ROD) [5]. Remediation of contaminated groundwater also has been ongoing at the 100-KR-4 OU under an interim action ROD [6].

A key component needed to support development of final remedies is a baseline risk assessment. The River Corridor Baseline Risk Assessment (RCBRA) was initiated in 2004 to characterize current and potential threats to human health and the environment [7]; [3]. In addition to waste sites located in upland areas and groundwater, the RCBRA evaluated soil, sediment and water located in riparian and near-shore areas. Further, the ecological risk assessment conducted as part of the RCBRA addresses residual contaminant concentrations at remediated waste sites in the upland zones and the transport of contaminants from waste sites to the Columbia River riparian and near shore zones [4].

The RCBRA evaluated ecological risks at representative riparian study sites located adjacent to, or where they may be directly affected by, known contaminated media (groundwater seeps, soil, or sediment). The RCBRA evaluated ecological risks at near-shore study sites potentially affected by contamination from Hanford Site sources in comparison to reference sites. Study sites were selected in areas where known contaminated groundwater plumes enter the Columbia River and in areas between the plumes [3]. Based on multiple lines of evidence, including soil bioassays, plant or terrestrial invertebrate toxicity benchmarks, and the results of wildlife exposure analyses, the RCBRA concluded that six of the 22 contaminants of potential ecological concern (COPECs) identified for the riparian and near-shore environment may present some level of risk for one or more of the assessment endpoints.

The six contaminants of ecological concern (COECs) identified in riparian and near-shore media mostly were metals and non-radiological inorganic constituents. With few exceptions (notably chromium and hexavalent chromium), there are ambient sources for these constituents in soil, sediment and water that are unrelated to the Hanford Site. Taking into consideration what is understood to be principal threat constituents in soil and groundwater at the 100-K decision area, compared with the contaminants identified by the RCBRA as posing ecological risks in riparian and near-shore media, additional analyses are summarized to provide better understanding of the CSM – the interrelationships between sources, transport mechanisms, exposure pathways and receptors – in the riparian and near-shore environment.

**CONCEPTUAL SITE MODEL DEVELOPMENT**

The objective for developing this CSM is to provide a tool for evaluating the potential for contaminants in riparian and near-shore media to be associated with releases from Hanford-related sources. The foundation for developing the CSM begins with the definition of environmental zones presented in the RCBRA [3]. These environmental zones (depicted in Figures 1 and 2) are:

- **Near-shore aquatic zone**: the near-shore aquatic zone includes the surface water of the Columbia River from the area that is permanently inundated by river water (i.e. the low-water mark, commonly referred to as the “green line”, where the periphyton remain green year-round) up to the riparian zone.
- **Riparian zone**: the riparian zone is a transition area between the aquatic environment in the near-shore zone and the upland zone. The riparian zone extends from the shoreline of the Columbia River to the point on the riverbank where upland vegetation becomes dominant. The riparian zone typically is narrow and varies in width depending on the slope of the riverbank.
- **Upland zone**: the upland zone consists of land that extends inland from the riparian zone and is situated approximately 3 m (10 ft) above the river high-water mark. The upland zone generally is dry and not readily influenced by river flow. Recharge to groundwater in this zone occurs largely from precipitation. The upland zone includes operational areas in the 100 Area decision areas and generally is where waste sites are located.
Figure 1. Environmental Zones in the Riparian/Near-Shore Area

Figure 2. Photograph Depicting the CSM Environmental Zones

Potential exposure pathways from source Operable Units (OUs) and the underlying groundwater OU located in the upland zone have been traced to media in the riparian and near-shore zones. An exposure pathway can be described as the physical course that a contaminant takes from the point of release to a receptor. The route of exposure is the means by which a contaminant comes into contact with a receptor. For an exposure pathway to be complete, all of the following components must be present:

- A source
- A mechanism of contaminant release and transport
An environmental transport medium
An exposure point
An exposure route
A receptor or exposed population

In the absence of any one of these components, an exposure pathway is considered incomplete and, therefore, creates no risk or hazard.

An additional consideration for contaminants detected in riparian and near-shore zones is a contaminant source, or sources, unrelated to Hanford Site operations that have been transported and deposited via the river. These other sources as well as potential exposure pathways in the riparian and near shore areas were considered in this CSM.

