

BULL RUN WATER SUPPLY HABITAT CONSERVATION PLAN

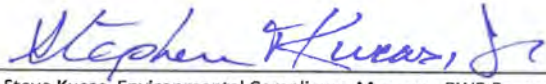
Annual Compliance Report 2017—Year 8



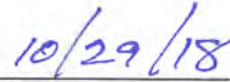
Final • November 2018



Under penalty of law, I certify that, to the best of my knowledge, after appropriate inquiries of all relevant persons involved in the preparation of this report, the information submitted is true, accurate, and complete.



Steve Kucas, Environmental Compliance Manager, PWB Resource Protection



Date

Contents

1. Executive Summary	1
2. Introduction	3
2.1 Habitat Conservation Plan Background.....	3
2.2 Annual Report Organization	4
3. HCP Monitoring, Research, and Adaptive Management Programs	5
3.1 Monitoring Program	5
3.2 Research Program.....	5
3.3 Adaptive Management Program.....	5
4. Monitoring Measures Status and Accomplishments	6
4.1 Compliance Monitoring.....	6
4.1.1 Bull Run Measures.....	6
4.1.2 Offsite Measures	33
4.1.3 Monitoring for Clean Water Act 401 Certification Conditions.....	45
4.2 Effectiveness Monitoring.....	46
4.2.1 Large Wood and Log Jam Placement.....	46
4.3 Research Program.....	48
4.3.1 Bull Run Research	48
4.3.2 Sandy River Basin Research	50
4.4 Adaptive Management Program.....	51

Appendixes

- A. Effectiveness Monitoring for Offsite In-Channel Conservation Measures
- B. Monitoring Results for Certification According to Section 401 of the Clean Water Act
- C. Lower Bull Run River Spawning Gravel Research
- D. Total Dissolved Gases in the Bull Run River
- E. Lower Bull Run River Adult Chinook Population
- F. Sandy River Basin Smolt Monitoring
- G. Lower Bull Run River Spawning Gravel Scour Research
- H. Western Toad Monitoring for Reservoir Operations
- I. Correspondence on Measures

Tables

Table 1. Flow Commitments for the Lower Bull Run River During Normal Water Years, Measured at USGS Gage No. 14140000, RM 4.7	7
Table 2. Dates, Inflow, and Flow Targets for October and November 2017	9
Table 3. Critical Spring and Fall Season Triggers.....	11
Table 4. Flow Commitments for the Lower Bull Run River During Water Years with Critical Spring Seasons.....	11
Table 5. Flow Commitments for the Lower Bull Run River During Water Years with Critical Fall Seasons	12
Table 6. Appropriate Numeric Temperature Criteria.....	17
Table 7. Easement Acre Targets and Acres Obtained for HCP Implementation, Year 8 (2017).....	34
Table 8. Location, Amount, and Estimate of Canopy Cover for Easements, HCP Year 8 (2017)	37
Table 9. Water Quality Parameters to Monitor for CWA Section 401 Certification	45
Table 10. Past Projects Funded through the HCP Habitat Fund	52
Table 11. Planned Projects to be Funded through the HCP Habitat Fund	54
Table 12. Summary of All Measures.....	55

Figures

Figure 1. USGS Gaging Stations for Compliance Monitoring	6
Figure 2. Lower Bull Run River Minimum and Actual Flows ^a in 2017	10
Figure 3. 7-Day Moving Average of Daily Maximum Water Temperature in the Lower Bull Run River at Larson's Bridge (USGS Gage No. 14140020) and at Little Sandy River (USGS Gage No. 14141500) for 2017	19
Figure 4. Reservoir 1 Elevations ^a During 2017	22
Figure 5. Reservoir 2 Elevations ^a During 2017	23
Figure 6. Reservoir 1 and Dam 1 During A Drawdown Period	24
Figure 7. Reed Canarygrass Removal, Spring 2017.....	25
Figure 8. Grass Stubble and Mineral Soils after Reed Canarygrass Removal, 2017	26
Figure 9. Placing Gravel in the Bull Run River in 2016.....	29
Figure 10. Looking Across the Sandy River at the Cornwall Easement (North Side)	36
Figure 11. Looking Across the Sandy River at the Camp Collins Easement (North Side)...	38
Figure 12. Typical Large Wood Placement	42
Figure 13. PWB Staff Evaluating Spawning Gravel in the Lower Bull Run River	48

Acronyms and Abbreviations

cfs	cubic feet per second
DO	dissolved oxygen
EDT	Ecosystem Diagnosis and Treatment
ESA	Endangered Species Act
HCP	Habitat Conservation Plan
JOM	juvenile outmigrants
LCR	Lower Columbia River
MSL	mean sea level
NMFS	National Marine Fisheries Service
O&M	operations and maintenance
ODEQ	Oregon Department of Environmental Quality
ODFW	Oregon Department of Fish and Wildlife
PGE	Portland General Electric
PHP	Portland Hydroelectric Project
PWB	Portland Water Bureau
RM	river mile
TDG	total dissolved gas
TMDL	total maximum daily load
USGS	U.S. Geological Survey
7DADM	7-day average of daily maximum temperature

1. Executive Summary

For 2017, the City met the terms and conditions of every HCP conservation measure with the exception of downstream water temperature targets. For 34 days mostly occurring from mid-September to mid-October, the temperature of the Bull Run River exceeded the HCP temperature target. The City presented the 2017 water temperature information to the Oregon Department of Environmental Quality, the National Marine Fisheries Service, and the Oregon Department of Fish and Wildlife. Those agencies directed the City to continue to monitor water temperatures in the lower Bull Run River in 2018 and to work with the agencies, starting in the spring, on operational measures to improve performance of the system for temperature control.

The Bull Run Water Supply Habitat Conservation Plan (HCP) is a 50-year plan to protect and improve aquatic habitat while continuing to manage the Bull Run River watershed as a water supply for the City of Portland (City), Oregon. The City created the HCP, with technical assistance from the Sandy River Basin Partners, to minimize and mitigate the effects of covered activities associated with the Bull Run water supply operations on listed and unlisted Endangered Species Act species and their associated habitat. The primary focus of the HCP is protection for ESA-listed anadromous fish under the jurisdiction of the National Marine Fisheries Service (NMFS), but the plan also includes other species. In 2009, NMFS issued an Incidental Take Permit to the City pursuant to Section 10(a)(1)(B) of the Endangered Species Act and signed an Implementing Agreement with the City. The HCP and each of its provisions are incorporated into those agreements.

In addition, in 2008, the Oregon Department of Environmental Quality's (ODEQ) approved the City's Temperature Management Plan for the Lower Bull Run River (Appendix I of the HCP). The City's plan addresses temperature requirements for the lower Bull Run River that are articulated in the Sandy River Basin Total Maximum Daily Load (TMDL) report.

In 2012, the City obtained a Clean Water Act 401 Certification from ODEQ for Portland's Bull Run Reservoir Hydroelectric Project associated with the improvements to the water intake towers at Bull Run Dam 2. A report on water quality monitoring required by the certification is included in this compliance report as Appendix B.

In 2016 PWB chose to begin monitoring water temperature and toad breeding site selection to determine whether Measure R-3, Reed Canarygrass Removal, was having the

desired outcomes for western toads (*Bufo boreas*) and northern red-legged frogs (*Rana aurora*). Appendix H summarizes the results of the monitoring.

The HCP includes 49 conservation measures to protect and improve habitat and to avoid or minimize the impacts of the Bull Run water supply system. Annual reports from the City are required to document compliance with the conservation measures, monitoring requirements, research efforts, and adaptive management actions that are implemented.

The eighth year of the HCP was 2017, referred to as Year 8 throughout this document. This is the eighth Annual Compliance Report.

Changing circumstances and conditions have required modifications to some of the original HCP measures. The changed measures were implemented with target amounts or locations that accounted for other measures that could not be implemented (for example, canceling a large wood project in one location and increasing the amount of large wood pieces in a second location). These changes are noted in this report and documented in an appendix of key correspondence with NMFS (Appendix I).

The City met the terms and conditions of every HCP conservation measure for 2017 with the exception of downstream water temperature targets. For 34 days, the temperature of the Bull Run River exceeded the HCP temperature target. The City presented the 2017 water temperature information to the Oregon Department of Environmental Quality, the National Marine Fisheries Service, and the Oregon Department of Fish and Wildlife. Those agencies directed the City to continue to monitor water temperatures in the lower Bull Run River in 2018 and to work with them, starting in the spring, on operational measures to improve performance of the system for temperature control.

2. Introduction

2.1 Habitat Conservation Plan Background

In April 2009, the National Marine Fisheries Service (NMFS) signed a Permit for Incidental Take of Threatened Species number 13812, granting the City of Portland (City) authorization to operate its Bull Run water supply subject to the provisions of the implementing agreement for the Bull Run Water Supply Habitat Conservation Plan (HCP). The Incidental Take Permit covers four anadromous fish species listed under the Endangered Species Act (ESA) of 1974—Lower Columbia River (LCR) Chinook salmon (*Oncorhynchus tshawytscha*), Columbia River chum salmon (*O. keta*), LCR coho salmon (*O. kisutch*), LCR steelhead (*O. mykiss*)—and Pacific eulachon (*Thaleichthys pacificus*).

The Bull Run HCP includes 49 habitat conservation measures that are expected to minimize and mitigate, to the maximum extent practicable, the effects of take on the covered fish and wildlife. The measures are designed to improve habitat conditions for the fish and 18 additional wildlife species in the Bull Run subbasin and the Sandy River Basin, watersheds that are part of the lower Columbia River Basin in northwest Oregon. The Sandy River Basin was included in the plan in order to fully address the Incidental Take Permit requirements.

Measures in the Bull Run include modifying water supply infrastructure, implementing seasonal flow regimes and downramping rates, placing gravel and large wood, establishing fish passage in certain streams, removing invasive species, and defining operational standards to avoid or minimize the effects of operations on the covered species. The measures in the Sandy River Basin, called offsite measures, include large wood and log jam placement, channel redesign and reconstruction, establishing fish passage in certain streams, establishing easements and making improvements in riparian zones, and acquiring land parcels and water rights.

The HCP measures are being implemented and monitored over the course of 50 years. Measures in some reaches are being implemented early in the term of the HCP to provide the greatest improvements over time. Not every measure was implemented in the first year, however. Other measures slated to be implemented later in the HCP time frame are mentioned by name in this report but are not extensively discussed. By necessity, the terms of some measures have changed in response to changes in the Sandy River watershed. The City has maintained full records of measure adjustment terms, including correspondence with NMFS, documenting approval of the changes. Correspondence is summarized in this compliance report appendix each year.

A key element of the HCP involves improving water temperature conditions for spawning and rearing salmonid fish. Compliance with this objective also fulfills the temperature objectives for the lower Bull Run River that are articulated in the Oregon Department of Environmental Quality's (ODEQ's) Sandy River Basin Total Maximum

Daily Load (TMDL) report (ODEQ 2005). The City's Temperature Management Plan for the Lower Bull Run River, approved by ODEQ in 2008, is Appendix I of the City's HCP.

2.2 Annual Report Organization

This report is organized to provide the status of work and planned accomplishments for HCP monitoring, the research efforts, and the Portland Water Bureau's adaptive management program. The monitoring section is divided into compliance and effectiveness monitoring. Within each of these monitoring subsections, information is provided for the Bull Run Watershed measures and for the offsite measures in the Sandy River Basin, respectively. Measures that share similar objectives (such as large wood placement or obtaining riparian easements) are grouped together. The introductory subsections titled Measure Commitments are taken directly from the HCP and are characterized by a font that is different from the rest of the report text.

The HCP outlines a specific program of monitoring, research, and adaptive management to evaluate habitat improvements resulting from the measures. The monitoring component includes both compliance and effectiveness monitoring. This seventh yearly report of accomplishments includes compliance monitoring information in Section 4.1, effectiveness monitoring information in Section 4.2, and a summary of the planned research in Section 4.3. Reports describing the monitoring, research, and results in detail are available as Appendixes A through H. Appendix I summarizes key correspondence between PWB and NMFS on obtaining authorization for changes to measures, including adjustments to the terms of selected measures.

Table 12, beginning on page 12, provides summary information for the status of each measure. The table outlines the measurable habitat objective, the method of compliance monitoring described in the HCP, the years in which the measure is planned to be implemented, and a description of the status. Table 12 also indicates where the effectiveness monitoring reports (Appendixes A, B, and H) and the research reports (Appendixes C, D, and E) are relevant to measures in this annual report. Measures that are not relevant to the current reporting year are shown with a gray background. Measures that are due to be started in future years are blank in the "Status" column.

3. HCP Monitoring, Research, and Adaptive Management Programs

3.1 Monitoring Program

The monitoring program for the HCP is designed to document compliance and verify progress toward meeting the goals and objectives outlined in Chapter 6 of the HCP. The monitoring program comprises both compliance and effectiveness monitoring. Compliance monitoring tracks progress implementing the HCP measures. Compliance monitoring reports focus on the work completed and planned for the following calendar year. Monitoring Results for Certification According to Section 401 of the Clean Water Act provides results of water quality monitoring in Bull Run Reservoir 2 and lower Bull Run River before and after the modifications to the water intake towers at Bull Run Dam 2 (see Appendix B). Effectiveness monitoring, described in detail in Appendix A, is provided for those measures for which the habitat outcomes are somewhat uncertain. Effectiveness monitoring data will enable an assessment of whether the measurable habitat objectives have been met.

3.2 Research Program

The research program for the HCP focuses on four components in the Bull Run River Watershed and one component in the larger Sandy River Basin. In the Bull Run Watershed, the City is studying the placement of spawning gravel, the degree of gravel scour in spawning beds suitable for Chinook spawning, the concentrations of total dissolved gases at certain locations, and the abundance of spawning Chinook adults. For the Sandy River Basin, the City is collaborating with other organizations doing research to measure the number of juvenile salmonid outmigrants at the reach and basin levels. See Appendixes C–F for detailed reports on the research and results.

3.3 Adaptive Management Program

Adaptive management is an approach that involves monitoring the outcomes of a project and, on the basis of the monitoring results, improving the way the project is managed. The City anticipates that, over the course of its 50-year HCP, scientific understanding of the issues relating to salmonid habitat will improve and some conditions will change such that some reconsideration and adaptation of its approach will be appropriate. The adaptive management program provides for ongoing evaluation of individual measures as well as milestones for evaluating the HCP as a whole. A key measure for adaptive management is the Habitat Fund, described in Section 4.4.

