Revised

Proposed Site-Specific Selenium Criterion for Hoopes Spring, Sage Creek, and Crow Creek near the Smoky Canyon Mine

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AMSL	Above Mean Sea Level
BAF	Bioaccumulation Factor
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CF	Conversion Factor
CFR	Code of Federal Regulations
cfs	cubic feet per second
CWA	Clean Water Act
dw	dry weight
EC/EC_x	Effect Concentration
EF	Enrichment Factor
ELS	Early Life Stage
ERG	Eastern Research Group
f	fraction
FAQ	Frequently Asked Questions
FCV	Final Chronic Value
FETAX	Frog Embryo Teratogenesis Assay Xenopus
GMCV	Genus Mean Chronic Value
IDEQ	Idaho Department of Environmental Quality
IDFG	Idaho Department of Fish and Game
IG	Implementation Guidance
kg/Ha	kilograms per hectare
LCL	Lower Control Limit
LOEC	Lowest Observed Effect Concentration

µg/g	micrograms per gram
µg/L	micrograms per liter
MDR	Minimum Data Requirements
mg/kg	milligrams per kilogram
NOEL	No Observed Effects Level
NPDES	National Pollutant Discharge Elimination System
ROD	Record of Decision
SETAC	Society of Environmental Toxicology and Chemistry
SMCV	Species Mean Chronic Value
SSD	Species Sensitivity Distribution
SSSC	Site-Specific Selenium Criterion
TMDL	Total Maximum Daily Load
TSD	Technical Support Document
UCL	Upper Control Limit
USEPA	United States Environmental Protection Agency
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
WDEQ	Wyoming Department of Environmental Quality
WQC	Water Quality Concentration
WQS	Water Quality Standards
YCT	Yellowstone Cutthroat Trout

EXECUTIVE SUMMARY

Simplot is proposing a chronic site-specific selenium criterion (SSSC) comprised of four elements for streams adjacent to its Smoky Canyon Mine in southeast Idaho. The SSSC is proposed to be applicable to the following stream areas (herein called "the Site"):

- Sage Creek: source to mouth, including
  - Hoopes Spring channel downstream of the spring complex;
  - South Fork Sage Creek downstream of the spring complex;
  - North Fork Sage Creek and tributaries (including Pole Canyon Creek); and
  - Sage Creek downstream of the confluence of Hoopes Springs to its confluence with Crow Creek.
- Crow Creek downstream of its confluence with Sage Creek to the Wyoming border.

Simplot's proposed SSSC (Table ES-1) is comprised of the U.S. Environmental Protection Agency (USEPA 2016a) four recommended criterion elements: an egg/ovary criterion, a whole-body or muscle criterion, a monthly average exposure criterion for water, and an intermittent exposure criterion for water. The following two tables summarize the elements proposed for the SSSC. Table ES-1 shows the criterion elements applicable to Hoopes Spring, Sage Creek, South Fork Sage Creek, North Fork Sage Creek, and Pole Canyon Creek. Table ES-2 shows the criterion elements applicable to Crow Creek from the confluence with Sage Creek to the Idaho-Wyoming state line.

Table ES-1. Summary of Proposed Site-Specific Selenium Criterion Elements, Sage Creek – Source to Mouth (unit US-9).

Chronic [1]			***Short-Term***
Egg-Ovary (mg/kg dw)	***Fish Tissue (mg/kg dw)***	***Water Column (µg/L)***	***Water Column (µg/L)***
Egg-Ovary	*Whole Body*	*Water Lotic*	*Water*
20.5 [1]	*13.6* [2]	*16.7* [3]	*Intermittent exposure Equation* [4,5]

Table ES-2. Summary of Proposed Site-Specific Selenium Criterion Elements, Crow Creek – Sage Creek Confluence to Wyoming State Line (unit US-8).

Chronic [1]			*Short-Term*
Egg-Ovary (mg/kg dw)	*Fish Tissue (mg/kg dw)*	*Water Column (µg/L)*	*Water Column (µg/L)*
Egg-Ovary	*Whole Body*	*Water Lotic*	*Water*
20.5 [1]	*12.5* [2]	*4.2* [3] [4,5]	*Intermittent exposure Equation* [4,5]

mg/kg dw = milligrams per kilogram dry weight, µg/L – micrograms per liter

Table Notes:

1. *Egg/ovary supersedes any whole body or water column element when fish egg/ovary concentrations are measured. Single measurement of an average or composite sample of eggs/ovaries from at least five (5) individuals of the same species. Not to be exceeded; DEQ will evaluate all representative egg-ovary data to determine compliance with this criterion element.*

2. *Fish tissue supersedes the water column element when both fish tissue (whole body) and water concentrations are measured.*

   Fish tissue elements are expressed as a single arithmetic average of tissue concentrations from at least five (5) individuals of the same species where the smallest individual is no less than seventy-five percent (75%) of the total length (size) of the largest individual. Not to be exceeded; DEQ will evaluate all representative egg-ovary data or whole-body data to determine compliance with this criterion element.

3. *Water column values are derived using the empirical bioaccumulation factor (BAF) method. Water column values are the applicable criterion element in the absence of steady-state condition fish tissue data. In fishless waters, selenium concentrations in fish from the nearest downstream waters may be used to assess compliance.*

4. *The 30-day average can be based on a single or multiple days of monitoring within a 30-day period. The geometric mean is used as the average.*

5. *Intermittent Exposure Equation =* $\frac{WQC_{30\,day} - C_{bkgrnd}\ (1-f_{int})}{f_{int}}$

   where $WQC_{30\text{-}day}$ is the water column monthly element, for either lentic or lotic waters; C_{bkgrnd} is the average background selenium concentration, and f_{int} is the fraction of any 30-day period during which elevated selenium concentrations occur, with f_{int} assigned a value ≥ 0.033 (corresponding to one day)

The proposed SSSC for the egg/ovary criterion element (20.5 mg/kg dw) is based on the most sensitive species which is brown trout with an EC_{10} of 20.5 mg/kg dw egg/ovary selenium. This EC_{10} was derived from wild trout collected from within the Study Area and applies to both the Hoopes Spring and Sage Creek area as well as Crow Creek downstream of Sage Creek. From the egg/ovary criterion element, a whole-body tissue concentration equivalent was derived using a conversion factor (CF = 1.46) of egg/ovary selenium to whole body selenium. The resulting whole-body tissue criterion element (14 mg/kg dw)[1] can be used as a compliance monitoring measure if egg/ovary tissue data are not available for Hoopes Spring and Sage Creek. For Crow Creek, the whole-body tissue criterion element corresponds to the rainbow trout whole body value of 12.5 mg/kg dw

The water criterion element is based on the empirical Bioaccumulation Factor (BAF) approach cited by USEPA (2016a) as one of two acceptable approaches for deriving a water criterion from an egg/ovary tissue criterion. Median BAFs were derived from paired brown trout tissue data and dissolved selenium concentrations measured at the time of fish tissue collection from 2006 to 2011. Two separate Site-specific BAFs were derived; one for each Site area.

Because the brown trout tissue data were for whole body, each value was converted to an egg/ovary concentration using the above-mentioned CF. The median whole body to egg/ovary converted BAF derived for Crow Creek (4.91)[2] divided into the egg/ovary criterion value (20.5 mg/kg dw) yields a dissolved water criterion of 4.2 µg/L. The median whole body to egg/ovary converted BAF derived for Hoopes Spring, Sage Creek, and South Fork Sage Creek (1.23) divided into the egg/ovary criterion value (20.5 mg/kg dw) yields a dissolved water criterion of 16.7 µg/L.

[1] The USEPA (2016a) whole body value for brown trout (13.2 mg/kg dw), is slightly lower but the proposed site-specific whole-body value is based on a more robust data set that is specific to the Site.

[2] The median whole body BAF is 3.36 which can also be converted to an egg/ovary BAF (3.36*1.46 = 4.91).

1.0 INTRODUCTION

The J.R. Simplot (Simplot) Smoky Canyon Mine is in Caribou County, in the southeast corner of Idaho, approximately 10 miles west of Afton, Wyoming and 23 miles east of Soda Springs, Idaho (Figure 1). The mine is situated on the eastern edge of the Webster Range overlooking Sage Valley to the east. Simplot is proposing a chronic site-specific selenium criterion (SSSC) for several streams adjacent to its Smoky Canyon Mine that are influenced by discharges of groundwater with elevated selenium concentrations ("the Site"). Site streams include Hoopes Spring, Sage Creek, South Fork Sage Creek, and Crow Creek downstream of Sage Creek (Figure 2).

Elevated selenium concentrations at the Site are a result of releases from historical mining activities at the Smoky Canyon Mine. Overburden materials removed to access the phosphate ore were placed in a cross-valley fill, external overburden disposal areas (ODAs) or used to backfill mining pits. Selenium has been released from these overburden materials to infiltrating water. Selenium then migrates to the underlying Wells Formation groundwater. Wells Formation groundwater discharges to surface water via springs (i.e., Hoopes Spring and South Fork Sage Creek Springs). These springs are located in the foothills transitioning into Sage Valley east of the Smoky Canyon Mine. Water from both springs flows into Sage Creek. Sage Creek flows into Crow Creek, which flows north/northeast and crosses the Idaho-Wyoming state line before discharging into the Salt River[3].

Development of the SSSC is supported by guidelines and processes outlined in state and federal regulations, which are described in more detail below. Currently, the State of Idaho's water quality standards include a chronic selenium criterion of 5 µg/L (based on United States Environmental Protection Agency [USEPA] 1987)[4]. The USEPA (1987) criterion was based on bluegill sunfish (*Lepomis macrochirus*) in lentic habitats. The Study Area (i.e. the Site and Crow Creek and Deer Creek [upgradient of Sage Creek]) consists of lotic, cold water habitats. Eleven years of fish

[3] Because Crow Creek flows across the State line, Simplot has been communicating with Wyoming Department of Environmental Quality on activities related to addressing selenium releases from historical mining practices. This update includes the site-specific water quality criterion proposed for Crow Creek as well as the pilot water treatment plant.

[4] Idaho Department of Environmental Quality (IDEQ) is in the process of adopting USEPA's (2016) National selenium criterion which is a multi-part criterion including egg/ovary, whole body and water criterion elements. The 2016 National criterion is based on white sturgeon.

survey data show that bluegill sunfish are not present in the habitats within the Study Area (see Section 2.2).

Literature reviewed early on in the process suggested that different species have different sensitivities to selenium (Lemly 1997; Holm et al. 2005; Hardy 2005; Gillespie and Baumann 1986; Coyle et al. 1993; Kennedy 2000; USEPA 2004). Further, geochemical differences in lotic (i.e., flowing waters) and lentic (i.e., standing waters) aquatic habitats influence selenium speciation (e.g., selenate versus selenite). Selenite, which is more bioavailable and toxic than selenate, is the dominant form occurring in lentic habitats. Selenate is dominant in lotic habitats like the habitats at the Site for which the SSSC is being proposed. Collectively, the geochemical behavior of selenium in the aquatic environment and sensitivity of fish species present suggested that developing an SSSC was appropriate for streams adjacent to the Smoky Canyon Mine.

Some trout species, including brook and cutthroat trout are generally less sensitive to selenium than bluegill sunfish (Holm 2002; Holm et al. 2003; Hardy et al. 2009; Kennedy et al. 2000; USEPA 2004, USEPA 2016). Simplot began a series of scientific studies into the effects of selenium on local trout at the Site in 2006. As part of the initial efforts to develop an SSSC, a Work Group[5] was convened comprised of state and federal technical experts, regulatory personnel, and Simplot representatives. The Idaho Department of Environmental Quality (IDEQ) led the SSSC Work Group, which provided valuable input into planning and development of the field and laboratory studies, review of documents, and on the direction of the SSSC development process. A combination of laboratory and field studies were conducted from 2006 to 2008 to develop the data necessary for an SSSC. In addition, continued literature reviews were conducted to compile up-to-date information on selenium toxicity in fish and aquatic biota. Collectively, these studies have become the basis for proposing an SSSC for the Site streams.

The criterion proposed herein is the culmination of many years of compiling and analyzing site-specific and non-site-specific data by Simplot, USEPA, and others. Release of the *Aquatic Life Ambient Water Quality Criterion for Selenium – Freshwater-2016* (USEPA 2016a) (hereafter referred to as the 2016 National Criterion) has further guided the SSSC development process by providing a more complete understanding of how USEPA intends to implement the selenium

[5] The SSSC Workgroup is comprised of representatives from Idaho Department of Environmental Quality (IDEQ), Idaho Department of Fish and Game (IDFG), United State Environmental Protection Agency (USEPA), Unites States Forest Service (USFS), Wyoming Department of Environmental Quality (WDEQ), and Simplot.

criterion as a tissue-based value, and how the toxicity data are integrated to collectively arrive at a single criterion value. Using the approaches described in USEPA (2016a) and the site-specific data, this proposal provides a criterion protective of aquatic species.

This SSSC proposal is organized into the following sections:

- Section 2 – Setting, Study Area, and Scope of Applicability
- Section 3 - Regulatory Requirements for Developing an SSSC
- Section 4 - Background and Chronology for the Current SSSC Proposal
- Section 5 – Site-Specific Studies and Literature
- Section 6 – Site-Specific Criterion Development
- Section 7 –Proposed Criterion Implementation
- Section 8 - References

2.0 SETTING, STUDY AREA, AND SCOPE OF APPLICABILITY

2.1 Setting

The Smoky Canyon Mine is located in Caribou County, Idaho, within the Southeastern Idaho Phosphate Mining District. Phosphate ore is extracted from the Phosphoria Formation in a series of open pits referred to as mine panels. Elevations at the mine range from 6,500 feet to 8,300 feet above mean sea level (AMSL). Slopes drain generally eastward, with streams flowing into the Salt River which flows to the Snake River. The closest main population center to the mine is the Star Valley community, which includes the town of Afton, Wyoming, approximately 10 miles directly east of the mine. The town of Afton has a population of approximately 1,900 (U.S. Census Bureau 2013). Caribou County has a cool and dry climate, with typical prevailing winds and weather patterns moving from west to east. Annual precipitation is typically in the range of 20 to 35 inches per year. The most abundant precipitation occurs in the spring and early summer months. In the winter months, snowfall averages 100 inches each year, and snow cover typically remains on the ground from November to March or April. Summer temperatures in the region normally range from 44 to 82 degrees Fahrenheit, while winter temperatures typically range from 4 to 28 degrees Fahrenheit (Mariah Associates 1988). The Smoky Canyon Ecological Risk Assessment provides a detailed description of the wildlife and plant species found in the area (Formation 2016).

2.2 Study Area

Investigations at the Smoky Canyon Mine have identified elevated concentrations of selenium in groundwater discharging to surface water via Hoopes Spring and South Fork Sage Creek Springs. The primary source of selenium to groundwater is overburden generated by historical mining operations. Primary areas affected by elevated selenium concentrations where Hoopes Spring and South Fork Sage Creek Springs discharge are: Hoopes Spring downstream of the spring complex; Pole Canyon Creek, Sage Creek from its confluence with the Hoopes Spring discharge channel to its confluence with Crow Creek; South Fork Sage Creek below the spring complex;

and Crow Creek from its confluence with Sage Creek to the Idaho-Wyoming state line[6] (Figure 2).

To characterize the streams influenced by the groundwater discharges, field monitoring was conducted at a number of locations within the Study Area (Figure 3).

- Four background locations – three on Crow Creek and a single location on Deer Creek, each upstream of Sage Creek; and
- Six locations from the Site – two on Hoopes Spring, two on Sage Creek, and two locations on Crow Creek downstream of Sage Creek.

A single reference site outside of the Crow Creek drainage was also monitored at South Fork Tincup Creek.

The Smoky Canyon Mine area and nearby Sage Valley to the east contain several perennial streams and two large springs: Hoopes Spring and South Fork Sage Creek Springs. Average daily high and low flows in the Hoopes Spring channel are 8.36 and 6.34 cubic feet per second (cfs), respectively. The source of water is discharging regional groundwater and flows have been observed to be nearly constant year-round over years of monitoring. Downstream of the South Fork Sage Creek Springs, average daily high and low flows are 10.7 and 8.47 cfs, respectively, which have also been relatively constant. Unnamed springs with lower flows are found in other parts of the Study Area (these do not have elevated concentrations of selenium). Selenium concentrations in springs not associated with Hoopes Spring or South Fork Sage Creek Springs are as follows:

- Lower Valley Spring #1: Total selenium = 1 to 3.6 µg/L
- North Sage Valley Spring (NSV-2): Total selenium = <0.0002 to 0.00093 µg/L
- North Sage Valley Spring #3: Total selenium = 0.0003 µg/L

[6] Recent monitoring data have indicated that selenium concentrations in surface waters of Crow Creek in Wyoming beyond the Idaho state line have exceeded the 5 µg/L standard.

In general, stream flows are low, and the creeks do not transport large quantities of sediment except during spring-runoff conditions (from snow melt and spring storms) when creeks may become more turbid. Sediment conditions are generally characteristic of headwater creeks with benthic substrates ranging from near bedrock to sand and cobbles covered by small boulders. Many creeks have enough fine sediments to result in moderate to high embeddedness of cobbles and small boulders. Fine sediment loads in the streams have historically been due to grazing activities in these watersheds, where livestock trample banks and denude riparian vegetation. Recent steps to mitigate these effects have been undertaken by Simplot, the United States Forest Service (USFS), and private landowners by fencing off stream areas from livestock use. These actions have resulted in improvements in stream bank stability. Mining operations do not generally affect sediment conditions because storm water catch basins are utilized to inhibit off-site migration of particles.

Based on the most current State of Idaho 303(d) list of impaired waters cited in the State Integrated Report, North Fork Sage Creek, Pole Canyon Creek, South Fork Sage Creek, and Sage Creek downstream of North Fork Sage Creek are listed as impaired due to selenium (IDEQ 2017). Crow Creek, Sage Creek, and South Fork Sage Creek are listed for non-contaminant impairments such as bacteria, sedimentation, and/or habitat issues. The creeks within the Sage Creek basins are subject to IDEQ water quality standards for their designated uses. All surface waters within the Study Area are designated for cold-water biota use. Water quality conditions in these basins are generally characterized by moderate hardness, low concentrations of suspended solids, and circumneutral pH conditions.

2.2.1 Aquatic Biological Community

Perennial streams within the Study Area contain several species of fish and a wide variety of aquatic macroinvertebrates. Overall, the fishery appears to be in fair to good condition at most locations with adequate fish densities, good condition factors, few abnormalities, multiple life stages, and expected species diversity (NewFields 2009). Fish species commonly encountered include: brown trout (*Salmo trutta*), Yellowstone cutthroat trout (*Oncorhynchus clarkii ssp*.) (YCT), longnose dace (*Rhinichthys cataractae*), redside shiner (*Richardsonius balteatus*), Utah sucker (*Catostomus ardens*), Paiute sculpin (*Cottus beldingi*), mottled sculpin (*Cottus bairdi*), speckled dace (*Rhinoichthys osculus*), and mountain whitefish (*Prosopium williamsoni*) (Table 1).

Less common species, that have been found include: brook trout (*Salvelinus fontinalis*), rainbow trout (*Onchorhyncus mykiss*), and northern leatherside chub (*Lepidomeda copei*). Amphibian and reptile species known to occur in the Study Area include tiger salamander (*Ambystoma tigrinum*), boreal chorus frog (*Pseudacris maculata*), rubber boa (*Charina bottae*), and western terrestrial garter snake (*Thamnophis elegans*).

Hoopes Spring and Sage Creek near Hoopes Spring are trout and sculpin dominated systems. Brown trout is the dominant trout species, but YCT are found throughout Hoopes Spring and Sage Creek. Farther downstream in Sage Creek, near Crow Creek, mountain whitefish are occasionally found. In Crow Creek downstream of Sage Creek, sculpins are found less frequently, while longnose and speckled dace are commonly found together with redside shiner. Utah suckers are also found in large deep pools. Paiute sculpin has been almost exclusively found, with occasional mottled sculpins collected intermittently. One leatherside chub was found in 2008 in an upper reach of Crow Creek. Dace species are typically found in the lower elevation Crow Creek areas whereas sculpin are predominant in the upper elevation reaches of Sage Creek and Crow Creek. Redside shiner and Utah sucker are also found in the lower elevation reaches.

Simplot has monitored fish populations and communities within the Study Area at various times since 2006 and the species encountered are shown in Table 1. Annual fish population and community surveys have been conducted in Hoopes Spring, Sage Creek, and Crow Creek. Appendix A includes additional information of the fish species present, abundance, and trout population estimates.

No white sturgeon (*Acipenser transmontanus*) or bluegill sunfish have been found at any locations monitored. Data to support this are provided in the annual Scientific Permit collection data reports provided to Idaho Department of Fish and Game (IDFG) following each monitoring event.

Bluegill sunfish are a warm-water fish species. In Idaho and most western states, bluegill are a non-native species that tend to be isolated in small impoundments and reservoirs that are stocked as part of panfish fishing opportunities. IDFG stocking data (1975 to 2005) for Southeast Idaho and the Upper Snake River basin indicate that bluegill sunfish have been stocked in McTucker Pond, Lamont Reservoir, Saint Johns Reservoir, Twin Lakes Reservoir, Rexburg City Pond, Gem

State Pond, Mud Lake, and Jim Moore Pond.[7] None of these areas fall within the Crow Creek drainage.

White sturgeon are not present in Crow Creek or in the Salt River. Crow Creek discharges to the Salt River approximately 16 river miles downstream from the State line. The Salt River flows into Palisades Reservoir, approximately 47 river miles downstream of the confluence with Crow Creek. The Idaho Falls Dam on the Snake River is approximately 103 river miles downstream of Palisades Reservoir. The closest water that contains sturgeon is the Snake River downstream of Palisades Reservoir at the Idaho Falls Dam (Personal Communication, Dave Teuscher, IDFG Southeast Regional Biologist).

2.3 Geographic Scope of Applicability

A proposal for an SSSC must define the geographic scope or area to which the criterion would apply. In the general context of site-specific criteria, a “site” may be a state, region, watershed, water-body, or segment of a water body. The site-specific criterion is to be derived to provide adequate protection for the entire site, however the site is defined (USEPA 1994). The geographic scope of applicability for the proposed SSSC is for Sage Creek (source to mouth) and tributaries and Crow Creek from Sage Creek confluence to the Idaho-Wyoming state line (Figure 2).

The water bodies being investigated are found within the Salt Subbasin, HUC 17040105, of the Upper Snake River Basin. Two subunits of the Salt Subbasin are potentially affected, including water body US-9 (Sage Creek – source to mouth) and water body US-8 (Crow Creek – source to Idaho/Wyoming border) as defined by the Idaho Administrative Code’s Water Quality Standards (IDAPA 58.01.02).

IDEQ’s 2014 Integrated Report (IDEQ 2017) identifies specific stream segments as being limited by one or more parameters that affect use attainment. Within the Integrated Report, hydrologic subunits are defined to identifying specific stream segments. These numeric stream segment identifiers from the Integrated Report are shown below together with a narrative description of where the SSSC would apply within each stream segment.

[7] Historical Stocking Records. https://idfg.idaho.gov/ifwis/fishingPlanner/stocking/?region=5&stock=5

Sage Creek and its tributaries include the following stream segments (Figure 3):

- ID17040105SK009_02e South Fork Sage Creek (7.93 miles) – applied to South Fork Sage Creek downstream of the spring complex.
- ID17040105SK009_03 Sage Creek – confluence with North Fork Sage Creek to mouth (3.22 miles) – applied to this entire segment.
- ID17040105SK008_04 Crow Creek – Deer Creek to border (10.42 miles) – applied to Crow Creek downstream of Sage Creek confluence to the Wyoming border.
- Hoopes Springs – no specific segment is identified; it falls within the larger segment identified above for Sage Creek.
- ID17040105SK009_02 North Fork Sage Creek (12.41 miles); and
- ID17040105SK009_02d Pole Canyon Creek (3.6 miles).

Monitoring locations used to characterize conditions in the Study Area are representative of the streams in the area. Therefore, while some specific streams were not characterized, the proposed SSSC is considered applicable and appropriate given the common sources, water quality, and proximity within the basin. For example, while the North Fork Sage Creek was not sampled as part of the SSSC studies, it has been characterized during other aquatic investigations at the Smoky Canyon Mine site and area. The North Fork Sage Creek is a source to Sage Creek and includes common water quality and aquatic species. The primary source of selenium to North Fork Sage Creek is Pole Canyon Creek, which only reaches the North Fork Sage Creek occasionally during high flow spring runoff conditions (see Section 5.2.3 for more information on North Fork Sage Creek and Pole Canyon Creek).

3.0 REGULATORY REQUIREMENTS AND GUIDELINES FOR DEVELOPING AN SSSC

The Clean Water Act (CWA) found in the Code of Federal Regulations (CFR) includes a provision (i.e., 40 CFR 131.11(b)) that allows for establishing site-specific water quality criteria. USEPA has delegated enforcement of the CWA to the State of Idaho, including decision-making related to the development of site-specific criteria.

The State of Idaho has specific requirements to be followed for developing a site-specific criterion (Idaho Administrative Code, IDAPA 58.01.02.275). Two that particularly apply are:

1) (275.01.a.i) “Resident species of a water body are more or less sensitive than those species used to develop a criterion,” and

2) (275.01.a.ii) “Biological availability and/or toxicity of a pollutant may be altered due to differences between the physicochemical characteristics of the water in a water body and the laboratory water used in developing a water quality criterion (e.g., alkalinity, hardness, pH, salinity, total organic carbon, suspended solids, turbidity, natural complexing, fate and transport water, or temperature).”

Because the current State of Idaho standard is based on species not present in southeast Idaho, and the Study Area characteristics are different than those conditions from which the standard was derived, the conditions are appropriate for developing a site-specific criterion. Further, IDAPA 275.01.b specifies that:

> “Any person may develop site-specific criteria in accordance with these rules. To ensure that the approach to be used in developing site-specific criteria is scientifically valid, the Department shall be involved early in the planning of any site-specific analyses so that an agreement can be reached concerning the availability of existing data, additional data needs, methods to be used in generating new data, testing procedures to be used, schedules to be followed and quality control and assurance provisions to be used. (8-24-94).”

To fulfill this requirement, the IDEQ facilitated a series of meetings in which various state and federal environmental and resource agency scientists (i.e., SSSC Work Group) met and reviewed study plans and study results compiled over a period of approximately three years. IDEQ and associated agencies were engaged early and often in the process of compilation and analyses of Site data to ensure the application of sound scientific principles.

Acceptable procedures for developing site-specific criteria are also identified in the rule:

> (275.01.h.i) "Site-specific analyses for the development of new water quality criteria shall be conducted in a manner which is scientifically justifiable and consistent with the assumptions and rationale in "Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses, USEPA 1985" (herein after referred to as Stephan et al. 1985); and,
>
> (275.01.h.ii) "Site-specific analyses for the modification of existing water quality criteria shall be conducted in accordance with one of the following procedures, as described in the *Water Quality Standards Handbook:*
>
> (1) Recalculation Procedure
>
> (2) Indicator Species Procedure
>
> (3) Resident Species Procedure
>
> (4) Water Effects Ratio
>
> (5) Other scientifically defensible procedures

USEPA's *Draft Technical Support for Adopting and Implementing EPA's 2016 Selenium Criterion in Water Quality Standards* (USEPA (2016b) indicates that the recalculation procedure should be used for site-specific fish tissue criterion development. In addition, it also recommends that USEPA's (2013) revised deletion process be used in conjunction with the recalculation procedure. USEPA (2013) describes a systematic manner where species are retained or deleted based on taxonomic rank for the purposes of deriving a species sensitivity distribution (SSD). The procedure allows for recalculating a criterion based on species known to be present or not present at a site or for a region, or for use of surrogate species that result in differences in sensitivity between site species and those used to derive the 2016 National Criterion. Using the methods described in Stephan et al. (1985), the recalculation procedure derives a final chronic value (FCV) calculated from regression analysis of the four most sensitive fish genus mean chronic values

(GMCVs); in this case extrapolating to the 5th percentile of the distribution represented by the tested genera. Effectively, the SSD results in a value that is protective of 95 percent of the species.

However, when either suitable effects data for fish or limited species assemblage or both occur at a site, the recalculation procedure may not be applicable. USEPA (1994) guidance on the Recalculation Procedure accounts for this as it recognizes that the species that occur at the site might represent a narrower mix of species than those in the national dataset. For sites with limited species assemblages, or inadequate effects data, a most sensitive species approach is appropriate and in accordance with applicable guidance (USEPA 1994). Further, Idaho water quality regulations allow the use of a most sensitive species approach to setting site-specific water quality criteria as stated in IDAPA 58.01.02, Section 275.01(h)(ii)(5)(b):

> "The data, testing procedures and application factors used to develop site-specific criteria shall reflect the nature of the pollutant (e.g., persistency, bioaccumulation potential, avoidance or attraction responses in fish, etc.), the designated and existing beneficial uses, and the most sensitive resident species of a water body."

Consistent with Federal guidance and State statutes this SSSC proposal adopts a most sensitive species approach. Applicability of the most sensitive species approach is based on the following: (1) brown trout are a resident species that are a recreationally important management species known to occur at the Site; (2) acceptable effects data, based on site-specific studies are available to quantify the toxicity of selenium for this species. Further, the test data for this species indicate it is highly sensitive to the toxic effects of selenium; in fact it is among the four most sensitive species used in the National dataset. Considering the limitations of using the recalculation procedure, a site-specific criterion based on a most sensitive species approach is proposed for this SSSC. It is considered to be protective of 100 percent of the species, is scientifically defensible, and is supported by state and federal guidance.

4.0 BACKGROUND AND CHRONOLOGY FOR THE CURRENT SSSC PROPOSAL

With over 10 years in the making, the chronology of events that have resulted in the present day SSSC proposal become an important facet in understanding the development process.

- August 2006 to August 2008 – Field data collection and laboratory studies conducted.

- August 2010 – A *Draft Interpretive Findings for Field and Laboratory Studies and Literature Review in Support of a Site-Specific Selenium Criterion* (Interpretive Report) (NewFields 2010) was submitted to the SSSC Work Group for review and solicitation of comments.

- March 2011 – The SSSC Work Group was informed by USEPA Region 10 that the United States Fish and Wildlife Service (USFWS) would provide comments on Simplot's Draft Interpretive Report (August 2010; NewFields 2010).[8]

- January 2012 – Simplot submitted its Proposed SSSC and a Technical Support Document (TSD)[9] (Formation 2012) to the IDEQ and the SSSC Work Group. The EC_{10} proposed for egg/ovary, based on survival for brown trout fry, was 20.8 milligrams per kilogram (mg/kg) dry weight (dw).

- January 2012 – The USFWS submitted its technical review, authored by Dr. Joe Skorupa, of the Draft Interpretive Report to the USEPA and published its review on the USFWS website. The USFWS review primarily focused on the Brown Trout Adult

[8] Involvement of the USFWS came at the direction of the United States Senate Committee on Environment and Public Works chaired by Senator Barbara Boxer. In March 2011, Senator Boxer sent a letter to Mr. Rowan Gould, Acting Director of USFWS, and to Ms. Lisa Jackson, Administrator of the USEPA. In the letter to Director Gould, Senator Boxer requested that scientists in the USFWS review the described document and provide "technical assistance" to the Committee on Environment and Public Works. In the letter to Administrator Jackson, Senator Boxer requests that USEPA "consider, and where relevant, integrate federal assistance from federal scientists from outside of the agency." The letter then states that the Committee on the Environment and Public Works will forward this information to USEPA. It should also be noted that when the SSSC Work Group was formed, USFWS was invited to join but did not do so.

[9] The Technical Support Document (TSD) is the revised Draft Interpretive Findings for Field and Laboratory Studies and Literature Review in Support of a Site-Specific Selenium Criterion (Interpretive Report). Revisions to the Interpretive Report were made to incorporate comments provided by the SSSC Workgroup.

Reproduction studies,[10] generating several questions about the study and the endpoints derived.

- December 2012 – Due to questions raised in the USFWS review, USEPA contracted the Eastern Research Group (ERG) to conduct a peer review of their analyses that utilized the Brown Trout Study data in the context of questions raised by USFWS. The result of this effort was the *External Peer Review of the Interpretation of Results of a Study on the Effect of Selenium on the Health of Brown Trout Offspring* (ERG 2012). In this document, six experts were charged with addressing five specific questions raised by the USFWS review.

- April 2013 – Simplot submitted responses to USFWS comments to the SSSC Work Group and USEPA. Included within the comment responses were two attachments: (1) *Data Quality Assurance Report: Reproductive Success Study with Brown Trout (Salmo trutta)* (AECOM 2012); and (2) Count of Normal Fish and Total Number of Fish for Each Sample from the Deformity Assessment. These additional data were included in the responses to comments to provide additional information to USEPA and other reviewers who were using the brown trout study data to derive EC_{10} values from that study for survival and deformities.

- June 2014 – USEPA altered some of its analyses to make use of the additional data submitted. Again, USEPA contracted for a Peer Review of pertinent questions regarding the revised analyses of the brown trout data. The result of that effort was the document titled *External Peer Reviewer Comments on Review of Draft USEPA Report, Analysis of the Brown Trout Selenium Toxicity Study Presented by Formation Environmental and Reviewed by U.S. Fish and Wildlife Service (June 2014)* (GLEC 2014). Similar to the previous peer review, six experts were charged with addressing five specific questions posed by USEPA about the analyses conducted.

- May 2014 – USEPA released its *External Peer Review Draft Aquatic Life Ambient Water Quality Criterion for Selenium – Freshwater 2014* (USEPA 2014). USEPA cited a range of egg/ovary thresholds derived from the brown trout data that ranged from

[10] The focus on the brown trout studies was the result of the initial analyses in the Interpretive Report that indicated brown trout were more sensitive to selenium than Yellowstone cutthroat trout.

15.91 to 21.16 mg/kg dw selenium. This range was based on three different endpoints (survival, deformities, and a combined endpoint of survival and deformities). USEPA used the most conservative EC_{10} (15.91 mg/kg) as the brown trout value.

- July 2014 – Simplot, along with other organizations and companies, provided comments on USEPA's Draft Peer Review document. The Eastern Research Group (ERG) was subsequently contracted by EPA to conduct a peer review of the 2014 Draft National Criterion. Seven reviewers provided their expert opinions on questions posed by USEPA and ERG regarding the 2014 Draft National Criterion, the results for which are compiled in the *External Peer Review of the Draft Aquatic Life Ambient Water Quality Criterion for Selenium – Freshwater 2014* (ERG 2014).

- July 2015 – USEPA released a Draft National Criterion for selenium and presented an alternative threshold value for brown trout using only the survival endpoint, which resulted in a value of 18.09 mg/kg dw egg/ovary selenium.

- July 2016 – USEPA released *Aquatic Life Ambient Water Quality Criterion of Selenium – Freshwater-2016* (USEPA 2016a), herein referred to as the 2016 National Criterion. Further reanalysis of the brown trout data resulted in an EC_{10} of 21 mg/kg dw egg/ovary selenium.[11] The survival endpoint data utilized was based on the data from hatch to swim up.

- September 2016 – USEPA released a series of draft implementation guidance (IG) documents and frequently asked questions (FAQ) documents to compliment the 2016 National Criterion. These draft IG and FAQ documents include the following:

    1. *Draft Technical Support for Adopting and Implementing EPA's 2016 Selenium Criterion in Water Quality Standards* (USEPA 2016b);

    2. *Technical Support for Fish Tissue Monitoring for Implementation of EPA's 2016 Selenium Criterion – Draft* (USEPA 2016c);

[11] See Appendix C of the 2016 National Criterion of EPA's analysis and rationale for the brown trout EC10 of 21 mg/kg dw egg selenium.

3. *Frequently Asked Questions (FAQs): Implementing the 2016 Selenium Criterion in Clean Water Act Sections 303(d) and 305(b) Assessment, Listing, and Total Maximum Daily Load (TMDL) Programs - Draft* (USEPA 2016d); and

4. *Frequently Asked Questions (FAQs): Implementing Water Quality Standards (WQS) that Include Elements Similar or Identical to EPA's 2016 Selenium Criterion in Clean Water Act Section 402 National Pollutant Discharge Elimination System (NPDES) Programs – Draft* (USEPA 2016e).

This chronology of events demonstrates (1) the level of scientific and regulatory examination by USEPA, USFWS, and a number of external peer reviewers on the brown trout data and interpretation, which were subsequently used in development of the 2016 National Criterion; and (2) the process and timing for developing the 2016 National Criterion and subsequent implementation guidance. The brown trout data provide an important threshold for the 2016 National Criterion, as they represent the third most sensitive species, preceded by white sturgeon and bluegill sunfish; two species not found in the vicinity of the Study Area. For this SSSC, the brown trout data provide an even more important threshold, as they represent information for the most sensitive species.

5.0 SITE-SPECIFIC STUDIES AND LITERATURE

To develop the science necessary for the proposed SSSC, Simplot completed a series of field studies that characterized (1) aquatic species, communities, and populations, (2) selenium exposure concentrations in water, sediment, dietary items, and (3) physical quality of the Study Area streams. Laboratory studies were conducted to assess responses of two primary management species to selenium exposure and maternal transfer. An ongoing task has included review of available peer reviewed and gray literature, which has been used to augment the findings of the field and laboratory studies.

The laboratory studies using brown trout and YCT provided the selenium-toxicity response data necessary to derive the proposed SSSC. Field monitoring studies provided for characterization of the exposure environment, the condition of the aquatic community, and the physical habitat. While the findings of the field monitoring studies are not used directly in the derivation of the proposed SSSC, they do provide additional support for the criterion. The literature review provided response data for other species that may be similar to species within the Study Area that were not tested as part of Simplot's studies.

5.1 Laboratory Studies

Simplot conducted three laboratory studies to assess the effects of selenium in trout species present in the Study Area. Two reproduction studies evaluated maternal transfer of selenium and its effects on developing young brown trout and YCT. A third study early life stage (ELS), evaluated the effects of selenium from aqueous and dietary exposure to developing young YCT that had no maternal selenium transfer. A brief description of the brown trout and YCT maternal transfer studies are provided below because of the importance of these studies in developing an SSSC.

The maternal transfer studies evaluated adult reproduction of wild trout from the Study Area and effects on developing young in a controlled laboratory setting. These studies were conducted independently, with one study using brown trout and the second using YCT. Trout were collected from different locations within the Study Area (Figure 3), covering a range of selenium exposure conditions during respective species spawning times. Eggs from females were fertilized in the field and transported to the laboratory for rearing. Method controls for the study were hatchery-raised fish. The full methods and results of these investigations are reported in the TSD (Formation 2012) and AECOM (2012) and summarized in USEPA (2016):

- *Appendix D - Final Brown Trout Laboratory Reproduction Studies Conducted in Support of Development of a Site-Specific Selenium Criterion* (Formation 2011).
- *Appendix E – Yellowstone Cutthroat Trout Adult Laboratory Reproduction Studies* (Formation 2012).
- *AECOM - Reproductive Success Study with Brown Trout (Salmo trutta). Data Quality Assurance Report. Final. December 2012.*

For both species, the effects of maternal selenium transfer in wild trout were evaluated by collecting eggs from females and milt from adult males from different locations representing a range of selenium exposure. Eggs were fertilized in the field and sent to the laboratory for rearing. Effects analyses evaluated egg selenium concentration versus survival, deformity, and growth endpoints. Data from both studies were submitted to USEPA for use in their derivation of the 2016 National Criterion.

As noted previously, Simplot's brown trout studies have been through numerous and rigorous evaluations. Recent reanalysis of the brown trout data by Simplot and USEPA (2016a) yielded an EC_{10} for survival of 20.5 and 21 mg/kg dw egg/ovary, respectively, using slightly different data sets.[12] While an EC_{10} was developed for the deformity data, the uncertainty in the predicted EC_{10} was high enough due to data variability that the survival endpoint was used as the primary effects endpoint.

Of the initial relationships evaluated for YCT, percent survival (hatch to test end) provided the best relationship to egg selenium concentrations, although the response was highly variable. Relying solely on the model output, the EC_{10} value was greater than 35 mg/kg dw egg selenium. Despite the use of multiple approaches and data transformations, clear dose response models using these effects endpoints were few. YCT data showed highly variable responses to egg

[12] USEPA (2016) used the brown trout survival hatch to swim up portion of the data set, while Simplot's reevaluation of the data, using similar methods as USEPA but using the survival to test termination portion of the dataset resulted in a slightly lower EC_{10}. Both USEPA (2016) and Simplot's reanalysis of the brown trout data utilized USEPA's Toxicity Relationship Analysis Program (TRAP) (version 1.30a) (USEPA 2013).

selenium concentrations. Examination of the data distribution, however, did suggest differences in responses between 22.3 and 27.9 mg/kg dw egg selenium. A decreased response was noted at egg selenium concentrations greater than 27.9 mg/kg dw for both survival and growth. Averaging the observed no-effect and potential effect concentrations resulted in a value of 25.1 mg/kg dw, which is expected to be lower than a derived EC_{10}. Simplot's initial assessment of the effects of selenium exposure on survival and deformities for YCT were concluded to be at some concentration greater than 25 mg/kg dw in eggs. The 2016 National Criterion suggested that the YCT data were highly variable and therefore a clear effect value could not be calculated from these data. USEPA (2016a) only looked at the data for the survival and deformities endpoints, each independently for the hatch to test end dataset. In their assessment of these data, a no observed effects concentration (NOEC) was suggested based on the individual endpoints up to 30 mg/kg dw in eggs with one treatment or egg batch showing 100 percent mortality at 40 mg/kg dw.

Simplot reassessed the YCT data by examining the hatchery data (e.g., a wild run of YCT from Henry's Lake) and Site wild fish data for the test period hatch to swim up to evaluate if the variability was reduced. The YCT data were reevaluated in 2014 and again in 2017 using a combined endpoint for surviving fry with no deformities (i.e., 'normal') using only the hatch-to-swim-up portion of the test (data are presented in Appendix B). This endpoint is similar to the endpoint used by USEPA for brown trout in the 2014 Draft Criterion, and was proposed for the YCT studies in comments on the 2014 Draft Criterion. One data point had an egg selenium concentration of 47.6 mg/kg dw and survival at >80 percent, which is not consistent with all the remaining YCT, brown trout, or cutthroat trout data from other studies. This data point was removed from the analysis, and the TRAP model run assuming a triangular distribution dose response model, yielded an EC_{10} of 28.62 mg/kg dw (lower confidence limit [LCL] = 27.29, upper confidence limit [UCL] = 30.00).

A second dose response curve and EC_{10} was derived based on further refinement of the dataset to remove two egg clutches from hatchery fish with extraordinarily low hatch success[13]. The

[13] The second dose response curve for a YCT combined endpoint presented herein included censoring (e.g., removal) 2 additional data points from the analysis. Closer examination of the data set showed that eggs from two hatchery trout had a very low hatch (<11% out of 600 eggs). For the entire data set, 5 hatchery trout had eggs with zero % hatch and 1 had <1% hatch. Henry's Lake trout are a wild population and there are a number of other factors which may have influenced poor hatch in these fish, including poor fertilization. Eight egg batches had 56% or better hatch. By only examining normal and surviving fry from hatch to swim up, some data were by default removed from the analysis, as

resulting EC_{10} for YCT surviving and normal fry from hatch to swim up was 28.39 ([LCL] = 27.07, [UCL] = 29.78) mg/kg dw egg selenium (Figure 4). There is clear variability in both the low exposure “hatchery fish” and higher exposure Site fish, which is indicative of the types of responses likely to occur from wild populations of fish, but are unrelated to selenium exposure. Censoring the additional two data points resulted in lower variability in the hatchery data, a better overall model fit, and a slightly more conservative EC_{10}. The resulting EC_{10} is consistent with the cutthroat trout data from the literature.

Use of this dataset for YCT provides for a reasonable dose response estimate based on the two sensitive toxicity test endpoints (i.e., survival and deformities), which combined result in a better model fit in the TRAP analysis. In this case, the binary categorization of fish as normal vs non-normal, with normal fish being only those with zero deformities, may overestimate the effects of selenium because the deformity rate of hatchery fish is actually greater than zero.

USEPA was unable to pursue these additional types of analyses because they didn't have the raw data to examine the hatch-to-swim-up endpoint for YCT and combined information for survival and normal fish. Furthermore, it is possible that USEPA omitted YCT from the national criterion because they already had sufficient information for the genus *Oncorhynchus*. For this Site, however, YCT is an important resident native species of high management importance and should be included in the consideration of the SSSC.

These analyses indicate that brown trout and YCT responses to selenium exposure are different. Brown trout are more sensitive in their response to maternally-accumulated selenium and its effects on developing young than are YCT. This finding is consistent with studies that have utilized several different trout species indicating sensitivity differences among similar species (e.g., Hardy 2005, Hardy et al. 2010, Rudolph et al. 2008, Nautilus Environmental 2011, Holm et al. 2005).

For the purpose of this SSSC proposal, the survival EC_{10} for brown trout of 20.5 mg/kg dw egg selenium will be used for deriving the egg/ovary criterion value. This EC_{10} will be evaluated along

no fry were assessed at the swim up thinning stage for some samples, if they had too few fry and were needed for the post swim up phase of the study. Censoring the additional two data points as done for the analysis ultimately used provided for a better overall model fit, a slightly more conservative EC_{10}, and eliminated from the analysis “control” wild fish that had very poor hatching success, possibly due to poor fertilization.

with other EC_{10} data from other species to derive an overall egg/ovary SSSC. The derivation process is discussed in more detail in subsequent sections.

5.2 Field Monitoring

As part of other regulatory and programmatic requirements, Simplot has routinely sampled and compiled selenium concentration data in surface water for a number of locations within and outside the Study Area. Concentrations of selenium at several of these locations have increased since 2008 reflecting the influence of groundwater discharged at Hoopes Spring. Temporal trends of selenium in surface waters at key locations are shown in Figures 5, 6 and 7. It is important to note that while selenium concentrations in surface waters have increased since the time most of the data for the SSSC studies were collected, the effects thresholds have not changed.

5.2.1 SSSC Monitoring – 2006 to 2008

Seasonal monitoring was conducted from 2006 to 2008 to characterize the selenium exposure conditions and productivity (or health) of the aquatic community within the Study Area. During each monitoring event, locations were sampled for a range of chemical, biological, and physical characteristics. Activities conducted to document and evaluate existing conditions included collection of water, sediment, periphyton, benthic invertebrates, and fish tissues for chemical analyses of selenium concentrations. Benthic community, fish population and community, and physical habitat quality assessments were conducted. Fish communities were sampled to characterize their density and diversity. Physical habitat attributes were measured to document the qualities of habitat conditions that exist at each location. A complete characterization and analyses of these data is presented in the TSD (Formation 2012). A summary of the chemical concentrations measured in the different media from 2006 to 2008 are presented in Table 2.

Selenium in Study Area streams undergoes a consistent seasonal trend. In Sage Creek and downstream Crow Creek, selenium concentrations are typically highest during the summer/fall low flow periods, and lowest during high spring runoff. The selenium loading from springs (i.e., Hoopes Spring and South Fork Sage Creek Springs) does not show seasonal effects and is relatively constant in any given year. Flows from these springs are relatively consistent. Although selenium concentrations have increased in recent years, concentrations also appear to have plateaued, and considering the implemented remedies, concentrations are predicted to begin decreasing in the future.

Because of the influence of physical habitat quality and quantity on the aquatic community, trout populations were evaluated relative to habitat characteristics. Sculpin population density and age class structure suggests that there is no difference in sculpin populations between high and low selenium concentration locations; rather, sculpin population density is more likely dictated by habitat conditions. While some specific habitat features are limiting the full potential of the fishery, the quality is not diminished substantially enough to negatively alter trout populations. Habitat quality data suggests overall, that good quality habitat is available, but external land uses exist that may limit the full range of the fishery potential.

5.2.2 Ongoing Monitoring – 2009 to Present

Since 2008, Simplot has continued fish population monitoring at a subset of locations. Collectively, the fish population data set spans a period of 11 years; from 2006 to 2016. The fish communities at the monitoring locations vary, and are influenced by several factors including the quality and quantity of water, food, and habitat factors (such as stream gradients, channel sizes, and stream temperatures, among others). Given the diversity of physical habitats, variations in the fish community composition are to be expected.

Trout population standing crop (biomass in kilogram per hectare kg/Ha) data are illustrated in Figure 8. The figure shows brown trout and YCT standing crop for each year for: (1) Crow Creek locations upstream of Sage Creek; (2) Hoopes Spring and Sage Creek; and (3) Crow Creek downstream of Sage Creek. In Crow Creek upstream of Sage Creek, brown trout biomass has fluctuated from as low as 9 and to as high as 100 kg/Ha over the 10-year period. This biomass estimate represents naturally changing conditions across upstream background locations where selenium concentrations are not elevated. In Hoopes Spring and Sage Creek, where selenium concentrations are elevated, brown trout biomass has ranged from just over 29 kg/Ha in 2015 to over 100 kg/Ha in 2006. Declining biomass estimates as early as 2012 may be indicative of potential selenium effects but it is unclear if other factors (described above) are not also contributing to the observed decrease. In Crow Creek downstream of Sage Creek, brown trout biomass has ranged from 43 kg/Ha in 2006 to 84 kg/Ha in 2012 and down to about 19 kg/Ha in 2016. In Crow Creek downstream of Sage Creek, selenium exposure is much lower than in Sage Creek, but still higher than background.

The Crow Creek locations upstream and downstream of Sage Creek show brown trout biomass estimates that are more similar to one another, while the Hoopes Spring and Sage Creek estimates vary widely; showing a distinct decrease as of fall 2013. How much of this is related to selenium concentrations versus other environmental factors is unclear.

For the YCT (Figure 8), biomass estimates across all three groups of locations are relatively similar from 2006 to 2011. In 2012, the upstream Crow Creek YCT biomass declined, while the Hoopes Spring and Sage Creek, and downstream Crow Creek biomass increased. From 2012 to 2016, YCT biomass remained lower in the upstream Crow Creek locations compared to previous years. YCT biomass in 2012 was the highest observed over the monitoring period for Hoopes Spring and Sage Creek, and Crow Creek downstream of Sage Creek locations. From 2013 to 2016, YCT biomass for Hoopes Spring and Sage Creek, and Crow Creek downstream of Sage Creek locations appears to remain with the range of biomass estimates for those locations prior to 2012. It is unclear what factors affected the apparent shift in 2012 given the decline in biomass observed at background locations.