Once the potential exposure pathways are identified and described, sampling and analytical data from various media are evaluated. The objectives for this evaluation included depicting the relative concentrations in the various riparian and near-shore media and evaluating data quality. Media in the riparian and near-shore areas that have been sampled include: groundwater, seeps, surface water, sediments, biota and soil. The results from this data evaluation are combined with the exposure pathway information (described previously) to determine if contaminant concentrations located at exposure points are potentially associated with Hanford Site activities.

An evaluation of potential ecological risks in riparian and near-shore zones was conducted as part of the RCBRA [3]. These results, which identified contaminants of ecological concern (COECs), are compared with the results from the data evaluation below to determine if those COECs might be associated with Hanford Site activities.

The site conceptual model needs to clearly include the transient nature of water exchange in this setting at multiple time scales. For example, a daily 3-m change in river levels superimposed with seasonal changes or alterations of site groundwater flows by remediation efforts likely causes seasonal shifts in the regional groundwater flow system that will consequently impact groundwater surface water exchange locations and rates. The complex geologic setting, aquifer heterogeneity, and transient nature of the surface water and groundwater results in a complex groundwater flow system. During major spring discharge events, river water may enter the banks and the adjacent groundwater system upstream of the Site and move laterally parallel to the river for some distance before discharging back into the river [8].

CONTAMINANT RELEASE AND TRANSPORT MECHANISMS

Release and transport mechanisms potentially most likely associated with the occurrence of Hanford Site contaminants in riparian and near-shore zones are overland transport from waste sites, and contaminant leaching from the vadose zone to underlying groundwater, followed by lateral transport in groundwater.

Overland Transport from Waste Sites

Hazardous and radioactive substances that are in surface materials can be transported away from facilities or known waste sites by surface runoff following precipitation events. Overland flow is water flow over the ground surface that occurs from precipitation, either rainfall or snowmelt that is greater than abstraction demands (interception, evapotranspiration or infiltration). In addition, overland flow can occur from the spillage of process waste that historically had been discharged into liquid waste disposal units. Factors that affect overland flow include topography, soil texture and vegetative cover, and frequency of precipitation. The Hanford Site is in a semiarid region and precipitation is more than balanced by
evaporation and transpiration such that substantial overland flow from precipitation is an unlikely occurrence. A more likely source for overland flow is spills or releases from liquid waste disposal facilities. Examples of overland flow at 100-K riparian sites include flows from various retention basins and erosion of the mile long trench over time. Because of the location of these basins being less than 1,000 ft from the shoreline, effluent leaked into the Columbia River [9].

**Contaminant Leaching from Waste Site Soils to Groundwater**

Contaminated wastes released from reactor support facilities, cooling water processing facilities, underground piping, liquid waste disposal sites, solid waste disposal sites, and surface spills were primary sources of contamination in 100-K during operations and secondary sources may have developed in vadose zone and aquifer materials. The potential for transport of contaminants within the vadose zone and aquifer at 100-K is affected by historical high volume liquid waste disposal during operations on vadose zone moisture and the water table, the development of secondary sources of contamination in the vadose zone material, groundwater/surface water interactions, and the effect of Columbia River stage fluctuations on contaminant transport.

One concept important to understanding contaminant fate and transport in the study area is the difference between site conditions during Hanford operations (1955 to 1971) and the current site conditions, which have developed since reactor operations ended. During operations, large volumes of reactor cooling water, containing water treatment chemicals (e.g., Cr(VI), sulfate, aluminum, etc.) and radionuclides (activation and fission products), were temporarily stored in retention basins prior to discharge to the Columbia River. The retention basins began leaking water to the 116-K-2 Trench. Additional releases of contaminants occurred at other operating areas; burial grounds received wastes containing mobile contaminants that may have leached to groundwater. Reactor cooling gas condensate cribs received condensed gases containing C-14 and other nuclides. Cooling water treatment plants released concentrated sodium dichromate solutions at various times via planned and unplanned releases. Leakage from spent fuel storage basins released radioactive and non-radioactive contaminants to the vadose zone where some migrated to underlying groundwater. Under current conditions, most of the high volume liquid effluent releases ended when reactor operations ceased in 1971. Secondary sources of contamination may remain at both un-remediated and remediated waste sites due to sorption to vadose zone material.