4. Monitoring Measures Status and Accomplishments

4.1 Compliance Monitoring

Most of the HCP measures pose very little uncertainty as to whether implementing the measures will meet the objectives. For these measures, the City is conducting compliance monitoring to track implementation and document completion.

4.1.1 Bull Run Measures

The City is using established United States Geological Survey (USGS) sites on the lower Bull Run and Little Sandy rivers to monitor river flow and water temperature. River flow compliance will be measured at USGS Gage No. 14140000 (at river mile [RM] 4.7 on the Bull Run River). This gage will also be used to determine compliance with the downramping rate. Compliance with temperature measures will be based on the temperature data recorded at USGS Gage No. 14140020 on the lower Bull Run River (at RM 3.8, the Larson's Bridge site) and at USGS Gage No. 14141500 on the Little Sandy River (at RM 1.95, the Little Sandy Dam site), as shown in Figure 1.

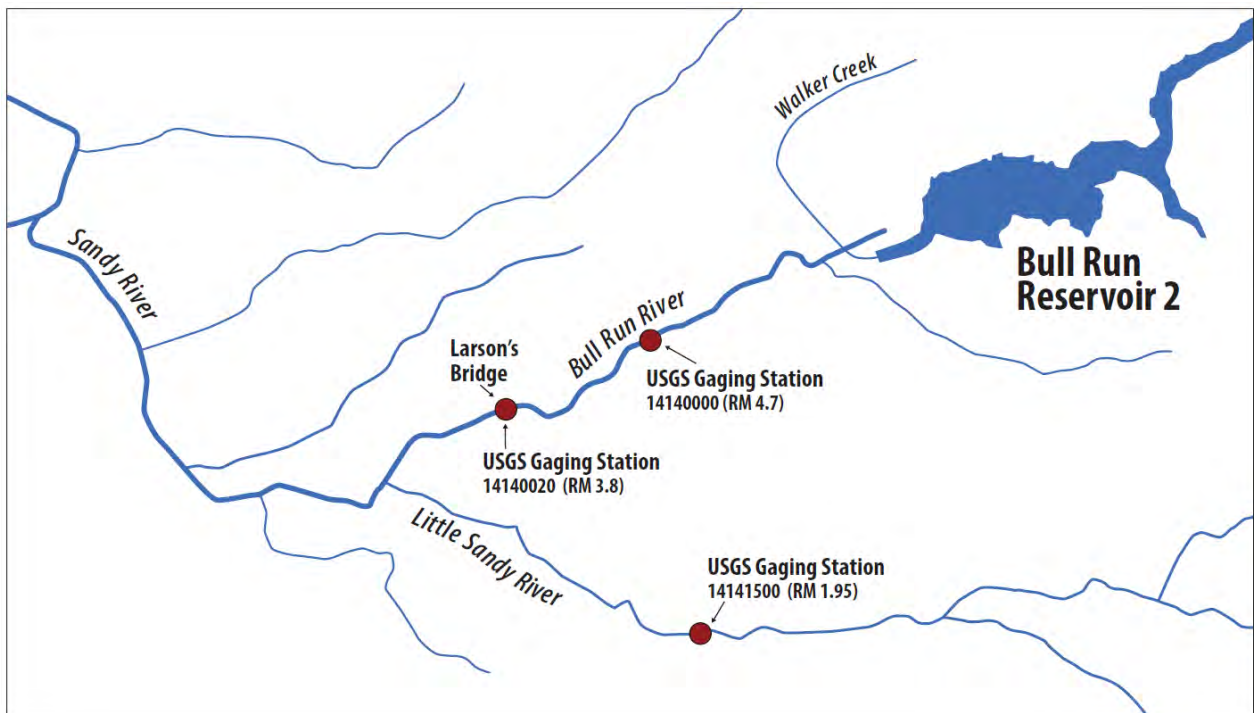


Figure 1. USGS Gaging Stations for Compliance Monitoring

Measure F-1—Minimum Instream Flow, Normal Water Years**Location:** Bull Run Watershed**Benefits:** Bull Run River flow**Contact:** Kristin Anderson, Hydrologist, PWB Resource Protection**Primary Objective**

Measure F-1 describes minimum instream flows to improve fish habitat conditions in the lower Bull Run River during normal water years. The measure includes guaranteed minimum flow amounts and other criteria that will maintain flow levels for spawning, rearing, and migrating salmonids and other aquatic species.

Measure Commitments

Measure F-1—Minimum Instream Flows, Normal Water Years: For HCP Years 1–50, the Bull Run water supply will be operated during normal water years to achieve the guaranteed flows in the lower Bull Run River specified in Table 1 (expressed in mean daily flows in cubic feet per second, cfs).

Table 1. Flow Commitments for the Lower Bull Run River During Normal Water Years, Measured at USGS Gage No. 14140000, RM 4.7

Time Period	Guaranteed Minimum Flow (cfs)	Required Percent of Inflow	Maximum Required Flow (cfs)
January 1–June 15	120	n/a ^a	n/a
June 16–June 30	Gradually decrease flows over 15 days from minimum of 120 cfs to a minimum of 35 cfs. If reservoir drawdown begins before June 30, decrease flows at no more than 2"/hour to reach the 20–40 cfs operating range, see below.		
July 1–September 30	Vary flow from 20 cfs to 40 cfs to manage downstream water temperature ^b		
October 1–October 31	70	50%	400
November 1–November 30	150	40%	400
December 1–December 31	120	n/a	n/a

^an/a = not applicable

^bSee Measure T-1.

For the period from June 16 to June 30, the guaranteed minimum flow of 120 cfs will be decreased by 5 cfs per day until the minimum of 35 cfs is achieved at Gage No. 14140000.

Variable flows will be implemented in summer (July through September) of normal water years. Water temperature is a key management concern during this season, and the reservoirs will be operated to take advantage of the limited amount of cold water that can be stored. Releases from the reservoirs will vary with weather conditions to better manage use of the available cold water. During mild weather, when temperatures in the river are naturally lower, less cold water will be released from the reservoirs. During warm weather, when cold water from the reservoirs is needed to moderate river temperatures, more cold water will be released. The resulting average summer flow in normal water years is expected to be 35 cfs.

Flow releases in October and November are defined as a percentage of reservoir inflow, with both upper and lower bounds as shown in Table 1. The City will provide a “floor” or minimum flow levels for the lower Bull Run River. The City will also cap the maximum flow level in October and November to allow the reservoir to refill to reduce the potential for unacceptable turbidity. The percentage of inflow released is higher in October than in November, but the total amount of water released will be higher in November because (1) the floor for the November minimum flow is higher than the floor for October and (2) inflow is generally higher in November than October.

Basing water release on a percentage of inflow will ensure that fall flow in the lower river is determined by flow into the reservoirs, not by the amount of water stored in the reservoirs or the amount diverted for municipal supply. Reservoir storage and diversions are both affected by water demand. Inflow is not affected by water demand.

The City will control streamflow releases below Dam 2 at Headworks (RM 6.0 on the Bull Run River) and the lower Bull Run River flow will be measured at USGS Gage No. 14140000 (RM 4.7). For purposes of determining streamflow releases in October and November, reservoir inflow will be measured and totaled for four USGS Gages (No. 14138850, Bull Run River at RM 14.8; No. 14138870, Fir Creek at RM 0.6; No. 14138900, North Fork Bull Run River at approximately RM 0.2; and No. 14139800, South Fork Bull Run River at RM 0.6). The daily mean flows of the four gages will be added and then multiplied by 1.2 to account for the ungaged area of reservoir inflows in the Bull Run watershed.

City staff will determine the week’s reservoir inflows once a week and determine the following week’s flow target based upon the inflow data. The first determination of reservoir inflow levels will occur prior to October 1. The flow releases to meet the targets will be implemented starting on October 1. Flow release targets will be set each week through the end of November.

Through the term of the HCP, the flow releases in the lower Bull Run River may exceed the guaranteed minimum flows in Table 1 if the reservoir inflows exceed demands for drinking water and the guaranteed minimum flows for fish.

The minimum flow requirements may not be met during the days that the Chinook surveys occur. Flows will be held to less than 150 cfs, as measured at USGS Gage No. 14140000, to allow safe surveying. The surveys are expected to occur approximately once per week from August through November. See Appendix F of the HCP for more details on the Chinook survey procedures.

Status of Work for Calendar Year 2017

The City met the minimum instream flow requirements of HCP Measure F-1 in 2017. Guaranteed minimum flows for normal water years were used as the flow targets for all months of 2017.

During October and November, guaranteed minimum flows were based on a percentage of total inflow to the Bull Run reservoirs during the previous week. Table 2 summarizes the dates and flows used to derive these calculations.

Table 2. Dates, Inflow, and Flow Targets for October and November 2017

Flow Target Period		Index Period		Average Inflow (cfs)	Flow Target (cfs)
From	To	From	To	During Index Period	
1-Oct	3-Oct	19-Sep	25-Sep	106	70
4-Oct	10-Oct	26-Sep	2-Oct	85	70
11-Oct	17-Oct	3-Oct	9-Oct	1066	400
18-Oct	24-Oct	10-Oct	16-Oct	2232	400
25-Oct	31-Oct	17-Oct	23-Oct	1807	400
1-Nov	7-Nov	24-Oct	30-Oct	770	308
8-Nov	14-Nov	31-Oct	6-Nov	686	274
15-Nov	21-Nov	7-Nov	13-Nov	396	158
22-Nov	28-Nov	14-Nov	20-Nov	1267	400
29-Nov	30-Nov	21-Nov	27-Nov	991	397

cfs: cubic feet per second

Releases from Bull Run Reservoir 2 were reduced on October 3, October 18, October 31, November 1, and November 7, 2017, to allow Portland Water Bureau (PWB) fish biologists to safely conduct spawning surveys in the lower Bull Run. On these days, the mean daily flow at USGS Gage No. 14140000 was less than the guaranteed minimum level, a reduction in stream flow that is allowed under the terms of the HCP measure.

Lower Bull Run River flows at USGS Gage No. 14140000 are depicted in Figure 2.

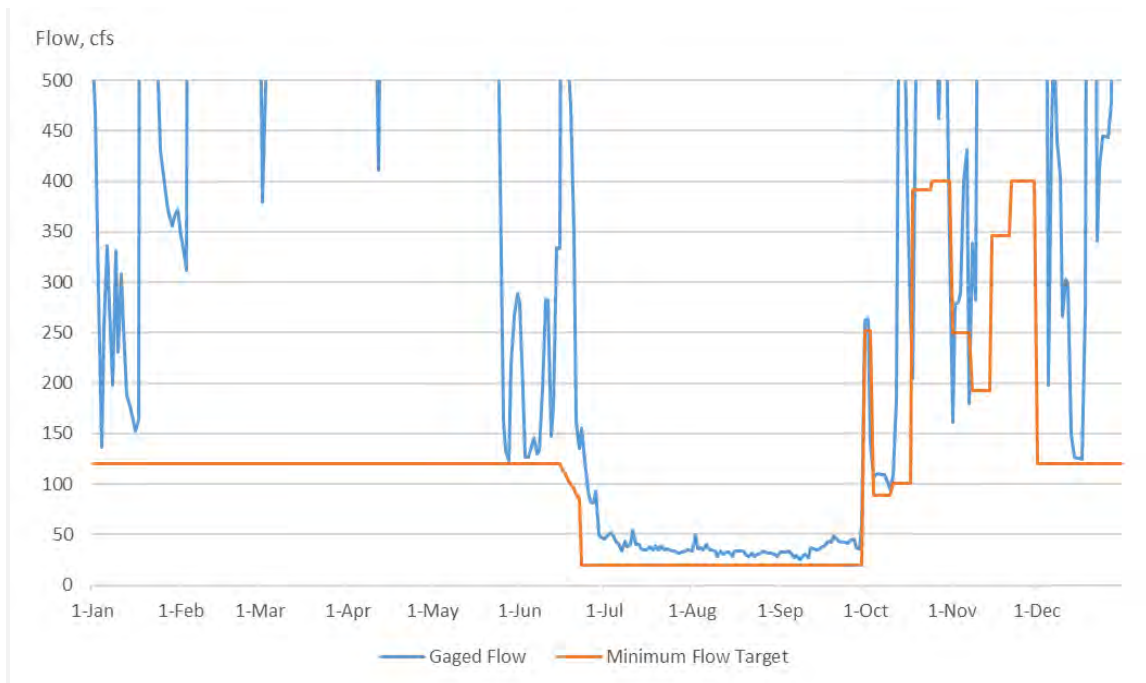


Figure 2. Lower Bull Run River Minimum and Actual Flows^a in 2017

^aFlows exceeding 500 cfs are not shown.

Planned Accomplishments for Calendar Year 2018

The City will continue to set the minimum flow levels early each day so that the daily averages meet or exceed the HCP minimum flow targets. Flow levels will be monitored in 2018 and compared to the guaranteed minimum flows. Normal-year or critical-year flow criteria will be applied as appropriate.

Measure F-2—Minimum Instream Flows, Water Years with Critical Seasons**Location:** Bull Run Watershed**Benefits:** Bull Run River flow**Contact:** Kristin Anderson, Hydrologist, PWB Resource Protection**Primary Objective**

Measure F-2 describes minimum instream flows that will be used during water years with critical seasons. These minimum flows will be used to achieve the guaranteed flows in the lower Bull Run River.

Measure Commitments

Measure F-2—Minimum Instream Flows, Water Years With Critical Seasons: During HCP Years 1–50, for any years that have a critical spring or fall season, the Bull Run water supply will be operated to achieve the guaranteed flows in the lower Bull Run River specified in Tables 3 and 4 (in mean daily flow in cfs). Fall flows in Table 3 will not be implemented more frequently than two years in a row and will not be implemented 4 years after a previous season of critical fall flows has been implemented (to avoid affecting the same age cohort twice). If a year does not have a critical spring or fall season, all flows will be the normal water year flows described in Measure F-1.

The triggers for a critical spring or fall season are defined in Table 3.

Table 3. Critical Spring and Fall Season Triggers

Critical Season	Trigger
Spring	Drawdown occurs prior to June 15
Fall	August and September inflows within lowest 10% of historical record (1940 to current HCP Year)

The response to a critical spring season is outlined in Table 4.

Table 4. Flow Commitments for the Lower Bull Run River During Water Years with Critical Spring Seasons

Time Period	Guaranteed Minimum Flow ^a (cfs)	
June 1–June 30	30	If critical spring season trigger is met, decrease flow after drawdown begins but no earlier than June 1. Maintain downramping rate described in Measure F-3, from 120 cfs to 30 cfs.