Because the standing crop estimates can be affected by the size and how many large fish are captured, a relative density estimate was also examined for brown trout, YCT, and sculpin (Figures 9 and 10). Fall surface water selenium concentrations for each year are also shown. Beginning upstream at Crow Creek sampling location CC-350, total selenium concentration in surface water is relatively low (<1.2 µg/L), and density estimates for all three species are relatively similar across years.

At the Hoopes Spring sampling location HS-3, while the record for each year is not complete, the available data do provide an indication of trends. Sculpin and YCT density estimates are relatively stable through time even though selenium increased to >80 µg/L in 2014 and later. Brown trout density estimates declined after 2012 to levels lower than initial estimates in 2006.

At Sage Creek (LSV-2C), sculpin density declined from 2006 to 2008, but rebounded in 2009 and increased steadily through 2013. Of the two trout species, brown trout are clearly dominant based on density until 2013, when YCT become more dominant. From 2011 to 2012, the surface water selenium concentration increased well above the annual averages from previous years and remained elevated from 2012 through 2016. A decline in brown trout density was observed in 2013. YCT density remained stable and increased in 2016. There is a fundamental shift in trout species dominance based on density which corresponds to increased and sustained higher concentrations of selenium in surface waters. It is important to note however, that these shifts and changes were not observed until annual selenium in surface water exceeded about 40 µg/L in Sage Creek. At Sage Creek (LSV-4) farther downstream, some of the fish population data are missing from 2007 to 2009 due to access issues, but the record is complete from 2010 on. Sculpin density appears consistent with Sage Creek upstream (LSV-2C), as do the brown trout and YCT density estimates.

At Crow Creek downstream of Sage Creek (CC-1A) a similar decline in brown trout density was observed after 2013; at about the same time annual average selenium concentrations in surface water increased. YCT density remained relatively consistent year to year in Crow Creek downstream of Sage Creek. Sculpin density showed an increasing trend over the 10-year period. Similar to Sage Creek, surface water concentrations of selenium increased starting in 2012.

The observed trends in brown trout density appear to correspond to increased surface water selenium concentrations. Overall, YCT and sculpin densities have remained relatively consistent at the different locations despite the increase in selenium concentrations in water. This observation of field population trends is consistent with studies concerning effect thresholds indicating cutthroat trout and sculpins as being less sensitive than brown trout.

5.2.3 Pole Canyon Creek and North Fork Sage Creek

Pole Canyon Creek and North Fork Sage Creek were not characterized as part of the SSSC studies, but both streams have been characterized as part of sampling conducted for the Site Investigation (SI) (NewFields 2005), Smoky Canyon Mine Remedial Investigation/Feasibility Study (RI/FS) (Formation 2015) and historical monitoring studies for the Smoky Canyon Mine. The characterization includes documented concentrations of selenium in water, sediment, macrophytes, periphyton, and benthic tissues. Some limited data from fish surveys are also available.

<u>Pole Canyon Creek</u>

Upper Pole Canyon Creek prior to and after construction of the cross-valley fill (ODA) in about November 1985 had total selenium concentrations of 2 ug/L or less up to 2004. Lower Pole Canyon Creek, prior to the ODA had total selenium concentrations that ranged from 2 to 100 ug/L. From November 1985 through July 2004, selenium in surface water at the Lower Pole Canyon

Creek location steadily increased with the highest concentration measured in May of 1999 (1000 ug/L). Figure 5 shows the selenium concentrations in surface waters at the Lower Pole Canyon Creek location beginning in 2004. After the pipeline diversion became operational in 2007, concentrations have been low (<5 µg/L) except during a brief time in 2011 (described in the RI/FS, and summarized in Appendix C of this proposal).

Some additional limited data on selenium concentrations in aquatic biota are also available to aid in understanding selenium bioaccumulation. In 2004, selenium in sediment at the location LP at the base of the ODA (the stream monitoring station through 2007 until the bypass pipeline was installed) had a concentration of 58.1 mg/kg dw. At LP-PD downstream of the bypass pipeline, selenium in sediments in 2010 was 13.4 mg/kg dw. In 2004, aquatic vegetation and periphyton samples were collected at Pole Canyon Creek locations upstream and downstream of the ODA. Upstream of the ODA, macrophytes had selenium concentrations that ranged from 0.48 to 1.7 mg/kg dw and periphyton had a concentration of 3 mg/kg dw. Downstream of the ODA, macrophytes had selenium concentrations that ranged from 66.1 to 87.7 mg/kg dw and periphyton had a concentration of 69.1 mg/kg dw. Total selenium in benthic invertebrate tissues at UP was 0.57 mg/kg wet weight (ww) while at the LP location it was 16.6 mg/kg ww. Based on the mean percent solids from other benthic invertebrate samples collected since 2006, these values would be equal to 2.84 mg/kg dw at UP and 82.59 mg/kg dw at LP. In 2010, benthic tissues had a total selenium concentration of 16.9 mg/kg dw at the LP-PD location.

Fish surveys (completed in 2004 and again in 2010) as well as historical monitoring (from 1979 and 1981) show that Pole Canyon Creek both upstream of the ODA and downstream of the ODA lacks fish. Current observations indicate that Pole Canyon Creek is intermittent and that flows only occasionally reach North Fork Sage Creek. Absence of perennial flow and connectivity as well as the presence of the ODA since 1985 are physical limitations to fish being present in this stream. Based on the above noted selenium concentrations in surface water, sediments, periphyton, macrophytes and benthos, it is possible that selenium concentrations were high enough prior to the ODA bypass pipeline to be toxic or fish actively avoided those concentrations in favor of waters with lower selenium concentrations. Since the installation of the bypass pipeline, sediment, water and benthic tissue selenium concentrations have decreased significantly.

North Fork Sage Creek

North Fork Sage Creek originates in the foothills of northwestern Sage Valley, flowing due east into the valley before turning and flowing south. A series of springs contribute to this headwater stream in Sage Valley where it is joined by Pole Canyon Creek. Downgradient of the ODA, Pole Canyon Creek is intermittent with flow only occasionally reaching North Fork Sage Creek during high-flow spring runoff conditions.

Similar to Pole Canyon Creek, some limited data are available in North Fork Sage Creek aquatic biota to aid in understanding selenium bioaccumulation in this stream. Total selenium in the North Fork Sage Creek at NSV6 downstream of Pole Canyon Creek has been documented twice a year since 1997. From 1997 to 2004, selenium concentrations in surface water have ranged from 1 to 41 ug/L at this location. Beginning in 2004 (Figure 5) the selenium concentration in surface water has typically been about 10 ug/l or less except in 2011 and once again in 2013. Sediment data from this location indicate concentrations ranged from 3.6 to 4.13 mg/kg dw in 1998 to 1999. In 2010, the concentration of selenium in sediments was 6.5 mg/kg dw. At NSV-5, upstream of the Pole Canyon Creek confluence in 2004, macrophyte concentrations of selenium ranged from 0.18 to 0.65 mg/kg dw. The benthic invertebrate tissue concentration at this location during 2004 was 1.09 mg/kg ww, which converted to dry weight assuming 20.1% moisture is 5.42 mg/kg dw. In 2010, the benthic tissue concentration at NSV-6 was 11.9 mg/kg dw.

Upper North Fork Sage Creek, near where one of the springs originates, was found to contain brown trout and high numbers of sculpin (Mariah Associates 1980). Sampling in the upper North Fork during the RI/FS in 2010 was hampered by poor visibility and excessive algal growth caused by large numbers of cattle present in the stream and muddy bottoms. The lower section of North Fork Sage Creek near the confluence with Sage Creek has been observed to contain fish. Although the lower North Fork Sage Creek was not sampled as part of the SSSC effort or the RI/FS, historical records as reported in the Draft EIS for the Smoky Canyon Phosphate Mine from Heiner (1979), Mariah Associates (1980), and Collins (1981) indicate that brown trout and YCT were present.

Summary

Both Pole Canyon Creek and North Fork Sage Creek have experienced past elevated concentrations of selenium in surface water, sediments, and biota. For both streams, concentrations have decreased due to implemented Non-Time Critical Removal Actions. The limited data suggests that while concentrations in water and some biological media has decreased, selenium is still somewhat elevated. At the LP-PD and NSV-6 locations, benthic tissue selenium concentrations in 2010 are similar to the benthic tissue concentrations observed at South Fork Sage Creek, and Sage Creek, suggesting that the SSSC developed for Hoopes Spring and Sage Creeks is applicable to Pole Canyon Creek and North Fork Sage Creek.

5.3 Literature

The literature has guided the development of the approach and design for this study. The literature was reviewed to examine applicable methods for evaluating selenium toxicity to aquatic life, identifying sensitive species and sensitive life stages, as well as identifying effective measurement endpoints for evaluating toxicity. In the analysis phase of the evaluation, the literature continues to be reviewed to assess how results from this study compare to those of others. This step provides an important "reality" check in making determinations about data applicability, accuracy, and representativeness for the Site.

5.3.1 Fish

The most comprehensive review of the literature is compiled in the 2016 National Criterion (USEPA 2016a). It includes reviews and independent analyses of data from each study. Reproduction and non-reproduction studies are reviewed for cold and warm water fish, and information for non-fish aquatic species sensitivities are also described. For most studies reviewed, deformities and/or survival were the common endpoints. Of the cold-water studies, those that would be the most important for developing an SSSC for streams within the Site, EC_{10} values range from 21 (brown trout) to 56 (Dolly Varden char) mg/kg dw egg selenium (Table 3). In almost all of the studies reviewed, the dose response was steep, and the effects were best correlated to egg selenium concentrations.

Brown Trout and Cutthroat Trout – Brown trout was the most sensitive salmonid tested. For the trout species, there was a relatively narrow range of effects thresholds. Westslope cutthroat trout had a SMCV of 26.2[14] mg/kg dw egg selenium, while rainbow trout were only slightly more

[14] The geometric mean of the EC_{10} values for westslope cutthroat trout.

sensitive at 24.5 mg/kg dw egg selenium. Studies by Hardy et al. (2005, 2010) indicated that there was no effect on survival or deformities for YCT at 16 mg/kg dw egg selenium, while the Formation (2012) studies, using the same species, indicated that the EC_{10} for surviving normal fry was 28.4 mg/kg dw egg selenium. Based on the USEPA (2016) assessment of the YCT data from Formation (2012) a no observed effects concentration (NOEC) was suggested based on the individual endpoints up to 30 mg/kg dw in eggs with one treatment or egg batch showing 100 percent mortality at 40 mg/kg dw.

Other Salmonid Species – USEPA (2016a) evaluated the brook trout data from Holm et al. (2005) and suggested that the effect threshold is greater than 48.7 mg/kg dw selenium due to the absence of any consistent concentration-response relationship up to the maximum observed egg concentration. Pilgrim (2009) examined rainbow, brook, and cutthroat trout for deformities and survival from reproductive studies, but due to the relatively high variability of the concentration responses for the replicate data using the deformity endpoint, none of these data were considered in the 2016 National Criterion development. For the USEPA (2016a) analysis, the genus *Salvelinus* is represented by the Dolly Varden data generated by the Golder (2009) study. Considering the survival data from Holm et al. (2005) and Pilgrim (2009), an EC_{10} for brook trout survival of 32 mg/kg dw egg selenium can be derived. Thus, the effects for brook trout may range from 32 to 48.7 mg/kg dw egg selenium.

For rainbow trout, USEPA (2016) integrated the data from Holm (2002) and Holm et al. (2003; 2005). The most sensitive larval deformity endpoint was found for larval edema resulting in an EC_{10} value of 9.5 mg/kg ww, which when converted to dry weight (USEPA assumed a 61% moisture content) resulted in an EC_{10} of 24.5 mg/kg dw.

Fathead Minnow – While USEPA (2016a) included the fathead minnow data from Schultz and Hermanutz (1990) as part of their "N" value for achieving 15 species, they did not include it in the reproduction studies distribution showing effects relative to egg selenium concentrations. Their rationale was that the uncertainty in the study was sufficient to not include it and an EC_{10} could not be determined from those data. USEPA (2016a) shows a lowest observed effects concentration (LOEC) for the Schultz and Hermanutz (1990) study of <25.6 mg/kg dw egg selenium meaning an EC_{10} would likely be lower than the LOEC value cited. This is inconsistent with much of the fathead minnow and cyprinid data suggesting cyprinids as a group are not particularly sensitive to selenium.

GEI (2008) data were also described but not utilized in the 2016 National Criterion derivation because USEPA (2016a) indicated that the high variability and lack of response made it difficult to derive an EC_{10}. GEI (2014) pointed out some of USEPA's inconsistencies in their use of some data sets versus others in its comments on the USEPA 2014 Draft Criterion document. GEI (2014) notes that USEPA used a generic egg to whole body conversion factor of 2 instead of the species-specific conversion factor of 1.4. They further noted that deformity rates in their study do increase with increasing whole-body selenium exposure, consistent with other studies used by USEPA. GEI (2014) recommended a chronic value of 42.067 mg/kg dw whole body, which was the lowest deformity response of the four evaluated. Converting to an egg concentration using a factor of 1.4 yields a chronic egg value of 58.89 mg/kg dw. USEPA (2016a) does cite the GEI (2008) data as well as Young et al. (2010) observations[15] to illustrate that fathead minnows are likely less sensitive than the LOEC based on the Schultz and Hermanutz (1990) study. An SMCV can be derived for fathead minnows by calculating the geometric mean of the GEI (2008) study EC_{10} and the Schultz and Hermanutz (1990) study LOEC, which equals 38.83 mg/kg dw egg selenium.

Sculpin – One study that was not submitted to USEPA for consideration in developing the 2016 National Criterion was by Golder and Nautilus Environmental (Nautilus) that examined the effects of dietary selenium on the reproductive capabilities of slimy sculpin (*Cottus cognatus*). These data were presented at the 34th Annual SETAC meeting by Lo et al. (2014). Dietary selenium effects in slimy sculpin were tested by Nautilus starting in 2011. Slimy sculpins were collected from the field and fed a selenium dosed diet for 7 months prior to being brought into spawning condition in the laboratory. They found that the no effect egg tissue concentration was 22.0 mg/kg dw selenium in adult slimy sculpin and that the effect threshold was greater than 22 mg/kg dw. The highest whole-body tissue measured in Lo et al. (2014) was 11 mg/kg dw. Thus, the EC_{10} is at some concentrations greater than 22 mg/kg dw egg selenium.

Given that the NOEC for slimy sculpin is currently cited as a greater than value and it is within the range of the most sensitive species, understanding sculpin sensitivity is important to determine whether this species is as sensitive as those species already identified as sensitive species. As part of this revised SSSC proposal, an analysis of the existing sculpin population, age class, and

[15] Fathead minnows remained after selenium contamination eliminated most other fish species from Belews Lake, including bluegill sunfish and largemouth bass.

whole-body selenium data was performed (Appendix D). The analysis supports the finding that sculpin are less sensitive to selenium than trout species. This conclusion is based on observations that while sculpin whole-body selenium concentrations substantially exceed the EC_{10} for YCT (14.5 mg/kg dw), that:

- Long term population density at affected sites (e.g., HS-3) is similar to or higher than at background locations;
- Important recruitment age classes (years 1-3) are present at locations with the highest selenium concentrations in water and dietary media; and
- Young fish are surviving the critical life stages where selenium toxicity is considered lethal, and adult fish are remaining abundant and reproducing.

These conclusions are based on 11 years of sculpin population monitoring. Results support the approach of including the unbounded Lo et al. (2010) study NOEC of greater than 22 mg/kg dw eggs. There is a sufficient weight of evidence that the upper bound effects threshold for sculpins is higher than the sensitive species used for the SSSC proposal criterion.

White Sucker – White sucker sensitivity to selenium was examined by de Rosemond et al. (2005) using field collected organisms from a lentic area in northern Saskatchewan. Two hundred eggs from four fish were used in the study. Eggs were randomly separated into groups of 100 eggs for rearing, yielding an N of 8 treatments/egg batches. Egg selenium concentrations ranged from 8.4 to 48.3 mg/kg dw. The authors acknowledge that the lack of controls negates interpretation of definitive endpoints and confounds the assessment of the developmental deformities as to whether or not they are typical for this population of white suckers. While limited data were available, USEPA's (2016a) review suggested that embryo/larval effects are not observed at concentrations in eggs reaching 40.3 mg/kg dw (geometric mean of the two high selenium concentrations in eggs). This species was not included in the 2016 National Criterion development because it was based on a small data set with no controls.

Muscatello and Janz (2009) examined northern pike and white suckers from an area similar to that in the de Rosemond et al. (2005) study; lentic habitats downstream of a uranium mine. In that study, five reference-site fish and four exposure-site fish were tested. Selenium concentrations from the exposure location in white sucker eggs (4.86±0.52 mg/kg dw) were significantly higher than reference location eggs (1.94±0.25 mg/kg dw). Among the four categories of deformities evaluated (spinal curvatures, craniofacial deformities, fin deformities, and edema), only edema in white sucker fry was significantly higher (~3%, $p < 0.05$) compared with the reference location. McDonald and Chapman (2007) indicate edema inclusion as a diagnostic deformity metric is debatable because it is reversible and not strictly a teratogenic effect. Muscatello and Janz (2009) found no significant differences in the frequencies of total deformities nor in the cumulative time to 50 percent eyed embryo, 50 percent hatch, and 50 percent swim-up between treatments. The authors concluded that white sucker fry originating from the exposure location displayed a slight increase in the incidence of edema that also could be associated with several factors (e.g., other metals, organic compounds, and ammonia) other than selenium and that overall, based on total deformities, no significant effects occurred.

The collective evidence indicates that no effects to white sucker are evident up to the USEPA suggested NOEC of 40.3 mg/kg dw when considering both the de Rosemond et al. (2005) and the Muscatello and Janz (2009) study. While a definitive EC_{10} cannot be readily derived from these published studies, the range of exposures, including reference location, low, and high selenium concentrations is more than adequate to arrive at a conclusion that effects occur at some level greater than 40.3 mg/kg dw. Effect information such as an EC_{10} is not needed, because the no effect concentration is greater than the most sensitive species utilized in the proposed SSSC.

5.3.2 Invertebrates

Overall, the literature suggests that reproductive endpoints in fish tend to be a sensitive indicator of excessive selenium and that invertebrates are less sensitive to selenium effects than fish. Long-term studies of benthic macroinvertebrate response to selenium exposure are few. Swift (2002) conducted long term (>1 year) experimental dosing studies on stream mesocosms and found no significant effect on benthic community abundance, diversity, or richness in the high (30 µg/L nominal) and moderate (10 µg/L nominal) experimental units, but *Tubifex* and Isopod numbers were reduced.

deBruyn and Chapman (2007) examined the literature to assess selenium sensitivity of macroinvertebrates and found that some invertebrates may be sensitive at body burdens similar to those protective of fish. USEPA (2016a) identified and reviewed three invertebrate studies that included dietary exposure for invertebrate species from which EC_{10} values could be derived. USEPA (2016a) derived an EC_{10} of 37.84 mg/kg dw for the rotifer, *Brachionus,* from the Dobbs et al. (1996) study and an effect level >140 mg/kg dw for the oligochaete, *Lumbriculous.* USEPA (2016a) also reviewed and presented findings of the Conley et al. (2009, 2011, and 2013) studies.

Conley at al. (2009, 2011, and 2013) published a series of studies for the mayfly, *Centroptilum.* Conley et al. (2009) conducted a dietary feeding study on uptake of selenium in mayflies. Measurable effects on fecundity were found at dietary concentrations of selenium less than 11 mg/kg. The diet was comprised of algae which concentrate selenium at several times the abiotic concentrations and also convert selenium into more bioavailable methylated forms. Conley et al. (2009) demonstrated that, like fish, benthic invertebrate exposure to, and effects from, selenium are based on the dietary intake. Using the BAF of 2.2 provided by Conley et al. (2009), the 11 mg/kg dietary value corresponds to an adult mayfly tissue selenium concentration equal to 24.2 microgram per gram (µg/g) dw. In subsequent work, Conley et al. (2011) found that bioaccumulation and influence of selenium on mayfly performance may be tied to resource availability and quantity. Conley et al. (2013) reported a bioaccumulation or trophic transfer factor of 2.1 and defined secondary reproductive effects at a dietary concentration of 12.8 mg/kg dw, thus supporting their earlier work that effects occur at dietary concentrations greater than 11 mg/kg dw. Again, using the BAF and applying that to the dietary concentration of 12.8 mg/kg dw, a whole-body tissue threshold of 26.9 mg/kg dw was derived. USEPA (2016a) translated the Conley et al. EC_{10} of 24.2 to a median whole-body concentration at trophic level 3 to 29.3 mg/kg dw.

The prevailing scientific evidence supports the current thinking that effects to developing fish are among the most sensitive aquatic biological indicators of excessive selenium exposure (USEPA 2004; Lemly 1996; Ogle and Knight 1996; Skorupa et al. 1996; Janz et al. 2010). This would suggest that if the biological response of fish is considered a very sensitive indicator of effects, fish species would be considered a sensitive aquatic receptor.

5.3.3 Amphibians

Recent reviews of scientific literature suggest that amphibians are less sensitive to the effects of metals than are fish (Kerby et al. 2010, Weltje et al. 2012). Kerby et al. (2010) evaluated a large number of exposure and toxicity tests including invertebrates, fish, and amphibians and found that amphibians may be less sensitive than other aquatic biota.

Weltje et al. (2012) conducted a comparative analysis of acute and chronic sensitivity of fish and amphibians for approximately 50 chemicals, including some metals, but mostly organic chemicals. Of the chemicals evaluated, the only metals evaluated were cadmium, copper, and zinc. The study compared chronic NOECs reported in the literature and/or regulations of various agencies. They found that amphibian NOECs were generally higher than sensitive fish species. The authors concluded that NOECs and water quality criteria generated for fish species will be generally protective of amphibians. They also concluded that additional amphibian testing may not be necessary for chemical risk assessment.

An overall conclusion from Kerby et al. (2009) and Weltje et al. (2012) is that amphibians are generally less sensitive than fish or other aquatic organisms to a broad range of environmental contaminants in water. However, neither of these reviews included dietary pathways that are important for exposure of aquatic vertebrates to selenium. Hopkins et al. (2006) examined developmental effects of selenium accumulation in maternal adults and transfer to developing embryos in eastern narrow-mouthed toads (*Gastrophryne carolinensis*). Female adult toads would have obtained most of the selenium body burden through dietary pathways. Similar to fish, selenium accumulated by the maternal parent is transferred to eggs and can affect developing young. The highest selenium accumulation in eggs (up to 80 to 100 mg/kg dw) was substantially higher than for trout eggs. Egg viability was higher, and deformities were lower (96 hour) than for reference eggs for all but one endpoint (craniofacial). These data suggest that *G. carolinensis* embryo development is less sensitive than brown trout to selenium in eggs. However, small samples sizes at the higher concentrations may have affected the ability to detect statistical differences. Interpretation of the Hopkins et al. (2006) study reveals an estimated NOEC threshold value of approximately 20 mg/kg dw[16] can be derived.

Unrine et al. (2007) evaluated metal concentrations in mollusks, insect larvae, bullfrog tadpoles, and fish collected from a coal-ash affected swamp area of the United States Department of Energy

[16] When all developmental criteria were considered collectively, offspring from the contaminated site experienced 19% lower viability, although egg selenium concentration and egg viability were not statistically related (Hopkins et al. 2006). While a true effects threshold related to amphibian body burdens was not derived in this study, there was a demarcation of effects relative to controls at the contaminated sites. The mean value of 42.4 mg/kg dw in whole body tissues has a large degree of uncertainty associated with it based on the standard error presented. The mean value (n=10) for the contaminated sites was based on data spanning a wide range of body burdens and Hopkins et al. (2006) state that their statistical power for detecting functional relationships between concentrations and effects was probably limited within the range of concentrations where effects should be predominant (e.g., egg selenium concentrations > 20 mg/kg dw).

Savannah River Site in South Carolina. Bullfrog tadpoles (*Rana catesbeiana*) accumulated between 1 and 4 times higher concentrations of several metals than other invertebrates and fish. For selenium, concentrations (whole body) in tadpoles were marginally higher (approximately 1.5 times) than concentrations in aquatic insect larvae (dragonfly genera *Tramea* and *Erythemis*), smallmouth bass (*Micropterus salmonoides)* and spotted sunfish (*Lepomis punctatus*). The swamp site from which these data were collected is a lentic system, and the pattern of relative concentrations among these groups may not be comparable to the lotic systems at the Site. However, the similar concentrations among the tadpoles and other aquatic biota suggest that anuran amphibians will not bioaccumulate selenium at substantially higher levels than the brown trout at the Site.

In a more recent study, Masse et al. (2015) derived an EC_{10} for the *Xenopus laevis*; a toad that is a standard test species in the Frog Embryo Teratogenesis Assay Xenopus (FETAX) toxicity assessment procedures. USEPA (2016a) reviewed this study and reports the authors EC_{10} values for abnormal spinal curvature, abnormal craniofacial structure and abnormal lens structure were 57.3, 38.4, and 34.5 mg/kg Se egg dw, respectively. The study identified an EC_{10} value of 44.9 mg/kg dw in eggs for total deformities.

6.0 SSSC DEVELOPMENT

The 2016 National Criterion is derived from a distribution of different selenium concentrations (e.g., EC_{10} values) in egg/ovary tissues based on survival and/or deformities according to the methods found in Stephan et al. (1985). There are minimum data requirements (MDRs) to be met (N=8) in order to provide sufficient types of acceptable aquatic toxicity data for developing a criterion outlined in Stephan et al. (1985) that are described in detail in the 2016 National Criterion. The 2016 National Criterion exceeds the MDRs with an N=15 and the brown trout data are the 3rd most sensitive species/genera of the 15 cited GMCVs for reproductive effects (USEPA 2016a). Eight fish egg/ovary thresholds were utilized at the genus level (Figure 3.1 of the 2016 National Criterion). Both fathead minnow data and *Gambusia* were included in the total N for a total of 10 fish GMCVs. Three invertebrate thresholds were also included which adjusts the total N to 13 GMCVs. Two additional values were waived as non-existing, non-essential values for invertebrates which brings the total N to 15. Page 59 of the 2016 National Criterion explains this waiver.[17]

The number of species in the database (N) plays a significant role in the criterion derivation process which is designed to calculate a more conservative criterion when N is small (Erickson and Stephan 1988). For this SSSC proposal, providing a representative N for the criterion derivation that meets the MDRs is difficult due to the limited species present at the Site and the availability of acceptable toxicity threshold data for fish from which to derive the SSD.

The current selenium dataset for fish maternal reproductive studies is limited. In addition, when small streams are being evaluated with limited species diversity, there simply are not enough species or data to use in USEPA's recalculation procedure. For example, of the 15 GMCVs utilized to compile the overall number of species in the 2016 National Criterion derivation, six of the eight fish studies were eliminated for this SSSC proposal (i.e., bluegill, white surgeon, largemouth bass, northern pike, desert pupfish, and mosquitofish) because they were either not found within the Study Area or not representative as a suitable surrogate for another similar

[17] Because the 5th percentile calculation methods for the FCV use actual numerical values for the GMCVs of the four most sensitive (fish) genera in the selenium dataset, it is only necessary to know that the more tolerant genera have GMCVs that are greater than those of the lowest four. A recommendation in the draft white paper on Aquatic Life Criteria for Contaminants of Emerging Concern Part I (U.S. EPA 2008b), which was supported by the Science Advisory Board, states "because only the four most sensitive genus mean chronic values (GMCVs) are used in the criterion calculations, chronic testing requirements for a taxon needed to meet an MDR should be waived if there is sufficient information to conclude that this taxon is more tolerant than the four most sensitive genera."

sensitive species. Fish reproductive studies remaining included brown trout, *Oncorhynchus* (Westslope cutthroat trout and rainbow trout), and Dolly Varden (representing the genus *Salvelinus*) for derivation of GMCVs. These data are insufficient for the SSD approach based on USEPA (2016) recommended methods, therefore a most sensitive species approach is appropriate. Other studies and endpoints other than those utilized by USEPA (2016a) are considered in this SSSC proposal to put the available data into context for species present at the Site.

6.1 Egg/Ovary Criterion

The key threshold for developing this SSSC is the brown trout EC_{10} that is based on survival of larval brown trout. USEPA (2016a) utilized Simplot's brown trout data and derived an EC_{10} of 21 mg/kg dw egg selenium based on survival from hatch to swim up. Simplot derived their own EC_{10} from the brown trout survival data using the full set of data (e.g., hatch to test termination), which was 20.5 mg/kg dw egg selenium. Two slightly different compilations of the brown trout survival data yielded two EC_{10} values that are remarkably similar and toxicologically not different. The approach and rationale for both the USEPA and Simplot EC_{10} derivations are described at length in USEPA (2016a) Appendix C and Simplot's Draft manuscript in revision for publication, *Effects of in situ selenium exposure and maternal transfer on the survival of brown trout (Salmo trutta) fry.*[18] Simplot's EC_{10} for brown trout was used for this SSSC proposal and it is the most sensitive value in the compilation of species for which acceptable egg/ovary effect threshold data are available (Table 3).

Brown trout (genus *Salmo*), represents the most sensitive species (EC_{10} = 20.5 mg/kg dw). The genus *Oncorhynchus* includes three sensitive species. Rainbow trout represent a sensitive species (EC_{10} = 24.5 mg/kg dw) that has the potential to be present at the Site (in Crow Creek). At least one hybrid rainbow/cutthroat trout has been captured in Crow Creek over the 11-year monitoring period. Westslope cutthroat trout are not present at this Site, but are included as a related cutthroat trout species to Yellowstone cutthroat trout. For these two species in the genus *Oncorhynchus*, the EC_{10}s are as follows: Westslope cutthroat trout (24.7 and 27.7 mg/kg dw) and YCT (28.4 mg/kg dw). The genus Salvelinus is represented in USEPA (2016) using the Dolly

[18] This draft manuscript is in revision based on comments from peer reviewers and can be provided upon request following the completion of revisions.

Varden (EC_{10} = 56.2 mg/kg dw). This SSSC proposal combined survival data from Holm et al. (2005) and Pilgrim (2009) to derive an EC_{10} for brook trout survival of 32 mg/kg dw egg selenium. Evaluation of the trout species present indicates that brown trout is the most sensitive species based on the egg/ovary effects data.

Compiled through multi-year site-specific monitoring and observations, a comprehensive species list for several locations within the Site is available, which includes salmonids, cyprinids, cottids, and catostomids (Table 1). For the fish species, limited but useful data are available to assess potential sensitivity to selenium. As a family, Cyprinids have been demonstrated to not be particularly sensitive to selenium. Considering the fathead minnow data described previously, an egg/ovary EC_{10} was derived equal to 38.83 mg/kg dw. USEPA (2016) evaluated laboratory effects data as well as population data for native cyprinids and concluded that "…native cyprinids appear to have a tolerance to selenium that is greater than centrarchid and salmonid species…" For sculpins, the limited effects data combined with the available field population and age-size class data indicate that sculpins are less sensitive than Yellowstone cutthroat trout or brown trout (Appendix D). The white sucker data, while limited, suggests a NOEC much higher than the EC_{10} for brown trout. The proposed SSSC for egg/ovary is the EC_{10} for brown trout which is equal to 20.5 mg/kg dw selenium. As the most sensitive species, the proposed egg/ovary SSSC concentration of 20.5 mg/kg dw should be protective of the aquatic life present in Hoopes Spring, Sage Creek (and tributaries), South Fork Sage Creek, and Crow Creek downstream of Sage Creek.

6.2 Whole-Body

USEPA (2016a) went through a similar species/genus selection process for deriving their whole-body tissue criterion as they did for the egg/ovary derivation. Egg/ovary effects data were converted to whole body equivalent concentrations using species specific CFs. As with the egg/ovary data, several species were removed from the list as not present, potentially present or representative as a suitable surrogate species.

For this SSSC proposal, the resident and potentially resident species are known and well documented. The whole-body criterion for the SSSC is based the most sensitive resident species from the whole-body tissue data available (Table 4).

Based on the egg/ovary data, brown trout are the most sensitive species. Using the site-specific conversion factor (1.46 described in Appendix E) applied to the egg/ovary value of 20.5 mg/kg dw yields a value of 14 mg/kg dw selenium for whole body. USEPA (2016a) derived a whole-body tissue selenium concentration for brown trout of 13.2 mg/kg dw using Simplot's data. This value is based on the no-effect concentration from the brown trout reproductive study where the associated egg/ovary value was 20.5 mg/kg dw[19]. Thus, the whole-body tissue value of 13.2 mg/kg dw is a no-effect threshold from USEPA (2016a). Because two defensible whole-body concentrations for brown trout are available, this SSSC proposal used the geometric mean value of the two (13.2 and 14) to arrive at a whole-body tissue concentration of 13.6 mg/kg dw for brown trout.

Among the salmonids, the lowest whole-body tissue concentration threshold is represented by rainbow trout at 12.5 mg/kg dw based on using a CF of 1.96 to convert the egg/ovary selenium concentration of 24.5 mg/kg dw. It should be noted that the original egg/ovary value is an exceptionally conservative estimate because it was derived based on edema, a transient deformity, which was the lowest EC_{10} of the deformities assessed. Further, USEPA (2016a) used a 61 percent moisture value to convert the wet weight egg/ovary data from the original study to dry weight. This percent moisture is suspected to be low for eggs. Yellowstone cutthroat trout and brown trout egg percent moistures ranged on average from 69 to 71 percent. Use of a higher percent moisture to convert the original wet weight egg/ovary data to dry weight would result in a higher egg/ovary concentration as well as a higher whole-body tissue concentration.

The whole-body species mean concentration for Westslope cutthroat trout is 13.3 mg/kg dw while the whole-body concentration for Yellowstone cutthroat trout is 14.5 mg/kg dw. The overall species geometric mean concentration is 13.7 mg/kg dw.

Of the species whole body thresholds presented in Table 4, the above three species have the lowest values. The slimy sculpin data as previously shown in the preceding section as well as in Appendix D, are represented by an unbounded NOEC for whole body of greater than 11 mg/kg dw. However, the Site population and age class data for the resident sculpin species indicate that populations are thriving at whole body concentrations well above the Yellowstone cutthroat

[19] The value 20.5 mg/kg dw is the egg concentration cited as no effects with a corresponding maternal whole-body tissue concentration of 13.2 mg/kg dw. These are the measured values from the brown trout study.

whole-body concentration of 14.5 mg/kg dw. Sculpins are therefore not considered a sensitive species based on whole body concentrations. Likewise, cyprinids and catostomids are also not considered sensitive based on whole body concentrations (Table 4).

As noted previously, rainbow trout may be present in Crow Creek based on the presence of a rainbow - cutthroat trout hybrid observed in 2009. This single individual may have migrated from downstream. Both the Auburn Fish Hatchery and Star Valley Trout Ranch located in the lower portion of the Stump Creek watershed are known to rear rainbow trout, among other species, and either one or both are plausible sources for escaped or potentially historically stocked rainbow trout.

In Hoopes Spring, Sage Creek, and Crow Creek historical monitoring was conducted in 1979, 1981, 1987, 1999, 2000, and 2004. The more recent consistent monitoring spans from 2006 to 2016. In nearly 40 years, only 2 rainbow trout have ever been documented in Hoopes Spring, Sage Creek or South Fork Sage Creek, and they were found in South Fork Sage Creek in 1979. These data indicate that this species is not resident, nor is its presence a management goal of the resource agencies. The conclusion from the Site survey data is that rainbow trout are absent from Sage Creek/Hoopes Spring, and only potentially present in Crow Creek as cutthroat hybrids that may have migrated from downstream sources. Based on this conclusion, separate whole-body criteria are proposed for the two stream segments.

Due to the potential presence of a rainbow trout hybrid, the whole-body tissue criterion for Crow Creek downstream of Sage Creek is set at 12.5 mg/kg dw. For Sage Creek and Hoopes Spring, the absence of rainbow trout for nearly 40 years indicates that brown trout should be used as the most sensitive species for this area. As noted previously, the whole-body value for brown trout is 13.6 mg/kg dw which is lower than the cutthroat mean value of 13.7 mg/kg dw. The proposed whole-body criterion element for Hoopes Spring and Sage Creek is 13.6 mg/kg dw.

Finally, future monitoring to assess compliance with the whole-body element of the criterion will be conducted based on collection and chemical analysis of brown trout whole body tissues. Brown trout are one of two recreationally important game species found at all locations within the Study Area (except Deer Creek) where tissue monitoring will be conducted for compliance monitoring. It is numerically the predominant of the two trout species found and is also a non-native species. The predominant tissue data base for the Study Area is for brown trout. Brown trout is the logical target species for monitoring. As recommended by USEPA (2016a), “Selection of the fish species in the aquatic system with the greatest selenium sensitivity and bioaccumulation potential is recommended."

6.3 Water

According to USEPA (2016a), a protective water concentration may be developed from the site-specific egg/ovary, whole body, or muscle criterion elements. Translation of the fish tissue criterion to a protective water concentration can be performed in a manner that accounts for site-specific conditions. Two approaches for developing a protective water concentration from tissue thresholds are offered as valid approaches. These include: (1) use of a mechanistic approach (Presser and Luoma 2010) to model selenium through the food chain, or (2) use of an empirical BAF approach. Appendix K of USEPA (2016a) outlines the two approaches and discusses their advantages and disadvantages. A protective water selenium concentration was derived using both methods because sufficient data were available to evaluate the similarity or dissimilarity between them.

6.3.1 Mechanistic Trophic Model

The mechanistic model approach is considered to be more comprehensive, but due to its many steps (i.e., trophic levels) it can be more uncertain. The primary uncertainty arises in the enrichment factor (EF) portion of the model. EFs can vary widely, as it is a ratio of algae, detritus, and sediment to water which can vary over time. Further, concentrations of sulfate have been shown to affect selenium uptake and the resulting bioaccumulation in freshwater organisms, including algae (Brix et al. 2005, Ogle and Knight 1996, Williams et al. 1994). For the purposes of this SSSC, all inputs for the mechanistic model were derived from samples collected on Site. Thus, the model is empirically based. The data, methods, assumptions, and calculations used to derive a water element from the egg/ovary SSSC are presented in Appendix F.

Using the mechanistic trophic model, protective water concentrations were derived using data compiled from 2006 to 2011 for two seasonal conditions: (1) Site streams – all seasons, and (2) Site streams – summer/fall seasons. In addition, these seasonal conditions were evaluated by individual streams and grouped streams (Table 5). For this dataset, the number of paired samples (water, sediment, periphyton, benthic invertebrate, sculpin, and trout) results in an N=37. Where multiple fish tissue samples were collected for a location and time period, the arithmetic mean was used as the representative concentration.

Using the egg/ovary value of 20.5 mg/kg dw as the basis, the dissolved water concentrations allowed such that the egg/ovary criterion is not exceeded are 13.0 µg/L (all Site streams – all seasons) and 13.7 µg/L (all Site streams – summer/fall seasons) (Table 5). Crow Creek downstream of Sage Creek was found to have higher EFs and $TTF_{composite}$ values, suggesting selenium bioaccumulation in Crow Creek was different than that observed in Hoopes Spring, Sage Creek, and South Fork Sage Creek. For Crow Creek, the allowable water concentrations that would not exceed the egg/ovary criterion value of 20.5 mg/kg dw via mechanistic trophic modeling was 4.8 µg/L (all seasons) and 6.4 µg/L (summer/fall seasons). The Hoopes Spring, Sage Creek, and South Fork Sage Creek allowable water concentrations were 16.1 µg/L (all seasons) and 18.9 µg/L (summer/fall seasons).

Figure 11 shows the relationship of predicted dissolved selenium from the mechanistic model versus the actual measured dissolved selenium concentrations. Overall, the linear relationship (R^2 = 0.89) indicates a strong relationship between predicted and measured dissolved selenium concentrations. Despite this relationship, the variability increases as selenium concentrations increase. The model sometimes over or under predicts the actual dissolved concentration, in some cases by a large margin (>10 µg/L) as selenium increases. The multiple trophic steps in the mechanistic model allow for introduced variability at each step. As selenium concentrations in the surface waters increase, the variability in each trophic accumulation step may also increase. For this SSSC proposal, this became important because selenium concentrations in surface water of the Site often exceed 10 µg/L, which may affect subsequent selenium bioaccumulation and integration into higher levels of the food chain.

6.3.2 Empirical BAF Model

The empirical BAF approach relies on a site-specific, field measured BAF (i.e., selenium tissue concentration divided by dissolved selenium concentration in surface water). It is a direct measure of selenium bioaccumulation into fish, without the trophic steps and requires no assumption on dietary intake. The BAF approach uses site-specific ratios developed that are not intended for use in other watersheds. Figure 12 includes two figures, one illustrating the whole-body selenium concentrations relative to the dissolved selenium concentrations for the dataset and the second showing the derived BAFs versus dissolved selenium concentrations in surface waters. If calculated based on individual fish, BAFs will always show variability because multiple whole-body concentrations can be measured relative to a single surface water concentration as shown in the upper graphic of Figure 12. Selenium concentrations among individual fish can vary widely even if they are collected from a narrow range of water concentrations. This is especially true for low selenium concentrations in water (Figure 12).

In Crow Creek downstream of Sage Creek, the variability in whole body concentrations leads to a wide range of BAFs at the lowest selenium concentrations (<3 ug/L). At higher water concentrations (e.g., above 5 ug/L) the range of BAFs decreases (Crow Creek, Sage Creek, South Fork Sage Creek) as shown in the lower graphics of Figure 12. The mechanism for higher bioaccumulation at low selenium concentrations in water and diet is not clear but may be related to dietary needs when selenium is low.

These results show two important trends:

1) BAFs tend to decrease as water selenium concentration increases and

2) The range and variability of whole body concentrations and BAFs is higher at low water selenium concentrations compared to higher water concentrations.

The first trend is commonly observed in water and other environmental media (Deforest et al. 2007; McGeer et al. 2003). Overall, these trends indicate that when setting the water column element of the selenium criterion, selection of the BAF used should consider the range of potential water column concentrations in which the criterion is expected to fall.

The second trend is important because it affects the ability to identify the effect of water column concentration on whole body (or other tissue) concentrations. When calculating the water column element of the criterion, the selected BAF must be representative of the water and fish tissue concentrations present to ensure that the criterion is protective without being under or overprotective. Stephan et al. (1985) note that:

> "Criteria should attempt to provide a reasonable and adequate amount of protection with only a small possibility of considerable overprotection or under protection."

Simply using the highest BAF will result in a water concentration (e.g., criterion) much lower than needed to be protective because the highest factors are associated with the lowest exposure concentrations (Deforest et al. 2007). This suggests that within this range of water concentrations, a composite measure of BAFs (e.g., median, average) best represents conditions in the stream.

The proposed criterion incorporates this relationship by using the median BAF from the 2006-2011 time period, rather than the BAF from more recent data where the selenium water and tissue concentrations are substantially higher. BAFs from more recent time periods are not used in the derivation of the water column criterion element.

The dataset for the BAF approach spanned the time period from 2006 to 2011[20] (Appendix G). The BAF approach relied solely on brown trout data collected from locations within the Site (Hoopes Spring, Sage Creek, South Fork Sage Creek, and Lower Crow Creek). Individual BAFs were derived for each trout tissue concentration and dissolved selenium concentration for a location and time, resulting in a dataset of N=294 samples. Multiple trout were captured for analysis at each location, while only a single water quality sample was collected, thus a range of BAFs were derived for each location and time.

The BAFs derived are based on whole body tissues, whereas the criterion is based on egg/ovary tissues. Whole body tissue concentration BAFs were converted to egg/ovary concentration BAFs to derive the allowable concentration that would not exceed the 20.5 mg/kg dw egg/ovary selenium SSSC and would be comparable to mechanistic model output.

$$BAF_{egg/ovary} = (C_{tissueWB} * CF)/C_w$$

Where: $BAF_{egg/ovary}$ = BAF equivalent for egg/ovary tissues

$C_{tissueWB}$ = Tissue concentration of selenium in whole body brown trout (mg/kg dw)

CF = Conversion Factor ratio for egg/ovary to whole body

C_w = Concentration of dissolved selenium in surface water (µg/L)

[20] Data from 2013 were not included in the BAF calculations because the whole-body fish tissue concentrations and resulting BAFs at some locations were substantially different than the range of BAFs derived during the 2006 to 2011 time frame. By limiting the BAFs to 2006 to 2011 time frame, the BAF dataset is more comparable to the mechanistic model data set spanning the same time period.

To derive the water concentration for each of the scenarios, a median BAF was derived (Appendix G), and the egg/ovary concentration of 20.5 mg/kg dw egg/ovary selenium was divided by the median BAF.

For the all Site streams – all seasons, the derived dissolved selenium concentration was 12.6 µg/L, while for the all Site streams – summer/fall seasons, the derived dissolved selenium concentration was 13.7 µg/L (Table 5). As above, Crow Creek was considered separately from the other Site streams due to differences in observed BAFs. For Crow Creek, the water concentrations allowable that would not exceed 20.5 mg/kg dw in egg/ovary are 4.2 µg/L (all seasons) and 5.0 µg/L (summer/fall seasons). For Hoopes Spring, Sage Creek, and South Fork Sage Creek, the water concentrations are 16.7 µg/L (all seasons) and 17.4 µg/L (summer/fall seasons) (Table 5).

6.3.3 Site-Specific Water Value

A logical expectation is that when using site-specific inputs for a mechanistic model approach and site-specific BAFs, the model outputs (e.g., predicted surface water concentrations) should be very similar. If the output from the two approaches is similar, then it suggests that either method could be used. If the outputs are not similar, it suggests that the variability of the input data may result in uncertainties that should be evaluated.

Dissolved selenium concentrations using the mechanistic model and empirical BAF approach were relatively similar (Table 5) for most all the scenarios evaluated. When the results of the two models are compared using data from individual locations, as shown in Figure 13, the predicted water criterion values show that the BAF model approach is a more conservative estimate of the water criterion element for data collected from this Site.

USEPA (2016) derived water concentrations using the trophic model approach with Simplot's data from the 2006 to 2008 time frame. For CC-1A, the water criterion value was 4.42 ug/L while for CC-3A, the value was 4.37 based on a criterion of 15.1 mg/kg dw egg selenium. The current Simplot proposal for the water criterion element for Crow Creek using an empirical BAF is 4.2 ug/L, a value more conservative (lower) than EPA's trophic model output.

Considering the above information, it is concluded that both approaches are equally effective in generating a protective selenium concentration in water for this Site using the site-specific inputs and assumptions. Based solely on the ease of data collection for future evaluations, this SSSC proposal recommends that the water value be based on the BAF approach.

While the summer/fall seasons are when selenium concentrations in water are highest, bioaccumulation is likely greatest, and egg formation and selenium deposition also occur in brown trout prior to fall spawning, the use of summer/fall data only excludes the spring time frame, when differential exposure occurs that influences bioaccumulation. As a conservative measure, the BAF approach that uses all the seasonal data is will be used for this proposed SSSC.

USEPA's (2016a) water value is based on the 20th percentile of a range of either lotic or lentic water concentrations from across the United States. For lotic waters, the 20th percentile value is 3.1 µg/L. This type of approach is needed because the 2016 National Criterion water concentration is applied across a broad range of conditions, species, landscapes, and regions. For this SSSC, there is no need to derive a 20th percentile, because the water value in this proposal is derived from an egg/ovary criterion based on a representative species assemblage with the most sensitive species data being generated from the site-specific threshold for brown trout which were exposed to a very distinct range of selenium concentrations in water and prey items. These data originate from the locations where the SSSC will be applied and where future monitoring for compliance will occur.

As noted previously, the different bioaccumulation characteristics of Crow Creek downstream of Sage Creek relative to those observed for Hoopes Spring, Sage Creek and South Fork Sage Creek suggest that two separate water criteria should be derived. The water SSSC for Crow Creek derived from the egg/ovary criterion is 4.2 µg/L dissolved selenium. The water SSSC for Hoopes Spring, Sage Creek, and South Fork Sage Creek derived from the egg/ovary criterion is 16.7 µg/L dissolved selenium.

7.0 PROPOSED CRITERION IMPLEMENTATION

Elevated selenium concentrations at the Site are a result of releases due to historical mining activities at the Smoky Canyon Mine. Overburden materials removed to access the phosphate ore were placed in a cross-valley fill, in external ODAs, or used to backfill mining pits. Selenium released to these materials infiltrates into underlying Wells Formation groundwater and is transported with groundwater to spring discharges to surface water (i.e., Hoopes Spring and South Fork Sage Creek Springs).

Under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Simplot has implemented two Non-Time-Critical Removal Actions (NTCRAs) at Pole Canyon, which have significantly reduced releases of selenium to the surrounding environment. The NTCRAs included isolating the ODA from Pole Canyon Creek (2006) and reducing infiltration into the ODA by installation of a cover (2013). Together these actions have reduced the release of selenium to the environment by approximately 90 percent.

In addition, Simplot is implementing a pilot study water treatment system at the springs that is predicted to further reduce selenium concentrations throughout the Site. Simplot began operation of a 250 gallon per minute (gpm) treatment system to remove selenium from Hoopes Spring water in 2015. This system is being expanded to 2,000 gpm capacity and is scheduled to be brought on line in October 2017. Once operational, it is expected to significantly reduce selenium loading and concentrations in downgradient streams. Remedial actions at the mine will reduce selenium concentrations in surface water over time to meet the SSSC (the expected timeframe will be documented in the Record of Decision [ROD]).

USEPA's guidance documents (e.g., USEPA 2016b, 2016c, 2016d, 2016e) for implementing the 2016 National Criterion are draft pending public review. Changes that may result from this review and the potential effect on this implementation plan are unknown. The implementation plan proposed in this section and illustrated in Figure 14 is relatively consistent with current draft USEPA implementation plan documents (Appendix H provides further details). While egg/ovary tissue has been demonstrated to be the most important endpoint to measure the effects of chronic exposure to selenium, it is not the most practical to monitor.

A more practical and efficient approach for compliance monitoring, which effectively utilizes the criterion elements, would involve beginning with monitoring for compliance with the water-column criterion element. Routine monitoring for surface water concentrations of selenium is already conducted as part Smoky Canyon's Comprehensive Environmental Monitoring Program. If the surface water monitoring indicates an exceedance of the water criterion, then whole-body tissue monitoring would be completed. Simplot may directly proceed with egg/ovary tissue monitoring and skip the whole-body tissue monitoring. Compliance with the egg/ovary tissue criterion is the ultimate compliance mechanism, but the whole-body tissue criterion may be used if it is not practical to obtain egg/ovary tissue data.