**Transport in Groundwater**

Groundwater flow and contaminant transport in the unconfined aquifer is also affected by Columbia River stage fluctuations. The increase in the river stage during the spring freshet pushes water inland and causes water table elevation increases throughout the area. Consequently, the hydraulic gradient is altered and less water flows into the river from the aquifer. During the low river stage in the fall, groundwater flow toward the river dominates. Depending on the location within the study area, direction variability in flow occurs because of these competing influences.

The groundwater system is highly dynamic being influenced by regional groundwater conditions, the local site remediation efforts, and the daily and seasonal variations of river stage. The main features of the current conceptual model are:

- Flow under the site and near the banks is generally assumed to be perpendicular to the river.
- Deeper geologic formations are assumed not to contribute to shallow groundwater or observed river exchanges along the river bank.
- The daily variability of river stage creates a complex zone of mixing within the near-bank groundwater system.
• Springs observed on the river banks are attributed to bank storage of river water and site groundwater discharging to the river when river stage drops.
• Site groundwater generally discharges to the banks via springs and through the bottom of the Columbia River immediately adjacent to the Site.

The site conceptual model needs to clearly include the transient nature of water exchange in this setting at multiple time scales. For example, a daily 3-m change in river levels superimposed with seasonal changes or alterations of site groundwater flows by remediation efforts likely causes seasonal shifts in the regional groundwater flow system that will consequently impact groundwater surface water exchange locations and rates. The complex geologic setting, aquifer heterogeneity, and transient nature of the surface water and groundwater results in a complex groundwater flow system. During major spring discharge events, river water may enter the banks and the adjacent groundwater system upstream of the Site and move laterally parallel to the river for some distance before discharging back into the river [8].

EXPOSURE POINTS

The RCBRA [3] defined the study zones to be the upland, riparian, near-shore aquatic zone, and aquatic zones as a vertical panel that extends down from the surface into the subsurface to some undetermined depth when, in reality, they are three-dimensional zones that change size over time. In particular, it is the vertical distribution of the receptors beneath the river and in the deposits adjacent to the river that potentially has the greatest implications for remedial actions, because the mechanisms of dilution and mixing of groundwater may not be as effective at greater depths and so there is greater potential for exposure to contaminants from groundwater.

In the studies of the Columbia River at the Hanford Site, the term hyporheic zone has been used as a general term to describe the zone of all groundwater and surface water mixing. Receptors in the riverbed and benthic and hyporheic zones can be exposed to contaminated (1) groundwater, (2) groundwater surface-water mixtures, or (3) surface water. These distinctions become important when identifying from analytical results in groundwater and surface water contaminants of potential ecological concern that are related to Hanford Site operations.

Investigation of riparian area soils was conducted as part of the RCBRA. The riparian assessment evaluated ecological risks at 18 study sites potentially affected by contamination from Hanford Site sources. Eleven study sites were selected from locations that may be adjacent to or directly affected by known contaminated media (groundwater seeps and springs, soil, sediment). These sites were located along the Columbia River shoreline near the operating areas (100-B/C, 100-K, 300 Area, etc.) and included six sites with relatively elevated contaminant concentrations and five sites with relatively low contaminant concentrations. Historic data and radiation surveys were used to determine the general contaminant levels at each site. Two of these riparian study sites were located near the 100-K decision area:

• **Riparian 2c.** This investigation area was located ~100 m downstream of the old Hanford townsite water intake (historic pumphouse) and just upstream of a major peninsula known as Coyote Rapids. Scattered metal debris was common throughout the site, and a small road that had been used extensively by Hanford Site personnel crossed a small portion of the upper end of the investigation area. This site’s average dimensions were 30 m by 200 m, but the widths varied from ~20 m to ~70 m and encompassed a total of approximately 4,600 m² of shoreline habitat. This site was also located in a relatively high depositional environment, and widened substantially near the downriver end. The site consisted of sediment-covered cobbles and a moderate cover of reed canary grass and other associated riparian taxa. Mulberry (*Morus spp.*) trees bounded the upper regions on nearly half of the investigation area. This site is located upstream of the 100-K decision area.
Riparian #5. This site is located ~0.5 km downstream of the 100-K East water intake structure. The shoreline boundary consists of a series of small points and bays with lightly scattered vegetation consisting of largely forbs and a few scattered short-statured mulberry (*Morus* spp.) trees. The substrate is predominantly large cobbles and boulders, with very little sediment/soil matrix visible on the ground surface. The average width of the site was ~17 m, and ranged from ~9 m to ~26 m at each end and in the center of the 200 m transect. The site encompassed ~4,500 m$^2$.