^a Measured at USGS Gage No. 14140000 (RM 4.7)

In any year of the HCP when a critical spring season has been triggered, there may be additional rain that temporarily raises reservoir inflow levels above outflow levels. The City may elect, in such circumstances, to raise the flow of the Bull Run River higher than the critical-period guaranteed minimums indicated in Table 4. Also, the City may elect to release more flow than the guaranteed minimum to the lower Bull Run River during critical spring seasons to meet water temperature objectives as described in Measure T-1 and T-2.

The trigger for the critical fall season is based on whether the mean daily flow for the August and September inflows to the Bull Run reservoirs are within the lowest 10 percent of historical flows for that time period. Throughout HCP Years 1–50, the 10th-percentile flow level will be updated annually to include new years of record.

The response to a critical fall season is outlined in Table 5.

Table 5. Flow Commitments for the Lower Bull Run River During Water Years with Critical Fall Seasons^a

Time Period	Guaranteed Minimum Flow ^a (cfs)	Required Percent of Inflow (cfs)	Maximum Required Flow (cfs)
October 1–October 15	20	If critical fall season trigger is met, continue to vary flow from 20–40 cfs to manage downstream water temperature	
October 16–October 31	30	50%	250
November 1–November 15	30	40%	250
November 16–November 30	70	40%	350
December 1–May 31	120	n/a	n/a

^aMeasured at USGS Gage No. 14140000 (RM 4.7)

The percentage of inflow and maximum flow requirements might not be met during the days that the Chinook surveys occur. Flows will be held to less than 150 cfs, as measured at USGS Gage No. 14140000, to allow safe surveying. The surveys are expected to occur approximately once per week from August through November. See Appendix F for more details on the Chinook survey procedures.

The City will control streamflow releases at Headworks (RM 5.9 on the Bull Run River) and the lower Bull Run River flow will be measured at USGS Gage No. 14140000 (RM 4.7). For purposes of determining streamflow releases in October and November, reservoir inflow will be measured and totaled for four USGS Gages (No. 14138850, Bull Run River at RM 14.8; No. 14138870, Fir Creek at RM 0.6; No. 14138900, North Fork Bull Run River at approximately RM 0.2; and No. 14139800, South Fork Bull Run River at RM 0.6). The daily mean flows of the four gages will be added and then multiplied by 1.2 to account for the ungaged area of reservoir inflows in the Bull Run watershed.

City staff will determine the previous week's reservoir inflows once each week and establish the next week's flow release target based on that inflow data. The first determination of streamflow level will occur prior to October 1. The flow releases to meet the targets will be implemented starting on October 1. Additional flow release targets will be set each week through the end of November.

Status of Work for Calendar Year 2017

The critical spring trigger was not met in 2017. Drawdown initially commenced on June 22, 2017.

The option to implement critical fall flows in 2017 was available if critical flow conditions had occurred. However, critical fall conditions did not occur in 2017. The lowest 10 percent of total reservoir inflow during August and September from 1940 through 2016 was 3.53 billion gallons. Total reservoir inflow during August and September of 2017 was 5.7 billion gallons, well above the critical fall threshold. Lower Bull Run River flows at USGS Gage No. 14140000 are depicted in Figure 2 on page 10.

Planned Accomplishments for Calendar Year 2018

The critical spring trigger will be assessed in 2018. If the trigger is met, the City will implement the appropriate guaranteed critical-year minimum flows per the conditions of the HCP. Because critical fall flows were implemented in 2014, critical fall flows are not allowed four years later in 2018, even if August and September inflow amounts are lower than the critical threshold.

Measure F-3—Flow Downramping

Location: Bull Run Watershed

Benefits: Bull Run River flow

Contact: Glenn Pratt, Hydroelectric Project Manager, Portland Bureau of Hydroelectric Power

Primary Objective

The City is committing to a low downramping rate to reduce effects on covered fish in the lower Bull Run and Sandy rivers.

Measure Commitments

Measure F-3—Flow Downramping: For HCP Years 1–50, the City will release flow into the lower Bull Run River, below Dam 2 as a result of hydropower operation, at a maximum downramping rate of no more than 2"/hour (0.17'/hour), as measured at USGS Gage No. 14140000 (RM 4.7). City staff will monitor recordings at USGS Gage No. 14140000 to ensure that the decreases adhere to this downramping rate.

This maximum downramping rate will not apply to events beyond the control of system operators, such as unexpected power grid interruptions, downed power lines, equipment failures, emergency responses at the Headworks as required to assure compliance with federal Safe Drinking Water standards, the mandatory annual testing of the powerhouse, and other circumstances that preclude the use of the North Tunnel or Diversion Pool at the City's water supply Headworks. The maximum downramping rate will also not apply when naturally occurring high flows, as measured at USGS Gage No. 14138850 (Bull Run RM 14.8), decrease by more than 2"/hour.

Status of Work for Calendar Year 2017

The City was in compliance with Measure F-3 in 2017.

Downward-stage fluctuations in the lower Bull Run River, as measured at USGS Gage No. 14140000, were maintained at or below a rate of 2 inches/hour for 99.78 percent of the time in 2017. Downramping exceedances occurred during 19.25 hours, or 0.22 percent of total operating hours during the monitoring year.

The effects analysis outlined in the HCP was based on predicted flow exceedances of 0.4 percent of total operating hours per year—a level of downramping flow exceedances that was determined to have minimum effects on covered fish species in the plan.

18.25 of the 19.25 hours of downramping exceedances were excluded from the fluctuation limit as allowed by Measure F-3; for those hours, the City analyzed the flow data to determine why the exceedances occurred. One of the 19.25 hours in 2017 was due to operator error. The City looked at each hour of the downramping exceedances to improve future operations. Accounting for each hour of the allowed downramping exceedances follows:

- 1 hour was associated with the failure of a wicket gate shear pin at Portland Hydroelectric Project Powerhouse 1 (P1) that required the unit to be taken off-line to allow the replacement of the shear pin. Powerhouse 2 (P2) was running at maximum flow with excess water going over the Dam 2 main spillway during that time. The instantaneous loss of flow at P1 resulted in a similar drop in the stage at Gage 14140000.
- 4 hours were associated with the mandatory testing of the new SCADA control system for the power plants that was installed to replace the old PGE SCADA, which was removed at the end of the Power Sales Agreement in August 2017.
- 1 hour was associated with operator error when the operator miscalculated the flow rate of the Howell-Bunger valve operations, making a larger adjustment to the valve than was necessary.
- 6.25 hours were associated with the disruption of service to the plants as a result of trees falling into the high-voltage lines and causing the plants to trip off-line.
- 7 hours were associated with the inflow of water beyond the ability of the two power houses to regulate despite being at full production.

Planned Accomplishments for Calendar Year 2018

Flow downramping will continue to be monitored in 2018.

Measure T-2—Post-infrastructure Temperature Management

Location: Bull Run Watershed

Benefits: Bull Run water temperature

Contact: Kristin Anderson, Hydrologist, PWB Resource Protection

Primary Objective

The City has altered its water supply infrastructure and its water supply operations to reduce water temperatures in the lower Bull Run River. The City's strategy relies on sharing the available cold water in the Bull Run reservoirs for drinking water and fish flow needs. The City stores cold water in the reservoirs in spring and early summer when overall temperatures are lower and will release the water throughout the summer and early fall when river temperatures are warmer. The multilevel intakes already existing at Dam 1 are used for this purpose. With the multi-level intakes at Dam 2, the City's target is to maintain the 7-day moving average of the maximum daily water temperature (7DADM) of the lower Bull Run River below either the numeric stream temperature criteria or the 7-day moving average of the maximum water temperature of the Little Sandy River, whichever is greater, with additional air temperature and calendar exceptions. Compliance with this measure fulfills the objectives of the City's Temperature Management Plan (TMP) for the Lower Bull Run River (Appendix I of the HCP).

Measure Commitments

Measure T-2—Post-infrastructure Temperature Management: Within HCP Years 1–5, the City will design, permit, and complete two significant changes to Bull Run water supply infrastructure to implement this conservation measure:

The Dam 2 intake towers will be modified to allow taking water from the reservoir at different levels.

The spillway rock weir in the Bull Run River immediately downstream of the Dam 2 spillway will be modified to allow rapid movement of flow through the spillway stilling basin.

After the infrastructure changes are made to the Dam 2 intake towers and the spillway rock weir, the City will manage flow to meet Oregon state water quality standards in the lower Bull Run River, as established in ODEQ's Sandy River Basin TMDL (ODEQ, 2005) and the ODEQ-approved Temperature Management Plan. The City will use the Little Sandy River water temperature (measured at USGS gauge 14141500) as a surrogate for the natural thermal potential of the lower Bull Run River. Water temperature compliance will be measured at Larson's Bridge on the main stem Bull Run River (USGS site 14140020). All water temperatures will be expressed as the 7-day moving average of the daily maximum temperature (Table 6).

Per the Sandy River Basin TMDL, Bull Run River water temperature target will be maintained

- at or below the appropriate biologically based numeric temperature criteria shown in Table 6 when the Little Sandy River temperature is below the criteria

Table 6. Appropriate Numeric Temperature Criteria

River Reach	Time Period	Habitat Use	Numeric Criterion (7-Day Average Maximum)
River Mile 0 to 5.3	June 16 to August 14	Salmonid rearing	16 °C
	August 15 to June 15	Salmonid spawning	13 °C
River Mile 5.3 to 5.8	June 16 to October 14	Salmonid rearing	16 °C
	October 15 to June 15	Salmonid spawning	13 °C

Source: ODEQ 2005

or

- at or below the Little Sandy River temperature (as adjusted, see below) when the Little Sandy River temperature is above the numeric criteria

Also per the TMDL, the Bull Run water temperature target will be adjusted above the actual measured Little Sandy temperatures as follows:

- Between August 16 and October 15, allowances will be made for a 1.0 °C departure above the Little Sandy temperature.
- If the 7-day moving average of daily maximum air temperature is above 27 °C, the lower Bull Run water temperature target will be the lower Little Sandy River water temperature plus 1 °C.
- If the 7-day moving average of daily maximum air temperature is above 28 °C, the lower Bull Run water temperature target will be the lower Little Sandy River water temperature plus 1.5 °C

The ODEQ temperature standards [OAR 340-041-0028(12)(c)] provide an additional exception if the maximum daily air temperature exceeds the 90th percentile of the 7-day average of the daily maximum air temperature calculated in a yearly series over the historical record. If this situation occurs in the lower Bull Run River, the numeric criteria and natural condition criteria (Little Sandy water temperatures as adjusted above) would not apply.

Daily maximum air temperatures will be recorded at the Water Bureau's Headworks facility below Dam 2 (approx. RM 6).

The Bull Run water temperature criteria will also not apply to events beyond the control of the water system operators, such as unexpected power grid interruptions, downed power lines, equipment failures, loss of computer contact with the Dam 2 intake towers, emergency responses at Headworks as required to assure compliance with federal Safe Drinking Water standards, the mandatory annual testing of the protection devices at the powerhouse, and other circumstances that preclude the use of the intake towers or diversion pool at the City's water supply Headworks.

Status of Work for Calendar Year 2017

Infrastructure changes (the addition of multi-level water intake gates on the north tower at Bull Run Reservoir 2) were completed in 2014, and the multi-level intakes were placed into operation for temperature management. 2017 was the fourth year of using the multi-level intakes for downstream temperature management. From spring through the fall, the City continued to use its flow calculator model for determining flow releases on a twice-daily basis using data from previous years to estimate in-stream heating under various conditions.

The bottom gates of the Bull Run Reservoir 2 North Tower were closed on February 28 to ensure that the coldest possible water was captured at the bottom of the reservoir. However, cold water was not isolated until thermal stratification started in early May. Prior to stratification, the temperature of the bottom of the reservoir increased or decreased with the temperature of the entire reservoir. Cool spring temperatures in April and May contributed to cool tributary inflows to the Bull Run reservoirs and delayed the onset of temperature stratification in the Bull Run reservoirs. Somewhat counterintuitively, these prolonged cool conditions allowed the bottom of each reservoir to warm at a more rapid rate than if stratification were established. The reason for this is that mixing still occurs throughout the reservoir when there is not strong stratification, so the bottom of the reservoirs warmed at about the same rate as the top. Once stratification became established, the rate of warming of the bottom slowed. Bottom temperatures at the end of June were similar to those in 2014–2016. However, mid-level temperatures were somewhat cooler. Early summer temperatures in the bottom layer of the reservoir were 8.1 °C, which is 1.1 °C warmer than the 7 °C projected during the development of Habitat Conservation Plan.

The City communicated the water temperature information to ODEQ, NMFS, and ODFW throughout 2017. Those agencies directed the City to continue to monitor water temperatures in the lower Bull Run River and to work with them, starting in May of each year, on operational measures to improve performance of the system for temperature control.

2017 was the first year since Measure T-2 has been implemented that did not have a critical spring. Drawdown of the Bull Run reservoirs started on June 22, 2017. Therefore, unlike the previous three years, the City did not confer with ODFW, NMFS, and ODEQ when seeking a gradual target increase from 13 °C to 16 °C in the first half on June.

The lower Bull Run 7-day average of daily maximum (7DADM) temperatures stayed below the moving temperature target through most of the summer management period, early June through the middle of September (Figure 3). On 12 days in 2017 (June 23–25, August 1–3, 21, 26–28, and September 2–3), the 90th percentile air temperature was exceeded. For all days that included these dates in its 7-day average (i.e., from six days before to six days after these dates), the temperature target did not have to be met. The City met the target in these periods despite this exception.

In mid-September, the Little Sandy temperature decreased rapidly, lowering the target beyond what could be achieved in the lower Bull Run. Starting September 15, lower Bull Run temperatures could no longer be held below the target temperature. For the period of September 15–20, lower Bull Run 7DADM temperature stayed close to the target, but departed farther from the target starting September 21. In early October, the bottom of Reservoir 2 warmed at an accelerated rate, marking the depletion of remaining cold water at the bottom of the reservoir resulting from increased minimum flows that began October 1.

Substantial rains in the Bull Run watershed that began October 7 cooled the Bull Run reservoirs, and the lower Bull Run 7DADM temperature declined to below 13 °C on October 20. Water temperature targets for the lower Bull Run were exceeded for 34 days from September 15 through October 19. During this time, the highest 7DADM temperature during this period was 16.1 °C, and the greatest departure from the target was 1.5 °C.