In the event that no fish are present at a location, the nearest downstream location where fish are present would be examined to assess if the tissue data indicate an exceedance. In this proposed approach, the egg/ovary criterion would still take precedence over whole body tissue or water elements of the criterion when egg/ovary tissue data are available. The whole-body tissue data take precedence over the water element of the criterion when whole body tissue data are available.

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TABLES

Table 1
Fish Species Present During Monitoring from 2006 to 2016

SPECIES	Crow Creek (Upstream)			Crow Creek (Downstream)		Deer Creek	Hoopes Spring	Sage Creek	
	CC-75	CC-150	CC-350	CC-1A	CC-3A	DC-600	HS-3	LSV-2C	LSV-4
Salmonidae									
Brown trout *(Salmo trutta)*	√	√	√	√	√		√	√	√
Cutthroat trout (*Oncorhynchus clarki bouvieri*)	√	√	√	√	√	√	√	√	√
Brook trout *(Salvelinus fontinalis)*				√	√			√	
Cuttbow trout (*O. mykiss x O. clarki bouvieri*)				√					
Mountain whitefish *(Prosopium williamsoni)*			√	√	√				√
Cottidae									
Paiute sculpin *(Cottus beldingi)*	√	√	√	√	√	√	√	√	√
Mottled sculpin *(Cottus bairdi)*	√	√		√	√	√			
Cyprinidae									
Longnose dace *(Rhinichthys cataractae)*		√	√	√	√				
Speckled dace (*Rhinichthys osculus*)		√	√	√	√				
Leatherside chub *(Snyderichtys copei)*			√						
Redside shiner *(Richardsonius balteatus)*		√	√	√	√				
Catostomidae									
Utah sucker *(Catostomus ardens)*		√	√	√	√				√
Mountain sucker *(Catostomus platyrhynchus)*			√						
Species Total:	**4**	**8**	**10**	**11**	**10**	**3**	**3**	**4**	**5**

Table 2
Summary of Water, Sediment, and Tissue Selenium Concentrations from the 2006 to 2008 Monitoring Events

Stream	Location	Monitoring Event	Water Concentration		Sediment	Periphyton	Benthos	Sculpin Mean	Trout Mean
			Total Selenium (mg/L)	Dissolved Selenium (mg/L)	Selenium (mg/kg dw)	Selenium (mg/kg dw)	Selenium (mg/kg dw)	Selenium (mg/kg dw)	Selenium (mg/kg dw)
Upstream of Sage Creek									
Crow Creek	CC-75	Fall 2006	0.00053	0.00057	0.61	1.01	3.11J-	5.58	4.05
		Spring 2007	0.00047J	0.00046J	0.6J	0.68J	**	5.03	5.35
		Fall 2007	0.00033J	0.00033J-	0.34	1.1J	**	3.77	3.18
		Spring 2008	0.0012	0.0012	0.54	2.7	4.45	7.19	*10.32*
		Fall 2008	0.0015U	0.0008	0.48J+	0.55	3.49	7.08	6.60
	CC-150	Fall 2006	0.00062	0.00067	0.88	1.2	4.94J-	6.01	5.83
		Spring 2007	0.00083J	0.00092J	0.43J	1.37J	4.46J	5.04	*8.67*
		Fall 2007	0.00059J	0.00068J-	0.54	0.77J	1.90	5.14	5.20
		Spring 2008	0.0018	0.0014	0.63	2.4	7.03	*10.73*	*10.14*
		Fall 2008	0.0023	0.0016	0.81J+	0.65	21.60	7.35	7.83
	CC-350	Fall 2006	0.00083	0.00082	1.30	1.5	2.11J-	6.47	6.28
		Spring 2007	0.00084J	0.0011J	0.52J	3.3J	4.2J	7.12	*8.53*
		Fall 2007	0.0002U	0.00026J-	0.55	0.77J	**	5.28	5.80
		Spring 2008	0.001	0.00089	0.7	3.4	10.60	*10.03*	*11.50*
		Fall 2008	0.0012U	0.0013	0.81	0.59	12.30	*9.53*	*7.95*
Hoopes Spring and Sage Creek									
Hoopes Spring	HS	Fall 2006	**0.0174**	0.0174	2.3	2.2	1.00J-	23.23	16.52
		Spring 2007	**0.0301J**	0.0205J	5.9J	12J	15.7J	23.25	25.00
		Fall 2007	**0.0242**	0.0214J-	1.1	3.9J	**	10.95	24.90
		Spring 2008	**0.0296**	0.0273	1.8J-	15.0	21.7	35.93	32.63
		Fall 2008	**0.0502**	0.0536	4.4	35.2	33.9	41.30	22.80
	HS-3	Fall 2006	**0.0108**	0.0092	7.0	6.5	12.47J-	21.85	20.60
		Spring 2007	**0.0198J**	0.018J	6.2J	12J	11.4J	18.57	18.83
		Fall 2007	**0.0158**	0.0161J-	7.5	6.2J	15.41	26.63	17.89
		Spring 2008	**0.0223**	0.026	2.1J-	28.5	28.4	23.93	26.30
		Fall 2008	**0.0402**	0.0375	8.1	24.2	24.7	23.68	28.97
Sage Creek	LSV-2C	Fall 2006	**0.0095**	0.0093	4.6	2.6	22.62J-	17.47	19.45
		Spring 2007	**0.0135J**	0.0135J	4.5J	8.09J	8.26J	11.38	12.78
		Fall 2007	**0.0144**	0.0143J-	5.4	18.5J	31.74	18.80	22.67
		Spring 2008	**0.0145**	0.0141	1.1J-	11.6	30.00	25.95	20.25
		Fall 2008	**0.0242**	0.0234	5.7	4.38	23.90	20.32	20.96
	LSV-4	Fall 2006	**0.007**	0.0068	3.3	7.42	10J-	20.01	16.20
		Spring 2007	**0.0103J**	0.0101J	3.9J	11.7J	9.08J	18.28	15.80
Downstream of Sage Creek									
Crow Creek	CC-1A	Fall 2006	0.0029	0.0027	1.80	3.64	3.53J-	9.94	9.76
		Spring 2007	0.0016J	0.0012J	1.10J	3.39J	12.9J	8.34	9.05
		Fall 2007	0.0014J	0.0022J-	0.67	3.2J	12.24	7.78	9.95
		Spring 2008	0.0032	0.0029	1.2	7.10	15.50	17.47	17.54
		Fall 2008	**0.0065**	0.0067	1.7	5.86	11.60	12.63	14.03
	CC-3A	Fall 2006	0.003	0.0029	1.3	3.10	5.48J-	14.45	11.15
		Spring 2007	0.0013J	0.0014J	0.73J	1.89J	5.41J	11.65	9.20
		Fall 2007	0.0011J	0.0018J-	0.93	3.8J	**	11.47	11.25
		Spring 2008	0.0036	0.0026	0.66J-	14.9	17.80	NM	15.38
		Fall 2008	**0.0058**	0.0058	1.3	1.67	11.20	20.20	19.68

Bold values exceed the State of Idaho Water quality standard for total selenium (0.005 mg/L)

J - Estimated

J- = Estimated, low bias

NM = Not Measured

** = Insufficient sample for reanalysis

Table 3
Effects Endpoints from Maternal Transfer Studies

Species	Source Study	Adult Exposure	Endpoint	Tissue	Endpoint Statistic	Selenium (µg/g dry weight)	Statistic Derivation Source
Brown Trout	Formation Environmental (2012)	Field	Alevin survival	Egg	EC10	20.5	a
Brown Trout	USEPA interpreation of Formation Environmental (2012)	Field	Alevin survival	Egg	EC10	21	b
Brook Trout	Holm et al. 2005	Field	Larval deformities	Egg	NOEC	>48.7	b,c
Brook Trout	Holm et al. 2005 ; Pilgrim 2009	Field	Larval survival	Egg	EC10	32	a
Rainbow Trout	Holm 2002; Holm et al. 2003; Holm et al. 2005[d]	Field	Larval deformities	Egg	EC10	24.5	b
Yellowstone Cutthroat Trout	Hardy 2005; Hardy 2010	Lab	Larval deformities/ survival	Egg	NOEC	>16.04	b,c
	USEPA interpreation of Formation Environmental (2012)	Field	Alevin survival and normal	Egg	NOEC	>30	b
	Formation Environmental (2012)	Field	Alevin survival and normal	Egg	EC10	28.4	a
Westslope Cutthroat Trout	Kennedy et al. 2000	Field	Larval deformities/ survival	Egg	NOEC	>21	c
	Rudolph et al. 2008	Field	Alevin survival	Egg	EC10	24.7	b
	Nautilus 2011; Elphick et al. 2009	Field	Alevin survival	Egg	EC10	27.7	b
Dolly Varden Char	Golder 2009[e]; McDonald et al. 2010	Field	Larval deformities	Egg	EC10	56.2	b
Slimy Sculpin	Lo et al. (2014)	Lab	Larval deformities and survival	Egg	NOEC	>22	f
Fathead Minnow	GEI (2008); Schultz and Hermanutz (1990)	Field	Larval deformities	Egg	EC10/LOEC	38.8	g
White Sucker	de Rosemond et al. 2005	Field	Larval deformities	Egg	NOEC	40.3	b

a Formation 2017

b USEPA (2016)

c Deforest et al. (2011)

d EC10 values from combined datasets 2000, 2001, and 2002 for deformities as reported in USEPA (2016)

e Published as McDonald et al. (2010) in Environmental Toxicology and Chemistry.

f Lo et al. 2014

g GEI (2014)

NOEC = no observed effect concentration

µg/g = micrograms per gram

Table 4
Whole Body Concentrations Derived from Egg/ovary Data for Each Species

Species	Source Study	Endpoint Statistic	Egg/ovary Selenium (mg/kg dw)	CF	Whole Body Selenium (mg/kg dw)	Statistic Derivation Source
Brown Trout	Formation Environmental (2012)	EC10	20.5	1.46	14.04	a
Brown Trout	USEPA interpretation of Formation Environmental (2012)	NOEC	21	none	13.2	b
Brook Trout	Holm et al. 2005	NOEC	>48.7	1.61	>30.2	b,c
Brook Trout	Holm et al. 2005	EC10	32	1.61	19.9	a
Rainbow Trout	Holm 2002; Holm et al. 2003; Holm et al. 2005[d]	EC10	24.5	1.96	12.5	b
Yellowstone Cutthroat Trout	USEPA interpretation of Formation Environmental (2012)	NOEC	>30	1.96	58.8	b
	Formation Environmental (2012)	EC10	28.4	1.96	14.5	a
Westslope Cutthroat Trout	Rudolph et al. 2008	EC10	24.7	1.96	12.6	b
	Nautilus 2011; Elphick et al. 2009	EC10	27.7	1.96	14.1	b
Dolly Varden Char	Golder 2009[e]; McDonald et al. 2010	EC10	56.2	1.61	34.9	b
Slimy Sculpin	Lo et al. (2014)	NOEC	22	none	11	f
Fathead Minnow	GEI (2008); Schultz and Hermanutz (1990)	EC10	38.83	1.4	27.7	g
White Sucker	de Rosemond et al. 2005	NOEC	>40.3	1.38	20.6	b

a Formation 2017
b USEPA (2016)
c Deforest et al. (2011)
d EC10 values from combined datasets 2000, 2001, and 2002 for deformities as reported in USEPA (2016)
e Published as McDonald et al. (2010) in Environmental Toxicology and Chemistry.
f Lo et al. 2014
g GEI (2014)
NOEC = no observed effect level
µg/g = micrograms per gram

Table 5
Variables Used in the Derivation of a Water Element Value Using the Mechanistic Trophic Model and Comparable BAF Model Output

Data Grouping	Variables						Mechanistic Model Predicted Selenium Concentration in water (µg/L)	Empirical BAF Predicted Selenium Concentration in water (µg/L)
	EF	$TTF_{invertebrate}$	$TTF_{sculpin}$	TTF_{trout}	$TTF_{composite}$	CF	Egg Criterion = 20.5 mg/kg dw	Egg Criterion = 20.5 mg/kg dw
Site Streams, all seasons	0.49	1.90	1.08	1.08	2.21	1.46	13.0	12.6
Hoopes Spring, all seasons	0.43	1.20	1.55	1.21	2.25	1.46	14.6	17.3
Sage Creek, all seasons	0.46	1.91	0.86	0.97	1.59	1.46	19.3	16.8
South Fork Sage Creek, all seasons	0.27	2.00	1.47	0.89	2.61	1.46	20.0	15.4
Crow Creek, all seasons	0.88	2.00	1.08	1.08	3.32	1.46	4.8	**4.2**
Sage and South Fork Sage Creeks, Hoopes Spring, all seasons	0.43	2.85	1.17	1.04	2.04	1.46	16.1	**16.7**
Site Streams, summer/fall seasons	0.43	2.13	1.09	1.04	2.40	1.46	13.7	13.7
Hoopes Spring, summer/fall seasons	0.40	1.50	1.47	1.21	2.66	1.46	13.3	19.6
Sage Creek, summer/fall seasons	0.39	1.98	0.84	0.97	1.60	1.46	22.6	17.4
South Fork Sage Creek, summer/fall seasons	0.27	2.00	1.47	0.89	2.61	1.46	20.0	15.4
Crow Creek, summer/fall seasons	0.67	2.49	1.12	1.18	3.28	1.46	6.4	5.0
Sage and South Fork Sage Creeks, Hoopes Spring, summer/fall seasons	0.37	1.9	1.09	0.97	2.01	1.46	18.9	17.4

Equation:

Mechanistic Trophic Model Equation: $C_{water} = Criterion_{egg} / TTF_{composite} \times EF \text{ X } CF$

Empirical BAF Equation: $C_{water} = Criterion_{egg} / BAF_{median}$

Where: C_{water} = predicted concentration in water

$Criterion_{egg}$ = Derived egg criterion value

$TTF_{composite}$ = Composite trophic transfer factor for all trophic levels, each value is a median value for the data grouping

EF = enrichment factor

CF = Conversion factor

BAF_{median} = The whole body BAF median for season/location scenario converted to egg BAF

Notes:

Site streams – Hoopes Spring (HS and HS-3), Sage Creek (LSV-2C and LSV-4), South Fork Sage Creek (LSS), Crow Creek d/s Sage (CC-1A and CC-3A).

All seasons - spring and summer/fall data

Fall Seasons – summer/fall data

Average EF is the arithmetic average of the periphyton EF and sediment EF

mg/kg dw = milligrams per kilogram dry weight

µg/L = micrograms per liter

Bold values are those selected as the SSSC water values.

FIGURES

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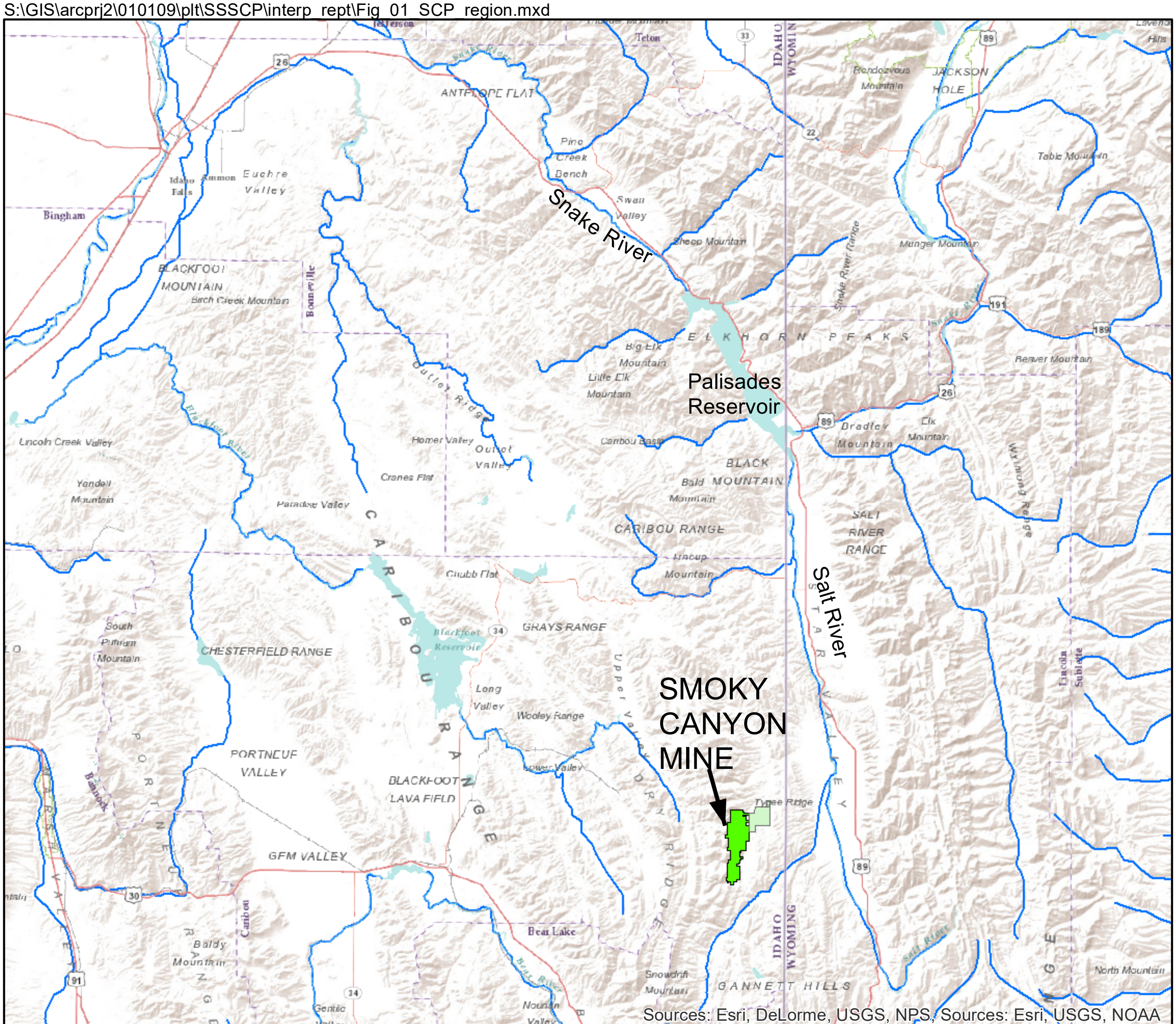

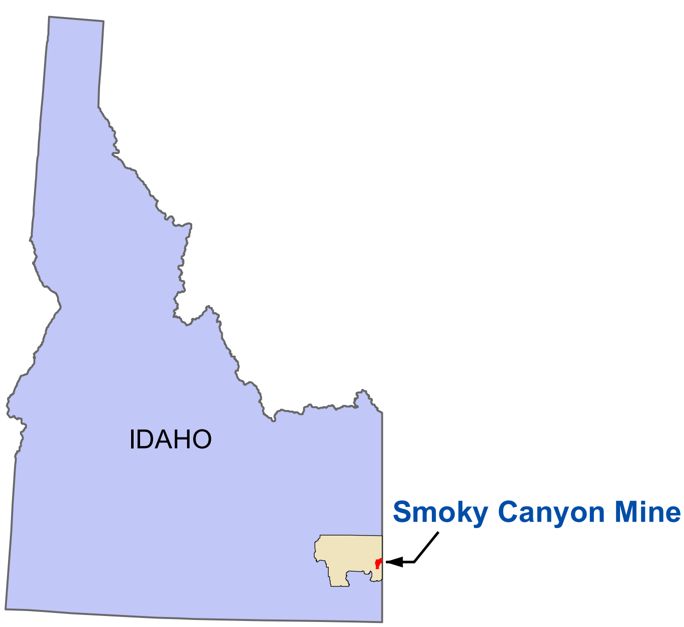

N

0 10 20 Miles

J.R. SIMPLOT COMPANY

SMOKY CANYON MINE

FIGURE 1

LOCATION OF THE SMOKY CANYON MINE

PRJ: 009-004.70	DATE: AUG 18, 2017
REV: 0	BY: CRL CHK: SMC

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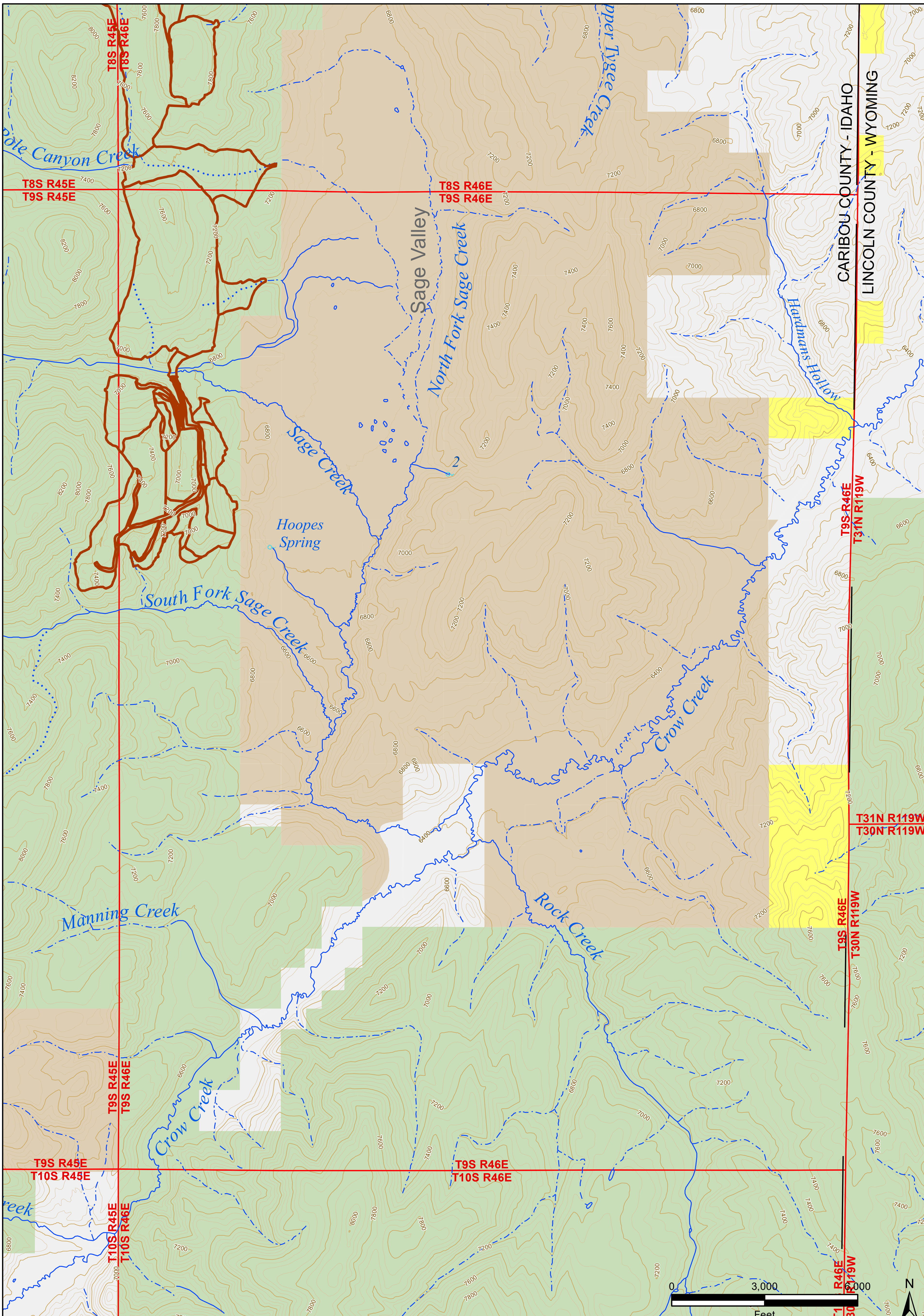

Legend

- Mine Disturbance
- Township/Range Boundaries
- J.R. Simplot Co.
- US Forest Service
- BLM
- Other Private

Notes: Mine disturbance area boundary includes a 50-foot buffer.

Topographic surface reflects 2004 conditions in mine disturbance areas.

J.R. SIMPLOT COMPANY

SMOKY CANYON MINE

FIGURE 2

SAGE CREEK AND CROW CREEK DRAINAGES

DATE: AUG 04, 2017

BY: CRL

FOR: SMC

FORMATION ENVIRONMENTAL

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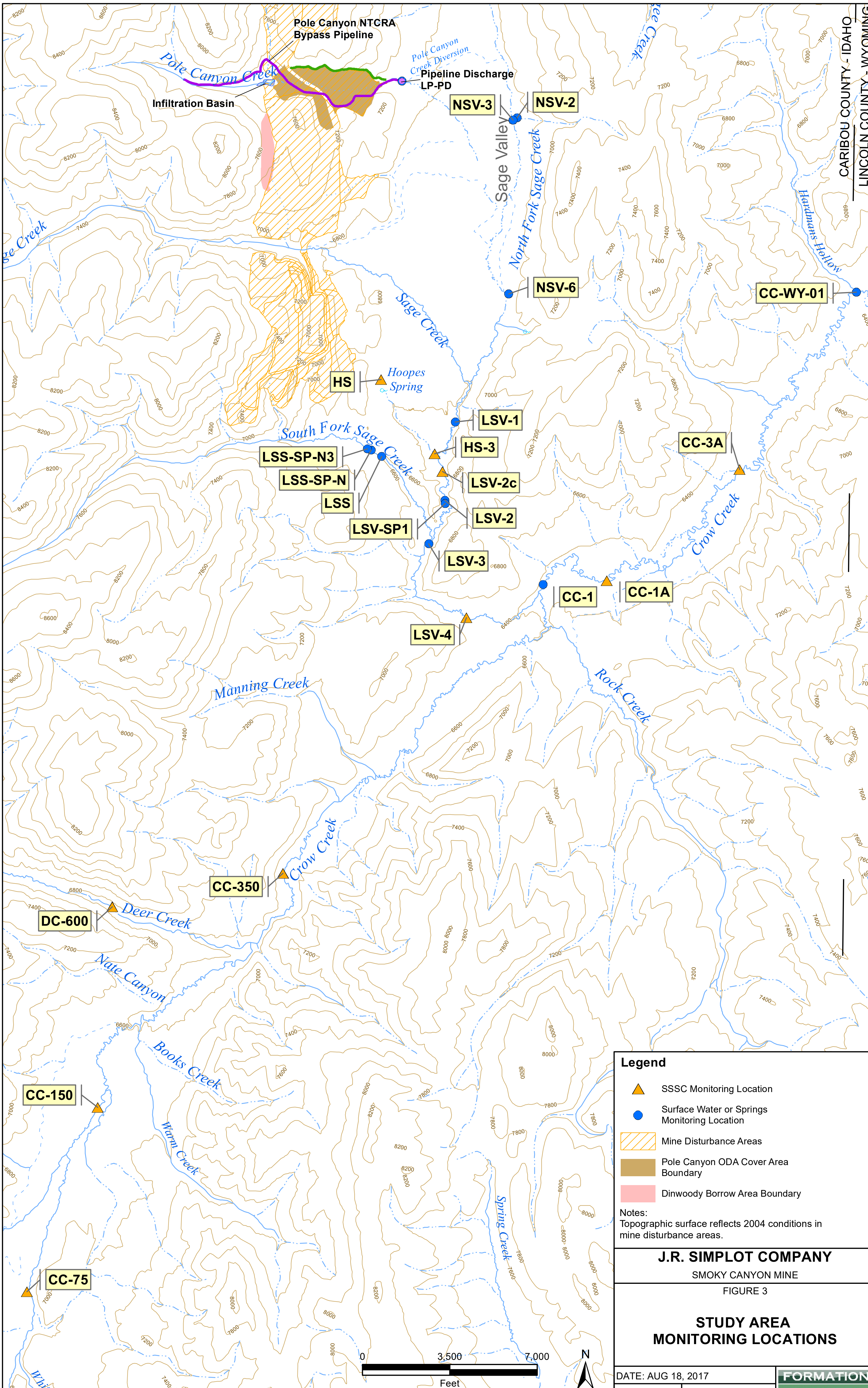

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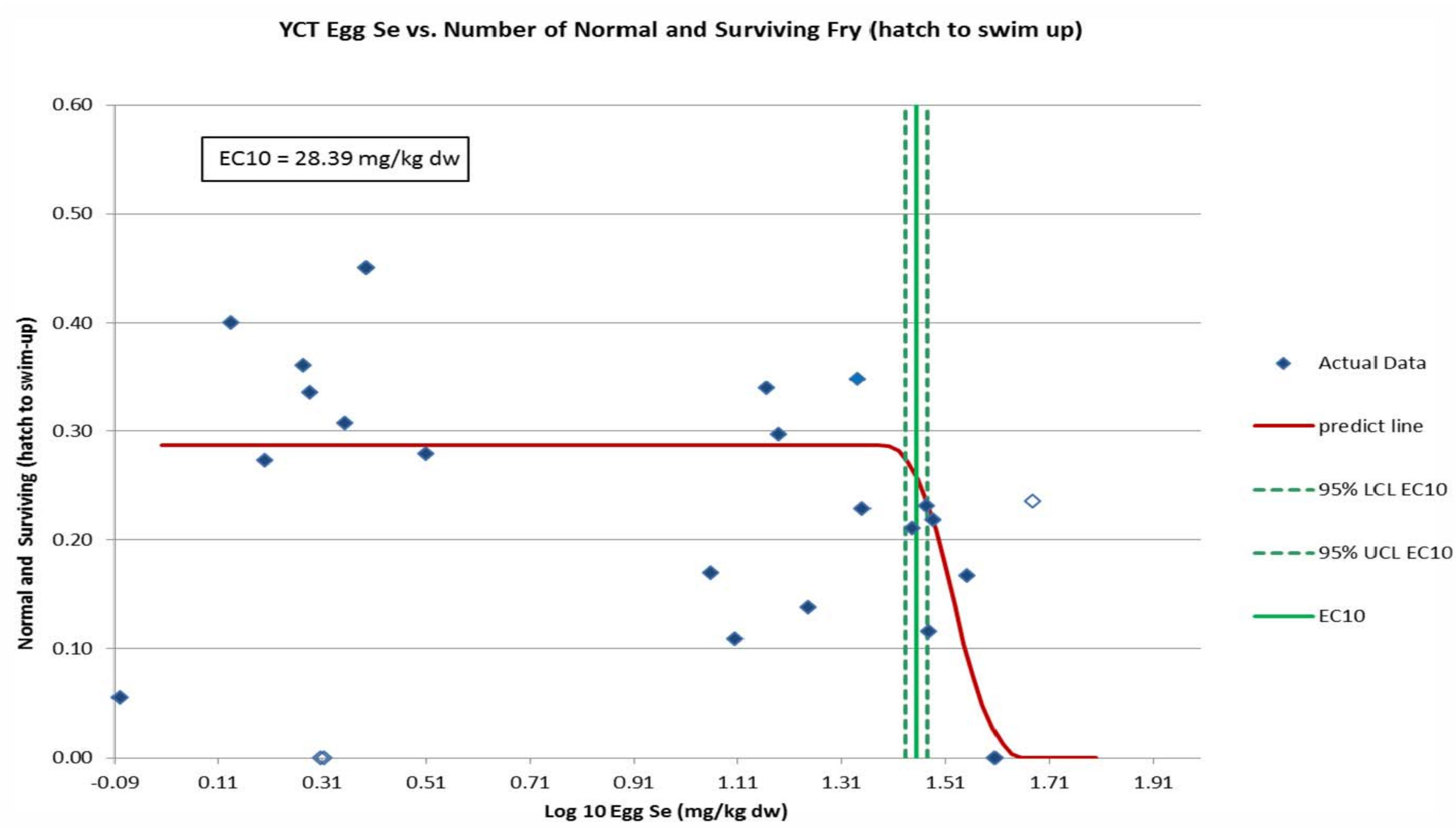


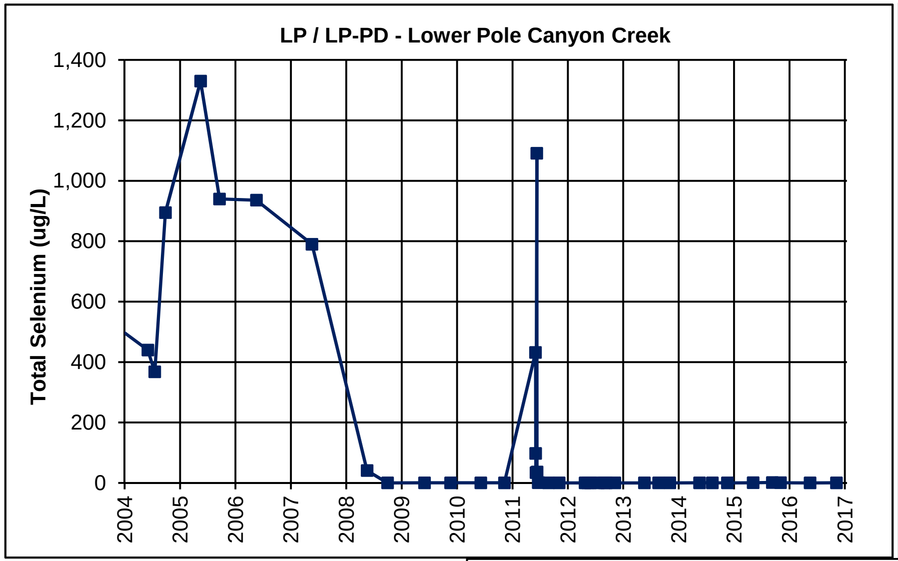
Note: Generated using a Triangular Distribution in EPAs TRAP program, Version 1.3a (USEPA 2015)
Hollow triangles represent data points that were excluded in the dose response analysis.

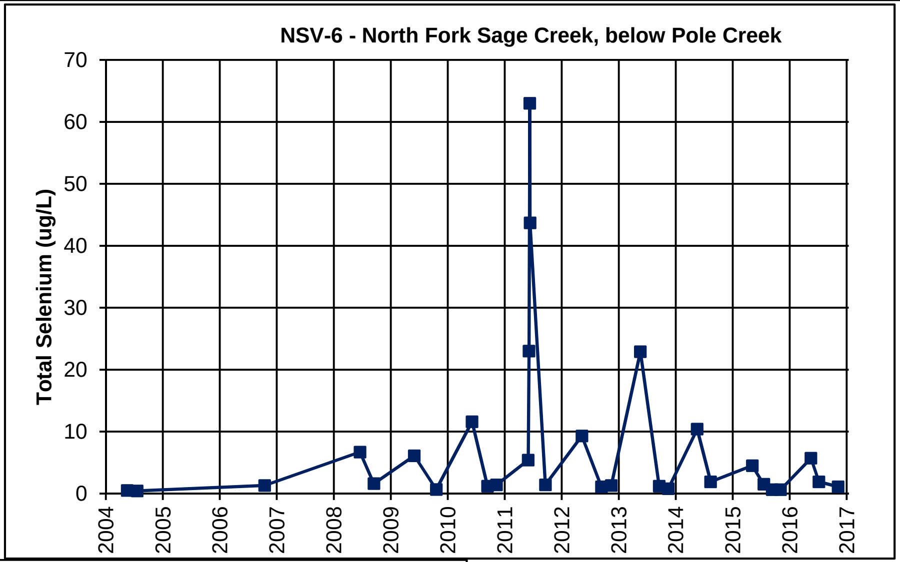
Figure 4

YCT Dose Response Curve for Egg Selenium versus the Number of Normal and Surviving Fry (hatch to swim up)

J.R. Simplot Company Smoky Canyon Mine		
PRJ: 009-004.70	DATE: April 2017	
REV: 0	BY: JPL	CHK: SMC

FORMATION ENVIRONMENTAL





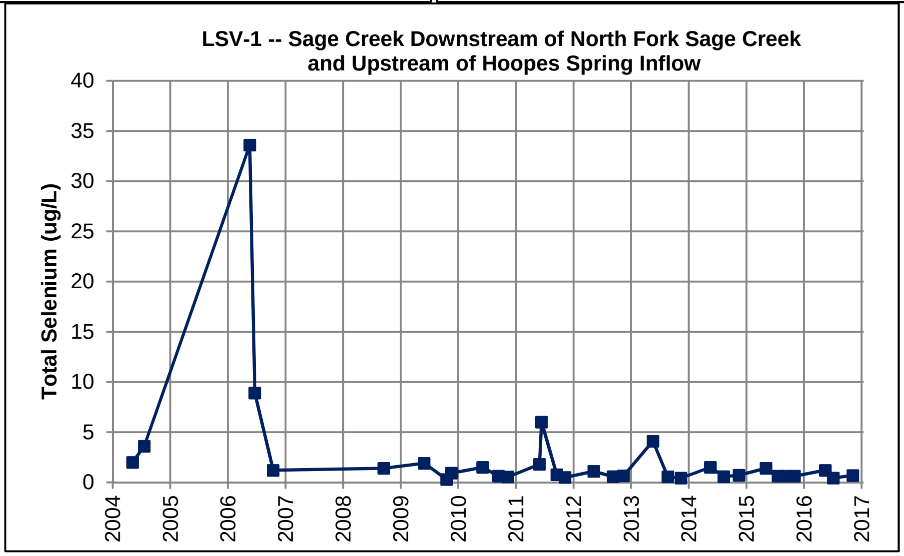


Figure 5

Long-Term Selenium Concentrations in Surface Waters: Pole Canyon Creek, North Fork Sage Creek and Sage Creek upstream of Hoopes Spring

J.R. Simplot Company
Smoky Canyon Mine

PRJ: 009-004.70	DATE: April 2017	
REV: 0	BY: JPL	CHK: SMC

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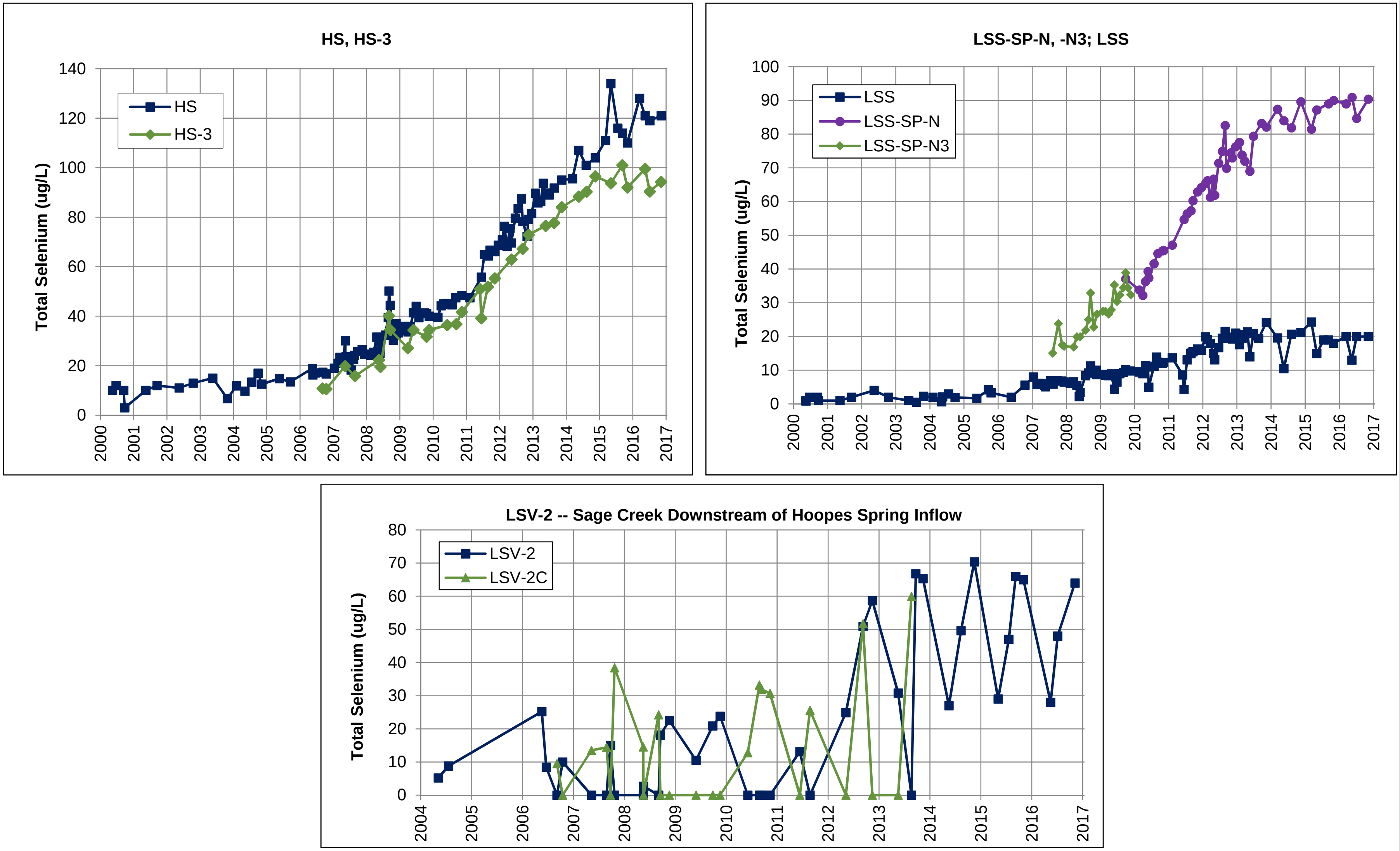

Figure 6

Long-Term Selenium Concentrations in Surface Waters: Springs and Upper Sage Creek

J.R. Simplot Company Smoky Canyon Mine		
PRJ: 009-004.70	DATE: April 2017	
REV: 0	BY: JPL	CHK: SMC

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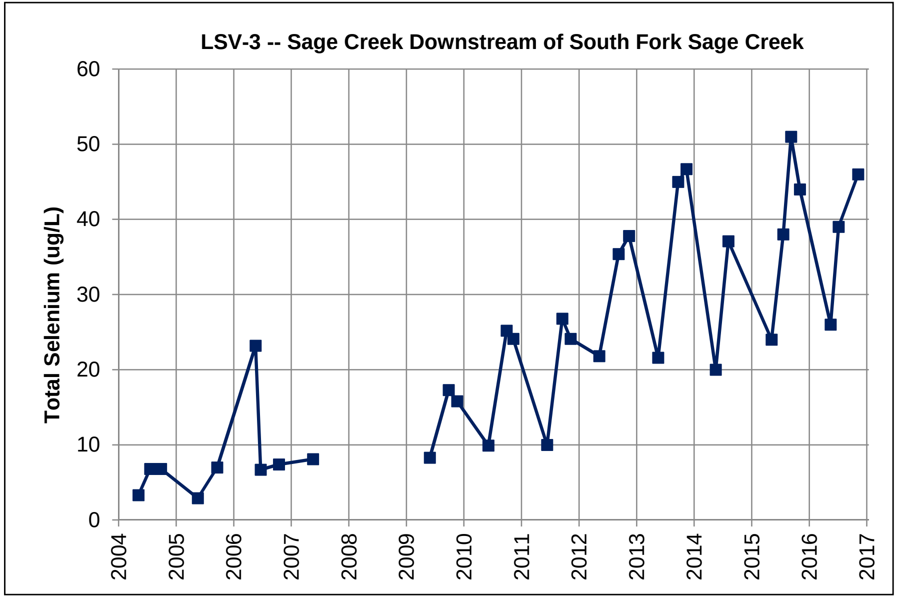

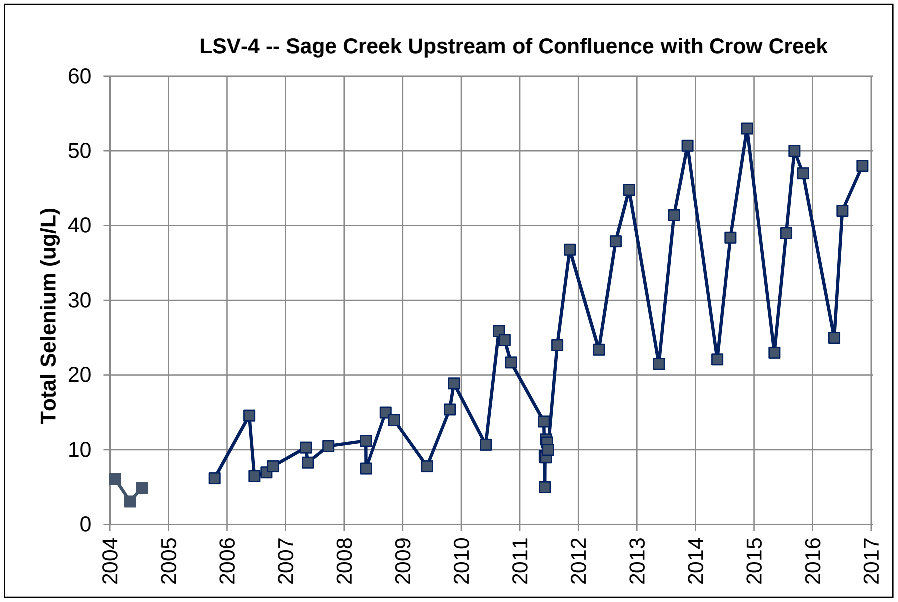

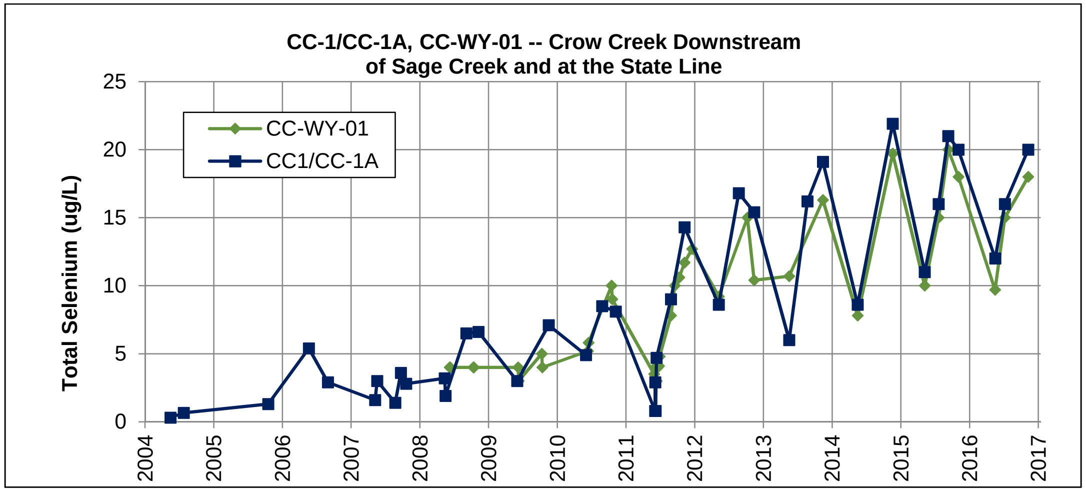

Figure 7

Long-Term Selenium Concentrations in Surface Waters: Lower Sage Creek and Crow Creek

J.R. Simplot Company
Smoky Canyon Mine

PRJ: 009-004.70	DATE: April 2017	
REV: 0	BY: JPL	CHK: SMC

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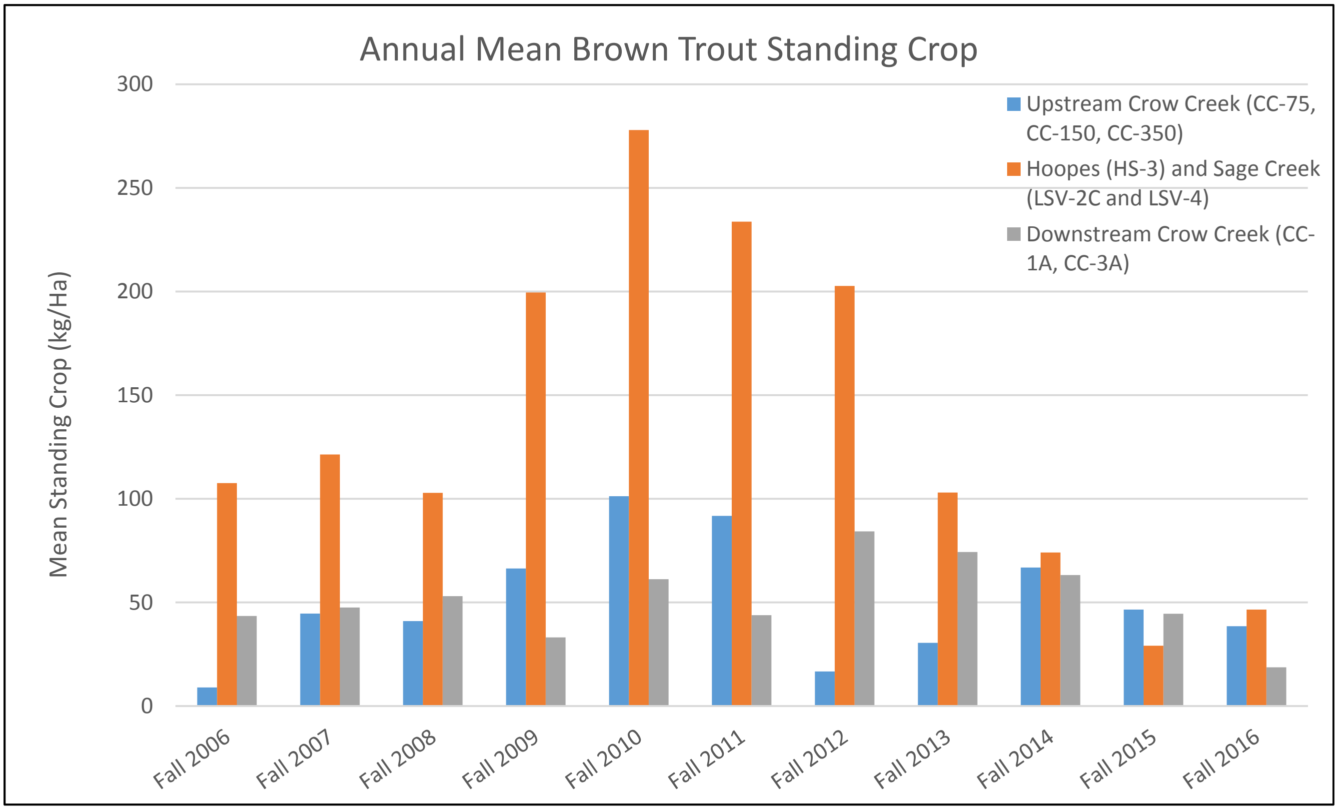