Soil samples represented surface soils of the 0- to 15-cm (0 to 6 in) depth interval using a systematic random design across a 200-m (656 ft)-long investigation area. The contaminants reflected in these soil samples include inorganics (metals), organic compounds including polycyclic aromatic hydrocarbons, phthalates and chlorinated pesticides, and radionuclides. Inorganics in riparian soil in the 100-K area that had been identified as COPECs in the RCBRA and that were evaluated further were: arsenic, barium, cadmium, chromium, hexavalent chromium, copper, lead, mercury and zinc. Organic compounds detected in 100-K soils were not identified as COPECs in the RCBRA with the exception of bis-2-ethylhexyl phthalate. Radionuclides were not identified as COPECs, however radionuclides detected in riparian area soils included C-14, Cs-137, Sr-90, Tc-99 (in a single replicate), and uranium isotopes. Biota sampling conducted in these sites is described in detail in the RCBRA [3].

Near-shore study sites sampled as part of the RCBRA in 2005 were located within three key contaminant plumes originating from Hanford Site operations (hexavalent chromium at the 100-K and 100-D Areas, strontium-90 at the 100-N Area, and uranium at the 300 Area, [10]. Ten additional study sites sampled in 2006 were located in selected regions where Hanford’s legacy materials were known or suspected to have been deposited. Study sites located in proximity to the 100-K site are summarized below:

- **Near-Shore Sites Cr1 Through Cr4.** Chromium sites 1 through 4 were located between 100-K and 100-N in permanently inundated areas where groundwater upwelling was also known to persist. The river was relatively symmetric with no adjacent islands or backwater channels there. The substrate consisted of moderately embedded gravels and cobbles. All sites were located in areas with no current when flows were about 70,000 cfs. Chromium site 3 was subjected to slightly more river flow than the other sites described in this area. The low water velocities at this site coupled with highly embedded substrates made it unsuitable as steelhead spawning habitat.

- **Near-Shore Site 2c.** This investigation area was located about 100 m downstream of the old Hanford townsie water intake (historic pump house), and just upstream of a major peninsula known as Coyote Rapids. This site was also located in a highly depositional river environment. The substrate generally consisted of gravels that were heavily embedded. A small macrophyte population persisted near this area.

Sediment, porewater and surface water samples were collected from these sites. Further discussion of these data is incorporated into the data evaluation presented below. Biota sampling performed at these sites is described in the RCBRA [3]. Contaminants detected principally in the sediment, porewater and surface water samples were inorganics and radionuclides.
GROUNDWATER ANALYTICAL DATA EVALUATION

Analytical data collected from the riparian and near-shore zones were evaluated to focus on the COPECs that could be related to Hanford Site operations. This data evaluation encompassed groundwater (characterized by near-river wells and aquifer tubes), seeps, surface water, sediments and riparian soil data, obtained from a range of Hanford Site sources. These sources included groundwater monitoring activities documented in the Annual Groundwater Monitoring reports, sampling of sediments, seeps and surface water conducted as part of the Surface Environmental Surveillance Program (SESP), and sampling of sediments, seeps, surface water and riparian soils conducted as part of the RCBRA.

These analytical results were compared with ecological benchmarks and criteria to confirm whether or not these should be identified as COPECs. Analytical data quality, in particular filtered versus unfiltered analyses of water samples, was taken into consideration in making the comparisons with benchmarks and criteria. The spatial relationships of contaminants concentrations in surface water, pore water and groundwater were evaluated to address considerations of whether or not detected contaminants were related to Hanford Site operations (i.e. originated from upland groundwater sources) or reflected ambient background conditions.

Data Sources and Processing

The data set used in this evaluation consisted of sampling and analysis data collected from 25 near shore monitoring wells, 69 aquifer tubes, five seep/spring locations, four pore water locations, and five surface water locations within the boundaries of the 100-KR-4 OU. A list of the near shore wells and aquifer tubes used in this evaluation is provided in Table 3-1 of the RCBRA [3]. Seep/spring, pore water and surface water sampling locations are based on sampling locations identified in the RCBRA. Figures 3-1 and 3-2 of the RCBRA show the locations for each type of water media.