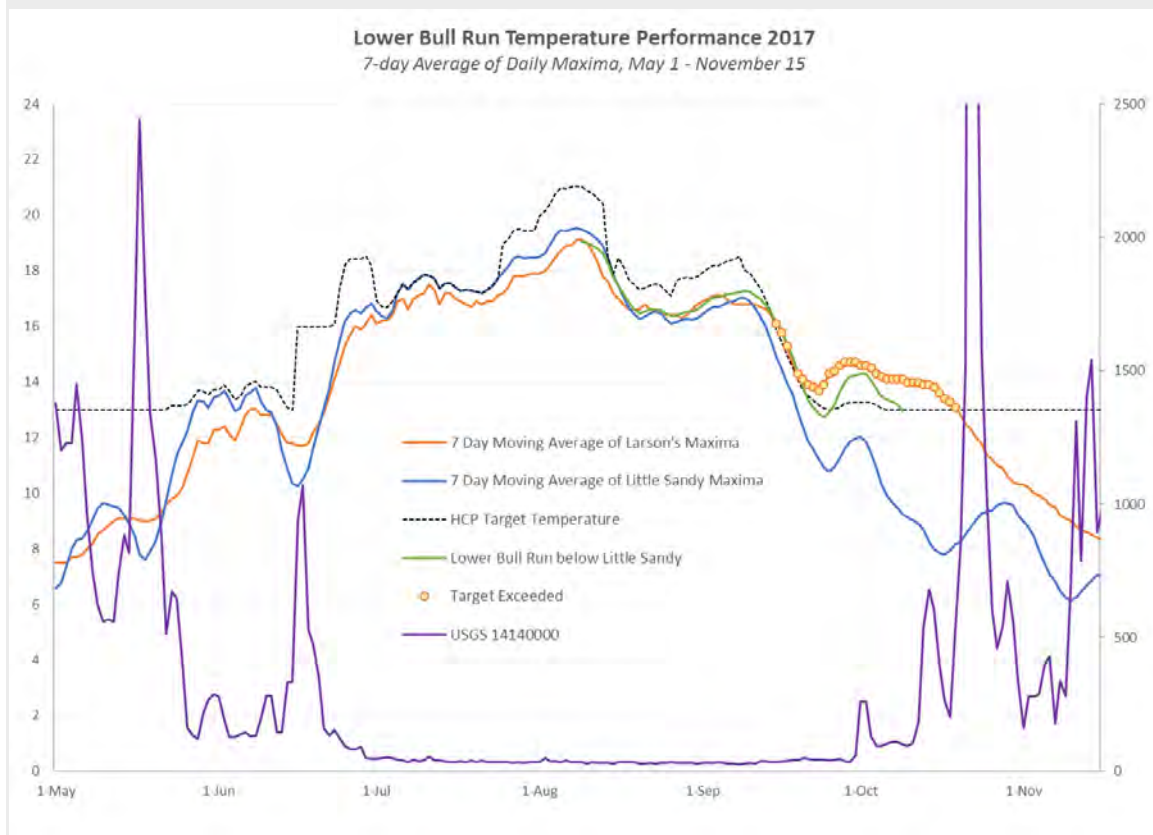


Figure 3. 7-Day Moving Average of Daily Maximum Water Temperature in the Lower Bull Run River at Larson's Bridge (USGS Gage No. 14140020) and at Little Sandy River (USGS Gage No. 14141500) for 2017. Target temperature combines numeric criteria, Little Sandy temperature, and air temperature and calendar exceptions. The modified target temperature represents the joint decision by Portland Water Bureau and regulators to preserve the cold water resource for later critical periods.

Planned Accomplishments for Calendar Year 2018

The City will manage flow releases from Headworks to maintain the 7-day average of daily maximum temperatures at Larson's Bridge according to Measure T-2, Post-Infrastructure Temperature Management. The fifth year operating the new multi-level intakes at Bull Run Dam 2 will be 2018. The City will incorporate knowledge from the first four years of operating with the new multi-level intakes to improve management tools and operations in 2018.

Measure R-1—Reservoir Operations

Location: Bull Run Watershed

Benefits: Avoids or minimizes cutthroat and rainbow trout mortality

Contact: Kristin Anderson, Hydrologist, PWB Resource Protection

Primary Objective

The City is continuing to manage the reservoirs to assure compliance with federal Safe Drinking Water Act standards and to avoid or minimize mortality of cutthroat and rainbow trout.

Measure Commitments

Measure R-1—Reservoir Operations: For HCP Year 1–50, the City will operate the two Bull Run reservoirs to avoid or minimize mortality of cutthroat and rainbow trout. The operating criteria for the reservoirs will be the following:

1. When the City is operating its hydroelectric powerhouses at the two Bull Run dams during the winter, the reservoir surface elevations will not normally vary outside of the upper two feet of the reservoirs' normal full pool range (except as noted in items 2 and 3 below). For Bull Run Reservoir No. 1, the elevation range is 1,034 to 1,036 feet above MSL. For Reservoir 2, the range is 858 to 860 feet above MSL.
2. The City will lower the surface elevation of the two reservoirs beyond the upper two feet of the normal full pool level only for water supply and/or quality reasons, for downstream fish habitat reasons, for dam safety reasons, or for repairs or maintenance to the dam or hydropower project facilities.
3. The City will operate the two reservoirs as needed to maintain required streamflows and water temperatures in the lower Bull Run River for covered species.
4. During the summer drawdown season, Reservoir 1 may be lowered to approximately elevation 970 feet above MSL and Reservoir 2 may be lowered to approximately 832 feet above MSL as needed for water supply purposes
5. At the end of each drawdown season, the two Bull Run reservoirs will be filled as rainfall, streamflow, and required downstream releases permit.
6. The spillway gates on Bull Run Dam No. 1 will be lowered onto the spillway crest in the spring to store additional water for use in the summer months. After the risk of major flooding has passed, and any habitat maintenance work has been completed in the upper reaches of Bull Run Reservoir No. 1 (see Measure R-3, Reed Canarygrass Removal), the water surface level in that reservoir will be raised to a summer supply full pool level of 1045 feet.
7. The City will use 4-cycle engines on its boats to minimize reservoir water pollution.

Status of Work for Calendar Year 2017

The Bull Run reservoirs were operated to meet the requirements of Measure R-1 in 2017. Graphs of the daily surface elevations of each reservoir are shown in Figures 4 and 5.

Reservoir 1 was operated within 2 feet of the spillway elevation (1,036 feet above mean sea level [MSL]) from January 1 through April 15, with brief storm-caused increases above 1036 feet above MSL. The spillway gates were lowered (closed) on April 15, and Reservoir 1 slowly filled to the top of the spillway gates and held there (1,043–1,045 feet) until Reservoir 1 started drawing down on June 23. Reservoir 1 reached a minimum elevation of 990.6 feet on September 18, then refilled to above 1,010 feet and was drawn back down to 990.5 feet on October 7, refilling to spillway elevation (1,036 feet) on October 21. Other shorter periods of drawdown occurred October through December due to high fish flow releases and preparation for fish flow surveys.

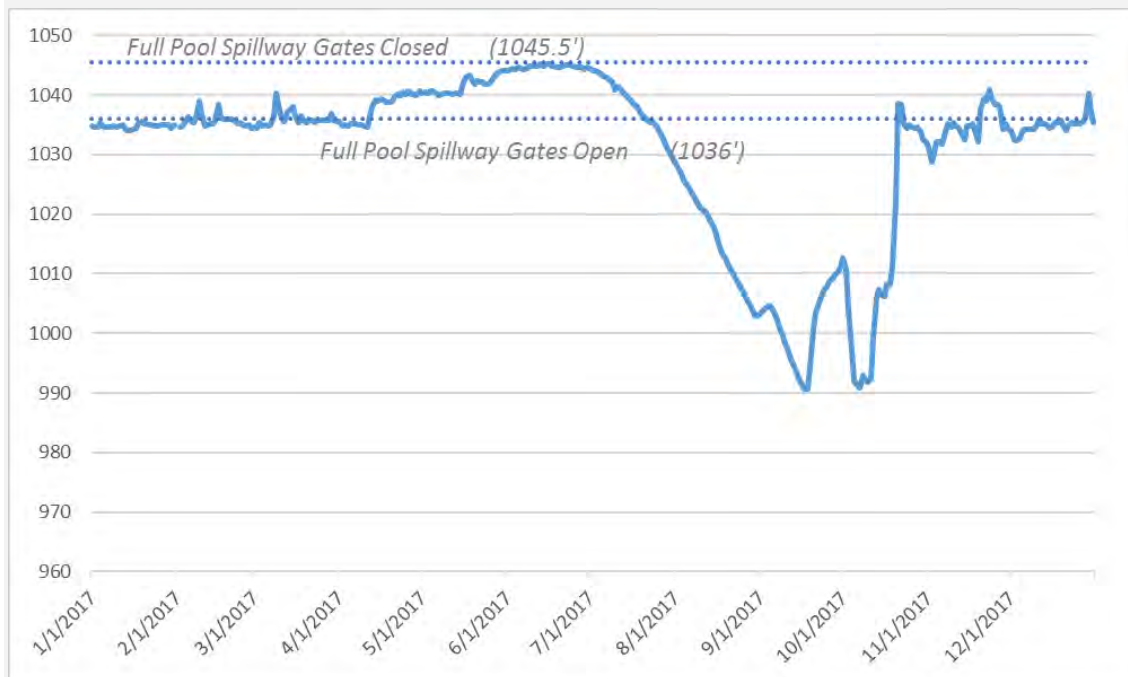


Figure 4. Reservoir 1 Elevations^a During 2017

^aReservoir elevations were recorded at midnight at USGS Gage No. 14139000 in feet above mean sea level (MSL). Reservoir elevations are also tracked via the Portland Water Bureau's SCADA system.

Reservoir 2 was operated within 2 feet of spillway elevation (860 feet) until August 11, when the level reached 857.9 feet. Work on the spillway as required by FERC necessitated that Reservoir 2 be brought down at times below 858 feet and, at other times, below 855 feet. This work occurred in the summer and into the early fall. Reservoir 2 reached its minimum elevation for 2017 of 848.3 feet on October 3, then refilled to spillway elevation (860 feet) on October 22. Reservoir 2 remained above the

858-foot elevation for the remainder of the year except for brief periods to handle minimum downstream fish flows or to prepare for downstream fish surveys.

The City used only 4-cycle engines on all powered boats operated on the Bull Run reservoirs.

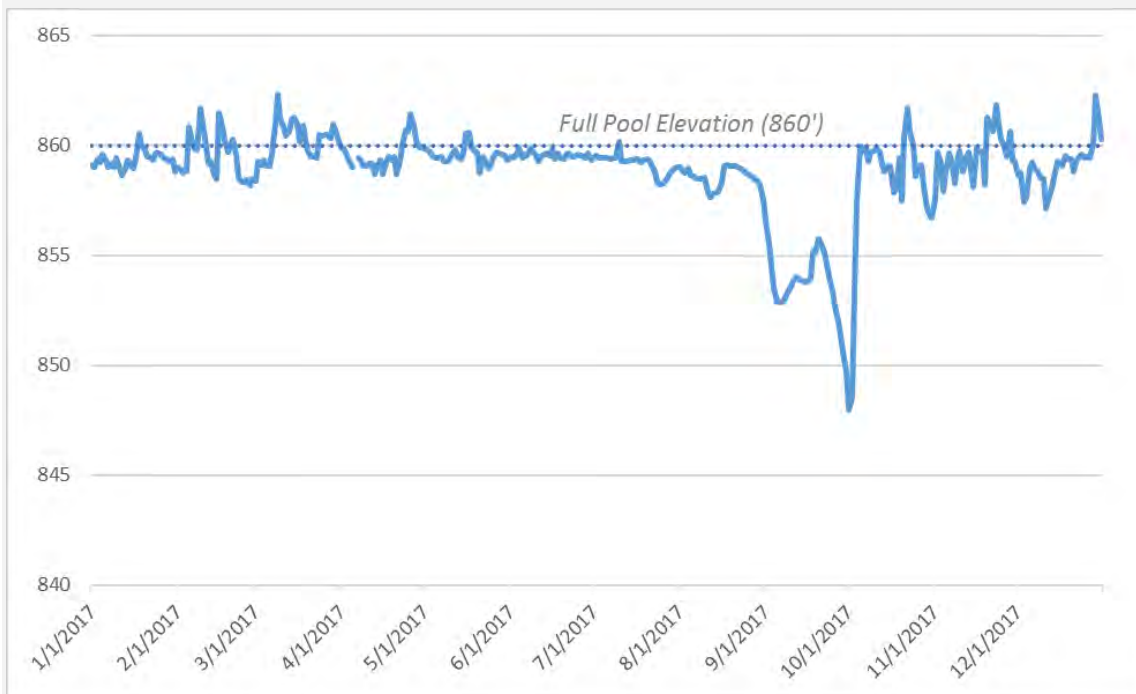


Figure 5. Reservoir 2 Elevations^a During 2017

^aReservoir elevations were recorded at midnight at USGS Gage No. 14139900 in mean feet above sea level (MSL). Reservoir elevations are also tracked via the Portland Water Bureau's SCADA system.



Figure 6. Reservoir 1 and Dam 1 During A Drawdown Period

Planned Accomplishments for Calendar Year 2018

Reservoir elevations will be managed in 2018 according to the commitments of this measure. All boats operated on the Bull Run reservoirs will be powered by 4-cycle engines or human power.

Measure R-3—Reed Canarygrass Removal

Location: Bull Run Watershed

Benefits: Improve terrestrial habitat for wildlife

Contact: John Deshler, Wildlife Biologist, PWB Resource Protection

Primary Objective

To improve breeding and rearing habitat for western toads and red-legged frogs at three areas along the upper end of Bull Run Reservoir 1 that the City has identified as important for reproduction and egg incubation.

Measure Commitments

Measure R-3—Reed Canarygrass Removal: For HCP Years 1–50, the City will cut and rake reed canarygrass away from three areas along the north bank of the upper end of Bull Run Reservoir 1. The City will access the site by boat from the reservoir and by trail. Power tools will be used for cutting the grass. Neither heavy equipment nor additional road access will be needed. The cutting will occur just prior to the summer season lowering of the spillway gates on Dam 1, which will flood the shallow area of the reservoir. The areas to be cut are approximately 10' x 15', 100' x 100', and 100' x 40'; this total area to be cut is approximately one-third acre.