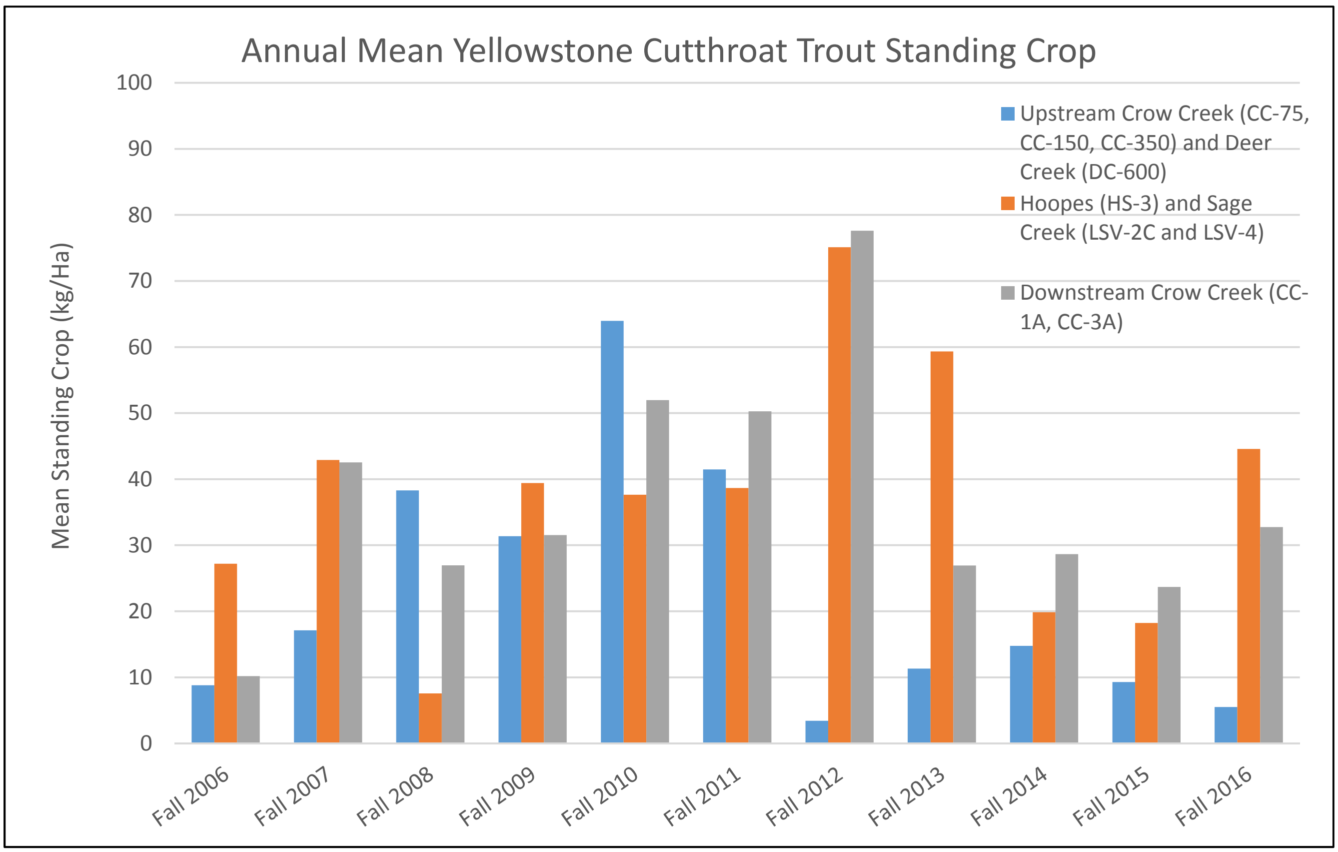

Figure 8

Annual Mean Brown Trout and YCT Standing Crop

J.R. Simplot Company
Smoky Canyon Mine

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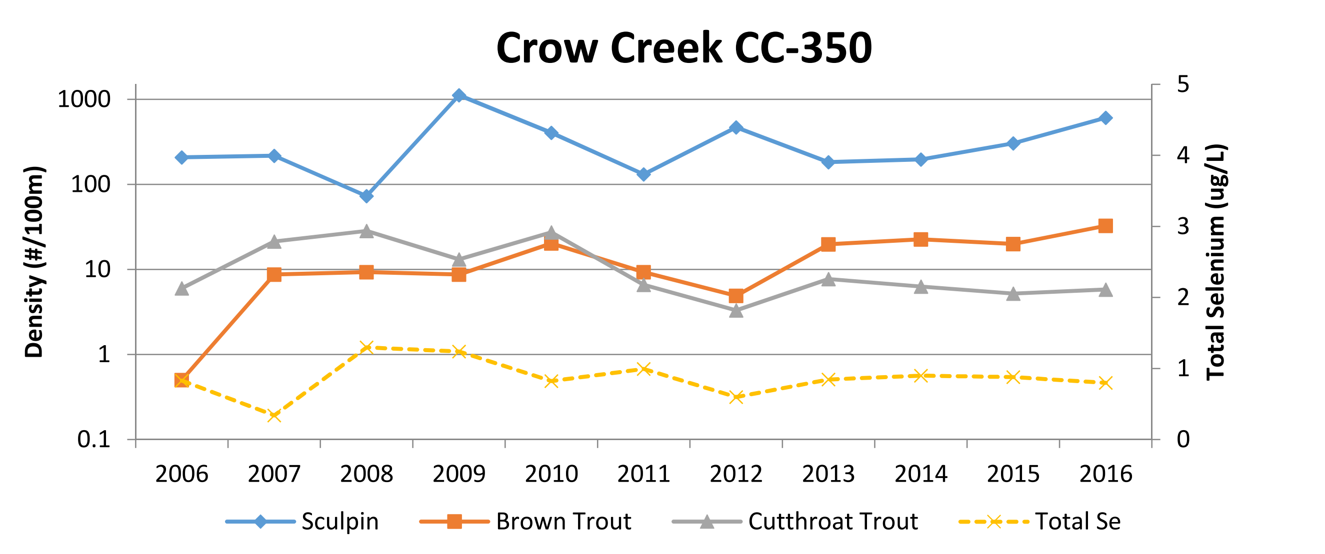
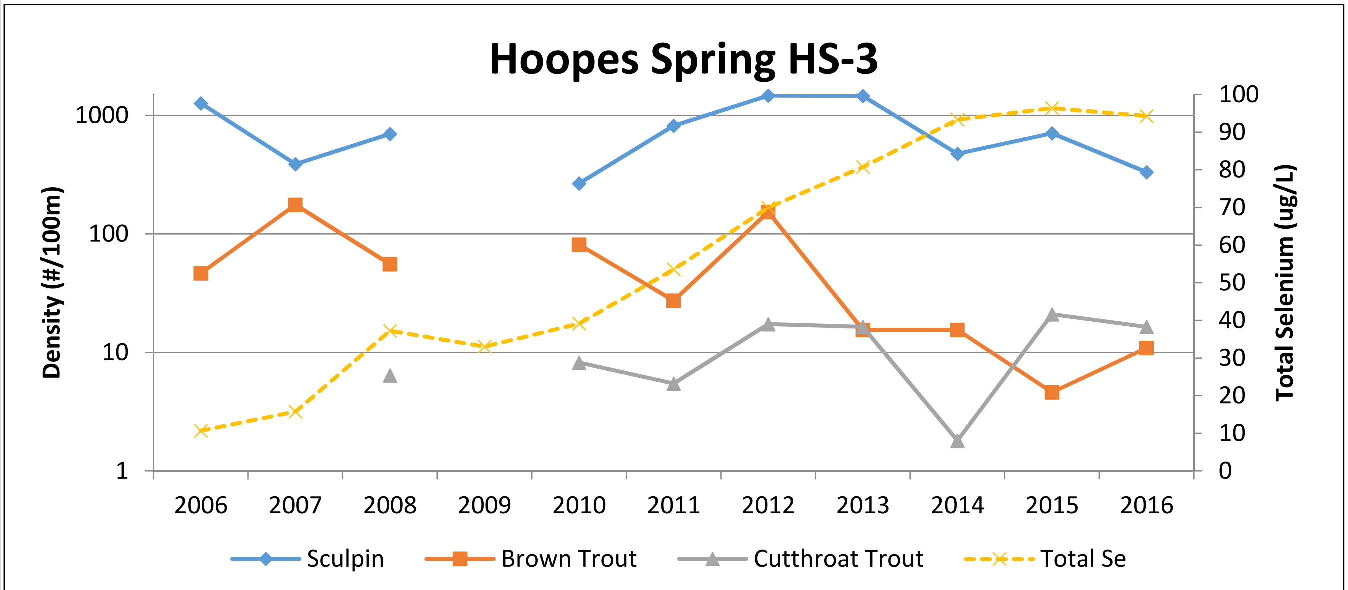
BY: JPL | CHK: SMC | DATE: April 2017





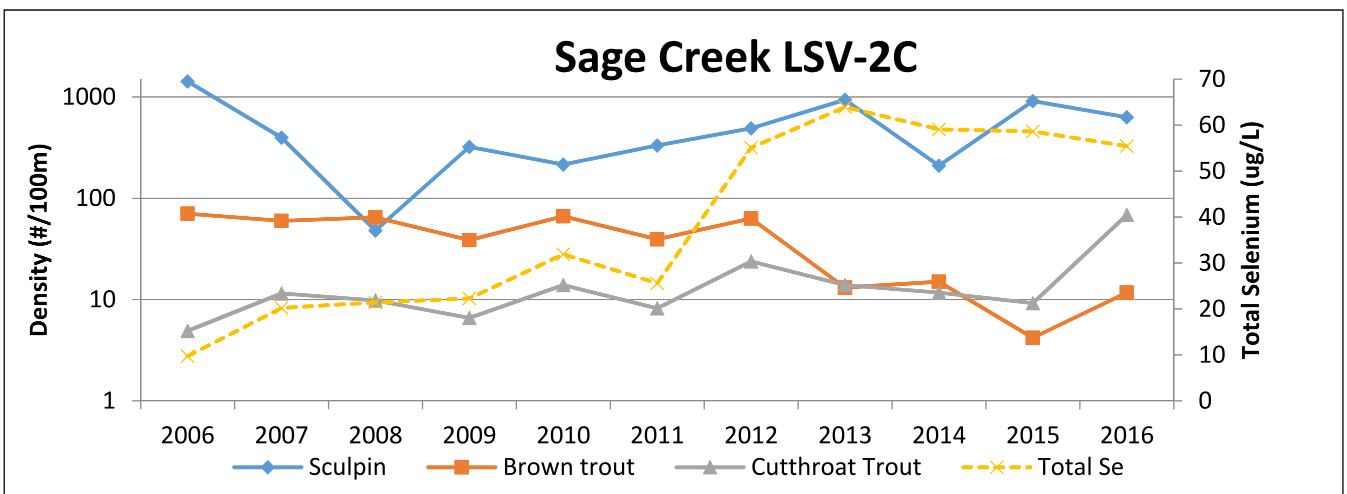


Figure 9

Longer Term Density of Brown Trout, YCT, and Sculpin compared to Fall Selenium Concentrations in Surface Waters: CC-350, HS-3, and LSV-2C

J.R. Simplot Company
Smoky Canyon
Mine

BY: JPL	CHK: SMC	DATE: April 2017

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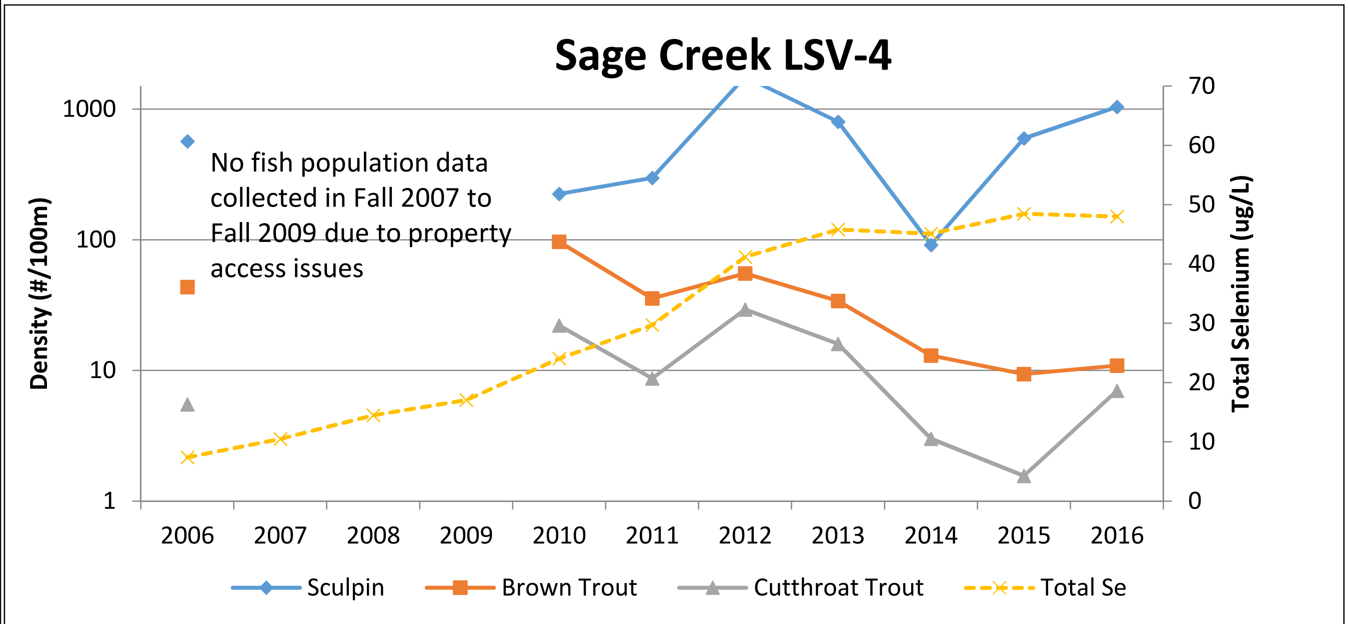


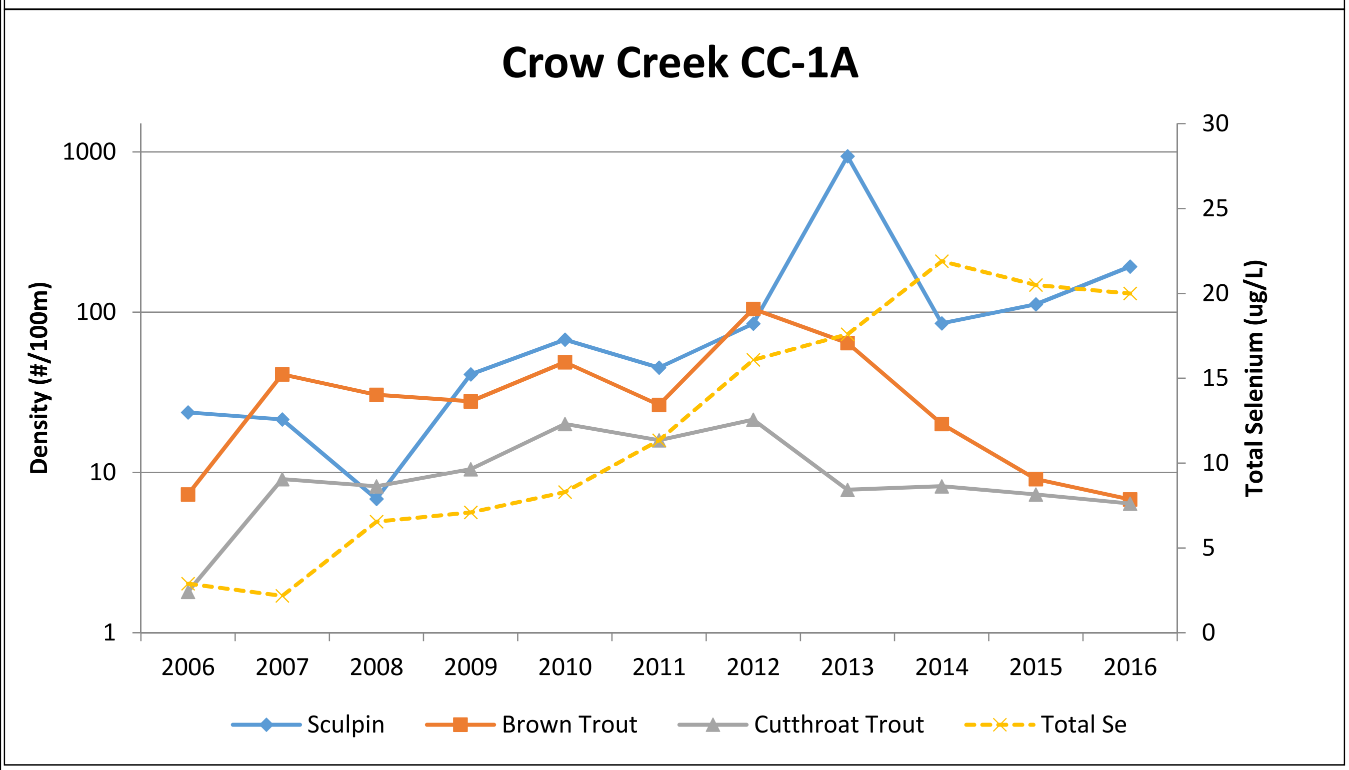


Figure 10

Longer Term Density of Brown Trout, YCT, and Sculpin compared to Fall Selenium Concentrations in Surface Waters: LSV-4 and CC-1A

J.R. Simplot Company
Smoky Canyon Mine

BY: JPL | CHK: SMC | DATE: April 2017

FORMATION ENVIRONMENTAL

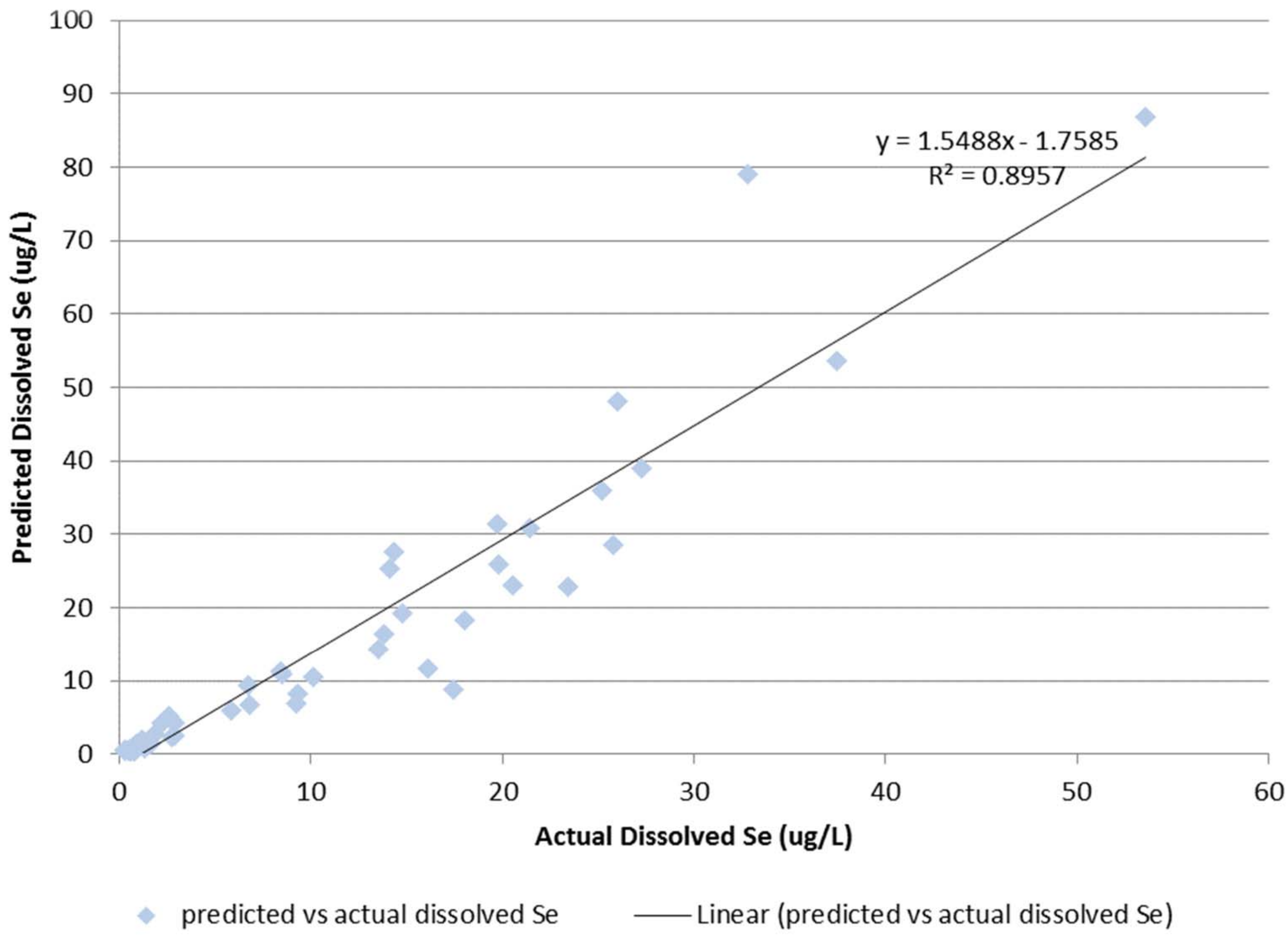
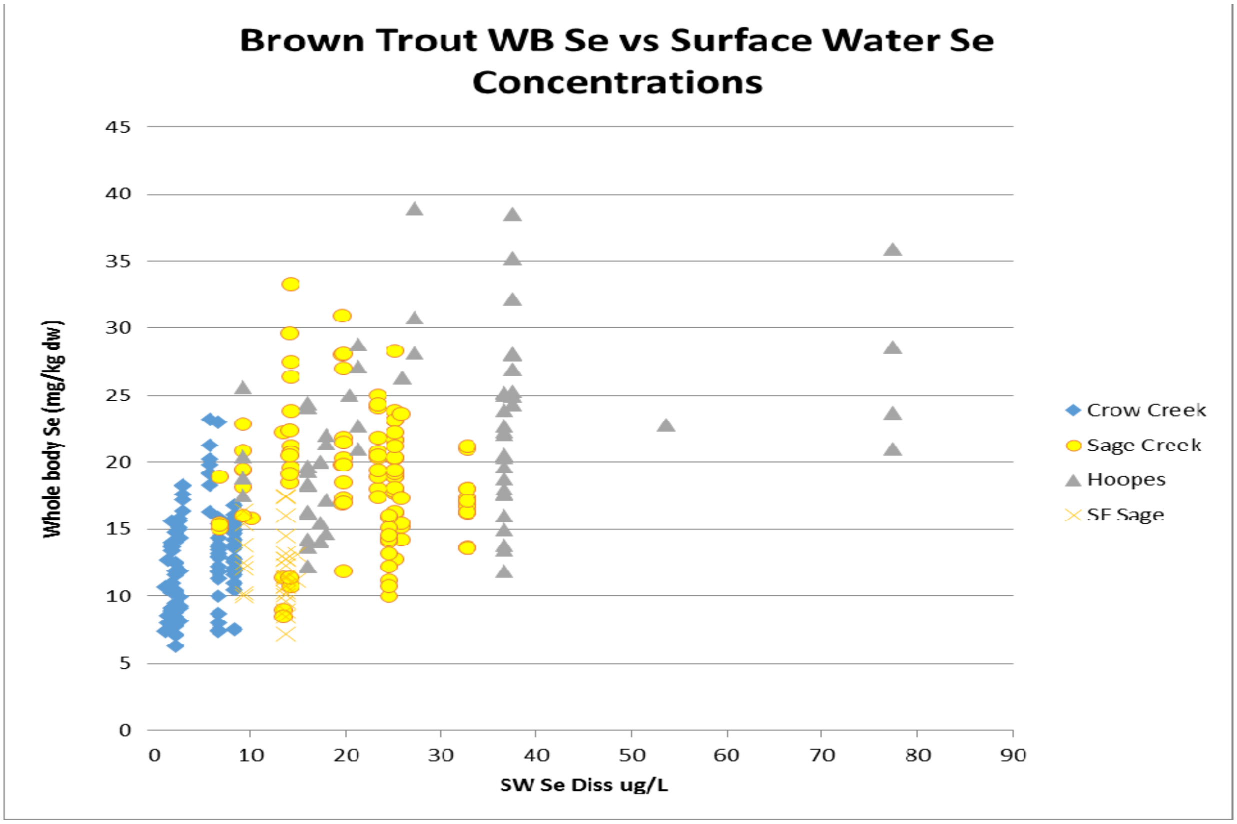


Figure 11

Relationship of Predicted vs Actual Dissolved Selenium Concentrations Derived from Mechanistic Trophic Model Approach

J.R. Simplot Company Smoky Canyon Mine		
PRJ: 009-004.70	DATE: April 2017	
REV: 0	BY: JPL	CHK: SMC
FORMATION ENVIRONMENTAL		



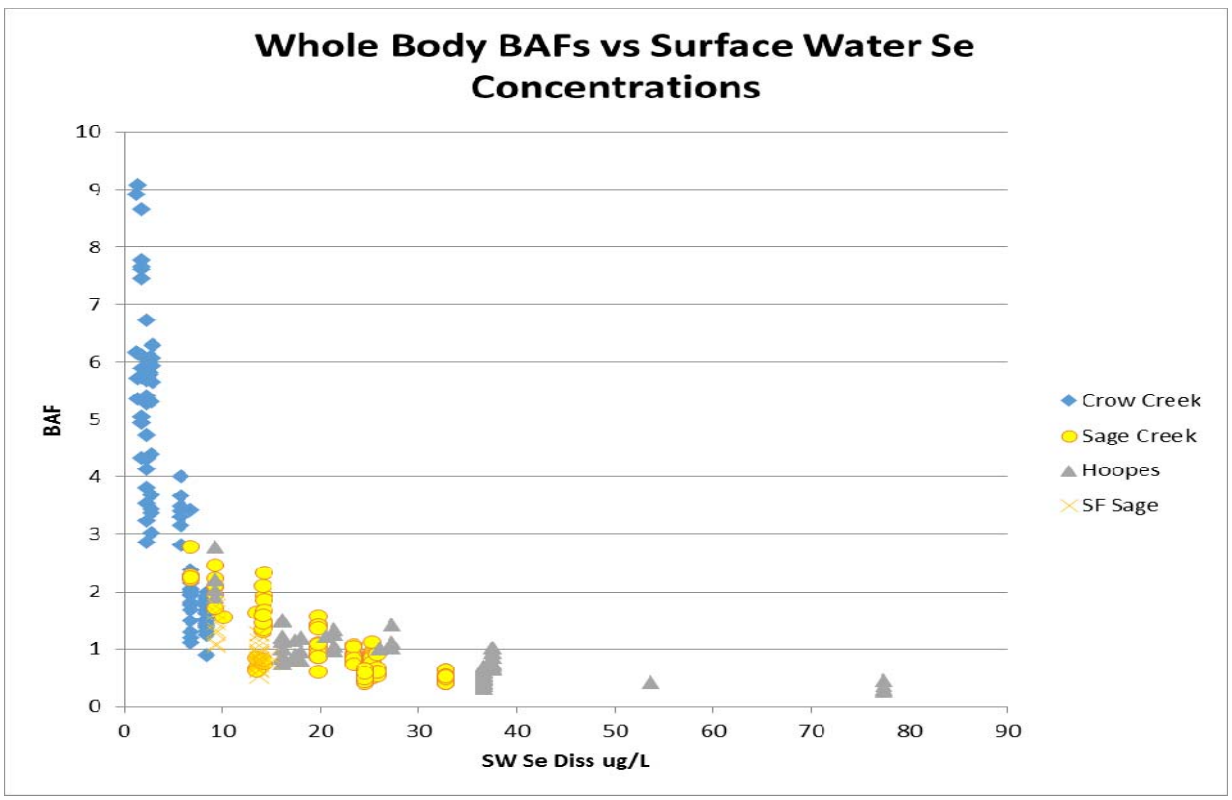


Figure 12

Relationship of Selenium Concentrations in Surface Water to Brown Trout Whole Body Selenium Concentrations and Whole Body BAFs

J.R. Simplot Company
Smoky Canyon Mine

FORMATION ENVIRONMENTAL

BY: JPL | CHK: SMC | DATE: April 2017

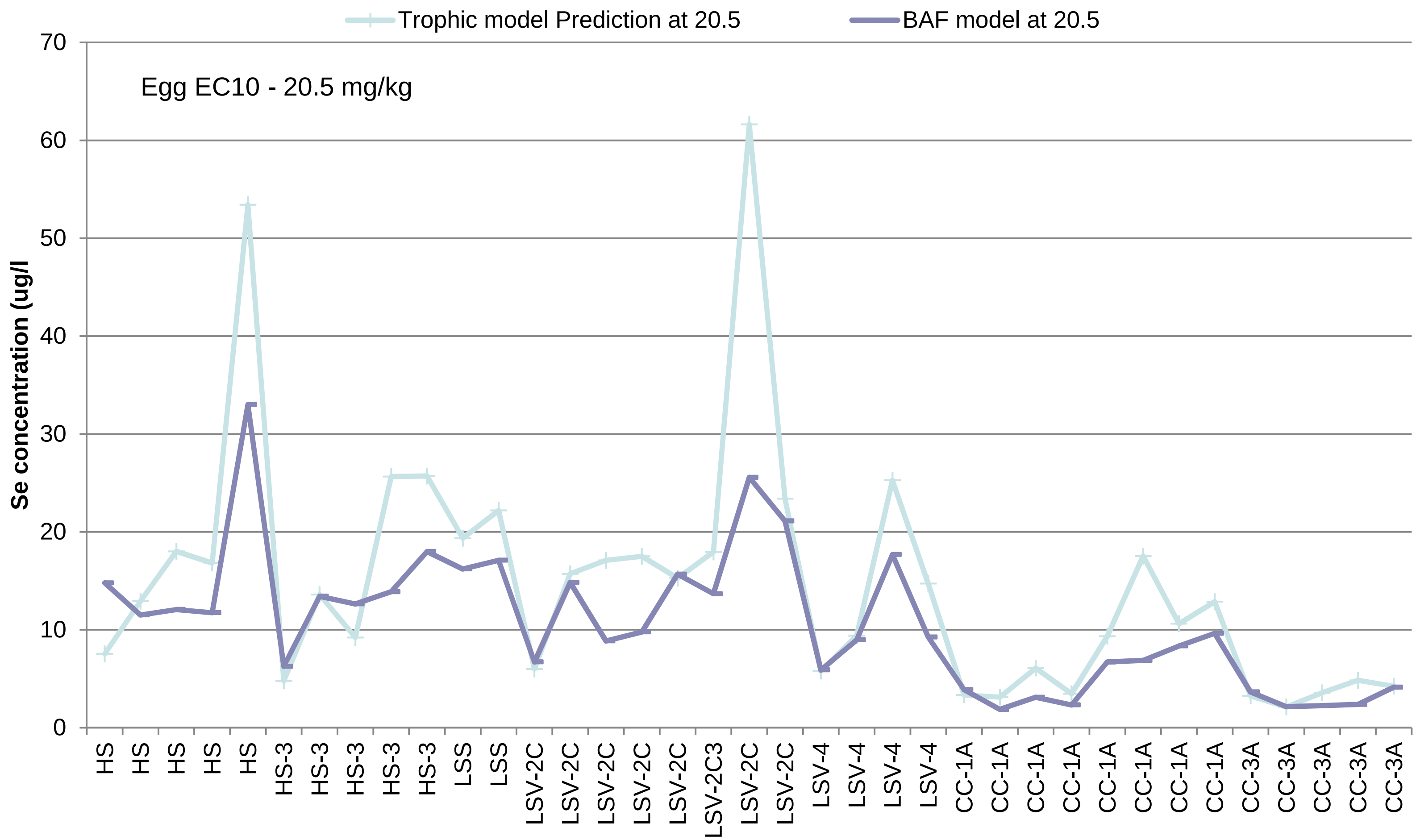


Figure 13
Comparison of Trophic Model vs. Empirical BAF Model Predicted Water Criterion Values for Sage Creek, Hoopes Spring, and Crow Creek Downstream of Sage Creek

J.R. Simplot Company Site-Specific Selenium Criterion		
PRJ: 0442-004-900.70	DATE: April 2017	
REV: 1	BY: SMC	CHK: SMC

FORMATION ENVIRONMENTAL

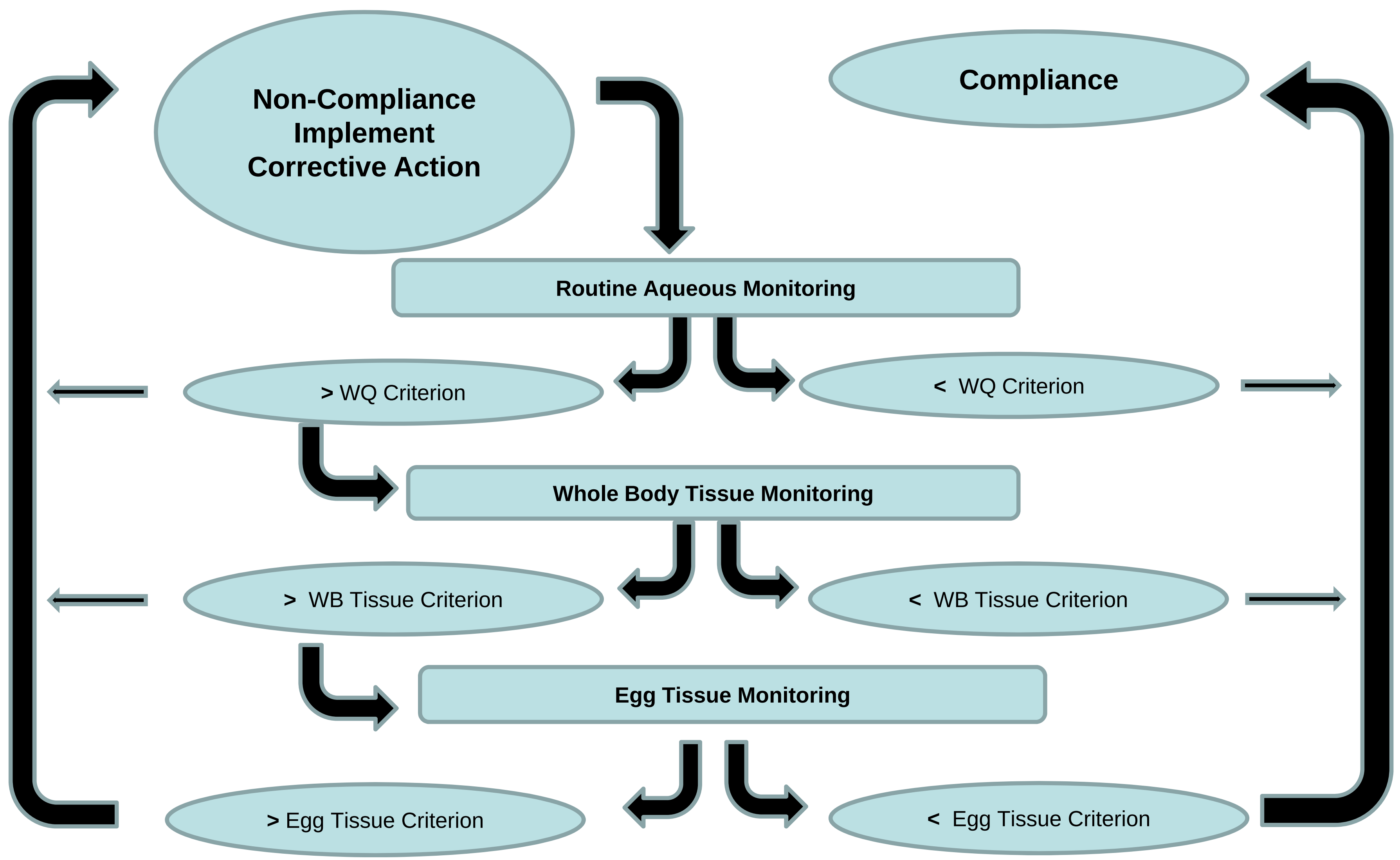


Figure 14
Flow Diagram for Implementing the Site-Specific Selenium Criterion for the Site

J.R. Simplot Company Site-Specific Selenium Criterion		
PRJ: 0442-004-900.70	DATE: April 2017	
REV: 1	BY: SMC	CHK: SMC

FORMATION ENVIRONMENTAL

Appendix A

Supporting Fishery Data

Table A-1
Summary of Fish Species, Numbers, Collected by Electrofishing, Fall 2006 - Fall 2016

Fall 2006	Location										Species Percent of Total Catch
	CC-75	CC-150	CC-350	CC-1A	CC-3A	DC-600	HS-3	HS-3A	LSV-2C	LSV-4	
Site Area (m^2)	333	548	1076	1806	1783	287	368	480	517	663	
Cutthroat Trout	2	5	7	4	9	71	--	ns	--	7	2%
Mountain Whitefish	--	--	2	--	10	--	--	ns	--	2	0.3%
Redside Shiner	--	5	--	8	43	--	--	ns	--		1%
Sculpin (*Cottus spp*.)	570	849	253	38	10	185	1188	ns	972	545	88%
Utah Sucker	--	--	--	1	2	--	--	ns	--	--	0.1%
Brown trout	19	42	1	13	34	--	48	ns	40	38	5%
Speckled Dace	--	6	88	18	86	--	--	ns	--	--	4%
Total Number of Fish	591	907	351	82	194	256	1236	ns	1012	592	
Fish/m^2	1.77	1.65	0.33	0.05	0.11	0.89	3.36	ns	1.96	0.89	
Fall 2007	CC-75	CC-150	CC-350	CC-1A	CC-3A	DC-600	HS-3	HS-3A	LSV-2C	LSV-4	Species Percent of Total Catch
Cutthroat Trout	2	14	33	19	28	64	12	ns	14	ns	5.6%
Longnose Dace	--	7	49	22	60	--	--	ns	--	ns	4.2%
Mountain Whitefish	--	--	5	23	15	--	--	ns	--	ns	1.3%
Redside Shiner	--	1	2	19	8	--	--	ns	--	ns	0.9%
Sculpin (*Cottus spp*.)	646	511	236	32	4	230	353	ns	311	ns	70%
Utah Sucker	--	--	--	--	7	--	--	ns	--	ns	0.2%
Brown trout	38	42	15	77	61	--	63	ns	65	ns	10.9%
Brook Trout	--	--	--	--	1	--	--	ns	--	ns	0.03%
Speckled Dace	--	5	5	96	122	--	--	ns	--	ns	6.9%
Total Number of Fish	686	580	345	288	306	294	428	ns	390	ns	
Fish/m^2	2.06	1.06	0.32	0.16	0.17	1.03	1.16	ns	0.76	ns	
Fall 2008	CC-75	CC-150	CC-350	CC-1A	CC-3A	DC-600	HS-3	HS-3A	LSV-2C	LSV-4	Species Percent of Total Catch
Cutthroat Trout	5	14	50	17	17	84	7	ns	12	ns	9%
Leatherside Chub	--	--	1	--	--	--	--	ns	--	ns	0.04%
Longnose Dace	--	--	4	8	48	--	--	ns	--	ns	2.6%
Mountain Whitefish	--	--	1	52	48	--	--	ns	--	ns	4.4%
Redside Shiner	--	--	--	16	26	--	--	ns	--	ns	1.8%
Sculpin (*Cottus spp*.)	225	131	113	12	5	145	643	ns	49	ns	58%
Utah Sucker		1	--	--	45	--	--	ns	--	ns	2%
Brown trout	22	31	17	53	63	--	46	ns	65	ns	13%
Speckled Dace	--	--	1	51	152	--	--	ns	--	ns	8.9%
Total Number of Fish	252	177	187	209	404	229	696	ns	126	ns	
Fish/m^2	0.76	0.32	0.17	0.12	0.23	0.80	1.89	ns	0.24	ns	
Fall 2009	CC-75	CC-150	CC-350	CC-1A	CC-3A	DC-600	HS-3	HS-3A	LSV-2C	LSV-4	Species Percent of Total Catch
Cuttbow: Rainbow Trout	--	--	--	1	ns	--	ns	ns	--	ns	0.05%
Cutthroat Trout	5	5	54	31	ns	62	ns	ns	8	ns	7.8%
Longnose Dace		1	6	15	ns	--	ns	ns	--	ns	1%
Mountain Whitefish	--	--	2	61	ns	--	ns	ns	--	ns	3%
Sculpin (*Cottus spp*.)	169	325	439	52	ns	273	ns	ns	363	ns	77%
Utah Sucker	--	--	2	1	ns	--	ns	ns	--	ns	0.14%
Brown trout	24	47	42	48	ns	--	ns	ns	45	ns	9.8%
Speckled Dace	--	--	--	23	ns	--	ns	ns	--	ns	1.1%
Total Number of Fish	198	378	545	232	ns	335	ns	ns	416	ns	
Fish/m^2	0.59	0.69	0.51	0.13	ns	1.17	ns	ns	0.81	ns	

Table A-1
Summary of Fish Species, Numbers, Collected by Electrofishing, Fall 2006 - Fall 2016

Fall 2010	CC-75	CC-150	CC-350	CC-1A	CC-3A	DC-600	HS-3	HS-3A	LSV-2C	LSV-4	Species Percent of Total Catch
Cutthroat Trout	19	14	50	36	20	112	10	ns	17	19	7.6%
Longnose Dace	--	--	10	19	58	--	--	ns	--	--	2.2%
Mountain Whitefish	--	--	3	35	119	--	--	ns	--	8	4.2%
Redside Shiner	--	--	1	6	7	--	--	ns	--	--	0.4%
Sculpin (*Cottus spp*.)	317	296	385	94	10	145	842	ns	275	277	67.6%
Young of year Trout	--	--	13	--	--	--	--	ns	1	--	0.4%
Utah Sucker	--	--	--	8	2	--	--	ns	--	--	0.3%
Brown trout	71	82	57	101	65	--	75	ns	78	43	14.6%
Brook Trout	--	--	--	1	--	--	--	ns	--	--	0.03%
Speckled Dace	--	--	--	38	68	--	--	ns	--	--	2.7%
Total Number of Fish	407	392	519	338	349	257	927	ns	371	347	
Fish/m^2	1.22	0.72	0.48	0.19	0.20	0.90	2.52	ns	0.72	0.52	
Fall 2011	CC-75	CC-150	CC-350	CC-1A	CC-3A	DC-600	HS-3	HS-3A	LSV-2C	LSV-4	Species Percent of Total Catch
Cutthroat Trout	11	11	12	30	ns	59	ns	ns	10	11	8.2%
Longnose Dace	--	--	1	19	ns	--	ns	ns	--	--	1.1%
Mountain Sucker	--	--	1		ns	--	ns	ns	--	--	0.06%
Mountain Whitefish	--	--	1	69	ns	--	ns	ns	--	6	4.3%
Redside Shiner	--	--	--	1	ns	--	ns	ns	--	--	0.06%
Sculpin (*Cottus spp*.)	315	104	168	76	ns	96	ns	ns	264	251	72.3%
Utah Sucker	--	--	--	4	ns	--	ns	ns	--	--	0.2%
Brown trout	28	49	17	50	ns	--	ns	ns	52	41	13.5%
Brook Trout	--	--	--	1	ns	--	ns	ns	--	--	0.06%
Speckled Dace	--	1	1	1	ns	--	ns	ns	--	--	0.2%
Total Number of Fish	354	165	201	251	ns	155	ns	ns	326	309	
Fish/m^2	1.06	0.30	0.19	0.14	ns	0.54	ns	ns	0.63	0.47	
Fall 2012	CC-75	CC-150	CC-350	CC-1A	CC-3A	DC-600	HS-3	HS-3A	LSV-2C	LSV-4	Species Percent of Total Catch
Cutthroat Trout	ns	ns	9	43	33	ns	18	ns	28	26	3.9%
Longnose Dace	ns	ns	5	28	24	ns	--	ns	--	--	1.4%
Mountain Whitefish	ns	ns	5	112	126	ns	--	ns	--	--	6.0%
Redside Shiner	ns	ns	--	--	7	ns	--	ns	--	--	0.2%
Sculpin (*Cottus spp*.)	ns	ns	501	168	29	ns	1005	ns	433	748	71.3%
Utah Sucker	ns	ns	--	2	24	ns	--	ns	--	--	0.6%
Brown trout	ns	ns	11	219	100	ns	86	ns	80	45	13.4%
Speckled Dace	ns	ns	--	18	110	ns	--	ns	--	--	3.2%
Total Number of Fish	ns	ns	531	590	453	ns	1109	ns	541	819	
Fish/m^2	ns	ns	0.49	0.33	0.25	ns	3.01	ns	1.05	1.24	
Fall 2013	CC-75	CC-150	CC-350	CC-1A	CC-3A	DC-600	HS-3	HS-3A	LSV-2C	LSV-4	Species Percent of Total Catch
Catostomus Species	ns	ns	--	1	--	ns	--	ns	--	--	0.03%
Cutthroat Trout	ns	ns	12	16	9	ns	10	ns	17	16	2.4%
Cyprinid Species	ns	ns	--	6	--	ns	--	ns	--	--	0.2%
Longnose Dace	ns	ns	13	26	61	ns	--	ns	--	--	3%
Mountain Whitefish	ns	ns	16	61	76	ns	--	ns	--	2	4.7%
Redside Shiner	ns	ns	--	12	8	ns	--	ns	--	--	0.6%
Sculpin (*Cottus spp*.)	ns	ns	302	164	69	ns	740	ns	567	712	77.9%
Utah Sucker	ns	ns	--	3	7	ns	--	ns	--	--	0.3%
Brown trout	ns	ns	39	85	68	ns	19	ns	17	34	8%
Brook Trout	ns	ns	--	--	--	ns	--	ns	1	--	0.03%
Speckled Dace	ns	ns	--	7	84	ns	--	ns	--	--	2.8%
Total Number of Fish	ns	ns	382	381	382	ns	769	ns	602	764	
Fish/m^2	ns	ns	0.36	0.21	0.21	ns	2.09	ns	1.17	1.15	

Table A-1
Summary of Fish Species, Numbers, Collected by Electrofishing, Fall 2006 - Fall 2016

Fall 2014	CC-75	CC-150	CC-350	CC-1A	CC-3A	DC-600	HS-3	HS-3A	LSV-2C	LSV-4	Species Percent of Total Catch
Cutthroat Trout	6	3	15	18	10	11	2	ns	14	3	4%
Longnose Dace	--	--	8	7	6	--	--	ns	--	--	1%
Mountain Whitefish	--	--	7	63	33	--	--	ns	--	5	5.3%
Redside Shiner	--	--	--	1	4	--	--	ns	--	--	0.2%
Sculpin (Cottus spp.)	357	240	216	120	29	77	265	ns	168	97	76%
Utah Sucker	--	--	1	1	14	--	--	ns	--	--	0.8%
Brown trout	18	34	46	36	48	--	16	ns	18	13	11%
Speckled Dace	--	--	--	7	18	--	--	ns	--	--	1%
Total Number of Fish	381	277	293	253	162	88	283	ns	200	118	
Fish/m^2	1.14	0.51	0.27	0.14	0.09	0.31	0.77	ns	0.39	0.18	

Fall 2015	CC-75	CC-150	CC-350	CC-1A	CC-3A	DC-600	HS-3	HS-3A	LSV-2C	LSV-4	Species Percent of Total Catch
Cutthroat Trout	ns	ns	15	17	5	ns	13	ns	16	2	2.7%
Longnose Dace	ns	ns	7	25	10	ns	--	ns	--	--	1.7%
Mountain Whitefish	ns	ns	4	41	25	ns	--	ns	--	1	2.8%
Redside Shiner	ns	ns	--	--	10	ns	--	ns	--	--	0.4%
Sculpin (Cottus spp.)	ns	ns	425	158	57	ns	439	ns	348	705	85%
Utah Sucker	ns	ns	1	--	4	ns	--	ns	--	1	0.2%
Brown trout	ns	ns	41	20	33	ns	6	ns	5	12	4.7%
Speckled Dace	ns	ns	--	8	46	ns	--	ns	--	--	2.2%
Total Number of Fish	ns	ns	493	269	190	ns	458	ns	369	721	
Fish/m^2	ns	ns	0.46	0.15	0.11	ns	1.24	ns	0.71	1.09	

Fall 2016	CC-75	CC-150	CC-350	CC-1A	CC-3A	DC-600	HS-3	HS-3A	LSV-2C	LSV-4	Species Percent of Total Catch
Cutthroat Trout	ns	ns	10	14	12	ns	24	3	23	9	3.8%
Longnose Dace	ns	ns	20	8	13	ns	--	--	--	--	1.6%
Mountain Whitefish	ns	ns	12	51	31	ns	--	--	--	4	3.9%
Redside Shiner	ns	ns	--	--	2	ns	--	--	--	--	0.1%
Sculpin (Cottus spp.)	ns	ns	542	139	61	ns	254	107	401	665	87%
Utah Sucker	ns	ns	13	5	24	ns	--	--	--	--	1.7%
Brown trout	ns	ns	65	18	17	ns	12	23	15	14	6.6%
Speckled Dace	ns	ns	--	15	92	ns	--	--	--	--	4.3%
Total Number of Fish	ns	ns	662	250	252	ns	290	133	439	692	
Fish/m^2	ns	ns	0.62	0.14	0.14	ns	0.79	0.28	0.85	1.04	
Total Number of Species	**4**	**8**	**10**	**11**	**10**	**3**	**3**	**3**	**4**	**5**	

Notes:

m^2 = square meters

-- = fish not collected

ns = location not sampled

Table A-2
Comparison of Trout Standing Crop Estimated (kg/Ha) Fall 2006 - Fall 2016

Standing Crop (kg/Ha)	CC-75	CC-150	CC-350	CC-1A	CC-3A[2]	DC-600[1]	HS-3	LSV-2C	LSV-4
Brown Trout									
Fall 2006	98.7	125.7	0.1	27	70	0	55	245.8	92.2
Fall 2007	72.5	86.6	14.2	40.2	56.3	0	95.1	154.1	NM
Fall 2008	45	83.8	18.3	48	58.6	0	45.8	231.1	NM
Fall 2009	99.5	121.9	24.1	33.2	NM	0	NM	199.6	NM
Fall 2010	193	169.3	31.8	34.6	108	0	130	315.5	523.3
Fall 2011	204	147.1	25.8	43.9	NM	0	NM	283.7	192.5
Fall 2012	NM	NM	16.7	58.8	120.8	NM	193.9	294.2	145.9
Fall 2013	NM	NM	30.5	58.3	94.7	NM	73.2	98.1	152.3
Fall 2014	77.4	104.3	37	43.7	91.4	0	58.8	116.3	59.4
Fall 2015	NM	NM	46.6	22.4	88.6	NM	12	33.5	61.3
Fall 2016	NM	NM	38.5	7.3	47.8	NM	32	65.9	61.8
Cutthroat Trout									
Fall 2006	2.4	13.8	2.2	7.8	13.3	83.0	0	32.4	22.8
Fall 2007	2	19.3	28.9	29.1	62.3	76.2	0	42.9	NM
Fall 2008	17.8	30.8	30.9	25.1	28.9	126.9	1.2	45.9	NM
Fall 2009	19.4	23.2	16.7	31.5	NM	129.1	NM	39.4	NM
Fall 2010	36.8	64.4	26.7	53.9	50.1	264.5	10.7	51.4	97.2
Fall 2011	24	88.3	7.7	50.3	NM	180.9	NM	45.9	32.5
Fall 2012	NM	NM	3.4	55.9	107.7	NM	35.7	115.6	102.7
Fall 2013	NM	NM	11.3	27.9	25.9	NM	44.3	69.4	68
Fall 2014	14.4	6.9	18	28.1	29.2	26.6	10.7	62	11.8
Fall 2015	NM	NM	9	31.9	17.6	NM	9.6	60	10.5
Fall 2016	NM	NM	5.5	24.6	43.6	NM	9.2	322	29.9
All Trout									
Fall 2006	101.1	139.5	2.3	34.8	83.3	83	55	278	115
Fall 2007	74.5	105.9	43.1	69.3	118.6	76.2	95.1	197	NM
Fall 2008	62.8	114.7	49.2	73.1	87.5	126.9	47.1	277	NM
Fall 2009	118.9	145.1	40.9	64.7	NM	129.1	NM	239	NM
Fall 2010	229.7	233.7	58.5	88.6	158.1	264.5	140.7	367	620.5
Fall 2011	228	235.4	33.5	94.1	NM	180.9	NM	330	225.1
Fall 2012	NM	NM	20.1	114.7	228.5	NM	229.6	410	248.6
Fall 2013	NM	NM	41.8	86.2	120.7	NM	117.5	168	220.3
Fall 2014	91.8	111.2	55	71.8	120.6	26.6	69.5	178	71.2
Fall 2015	NM	NM	44	31.9	91.3	NM	41.2	94	91.7
Fall 2016	NM	NM	44	32	91	NM	41	388	92

Notes:

[1] = Fall 2014 - DC-600 site length shortened to 170 feet due to beaver activity.