The data set used in this evaluation was obtained from the Hanford Environmental Information System (HEIS) and included the following types of information:

- Analytical results from both unfiltered and filtered samples
- Data qualification and data validation flags, including rejected results
- Results for a given analyte reported by more than one analytical method
- Parent, field duplicate, and field split sample results

The analytical data were processed to eliminate unusable results and thus identify one set of results per sampling location and date of sample collection.

Finally, action levels were used for comparison with analytical results in water to identify COPECs, and were derived from available sources of chemical-specific ARARs and default exposure assumptions. For use in identifying COPECs, the action level was selected from lowest of the available values for protection of aquatic receptors from federal and state chemical specific ARARs.

Identification of Initial Contaminants of Interest

After extracting and processing the groundwater analytical data set, a multi-step screening process was used to identify initial contaminants of interest. The steps were:

- Apply exclusion criteria: The single exclusion criterion used was the absence of toxicity information for an analyte – if there were no aquatic criteria available, that analyte was not carried into the next step of the data evaluation.
- Identify nondetected analytes: Chemicals and radionuclides that have been analyzed for, but not detected in any sample (collected from appropriate locations, with adequate detection limits), are
eliminated as contaminants of interest. All analytes detected at least once were carried forward to the next step.

- Identify analytes with maximum detected concentrations less than their respective action levels: If the maximum detected concentration of an analyte was less than its action level, the analyte was eliminated as an initial contaminant of interest.

At the end of this process, any analyte is identified as an initial COPC if its maximum detected concentration exceeds its action level. Uncertainty analyses are conducted for these analytes to confirm whether they should be retained as final COPCs. Table 1 provides a summary of the analytes with maximum detected concentrations greater than their respective action level for each water media.

<table>
<thead>
<tr>
<th>Table 1. Summary of Analytes with Concentration Greater than Action Level</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Near Shore Media</strong></td>
</tr>
<tr>
<td>Aluminum</td>
</tr>
<tr>
<td>Copper</td>
</tr>
<tr>
<td>Lead</td>
</tr>
<tr>
<td>Selenium</td>
</tr>
<tr>
<td><strong>Aquifer Tube Media</strong></td>
</tr>
<tr>
<td>Aluminum</td>
</tr>
<tr>
<td>Iron</td>
</tr>
<tr>
<td><strong>Pore Water Media</strong></td>
</tr>
<tr>
<td>Aluminum</td>
</tr>
<tr>
<td>Methoxychlor</td>
</tr>
<tr>
<td><strong>Seep/Spring Media</strong></td>
</tr>
<tr>
<td>Aluminum</td>
</tr>
<tr>
<td>Copper</td>
</tr>
<tr>
<td>Mercury</td>
</tr>
<tr>
<td><strong>Surface Water Media</strong></td>
</tr>
<tr>
<td>None</td>
</tr>
</tbody>
</table>

**Uncertainty Analyses for Initial COPCs**

Analytical results were aggregated across the various media to provide a profile of concentrations for individual contaminants. For example, Aluminum concentrations in the near shore media reported 10 non-filtered concentrations greater than the action level. Filtered concentrations in the near shore media reported four detections greater than the action level, two of which were reported in the laboratory method blank. Unfiltered concentrations were reported at concentrations greater than the action level in aquifer tube, pore water, and seep/spring media. Filtered concentrations were reported at concentrations less than the action level in aquifer tube, pore water, and seep/spring media. The results of this evaluation indicate that aluminum concentrations are associated with particulate fraction in unfiltered samples, and dissolved aluminum is not reported above aquatic water quality criteria.

Lead is another example where it was found that concentrations in the near shore media reported two non-filtered and two filtered concentrations greater than the action level. Filtered near shore results greater than the action level were analyzed by Method 6010. Filtered near shore lead concentrations analyzed by Method 6010 have MDLs that range from 3.1 μg/L to 42 μg/L. Detected lead results analyzed by Method 200.8 reported concentrations less than the action level. Lead was not detected above the action level in unfiltered aquifer tube, or pore water samples. That is, the old analytical method was not adequate for measuring lead concentrations at or below the action level in near shore samples, and not detected above action level in aquifer tube, seep/spring, or pore water samples. A similar conclusion was reached for methoxychlor.
Similar analyses were conducted for cadmium, copper, iron, lead, mercury, nickel, selenium, silver, and zinc to conclude that all observed concentrations are below the action level when considering data quality.