Status of Work for Calendar Year 2017

The City met the requirements of Measure R-3 by cutting and removing reed canarygrass from the three areas in April (Figure 7).



Figure 7. Reed Canarygrass Removal, Spring 2017

In 2017, as in 2016, two additional steps were taken that had not been implemented in prior years. First, toad breeding was monitored at the three areas from April 18 through August 9. During monitoring, data on water temperature and water level were collected, and the location, onset, magnitude, duration, and outcomes of breeding were recorded. Appendix H in this report provides more information on the monitoring effort. Second, reed canarygrass was cut and removed again in September at the three areas to improve breeding and rearing habitat for toads and frogs for the following year (2018). The late-summer cutting was timed to occur prior to the normal recharge of Reservoir 1 in early fall so that the areas would be flooded soon after the cutting, and reed canarygrass growth would be restricted through the fall and winter months.

During the cutting, City staff worked at the north bank of the upper end of Bull Run Reservoir 1 within the western toad and red-legged frog breeding areas. After the three areas were cut, the grass was removed with rakes and pitchforks, leaving grass stubble and exposed mineral soil (Figure 8).



Figure 8. Grass Stubble and Mineral Soils after Reed Canarygrass Removal, 2017

Planned Accomplishments for Calendar Year 2018

Beginning in 2018, PWB will change the objective of Measure R-3. In contrast to cutting grass in an attempt to raise the water temperature as was done from 2011 to 2017, the new objective is to more widely and aggressively treat the reed canarygrass at the primary area where toads are concentrating their breeding. The goal of the more aggressive treatment is to make the primary breeding area more closely resemble habitat

at other toad breeding sites on the west slope of the Cascades where reed canarygrass has not invaded. Typically, toad breeding sites are nearly devoid of vegetation.

The total area proposed for treatment in 2018 will be equal to or greater than the combination of the areas of the three locations that were cut annually from 2011 to 2017. The City will focus treatment on the area that toads are actually selecting.

Treatment in 2018 will include cutting (weed-whacking) and removal of grass, as has been done in prior years. However, treatment may also include hand-pulling, solarization, flooding, or other non-toxic methods that reduce the grass and maintain water quality. The City believes that focusing the treatment in the primary breeding area may improve toad productivity, and in doing so, the City will be going above and beyond the prior, less-specific, original objective of Measure R-3 (cutting and removing grass).

The new objective is to improve the toad breeding habitat by reducing reed canarygrass. Reed canarygrass cannot be completely removed. Complete removal is desirable, but not possible, even within a small area, due to the extent, density, and veracity of the invasive weed, and because the type and timing of treatment may be limited because the area lies within Reservoir 1 (below the high-water mark). Because the breeding area is within the reservoir, only non-toxic methods may be used and may be used only during limited seasons when the area is not inundated for water storage.

The City would stop cutting and removing grass at one of the three areas: the area where no breeding has been documented during the past two years. The third area will continue to be cut because a few toads occasionally breed there and because the area contains other desirable native vegetation (e.g., *Carex glauca*) that might otherwise be crowded out without reed canarygrass control.

The goals of monitoring will also change to reflect the new objective for Measure R-3.

Measure H-1—Spawning Gravel Placement

Location: Bull Run Watershed

Benefits: Improve instream habitat

Contact: Burke Strobel, Fish Biologist, PWB Resource Protection

Primary Objective

The City is replenishing spawning gravel and mimic natural supply and accumulation in the lower Bull Run River. The three selected sites provide the best combinations of access for delivery of gravel to the river and proximity to known spawning areas (CH2M HILL 2000).

Measure Commitments

Measure H-1—Spawning Gravel Placement: The City will augment spawning gravel in the lower Bull Run River and monitor the effects of the gravel placements. A total of 1,200 cubic yards of gravel will be placed in the river annually during HCP Years 1–5; 600 cubic yards will be placed annually for the remainder of the HCP term (HCP Years 6–50). The gravel will consist of a spawning matrix composed of medium to very coarse material (0.5 to 4 inches) that has been washed or sorted to remove fine sediment. The City will purchase gravel from companies with current valid permits for the mining or removal of gravel. The City will only purchase gravel that comes from areas outside of river floodplains.

Gravel will be placed in the river downstream of the City's water supply intakes. Equal amounts will be placed at three locations:

- 1,200 feet downstream of the Plunge Pool at RM 5.7
- 450 feet downstream of USGS Gage No. 1414000 at RM 4.7
- 600 feet downstream of Larson's Bridge at RM 4.0

Spawning gravel placement will occur in December after the primary fall Chinook salmon spawning period, and before steelhead spawning starts in the spring.

Gravel placements will continue as described above unless

- the lower Bull Run River does not experience high enough flows to distribute the gravel at the three placement locations

or

- the gravel placement is determined to be ineffective for creating spawning habitat for the covered species.

If either of these two conditions arises, the City will work with the NMFS to modify implementation of the measure as needed.

Appendix F of the HCP describes how the City will assess the effectiveness of the placed spawning gravel.

Status of Work for Calendar Year 2017

The City met the requirements of the HCP measure. The City successfully placed 600 cubic yards of spawning gravel in the lower Bull Run River in January 2017, at three specified locations. Using trucks with conveyor belts, the City placed a total of 200 cubic yards of gravel into the river at each location in late January 2017 (Figure 9). The gravel was obtained from a gravel quarry located near Estacada, Oregon, from an old alluvial terrace above the Clackamas River. The material complies with the specifications described in the measure.

Conveyor trucks were able to throw gravel to the middle of the Bull Run River, where it later was moved downstream by high flows. River flows during implementation of the project ranged from approximately 363 cfs to approximately 388 cfs. No gravel was placed in pools.



Figure 9. Placing Gravel in the Bull Run River in 2016

Gravel placement did not result in accumulations great enough to hinder the movement of fish at any of the three sites. A high flow (6,830 cfs) on March 10, 2017, redistributed most of the placed gravel.

Planned Accomplishments for Calendar Year 2018

Spawning gravel will be placed in the lower Bull Run River in January 2018. The placement methods will be similar to those used in previous years. A total of 600 cubic yards of spawning gravel will be placed, as called for in Measure H-1, in HCP Years 6-50.

Measure H-2—Riparian Land Protection

Location: Bull Run Watershed

Benefits: Improve riparian and instream habitat

Contact: Steve Kucas, Environmental Compliance Manager, PWB Resource Protection

Primary Objective

City-owned lands along the lower Bull Run River are capable of providing riparian habitat at a level comparable to unmanaged late-seral forest. The City will continue managing these lands for the duration of the HCP so that their value to instream habitat will be maintained, and in some cases improved.

Measure Commitments

Measure H-2—Riparian Land Protection: For HCP Years 1–50, City-owned lands adjacent to the lower Bull Run River will be managed for the conservation of riparian habitat. The City will not cut trees within 200 feet of the river’s average high water level on City-owned lands for the term of the HCP. A tree, as defined here, is any coniferous species with a minimum average diameter at breast height of 12 inches. Exceptions will include selective tree cutting to construct, maintain, and operate water supply and treatment facilities, water monitoring facilities, power lines, roads, and bridges. The City will also remove trees if they threaten City facilities, pose a significant risk to human safety, or when the City and NMFS determine selective cutting is desirable for the purpose of maintaining or improving riparian habitat. If trees are removed, the City will assess the site to determine whether an appropriate riparian species could be planted where the tree (or trees) was removed and will replant trees where feasible. The planted trees will be species that do not grow as tall as the removed trees. See also Measures W-1 and W-2.

Status of Work for Calendar Year 2017

The City met the requirements of Measure H-2. The City did not cut trees within 200 feet of Bull Run River's average high water level on City-owned lands in 2017. The City also managed invasive species on lower Bull Run River riparian land.

Planned Accomplishments for Calendar Year 2018

The City will continue to monitor activities within 200 feet of the Bull Run River.

Measure O&M-1—Bull Run Infrastructure Operations and Maintenance

Location: Bull Run Watershed

Benefits: Avoid or minimize effects of operations and maintenance activities on covered lands

Contact: Steve Kucas, Environmental Compliance Manager, PWB Resource Protection

Primary Objective

The City will implement the Bull Run Infrastructure Operations and Maintenance (O&M) measure to address the potential impacts of maintaining and operating its water supply facilities in the watershed.

Measure Commitments

Measure O&M-1—Bull Run Infrastructure Operations and Maintenance: For HCP Years 1–50, the City will take the following actions to avoid or minimize effects on species covered or addressed in the HCP in the Bull Run watershed:

Covered Lands

- The City will prevent paint and debris from falling in the river during bridge and conduit maintenance at all active stream crossings.
- The City will avoid or minimize erosion during repair and maintenance of all water supply infrastructure.
- Water drained from the conduits will be dechlorinated and routed through energy dissipaters prior to releases in the nearest waterway.
- The City will not use insecticides on covered lands. The City will allow BPA to use the herbicide Garlon 3A in a limited manner on the BPA transmission line easement on City land (see Section 8.7 for more information). The City will avoid or minimize use of other herbicides on covered lands except as necessary to control invasive plants. Plans for herbicide use that might affect habitat for covered species will be provided to NMFS for preapproval.
- The City will use fertilizers on lands if necessary to encourage plant establishment and growth after projects that cause ground disturbance (e.g., as part of hydroseeding).
- The City will remove trees in riparian areas if they threaten City facilities or pose a significant risk to human safety. The City will plant replacement trees, in the same approximate locations, if trees of greater than 12 inches diameter at breast height are cut.

Sandy River Station

- Within HCP Years 1–10, the City will evaluate stormwater drainage at Sandy River Station and improve facilities if needed.

Status of Work for Calendar Year 2017

The City followed all of the commitments stated in Measure O&M-1.

Planned Accomplishments for Calendar Year 2018

The City will continue to monitor the commitments stated in Measure O&M-1.

Measure O&M-2—Bull Run Spill Prevention

Location: Bull Run Watershed

Benefits: Avoid or minimize effects of operations and maintenance activities on covered lands

Contact: Steve Kucas, Environmental Compliance Manager, PWB Resource Protection

Primary Objective

The City will implement the Bull Run Spill Prevention measure to address the potential impacts of maintaining and operating its water supply facilities in the watershed.

Measure Commitments

Measure O&M-2—Bull Run Spill Prevention: For HCP Years 1–50, the City will implement the following actions to avoid or minimize spill effects on the species covered or addressed in the HCP in the Bull Run and Sandy rivers:

Headworks

- Fuel and chlorine deliveries will be escorted by a pilot car via paved roads.
- Secondary containment will be provided for the fuel tanks.
- Containment basins will be inspected and pumped out as needed.

Sandy River Station

- Secondary containment systems will be provided for the fuel tanks and pumps to contain any leaks. Containment basins will be inspected and pumped out as needed.
- Within Years 1–5 of the HCP, the City will evaluate the feasibility of moving existing fuel tanks and pumps out of the Sandy River floodplain. This feasibility analysis will be done in conjunction with a City capital improvement project.

Status of Work for Calendar Year 2017

The City complied with all of the commitments in Measure O&M-2 in 2017.

Planned Accomplishments for Calendar Year 2018

The City will continue to monitor adherence to the commitments in Measure O&M-2.

4.1.2 Offsite Measures

The City is implementing conservation measures on land in various locations throughout the Sandy River Basin. The measures are grouped by type: riparian easements and improvements, acquisition of water rights, fish passage, carcass placement, large wood and log jam placement, channel restoration, and terrestrial wildlife habitat conservation.

4.1.2.1 Riparian Easements and Improvements

The City will obtain easements from willing landowners for a total of 373 acres of riparian lands. The current easement targets are 166, 99, and 108 acres for the lower, middle, and upper Sandy River watershed, respectively (Table 7). For adaptive management reasons, the easement targets have been changed slightly for individual conservation measures. Compliance will be determined by the acres specified, aggregated into the three portions of the basin. The City must obtain the total target acreage by Year 15 of the HCP (2024).

When applicable, the measurable habitat objectives define a number of acres for riparian easements. The intent is for the easements to provide a minimum of a 100-foot-wide buffer from the top of the mean high-water level in the specified reach. The total acres per reach may or may not be contiguous, depending on the opportunities to contact willing sellers.

Table 7. Easement Acre Targets and Acres Obtained for HCP Implementation, Year 8 (2017)

Measure Code	Reaches	HCP Years	Easement Acre Targets	Acres Obtained by Year		Total Acres Obtained
				2010–2016	2017	
Lower Sandy Watershed						
H-11	Sandy 1	2010–2014	0	—	—	—
H-12	Sandy 2	2010–2014	143	145	0	145
H-13	Gordon 1A, 1B	2010–2014	23	23	0	23
		Subtotal	166	168	0	168
Middle Sandy Watershed						
H-14	Sandy 3	2020–2024	7	17	0	17
H-15	Cedar 2 & 3	2015–2019	49	25	—	25
H-16	Alder 1A & 2	2010–2014	43	0	0	0
— ^a	Lower Bull Run River	2012	0	34	0	34
		Subtotal	99	76	0	76
Upper Sandy Watershed						
	Sandy 7		0	0	29	29
H-18	Sandy 8	2020–2024	25	2	0	2
H-19	Salmon 1	2015–2019	23	0	0	0
H-20	Salmon 2	2020–2024	36	0	0	0
H-21	Salmon 3	2020–2024	12	0	0	0
H-22	Boulder 1	2010–2014	0	0	0	0
H-28	Zigzag 1A & 1B	2020–2024	12	0	0	0
		Subtotal	108	2	0	2
Grand Total			373	246	29	275

^aNo associated HCP measure. The City of Portland acquired land around the lower Bull Run River, as authorized by NMFS, on September 16, 2011 (see summary in Appendix I, Item 3).

Measures H-12 and H-13–Riparian Easements and Improvements

Location: Lower Sandy River, middle Sandy River, and upper Sandy River watersheds

Benefits: Improve riparian and instream habitat

Contact: Angie Kimpo, Environmental Program Coordinator

Primary Objective

The City has identified habitat conservation measures that will improve riparian-zone conditions. The land easements will improve a minimum of 100 feet of riparian forest on either side of the active channel width of the river or creeks. The conservation measures include silvicultural practices (e.g., selective thinning and tree planting) to improve the riparian zones. The acreage totals for the land protection easements are calculated by multiplying the lineal distance of the stream by the amount of riparian forest protected by the easement.