[2] = Fall 2010 - Meander cut off reduced CC-3A reach length by 200 feet.

NM = Not Measured

kg/Ha = kilograms per hectare

Appendix B

Yellowstone Cutthroat Trout Data

Table B-1
Yellowstone Cuthroat Trout Survival and Count of Normal Fry from Hatch to Swimup

Location/ Sample ID	Se - Egg (mg/kg dw)	Initial eggs	Total Hatched	Dead-hatch to swim up	Total # survived	% Survival at swim up	Normal (0) at swim up	Total assessed through swim up	Sum total assessed + dead at swim up	Fraction normal +survived (0)
HL/002	2.03	600	69	10	59	0.86	0	14	24	0.000
HL/003	2.48	600	341	17	324	0.95	110	227	244	0.451
HL/004	1.36	600	456	19	437	0.96	143	338	357	0.401
HL/006	0.83	600	367	102	265	0.72	15	167	269	0.056
HL/007	2.26	600	442	18	424	0.96	106	327	345	0.307
HL/008	1.87	600	469	36	433	0.92	133	332	368	0.361
HL/011	3.23	600	338	21	317	0.94	65	212	233	0.279
HL/012	1.58	600	501	25	476	0.95	109	374	399	0.273
HL/013	1.93	600	527	24	503	0.95	143	402	426	0.336
HL/015	2.06	600	62	6	56	0.90	0	19	25	0.000
LSV2C/001	40.1	600	556	536	0	0.00	0	0	536	0.000
LSV2C/002	30.0	550	444	71	373	0.84	40	273	344	0.116
LSV2C/003	35.6	650	645	121	524	0.81	91	423	544	0.167
LSV2C/004	30.5	600	571	58	513	0.90	103	413	471	0.219
DC/001	22	600	325	24	301	0.93	79	203	227	0.348
DC/002	15.4	600	511	25	486	0.95	122	386	411	0.297
DC/003	11.4	400	439	10	429	0.98	58	331	341	0.170
DC/004	12.7	100	64	4	60	0.94	7	60	64	0.109
CC-150/001	17.6	300	235	11	224	0.95	19	126	137	0.139
CC-350/001	27.9	400	162	19	143	0.88	12	38	57	0.211
CC-350/002	29.7	750	707	69	638	0.90	141	541	610	0.231
CC-350/003	22.3	500	386	17	369	0.96	66	272	289	0.228
CC-350/004	14.6	600	519	8	511	0.98	143	413	421	0.340
CC-350/005	47.6	600	483	61	422	0.87	91	326	387	0.235

Samples highlighted had 11% or less successfully hatched eggs out of an initial 600 eggs possibly due to poor fertilization

Appendix C

Supporting Data and Information for Pole Canyon Creek and North Fork Sage Creek

Actions Implemented in the Pole Canyon Creek Drainage
to Improve Downgradient and Downstream Water Quality

The Pole Canyon Overburden Disposal Area (ODA) at the Smoky Canyon Mine is a cross-valley fill which consists of naturally seleniferous waste rock that covers approximately one mile of the original Pole Canyon Creek channel. Water quality in Pole Canyon Creek was affected by the ODA which was constructed as part of permitted mining operations. Upstream of the ODA, the Pole Canyon Creek watershed covers approximately 1,100 acres and is not a source of selenium to surface water. The upper watershed lies upon the Triassic Dinwoody and Thaynes Formations, which are comprised of shale, sandstone, and limestone. Approximately 500 feet upstream of the ODA, the creek crosses over the low permeability Meade Peak Formation (i.e., Rex Chert member, upper ore zone, middle waste shale, and lower ore zone). The ODA itself overlies an outcrop of the Wells Formation, which is primarily comprised of limestone. Studies conducted prior to ODA construction indicated that a significant portion of Pole Canyon Creek flow was lost to the underlying bedrock where the creek crossed the relatively permeable Wells Formation (Ralston, 1979).

Upon construction of the cross-valley fill in Pole Canyon, which occurred from 1985 through 1990, Pole Canyon Creek water entered the upstream side of the ODA and then a portion was lost to Wells Formation bedrock and alluvial deposits beneath the ODA and the remaining water was discharged at the downstream end, or toe, of the ODA. During the relatively dry months from late summer through late spring, most of the creek flow was lost under the ODA to the Wells Formation and alluvial deposits. The creek water that emerged from the toe of the ODA was quickly lost to alluvial deposits before the creek crossed Sage Valley. During the fall of very dry years, all Pole Canyon Creek flow was lost underneath the ODA and no measurable flow occurred at the toe. During typical spring runoff (i.e., high-flow) conditions, discharge from the toe of the ODA flowed in the Pole Canyon Creek channel toward Sage Valley. The creek discharge from the ODA was then either lost to alluvial deposits or flowed across Sage Valley to eventually join the north fork of Sage Creek.

Data for Pole Canyon Creek monitoring locations upstream (UP-PD) and downstream (LP and LP-PD) of the ODA and the ODA toe seep (LP-1) show that the selenium concentrations in upper Pole Canyon Creek (upstream of the ODA) are very low (less than 0.0007 mg/L and generally not detected), showing that this upper reach of the stream is not a source of selenium to Pole Canyon Creek. Before implementation of the Pole Canyon Non-Time-Critical Action (NTCRA) in 2007 and 2008, which focused on improvements in water management, selenium concentrations in lower Pole Canyon Creek (at LP) consistently exceeded the state water chronic aquatic life criterion (0.005 mg/L) and ranged from 0.368 to 1.33 mg/L. During this pre-NTCRA period, Pole Canyon Creek water entered the upstream side of the ODA. A portion of the creek water was lost to Wells Formation bedrock and alluvial deposits beneath the ODA and the remaining creek water was discharged at the downstream end, or toe, of the ODA. The contact of upper Pole Canyon Creek water with the seleniferous ODA materials resulted in significantly increased concentrations of selenium, as noted above, in lower Pole Canyon Creek downstream from the ODA toe. Also during this period, selenium concentrations were measured at the toe seep discharge location (LP-1), which is located upgradient of its discharge into the Pole Canyon Creek channel. Selenium concentrations at LP-1 were higher than those measured in the creek at LP, and ranged from 0.682 to 1.89 mg/L.

Simplot completed the Pole Canyon water management NTCRA in 2007 and 2008 in accordance with the October 2006 Settlement Agreement entered into by the USFS, USEPA, and IDEQ (2006). The key component of this water management NTCRA is routing of Pole Canyon Creek around the ODA via a pipeline. This bypass pipeline was completed in September 2007 and has remained operational since. A second component, the infiltration basin, was also completed in 2007. The infiltration basin is designed to capture Pole Canyon Creek flows that develop in the 487-acre area downstream of the pipeline inlet and direct that water into the Wells Formation aquifer on the upstream side of the ODA before the water comes in contact with the ODA materials. A third component of the water management NTCRA, the run-on control channel, was constructed and completed in late 2008. The NTCRA construction activities are described in the Final Construction Completion Report (NewFields et al., 2009).

As the first water management NTCRA component, the bypass pipeline conveys surface water via gravity flow from the uppermost 615 acres, or approximately 60 percent, of the upper Pole Canyon Creek watershed over and around the ODA and discharges this water back into the creek channel downstream from the ODA. Upper Pole Canyon Creek enters the pipeline via an inlet structure that is designed to keep sediment and debris from entering the pipeline. If the flow is greater than the pipeline capacity of 44 cfs, the excess creek flow would continue down the original creek channel to the infiltration basin directly upstream of the ODA. Exceedance of the pipeline capacity is expected to occur very infrequently (i.e., on the order of once every several decades). The pipeline inlet and outlet structures are equipped with weirs, pressure transducers, and data-loggers to continuously monitor the pipeline flow, with telemetry equipment in place to allow access to flow measurements throughout the year.

Once the bypass pipeline became operational, the resulting decrease in selenium concentrations was rapid as Pole Canyon Creek stream flows upstream of the ODA were collected, directed through the bypass pipeline around the ODA, and discharged downstream of the ODA as monitored in lower Pole Canyon Creek at LP-PD. With the exception of a brief spike in early June 2011, in the four years since implementation of the RA selenium concentrations in lower Pole Canyon Creek at LP-PD have ranged from non-detected to 0.00047 mg/L. Note that in 2011, the infiltration basin was allowed to fill beyond its operational limits, as agreed by the Agencies and Simplot, and a spike in selenium concentrations was observed at LP-PD (lower Pole Canyon Creek downstream from the pipeline discharge). It is important to differentiate the source of selenium during this time frame. The selenium concentrations in the water discharging from the pipeline were unchanged, as this water is entirely from upper Pole Canyon Creek and is unaffected by the ODA. However, seepage at the toe of the ODA at LP-1 was increased due to the increased ponding of water in the infiltration basin. A portion of this significantly increased seepage flow did not infiltrate into the alluvium and, therefore, reached the lower Pole Canyon

Creek channel and comingled with flows discharging from the pipeline resulting in the brief spike in selenium concentrations at LP-PD. Once the infiltration basin was brought back to within its normal operational limits, the characteristics of seepage flow exiting the ODA toe (at LP-1) returned to normal conditions. With the RA operating, the low-volume, high-concentration residual toe seepage does not reach the creek channel and, therefore, does not affect selenium concentrations in lower Pole Canyon Creek. This is evidenced by the consistent selenium concentrations measured at LP-PD at less than 0.001 mg/L.

The infiltration basin, which is the second water management NTCRA component, was constructed on the Wells Formation directly upstream of the ODA by scraping the alluvial material off and blasting the Wells Formation to create a very permeable basin floor. A liner was installed on the east side of the basin on the west-facing slope of the ODA, from the basin floor to a height of approximately 45 feet, to prevent movement of water from the basin directly into nearby overburden (NewFields et al., 2009). Under normal operating conditions, the infiltration basin typically does not pond, and only during unusual conditions would ponding occur, which could result in movement of water from the basin directly into the overburden, though at a reduced rate due to the liner (Formation, 2012b). The liner is constructed of 80-mil high-density polyethylene (HDPE) and is covered with a geotextile cushion and riprap. The bottom of the liner is keyed into the material in the bottom of the basin with two 2-foot wide by 3-foot deep trenches.

A sedimentation basin was constructed directly upstream of the infiltration basin to reduce the amount of sediment entering the infiltration basin that could ultimately reduce the infiltration rate through the infiltration basin floor over time. The infiltration basin captures runoff from approximately 487 acres of the upper Pole Canyon Creek watershed, or approximately 40 percent of the watershed; this area is located between the pipeline inlet structure and the infiltration basin. A flume, pressure transducer, and data-logger were installed within the creek channel directly above the sedimentation basin in early 2009 to monitor the creek flow entering the infiltration basin. Water entering the basin infiltrates into the underlying bedrock.

The third water management NTCRA component, the run-on control channel, was designed to intercept runoff from the hillside adjacent to the ODA to the north and divert it around the ODA and back to the creek channel downstream from the ODA. It was designed to capture runoff from the upslope area of approximately 95 acres and to convey the runoff generated by a 100-year storm event with an additional freeboard allowance (NewFields et al., 2009).

Several years later, in 2015, Simplot implemented an additional NTCRA which involved construction of an engineered cover on the Pole Canyon ODA using locally available Dinwoody and chert. The new cover system further reduces selenium releases from the ODA by decreasing the amount of infiltration into the ODA materials from incident precipitation and snowmelt runoff. By decreasing these remaining sources of water to the overburden, the ODA toe seep is expected to be eliminated or decreased significantly. Combined, the two Pole Canyon NTCRAs have significantly reduced the potential for selenium loading from the Pole Canyon ODA source.

Location Descriptions

Location	Description
UP	Pole Canyon Creek Upstream of ODA
NSV-5	North Fork Sage Creek (upstream of inflow from Pole Canyon Creek)
LP	Pole Canyon Creek (stream station through 2007, downstream of ODA toe)
LP-PD	Pole Canyon Creek (at bypass pipeline discharge, since 2008)
NSV-6	North Fork Sage Creek (downstream of inflow from Pole Canyon Creek)
LSV-1	Sage Creek (downstream of inflow from North Fork Sage Creek)

Surface Water Results for Pole Canyon Creek, North Fork Sage Creek, and Sage Creek

Sample Location	Date	Selenium, Dissolved			Selenium, Total			Conductivity	Flow	ORP	DO	pH	Temperature	Turbidity
		mg/L	LQ	VQ	mg/L	LQ	VQ	umhos/cm	cfs	mV	mg/L	SU	C	NTU
UP	10/1/1979	---	---	---	0.001	---	---	---	---	---	---	---	---	---
UP	9/15/1981	---	---	---	0.001	---	---	---	---	---	---	---	---	---
UP	9/15/1983	---	---	---	0.002	---	---	---	---	---	---	---	---	---
UP	5/15/1984	---	---	---	0.002	---	---	---	---	---	---	---	---	---
UP	9/15/1984	---	---	---	0.004	---	---	---	---	---	---	---	---	---
UP	5/15/1985	---	---	---	0.002	---	---	---	---	---	---	---	---	---
UP	9/15/1985	---	---	---	0.002	---	---	---	---	---	---	---	---	---
UP	5/15/1986	---	---	---	0.001	---	---	---	---	---	---	---	---	---
UP	9/15/1986	---	---	---	0.001	---	---	---	---	---	---	---	---	---
UP	5/15/1987	---	---	---	0.001	---	---	---	---	---	---	---	---	---
UP	9/15/1987	---	---	---	0.001	---	---	---	---	---	---	---	---	---
UP	9/15/1990	---	---	---	0.001	---	---	---	---	---	---	---	---	---
UP	5/15/1991	---	---	---	0.001	---	---	---	---	---	---	---	---	---
UP	9/15/1991	---	---	---	0.001	---	---	---	---	---	---	---	---	---
UP	5/15/1992	---	---	---	0.001	---	---	---	---	---	---	---	---	---
UP	9/15/1992	---	---	---	0.001	---	---	---	---	---	---	---	---	---
UP	5/15/1993	---	---	---	0.001	---	---	---	---	---	---	---	---	---
UP	9/15/1993	---	---	---	0.001	---	---	---	---	---	---	---	---	---
UP	5/15/1994	---	---	---	0.001	---	---	---	---	---	---	---	---	---
UP	9/15/1994	---	---	---	0.001	---	---	---	---	---	---	---	---	---
UP	5/15/1995	---	---	---	0.001	---	---	---	---	---	---	---	---	---
UP	9/15/1995	---	---	---	0.001	---	---	---	---	---	---	---	---	---
UP	5/15/1996	---	---	---	0.001	---	---	---	---	---	---	---	---	---
UP	9/15/1996	---	---	---	0.001	---	---	---	---	---	---	---	---	---
UP	5/15/1997	---	---	---	0.001	---	---	---	10.62	---	---	---	---	---
UP	6/15/1997	---	---	---	---	---	---	---	2.85	---	---	---	---	---
UP	7/15/1997	---	---	---	---	---	---	---	0.64	---	---	---	---	---
UP	8/15/1997	---	---	---	---	---	---	---	0.37	---	---	---	---	---
UP	9/15/1997	0.0000797	---	---	0.00022	---	---	---	0.35	---	---	---	---	---
UP	10/15/1997	---	---	---	---	---	---	---	0.22	---	---	---	---	---
UP	5/15/1998	---	---	---	0.001	---	---	---	---	---	---	---	---	---
UP	6/3/1998	---	---	---	---	---	---	---	10.62	---	---	---	---	---
UP	7/1/1998	---	---	---	---	---	---	---	2.22	---	---	---	---	---
UP	8/4/1998	---	---	---	---	---	---	---	1.19	---	---	---	---	---
UP	9/1/1998	---	---	---	---	---	---	---	0.46	---	---	---	---	---
UP	9/15/1998	---	---	---	0.001	---	---	---	---	---	---	---	---	---
UP	10/12/1998	---	---	---	---	---	---	---	0.43	---	---	---	---	---
UP	11/5/1998	---	---	---	---	---	---	---	0.22	---	---	---	---	---
UP	5/15/1999	---	---	---	0.001	---	---	---	---	---	---	---	---	---
UP	9/15/1999	---	---	---	0.001	---	---	---	---	---	---	---	---	---
UP	5/15/2000	---	---	---	0.001	---	---	---	---	---	---	---	---	---
UP	6/22/2000	0.001	---	---	0.001	---	---	290	1.33	185	5.5	8.7	14.6	---
UP	9/1/2000	---	---	---	---	---	---	393	0.07	230	16.9	7.8	6.8	164
UP	9/15/2000	---	---	---	0.001	---	---	---	---	---	---	---	---	---
UP	9/26/2000	0.001	---	---	0.001	---	---	---	---	---	---	---	---	---
UP	5/15/2001	---	---	---	0.001	---	---	---	---	---	---	---	---	---
UP	9/15/2001	---	---	---	0.001	---	---	---	---	---	---	---	---	---
UP	5/16/2002	0.001	U	---	0.001	U	---	275	1.94	---	10.02	8.2	3.65	5.45
UP	10/17/2002	0.001	B	J	0.001	B	J	185	0.08	---	9.94	7.49	1.51	1.2
UP	5/23/2003	0.001	U	---	0.001	U	---	332	2.57	---	7.19	7.3	7.8	22.7
UP	10/29/2003	0.0002	U	UJ	0.0002	U	---	220	0.035	---	8.8	8.43	4.1	0.52
UP	5/7/2004	0.0003	U	---	0.00052	B	J-	238	1.75	---	9.94	7.56	3.7	26.3

Surface Water Results for Pole Canyon Creek, North Fork Sage Creek, and Sage Creek

Sample Location	Date	Selenium, Dissolved			Selenium, Total			Conductivity	Flow	ORP	DO	pH	Temperature	Turbidity
		mg/L	LQ	VQ	mg/L	LQ	VQ	umhos/cm	cfs	mV	mg/L	SU	C	NTU
UP	7/20/2004	0.00036	B	---	0.0003	U	U	338	0.43	---	9.48	8.21	8.37	1.71
UP	9/28/2004	0.0003	U	---	0.0003	U	---	195	0.067	---	6.5	8.15	2.3	1.34
UP	9/20/2005	0.0002	U	---	0.00025	B	---	230	0.16	---	9.8	7.07	6.2	2.65
UP	5/13/2006	---	---	---	---	---	---	---	3.79	---	---	---	---	---
UP	5/21/2006	0.00035	B	---	0.00081	B	---	211	---	---	9.5	8.39	7.5	12.8
UP	10/16/2006	0.00069	B	---	0.0002	U	---	200	1.04	---	10.6	8.49	3.9	2.4
UP	5/20/2007	---	---	---	---	---	---	196	---	---	8.72	8.61	3.3	2.86
UP	5/22/2007	0.00031	B	---	0.00032	B	---	---	---	---	---	---	---	---
LP	6/5/1979	---	---	---	0.01	---	---	---	---	---	---	---	---	---
LP	10/1/1979	---	---	---	0.001	---	---	---	---	---	---	---	---	---
LP	9/15/1982	---	---	---	0.02	---	---	---	---	---	---	---	---	---
LP	5/15/1983	---	---	---	0.1	---	---	---	---	---	---	---	---	---
LP	5/15/1984	---	---	---	0.002	---	---	---	---	---	---	---	---	---
LP	5/15/1985	---	---	---	0.002	---	---	---	---	---	---	---	---	---
LP	5/15/1986	---	---	---	0.002	---	---	---	---	---	---	---	---	---
LP	5/15/1987	---	---	---	0.037	---	---	---	---	---	---	---	---	---
LP	5/15/1991	---	---	---	0.07	---	---	---	---	---	---	---	---	---
LP	9/15/1991	---	---	---	0.115	---	---	---	---	---	---	---	---	---
LP	5/15/1992	---	---	---	0.125	---	---	---	---	---	---	---	---	---
LP	9/15/1992	---	---	---	0.19	---	---	---	---	---	---	---	---	---
LP	5/15/1993	---	---	---	0.17	---	---	---	---	---	---	---	---	---
LP	5/15/1994	---	---	---	0.262	---	---	---	---	---	---	---	---	---
LP	5/15/1995	---	---	---	0.5	---	---	---	---	---	---	---	---	---
LP	9/15/1995	---	---	---	0.32	---	---	---	---	---	---	---	---	---
LP	5/15/1996	---	---	---	0.21	---	---	---	---	---	---	---	---	---
LP	9/15/1996	---	---	---	0.69	---	---	---	---	---	---	---	---	---
LP	5/15/1997	---	---	---	0.33	---	---	---	4.81	---	---	---	---	---
LP	6/15/1997	---	---	---	---	---	---	---	2.32	---	---	---	---	---
LP	7/15/1997	---	---	---	---	---	---	---	0.42	---	---	---	---	---
LP	8/15/1997	---	---	---	---	---	---	---	0.08	---	---	---	---	---
LP	5/15/1998	---	---	---	0.22	---	---	---	---	---	---	---	---	---
LP	6/3/1998	---	---	---	---	---	---	---	2.9	---	---	---	---	---
LP	7/1/1998	---	---	---	---	---	---	---	1.93	---	---	---	---	---
LP	8/4/1998	---	---	---	---	---	---	---	0.42	---	---	---	---	---
LP	5/15/1999	---	---	---	1	---	---	---	---	---	---	---	---	---
LP	5/15/2000	---	---	---	0.71	---	---	---	---	---	---	---	---	---
LP	6/22/2000	0.5	---	---	0.51	---	---	410	0.55	220	8.5	8.2	11.7	---
LP	5/15/2001	---	---	---	0.47	---	---	---	---	---	---	---	---	---
LP	5/15/2002	1.11	---	---	0.86	---	---	1037	2.02	---	13.62	7.76	8.83	3.91
LP	5/24/2003	0.64	---	---	0.58	---	---	771	1.76	---	6.52	7.18	10.6	8.19
LP	5/7/2004	---	---	---	---	---	---	734	0.99	---	8.24	7.21	8.01	---
LP	6/4/2004	0.308	---	---	0.44	---	---	455	0.9	---	10.78	7.49	7.76	1.11
LP	7/20/2004	0.356	---	---	0.368	---	---	731	0.19	---	8.67	7.85	12.01	0.88
LP	9/28/2004	0.822	---	---	0.895	---	---	780	0.011	---	7.2	8.26	9.6	3.02
LP	5/18/2005	1.27	---	---	1.33	---	---	600	4.49	---	7.8	7.56	5.8	93.9
LP	9/20/2005	0.926	---	---	0.94	---	---	730	0.004	---	8.9	7.71	11.1	0.73
LP	5/21/2006	0.928	---	---	0.936	---	---	492	4.97	---	9.5	7.51	6.5	46.4
LP	5/22/2007	0.703	---	---	0.79	---	---	500	0.682	---	9.1	8.04	6.1	0.41
LP-PD	5/19/2008	0.0646	---	---	0.0409	---	---	239	7.37	---	11.86	8.49	4.72	41.9
LP-PD	8/27/2008	---	---	---	---	---	---	---	0.151	---	---	---	---	---
LP-PD	10/1/2008	0.0002	U	---	0.0002	U	---	250	---	---	12.74	8.55	9.24	0.46
LP-PD	6/2/2009	0.0002	U	---	0.00041	B	---	348	3.58	233.1	10.69	7.27	5.06	3.28

Surface Water Results for Pole Canyon Creek, North Fork Sage Creek, and Sage Creek

Sample Location	Date	Selenium, Dissolved			Selenium, Total			Conductivity	Flow	ORP	DO	pH	Temperature	Turbidity
		mg/L	LQ	VQ	mg/L	LQ	VQ	umhos/cm	cfs	mV	mg/L	SU	C	NTU
LP-PD	11/21/2009	0.0002	U	---	0.00045	B	---	333	0.143	226.5	11.92	8.69	3.17	9.47
LP-PD	6/8/2010	0.0002	B	U	0.0005	B	U	341	2.03	126.7	10.24	8.62	6.9	15.6
LP-PD	8/26/2010	---	---	---	---	---	---	310	---	279	9.53	7.91	10.58	1.59
LP-PD	11/11/2010	0.00037	B	---	0.00044	B	---	358	0.2	211.8	12.42	8.36	4.07	0.62
LP-PD	6/4/2011	0.432	---	---	0.432	---	---	453	---	36.5	13.9	7.45	6.1	0.36
LP-PD	6/5/2011	0.099	---	---	0.098	---	---	312	---	15.1	15.71	7.83	4.88	---
LP-PD	6/7/2011	0.027	---	---	0.034	---	---	297	---	39.8	14.84	8.23	4.84	42.8
LP-PD	6/12/2011	1.012	---	---	1.091	---	---	---	---	---	---	---	---	---
LP-PD	6/14/2011	0.043	---	---	0.043	---	---	345	---	117	14.04	7.08	6.68	7.09
LP-PD	6/21/2011	0.001	---	---	0.001	---	---	332	---	166.2	9.71	8.52	7.27	---
LP-PD	6/27/2011	0.001	---	---	0.001	---	---	---	---	---	---	---	---	---
LP-PD	8/28/2011	0.00046	B	---	0.00047	B	---	332	---	88.3	9.21	8.31	9.29	9.65
LP-PD	11/7/2011	0.00025	B	---	0.00022	B	---	209.3	0.083	183.7	10.87	8.73	3.3	0.77
LP-PD	4/25/2012	0.00022	J	---	0.00045	J	---	295	---	54	13.57	8.21	5.02	12
LP-PD	5/11/2012	0.0002	U	---	0.0002	U	---	336.7	1.17	184.7	9.8	8.92	4.9	4.16
LP-PD	5/30/2012	0.0002	U	---	0.00023	J	---	275	---	173.6	13.18	8.41	6.89	3.68
LP-PD	7/23/2012	0.0002	U	---	0.00026	J	---	280	---	172.8	12.74	8.48	9.33	2.43
LP-PD	8/30/2012	0.0002	U	---	0.0002	U	---	324	0.15	83.9	11.93	8.56	11.94	2.31
LP-PD	9/13/2012	0.0002	U	---	0.0002	U	---	345	---	164	8.69	8.9	9.73	141.6
LP-PD	11/7/2012	0.0002	U	---	0.0002	U	---	284	0.106	11.2	21.04	8.26	5.43	0.63
LP-PD	5/21/2013	0.0002	U	---	0.0002	U	---	292	2.49	179.9	14.57	8.49	5.56	0.25
LP-PD	8/23/2013	0.0002	U	---	0.0002	U	---	294.9	0.148	100.9	8.07	8.61	11.2	0.37
LP-PD	11/5/2013	0.0002	U	---	0.0002	U	---	358.3	0.086	42.9	10.11	8.66	4.03	1.9
LP-PD	5/20/2014	0.00025	J	---	0.00031	J	---	351.6	5.74	67.6	10.69	8.6	5.45	4.15
LP-PD	8/12/2014	0.00052	J	U	0.00044	J	U	388	0.38	51.7	9.29	8.92	10.52	3.96
LP-PD	11/19/2014	0.0002	U	---	0.00052	U	---	368.4	0.086	245.6	10.33	8.48	3.2	2.92
LP-PD	5/8/2015	0.00062	U	---	0.00062	U	UJ	434	24.71	139.8	11.15	8.49	5.31	6.83
LP-PD	9/12/2015	0.00062	U	---	0.0014	J	---	402	0.169	148.7	9.1	8.73	9.12	2.45
LP-PD	11/5/2015	0.00062	U	---	0.00062	U	---	362	8.61	143.8	11.38	7.31	5.41	8
LP-PD	5/18/2016	0.0002	U	---	0.0002	U	---	350.4	2.5	-38.9	9.77	8.37	5.1	5.34
LP-PD	11/7/2016	0.0002	J	---	0.0004	J	---	404.6	0.16	3.24	10.11	8.45	5.54	2.43
NSV-5	6/6/1979	---	---	---	0.01	---	---	---	---	---	---	---	---	---
NSV-5	10/2/1979	---	---	---	0.001	---	---	---	---	---	---	---	---	---
NSV-5	9/16/1997	0.00546	---	---	0.0031	---	---	---	---	---	---	---	---	---
NSV-5	5/1/1998	---	---	---	0.00041	---	---	---	---	---	---	---	---	---
NSV-5	5/19/1998	---	---	---	0.00041	---	---	---	---	---	---	---	---	---
NSV-5	9/15/1999	---	---	---	0.00082	---	---	---	---	---	---	---	---	---
NSV-5	5/15/2002	0.001	U	---	0.001	U	---	467	0.075	---	8.48	8.31	18.09	---
NSV-5	10/18/2002	0.001	U	U	0.001	U	U	---	---	---	---	---	---	---
NSV-5	5/24/2003	0.001	U	---	0.001	U	---	388	0.015	---	2.6	7.79	17.7	13.8
NSV-5	10/28/2003	0.0002	U	UJ	0.00032	B	J-	800	0.083	---	2.8	8.09	8.7	11.3
NSV-5	5/19/2004	0.0003	U	---	0.0003	U	---	---	---	---	---	---	---	---
NSV-5	7/22/2004	0.0003	U	U	0.0013	---	U	596	0.03	---	1.4	7.31	19.5	1000
NSV-5	6/19/2008	0.00052	B	---	0.00053	B	---	292	---	---	---	7.96	18.2	14
NSV-5	9/16/2008	0.00047	B	---	0.00039	B	---	277	---	---	7.44	7.84	10.4	1.03
NSV-5	6/2/2009	0.00029	B	---	0.00072	B	---	200	0.533	192.4	5.98	7.9	19.61	25.41
NSV-5	10/21/2009	0.0002	U	---	0.0002	U	---	405	---	-8.9	12.93	8.34	8.39	9.47
NSV-5	6/7/2010	0.0004	B	U	0.0005	B	U	320	0.212	143.5	9.04	7.84	13.45	11.5
NSV-5	9/28/2010	0.00024	B	---	0.00026	B	---	320	---	-44.3	8.54	7.76	11.15	18.31
NSV-5	11/11/2010	0.00033	B	---	0.0003	B	---	459	---	219.4	14.89	7.76	0.19	3.58
NSV-5	6/14/2011	0.037	---	---	0.0444	---	---	241	2.057	35	8	8.07	20.71	25.8
NSV-5	9/20/2011	0.00025	B	---	0.00054	B	---	404	---	109.8	9.01	8.2	11.57	5.27

Surface Water Results for Pole Canyon Creek, North Fork Sage Creek, and Sage Creek

Sample Location	Date	Selenium, Dissolved			Selenium, Total			Conductivity	Flow	ORP	DO	pH	Temperature	Turbidity
		mg/L	LQ	VQ	mg/L	LQ	VQ	umhos/cm	cfs	mV	mg/L	SU	C	NTU
NSV-5	5/11/2012	0.00022	J	---	0.00024	J	---	389.8	0.101	103	8.43	8.03	12.2	14.29
NSV-5	9/13/2012	0.00076	J	---	0.00085	J	---	496	---	132.7	2.29	7.78	11.93	379.5
NSV-5	11/15/2012	0.00032	J	---	0.00029	J	---	383.2	---	70.3	10.64	8.23	0.1	37.03
NSV-5	5/21/2013	0.00031	J	---	0.00036	J	---	370.8	---	104.7	9.53	8	7.9	9.67
NSV-5	9/18/2013	0.00021	J	---	0.00046	J	---	366.9	---	41.3	8.07	8.36	9.74	18.1
NSV-5	11/15/2013	0.00021	J	---	0.00033	J	---	435	---	202.5	11.35	6.06	0.65	1.88
NSV-5	5/20/2014	0.00037	J	---	0.0004	J	---	355	0.21	-133.6	9.63	7.53	11.64	2.74
NSV-5	8/14/2014	0.00043	J	U	0.00037	J	U	530.5	0.086	60.6	7.29	8.5	17.32	5.83
NSV-5	5/8/2015	0.00062	U	---	0.00062	U	---	233	---	103.8	9.75	8.05	9.41	22
NSV-5	7/21/2015	0.00062	U	---	0.00062	U	---	412.9	0.067	57.1	7.11	8.55	18.43	2.25
NSV-5	9/12/2015	0.00011	U	---	0.00062	U	---	461	---	71.9	7.85	8.49	13.25	9.36
NSV-5	11/5/2015	0.00062	U	---	0.00062	U	---	426	---	304.2	6.37	6.24	1.19	14.9
NSV-5	5/18/2016	0.00018	J	U	0.00024	U	---	265.6	---	-25.8	7.07	7.81	12.2	28.7
NSV-5	7/8/2016	0.00011	J	U	0.00014	J	U	391	---	95	10.2	8.49	9.37	18.7
NSV-5	11/8/2016	0.00024	U	---	0.0003	J	---	370	---	-8	8.86	8.06	6.46	6.75
NSV-6	6/6/1979	---	---	---	0.01	---	---	---	---	---	---	---	---	---
NSV-6	10/2/1979	---	---	---	0.001	---	---	---	---	---	---	---	---	---
NSV-6	9/16/1997	0.00371	---	---	0.00323	---	---	---	---	---	---	---	---	---
NSV-6	5/1/1998	---	---	---	0.041	---	---	---	---	---	---	---	---	---
NSV-6	5/19/1998	---	---	---	0.041	---	---	---	---	---	---	---	---	---
NSV-6	9/1/1998	---	---	---	0.0019	---	---	---	---	---	---	---	---	---
NSV-6	9/16/1998	---	---	---	0.0019	---	---	---	---	---	---	---	---	---
NSV-6	9/15/1999	---	---	---	0.0019	---	---	---	---	---	---	---	---	---
NSV-6	5/1/2000	---	---	---	0.01	---	---	---	---	---	---	---	---	---
NSV-6	5/16/2000	---	---	---	0.0079	---	---	---	---	---	---	---	---	---
NSV-6	5/15/2002	0.001	B	---	0.001	B	---	619	0.82	---	11.4	8.07	8.41	3.02
NSV-6	10/18/2002	0.001	U	U	0.001	U	U	512	0.05	---	10.6	8.75	0.15	3.7
NSV-6	5/24/2003	0.001	U	---	0.001	U	---	626	0.047	---	3.61	8.24	21.4	5.84
NSV-6	10/28/2003	0.0002	U	UJ	0.001	---	J-	350	0.154	---	8.1	8.27	4.4	1.01
NSV-6	5/19/2004	0.00046	B	---	0.0005	B	---	---	---	---	---	---	---	---
NSV-6	7/22/2004	0.00045	B	---	0.00043	B	---	664	0.27	---	5.6	8.05	15.89	2.08
NSV-6	10/17/2006	0.0013	B	---	0.0013	B	---	360	0.932	---	10.2	8.13	5.9	5
NSV-6	6/19/2008	0.0067	---	---	0.0067	---	---	511	2.77	---	11	8.12	15.95	4
NSV-6	9/16/2008	0.0016	B	---	0.0016	B	---	463	0.46	---	16.12	8.08	10.41	6.18
NSV-6	6/2/2009	0.0041	---	---	0.0061	---	---	508	7.44	179.4	7.92	8.21	17.19	5.91
NSV-6	10/21/2009	0.00055	B	---	0.00066	B	---	579	---	32.9	12.65	8.16	9.24	16
NSV-6	6/7/2010	0.0108	---	---	0.0116	---	---	488	1.54	118.8	9.52	7.91	11.8	10
NSV-6	8/26/2010	---	---	---	---	---	---	546	0.201	230.6	13.4	8.18	21.32	9.71
NSV-6	9/14/2010	0.00076	B	---	0.0012	B	---	672	0.192	283.4	10.49	7.65	8.73	11.94
NSV-6	11/11/2010	0.0009	B	---	0.0014	B	---	708	0.392	214	12.8	7.81	0.56	56.06
NSV-6	6/2/2011	0.0052	---	---	0.006	---	---	366	---	13.7	11.34	7.62	13.13	11
NSV-6	6/7/2011	0.023	---	---	0.023	---	---	365	---	-17.2	10.16	7.71	15.05	---
NSV-6	6/12/2011	0.063	---	---	0.063	---	---	---	---	---	---	---	---	---
NSV-6	6/14/2011	0.041	---	---	0.043	---	---	432	7.19	37.4	10.05	8.55	22.47	7.85
NSV-6	9/20/2011	0.001	B	---	0.0014	B	---	557	---	108.6	10.15	8.2	8.46	6.53
NSV-6	5/11/2012	0.0094	---	---	0.0093	---	---	491.9	1.18	214.7	10.19	8.16	6.8	19.83
NSV-6	9/13/2012	0.0011	J	---	0.0011	J	---	507	---	163.5	12.32	8.78	12.01	212.4
NSV-6	11/15/2012	0.00094	J	---	0.0013	J	---	661.4	---	23.5	9.53	8.08	0.2	52.56
NSV-6	5/21/2013	0.0219	---	---	0.0229	---	---	518.8	1.74	118.8	10.63	8.18	6.1	15.83
NSV-6	9/18/2013	0.0008	J	---	0.0012	J	---	588.8	---	42.1	10.04	8.44	11.5	8.85
NSV-6	11/15/2013	0.0007	J	---	0.00078	J	---	665	---	155.4	10.77	6.88	0.04	28.7
NSV-6	5/20/2014	0.0101	---	---	0.0104	---	---	487	1.77	-146.6	11.03	7.67	7.55	11.2

Surface Water Results for Pole Canyon Creek, North Fork Sage Creek, and Sage Creek

Sample Location	Date	Selenium, Dissolved			Selenium, Total			Conductivity	Flow	ORP	DO	pH	Temperature	Turbidity
		mg/L	LQ	VQ	mg/L	LQ	VQ	umhos/cm	cfs	mV	mg/L	SU	C	NTU
NSV-6	8/14/2014	0.0019	J	U	0.0019	J	U	639.1	0.292	60.1	9.08	8.74	19.79	9.87
NSV-6	5/8/2015	0.0043	---	---	0.0045	---	---	469	---	120	10.6	8.09	7.44	13.5
NSV-6	7/21/2015	0.0017	J	---	0.0015	J	---	497	0.558	55.1	10.05	8.85	17.2	4.25
NSV-6	9/12/2015	0.00062	J	---	0.00062	U	---	572	0.135	129.9	10.2	8.43	11.96	7.86
NSV-6	11/5/2015	0.00062	U	---	0.00062	U	---	606	0.286	276.2	6.48	7.13	0.86	13.8
NSV-6	5/18/2016	0.0057	---	---	0.0057	---	---	413.5	3.72	-25.8	8.75	8	8.7	7.86
NSV-6	7/8/2016	0.0016	J	U	0.0019	J	U	475	0.337	142.6	11	8.56	9.28	9.55
NSV-6	11/8/2016	0.001	J	---	0.0011	J	---	492	0.56	77.3	10.55	8.38	5.13	14.3
LSV-1	6/11/2001	0.001	U	---	0.001	U	---	---	---	---	---	---	---	---
LSV-1	6/12/2001	---	---	---	0.001	---	---	---	---	---	---	---	---	---
LSV-1	9/17/2001	0.0011	---	---	0.0012	---	---	---	---	---	---	---	---	---
LSV-1	9/18/2001	---	---	---	0.0012	---	---	---	---	---	---	---	---	---
LSV-1	5/16/2002	0.001	B	---	0.001	U	---	485	1.88	---	6.51	8.35	17.29	3.65
LSV-1	10/17/2002	0.001	U	U	0.001	U	U	263	0.25	---	12.5	7.38	4.26	1.7
LSV-1	5/22/2003	0.002	B	---	0.001	U	---	443	0.82	---	7.13	7.48	10.4	5.41
LSV-1	10/27/2003	0.0011	---	---	0.0013	---	---	336	0.605	---	12.73	8.26	1.5	0.7
LSV-1	5/8/2004	0.00077	B	J-	0.002	---	J-	307	1.6	---	7.89	7.91	4.37	1.65
LSV-1	7/21/2004	0.00081	B	J+	0.0036	---	---	444	1.4	---	8.71	8.32	17.44	0.67
LSV-1	5/21/2006	---	---	---	0.0336	---	---	325	---	---	7.8	8.35	15.6	20
LSV-1	6/22/2006	0.0087	---	---	0.0089	---	---	---	---	---	---	---	---	---
LSV-1	10/17/2006	---	---	---	0.0012	B	---	365	2.57	---	9.2	8.36	7.7	4.6
LSV-1	9/17/2008	0.0015	B	---	0.0014	B	---	362	4.06	---	11.84	8.44	15.05	7.42
LSV-1	5/31/2009	0.00089	B	---	0.0019	B	---	409	22.27	145.3	7.36	8.22	12.45	144.4
LSV-1	10/21/2009	0.0002	U	---	0.00029	B	---	413	---	120.4	12.31	8.47	10.02	12.8
LSV-1	11/20/2009	0.00083	B	---	0.00092	B	---	452	2.79	215.2	13.24	8.34	1.55	19.87
LSV-1	6/6/2010	0.0015	B	---	0.0015	B	U	379	16.41	98.4	8.04	7.4	13.37	8.36
LSV-1	9/14/2010	0.0005	B	---	0.00062	B	---	474	1.46	266.9	7.26	8.42	16.41	0
LSV-1	11/13/2010	0.00044	B	---	0.00054	B	---	458	2.87	-79.4	14.68	8.38	2.08	5.06
LSV-1	6/1/2011	0.001	---	---	0.001	---	---	316	---	10.04	12.04	8.73	14.73	6.56
LSV-1	6/14/2011	0.0061	---	---	0.006	---	---	372	54.67	94.9	8.46	8.11	13.83	52.41
LSV-1	9/19/2011	0.00071	B	---	0.00077	B	---	383	---	212.5	9.48	8.44	11.8	6.24
LSV-1	11/10/2011	0.00054	B	---	0.00049	B	---	393.3	4.64	175.8	12.11	8.55	1.3	12.58
LSV-1	5/10/2012	0.0011	J	---	0.0011	J	---	337.3	10.86	198.6	8.01	8.61	14	11.5
LSV-1	9/10/2012	0.00062	J	---	0.00057	J	---	409	---	72.3	13.48	8.48	12.91	1.32
LSV-1	11/15/2012	0.00069	J	---	0.00065	J	---	404.5	0.873	30.3	10.71	8.46	3.8	2.7
LSV-1	5/20/2013	0.0036	---	---	0.0041	---	---	368.7	11.41	242.1	10.25	8.5	9.6	15.18
LSV-1	8/23/2013	0.00057	J	---	0.00056	J	---	347.3	---	121.5	9.39	8.29	15	2.59
LSV-1	11/14/2013	0.00029	J	---	0.00043	J	---	420	1.6	253.5	11.72	7.16	4.82	3.65
LSV-1	5/19/2014	0.001	J	---	0.0015	J	---	347	22.17	-73.6	11.19	7.06	10.47	10.7
LSV-1	8/13/2014	0.00065	J	U	0.00057	J	U	412.6	1.59	37.9	8.92	8.95	16.06	7.2
LSV-1	11/17/2014	0.00062	J	---	0.00072	J	---	435.9	2.185	15.1	11.56	8.3	0.2	2.94
LSV-1	5/7/2015	0.0012	J	---	0.0014	J	---	425	19.39	118.1	10.48	8.42	9.31	22.1
LSV-1	7/22/2015	0.00062	U	---	0.00062	U	---	362.7	8.46	79.6	8.9	8.69	15.16	1.97
LSV-1	9/10/2015	0.00062	U	---	0.00062	U	UJ	318	4.08	117	8.34	8.76	16.61	1.72
LSV-1	11/4/2015	0.00062	U	UJ	0.00062	U	UJ	436	2.92	31.6	5.8	8.22	5.21	4.08
LSV-1	5/17/2016	0.0012	J	---	0.0012	J	---	370.3	23.45	108.3	10.65	8.25	8.9	22.6
LSV-1	7/7/2016	0.00038	J	U	0.00043	J	U	335	9.04	94.3	10.04	8.51	12.54	6.28
LSV-1	11/8/2016	0.00047	J	---	0.00069	J	---	378	3.58	99.7	10.34	8.67	7.08	3.7

Surface Water Results for Pole Canyon Creek, North Fork Sage Creek, and Sage Creek

Sample Location	Date	Selenium, Dissolved			Selenium, Total			Conductivity	Flow	ORP	DO	pH	Temperature	Turbidity
		mg/L	LQ	VQ	mg/L	LQ	VQ	umhos/cm	cfs	mV	mg/L	SU	C	NTU

ORP = oxidation reduction potential

DO = dissolved oxygen

LQ = Laboratory Qualifier, VQ = Validation Qualifier

"---" = not analyzed or qualifier not assigned

Laboratory qualifiers: B and J - Estimated value reported between the Method Detection Limit and Practical Quantitation Limit;
U - Not detected at reported Detection Limit

Validation qualifiers: J - Estimated; J- -Estimated with a possible low bias; J+ -Estimated with a possible high bias;
U - Not detected at reported Detection Limit; UJ - Estimated, not detected

Sediment Results for Pole Canyon Creek, North Fork Sage Creek, and Sage Creek

Sample Location	Location Description	Date	Depth Range (inches)	Selenium (mg/kg)	LQ	VQ
UP	Pole Canyon Creek (upstream of ODA)	7/24/2004	N.A.	0.46	---	---
LP	Pole Canyon Creek (stream station through 2007, downstream of ODA toe)	7/22/2004	N.A.	58.1	---	---
LP-PD	Pole Canyon Creek (at bypass pipeline discharge, since 2008)	8/26/2010	0-4	13.4	---	---
NSV-5	North Fork Sage Creek (upstream of inflow from Pole Canyon Creek)	9/1/1998	N.A.	0.48	---	---
NSV-5	North Fork Sage Creek (upstream of inflow from Pole Canyon Creek)	9/16/1998	N.A.	0.48	---	---
NSV-5	North Fork Sage Creek (upstream of inflow from Pole Canyon Creek)	9/15/1999	N.A.	0.77	---	---
NSV-5	North Fork Sage Creek (upstream of inflow from Pole Canyon Creek)	7/22/2004	N.A.	0.37	---	---
NSV-6	North Fork Sage Creek (downstream of inflow from Pole Canyon Creek)	9/1/1998	N.A.	4.13	---	---
NSV-6	North Fork Sage Creek (downstream of inflow from Pole Canyon Creek)	9/16/1998	N.A.	4.1	---	---
NSV-6	North Fork Sage Creek (downstream of inflow from Pole Canyon Creek)	9/15/1999	N.A.	3.6	---	---
NSV-6	North Fork Sage Creek (downstream of inflow from Pole Canyon Creek)	8/26/2010	0-4	6.5	---	---
LSV-1	Sage Creek (downstream of inflow from North Fork Sage Creek)	6/12/2001	N.A.	2.8	---	---
LSV-1	Sage Creek (downstream of inflow from North Fork Sage Creek)	6/12/2001	N.A.	2.8	---	---
LSV-1	Sage Creek (downstream of inflow from North Fork Sage Creek)	11/13/2010	0-4	1.6	---	---

"LQ" = Laboratory Qualifier, "VQ" = Validation Qualifier
"N.A." = not available
"---" = qualifier not assigned

Aquatic Biota Results for Pole Canyon Creek and North Fork Sage Creek - Macrophytes, Periphyton, Benthic Invertebrates

Sample Location	Location Description	Aquatic Biota Description	Date	Dry vs Wet Basis	Selenium (mg/kg)	LQ	VQ
UP	Pole Canyon Creek (upstream of ODA)	Macrophytes (Equisetum)	7/24/2004	Dry	0.48	---	---
UP	Pole Canyon Creek (upstream of ODA)	Macrophytes (Filamentous algae)	7/24/2004	Dry	1.64	---	---
UP	Pole Canyon Creek (upstream of ODA)	Macrophytes (Bryophyte)	7/24/2004	Dry	1.7	---	---
LP	Pole Canyon Creek (stream station through 2007, downstream of ODA toe)	Macrophytes; (Bryophyte, moss)	7/22/2004	Dry	66.1	---	---
LP	Pole Canyon Creek (stream station through 2007, downstream of ODA toe)	Macrophytes (Watercress)	7/22/2004	Dry	87.7	---	---
NSV-5	North Fork Sage Creek (upstream of inflow from Pole Canyon Creek)	Macrophytes (Duckweed)	7/22/2004	Dry	0.65	---	---
NSV-5	North Fork Sage Creek (upstream of inflow from Pole Canyon Creek)	Macrophytes (Juncas)	7/22/2004	Dry	0.18	B	---
UP	Pole Canyon Creek (upstream of ODA)	Periphyton	7/24/2004	Dry	3	B	---
LP	Pole Canyon Creek (stream station through 2007, downstream of ODA toe)	Periphyton	7/22/2004	Dry	69.1	---	---
UP	Pole Canyon Creek (upstream of ODA)	Benthic Invertebrate	7/24/2004	Wet	0.57	---	---
LP	Pole Canyon Creek (stream station through 2007, downstream of ODA toe)	Benthic Invertebrate	7/22/2004	Wet	16.6	---	---
LP-PD	Pole Canyon Creek (at bypass pipeline discharge, since 2008)	Benthic Invertebrate	8/26/2010	Dry	16.9	---	---
NSV-5	North Fork Sage Creek (upstream of inflow from Pole Canyon Creek)	Benthic Invertebrate	7/22/2004	Wet	1.09	---	---
NSV-6	North Fork Sage Creek (downstream of inflow from Pole Canyon Creek)	Benthic Invertebrate	8/26/2010	Dry	11.9	---	---

LQ = Laboratory Qualifier, VQ = Validation Qualifier
"---" = qualifier not assigned
B qualifier = estimated value reported between the Method Detection Limit and the Practical Quantitation Limit

Selenium Concentrations in Abiotic and Biotic Media, Derivation of Enrichment Factors and the Benthic TTF

Location	Date	Diss Se	Periphyton	Sediment	Benthos	EF algae	EF Sed	EF total	Benthic TTF
		ug/L	mg/kg dw	mg/kg dw	mg/kg dw				
UP	Jul-04	0.36	3	0.46	2.84	8.33	1.28	3.26	64.44
NSV-5	Jul-04	0.3	0.41	0.37	5.42	1.37	1.23	1.30	146.86
LP	Jul-04	356	69.1	58.1	82.59	0.19	0.16	0.18	76.41
LP-PD	Aug-10	0.37	ND	13.4	16.9		36.22	36.12	1.26
NSV-6	Aug-10	0.76	ND	6.5	11.9		8.55	8.55	1.83

Benthic tissue concentrations reported as ww were converted to dw using 20.1% solids value (derived from the mean of 2006 to 2008 benthic tissue %moisture data).