**Data Evaluation Summary**

A range of inorganic and radionuclide contaminants were detected in near-river groundwater samples collected from the 100-KR-4 OU. In many cases, these contaminants also could be detected in aquifer tube, pore water, spring/seep and surface water samples. In most cases, the analytical results that were most relevant to assessing aquatic water quality (i.e. from filtered analyses) were at concentrations below aquatic criteria. In other cases where concentrations higher than aquatic criteria were observed, these results were associated with analytical data quality issues such as presence of contamination in blank samples, or elevated detection limits relative to the criteria.

With the exception of hexavalent chromium, the analytical results addressed in this evaluation did not provide evidence that contaminants from Hanford Site groundwater or associated with Hanford Site operations were potentially being discharged to riparian or near-shore media, or to the Columbia River.

**SUMMARY OF ECOCLOGICAL RISKS**

Ecological risks in riparian and near-shore areas were assessed as part of the RCBRA [3]. The RCBRA evaluated risks to an array of assessment endpoints using multiple measures of exposure, effect, and ecosystem/receptor characteristics at representative near-shore study sites. The study sites were selected to represent locations that may be adjacent to or directly affected by known contaminated media (groundwater seeps and springs, soil, sediment).

**Risks to Terrestrial Plants**

Concentrations of some COPECs in riparian soil exceeded literature-based plant benchmark concentrations, indicating that effects in plants might occur. Soil concentrations for arsenic, chromium, lead, vanadium, and zinc were greater than benchmarks, suggesting a potential for adverse effects. However, other lines of evidence obtained through seven different measures in bioassay testing indicate that COPECs may not adversely affect riparian plants, including those at the rare plant sites which performed better than bioassays from reference soils. Bioassays showed no differences in plant growth between study sites and reference sites. Some COPECs were detected in plant tissues, but the concentrations of the COPECs did not differ between study sites and reference sites. Similar to the upland plant data, COPEC concentrations found in riparian plant tissues did not correlate to those in riparian soil. Therefore, although soil concentrations are greater than plant benchmark for some COPECs, the weight attributed to this line of evidence is low and benchmark hazard quotient (HQ) results do not overwhelm the conclusions of the other lines of evidence. Based on this analysis, there are no COPECs in riparian soils that warrant further evaluation, based on risks to terrestrial plants.

**Risks to Aquatic Plants**

Potential effects on aquatic plants were evaluated through results of a bioassay in sediment and comparison of sediment and pore water concentrations to benchmarks. For the River Corridor as a whole, sediment concentrations were greater than benchmarks for eight COPECs (antimony, barium, cadmium, chromium, manganese, phosphorous, selenium, and zinc), and this information suggests a potential for adverse effects. Pore water concentrations at study sites were greater than the water standards or criteria for five COPECs (aluminum, cadmium, chromium, hexavalent chromium, and lead). Risks to aquatic plants based on toxicity testing showed some relationships with confounding factors and some COPECs. Nevertheless, there were clear measures of exposure (i.e. accumulation into plants), primarily for
inorganic COPECs that were detected in pore water and sediment. Of the key groundwater contaminants, only hexavalent chromium had concentrations of ecological relevance in the near-shore environment. Laboratory bioassays (i.e., toxicity tests) were conducted with field-collected sediments. No risks to aquatic plants were noted based on toxicity testing. Hexavalent chromium in groundwater in the 100-K area, which represents a potential source for porewater concentrations that exceed water quality criteria, warrants further evaluation for potential remedies.