A general riparian easement and improvement measure description is provided so that duplicate text is not repeated. The specific HCP measures from the three areas of the Sandy River Basin differ only by the total acreage targets.

Measure Commitments

Within HCP Years 1–5, the City will acquire 100-foot-wide land protection easements from willing private landowners for at least XX acres which will comprise the total number of lineal feet x 100 feet of riparian width on either side of the Sandy River in the named reaches. At a minimum, the easements will be maintained for the term of the HCP. The City will also consider, on a voluntary and case-by-case basis, obtaining easements with durations longer than the term of the HCP and greater than 100 feet wide. The HCP funding for purchasing and maintaining each easement will be limited to what is defined in Chapter 11 of the HCP for that measure. The easement areas will be managed to support forest of ≥ 70 percent conifer trees (by canopy cover) where site conditions are conducive to the growth of conifers. Deciduous trees will be selectively thinned and the easement will be replanted with conifers. If the easement area is not conducive to the growth of conifers, the area will be managed to support the growth of native hardwood species. Management of the easements will also include control of invasive plant species.

Status of Work for Calendar Year 2017

Since the creation of the conservation easement measures in the HCP, land ownership in the Sandy River Basin has changed tremendously. Many private land parcels have been purchased and converted to public lands in the target areas for the HCP easements. The City will continue to assess potential easements and communicate with NMFS about potential habitat benefits and acreage totals for various locations in the Sandy River Basin.

The City is ahead of schedule for acquiring conservation easements in the Sandy River Basin. Currently, the City has finalized easements for 275 acres (Table 7). The City acquired a new easement in 2017 of 29 acres on reach Sandy 7 in the Middle Sandy.

For all easements or acquired riparian buffer areas, canopy cover will be estimated both prior to work on site and after planting to determine progress towards canopy cover goals. Canopy cover estimates have not yet been determined for all acquired easements.

Table 8 summarizes the location, acreage total, and condition of the canopy cover for the easements that the City has obtained to date.

The City is obligated to treat all easement areas so that the canopy cover exceeds 70 percent conifer trees, or native hardwood species as the site conditions dictate, over the term of the HCP. The canopy cover for the Camp Collins, Mench, TNC Kingfisher, and TNC Hyman easements exceed the ≥ 70 percent criterion stated in the HCP. The City will continue to track the canopy cover for all easements.

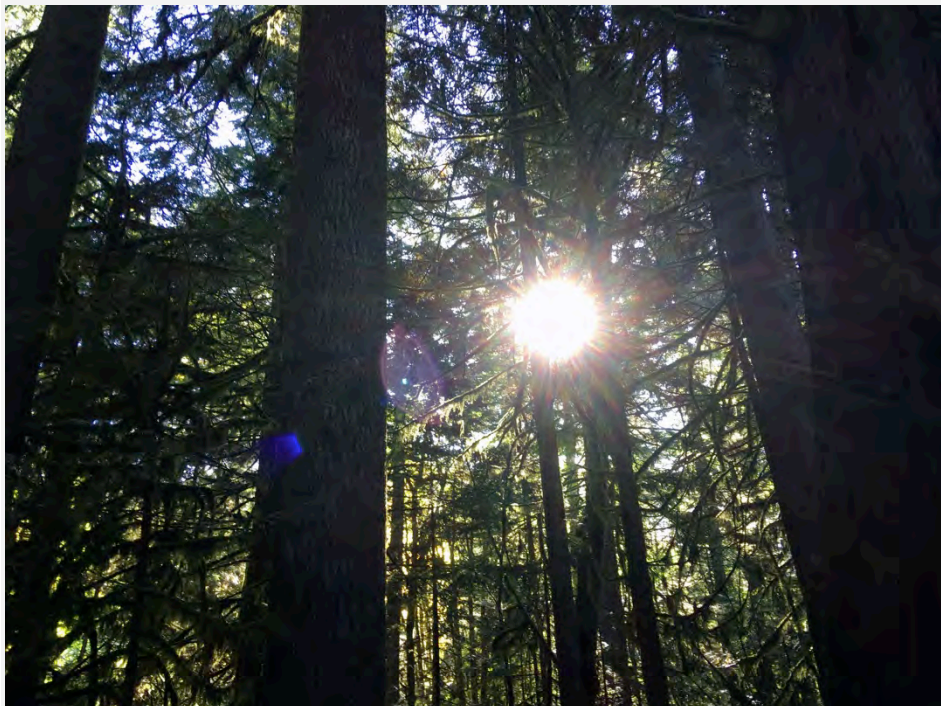


Figure 10. Looking Across the Sandy River at the Cornwall Easement (North Side)

Table 8. Location, Amount, and Estimate of Canopy Cover for Easements, HCP Year 8 (2017)

Reach/ Property Owner	Year Acquired	Number of Easements	Acres	Initial Canopy Cover Estimate ^a	Five-Year Canopy Cover Estimate
Gordon 1A & 1B		2	23 Total		
Maunder	2011		3	47%	
Bonner	2012		20	33%	
Sandy 2		1	145 Total		
TNC Kingfisher	2014		25	71%	
TNC Cornwall	2014		13	64%	
TNC Diack	2014		35	53%	
TNC Hyman	2014		2	82%	
TNC Partridge	2014		16	40%	
Camp Collins	2013	1	54	85%	
Cedar 2 & 3		2	25 Total		
Lowy	2015		9	30%	
Harrison	2015		16	61%	
Lower Bull Run			34 Total		
City of Portland	2013		34	52%	
Sandy 3		1	17 Total		
Rayne	2011		17	28%	45%
Sandy 7		1	29 total		
Clackamas County	2017		29	-	
Sandy 8		1	2 Total		
Mench	2011		2	92%	96%

Abbreviation: TNC is The Nature Conservancy

^aCanopy cover data are collected approximately within the first year of easement acquisition and every 5 years after that. Clackamas County easement canopy data will be collected during late winter 2018. Five-year monitoring results will be available by April 1, 2018, for the Maunder easement. Both sets of data will be reported in the HCP Compliance Report for 2018.

Planned Accomplishments for Calendar Year 2018

The City will continue to pursue easements to meet specific HCP targets. The City will provide updates to NMFS to report progress towards meeting habitat goals.



Figure 8. Looking Across the Sandy River at the Camp Collins Easement (North Side)

Measures H-23 and H-24–Salmon 2 Miller Quarry Acquisition and Restoration

Location: Salmon River watershed

Benefits: Improve riparian and instream habitat

Contact: Steve Kucas, Environmental Compliance Manager

Primary Objectives

Acquire the Miller Quarry parcel on the Salmon River and implement measures to improve riparian-zone conditions.

Measure Commitments

H-23: Within HCP Years 6–10, the 40-acre Miller Quarry parcel in reach Salmon 2 will be purchased. The restoration commitments are described in Measure H-24.

H-24: Within HCP Years 11–15, the City will remove riprap along 0.25 mile of riverfront of the Miller Quarry parcel to reconnect floodplain and side-channel habitat. Approximately 1,000 feet of new side channel will be opened. 160 pieces of LW will be placed in the side channel to create approximately eight log jams. Approximately four acres of riparian zone will be amended with soil and then replanted with suitable riparian species.

Status of Work for Calendar Year 2017

The City has worked on acquisition of the Miller Quarry property since 2011. The steps that the City has taken were described in the 2016 Annual Compliance Report. The sellers are still reluctant to proceed with a sale.

The City is unable to complete the purchase and, subsequently, the restoration of the Miller Quarry property on the Salmon River.

Planned Accomplishments for Calendar Year 2018

The City will discuss the impacts of not being able to implement Measures H-23 and H-24 with NMFS. The City believes that the habitat benefits projected for these measures could be made up by the implementation of other conservation easement acquisitions.

4.1.2.2 Water Rights

Measure F-5—Cedar Creek Purchase Water Right

Location: Cedar Creek in Sandy River Basin

Benefits: Improve instream habitat

Contact: Hassan Basagic, Watershed GIS Specialist, PWB Resource Protection

Primary Objective

Cedar Creek is a populated watershed with numerous privately owned parcels and associated water rights for rural residential and agricultural purposes. The creek has elevated water temperatures in late summer, partially due to water withdrawals. The City will acquire water rights to improve water quality and base flows in Cedar Creek for steelhead, coho, and cutthroat trout.

Measure Commitments

Measure F-5—Cedar Creek Purchase Water Rights: Within the first 10 years of the HCP term, the City will acquire approximately 50 percent of the current certificated surface water rights that affect summer flows on Cedar Creek. These water rights will be acquired from willing sellers and will be converted to instream use for at least the term of the HCP.

Status of Work for Calendar Year 2017

In previous annual compliance reports, the City documented the history of action taken for this conservation measure. The City has found no willing sellers of certified surface water rights in the Cedar Creek drainage. The City will not be able to implement this measure.

Planned Accomplishments for Calendar Year 2018

The City will work with NMFS to discuss the benefits of this measure to determine whether the City can compensate with other HCP measures.

4.1.2.3 Large Wood Placement

Measure H-4—Sandy 2 Log Jams

Location: Sandy River

Benefits: Improve instream habitat

Contact: Burke Strobel, Fish Biologist, PWB Resource Protection

Primary Objective

The City's large wood measures are being implemented to help restore key habitat for fish. The large wood additions for Measure H-4, for example, will increase habitat complexity, providing benefits such as pools and cover for migrating, spawning, and rearing fish in the Sandy River reach 2.

Section 4.2.1 of this report describes the effectiveness monitoring methods for these measures.

Measure Commitments

The commitments for Measure H-4 have been changed from what was described in the HCP to incorporate benefits from another measure, H-9, which will not be implemented, and to move H-4 benefits planned for Sandy 1 to Sandy 2. Within HCP Years 6–10, the City will work with willing landowners to place a minimum of 530 key logs into the Sandy River in a way that restores flow to at least 2,100 lineal feet of side channel. The City will also increase off-channel habitat in the reach by 8,164 square feet. Large wood will be placed avoiding federal land, land without landowner permission, and land where the preexisting large wood quantity is already adequate. Large wood quantities were chosen to achieve placement densities of approximately 75 pieces per mile on average for the originally planned treatment reach, Sandy 2. Individual LW pieces will be sound conifer logs with a small-end diameter of at least 12 inches and a length of at least 30 feet. The key pieces will be placed to collect other additional woody debris. If available, large root wads will also be selected for placement. Artificial anchoring of the wood will be used only when wood movement cannot be tolerated. Anchoring will be used only if the large wood might move downstream and damage road culverts, bridges, private property, or other streamside improvements. It is desirable for the stream to redistribute the placed large wood to some extent, as long as damage is avoided. Methods and timing for LW placement will be determined in consultation with NMFS and the ODFW.

The LW placements will be maintained for 15 years. Year 1 of the maintenance will be the calendar year following the wood placement.

Effectiveness monitoring is described in Section 4.2.1 of this report.

Status of Work for Calendar Year 2017

Under the terms of HCP measure H-4, Sandy 2 Log Jams, the City is obligated to place 530 key logs in the Sandy River in a way that activates at least 2,100 feet of side channel at bankfull flows and to create 8,164 square feet of off-channel habitat. HCP Measure H-9 will not be implemented, and habitat goals were added to Measure H-4 (see Appendix I, Item 5), including the addition of off-channel habitat and the placement of additional large wood.



Figure 9. Typical Large Wood Placement

H-4 Sandy 1 and 2 Log Jams

Construction relating to Measure H-4 was initiated in 2017. One of two engineered log jams was completed along the Sandy River; 44 rootwads were placed in a perennial side channel; flow was restored to and 30 rootwads were placed in a floodplain tributary channel. Delays due to elevated fire hazard and difficult site conditions prevented the completion of the remainder of Measure H-4 in 2017. Materials were staged, and erosion control measures were implemented to prepare the construction site for inactivity during the winter. The construction tasks remaining in Measure H-4 will be undertaken in 2018. Even though the revised Measure H-4 indicated placing a minimum of 530 key logs, the City is planning to place more large wood to meet HCP habitat goals.

Planned Accomplishments for Calendar Year 2018

Sandy 2 Log Jams

The City plans to complete construction relating to this measure in the summer of 2018. Revegetation work will begin for the aspects of Measure H-4 that were completed in 2017.

4.1.2.4 Terrestrial Wildlife Habitat Conservation

Measures W-1, W-2, and W-3—Minimum Impacts to Spotted Owls, Bald Eagles, and Fishers

Location: Sandy River Basin

Benefits: Avoid disturbance of species' habitat

Contact: Steve Kucas, Environmental Compliance Manager, PWB Resource Protection

Primary Objectives

The objective for Measures W-1 and W-2 is to avoid or minimize the periodic, temporary disturbance of habitat that might otherwise result from the routine operation, maintenance, and repair of water supply facility from implementation of HCP measures.

Although fishers have not been found in the Sandy River Basin, the City developed Measure W-3 as a contingency habitat measure to avoid or minimize impacts to fishers during the performance of covered activities in the basin.

Measure W-1 Commitments

Measure W-1—Minimize Impacts to Nesting Spotted Owls: For the term of the HCP, the City will take steps to avoid or minimize impacts to nesting spotted owls on all covered lands. The terms of the measure are described on page 7-66-7-69 of the HCP.

Measure W-2 Commitments

Measure W-2—Minimize Impacts to Bald Eagles: For the term of the HCP, the City will take steps to avoid or minimize impacts to bald eagles on all covered lands. The terms of the measure are described on page 7-69-7-74 of the HCP.

Measure W-3 Commitment

Measure W-3—Minimize Impacts to Fishers: If the fisher is found to occur within 30 miles of the Bull Run watershed, or the locations of any unfinished HCP measures, the City will meet with USFWS to discuss whether any steps need to be taken to avoid or minimize impacts to fishers during the performance of the covered activities.

Status of Work for Calendar Year 2017

For Measures W-1, W-2, and W-3, the City avoided or minimized impacts to spotted owls and bald eagles for all City projects in 2017.

Fishers have not been found to occur anywhere near the Bull Run Watershed, and therefore no avoidance or minimization actions were necessary.

Planned Accomplishments for Calendar Year 2018

The City will continue to evaluate potential impacts to spotted owls and eagles when considering City projects. The City will continue to be vigilant about any information related to fishers and will consider such information during the performance of covered activities.