ND - No Data

EF - Enrichment Factor

TTF- Trophic Transfer Factor

Appendix D

Sculpin Assessment - Population and Selenium Sensitivity

Sculpin Assessment

Populations and Selenium Sensitivity at Hoopes Spring, Sage Creek, and Crow Creek

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1 INTRODUCTION

During the negotiated rulemaking on revising the selenium criteria for aquatic life, an issue raised is the sensitivity of sculpin to selenium. The sensitivity of sculpin is relevant to the proposed site specific selenium criterion (SSSC) for Hoopes Spring, Sage Creek, and Lower Crow Creek (herein called the "Site"). The objectives of this document are: (1) to review the science and studies on the toxicity of selenium to sculpin, and evaluate data from the Smoky Canyon Site (Figure 1) to address whether sculpin are more or less sensitive to selenium than trout species used in the calculation of the proposed SSSC; and (2) to discuss how the available sculpin data can be used in criteria derivation.

Studies and information that address these objectives include:

1) data from field and laboratory studies on sculpin;
2) demographic population data for sculpin, collected over several years from the Site; and
3) long term population monitoring at the same locations.

Section 2 provides background information on pertinent aspects of freshwater sculpin life history. Sections 3, 4, and 5 provide an overview of data regarding selenium toxicity and selenium concentrations in sculpin from the Site, as well as Site-specific demographic and long-term sculpin population trends. Section 6 describes how these data are appropriate for the SSSC process and are consistent with USEPA's use of information and data for the 2016 National Criterion. Conclusions are provided in Section 7.

2 SCULPIN LIFE HISTORY

There are two sculpin species present in the Crow Creek drainage and associated tributaries at the Site: Paiute sculpin (*Cottus beldingi*) and mottled sculpin (*Cottus bairdi*). Paiute sculpin are the dominant species found at all sampling locations within the Crow Creek drainage, and mottled sculpin are only found occasionally. The life history information presented here is for Paiute sculpin.

2.1 Habitat and Feeding

Quist et al. (2004) found that Paiute sculpin have an affinity for fast water habitats, particularly riffles with large substrate, whereas mottled sculpin were more commonly found in lower gradient, lower elevation streams with deep pool habitat that were spring fed. Both typically had low summer water temperatures. Paiute sculpin are typically found in rubble or gravel riffle areas in clear, cold creeks and small to medium rivers that have a slight to moderate gradient, also in lakes in areas with a rubble or gravel substrate or in aquatic beds in deep water (Moyle 1976). In a study by Skyler (2008) focusing only on Paiute sculpin in several Utah streams, the author found that:

> *"The very strong relation between water column velocity and population structure indicates that a range of stream sizes promotes diversity among populations. Swifter streams had populations with larger individuals and distributions were more skewed to the left, whereas slower streams had populations with smaller individuals and distributions were more skewed to the right."*

Other studies have found that predation risk, predator abundance, and prey availability affect Paiute sculpin size and distribution (Anderson 1985; Quist et al. 2004). Site-specific data from the Crow Creek drainage indicate that Paiute sculpin are found in a variety of habitats and substrate combinations, but tend to be more prevalent in higher gradient, lower temperature streams.

Sculpin (Cottus spp.) exhibit low mobility and high site fidelity (Gray et al. 2004; Natsumeda 2007; Petty and Grossman 2007; Schmetterling and Adams 2004), and have been used in fish monitoring programs as sentinel or indicator species (Gibbons et al. 1998; Mebane 2001).

Paiute sculpin primarily feed on aquatic insects, but can be cannibalistic (Johnsen 1985). Johnsen (1985) found that the Paiute sculpin diet observed in their studies was comprised primarily of aquatic invertebrates (99 percent), but in one drainage, gut contents included fish remains, all identified as Paiute sculpin.

2.2 Reproduction

Paiute sculpin spawn near rocks located on gravel substrate. In streams, these fish usually spawn in riffles. In Lake Tahoe, spawning occurs in wave-swept littoral locations or near mouths of streams; spawning may also occur in deeper water (Moyle 1976). Baxter and Stone (1995) stated that the spawning behavior of Paiute sculpin has not been described in detail but suggested that they are late spring spawners, which is confirmed by the Idaho American Fisheries Society (AFS) chapter website (AFS no date). In Lake Tahoe, Paiute sculpin spawn in the spring. Eggs are laid in clusters on the undersides of rocks and are guarded by the male.

2.3 Age – Length Relationships

Age-length relationships were used in conjunction with length measurements of fish from the Site sampling locations to assess the relative ages of fish in populations.

Insufficient empirical data were available to establish age-length relationships for Paiute sculpin. Therefore, an age-length relationship developed for Wood River sculpin (*Cottus leiopomus*) from the Wood River basin in central Idaho was used (Meyer et al. 2008). Wood River sculpin have life cycles, life spans, and sizes similar to Paiute sculpin (Meyer et al., 2008, Fishbase accessed August 2017). Wood River sculpin in the Meyer et al. study reached sexual maturity at about age

3 and were 60 mm in length. Wood River sculpin grew to a maximum length of 120 mm and had a maximum life span of 5 to 7 years.

Based on these data, three age categories were identified for purposes of this analysis:

- Age 1/2 (less than 60 mm in length): Fish that have not reached sexual maturity.
- Age 3/4 (>60 to <90 mm): Fish that have survived to reproductive age.
- Age 5 and older (90 mm or greater): Fish that have lived a normal life-span.

3 SELENIUM CONCENTRATIONS IN SCULPIN TISSUE

3.1 No-Observed-Effects Concentration for Selenium in Sculpin

Dietary selenium effects in slimy sculpin (*Cottus cognatus*) were tested by Nautilus Environmental in 2011 and 2012 and the results were presented by Lo et al. (2014) at the Society of Environmental Toxicology and Chemistry (SETAC) conference in 2014. Slimy sculpin were collected from the field, transferred to the laboratory, and fed a selenium-dosed diet (lumbriculous) for 7 months prior to inducing spawning in the laboratory. Nominal dietary doses (i.e., the amount added to the diet) included 0 milligrams per kilogram (mg/kg) selenium as control and 10, 20, and 40 mg/kg dry weight (dw) as treatments. Eggs were fertilized in the laboratory and allowed to develop for 7 to 10 days after fry feeding commenced. Adult fish were analyzed for whole-body selenium concentrations. Eggs were analyzed for selenium, and hatching development and survival were tracked for the fry.

Fish fed dietary doses with the highest selenium concentration (40 mg/kg dw) resulted in an adult mean whole-body tissue concentration of 9.61 mg/kg dw and a mean egg tissue concentration of 19.43 mg/kg dw. No significant adverse effects were observed for hatching success, fry survival, or deformities. The authors concluded that the NOEC for egg tissue was greater than 22.0 mg/kg selenium dw (the maximum concentration observed in eggs), making the NOEC from this study ‘unbounded’ because no upper bound was observed for the no-effects concentration range. The highest whole-body tissue selenium concentration observed in the adult slimy sculpin was 11 mg/kg dw.

Although the NOEC is unbounded, it does provide a useful starting point to assess potential sculpin sensitivity. Because the highest dietary dose resulted in no effects, the actual NOEC is higher. Further, based on observations from other maternal fish reproductive studies, the EC_{10} will be higher than the NOEC.

3.2 Whole Body Tissue Selenium Concentrations – Background and Site Locations

Figure 1 illustrates the locations where data for sculpin have been collected at the Site since 2006. A subset of locations has been sampled annually, while other locations have been sampled to fulfill different project-specific needs. Background locations are those identified as being upstream of the Sage Creek discharge to Crow Creek (CC-75, CC-150, CC-350) and Deer Creek (DC-600). Site locations include those downstream of Hoopes Spring and/or South Fork Sage Creek Springs and include HS-3, LSV-2C, LSV-4, CC-1A, and CC-3A.

Background and reference sculpin tissue selenium concentrations ranged from 2 to 14.7 mg/kg dw across a dissolved selenium concentration range in surface water of 0.2 to 3.4 micrograms per liter (µg/L) from 2006 to 2013 (Figure 2). The highest background concentration measured in whole body tissue (14.7 mg/kg dw) was from a sampling location in Crow Creek upstream of Sage Creek (CC-150) with a corresponding water selenium concentration of 1.4 µg/L.

During this same time period, sculpin whole-body selenium concentrations from Site locations (HS-3, LSS, LSV-2C, LSV-4) closest to the source areas ranged from 8.2 to 58.8 mg/kg dw, associated with dissolved selenium concentrations in surface water that ranged from 6.8 to 77.4 µg/L (Figure 3). Farther downstream in Crow Creek, whole-body selenium concentrations ranged from 5.5 to 29.4 mg/kg dw across dissolved selenium concentrations in surface water that ranged from 1.2 to 15.9 µg/L. Formation (2012) found a strong positive relationship between sculpin whole-body tissue concentrations and selenium concentrations in surface water (R^2 = 0.8).

Sixteen of 292 (5.5 percent) background whole-body sculpin tissue samples exceeded the whole-body NOEC (11 mg/kg dw) cited in the Lo et al. (2014) study (Figure 2). Selenium concentrations were higher in sculpin from Site sampling locations than from downstream locations, with 199 of 223 (89 percent) whole-body tissue selenium samples above the NOEC (Figure 3).

The subsections that follow provide context for the whole-body tissue data that exceeded the NOEC, based on populations of sculpin and age class distributions, and assess the whole-body tissue selenium concentration at which some apparent effects may be observed.

4 SITE-SPECIFIC SCULPIN POPULATION DATA

The primary Site-specific data available for evaluating sculpin are: relative abundance of age classes, population density, and corresponding selenium concentrations in surface water. These data are available over an 11-year period (2006 to 2016). Data for whole-body selenium concentrations in sculpin are available for a 7-year period for most sampling locations (2006 to 2011 and 2013). These data are used to determine if sculpin are developing, reproducing, and surviving at levels that support a self-sustaining population at various locations. Combined with the selenium concentrations in adult fish tissue and in surface water, the data allow for an evaluation of the potential relationship between selenium concentrations and reproduction or recruitment of fish to reproductive ages; two factors that are essential to a self-sustaining population.

Relative to trout, particularly adult trout, sculpin have high site fidelity during their lifetime, meaning that they remain in a relatively small area of a stream over their life span. For this reason, the sculpin populations included in this analysis consist of fish that have likely spent their entire lives at or near the sampling locations.

The approach used in this white paper is consistent with the general consensus from various experts on factors important in assessing the environmental effects of selenium on fish populations. Janz et al. (2010) notes the following:

> *"Because the prevalent adverse effect of Se* [selenium] *in laboratory toxicity tests with fish is reproductive failure due to deformities in early life stage fish, monitoring relevant characteristics of fish populations is recommended. These characteristics include changes or differences in the age distribution and relative abundance of different age classes over time or from reference conditions. Young-of-year (age-0) fish would be the most directly relevant age class to target to detect reproductive failure. However, abundance estimates of age-0 fish are often more variable than those of older and larger fish, and are likely influenced by high measurement error from variability in emergence timing and low capture efficiency. This may limit the effectiveness of detecting trends in the relative abundances of age-0 fish between sites or over time using routine methods (e.g., electrofishing or direct observation). Instead, adaptation of non-routine methods that are specifically targeted for detecting trends in survival to emergence of early life stage fish such as fry emergence studies may be needed (Curry and MacNeill 2004).*
>
> *Thus, for Se, detecting an effect requires monitoring of recruitment failure and, in some instances, species richness and composition. Recruitment failure is the logical population-level consequence of reproductive impairment. The general indication of recruitment failure in fish populations is a shift in the age distribution toward older and fewer fish."*

4.1 Site-Specific Age Classes Present

Adverse developmental effects of selenium are largely associated with early life stages. Age 1/2 sculpins represents fish that have survived the early life-stage and have developed to feed and survive independently in the wild. The age 1/2 class represents fish that are beyond the age when selenium has most of its effects and have reached 'recruitment' to free-living populations. The age 3/4 class represents fish that have survived to sexual maturity and contribute to reproduction and future recruitment. The age 5 and older class represents fish that have survived a normal life span. Direct measures of developmental deformities and reproduction success are not available for sculpin at the Site. However, fish in these age groups can be compared among sampling locations to assess whether populations from selenium-affected sites differ from populations in upstream background locations.

Sculpin age-class data from fall 2006 to fall 2016 are illustrated in Figures 4 and 5. Data from three background locations (CC-150, CC-350, and DC-600), and three affected locations (HS-3, LSV-2C, and CC-1A) are shown. Figure 6 shows the median frequency for each location in each size class. These data represent a subsample of approximately 100 sculpin from each location that were weighed and measured during each annual sampling period. Data represent all sculpin sampled when fewer than 100 fish were collected.

For background locations (Figure 4), sculpin in age classes 1/2 and 3/4 were present in all years, but with substantial year-to-year variability, especially at locations CC-150 and CC-350. In most years, age class 3/4 fish were relatively more abundant in the samples than age class 1/2 fish. However, this could reflect the relative inefficiency in collecting small fish, which could be exacerbated by attempting to sample small fish in large creeks such as Crow Creek (CC-350). Age class 5 fish were also consistently present, but at a much lower relative abundance.

All three age classes were also consistently present for affected Site locations, with some notable differences compared to background locations. The relative abundance of age class 1/2 fish was more variable at Site locations than at background locations, with very few or no fish collected in some years. Age class 3/4 sculpin were consistently more abundant in samples from Site and background streams. This likely indicates that although younger fish may have been under-sampled, fish from age class 1/2 were surviving and maturing into reproductive adult stages. Age class 5 fish were relatively more abundant at Site locations than at background sampling locations.

The long-term trend for sculpin in each age class from 2006 to 2016, based on the median for each location, suggests that at all locations, age class 1/2 fish were consistently present at a similar frequency from year to year (Figure 6). Age class 3/4 fish were present at a higher frequency at background locations CC-350 and DC-600 than at Site locations HS-3, LSV-2C, and CC-1A.

The median sculpin length was used to assess potential long-term trends at a subset of locations, including one background location (CC-350) and three Site locations (HS-3, LSV-2C, and CC-1A). Overall median sculpin length should increase if recruitment of small fish into the population fails consistently and only larger fish are present. Figure 7 shows the median sculpin length through time and illustrates the annual variability.

Median sculpin length for background and Site locations are relatively similar annually except for the fall 2008 and fall 2014 time periods. In 2008, locations LSV-2C and CC-350 had sculpin with higher overall median lengths than at locations CC-1A and HS-3. In 2014, median sculpin length diverged and was substantially higher at LSV-2C and HS-3 than at CC-350 and CC-1A. Median sculpin length at HS-3 continued to increase through 2016 whereas sculpin length decreased at LSV-2C.

Corresponding selenium concentrations in surface water at these locations showed increasing trends each year at HS-3, LSV-2C, and CC-1A, while the selenium concentration in water at CC-350 remained low and relatively stable (Figure 7). The observed divergence of median sculpin length to larger sizes in 2014 with corresponding increases in selenium water concentrations at HS-3 and LSV-2C may indicate a potential effect on the sculpin population where recruitment is reduced resulting in a shift to a population with larger fish. The average selenium concentrations in surface water in 2014 were 49.6 µg/L (LSV-2C) and 79 µg/L (HS-3).

Water and tissue concentrations at background locations did not change substantially, while water and tissue selenium concentrations increased at Site locations. For 2006 to 2013 data, there was no apparent relationship between median sculpin length and water or tissue selenium concentrations. If recruitment were being significantly impacted by selenium concentrations, median sculpin length should increase as the loss of smaller fish representing these younger age classes disappear.

The consistent presence of age class 1/2 sculpin at all locations indicates that reproduction and survival through early life stages is occurring, even at locations where selenium concentrations in water are elevated. The consistent levels of age class 3/4 and age class 5 fish at all locations shows that fish are successfully reaching reproductive maturity and that life-spans are normal and do not appear to be changing.

Other factors including predation[1], structural habitat variables, water temperature, and water quality may play a role in the absence of some sizes of fish. At CC-350 (upgradient of the Site), the abundance of brown trout and Yellowstone cutthroat trout is similar (about 50 percent each), thus predation there is not nearly as high as it is at LSV-2C and CC-3A where brown trout are the predominant species in terms of abundance and size. At DC-600, no brown trout are found, and Yellowstone cutthroat trout are the only trout species present, thus predation is likely much lower. At HS-3, brown trout are predominant, but the population consists of smaller adults at Hoopes Spring as compared to Sage Creek and Crow Creek populations.

4.2 Selenium Concentrations in Whole-Body Tissues

Selenium in adult fish tissue or eggs has been shown to be the best predictor of developmental effects of selenium (USEPA 2016). As noted in Section 3.1, the best available estimate of a selenium toxicity threshold for sculpin is an unbounded NOEC corresponding to 11 mg/kg whole body selenium concentration in slimy sculpin (Lo et al. 2014). No selenium toxicity test data are available for sculpin from the Site. However, data show no relationship between whole-body selenium concentration in fish and the relative abundance of age class 1/2 fish in the sampled population. The lack of relationship was observed for fish tissue up to about 27 mg/kg dw selenium, which is the highest concentration for which multiple data points are available from the Site (Figure 8). Similarly, the median length of sculpin from background and Site sampling locations show no correlation to whole-body selenium concentrations for the same concentration range (Figure 9). The lack of correlation indicates that no dose-response relationship for these endpoints can be shown for concentrations below whole-body selenium concentrations of about

[1] Adult brown trout are primarily piscivorous and sculpin make up a larger percentage of their diet.

27 mg/kg dw. This is substantially higher than the Yellowstone cutthroat trout EC_{10} of 14.5 mg/kg dw.

4.3 Long Term Population Trends

Sculpin population data were compiled for locations with the longest continuous or partially continuous records from 2006 to 2016. The population data, expressed as density (number of fish/100m^2), were collected from locations with known lengths and widths for each stream reach. Figure 10 shows the population density data for sculpin from one upgradient background location (CC-350) and four locations within the Site downstream of the primary sources located at Hoopes Spring and South Fork Sage Creek Springs.

The following supporting information is relevant:

- CC-350 – Sculpin density ranges from 22 to 190 with a median density of 69 sculpin/100m^2.
- HS-3 – Sculpin density ranges from 79 to 437 with a median density of 227 sculpin/100m^2.
- LSV-2C – Sculpin density ranges from 26 to 520 with a median density of 116 sculpin/100m2.
- LSV-4 – Sculpin density ranges from 42 to 336 with a median density of 134 sculpin/100m2.
- CC-1A – Sculpin density ranges from 5 to 22with a median density of 10 sculpin/100m2.

The most obvious characteristic of Figure 10 is that the population density can vary from year to year, but the variation does not appear to be related to environmental selenium concentrations. The highest population density often occurred at HS-3 and LSV-2C (where the selenium concentrations were highest) and the lowest population density occurred at CC-1A. Also, median population densities at HS-3, LSV-2C, and LSV-4 were approximately 3, 1.7, and 2 times higher, respectively, than the background density at CC-350. A number of factors affect the data distribution for each location including, among others, predation, stream flow, habitat, water temperature, and water quality. However, high population densities at locations with the highest selenium concentrations suggest that sculpin are successfully reproducing. A good example of this occurred at HS-3, where sculpin densities were variable but equally as high in 2012 and 2013 as they were in 2006 and 2008 when surface water selenium concentrations were much lower (See Figure 8).

Beginning in 2014 and continuing through 2016, the sculpin density for HS-3 was consistently lower than during previous years, and the median sculpin length increased at location HS-3. This corresponded to a period with the highest selenium concentrations measured in surface water. Therefore, these data suggest that starting in about 2014, environmental selenium concentrations at HS-3 may have become high enough to elicit a negative population level response.

5 APPLICABILITY AND USE OF SCULPIN DATA FOR CRITERIA DERIVATION

The data presented herein show that use of the sculpin unbounded NOEC presented by Lo et al. (2014) in the SSSC calculation was appropriate, and reflects site-specific conditions. Use of the information is consistent with the approach used by USEPA (2016) when considering similar types of data in the National Criterion document.

5.1 USEPA Treatment of Data from Other Small-Bodied Fish Taxa

In identifying the genus-mean-chronic values (GMCVs) for their criterion calculation, USEPA (2016) notes the following rationale for excluding fish from the family Cyprinidae (pg E-41),

> *"The available studies with native cyprinids indicate that a variety of native cyprinid genera (e.g. chubs, shiners, dace) have stable, diverse populations and are reproducing successfully (based on length frequency data) in selenium impacted waters at whole body concentrations far exceeding our proposed whole body criterion element of 8.0 mg/kg dw. Taken together, the available studies (Hamilton et al. (1998), NAMC (2008), Presser (2013), USGS (2012)), indicate that native cyprinids as a family are not expected to be overly sensitive to selenium when compared with other families of freshwater fish."*

Data from the overall Site, and location HS-3 in particular, indicate that sculpin populations are stable over a wide range of selenium concentrations, and are also not overly sensitive to selenium. The whole-body tissue concentrations for sculpin presented herein indicate that sculpin are much less sensitive to selenium than the NOEC value presented and are less sensitive than trout species used in the derivation of the SSSC.

5.2 Consistent with USEPA 2016 Approach

To derive the National Criterion, USEPA compiled 15 GMCVs, but only the four most sensitive were used to derive the final criterion value. However, using the methods of Stephan et al. (1985) a representative species assemblage must be utilized satisfying the eight-family requirement for criterion derivation. USEPA utilized two species, fathead minnow and mosquito fish, to make up the 15 GMCVs even though mosquito fish were excluded from the reproductive impairment studies considered because it is a livebearer and fathead minnow data were excluded due to uncertainty in the endpoints and resulting EC_{10} values. Nonetheless, USEPA concluded that these species provide representative data that are less sensitive than the four most sensitive species used in the criterion derivation.

Simplot utilized the sculpin data to derive its proposed SSSC despite the fact that the only available data for sculpin was an unbounded NOEC. Based on Site knowledge of sculpin populations, it was evident that sculpin are not sensitive to selenium, nor as sensitive as either trout species found at the Site. Inclusion of sculpin in the SSSC derivation is consistent with USEPA's approach for the National Criterion derivation.

5.3 Sculpin Sensitivity Relative to Trout Species

Site data indicate that sculpin are not among the four most sensitive species at the Site. The robust sculpin population at HS-3 was sustained with adult selenium concentrations considerably higher than the EC_{10} threshold for Yellowstone cutthroat trout. These data show that sculpin are not among the sensitive species considered for the SSSC and are consistent with USEPA's use of data on cyprinids.

Selenium concentrations in water at HS-3 are by far the highest observed at the Site over several years and have increased over time (Figure 7). Whole-body selenium concentrations in sculpin are consistently elevated, typically exceeding the EC_{10} value reported for trout species by a wide margin. For example, the whole-body selenium concentration corresponding to the EC_{10} for Yellowstone cutthroat trout eggs is about 14.5 mg/kg dw[2]. Over 95 percent of the adult sculpin sampled at HS-3 exceeded this value (range 16 to 35 mg/kg) for the period 2006 to 2013. Despite these elevated selenium concentrations, population density of sculpin at HS-3 for this time period was among the highest of any sampling location, including background locations (Figure 10); and numbers of young fish in age classes 1/2, and older fish in age class 5 remained among the highest of the sampling locations. These data indicate that while adult sculpin have concentrations well above Yellowstone cutthroat trout EC_{10}, young fish at this location are surviving the critical life stages where selenium toxicity is typically lethal, and maturing to reproductive adult fish.

6 CONCLUSIONS

This white paper addresses a narrow, but potentially important implication of comments from ICL regarding the relative sensitivity of sculpin species to selenium toxicity. ICL comments imply that the Lo et al. (2014) data show that sculpin are more sensitive to selenium toxicity than one or more trout species used in developing the SSSC, and that the NOEC estimated by Lo et al. should be used directly in calculating the SSSC.

Based on whole-body selenium concentrations and population data from the Site, we show that sculpin are likely substantially more tolerant of selenium than Yellowstone cutthroat trout, which are the most tolerant of the trout species included in the SSSC calculation. Specifically, Site data show that robust sculpin populations persist even in areas where selenium concentrations in adult sculpin tissues substantially exceed the EC_{10} for Yellowstone cutthroat trout and the NOEC estimated by Lo et al. for slimy sculpin. It is also shown that Simplot's use of sculpin data is

[2] Based on an egg concentration of 28.4 mg/kg dw derived and presented in the Proposed Site-Specific Selenium Criterion for Hoopes Spring, Sage Creek, and Crow Creek near the Smoky Canyon Mine (Formation 2017) and a trout conversion factor of 1.96.

consistent with USEPA use of data from less-sensitive species such as cyprinids and mosquito fish during development of the National Criterion.

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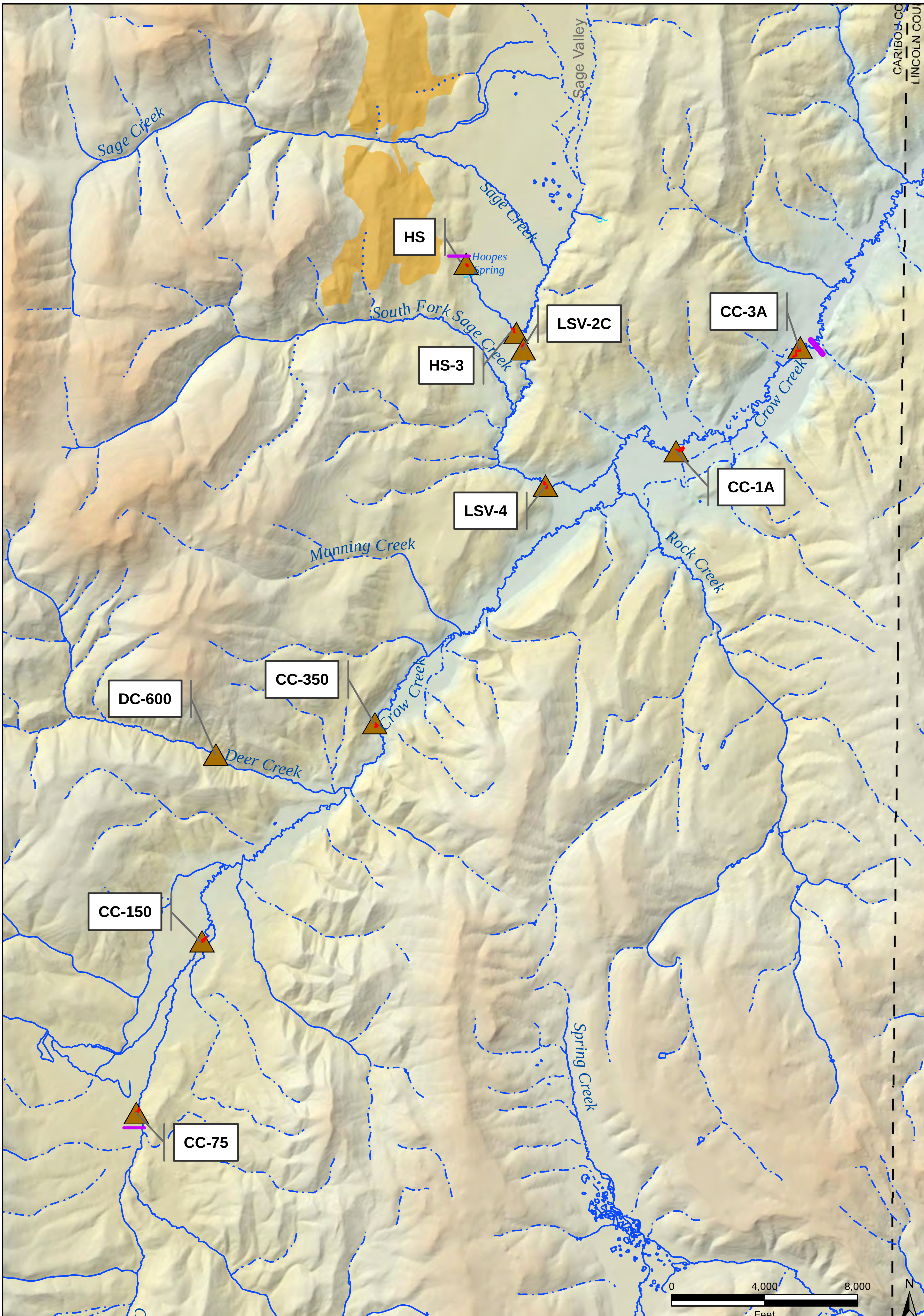

Legend

- Monitoring Locations
- Reach Location
- Mine Disturbance Areas

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SCULPIN WHITE PAPER

FIGURE 1

SAMPLE LOCATIONS IN SAGE CREEK, CROW CREEK, AND HOOPES SPRING IN SOUTHEAST IDAHO

DATE: OCT 30, 2017

BY: CRL | FOR: SMC

FORMATION ENVIRONMENTAL

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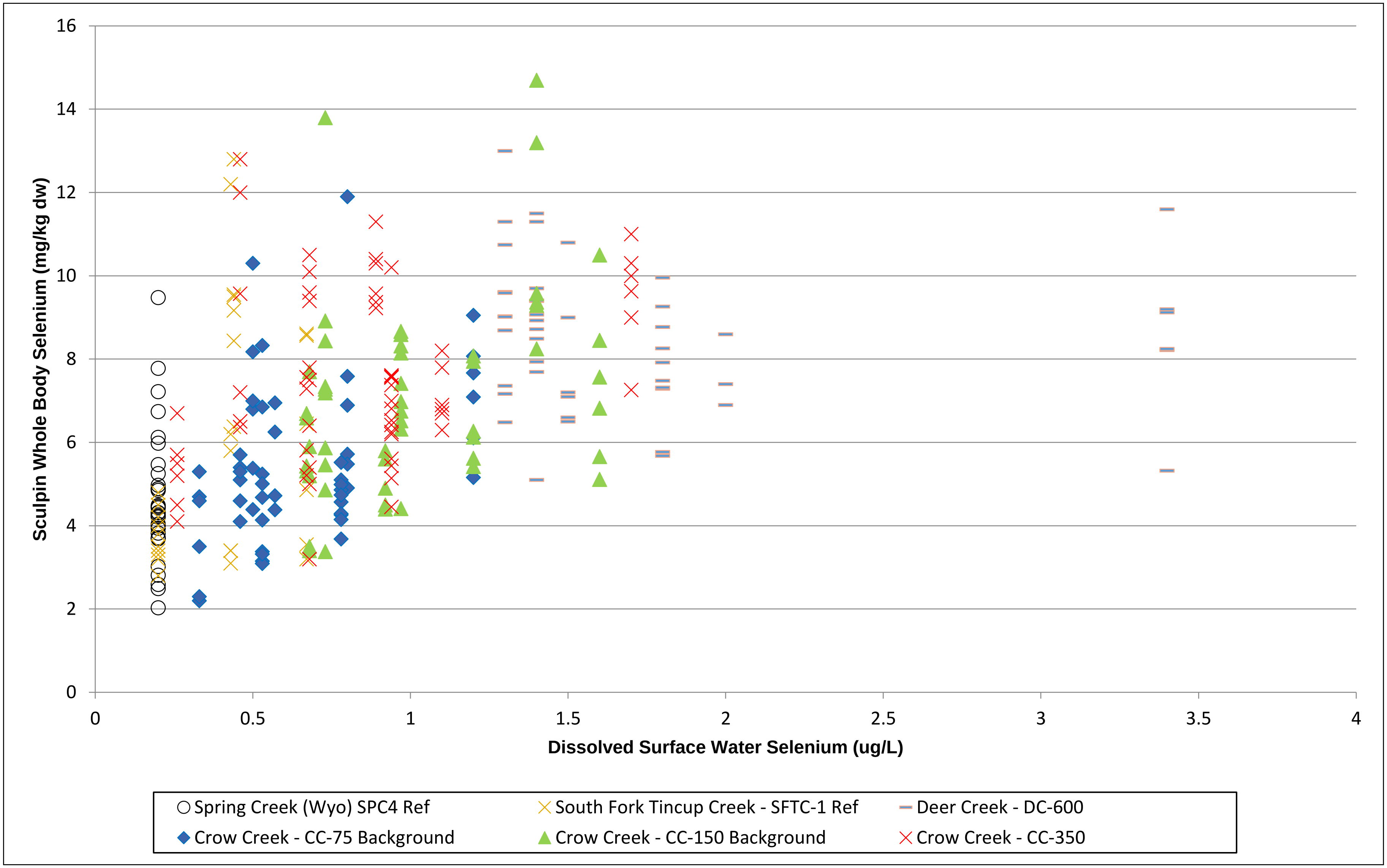

FIGURE 2
Individual Sculpin Whole Body Selenium Versus Surface Water Selenium at Background and Reference Locations

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FOR: SMC

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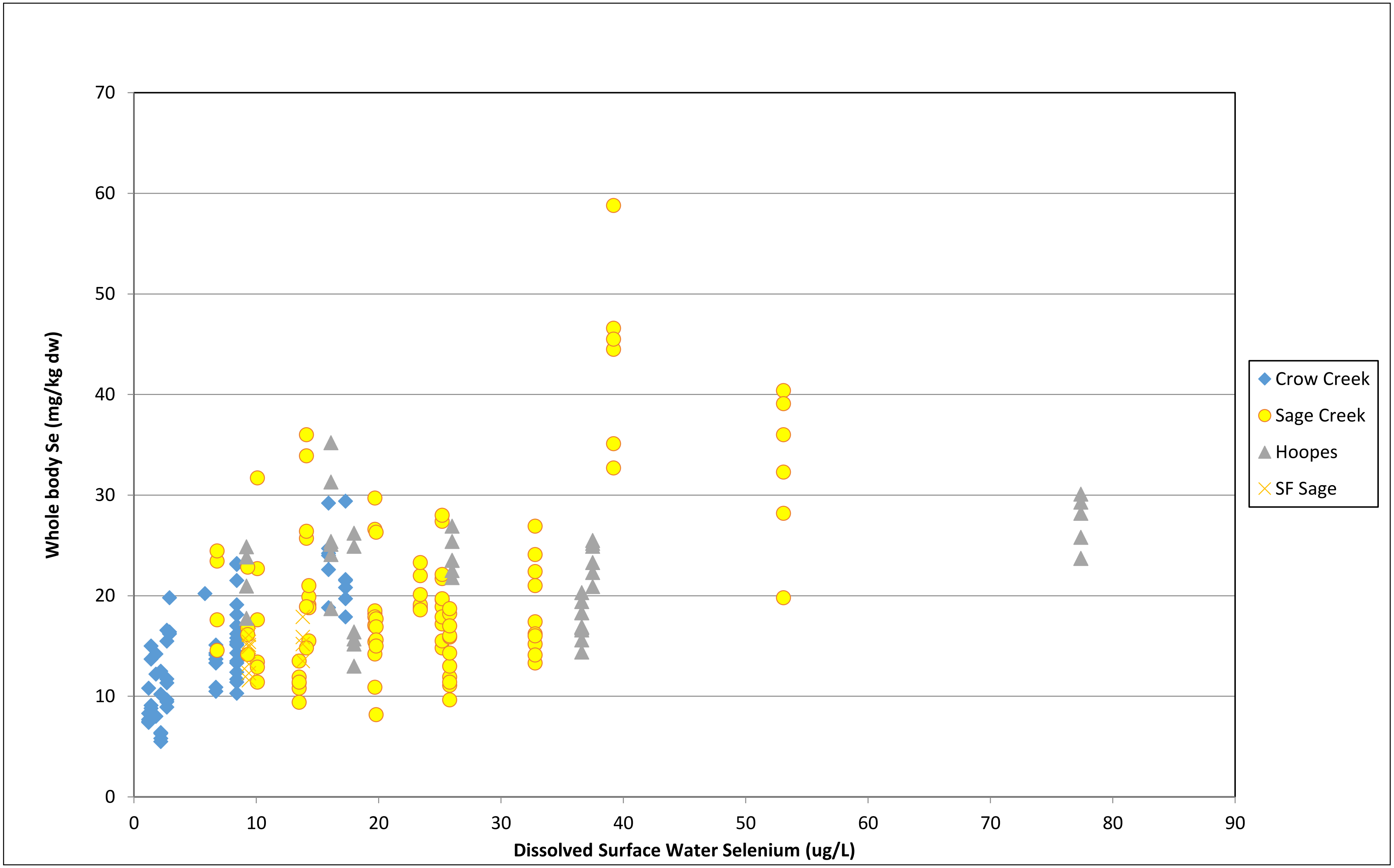

FIGURE 3
Individual Sculpin Whole Body Selenium Versus Surface Water Selenium at Site Locations

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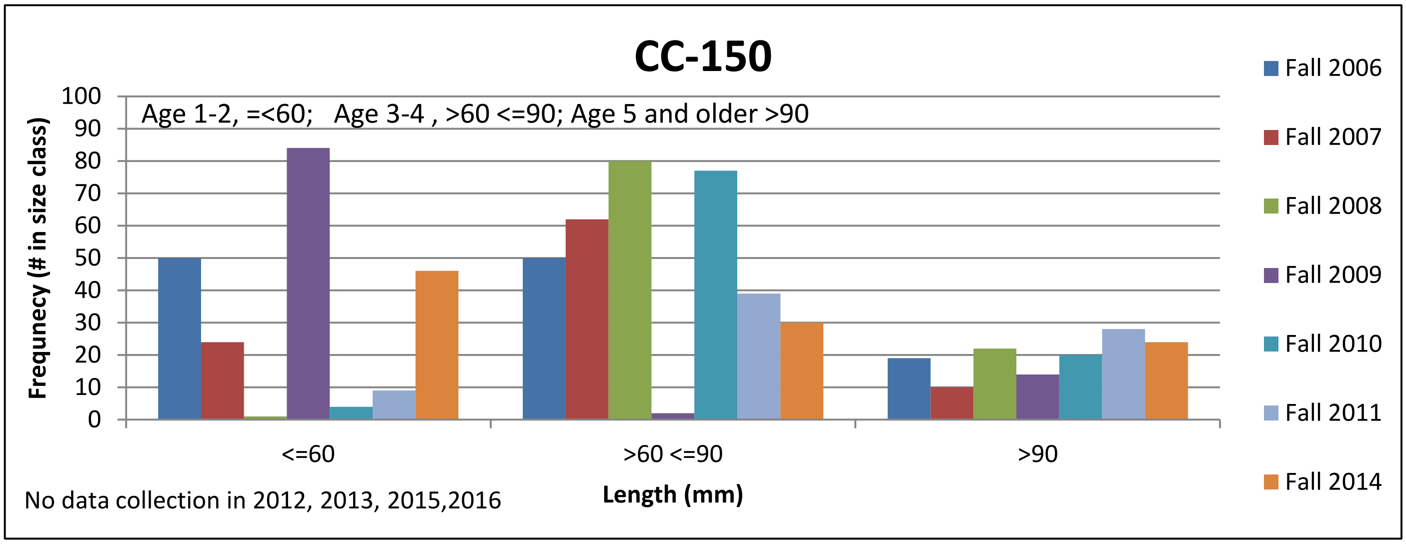

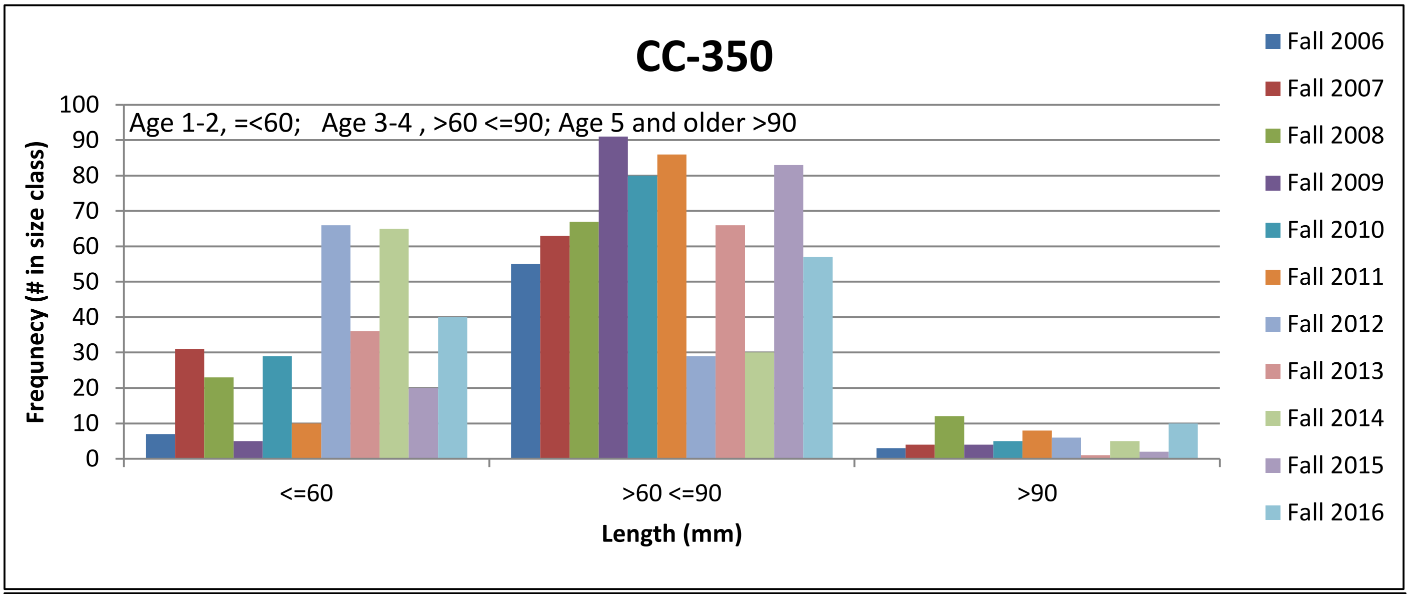

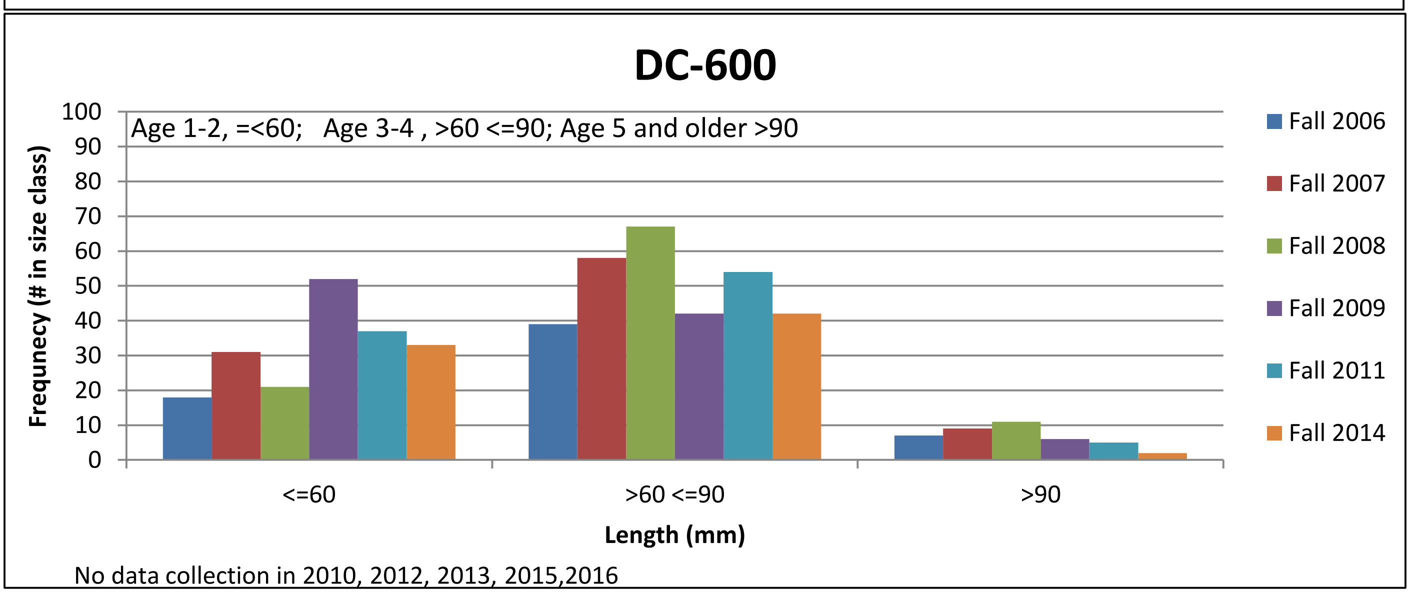

FIGURE 4
Frequency of Sculpin Lengths at Different Age Classes from Fall 2006 to 2016 for Background Locations

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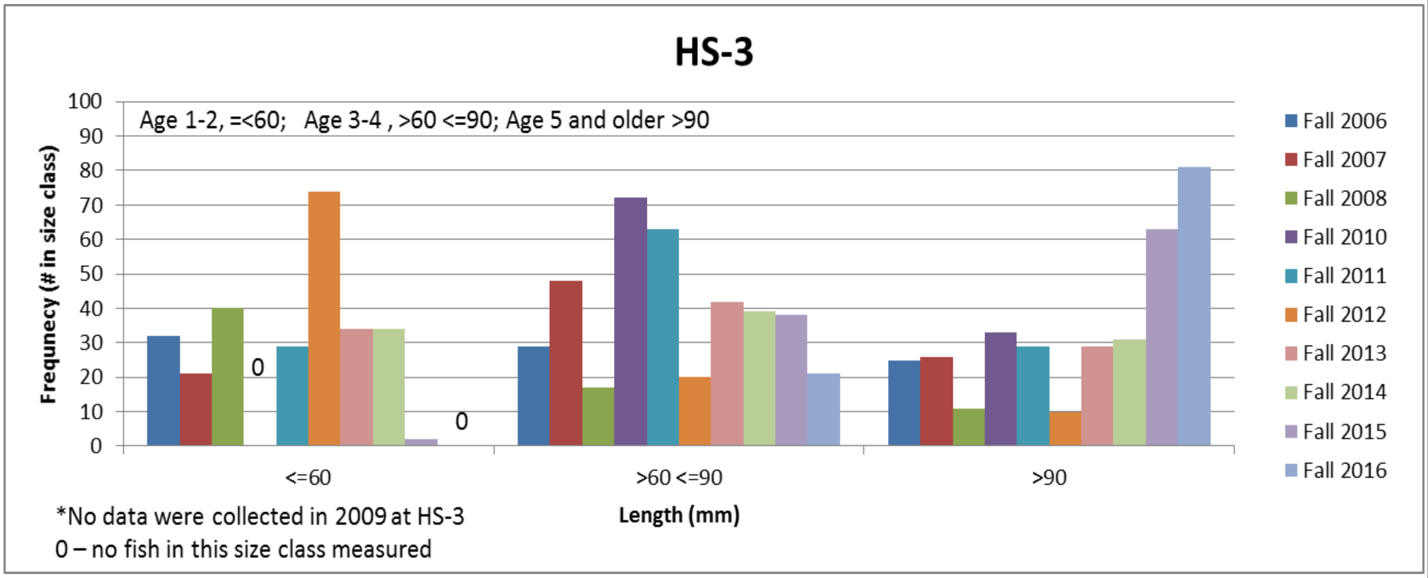