**Risks to Terrestrial Invertebrates**

Concentrations of some COPECs in riparian soil exceeded literature-based benchmarks protective of terrestrial invertebrates; in the 100-K area, concentrations of zinc were higher than the benchmark value for protection of terrestrial invertebrates. Terrestrial invertebrate tissue concentrations which provide an indication of contaminant uptake and bioavailability were measured at River Corridor study sites and reference locations. Statistical differences in tissue concentrations of zinc in terrestrial organisms were noted between River Corridor and reference study sites; this relationship is based on data across the entire River Corridor, and should not be inferred as a relationship that is specific for the 100-K area. However, there is insufficient evidence for COPECs in general of a correlation between tissue concentrations in terrestrial invertebrates and concentrations in soil [3]. Toxicity testing with nematodes showed no statistically significant differences in toxicity between COPEC concentrations in River Corridor study site and reference area soils with concentrations samples at zinc levels as high as 393 mg/kg. More recent bioassays conducted in the Central Plateau showed no significant difference in toxicity in waste site and reference area soils and no correlation with zinc in soil at concentrations as high as 8980 mg/kg. While zinc concentrations were higher than protective benchmark concentrations, there was no statistically significant relationship between zinc concentrations in terrestrial invertebrate tissue and soil concentrations, and there was no relationship between nematode survival and soil concentrations. Based on this analysis, there are no COPECs in riparian soil warranting further evaluation based on risks to terrestrial invertebrates.

**Risks to Aquatic Invertebrates**

The primary lines of evidence used to evaluate risks to aquatic invertebrates are field surveys, the results of bioassays, and comparison of sediment and water concentrations to benchmarks. Risks to aquatic macroinvertebrates based on toxicity testing showed some relationships with confounding factors and some COPECs. Histopathology measures differed in study sites compared to reference sites; these measures also showed some negative relationships with COPECs. However, sediment bioassays at site 2c selected to represent the 100-K Area showed no difference in amphipod (*hyalella azteca*) growth relative to reference sites, and the survival at Site 2c was higher than that for the reference sites. Likewise, survival and reproduction tests on water fleas in pore water showed no difference at five sites representing 100-K area (2c, Cr1, Cr2, and Cr4) relative to reference sites. Clams were also monitored for survival. There was a statistical decrease in survival at study sites compared to reference sites, but there was no correlation of clam survival with COPECs.

**Community Structure Measures**

Key community metrics do not suggest that contaminant-related impacts to benthic macroinvertebrates are evident in aquatic study sites as a group, as evident by the comparison of EPT data form study sites relative to reference sites. Most of the aquatic community measures did not differ between the study sites and reference sites. There were exceptions among the large number of aquatic community measures evaluated, but the agreement among measures was weak and the biological significance to populations is not evident.
Measures of Exposure

There were clear measures of exposure (accumulation), primarily for inorganic COPECs that were detected in water, sediment, and tissues. There were no statistically significant correlations between COPEC concentrations in pore water or sediment with tissues of aquatic organisms, indicating a lack of significant COPEC bioaccumulation. Further, no tissue effect levels for COPECs in invertebrate tissue were exceeded.

Most histopathology measures of clams and mussels showed no significant differences between study sites and reference. Though there were some exceptions, COPEC concentrations generally did not correlate with differences in histopathology measures.

Weight of Evidence

While abiotic measurements do exceed literature based screening values for some COPECs, this line of evidence is generally given the lowest weight given the lack of site-specificity in the literature based values. This certainly applies to the data available for the Columbia River next to the Hanford Site where biological measures give a much different perspective. While there are a handful of measures that showed some differences between locations adjacent to the site and upstream references, the majority of biological measures suggest no clear or compelling toxicity in the River Corridor as a whole. Moreover, observed differences most often show no correlation with COPEC measurements but rather with available habitat structure. With respect to 100-k area sites, the data is even more compelling as there appears to be no unacceptable risk to aquatic invertebrates in the sites chosen to represent the 100-K Area.

Of the key plume contaminants investigated, only hexavalent chromium had concentrations of ecological relevance in the near-shore environment for the 100-K decision area. Hexavalent chromium in groundwater in the 100-K area, which represents a potential ongoing source for porewater concentrations that exceed water quality criteria, and therefore warrants further evaluation. This conclusion is applicable to both aquatic invertebrates and amphibians.