4.1.3 Monitoring for Clean Water Act 401 Certification Conditions

As part of HCP Measure T-2—Post-infrastructure Temperature Management—PWB has completed a project to modify a water intake tower at Bull Run Dam 2 to allow withdrawal of water from the reservoir at different levels. PWB has a non-capacity license amendment with the Federal Energy Regulatory Commission (FERC) for the tower modifications. According to Section 401 of the Clean Water Act (CWA) and as part of the condition of the amended hydroelectric project license from FERC, the Oregon Department of Environmental Quality (ODEQ) reviewed the impacts of the proposed Bull Run Dam 2 Tower project on water-quality parameters that have the potential to be affected by construction on the intake tower. The five water-quality standards that have the potential to be affected by work in Bull Run Reservoir 2 are listed in Table 9 with the language from the Oregon Administrative Rule that describes the standard.

Table 9. Water Quality Parameters to Monitor for CWA Section 401 Certification

Water Quality Parameter	Potential Impact Description in Oregon Administrative Rule
Nuisance Phytoplankton Growth	Changes in reservoir circulation may lead to changes in nutrient concentrations, which in turn may lead to algal blooms.
Creation of Taste, Odors, Toxic Conditions	Taste and odor or toxic conditions can occur from nuisance algal blooms.
Dissolved Oxygen	Changes in water circulation in reservoir may alter dissolved oxygen concentration, especially at depth with change in residence time deep in reservoir; algal bloom respiration and decay may also consume dissolved oxygen.
pH	Algal blooms may cause spikes in pH values.
Temperature	Changes in withdrawal depth may result in temperature changes downstream.

Prior to the Dam 2 Tower improvements (from 2009 to 2013), PWB gathered monitoring data to provide baseline information. Monitoring data from 2016 were compared to the baseline data. Reservoir monitoring for 401 certification conditions in 2016 showed results were within anticipated ranges, with the exception of low dissolved oxygen levels at the base of Reservoir 2 that persisted for approximately six weeks, from August 9 through September 20, 2016. The period of low dissolved oxygen levels at the base of Reservoir 2 does not represent a significant change to water quality. Appendix B of this report describes the monitoring efforts and results in detail.

4.2 Effectiveness Monitoring

The City is conducting effectiveness monitoring for some of the HCP conservation measures. Those measures include large wood placement/log jam creation, side-channel development, river mouth reestablishment, and floodplain reconnection. For these measures, there is some degree of uncertainty about the biological effectiveness.¹ All effectiveness monitoring is conducted to test the hypothesis that at least 80 percent of the projected changes in the key habitat variables will occur in each stream reach. The City is using the habitat variable ratings from the Ecosystem Diagnosis and Treatment (EDT) model and has provided estimated improvements from HCP measures in Appendix E of the HCP. For a detailed description of effectiveness monitoring for offsite in-channel conservation measures, including sampling methods and assessment procedures, see Appendix A of the HCP.

4.2.1 Large Wood and Log Jam Placement

Measures H-4 and H-17—Large Wood Placement

Location: Sandy River and Cedar Creek in the Sandy River Basin

Benefits: Instream habitat

Contact: Burke Strobel, Fish Biologist, PWB Resource Protection

Primary Objective

The City's large wood measures are being implemented to help restore key habitat for fish. The large wood additions will increase habitat complexity, providing benefits such as pools and cover for migrating, spawning, and rearing fish in Gordon Creek reaches 1A and 1B, Trout Creek reach 1A, Cedar Creek reaches 2 and 3, and Sandy River reach 2.

Measure Commitments

The measure commitments for HCP Measures H-4 and H-17 are described in Section 4.1.2.3, which starts on page 41 of this report.

Measurable Habitat Objectives

The measurable habitat objectives for the large wood measures share the common objective of achieving 80 percent of the predicted increase in pieces of large wood within 15 years of implementation. Additional habitat objectives created for reach 2 of Sandy River are to achieve 80 percent of the predicted increase in off-channel habitat within 15 years of implementation. Additional habitat objectives for reaches 2 and 3 of Cedar

¹ In some cases, the City does not plan to conduct effectiveness monitoring because the outcomes are already known and are well-supported by the available scientific literature.

Creek are to achieve 80 percent of the predicted increase in beaver ponds and pools within 15 years of implementation.

Effectiveness Monitoring Method

To test whether the habitat variable ratings in the current EDT database are representative of pre-project conditions, and to determine whether the projected increases in habitat ratings are an accurate representation of post-project conditions, the City is implementing the following monitoring methodology:

- Conduct baseline habitat surveys in both the project reaches and in upstream control reaches, where no habitat enhancement projects are planned.
- Conduct post-project habitat surveys in both the project reaches and in upstream control reaches.
- Compare the baseline and post-project survey results for project and control reaches. Effectiveness will be evaluated by comparing observed changes with the measurable habitat objectives, after adjusting for background changes observed in control reaches.

Status of Work for Calendar Year 2017

The City fully complied with the effectiveness monitoring as required by the HCP for Measures H-4 and H-17 in 2017. Baseline monitoring continued for Measure H-4 and post-treatment monitoring began for Measure H-17. The specific monitoring accomplishments are referenced by measure name (e.g., Cedar 2 and 3 LW Placement) in Appendix A of this report.

Planned Accomplishments for Calendar Year 2018

The collection of baseline data for effectiveness monitoring will be initiated in 2018 in the Zigzag River reach 2 for Measure H-27 (to be implemented in 2019 or 2020). Post-treatment data collection for effectiveness monitoring will be conducted in 2018 in Little Sandy for Measure H-3. Baseline and post-treatment habitat surveys will follow protocols identical to those used in 2017.

4.3 Research Program

4.3.1 Bull Run Research

4.3.1.1 Spawning Gravel Placement

Under the HCP, the City places spawning gravel in the lower Bull Run River to increase spawning habitat, primarily for Chinook salmon and steelhead. Each year, the City evaluates the gravel placement to determine the amount of resulting surface area covered by gravel suitable for spawning salmon and steelhead (see Figure 13).

The City conducted this evaluation of spawning gravel placement as planned in 2017. The combined surface area of adequately sized spawning gravel patches was significantly higher than the baseline average for steelhead and for Chinook at all flows. The surface area of spawning gravel in 2017 was within the range of previous years (2010–2016) at all locations and flows, but was less than in 2016. A detailed account of the gravel placement protocol is available in Appendix F of the HCP. The current status of spawning gravel placement is detailed in Appendix C of this report.



Figure 13. PWB Staff Evaluating Spawning Gravel in the Lower Bull Run River

4.3.1.2 Total Dissolved Gas

The City has evaluated the structures, valves, and turbines in the Bull Run water supply system since 2005 to determine whether any facilities would exceed the state standard for total dissolved gas (TDG). For the state standard, the concentration of total dissolved gas relative to atmospheric pressure at a sample collection point may not exceed 110

percent of saturation, except when stream flow exceeds the ten-year, seven-day average flood. No additional TDG data were collected in 2017 because the appropriate flow conditions for monitoring did not occur.

The City has measured TDG levels in excess of 110 percent at river flows below the 10-year, 7-day average flood (7Q10) flow on three occasions in the past. On all three occasions the water with high TDG levels had not yet had a chance to mix with the low-TDG water from Powerhouse 2. The average saturation level for TDG in the river was calculated to be less than 110 percent.

The detailed account of the TDG evaluation protocol is available in Appendix F of the HCP. The results of the TDG evaluation are in Appendix D of this report.

4.3.1.3 Bull Run Adult Chinook Population

In conjunction with other agencies in the Sandy River Basin, the City has partially funded research of the status of fish listed under the Endangered Species Act. The results of the research will be evaluated along with the results of the City's effectiveness monitoring to determine the City's adaptive management response over time.

The City collects adult Chinook salmon information for the lower Bull Run River. The City conducts annual surveys of the lower river from RM 0 to RM 6.0 to count adult spring and fall Chinook salmon from August through mid-December. Surveys will be conducted on a weekly basis, provided instream flows allow for safe navigation of the river channel. Overall, the City anticipates funding 20 years of surveys over the 50-year term of the HCP.

The City conducted this annual survey of the Bull Run Chinook population as planned in 2017, but extreme risk from fires in the Columbia River Gorge in September and high flows in October and November prevented scheduled surveys from being conducted on seven occasions. The peak adult Chinook count, minimum escapement² estimate, and cumulative redd count in 2017 were within the range of previous years' estimates, 2005–2016.

A detailed description of the Bull Run Adult Chinook Population Research protocol is available in Appendix F of the HCP. Protocols followed on two occasions in late August and early September 2015 differed from those described in HCP Appendix F because of the operation of a weir near the mouth of the Bull Run River by ODFW to collect returning adult hatchery Chinook salmon. These protocol changes and the results of the current year's survey are available in Appendix E of this report.

² Escapement is the number of fish that avoid or escape all harvest and return to spawn in their home streams.

4.3.2 Sandy River Basin Research

4.3.2.1 Sandy River Basin Juvenile Outmigrants

Although the HCP is habitat-based and not focused on the specific population responses of the species, information about juvenile outmigrants (JOM) is needed to obtain a complete picture of the condition and change in freshwater productivity through time. The results of the JOM research will be evaluated with other monitoring results to determine the City's adaptive management response over time.

The City will provide funds for collecting JOM information in the Sandy River Basin. This money will be leveraged with other funds to create a coordinated monitoring program. Twelve sites in the basin will be monitored and will serve as an index for the entire basin.

The City and its partners monitored JOM production in nine streams, one more than planned, in 2017: Lost Creek, Clear Creek, Still Creek, Salmon River, Cedar Creek, Bull Run River, Little Sandy River, Gordon Creek, and Beaver Creek. Population estimates were calculated for steelhead and coho smolts in all nine streams and fork length distributions, condition factors, and emigration patterns were analyzed. The average ages of smolts from the Bull Run River, Little Sandy River, and Beaver Creek from 2017 were calculated by aging fish using fish scale samples, and those ages were added to age distribution information for all trap sites derived from fish scales collected between 2009 and 2016.

Steelhead and coho smolts from different streams in the Sandy River Basin showed significant differences in weighted mean fork length of smolts. Low-elevation streams had longer smolts than high-elevation streams.

Steelhead and coho smolts from different streams in the Sandy River Basin also showed significant differences in mean condition factors. Condition factors negatively correlated weakly with fork length.

Steelhead smolts emigrated earlier than coho smolts, on average, in all streams. Steelhead from all streams emigrated at approximately the same time, while coho emigrated earlier from low-elevation than from higher-elevation streams.

High-elevation streams had a larger proportion of older age steelhead and coho smolts. Length-at-age calculations revealed that steelhead smolt fork lengths are shorter on average for a given age in higher-elevation streams than in lower elevation streams, as is seen in coho, but this fact is masked by their older average age

The City's specific commitments and the approach to JOM research are outlined in Appendix F of the HCP. The results of this research are presented in Appendix F of this report.

4.4 Adaptive Management Program

The Bull Run HCP defined adaptive management along two concurrent tracks: adaptive responses for individual measures and decision milestones for addressing the effectiveness of the HCP as a whole. Through monitoring, the City will evaluate its progress on implementation as well as effectiveness of the measures. Should monitoring results indicate, the City will use its adaptive management program to change its approach.

If monitoring results indicate that a measure cannot be implemented, that an instream measure has not met its measurable objective, or that factors outside the City's control have reduced the habitat benefits of a measure by more than 20 percent, then the City will implement adaptive management. The adaptive management response includes several factors: consultation with NMFS, site surveys, and rerunning the EDT model to characterize baseline watershed conditions.

If, after taking these steps, the City and NMFS reach the conclusion that an additional or substitute measure is necessary, the City will follow the guidelines outlined in Chapter 9 (Section 9.4.3) of the HCP in its approach. Costs for implementing additional measures after the original measure has been implemented will be paid from the adaptive management section of the Habitat Fund. See the description of the Habitat Fund measure, below.

Measure H-30—Habitat Fund

Location: Covered lands

Benefits: Assists in meeting HCP objectives

Contact: Steve Kucas, Environmental Compliance Manager, PWB Resource Protection

The adaptive management portion of the Habitat Fund will be used to implement additional projects if one or more of the offsite measures does not meet its objectives. The Sandy River Basin Partners' portion of the fund will be used to implement additional habitat projects that help compensate for water system impacts not fully addressed by other projects. The details of the Habitat Fund measure are presented in Chapters 7 and 11 of the HCP.

Primary Objective

The Habitat Fund enables adaptive management and allows the City to address water system impacts that may not otherwise be addressed, respond to unknown future opportunities, and contribute to partnership projects.

Measure Commitments

The City will provide money to create a Habitat Fund of \$9 million. A \$5-million portion of the Habitat Fund is available in four increments prior to HCP Year 20 and is dedicated to partnership projects. The increments are described in Chapters 9 and 11

of the HCP (see also Figure 11-1). The remaining \$4 million is dedicated to adaptive management needs but will be used for additional partnership projects if not needed for adaptive management (see Chapters 9 and 11). Projects will be selected in consultation with the HCP Implementation Committee (see Chapter 9) and will be guided by the Sandy River Basin Restoration Strategy. The City and NMFS will make the final project selection decisions.

Of the \$5 million, the City will specifically dedicate \$1.7 million toward habitat enhancement projects on the Salmon River to be implemented jointly by the Sandy River Basin Partners, and with additional funds from the Partners and/or from grants. If partnership funds cannot be obtained to implement these projects, the City funds will be used for other projects in the Sandy River Basin.

Based on an informal agreement in October 2004, the City will also work with the Partners to provide resources from the \$5-million portion of the Habitat Fund to (1) participate in basin-wide efforts to control invasive plants that threaten riparian habitat, and (2) build the organizational capacity of the Partners to implement the basin-wide Restoration Strategy, including outreach.

Status of Work for Calendar Year 2017

The City was in full compliance with Measure H-30—Habitat Fund.

Through June 2019, the City committed to fund one project for building funding capacity for the Sandy River Basin Partners, two projects to do scale analysis, one culvert replacement project in the Salmon River Basin, and eight restoration projects for the upper Sandy River, the Salmon River, Lost Creek, or Still Creek, which are priority restoration areas for the partners.

The City has committed a total of \$1,031,626 of Habitat Fund dollars through June 2019 to projects implemented by Sandy River Basin Partners. Table 10 shows the past projects that have been funded through the HCP Habitat Fund.