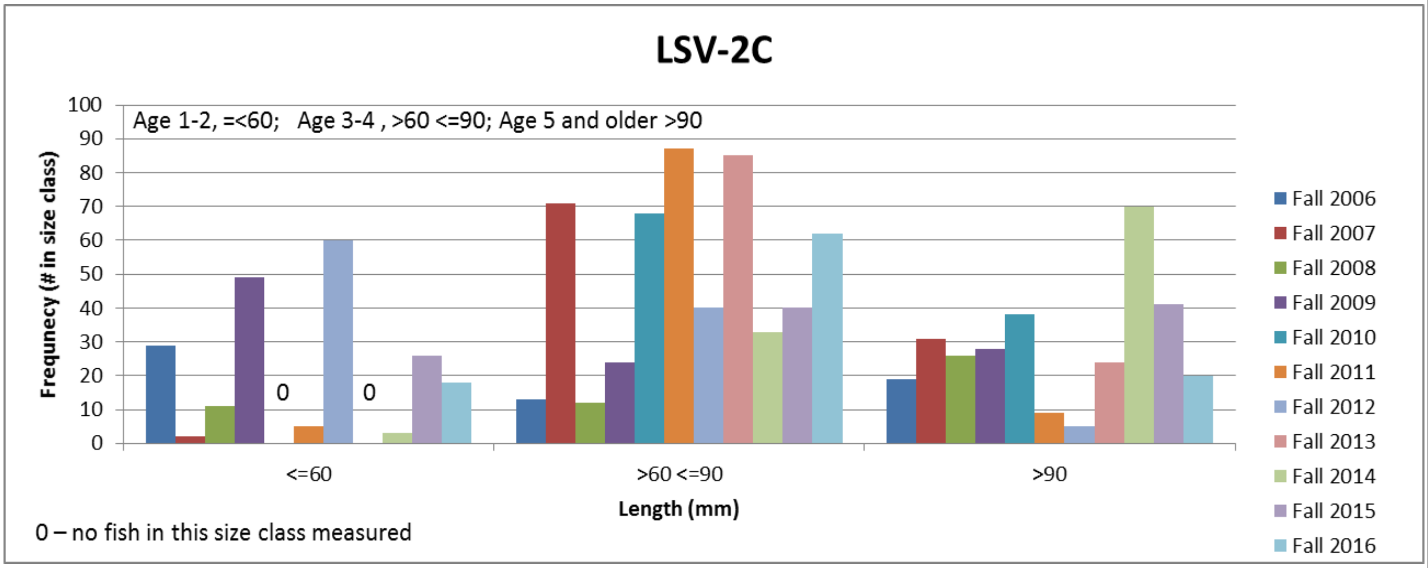

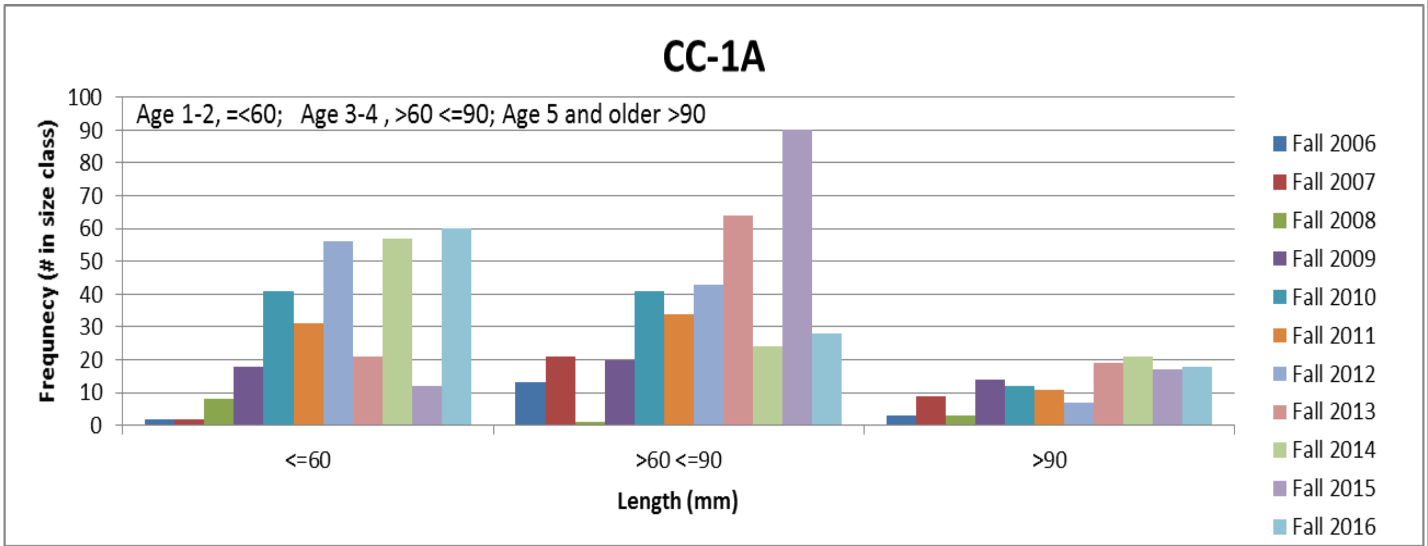

FIGURE 5
Frequency of Sculpin Lengths at Different Age Classes from Fall 2006 to 2016 for Site Locations

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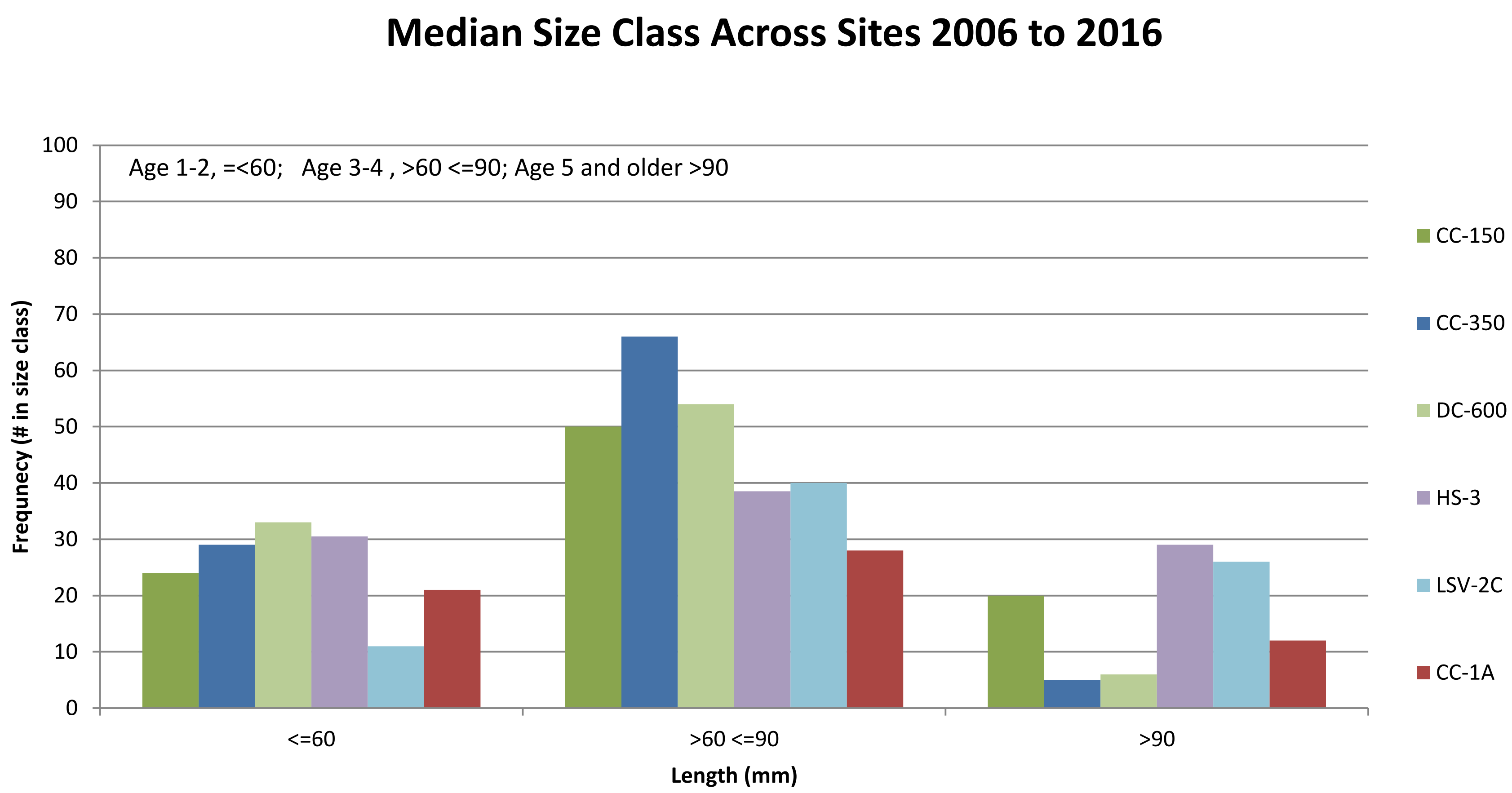

FIGURE 6
Median Frequency of Sculpin Lengths at Different Age Classes From Fall 2006 to 2016 for Background and Site Locations

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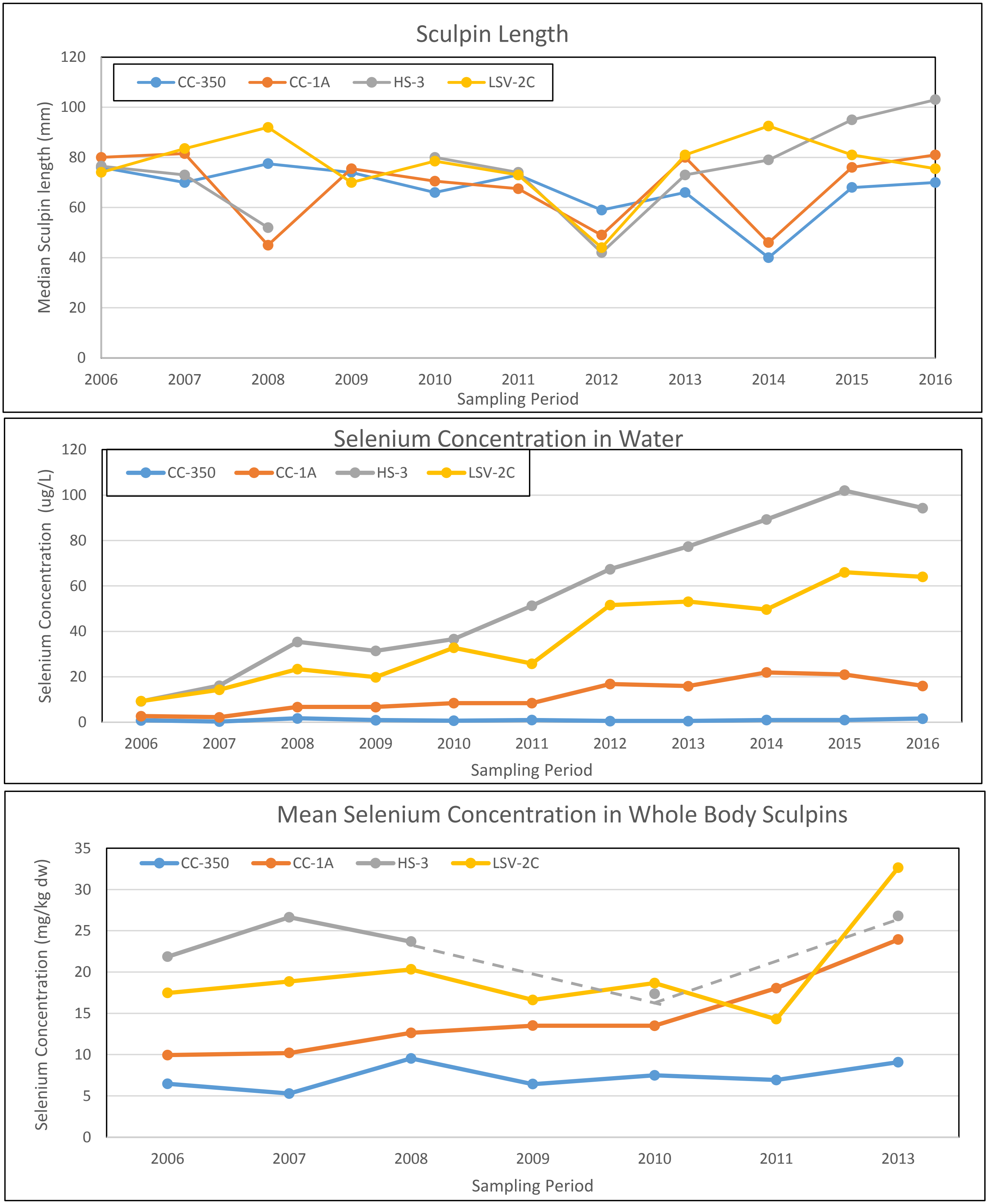

FIGURE 7

Median Sculpin Length from 2006 to 2016 for Background and Site Locations and Corresponding Surface Water and Whole Body Selenium Concentrations

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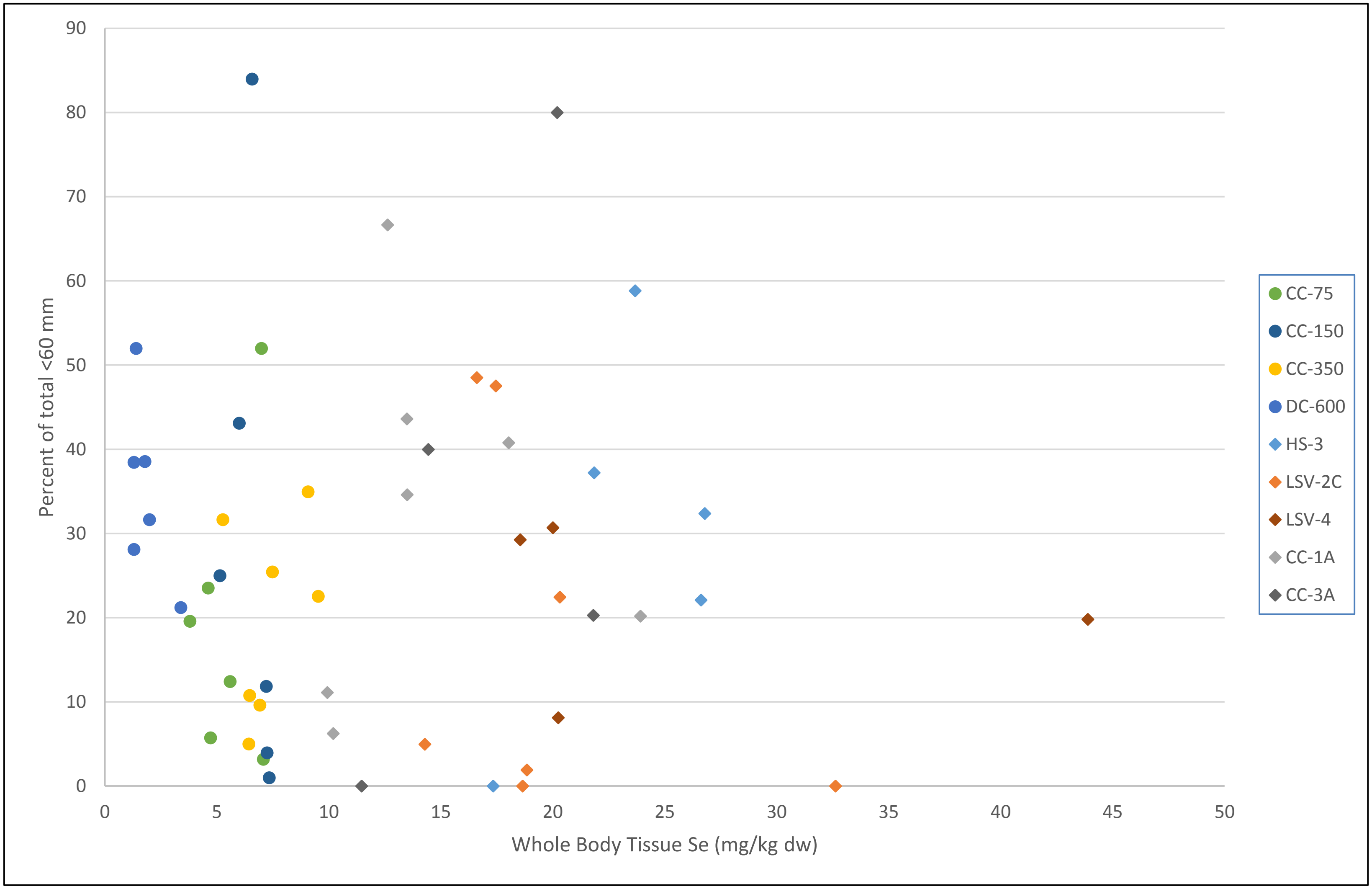

FIGURE 8
Percent of Sculpin <60mm In Length Relative to Mean Sculpin Whole Body Tissue Concentrations Measured During the Same Time and Location of Capture

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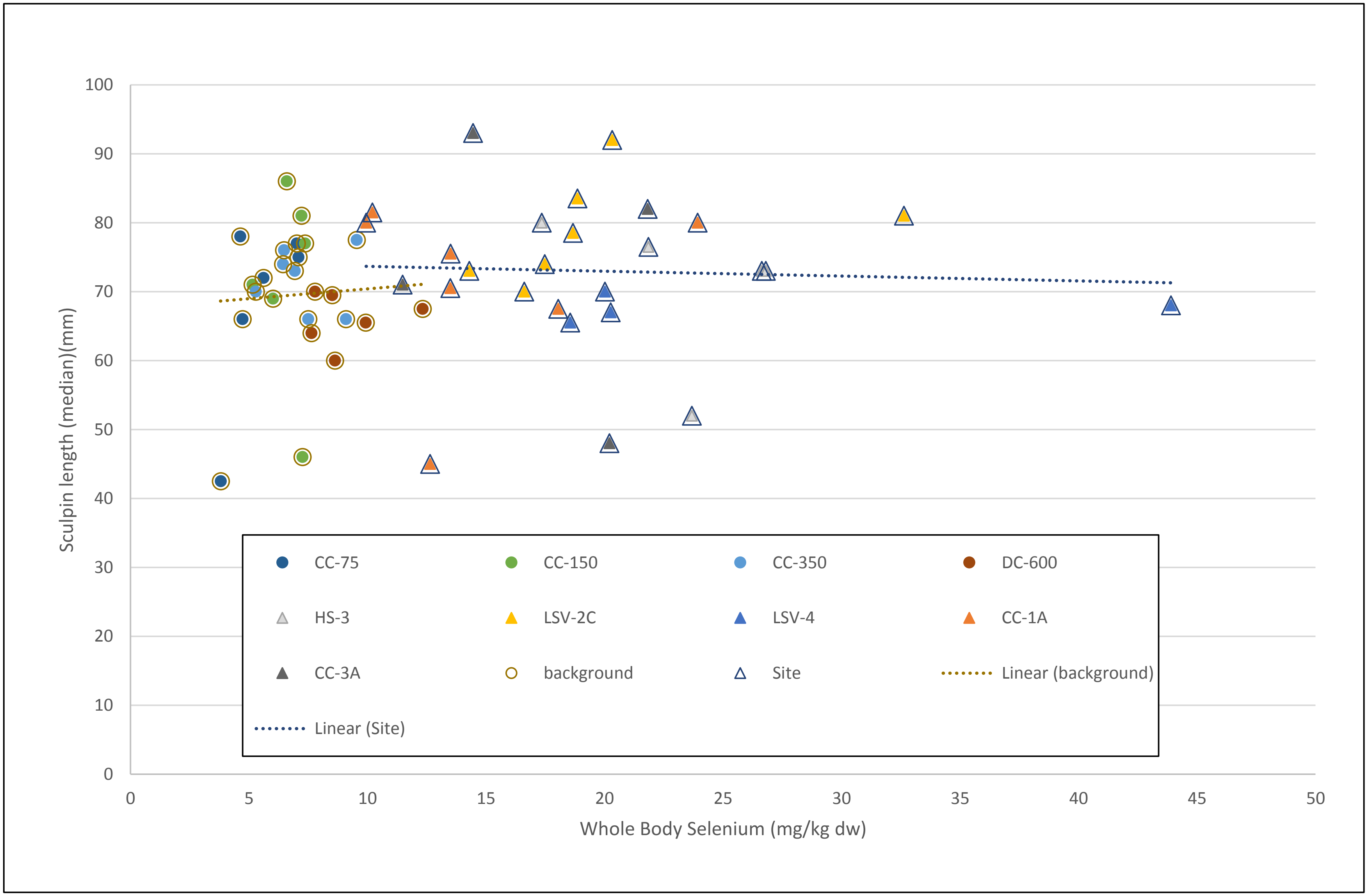

FIGURE 9
Median Sculpin Length for Background and Site Locations Relative to Mean Whole Body Tissue Concentrations for Sculpins Captured During the Same Time

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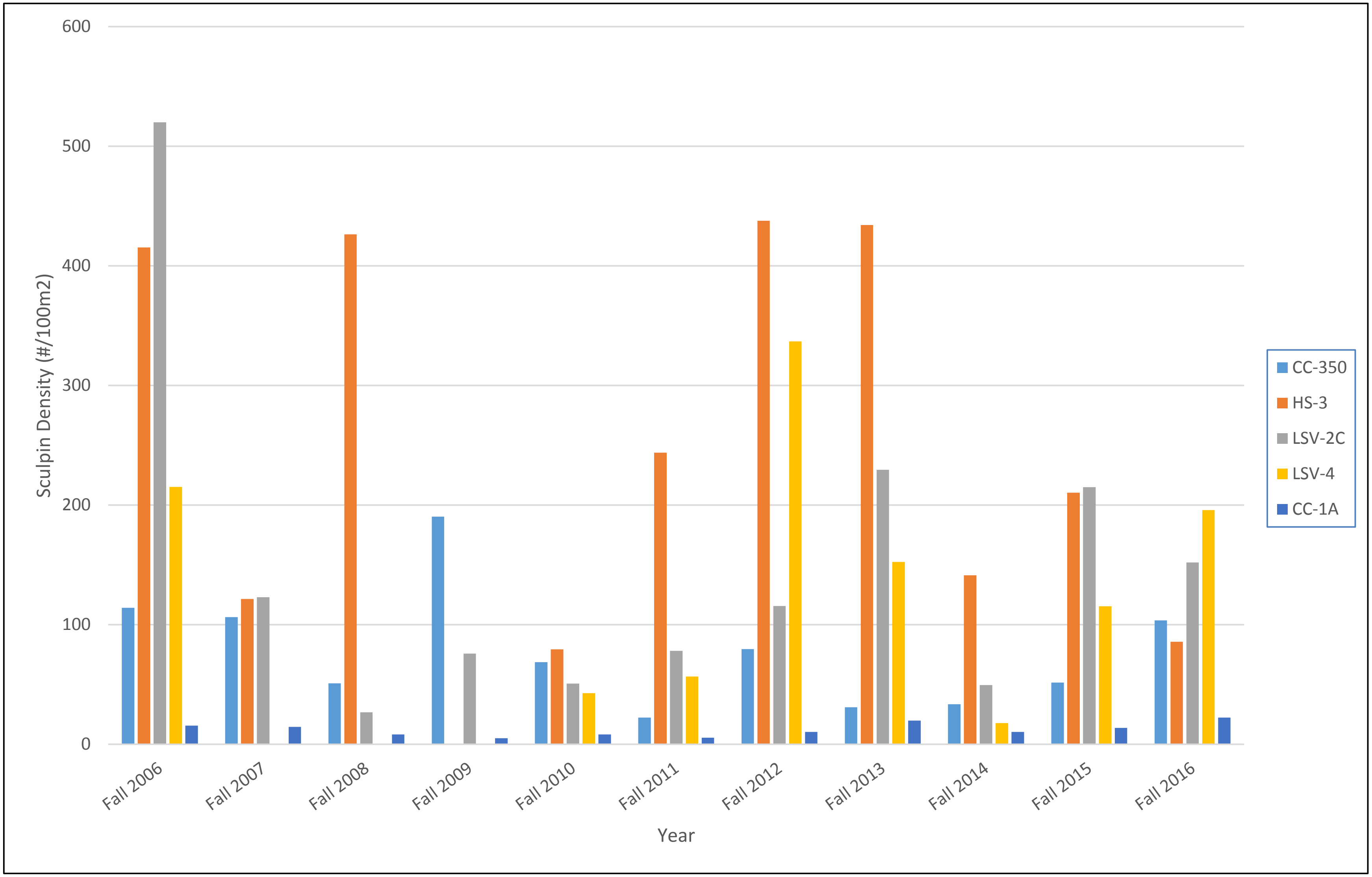

FIGURE 10
Sculpin Population Density at Background and Site Locations, 2006 To 2016

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Appendix E

Brown Trout Whole Body and Egg/ovary Data and Derivation of Site-Specific Conversion Factors

Derivation of a Site-Specific Brown Trout Conversion Factor

USEPA (2016a) derived a whole body tissue concentration for brown trout of 13.2 mg/kg dw using Simplot's brown trout data. This value is based on the no-effect concentration from the brown trout reproductive study where the associated egg/ovary value was 20.5 mg/kg dw[1]. Thus, the whole body tissue value of 13.2 mg/kg dw is a no-effect threshold from USEPA (2016a).

Based on the site-specific data, and using the procedures outlined in USEPA (2016a), the brown trout conversion factor (CF) for egg/ovary to whole body is 1.45.[2] Applying the CF to the egg/ovary EC_{10} (20.5 mg/kg dw) yields a value of 14.1 mg/kg. Additional data are available for this Site (i.e., paired whole body and egg tissues) (Table E-1) which includes six additional egg and whole body tissue pairs of data. The six females were believed to be ripe and were sacrificed to determine if eggs were present. In each, eggs were present and excised. Separate egg and whole body tissues samples were submitted for chemical analyses. The ratios from these six additional samples fall within the range of egg to whole body ratios derived from the fish used in the reproduction study (Table E-1). The addition of the six pairs of data results in an N=40 for the derivation of CFs. The median value for all of these Site data is 1.46 (±0.67). In this case, the standard deviation for the CF using only data developed for this study (including those collected as preliminary samples) is considerably lower than the USEPA (2016a) standard deviation of 1.81 that included the Osmundson et al. (2007) data. Based on these data, the CF proposed for the SSSC is 1.46. Dividing the proposed egg/ovary criterion (20.5 mg/kg dw) by the CF (1.46) yields a whole body value for brown trout of 14.0 mg/kg dw selenium.

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[1] The value 20.5 mg/kg dw is the egg concentration cited as no effects with a corresponding maternal whole body tissue concentration of 13.2 mg/kg dw. These are the measured values from the brown trout study.

[2] The value 1.45 is derived as the median CF of all the paired brown trout whole body and egg tissue values from Simplot's brown trout studies and Osmundson et al. (2007). Inclusion of the Osmundson et al. (2007) data introduces CF data from outside the Site, but more importantly, those data are for whole body and ovaries.

Table E-1
Brown Trout Paired Whole Body and Egg Tissue Selenium Concentrations

Location	Sample	Units	Selenium Concentration		WB/Egg Ratio
			Whole Body	Egg	
Crow Creek	CC150-FT009	mg/kg dw	8.4	12.8	1.52
Crow Creek	CC150-FT011	mg/kg dw	5.6	8.4	1.50
Crow Creek	CC150-FT012	mg/kg dw	6.7	8.5	1.27
Crow Creek	CC150-FT013	mg/kg dw	5.9	8.4	1.42
Crow Creek	CC150-FT015	mg/kg dw	6	9.1	1.52
Crow Creek	CC150-FT016	mg/kg dw	7	7.5	1.07
Crow Creek	CC150-FT017	mg/kg dw	5.6	6.6	1.18
Crow Creek	CC150-FT018	mg/kg dw	4.7	6.9	1.47
Crow Creek	CC150-FT020	mg/kg dw	7.2	6.2	0.86
Crow Creek	CC350-FT006	mg/kg dw	9.2	14	1.52
Crow Creek	CC350-FT007	mg/kg dw	5.5	6.9	1.25
Crow Creek	CC350-FT008	mg/kg dw	8.5	9.5	1.12
Sage Creek	LSV2c-002	mg/kg dw	8.9	12.8	1.44
Sage Creek	LSV2c-003	mg/kg dw	13.8	40.3	2.92
Sage Creek	LSV2c-004	mg/kg dw	17.9	36	2.01
Sage Creek	LSV2c-005	mg/kg dw	13.6	26.8	1.97
Sage Creek	LSV2c-006	mg/kg dw	17.2	26.9	1.56
Sage Creek	LSV2c-007	mg/kg dw	6.7	18.6	2.78
Sage Creek	LSV2c-008	mg/kg dw	9.6	17.7	1.84
Sage Creek	LSV2c-010	mg/kg dw	22.6	38.8	1.72
Sage Creek	LSV2c-012	mg/kg dw	7.2	13.2	1.83
Sage Creek	LSV2c-016	mg/kg dw	9.2	13.4	1.46
Sage Creek	LSV2c-017	mg/kg dw	13.2	20.5	1.55
Sage Creek	LSV2c-019	mg/kg dw	8.6	12.5	1.45
Sage Creek	LSV2c-020	mg/kg dw	11.3	11.2	0.99
Sage Creek	LSV2c-021	mg/kg dw	20	28.1	1.41
Saratoga Hatchery	SC-001	mg/kg dw	3.6	0.76	0.21
Saratoga Hatchery	SC-002	mg/kg dw	4.1	0.94	0.23
Saratoga Hatchery	SC-003	mg/kg dw	3.7	0.83	0.22
Saratoga Hatchery	SC-004	mg/kg dw	4.3	0.92	0.21
Saratoga Hatchery	SC-005	mg/kg dw	3	1.20	0.40
Saratoga Hatchery	SC-006	mg/kg dw	3.1	1.20	0.39
Saratoga Hatchery	SC-008	mg/kg dw	2.7	1.00	0.37
Saratoga Hatchery	SC-009	mg/kg dw	2.5	0.96	0.38
Crow Creek[1]	CC150-FT0013	mg/kg dw	5.4	10.8	2.00
Crow Creek[1]	CC1A-FT001	mg/kg dw	6.4	11.5	1.80
Crow Creek[1]	CC1A-FT0012	mg/kg dw	8.7	19	2.18
Crow Creek[1]	CC3A-FT101	mg/kg dw	8	10.5	1.31
Sage Creek[2]	LSV2c-FT0025	mg/kg dw	23.8	44.7	1.88
Sage Creek[2]	LSV2c-FT0030	mg/kg dw	17.3	41.2	2.38

[1] Pre spawning samples collected in October 2007 to assess condition.

[2] Pre spawning samples collected in November 2007 to assess condition.

Appendix F

Data Inputs and Derivation Methods used in the Mechanistic Trophic Model Approach

1.0 INTRODUCTION

USEPA's National Criterion (2016) utilizes the Presser and Luoma (2010) model as its basis for the mechanistic trophic model approach. It is similar to a wildlife dietary uptake model, in that it allows for selenium to be modeled up from a water concentration to higher trophic levels with some basic information on selenium concentrations in ambient surface waters, sediments, and algae. It can also be used to back calculate a water concentration from the same types of information. Both USEPA (2016) and Presser and Luoma (2010) provide approaches to derive the basic enrichment factors (EFs) and trophic transfer factors (TTFs) if site data are limited. This study, however, has generated data for nearly every level of the food chain as well as concentrations in abiotic media. As such, the data for this Site are abundant and only the modeling processes (as opposed to more generic data) used in the Presser and Luoma (2010) modeling approach are needed to derive EF and TTF model inputs.

Monitoring was conducted from 2006 to 2008 across two spring seasons and three fall seasons, providing a range of selenium concentration data in abiotic and biotic media, and covering an array of potential exposure conditions. Additional data were also collected at select locations in 2009, 2010, and/or 2011 for other monitoring program requirements. When all the necessary input data were available for a location and time period, then the suite of data (e.g., surface water, sediment, and biotic data) were included for use in the model. This modeling approach included those data collected within the Study Area only (i.e., South Fork Tincup Creek (SFTC-1) was not included).

Effective use of the available site-specific information requires integration of the data into representative model inputs (EFs and TTFs). Data for two types of seasonal conditions were integrated across each year/location combination using the median value. The seasonal conditions were all seasons (spring, summer, and fall) and summer/fall. The summer/fall seasonal condition was considered separately from the all season condition because the endpoint being evaluated (e.g., brown trout survival—the most sensitive endpoint developed) prompted consideration of potential seasonal differences, as well as differences between background and areas downstream of the source (i.e., the Site). The following subsections describe how the data were integrated to derive representative EFs and TTFs.

1.1 Derivation of EFs

Presser and Luoma (2010) define EF as a partition descriptor for selenium from the water to particulate fractions (e.g., algae, detritus, and sediments). Phase transformation reactions from dissolved to particulate selenium are of toxicological significance because particulate selenium is the primary form by which selenium enters food webs (Cutter and Bruland 1984; Oremland et al. 1989; Luoma et al. 1992). The different biogeochemical transformation reactions also result in different forms of selenium in particulate material—organo-selenium, elemental selenium, or adsorbed selenium—which in turn affects the bioavailability of selenium to invertebrates depending on how an invertebrate processes the complex water, sediment, and particulate milieu that composes its environment (Presser and Luoma 2010).

Field observations and empirical data were used to quantify this relationship, which is expressed as:

$$EF = C_{particulate}/C_{water}$$

Where

$C_{particulate}$ = selenium concentration in algae (periphyton), detritus, and/or sediments

C_{water} = selenium concentration in surface water (dissolved concentration)

Field data collected included selenium concentrations in both sediments and periphyton; therefore, EFs can be derived for sediment and periphyton. Presser and Luoma (2010) suggest that if the data are available, averaging concentrations of selenium in sediment, detritus, biofilm, and algae may help to define EF and take into account partitioning in different media and best represent the dynamic conditions present in an aquatic system. Bed sediments are the least desirable choice for calculating EFs, especially if the sediments vary from sands to fine-grained materials, due to possible dilution of selenium concentrations from the high mass of inorganic materials (resulting in artificially low EFs). For this site-specific assessment, however, selenium concentrations in sediments and surface waters from the same locale were strongly related, suggesting that there is some degree of partitioning of selenium to sediments from surface water that warrants its inclusion in deriving the EF. Further, the EFs derived using sediments for this site-specific assessment are not always lower than the EFs derived for periphyton. Because periphyton is the primary selenium accumulator at the base of the food chain and some partitioning of selenium from the aqueous phase to sediments occurs, EFs for both periphyton and sediment were developed.

Integrating EFs

USEPA (2016) recommends that where there are multiple EFs for a location (e.g., sediment, algae, and/or detritus) that the geometric mean be derived to yield a single EF. For this effort, two different EFs were derived for each location and time period, a periphyton EF and a sediment EF. Location and time-specific EFs were then averaged using a geometric mean and an arithmetic mean to derive EFs. Due to the effect EFs have on the final predicted water value, two regressions were run to assess the relationship between the predicted dissolved water selenium concentration versus the measured water selenium concentration using a final EF based on a geometric mean and one based on an arithmetic mean. The linear regression showing the best relationship (i.e., higher R2) was for the regression using the arithmetic mean derived EFs, thus these values were used in all subsequent calculations.

1.2 Derivation of Trophic Transfer Factors (TTFs)

A key aspect of selenium risk is bioaccumulation (i.e., internal exposure) in prey and predators (Luoma and Rainbow 2005). Just as the EFs were used to describe partitioning of selenium at the base layers of the food chain, TTFs are derived to describe the accumulation of selenium from lower trophic levels to upper trophic levels. They link particulate, invertebrate, and predator selenium concentrations. TTFs differ from traditional BAFs in that BAFs are almost always implemented as the selenium concentration in an animal relative to selenium in water, whereas the TTF is the selenium concentration in the animal relative to the selenium concentration in its prey.

Due to the large amount of data collected for this project, measured concentrations of selenium in organisms from different trophic levels provide the most direct data available for selenium bioaccumulation. Benthic macroinvertebrates, sculpin, and trout were collected within 24 hours of one another at each location during each of the seasonal monitoring events. These data are also paired with the site-specific surface water, sediment, and periphyton data.

Invertebrates

For benthic invertebrates, composite community samples were collected, representing a cross-section of the resident benthic invertebrate community. Of the possible 42 time and location data points (i.e., benthic community selenium tissue samples), five were missing selenium concentrations due to insufficient sample volume. Data for these five points were predicted using a linear regression of the selenium concentrations in periphyton versus the selenium concentrations in benthic tissues. The regression relationship y = 0.8274x+6.8244 (R^2 = 0.55) was used to predict missing benthic tissue concentrations.

Selenium concentrations in benthic tissues were measured from a multi-species sample. From these field collected data, a site-specific $TTF_{invertebrates}$ was derived as follows:

$$TTF_{invertebrate} = C_{invertebrate} / C_{particulate}$$

Where

$C_{invertebrate}$ = selenium concentration (milligrams per kilogram dry weight [mg/kg dw]) in benthic macroinvertebrates

$C_{particulate}$ = selenium concentration (mg/kg dw) in particulate materials

The $C_{particulate}$ term is the sum of 10 percent sediment selenium and 90 percent periphyton selenium concentrations. As noted previously, the average of sediment and periphyton concentrations were used in the derivations of EF. For benthic invertebrates, an assumption was made that the bulk of their selenium intake was through ingestion of selenium-containing periphyton. Using this approach, a range of $C_{particulate}$ for invertebrates was derived for each location and seasonal sample. Benthic invertebrate tissue selenium concentrations (i.e., $C_{invertebrate}$) were divided by the particulate fractions of selenium in periphyton and sediment as indicated above.

Sculpin

Sculpin are ubiquitous throughout the monitoring locations, but are more abundant at some locations than others. Sculpin are important components of fish assemblages in the Western United States (Quist et al. 2004), are native species, and often numerically dominant fish assemblages of streams of the interior Rocky Mountain region (Baily 1952; Jones 1972 [cited from Quist et al 2004]). They represent a secondary consumer in the food chain and are primarily benthic invertivores, although they have been documented to be cannibalistic (Johnson 1985).

For this assessment, the $TTF_{sculpin}$ was derived using benthic invertebrates as the primary food source. The $TTF_{sculpin}$ was derived as follows:

$$TTF_{sculpin} = C_{sculpin}/C_{invertebrate}$$

Where:

$C_{sculpin}$ = mean selenium concentration in sculpin from a location and time period (mg/kg dw)

$C_{invertebrate}$ = selenium concentration in benthic invertebrates (mg/kg dw) from the same location and time period

The $TTF_{sculpin}$ was derived by dividing the measured selenium concentration in sculpin tissues (arithmetic average for a location) by the selenium concentrations in benthic invertebrates from the same location for each seasonal sample.

Trout

Trout are the apex aquatic species in the site-specific trophic bioaccumulation food web. TTF_{trout} was derived to describe the transfer of selenium via the dietary pathway to a top-level predator, in this case brown trout. Adult brown trout are opportunistic feeders. The diets of brown trout have been described as “diversified,” and their food habits range broadly with variation in size and age, spatial and temporal variability in food availability, behavior, and habitat characteristics (Simpson and Wallace 1982, Bachman 1991, Baxter and Stone 1995, Bridcut and Giller 1995).

Adult brown trout are considered to be primarily piscivores as adults, and while they continue to consume macroinvertebrates, size selection of the prey items increases as the fish matures. With the exception of extremely productive systems that produce dense populations of aquatic invertebrates, most larger brown trout (> 310 mm [12.2 inches]) inhabiting large streams, rivers, and lakes are thought to transition from a diet composed predominately of invertebrates to one comprised mainly of fish and crayfish (Bachman 1991). Certainly, the ratio of forage fish to invertebrates in the brown trout diet will vary with fish size, brown trout gape size, and prey type and availability, among other factors.

As trout size increases, the proportion of fish in the diet would logically be expected to increase. By the time adults reach a size of about 16 to 18 inches or larger, one would expect that the proportion of fish in their diet to exceed 50 percent, especially if fish as prey are readily available. The brown trout habitat suitability index (HSI) (Raleigh et al. 1986) states that at 25 cm (~8 inches), fish as prey items will begin to enter the adult brown trout diet. Other considerations for the trout diet include the proportion of the invertebrates in the diet that are terrestrial, crustaceans such as crayfish, and/or freshwater shrimp.

The literature base describing brown trout diets is as varied as the different diets reported. To account for this, TTF_{trout} included a mixed diet proportion of sculpin (i.e., forage fish) and invertebrates for adult brown trout.

The equation to derive TTF_{trout} is described below:

$$TTF_{trout} = C_{trout}/\left(0.5 \times C_{sculpin}\right) + (0.5 \times C_{invertebrate})$$

Where:

C_{trout} = mean selenium concentration in brown trout from a location and time period

$C_{sculpin}$ = mean selenium concentration in sculpin (mg/kg dw) from the same location and time period

$C_{invertebrate}$ = selenium concentration in benthic invertebrates (mg/kg dw) from the same location and time period

To derive TTF_{trout}, C_{trout} was divided by the sum of the assumed dietary intake, 50% sculpin and 50% invertebrates.

Composite

The variable $TTF_{composite}$ brings all of the dietary intake variables into a single variable for use in the final equation. USEPA (2016) indicates that the parameter $TTF_{composite}$ quantitatively represents all dietary pathways of selenium exposure for a particular fish species within an aquatic system. It is derived from the individual TTFs for each trophic level modeled and represents the food web characteristics of the aquatic system.

For this Site-Specific Selenium Criterion (SSSC), $TTF_{composite}$ represents a fourth level food web as follows:

$$TTF_{composite} = TTF_{trout} \times TTF_{sculpin} \times TTF_{invertebrate}$$

Where:

TTF_{trout} = trophic transfer factor for brown trout from a location and time period

$TTF_{sculpin}$ = trophic transfer factor for sculpin from the same location and time period

$TTF_{invertebrate}$ = trophic transfer factor for benthic invertebrates from the same location and time period

1.3 Derivation of Conversion Factors

Because the primary selenium criterion element is expressed as a concentration in the eggs and/or ovaries, a conversion factor (CF) quantifies the relationship between the concentration of selenium in the eggs and/or ovaries and the average concentration of selenium in the whole body or muscle tissues (USEPA 2016). From the brown trout maternal study, 34 pairs of egg and whole body data were available. Of these, 26 pairs were from wild collected fish and 8 pairs were from hatchery fish. Additional data were available for this Site collected just prior to the field work done for the brown trout study (Table 6 in main document). Six additional egg and whole body tissue pairs of data were collected in late October 2007 during the first attempt to collect ripe females. The six females were believed to be ripe and were sacrificed to determine if eggs were present. In each, eggs were present and excised. Separate egg and whole body tissues samples were submitted for chemical analyses. The ratios from these six additional samples fall within the range of egg to whole body ratios derived from the fish used in the reproduction study (Table 6). Addition of the six pairs of data results in an N=40 for the derivation of CFs. The median value for Site data is 1.46 (±0.67). In this case, the standard deviation for the CF using only data developed for this study (including those collected as preliminary samples) is considerably lower than the USEPA (2016) standard deviation of 1.81 that included data from another study (e.g., Osmundson et al. (2007)).

Based on these site-specific data, the CF proposed for the SSSC is 1.46 and is derived as follows:

$$CF = C_{egg}/C_{whole\ body}$$

Where:

CF = Whole body to egg conversion factor

C_{eggn} = selenium concentration in egg tissues from maternal parent (mg/kg dw)

$C_{whole\ body}$ = selenium concentration in whole body tissues of the maternal parent (mg/kg)

2.0 DERIVATION OF THE AQUEOUS SELENIUM CONCENTRATION FROM TISSUE CONCENTRATIONS

The previous sections identified model input variables, described how each variable was derived, and used site-specific data to derive each model component. Below, the equation for derivation of an aqueous value based on effects in eggs is presented.

$$C_{water} = \frac{C_{egg}}{TTF_{composite}\ x\ EF\ x\ CF}$$

Where

C_{water} = predicted dissolved water concentration of selenium (micrograms per liter [ug/L])

C_{egg} = target egg selenium criterion (19.9 mg/kg dw)

EF = selenium concentration (mg/kg dw) in particulate materials / dissolved selenium concentration in water [$C_{particulate}$ (periphyton, detritus, sediments) / C_{water}] (liters per kilogram dry weight [L/kg dw])

CF = Whole body to egg conversion factor

To derive the water selenium concentration using the above equation, the input variables were derived as described in the previous section for each location and time period. Data for two types of seasonal conditions were integrated across each year/location combination using the median value. The seasonal conditions were all seasons (spring, summer, and fall) and summer/fall seasons. Input variable data are shown in Table 1 of this Appendix along with the individual modeled derived variables and model output. Table 7 in the text shows the median input variables and output from the model in terms of predicted water concentrations at an egg selenium concentration of 19.9 mg/kg dw for the different season and location groupings.