Risk to wildlife

For riparian soils, field ecological measures of the small mammal community were developed as qualitative information on the status of these populations. Estimated dietary contaminant exposures and biological concentrations in bird or small mammal tissues are compared to ecological effects levels established for dietary ingestion or related to tissue residues. For selected COPECs (cadmium, chromium, lead, selenium and PCBs), measured tissue concentrations in small mammals trapped in River Corridor study sites were not greater than reference areas, and were less than available tissue effect levels. Dietary exposure to terrestrial birds and mammals estimated using wildlife exposure models, estimated for riparian concentrations across the River Corridor indicated potential exposure higher than lowest observed adverse effect level (LOAEL)-based benchmark values for copper, selenium, vanadium, and zinc. However, with the exception of zinc, concentrations of these metals in soil in the 100-K area fall within Hanford site-wide background, and therefore should not warrant further evaluation. Refined (Tier 2) screening levels for wildlife exposure to zinc presented in the Remedial Investigation/Feasibility Study report [11] were compared with the highest zinc concentration in 100-K riparian soil. The results from this comparison show that zinc concentrations fall below the Tier 2 value. Therefore, zinc concentrations in riparian soil do not warrant further evaluation based on risks to wildlife. It must be stated that the Remedial Investigation/Feasibility Study decision documents have not been approved by the regulatory agencies yet.
Within the RCBRA, information on dietary contaminant exposures were also compared to ecological effects levels for diet to assess risks to birds or mammals potentially exposed to contaminants in near-shore sediments or water. On a River Corridor-wide basis, there is potential for adverse effects of COPECs in diet to birds based on LOAEL-based benchmarks for exposures at study sites based on dietary exposure to barium, chromium, copper, nickel, and selenium. There is potential for adverse effects of COPECs in diet to mammals based on LOAEL-based benchmarks for exposures at study sites based on dietary exposure to aluminum, nickel, and selenium. Because EPA has determined that ecological exposures to aluminum in soil at circumneutral pH are not likely to drive ecological risk; it is logical to extrapolate this determination from soil to another solid exposure medium (sediment). In general, the magnitudes of the exceedances were relatively low.

**Risk to Fish**

Pore water concentrations at study sites were greater than the water standards or criteria for five COPECs (aluminum, cadmium, chromium, hexavalent chromium, and lead). However, most other lines of evidence suggest that risk to fish in the Columbia River is not unacceptable. In general across the River Corridor, fish were smaller (in length and mass) at study sites relative to reference sites. There were no strong trends in fish histopathological observations between those collected at study sites and those from reference site locations. No tissue COPECs were correlated with histopathological endpoints associated with adverse effects at study sites. There were no exceedances of tissue effects levels for near-shore aquatic COPECs measured in fish tissue. In addition, evidence of greater contaminant uptake in fish from study sites was not apparent for most COPECs and tissues. For the 100-K area, hexavalent chromium in groundwater, which represents a potential source for porewater concentrations that exceed water quality criteria, warrants further evaluation in the FS. Hexavalent chromium concentrations in multiple near shore wells and aquifer tubes exceed ambient water quality criteria suggesting an ongoing source. Other COPECs detected in pore water above ambient water criteria do not appear to be issues in groundwater or aquifer tubes suggesting that the 100-K area is not the source of observed elevated concentrations.

**CONCLUSIONS**

The purpose for preparing this CSM was to address, on a reactor decision area basis, the potential for Hanford Site contaminants in soil or groundwater to migrate to riparian or near-shore areas at concentrations that could be of concern for ecological receptors. This CSM supplements the analysis of River Corridor-wide ecological risks presented in the ecological risk assessment of the RCBRA [3]. The RCBRA identified on a site-wide basis some contaminants of ecological concern that warranted further evaluation. Based on the results of the further evaluation contained in this CSM, with the exception of hexavalent chromium, detected concentrations of contaminants in riparian or near-shore media are not reliably detectable at levels of ecological concern, or are not associated with contamination in soil or groundwater resulting from Hanford Site operations. Therefore, for purposes of alternatives evaluation in the 100-K Feasibility Study, hexavalent chromium in groundwater should be considered the only contaminant of ecological concern.

There are uncertainties in this evaluation related to analytical data quality. With the exception of most recently collected analytical data in groundwater, analytical methods had MDLs that were either close to or higher than aquatic criteria; when methods with adequate detection limits are used, the results show that contaminant concentrations are less than aquatic criteria. In many cases where analytical results were higher than aquatic criteria, it was determined that the results were based on unfiltered samples. Unfiltered analytical results are inappropriate for comparison with aquatic criteria; in general, filtered analytical results were less than aquatic criteria. In some cases where concentrations were reported higher than aquatic criteria, further evaluation of the data revealed it was qualified because of the presence of blank contamination. The analytical detection limit considerations and data quality issues further support
the conclusion that contaminants concentrations in water were not reliably detected above levels of ecological significance.

REFERENCES