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Table F-1

Site-Specific Measurement Data Inputs for Mechansitic Model Variable Derivation and Prediction of Site-Specific Water Concentrations

Site Specific Measurement Data (inputs)								Mechansitic Model Variables (derived from inputs)									Prediction
Location	Monitoring Event	Dissolved Se (ug/L)	Sediment Total Se (mg/kg dw)	Periphyton Se (mg/kg dw)	Benthic Tissue Se (mg/kg dw)	Sculpin Tissue Se (mg/kg dw)	Brown Trout Tissue Se (mg/kg dw)	Benthic diet	Mean EF	Sediment EF	Algae EF	TTF Benthos	TTF Sculpin	Trout diet	TTF trout	TTF composite	Dissolved Se (ug/L) @ egg criterion 20.5 mg/kg dw
CC-75	Fall 2006	0.6	0.61	1.01	3.11	5.58	4.05	0.97	1.31	1.02	1.68	3.21	1.79	4.34	0.93	5.36	2.00
CC-75	Spring 2007	0.5	0.6	0.68	7.38	5.03	5.35	0.67	1.28	1.20	1.36	10.98	0.68	6.21	0.86	6.46	1.70
CC-75	Fall 2007	0.3	0.34	1.1	7.73	3.77	3.18	1.02	2.40	1.13	3.67	7.55	0.49	5.75	0.55	2.04	2.87
CC-75	Spring 2008	1.2	0.54	2.7	4.45	7.19	10.32	2.48	1.35	0.45	2.25	1.79	1.62	5.82	1.77	5.13	2.03
CC-75	Fall 2008	0.8	0.48	0.55	3.49	7.08	6.60	0.54	0.64	0.60	0.69	6.43	2.03	5.29	1.25	16.28	1.34
CC-75	Fall 2009	0.50	0.62	1.30	2.10	7.01	6.07	1.23	1.92	1.24	2.60	1.70	3.34	4.56	1.33	7.58	0.96
CC-75	Fall 2010	0.5	0.62	1.28	3.38	4.72	5.58	1.21	1.90	1.24	2.56	2.78	1.40	4.05	1.38	5.35	1.38
CC-150	Fall 2006	0.7	0.88	1.2	4.94	6.01	5.83	1.17	1.49	1.26	1.71	4.23	1.22	5.47	1.07	5.48	1.72
CC-150	Spring 2007	0.9	0.43	1.37	4.46	5.04	8.67	1.28	1.00	0.48	1.52	3.50	1.13	4.75	1.82	7.21	1.95
CC-150	Fall 2007	0.7	0.54	0.77	1.90	5.14	5.20	0.75	0.94	0.77	1.10	2.54	2.71	3.52	1.48	10.16	1.48
CC-150	Spring 2008	1.4	0.63	2.4	7.03	10.73	10.14	2.22	1.08	0.45	1.71	3.16	1.53	8.88	1.14	5.51	2.35
CC-150	Fall 2008	1.6	0.79	0.65	21.60	7.35	7.83	0.66	0.45	0.49	0.41	32.53	0.34	14.48	0.54	5.99	5.21
CC-150	Fall 2010	0.7	0.49	1.58	5.61	7.25	6.29	1.47	1.48	0.70	2.26	3.81	1.29	6.43	0.98	4.82	1.97
CC-350	Fall 2006	0.8	1.3	1.5	2.11	6.47	6.28	1.48	1.75	1.63	1.88	1.43	3.07	4.29	1.46	6.40	1.25
CC-350	Spring 2007	1.1	0.52	3.3	4.20	8.1	8.53	3.02	1.74	0.47	3.00	1.39	1.93	6.15	1.39	3.72	2.18
CC-350	Fall 2007	0.3	0.55	0.77	7.50	5.28	5.78	0.75	2.20	1.83	2.57	10.03	0.70	6.39	0.90	6.38	1.00
CC-350	Spring 2008	0.9	0.7	3.4	10.60	11.23	11.50	3.13	2.28	0.78	3.78	3.39	1.06	10.92	1.05	3.78	1.63
CC-350	Fall 2008	1.3	0.81	0.59	12.30	9.53	7.95	0.61	0.54	0.62	0.45	20.10	0.77	10.92	0.73	11.34	2.30
CC-350	Fall 2010	0.7	0.6	1.55	2.93	7.49	7.41	1.46	1.54	0.86	2.21	2.01	2.56	5.21	1.42	7.32	1.25
CC-350	Fall 2011	0.9	0.99	3.18	4.24	6.92	8.33	2.96	2.32	1.10	3.53	1.43	1.63	5.58	1.49	3.49	1.74
HS	Fall 2006	17.4	2.3	2.2	1.00	23.23	16.52	2.21	0.13	0.13	0.13	0.45	23.23	12.12	1.36	14.40	7.54
HS	Spring 2007	20.5	5.9	12.00	15.70	23.25	25.00	11.39	0.44	0.29	0.59	1.31	1.48	19.48	1.28	2.49	12.93
HS	Fall 2007	21.4	1.1	3.90	**10.01**	10.95	24.90	3.62	0.12	0.05	0.18	2.57	1.09	10.48	2.38	6.67	18.02
HS	Spring 2008	27.3	1.8	15.0	21.7	35.93	32.63	13.68	0.31	0.07	0.55	1.45	1.66	28.82	1.13	2.71	16.82
HS	Fall 2008	53.6	4.4	35.2	33.9	41.30	22.80	32.12	0.37	0.08	0.66	0.96	1.22	37.60	0.61	0.71	53.43
HS-3	Fall 2006	9.2	7	6.5	12.47	21.85	20.60	6.55	0.73	0.76	0.71	1.90	1.75	17.16	1.20	4.00	4.78
HS-3	Spring 2007	18	6.2	12.00	11.40	18.57	18.83	11.42	0.51	0.34	0.67	1.00	1.63	14.98	1.26	2.04	13.60
HS-3	Fall 2007	16.1	7.5	6.20	15.41	26.63	17.89	6.33	0.43	0.47	0.39	2.43	1.73	21.02	0.85	3.58	9.22
HS-3	Spring 2008	26	2.1	28.5	28.4	23.93	26.30	25.86	0.59	0.08	1.10	1.10	0.84	26.17	1.01	0.93	25.65
HS-3	Fall 2008	37.5	8.1	24.2	24.7	23.68	29.27	22.59	0.43	0.22	0.65	1.09	0.96	24.19	1.21	1.27	25.70
LSS	Fall 2010	13.80	1.2	4.73	9.65	15.63	11.95	4.38	0.21	0.09	0.34	2.20	1.62	12.64	0.95	3.38	19.36
LSS	Fall 2011	14.8	1.9	7.60	12.60	17	12.15	7.03	0.32	0.13	0.51	1.79	1.33	14.66	0.83	1.97	22.19
LSV-2C	Fall 2006	9.3	4.6	2.6	22.62	17.47	19.45	2.80	0.39	0.49	0.28	8.08	0.77	20.04	0.97	6.05	5.99
LSV-2C	Spring 2007	13.5	4.5	8.09	8.26	11.38	12.78	7.73	0.47	0.33	0.60	1.07	1.38	9.82	1.30	1.92	15.72
LSV-2C	Fall 2007	14.3	5.4	18.50	31.74	18.85	22.67	17.19	0.84	0.38	1.29	1.85	0.59	25.30	0.90	0.98	17.10
LSV-2C	Spring 2008	14.1	1.1	11.6	30.00	25.95	20.25	10.55	0.45	0.08	0.82	2.84	0.87	27.98	0.72	1.78	17.51
LSV-2C	Fall 2008	23.4	5.7	4.38	23.90	20.32	20.96	4.51	0.22	0.24	0.19	5.30	0.85	22.11	0.95	4.27	15.27
LSV-2C[3]	Fall 2009	19.80	11.9	13.00	25.50	16.61	20.32	12.89	0.63	0.60	0.66	1.98	0.65	21.06	0.97	1.24	17.96
LSV-2C	Fall 2010	32.80	7.0	13.30	53.40	18.66	18.01	12.67	0.31	0.21	0.41	4.21	0.35	36.03	0.50	0.74	61.63
LSV-2C	Fall 2011	25.8	5.5	8.54	12.70	14.29	17.16	8.24	0.27	0.21	0.33	1.54	1.13	13.50	1.27	2.21	23.39
LSV-4	Fall 2006	6.8	3.3	7.42	10.00	20.01	16.20	7.01	0.79	0.49	1.09	1.43	2.00	15.01	1.08	3.08	5.78

Table F-1

Site-Specific Measurement Data Inputs for Mechansitic Model Variable Derivation and Prediction of Site-Specific Water Concentrations

Site Specific Measurement Data (inputs)								Mechansitic Model Variables (derived from inputs)									Prediction
Location	Monitoring Event	Dissolved Se (ug/L)	Sediment Total Se (mg/kg dw)	Periphyton Se (mg/kg dw)	Benthic Tissue Se (mg/kg dw)	Sculpin Tissue Se (mg/kg dw)	Brown Trout Tissue Se (mg/kg dw)	Benthic diet	Mean EF	Sediment EF	Algae EF	TTF Benthos	TTF Sculpin	Trout diet	TTF trout	TTF composite	Dissolved Se (ug/L) @ egg criterion 20.5 mg/kg dw
LSV-4	Spring 2007	10.1	3.9	11.70	9.08	18.28	15.80	10.92	0.77	0.39	1.16	0.83	2.01	13.68	1.15	1.93	9.40
LSV-4	Fall 2010	25.20	4.7	10.50	24.10	20.25	20.01	9.92	0.30	0.19	0.42	2.43	0.84	22.18	0.90	1.84	25.27
LSV-4	Fall 2011	19.7	2.0	17.20	17.60	18.55	29.90	15.68	0.49	0.10	0.87	1.12	1.05	18.08	1.65	1.96	14.72
CC-1A	Fall 2006	2.7	1.8	3.64	3.53	9.94	9.76	3.46	1.01	0.67	1.35	1.02	2.82	6.74	1.45	4.17	3.34
CC-1A	Spring 2007	1.2	1.1	3.39	12.9	9.31	9.05	3.16	1.87	0.92	2.83	4.08	0.72	11.11	0.81	2.40	3.13
CC-1A	Fall 2007	2.2	0.67	3.20	12.24	7.78	9.95	2.95	0.88	0.30	1.45	4.15	0.64	10.01	0.99	2.62	6.08
CC-1A	Spring 2008	2.9	1.2	7.10	15.50	17.13	17.54	6.51	1.43	0.41	2.45	2.38	1.11	16.32	1.08	2.83	3.47
CC-1A	Fall 2008	6.7	1.7	5.86	11.60	12.41	14.03	5.44	0.56	0.25	0.87	2.13	1.07	12.01	1.17	2.66	9.34
CC-1A	Fall 2009	6.6	2.8	5.93	32.10	10.81	13.50	5.62	0.66	0.42	0.90	5.71	0.34	21.46	0.63	1.21	17.53
CC-1A	Fall 2010	8.50	1.5	7.58	8.87	13.49	14.30	6.97	0.53	0.18	0.89	1.27	1.52	11.18	1.28	2.47	10.62
CC-1A	Fall 2011	8.40	1.7	4.89	16.70	18.04	12.24	4.57	0.39	0.20	0.58	3.65	1.08	17.37	0.70	2.78	12.87
CC-3A	Fall 2006	2.9	1.45	3.10	5.48	14.45	11.15	2.94	0.78	0.50	1.07	1.87	2.64	9.97	1.12	5.51	3.25
CC-3A	Spring 2007	1.4	0.74	1.89	5.41	11.62	9.20	1.78	0.94	0.53	1.35	3.05	2.15	8.52	1.08	7.07	2.11
CC-3A	Fall 2007	1.8	0.83	3.80	**9.97**	9.07	11.25	3.50	1.29	0.46	2.11	2.85	0.91	9.52	1.18	3.06	3.57
CC-3A	Spring 2008	2.6	0.66	14.9	17.80	13.16	15.38	13.48	2.99	0.25	5.73	1.32	0.74	15.48	0.99	0.97	4.84
CC-3A	Fall 2008	5.8	1.3	1.67	11.20	13.01	19.68	1.63	0.26	0.22	0.29	6.86	1.16	12.11	1.63	12.95	4.23

Bold values were predicted from linear regression

Appendix G

Data Inputs and Derivation Methods used in the Empirical BAF Approach

Table G-1
Site-Specific Brown Trout Whole Body Tissue and Surface Water Selenium Concentrations for Deriving Whole Body and Egg BAFs

Station	Date	Year	Whole Body Se mg/kg dw	Species	SW Se Diss ug/L	Whole Body BAF FT (mg/kg) / SW (ug/L))	Egg BAF (WB to Egg CF = 1.46)
CC-1A	September 1, 2006	2006	11.86	Brown Trout	2.7	4.39	6.412
CC-1A	September 1, 2006	2006	8.15	Brown Trout	2.7	3.02	4.405
CC-1A	September 1, 2006	2006	9.28	Brown Trout	2.7	3.44	5.017
CC-1A	May 10, 2007	2007	7.40	Brown Trout	1.2	6.17	9.003
CC-1A	May 10, 2007	2007	10.70	Brown Trout	1.2	8.92	13.018
CC-1A	August 25, 2007	2007	14.80	Brown Trout	2.2	6.73	9.822
CC-1A	August 25, 2007	2007	7.10	Brown Trout	2.2	3.23	4.712
CC-1A	August 25, 2007	2007	11.60	Brown Trout	2.2	5.27	7.698
CC-1A	August 25, 2007	2007	12.50	Brown Trout	2.2	5.68	8.295
CC-1A	August 25, 2007	2007	9.10	Brown Trout	2.2	4.14	6.039
CC-1A	August 25, 2007	2007	10.40	Brown Trout	2.2	4.73	6.902
CC-1A	August 25, 2007	2007	7.80	Brown Trout	2.2	3.55	5.176
CC-1A	August 25, 2007	2007	11.90	Brown Trout	2.2	5.41	7.897
CC-1A	August 25, 2007	2007	8.40	Brown Trout	2.2	3.82	5.575
CC-1A	August 25, 2007	2007	9.50	Brown Trout	2.2	4.32	6.305
CC-1A	August 25, 2007	2007	6.30	Brown Trout	2.2	2.86	4.181
CC-1A	May 14, 2008	2008	17.60	Brown Trout	2.9	6.07	8.861
CC-1A	May 14, 2008	2008	18.20	Brown Trout	2.9	6.28	9.163
CC-1A	May 14, 2008	2008	18.30	Brown Trout	2.9	6.31	9.213
CC-1A	May 14, 2008	2008	17.20	Brown Trout	2.9	5.93	8.659
CC-1A	May 14, 2008	2008	16.40	Brown Trout	2.9	5.66	8.257
CC-1A	September 6, 2008	2008	14.40	Brown Trout	6.7	2.15	3.138
CC-1A	September 6, 2008	2008	15.40	Brown Trout	6.7	2.30	3.356
CC-1A	September 6, 2008	2008	11.80	Brown Trout	6.7	1.76	2.571
CC-1A	September 6, 2008	2008	15.90	Brown Trout	6.7	2.37	3.465
CC-1A	September 6, 2008	2008	8.04	Brown Trout	6.7	1.20	1.752
CC-1A	September 6, 2008	2008	13.20	Brown Trout	6.7	1.97	2.876
CC-1A	September 6, 2008	2008	11.30	Brown Trout	6.7	1.69	2.462
CC-1A	September 6, 2008	2008	13.50	Brown Trout	6.7	2.01	2.942
CC-1A	September 6, 2008	2008	13.80	Brown Trout	6.7	2.06	3.007
CC-1A	September 6, 2008	2008	23.00	Brown Trout	6.7	3.43	5.012
CC-1A	September 10, 2009	2009	7.43	Brown Trout	6.6	1.13	1.644
CC-1A	September 10, 2009	2009	8.73	Brown Trout	6.6	1.32	1.931
CC-1A	September 10, 2009	2009	13.70	Brown Trout	6.6	2.08	3.031
CC-1A	September 10, 2009	2009	12.90	Brown Trout	6.6	1.95	2.854
CC-1A	September 10, 2009	2009	13.00	Brown Trout	6.6	1.97	2.876
CC-1A	September 10, 2009	2009	7.48	Brown Trout	6.6	1.13	1.655
CC-1A	September 10, 2009	2009	9.99	Brown Trout	6.6	1.51	2.210
CC-1A	September 10, 2009	2009	11.90	Brown Trout	6.6	1.80	2.632
CC-1A	September 10, 2009	2009	12.20	Brown Trout	6.6	1.85	2.699
CC-1A	August 30, 2010	2010	11.60	Brown Trout	8.4	1.38	2.016
CC-1A	August 30, 2010	2010	16.10	Brown Trout	8.4	1.92	2.798
CC-1A	August 30, 2010	2010	14.20	Brown Trout	8.4	1.69	2.468
CC-1A	August 30, 2010	2010	12.60	Brown Trout	8.4	1.50	2.190

Table G-1
Site-Specific Brown Trout Whole Body Tissue and Surface Water Selenium Concentrations for Deriving Whole Body and Egg BAFs

Station	Date	Year	Whole Body Se mg/kg dw	Species	SW Se Diss ug/L	Whole Body BAF FT (mg/kg) / SW (ug/L))	Egg BAF (WB to Egg CF = 1.46)
CC-1A	August 30, 2010	2010	13.80	Brown Trout	8.4	1.64	2.399
CC-1A	August 30, 2010	2010	15.30	Brown Trout	8.4	1.82	2.659
CC-1A	August 30, 2010	2010	15.80	Brown Trout	8.4	1.88	2.746
CC-1A	August 30, 2010	2010	16.80	Brown Trout	8.4	2.00	2.920
CC-1A	August 30, 2010	2010	14.90	Brown Trout	8.4	1.77	2.590
CC-1A	August 30, 2010	2010	11.90	Brown Trout	8.4	1.42	2.068
CC-1A	August 27, 2011	2011	10.50	Brown Trout	8.4	1.25	1.825
CC-1A	August 27, 2011	2011	12.10	Brown Trout	8.4	1.44	2.103
CC-1A	August 27, 2011	2011	11.90	Brown Trout	8.4	1.42	2.068
CC-1A	August 27, 2011	2011	15.50	Brown Trout	8.4	1.85	2.694
CC-1A	August 27, 2011	2011	12.80	Brown Trout	8.4	1.52	2.225
CC-1A	August 27, 2011	2011	11.00	Brown Trout	8.4	1.31	1.912
CC-1A	August 27, 2011	2011	14.70	Brown Trout	8.4	1.75	2.555
CC-1A	August 27, 2011	2011	7.52	Brown Trout	8.4	0.90	1.307
CC-1A	August 27, 2011	2011	12.80	Brown Trout	8.4	1.52	2.225
CC-1A	August 27, 2011	2011	13.60	Brown Trout	8.4	1.62	2.364
CC-3A	September 4, 2006	2006	9.96	Brown Trout	2.9	3.43	5.015
CC-3A	September 4, 2006	2006	9.14	Brown Trout	2.9	3.15	4.600
CC-3A	September 4, 2006	2006	14.34	Brown Trout	2.9	4.95	7.222
CC-3A	May 11, 2007	2007	12.70	Brown Trout	1.4	9.07	13.244
CC-3A	May 11, 2007	2007	8.60	Brown Trout	1.4	6.14	8.969
CC-3A	May 11, 2007	2007	7.50	Brown Trout	1.4	5.36	7.821
CC-3A	May 11, 2007	2007	8.00	Brown Trout	1.4	5.71	8.343
CC-3A	August 26, 2007	2007	13.40	Brown Trout	1.8	7.44	10.869
CC-3A	August 26, 2007	2007	15.60	Brown Trout	1.8	8.67	12.653
CC-3A	August 26, 2007	2007	8.90	Brown Trout	1.8	4.94	7.219
CC-3A	August 26, 2007	2007	9.10	Brown Trout	1.8	5.06	7.381
CC-3A	August 26, 2007	2007	14.00	Brown Trout	1.8	7.78	11.356
CC-3A	August 26, 2007	2007	13.80	Brown Trout	1.8	7.67	11.193
CC-3A	August 26, 2007	2007	9.10	Brown Trout	1.8	5.06	7.381
CC-3A	August 26, 2007	2007	10.60	Brown Trout	1.8	5.89	8.598
CC-3A	August 26, 2007	2007	7.80	Brown Trout	1.8	4.33	6.327
CC-3A	August 26, 2007	2007	10.30	Brown Trout	1.8	5.72	8.354
CC-3A	August 26, 2007	2007	11.00	Brown Trout	1.8	6.11	8.922
CC-3A	August 26, 2007	2007	8.90	Brown Trout	1.8	4.94	7.219
CC-3A	August 26, 2007	2007	13.70	Brown Trout	1.8	7.61	11.112
CC-3A	May 15, 2008	2008	15.10	Brown Trout	2.6	5.81	8.479
CC-3A	May 15, 2008	2008	15.80	Brown Trout	2.6	6.08	8.872
CC-3A	May 15, 2008	2008	15.00	Brown Trout	2.6	5.77	8.423
CC-3A	May 15, 2008	2008	15.60	Brown Trout	2.6	6.00	8.760
CC-3A	September 7, 2008	2008	16.30	Brown Trout	5.8	2.81	4.103
CC-3A	September 7, 2008	2008	21.30	Brown Trout	5.8	3.67	5.362

Table G-1
Site-Specific Brown Trout Whole Body Tissue and Surface Water Selenium Concentrations for Deriving Whole Body and Egg BAFs

Station	Date	Year	Whole Body Se mg/kg dw	Species	SW Se Diss ug/L	Whole Body BAF FT (mg/kg) / SW (ug/L))	Egg BAF (WB to Egg CF = 1.46)
CC-3A	September 7, 2008	2008	19.80	Brown Trout	5.8	3.41	4.984
CC-3A	September 7, 2008	2008	23.20	Brown Trout	5.8	4.00	5.840
CC-3A	September 7, 2008	2008	20.20	Brown Trout	5.8	3.48	5.085
CC-3A	September 7, 2008	2008	18.30	Brown Trout	5.8	3.16	4.607
CC-3A	September 7, 2008	2008	19.20	Brown Trout	5.8	3.31	4.833
CC-3A	September 7, 2008	2008	19.10	Brown Trout	5.8	3.29	4.808
LSV-4	September 5, 2006	2006	15.49	Brown Trout	6.8	2.28	3.326
LSV-4	September 5, 2006	2006	18.91	Brown Trout	6.8	2.78	4.060
LSV-4	September 5, 2006	2006	15.07	Brown Trout	6.8	2.22	3.237
LSV-4	September 5, 2006	2006	15.34	Brown Trout	6.8	2.26	3.293
LSV-4	May 9, 2007	2007	15.80	Brown Trout	10.1	1.56	2.284
LSV-4	August 25, 2010	2010	23.10	Brown Trout	25.2	0.92	1.338
LSV-4	August 25, 2010	2010	17.70	Brown Trout	25.2	0.70	1.025
LSV-4	August 25, 2010	2010	16.20	Brown Trout	25.2	0.64	0.939
LSV-4	August 25, 2010	2010	12.80	Brown Trout	25.2	0.51	0.742
LSV-4	August 25, 2010	2010	16.30	Brown Trout	25.2	0.65	0.944
LSV-4	August 25, 2010	2010	23.80	Brown Trout	25.2	0.94	1.379
LSV-4	August 25, 2010	2010	17.80	Brown Trout	25.2	0.71	1.031
LSV-4	August 25, 2010	2010	23.10	Brown Trout	25.2	0.92	1.338
LSV-4	August 25, 2010	2010	18.90	Brown Trout	25.2	0.75	1.095
LSV-4	August 25, 2010	2010	20.30	Brown Trout	25.2	0.81	1.176
LSV-4	August 25, 2010	2010	21.70	Brown Trout	25.2	0.86	1.257
LSV-4	August 25, 2010	2010	18.90	Brown Trout	25.2	0.75	1.095
LSV-4	August 25, 2010	2010	19.20	Brown Trout	25.2	0.76	1.112
LSV-4	August 25, 2010	2010	20.40	Brown Trout	25.2	0.81	1.182
LSV-4	August 25, 2010	2010	18.10	Brown Trout	25.2	0.72	1.049
LSV-4	August 25, 2010	2010	21.70	Brown Trout	25.2	0.86	1.257
LSV-4	August 25, 2010	2010	22.20	Brown Trout	25.2	0.88	1.286
LSV-4	August 25, 2010	2010	21.20	Brown Trout	25.2	0.84	1.228
LSV-4	August 25, 2010	2010	19.40	Brown Trout	25.2	0.77	1.124
LSV-4	August 25, 2010	2010	28.30	Brown Trout	25.2	1.12	1.640
LSV-4	August 24, 2011	2011	19.80	Brown Trout	19.7	1.01	1.467
LSV-4	August 24, 2011	2011	28.00	Brown Trout	19.7	1.42	2.075
LSV-4	August 24, 2011	2011	16.90	Brown Trout	19.7	0.86	1.252
LSV-4	August 24, 2011	2011	30.90	Brown Trout	19.7	1.57	2.290
LSV-2C	September 6, 2006	2006	20.84	Brown Trout	9.3	2.24	3.271
LSV-2C	September 6, 2006	2006	22.82	Brown Trout	9.3	2.45	3.582
LSV-2C	September 6, 2006	2006	16.00	Brown Trout	9.3	1.72	2.512
LSV-2C	September 6, 2006	2006	19.39	Brown Trout	9.3	2.09	3.045
LSV-2C	September 6, 2006	2006	19.50	Brown Trout	9.3	2.10	3.062
LSV-2C	September 6, 2006	2006	18.13	Brown Trout	9.3	1.95	2.846
LSV-2C	May 12, 2007	2007	9.00	Brown Trout	13.5	0.67	0.973

Table G-1
Site-Specific Brown Trout Whole Body Tissue and Surface Water Selenium Concentrations for Deriving Whole Body and Egg BAFs

Station	Date	Year	Whole Body Se mg/kg dw	Species	SW Se Diss ug/L	Whole Body BAF FT (mg/kg) / SW (ug/L))	Egg BAF (WB to Egg CF = 1.46)
LSV-2C	May 12, 2007	2007	11.40	Brown Trout	13.5	0.84	1.233
LSV-2C	May 12, 2007	2007	22.20	Brown Trout	13.5	1.64	2.401
LSV-2C	May 12, 2007	2007	8.50	Brown Trout	13.5	0.63	0.919
LSV-2C	August 28, 2007	2007	10.80	Brown Trout	14.3	0.76	1.103
LSV-2C	August 28, 2007	2007	27.50	Brown Trout	14.3	1.92	2.808
LSV-2C	August 28, 2007	2007	19.60	Brown Trout	14.3	1.37	2.001
LSV-2C	August 28, 2007	2007	26.40	Brown Trout	14.3	1.85	2.695
LSV-2C	August 28, 2007	2007	21.20	Brown Trout	14.3	1.48	2.164
LSV-2C	August 28, 2007	2007	20.70	Brown Trout	14.3	1.45	2.113
LSV-2C	August 28, 2007	2007	33.30	Brown Trout	14.3	2.33	3.400
LSV-2C	August 28, 2007	2007	23.80	Brown Trout	14.3	1.66	2.430
LSV-2C	August 28, 2007	2007	20.70	Brown Trout	14.3	1.45	2.113
LSV-2C	May 16, 2008	2008	18.50	Brown Trout	14.1	1.31	1.916
LSV-2C	May 16, 2008	2008	19.10	Brown Trout	14.1	1.35	1.978
LSV-2C	May 16, 2008	2008	11.40	Brown Trout	14.1	0.81	1.180
LSV-2C	May 16, 2008	2008	20.50	Brown Trout	14.1	1.45	2.123
LSV-2C	May 16, 2008	2008	22.40	Brown Trout	14.1	1.59	2.319
LSV-2C	May 16, 2008	2008	29.60	Brown Trout	14.1	2.10	3.065
LSV-2C	September 5, 2008	2008	21.80	Brown Trout	23.4	0.93	1.360
LSV-2C	September 5, 2008	2008	25.00	Brown Trout	23.4	1.07	1.560
LSV-2C	September 5, 2008	2008	24.10	Brown Trout	23.4	1.03	1.504
LSV-2C	September 5, 2008	2008	20.80	Brown Trout	23.4	0.89	1.298
LSV-2C	September 5, 2008	2008	20.40	Brown Trout	23.4	0.87	1.273
LSV-2C	September 5, 2008	2008	18.00	Brown Trout	23.4	0.77	1.123
LSV-2C	September 5, 2008	2008	20.50	Brown Trout	23.4	0.88	1.279
LSV-2C	September 5, 2008	2008	24.30	Brown Trout	23.4	1.04	1.516
LSV-2C	September 5, 2008	2008	18.90	Brown Trout	23.4	0.81	1.179
LSV-2C	September 5, 2008	2008	19.40	Brown Trout	23.4	0.83	1.210
LSV-2C	September 5, 2008	2008	17.40	Brown Trout	23.4	0.74	1.086
LSV-2C	September 12, 2009	2009	17.30	Brown Trout	19.8	0.87	1.276
LSV-2C	September 12, 2009	2009	21.80	Brown Trout	19.8	1.10	1.607
LSV-2C	September 12, 2009	2009	28.10	Brown Trout	19.8	1.42	2.072
LSV-2C	September 12, 2009	2009	20.30	Brown Trout	19.8	1.03	1.497
LSV-2C	September 12, 2009	2009	27.00	Brown Trout	19.8	1.36	1.991
LSV-2C	September 12, 2009	2009	19.80	Brown Trout	19.8	1.00	1.460
LSV-2C	September 12, 2009	2009	18.50	Brown Trout	19.8	0.93	1.364
LSV-2C	September 12, 2009	2009	17.00	Brown Trout	19.8	0.86	1.254
LSV-2C	September 12, 2009	2009	21.50	Brown Trout	19.8	1.09	1.585
LSV-2C	September 12, 2009	2009	11.90	Brown Trout	19.8	0.60	0.877
LSV-2C	August 28, 2010	2010	16.30	Brown Trout	32.8	0.50	0.726
LSV-2C	August 28, 2010	2010	21.00	Brown Trout	32.8	0.64	0.935
LSV-2C	August 28, 2010	2010	17.20	Brown Trout	32.8	0.52	0.766

Table G-1
Site-Specific Brown Trout Whole Body Tissue and Surface Water Selenium Concentrations for Deriving Whole Body and Egg BAFs

Station	Date	Year	Whole Body Se mg/kg dw	Species	SW Se Diss ug/L	Whole Body BAF FT (mg/kg) / SW (ug/L))	Egg BAF (WB to Egg CF = 1.46)
LSV-2C	August 28, 2010	2010	21.20	Brown Trout	32.8	0.65	0.944
LSV-2C	August 28, 2010	2010	18.00	Brown Trout	32.8	0.55	0.801
LSV-2C	August 28, 2010	2010	16.70	Brown Trout	32.8	0.51	0.743
LSV-2C	August 28, 2010	2010	17.40	Brown Trout	32.8	0.53	0.775
LSV-2C	August 28, 2010	2010	16.30	Brown Trout	32.8	0.50	0.726
LSV-2C	August 28, 2010	2010	17.00	Brown Trout	32.8	0.52	0.757
LSV-2C	August 28, 2010	2010	18.00	Brown Trout	32.8	0.55	0.801
LSV-2C	August 28, 2010	2010	16.20	Brown Trout	32.8	0.49	0.721
LSV-2C	August 28, 2010	2010	13.60	Brown Trout	32.8	0.41	0.605
LSV-2C	August 28, 2010	2010	13.70	Brown Trout	32.8	0.42	0.610
LSV-2C	August 28, 2010	2010	13.60	Brown Trout	32.8	0.41	0.605
LSV-2C	August 28, 2010	2010	16.70	Brown Trout	32.8	0.51	0.743
LSV-2C	August 28, 2010	2010	16.30	Brown Trout	32.8	0.50	0.726
LSV-2C	August 28, 2010	2010	17.10	Brown Trout	32.8	0.52	0.761
LSV-2C	August 26, 2011	2011	15.20	Brown Trout	25.8	0.59	0.860
LSV-2C	August 26, 2011	2011	14.20	Brown Trout	25.8	0.55	0.804
LSV-2C	August 26, 2011	2011	17.30	Brown Trout	25.8	0.67	0.979
LSV-2C	August 26, 2011	2011	15.50	Brown Trout	25.8	0.60	0.877
LSV-2C	August 26, 2011	2011	23.60	Brown Trout	25.8	0.91	1.336
LSV-3	August 25, 2010	2010	14.30	Brown Trout	24.5	0.58	0.852
LSV-3	August 25, 2010	2010	15.90	Brown Trout	24.5	0.65	0.948
LSV-3	August 25, 2010	2010	14.10	Brown Trout	24.5	0.58	0.840
LSV-3	August 25, 2010	2010	13.20	Brown Trout	24.5	0.54	0.787
LSV-3	August 25, 2010	2010	14.30	Brown Trout	24.5	0.58	0.852
LSV-3	August 25, 2010	2010	10.00	Brown Trout	24.5	0.41	0.596
LSV-3	August 25, 2010	2010	14.20	Brown Trout	24.5	0.58	0.846
LSV-3	August 25, 2010	2010	11.20	Brown Trout	24.5	0.46	0.667
LSV-3	August 25, 2010	2010	10.80	Brown Trout	24.5	0.44	0.644
LSV-3	August 25, 2010	2010	15.10	Brown Trout	24.5	0.62	0.900
LSV-3	August 25, 2010	2010	12.20	Brown Trout	24.5	0.50	0.727
LSV-3	August 25, 2010	2010	16.00	Brown Trout	24.5	0.65	0.953
LSV-3	August 25, 2010	2010	14.60	Brown Trout	24.5	0.60	0.870
HS	September 8, 2006	2006	14.07	Brown Trout	17.4	0.81	1.180
HS	September 8, 2006	2006	20.00	Brown Trout	17.4	1.15	1.678
HS	September 8, 2006	2006	15.48	Brown Trout	17.4	0.89	1.299
HS	May 14, 2007	2007	25.00	Brown Trout	20.5	1.22	1.780
HS	August 24, 2007	2007	27.10	Brown Trout	21.4	1.27	1.849
HS	August 24, 2007	2007	22.70	Brown Trout	21.4	1.06	1.549
HS	August 24, 2007	2007	21.00	Brown Trout	21.4	0.98	1.433
HS	August 24, 2007	2007	28.80	Brown Trout	21.4	1.35	1.965
HS	May 17, 2008	2008	28.20	Brown Trout	27.3	1.03	1.508
HS	May 17, 2008	2008	38.90	Brown Trout	27.3	1.42	2.080

Table G-1
Site-Specific Brown Trout Whole Body Tissue and Surface Water Selenium Concentrations for Deriving Whole Body and Egg BAFs

Station	Date	Year	Whole Body Se mg/kg dw	Species	SW Se Diss ug/L	Whole Body BAF FT (mg/kg) / SW (ug/L))	Egg BAF (WB to Egg CF = 1.46)
HS	May 17, 2008	2008	30.80	Brown Trout	27.3	1.13	1.647
HS	September 4, 2008	2008	22.80	Brown Trout	53.6	0.43	0.621
HS-3	September 6, 2006	2006	17.52	Brown Trout	9.2	1.90	2.780
HS-3	September 6, 2006	2006	20.43	Brown Trout	9.2	2.22	3.242
HS-3	September 6, 2006	2006	25.61	Brown Trout	9.2	2.78	4.064
HS-3	September 6, 2006	2006	18.84	Brown Trout	9.2	2.05	2.990
HS-3	May 12, 2007	2007	22.00	Brown Trout	18	1.22	1.784
HS-3	May 12, 2007	2007	14.70	Brown Trout	18	0.82	1.192
HS-3	May 12, 2007	2007	21.40	Brown Trout	18	1.19	1.736
HS-3	May 12, 2007	2007	17.20	Brown Trout	18	0.96	1.395
HS-3	August 28, 2007	2007	19.70	Brown Trout	16.1	1.22	1.786
HS-3	August 28, 2007	2007	18.40	Brown Trout	16.1	1.14	1.669
HS-3	August 28, 2007	2007	18.30	Brown Trout	16.1	1.14	1.660
HS-3	August 28, 2007	2007	13.70	Brown Trout	16.1	0.85	1.242
HS-3	August 28, 2007	2007	24.10	Brown Trout	16.1	1.50	2.185
HS-3	August 28, 2007	2007	16.20	Brown Trout	16.1	1.01	1.469
HS-3	August 28, 2007	2007	12.20	Brown Trout	16.1	0.76	1.106
HS-3	August 28, 2007	2007	24.40	Brown Trout	16.1	1.52	2.213
HS-3	August 28, 2007	2007	19.30	Brown Trout	16.1	1.20	1.750
HS-3	August 28, 2007	2007	16.30	Brown Trout	16.1	1.01	1.478
HS-3	August 28, 2007	2007	14.20	Brown Trout	16.1	0.88	1.288
HS-3	May 16, 2008	2008	26.30	Brown Trout	26	1.01	1.477
HS-3	September 5, 2008	2008	24.30	Brown Trout	37.5	0.65	0.946
HS-3	September 5, 2008	2008	28.10	Brown Trout	37.5	0.75	1.094
HS-3	September 5, 2008	2008	32.20	Brown Trout	37.5	0.86	1.254
HS-3	September 5, 2008	2008	25.30	Brown Trout	37.5	0.67	0.985
HS-3	September 5, 2008	2008	24.90	Brown Trout	37.5	0.66	0.969
HS-3	September 5, 2008	2008	35.20	Brown Trout	37.5	0.94	1.370
HS-3	September 5, 2008	2008	26.90	Brown Trout	37.5	0.72	1.047
HS-3	September 5, 2008	2008	28.00	Brown Trout	37.5	0.75	1.090
HS-3	September 5, 2008	2008	38.50	Brown Trout	37.5	1.03	1.499
HS-3	August 28, 2010	2010	22.30	Brown Trout	36.6	0.61	0.890
HS-3	August 28, 2010	2010	25.10	Brown Trout	36.6	0.69	1.001
HS-3	August 28, 2010	2010	20.40	Brown Trout	36.6	0.56	0.814
HS-3	August 28, 2010	2010	15.00	Brown Trout	36.6	0.41	0.598
HS-3	August 28, 2010	2010	18.80	Brown Trout	36.6	0.51	0.750
HS-3	August 28, 2010	2010	13.80	Brown Trout	36.6	0.38	0.550
HS-3	August 28, 2010	2010	16.00	Brown Trout	36.6	0.44	0.638
HS-3	August 28, 2010	2010	11.90	Brown Trout	36.6	0.33	0.475
HS-3	August 28, 2010	2010	22.70	Brown Trout	36.6	0.62	0.906
HS-3	August 28, 2010	2010	22.10	Brown Trout	36.6	0.60	0.882
HS-3	August 28, 2010	2010	17.60	Brown Trout	36.6	0.48	0.702

Table G-1
Site-Specific Brown Trout Whole Body Tissue and Surface Water Selenium Concentrations for Deriving Whole Body and Egg BAFs

Station	Date	Year	Whole Body Se mg/kg dw	Species	SW Se Diss ug/L	Whole Body BAF FT (mg/kg) / SW (ug/L))	Egg BAF (WB to Egg CF = 1.46)
HS-3	August 28, 2010	2010	23.90	Brown Trout	36.6	0.65	0.953
HS-3	August 28, 2010	2010	17.70	Brown Trout	36.6	0.48	0.706
HS-3	August 28, 2010	2010	19.70	Brown Trout	36.6	0.54	0.786
HS-3	August 28, 2010	2010	20.60	Brown Trout	36.6	0.56	0.822
HS-3	August 28, 2010	2010	25.00	Brown Trout	36.6	0.68	0.997
HS-3	August 28, 2010	2010	13.50	Brown Trout	36.6	0.37	0.539
HS-3	August 28, 2010	2010	25.20	Brown Trout	36.6	0.69	1.005
HS-3	August 28, 2010	2010	18.00	Brown Trout	36.6	0.49	0.718
HS-3	August 26, 2011	2011	21.00	Brown Trout	77.4	0.27	0.396
HS-3	August 26, 2011	2011	23.70	Brown Trout	77.4	0.31	0.447
HS-3	August 26, 2011	2011	35.90	Brown Trout	77.4	0.46	0.677
HS-3	August 26, 2011	2011	28.60	Brown Trout	77.4	0.37	0.539
LSS	September 13, 2009	2009	12.10	Brown Trout	9.4	1.29	1.879
LSS	September 13, 2009	2009	13.80	Brown Trout	9.4	1.47	2.143
LSS	September 13, 2009	2009	10.00	Brown Trout	9.4	1.06	1.553
LSS	September 13, 2009	2009	15.40	Brown Trout	9.4	1.64	2.392
LSS	September 13, 2009	2009	16.40	Brown Trout	9.4	1.74	2.547
LSS	September 13, 2009	2009	12.50	Brown Trout	9.4	1.33	1.941
LSS	September 13, 2009	2009	10.20	Brown Trout	9.4	1.09	1.584
LSS	August 26, 2010	2010	12.30	Brown Trout	13.8	0.89	1.301
LSS	August 26, 2010	2010	13.20	Brown Trout	13.8	0.96	1.397
LSS	August 26, 2010	2010	11.50	Brown Trout	13.8	0.83	1.217
LSS	August 26, 2010	2010	11.47	Brown Trout	13.8	0.83	1.213
LSS	August 26, 2010	2010	9.61	Brown Trout	13.8	0.70	1.017
LSS	August 26, 2010	2010	12.80	Brown Trout	13.8	0.93	1.354
LSS	August 26, 2010	2010	8.88	Brown Trout	13.8	0.64	0.939
LSS	August 26, 2010	2010	7.17	Brown Trout	13.8	0.52	0.759
LSS	August 26, 2010	2010	10.10	Brown Trout	13.8	0.73	1.069
LSS	August 26, 2010	2010	11.30	Brown Trout	13.8	0.82	1.196
LSS	August 26, 2010	2010	10.80	Brown Trout	13.8	0.78	1.143
LSS	August 26, 2010	2010	8.53	Brown Trout	13.8	0.62	0.902
LSS	August 26, 2010	2010	10.30	Brown Trout	13.8	0.75	1.090
LSS	August 26, 2010	2010	10.80	Brown Trout	13.8	0.78	1.143
LSS	August 26, 2010	2010	17.40	Brown Trout	13.8	1.26	1.841
LSS	August 26, 2010	2010	14.50	Brown Trout	13.8	1.05	1.534
LSS	August 26, 2010	2010	17.50	Brown Trout	13.8	1.27	1.851
LSS	August 26, 2010	2010	16.00	Brown Trout	13.8	1.16	1.693
LSS	August 26, 2010	2010	12.80	Brown Trout	13.8	0.93	1.354
LSS	August 28, 2011	2011	13.10	Brown Trout	14.9	0.88	1.284
LSS	August 28, 2011	2011	11.20	Brown Trout	14.9	0.75	1.097

Table G-1
Site-Specific Brown Trout Whole Body Tissue and Surface Water Selenium Concentrations for Deriving Whole Body and Egg BAFs

Station	Date	Year	Whole Body Se mg/kg dw	Species	SW Se Diss ug/L	Whole Body BAF FT (mg/kg) / SW (ug/L))	Egg BAF (WB to Egg CF = 1.46)

Grouping	Season	Median WB BAF	Median Egg BAF
All Site	All Seasons	1.112	1.624
Hoopes	All Seasons	0.81	1.19
Sage	All Seasons	0.84	1.22
Crow	All Seasons	3.36	4.91
South Sage	All Seasons	0.91	1.33
Hoopes, Sage, SF Sage	All Seasons	0.84	1.23
All Site	Summer/fall	1.027	1.499
Hoopes	Summer/fall	0.72	1.05
Sage	Summer/fall	0.81	1.18
Crow	Summer/fall	2.81	4.10
South Sage	Summer/fall	0.91	1.33
Hoopes, Sage, SF Sage	Summer/fall	0.81	1.18

Appendix H

Implementation Plan

1.0 IMPLEMENTATION CONSIDERATIONS

The 2016 National criterion recommends that the egg/ovary criterion element take precedence over whole-body tissue or water elements of the criterion. In the absence of egg-ovary data, the whole-body tissue data take precedence over the water element of the criterion. In the absence of egg-ovary or whole-body data (e.g., in fishless waters), the water element of the criterion can be used for routine monitoring and compliance assessment. Figure H-1 provides a flow diagram of monitoring actions relative to gaging compliance with the proposed SSSC.

While egg tissue has been demonstrated the most important endpoint to measure the effects of chronic exposure to selenium, it is not the most practical to monitor. Collecting egg tissue requires that fish be present for monitoring at a specific time of year (i.e., during or just prior to spawning), and requires manually spawning eggs from maternal fish. In addition, while the general spawning period may be known, capture of pre-spawn female fish requires a larger effort than simple collection of fish for whole body tissue analysis. The data collected at the Site has generated a well-supported egg criterion that has been translated to two water criteria using USEPA (2016) recommended approaches, yielding a water concentration protective of fish populations. In effect, if concentrations of selenium are less than 4.2 µg/L in surface waters for Crow Creek downstream of Sage Creek or 16.7 ug/L in Hoopes Spring, Sage Creek, or South Fork Sage Creek, then egg concentrations should be less than 20.5 mg/kg dw. Collection of water quality samples is therefore the primary focus of the compliance monitoring effort.

1.1 Site-Specific Considerations

Elevated selenium concentrations at the Site are a result of releases due to historical mining activities at the Smoky Canyon Mine. Overburden materials removed to access the phosphate ore were placed in external overburden disposal areas (ODAs) or used to backfill mining pits. Selenium has been released from these materials to underlying Wells Formation groundwater and transported with groundwater to spring discharges to surface water (i.e., Hoopes Spring and South Fork Sage Creek Springs).

Under CERCLA Simplot has implemented two early remedial actions at a key ODA (Pole Canyon ODA), which have significantly reduced releases of selenium to the surrounding environment. Because of the time that groundwater takes to travel from the ODA to the springs it will take several years before reductions in selenium concentrations will be realized at the springs. In addition, Simplot is implementing a pilot study water treatment system at the springs that will reduce selenium concentrations. This will treat 2,000 gallons per minute of water from the springs using a fluidized biological reactor technology. Site-wide remedial actions are also being evaluated under the CERCLA program and a remedy will be selected by the regulatory agencies and documented in a Record of Decision. The actions will then be implemented by Simplot. The actions are expected to be a combination of source controls at the ODAs and water treatment.

The actions will reduce selenium concentrations in surface water over time to meet the selenium criterion (the expected timeframe will be documented in the ROD).

As such selenium concentrations are currently above the criterion but will reduce over time. This is an important consideration in the overall monitoring and interpretation. In the near future, selenium concentrations will continue to be above the criterion, but at some future time frame will come within range of it. Fish tissue concentrations would still expected to be above the criterion for few years until selenium concentrations decline in dietary food items.

These site-specific considerations are accounted for in the proposed implementation approach set out below. In the period while concentrations are reducing to the range of the criterion due to the effect of remedial actions, selenium concentration monitoring will be required in water only. Once the concentrations have been close or below the water criterion for 2 years, the compliance approach described below will take effect.

1.2 Proposed Implementation Approach

Using surface water selenium concentrations will allow for a less destructive form of evaluating compliance with the proposed SSSC (i.e., as compared to fish tissue sampling) and is the preferred method of routine monitoring. During the course of monitoring surface water selenium concentrations, if the water-criterion-element value is not exceeded, then it would be concluded that the egg-criterion-element is not exceeded, and correspondingly that the selenium concentrations would not have adverse effects on fish populations. In the event that an exceedance of the water criterion occurs, tissue monitoring could occur as a follow up, if fish are present. In the event no fish are present in a waterbody, the nearest downstream location where fish are present would be examined to assess if the tissue data indicate an exceedance. Therefore, although surface water selenium measurement will be an effective monitoring tool, the ultimate decision on compliance would depend on the tissue data.

Monitoring to evaluate compliance would include selecting representative locations, the frequency of sampling, and establishing how the data would be used to determine compliance. The subsections that follow present key components of how to effectively implement the SSSC.

1.2.1 Monitoring Locations and Frequency

Water quality varies within each of the Site drainages. The purpose of the monitoring locations described below is to provide representative selenium measurement data in surface water. Due to the record of selenium measurement data in surface waters at several locations, the following locations are proposed as routine monitoring locations for surface water to assess compliance (Figure E-2):

- **HS-3:** Hoopes Spring channel near the confluence with Sage Creek.

- **LSS:** Lower South Fork Sage Creek to monitor surface water downstream of the SFSCS complex.

- **LSV-2C:** Sage Creek downstream of Hoopes Spring.

- **LSV-4:** Sage Creek near confluence of Sage Creek and Crow Creek to monitor area after Sage Creek receives waters from both Hoopes Spring and SFSC.

- **CC-350:** Crow Creek upstream of Sage Creek and downstream of Deer Creek to monitor potential influence of Panels F and G.

- **CC-1A:** Crow Creek downstream of Sage Creek

- **Crow Creek at the State Line:** Monitor a location to be determined immediately upstream of the Idaho-Wyoming state line.

- **LP-PD**: Pole Canyon Creek downstream of the pipeline diversion outfall

- **NSV-6** or Upstream of Sage Creek and North Fork Sage Creek confluence.

Semi-annual surface water monitoring is proposed to evaluate compliance with the SSSC: spring (April or May) and fall (August or September). The data collected in the fall (low-flow conditions) will be used to evaluate compliance. Data collected in the spring are used to provide additional temporal data on how selenium levels may be changing. A grab sample will be collected at each location for selenium analysis.

1.2.2 Aggregation of Data to Assess Compliance

If the selenium concentration in the grab sample collected each fall is below the criterion then compliance would be demonstrated at that location. If the concentration is above the criterion at that location, then the following process would be implemented (after the initial period of reducing concentrations, as described above).

Water Element - For a bioaccumulative chemical such as selenium, a short-term exposure (e.g., days) at or above the water SSSC element is not likely to be of sufficient magnitude or duration for adverse bioaccumulation. Compliance with the water criterion is based on a 30-day average. If selenium concentrations exceed the water SSSC element at a particular location, monitoring at each location where an exceedance occurs would be immediately followed by four weeks of monitoring (once per week or more frequently).

If the average selenium concentration is above the criterion, then Simplot may elect to implement a Corrective Action to reduce concentrations, or to collect whole body tissue data at the same locations, as described below.

Whole-Body Tissue Element - Details for monitoring whole body fish tissue would be compiled in a Work Plan prepared prior to field efforts. For whole body tissue analyses, the size of the fish would be consistent with the Interagency Fish Tissue Protocol, which focuses on collection of juveniles (< 100 mm and, if need be, up to 150 mm). No gender specificity would be required for juvenile fish destined for whole body analysis. Juvenile fish could be sampled during any time period, but due to selenium behavior at this Site, which increases as flow decrease, ideal monitoring will occur in late summer or fall. From each location where the water-criterion-element value is exceeded, five to ten trout would be collected for selenium tissue analysis. All ten trout would be the same species, preferably brown trout.

Whole-body tissue data would be aggregated as an arithmetic mean, but typical summary statistics would be developed if sufficient numbers of samples are collected from a location (mean, median, maximum, minimum, standard deviation, and upper and lower 95 percent confidence intervals). If the arithmetic mean whole body selenium concentration is below the whole body tissue criterion, then compliance is demonstrated and no additional monitoring or actions are required. The monitoring program would return to routine water quality monitoring. If the average selenium concentration is above the criterion, then Simplot may elect to implement a Corrective Action to reduce concentrations, or to collect egg tissue data at the same locations, as described below.

Egg Tissue Element - Details for monitoring egg tissue will be compiled in a Work Plan prepared prior to field efforts. If egg tissue monitoring is to be conducted, it would occur during the fall spawning period. The location would be based on the surface water monitoring location, and should focus on locations that include a mixture of habitats including favorable spawning gravels with appropriate water velocity and nearby deep pools or cover. Fall egg-tissue collection would be timed to correspond to the presence of pre-spawn females.

If egg tissues are being collected, pre-spawn female brown trout is the target species. Fish size should be greater than 300 mm or larger. Collection of egg tissue samples is highly destructive sampling because it removes eggs from the next year's age class. Therefore, if egg tissues are to be collected, it is suggested that eggs from five or fewer adult females be collected for a location. Five grams is expected to be adequate for selenium egg-tissue concentration analysis. Of the egg-donor fish, three should be retained for whole body tissue analysis and complete egg stripping. Eggs and whole body maternal fish would be sent to the laboratory as two separate samples for analysis for each fish.

Analytical data for egg-tissue measurements would be aggregated using typical summary statistics (mean, median, maximum, minimum, standard deviation, and upper and lower 95 percent confidence intervals). The compliance measure would be the arithmetic mean. If the mean concentration is below the criterion then compliance is demonstrated and no additional monitoring or actions are required. The monitoring program would return to routine water quality monitoring. If the average selenium concentration is above the criterion, then Simplot will assess the reasons for the non-compliance and propose Corrective Actions to remedy them.

1.3 Reporting

Reporting surface water quality data, whole body tissue data, and or egg tissue data to IDEQ will require that laboratory analytical results be obtained in a timely fashion. Typically, results can be obtained within 2-3 weeks. Result of monitoring would be due to the Agencies within 45 days of the initial monitoring. The reporting format will discussed with IDEQ.

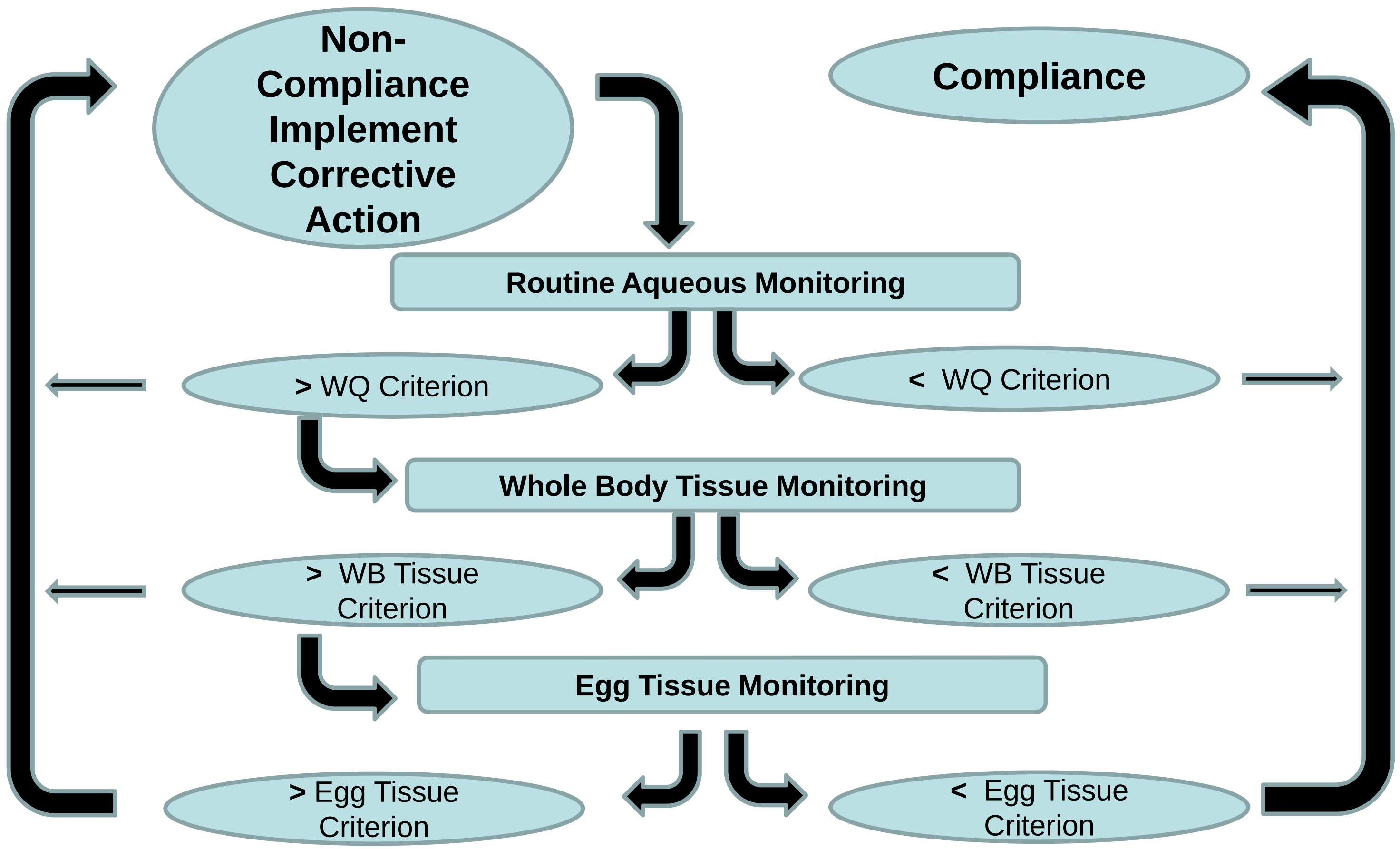

Figure H-1
Flow Diagram for Implementing the Site-Specific Selenium Criterion for the Site

J.R. Simplot Company
Site-Specific Selenium Criterion

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REV: 1	BY: SMC · CHK: SMC

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