Table 10. Past Projects Funded through the HCP Habitat Fund

Number	Project Partner	Amount	Duration	Purpose
Grant Agreement 32000035	Oregon Trout	\$25,000	2009	Build the capacity of the Sandy River Basin Partners in obtaining additional funding to help implement the Partners' restoration strategy
Grant Agreement 182484	Freshwater Trust	\$50,000	July 2009 through June 2010	Partially fund implementation of the Sandy River Basin Short-Term Restoration Strategy, partially fund stream restoration measures in the Salmon River and the Salmon River subbasin.
Grant Agreement 30001899	Freshwater Trust	\$50,000	July 2010 through June	Partially fund design and construction of habitat

Table 10. Past Projects Funded through the HCP Habitat Fund

Number	Project Partner	Amount	Duration	Purpose
			2011	restoration projects to reconnect isolated habitat, restore habitat complexity, and monitor project impacts in the Salmon River subbasin.
Grant Agreement 32000592	Freshwater Trust	\$50,000	July 2011 through June 2012	Fund design and construction of habitat restoration projects to reconnect isolated habitat and restore habitat complexity in the Salmon River subbasin.
Grant Agreement 30002765	Freshwater Trust	\$70,780	Summer of 2012	Fund the purchase and installation of a culvert on side-channel 18 of the Salmon River.
Grant Agreement 32001021	Freshwater Trust	\$127,500	July 2014 through June 2015	Fund the design and construction of habitat restoration projects on the Salmon River and Still Creek.
Intergovernmental Agreement 30004381	Oregon Department of Fish and Wildlife	\$12,105	July 2014 through June 2015	Complete a scale analysis of juvenile coho salmon and steelhead smolts to determine age structure and freshwater productivity.
Grant Agreement 32001148	Freshwater Trust	\$100,000	July 2015 through June 2016	Fund the design and construction of habitat restoration projects in Still Creek.
30005230	Freshwater Trust	\$96,458	July 2016 through June 2017	Fund the design and construction of habitat restoration projects on the Salmon River and Still Creek.
32001339	Sandy River Basin Watershed Council	\$145,000	July 2016 through June 2017	Restoration work on the upper Sandy River.
Intergovernmental Agreement 30004381	Oregon Department of Fish and Wildlife	\$6,385	July 2016 through June 2017	Complete a scale analysis of juvenile coho salmon and steelhead smolts to determine age structure and freshwater productivity.
32001489	Freshwater Trust	\$148,398	July 2017 through June 2018	Restoration work on the Salmon River and Still Creek.
Subtotal for Past Projects		\$881,626		

Planned Accomplishments for Calendar Year 2018

The City has approved one project from Sandy River Basin Partners to be implemented between July 2018 and June 30, 2019. The City will provide funding to The Freshwater Trust to support construction of habitat restoration projects on the Salmon River and Lost Creek. Table 11 shows the project planned to be funded through the HCP Habitat Fund.

Table 11. Planned Projects to be Funded through the HCP Habitat Fund

Number	Project Partner	Amount	Duration	Purpose
Not yet assigned	Freshwater Trust	\$150,000	July 2018 through June 2019	Restoration work on the Salmon River and Lost Creek.
Subtotal for Planned Projects		\$150,000		

Table 12. Summary of All Measures

This table includes all of the HCP measures. Measures that are not relevant to this reporting year are shaded with a gray background. The Status column shows the activity for the measure in 2016 (HCP Year 7), whether the measure has been completed or removed from the HCP, and other relevant information. If the Status column is blank, the measure is yet to be implemented. In some cases, the status description includes a reference to an appendix where more detailed measure information is available.

Bull Run Measures—Compliance					
#	Measure	Measurable Habitat Objective	Compliance Monitoring	HCP Years	Status
F-1	Minimum Instream Flow, Normal Water Years	Provide instream flows	Record hourly flows at USGS Gage No. 1414000	2010–59	Ongoing measure. Measure was in full compliance for 2017.
F-2	Minimum Instream Flows, Water Years with Critical Seasons	Provide instream flows	Record hourly flows at USGS Gage No. 1414000	2010–59	Ongoing measure. Measure was in full compliance for 2017.
F-3	Flow Downramping	Maintain downramping rate at or below 2"/hour	Record hourly flows at USGS Gage No. 14140000	2010–59	Ongoing measure. Measure was in full compliance in 2017.
F-4	Little Sandy Flow Agreement	Avoid conflicts with natural instream flows	Document completion of flow agreement	2010–14	Measure was completed in 2014. Confirmed by NMFS December 4, 2014 (see Appendix I, Item 9).
T-1	Pre-infrastructure Temperature Management	<u>Pre-infrastructure objective:</u> Maintain water temperatures at or below 21 °C at Larson's Bridge	Record water temperatures hourly for the lower Bull Run River and Little Sandy River	2010–13	Measure was in full compliance for 2010–2013. Measure was completed in 2013.

Bull Run Measures–Compliance

#	Measure	Measurable Habitat Objective	Compliance Monitoring	HCP Years	Status
T-2	Post-infrastructure Temperature Management	<u>Post-infrastructure objective:</u> Maintain water temperatures at their natural thermal potential	Record water temperatures hourly for the lower Bull Run River and Little Sandy River	2014–59	Ongoing measure. All infrastructure changes for the measure were completed by 2014. The City did not meet some water temperature targets in 2017.
P-1	Walker Creek Fish Passage	Provide year-round upstream and downstream passage for steelhead and coho	Document passage conditions compared with NMFS design criteria	2010–14	Measure was completed in 2010.
R-1	Reservoir Operations	Avoid or minimize mortality of cutthroat and rainbow trout	Document reservoir surface elevations	2010–59	Ongoing measure. Measure was in full compliance for 2017.
R-2	Cutthroat Trout Rescue	Prevent mortality of cutthroat trout in spillway canal	Document any fish mortality that occurs in the canal and/or during handling (prior to release)	2010–59	Measure was implemented from 2010–2012. Benefits to cutthroat trout were very low. The measure was cancelled in 2013. Change authorized by NMFS, April 26, 2013 (see Appendix H, Item 7 in the 2013 report).
R-3	Reed Canarygrass Removal	Improve one-third acre of habitat for Western toad, red-legged frog, and northwestern salamander through annual removal of reed canarygrass	Provide photo documentation of sites after reed canarygrass removal	2010–59	Ongoing measure. Measure was in full compliance for 2017. Appendix H summarizes 2017 monitoring conducted to determine whether the measure is having the desired outcomes.

Bull Run Measures–Compliance

#	Measure	Measurable Habitat Objective	Compliance Monitoring	HCP Years	Status
H-1	Spawning Gravel Placement	Supply spawning gravel in amounts equivalent to natural accumulation	Survey the lower Bull Run River (RM 1.5–RM 6.0) annually in Years 2–11 and every five years thereafter Document the amount of gravel placed, the placement locations, and amount of gravel usable for spawning by fish in annual report as described in Appendix F of the HCP	2010–59	Ongoing measure. Measure was in full compliance for 2017.
H-2	Riparian Land Protection	Preserve the riparian forest on City land along the lower Bull Run River	Survey riparian forest condition during annual spawning and gravel surveys; document results in annual report	2010–59	Ongoing measure. Measure was in full compliance for 2017.
O&M-1	Bull Run Infrastructure Operations and Maintenance	Avoid or minimize the effects of operations and maintenance activities on covered lands in the Bull Run Watershed	Document any releases of sediment or debris to the reservoirs, the lower Bull Run River, or any tributary streams Document changes in stormwater facilities at Sandy River Station, if needed Document tree planting and success of revegetation efforts	2010–59	Ongoing measure. Measure was in full compliance for 2017.
O&M-2	Bull Run Spill Prevention	Avoid or minimize effects of spills from water supply operations on covered species in the Bull Run River and the Sandy River below the confluence with the Bull Run	Document any spills to the reservoirs, the lower Bull Run River, or to any tributary streams	2010–59	Ongoing measure. Measure was in full compliance for 2017.

Offsite Measures–Compliance					
#	Measure	Measurable Habitat Objective	Compliance Monitoring	HCP Years	Status
Riparian Easements and Improvements					
H-11	Sandy 1 Riparian Easement and Improvement	Establish riparian forest of $\geq 70\%$ site potential trees (by canopy cover) for approximately 11 acres (with 100-foot buffer widths) within 15 years	Complete an aerial photograph analysis or site survey to determine whether planting is needed Repeat the analysis every five years for the term of the HCP to verify that initial planting has succeeded and/or if replanting is warranted Document date riparian easement is completed and when site potential forest is established	2010–14	Measure will not be implemented. Acreage target was moved to Measure H-12 Sandy 2 Riparian Easement and Improvement. Change authorized by NMFS on January 5, 2012 (see Appendix G, Item 5 in the 2012 report).
H-12	Sandy 2 Riparian Easement and Improvement	Establish riparian forest of $\geq 70\%$ site potential trees (by canopy cover) for approximately 62 acres (with 100-foot buffer widths) within 15 years	Same as above	2010–14	Measure was completed in 2014. All easement acreage targets have been met for the lower Sandy River Basin. Canopy cover monitoring is ongoing.

Offsite Measures–Compliance					
#	Measure	Measurable Habitat Objective	Compliance Monitoring	HCP Years	Status
H-13	Gordon 1A and 1B Riparian Easement and Improvement	<p>Establish riparian forest of $\geq 70\%$ site potential trees (by canopy cover) for approximately 78 acres within 15 years of establishment of easement</p> <p>Fifteen (15) acres are added to this measure to compensate for the acreage anticipated from Boulder 1 Riparian Easement and Improvement (H-22).</p>	<p>Complete an aerial photograph analysis or site survey to determine whether planting is needed</p> <p>Repeat the analysis every five years for the term of the HCP to verify that initial planting has succeeded and/or if replanting is warranted</p> <p>Document date riparian easement is completed and when site potential forest is established</p>	2010–14	23 acres of easement area obtained in Gordon Creek (20 acres in 2012; 3 acres in 2011). 70 acres moved to Sandy 2 Riparian Easement and Improvement. Change authorized by NMFS on September 25, 2012 (see Appendix G, Item 6 in the 2012 report). Measure was completed in 2014. All easement acreage targets have been met for the lower Sandy River Basin. Canopy cover monitoring is ongoing.
H-14	Sandy 3 Riparian Easement and Improvement	Establish riparian forest of $\geq 70\%$ site potential trees (by canopy cover) for approximately 7 acres (with 100-foot buffer widths) within 15 years of establishment of easement	Same as above	2020–24	Measure was completed in 2012. Canopy cover monitoring is ongoing.
H-15	Cedar 2 and 3 Riparian Easement and Improvement	Establish riparian forest of $> 70\%$ site potential trees (by canopy cover) for approximately 49 acres (with 100-foot buffer widths) within 15 years of establishment of easement	Same as above	2015–19	25 acres of easement area obtained in Cedar Creek in 2015. Measure is in process. Canopy cover monitoring is ongoing.

Offsite Measures–Compliance					
#	Measure	Measurable Habitat Objective	Compliance Monitoring	HCP Years	Status
H-16	Alder 1A and 2 Riparian Easement and Improvement	Establish riparian forest of >70% site potential trees (by canopy cover) for approximately 43 acres (with 100-foot buffer widths) within 15 years of establishment of easement	Same as above	2010–14	PWB is not pursuing easement acreage in Alder Creek due to unwillingness of private landowners to participate in program. The City is obtaining easements in reaches Sandy 7 and 8 to compensate for the acreage that could not be obtained in Alder Creek. Change authorized by NMFS, July 12, 2013, and February 13, 2017 (see Appendix I, Items 11 and 12).
	Sandy 7 Riparian Easement and Improvement	Establish riparian forest of \geq 70% site potential trees (by canopy cover, with 100-foot buffer widths) within 15 years of establishment of easement	Same as above		29 acres of easement acquired in 2017. This is a new target area. Change authorized by NMFS on February 13, 2017. Permission given to acquire easements on Sandy 7, 8 in lieu of Salmon 1, 2, 3 (see Appendix I, Item 12 in the 2017 report).
H-18	Sandy 8 Riparian Easement and Improvement	Establish riparian forest of \geq 70% site potential trees (by canopy cover) for approximately 25 acres (with 100-foot buffer widths) within 15 years of establishment of easement	Same as above	2020–24	Measure has been partially completed—PWB anticipates full compliance by 2024.

Offsite Measures–Compliance					
#	Measure	Measurable Habitat Objective	Compliance Monitoring	HCP Years	Status
H-19	Salmon 1 Riparian Easement and Improvement	Establish riparian forest of $\geq 70\%$ site potential trees (by canopy cover) for approximately 23 acres (with 100-foot buffer widths) within 15 years of establishment of easement	Same as above	2015–19	This measure will not be implemented. The City is pursuing easements in Sandy 7, 8 to compensate for the acreage that could not be obtained in Salmon 1, 2, or 3. Change authorized by NMFS, February 13, 2017 (see Appendix I, Item 12, in the 2017 report).
H-20	Salmon 2 Riparian Easement and Improvement	Establish riparian forest of $\geq 70\%$ site potential trees (by canopy cover) for approximately 36 acres (with 100-foot buffer widths) within 15 years. of establishment of easement	Same as above	2020–24	
H-21	Salmon 3 Riparian Easement and Improvement	Establish riparian forest of $\geq 70\%$ site potential trees (by canopy cover) for approximately 12 acres (with 100-foot buffer widths) within 15 years of establishment of easement	Same as above	2020–24	
H-22	Boulder 1 Riparian Easement and Improvement	Establish riparian forest of $> 70\%$ site potential trees (by canopy cover) for approximately 15 acres (with 100-foot buffer widths) within 15 years of establishment of easement	Same as above	2010–14	This measure will not be implemented. The City has obtained easements in Gordon Creek and the lower Sandy River to compensate for the acreage that could not be obtained in Boulder Creek. Change authorized by NMFS, May 11, 2011 (see Appendix F, Item 1, in the 2011 report).

Offsite Measures–Compliance					
#	Measure	Measurable Habitat Objective	Compliance Monitoring	HCP Years	Status
H-28	Zigzag 1A/1B Riparian Easement and Improvement	Establish riparian forest of >70% site potential trees (by canopy cover) for approximately 12 acres (with 100-foot buffer widths) within 15 years of establishment of easement	Same as above	2020–24	
H-23	Salmon 2 Miller Quarry Acquisition	Negotiate a sales agreement for the Miller Quarry property.	<p>Document purchase of the site in annual report</p> <p>Complete an aerial photograph analysis or site survey to determine whether planting is needed</p> <p>Repeat the analysis every five years for the term of the HCP to verify that initial planting has succeeded and/or if replanting is warranted</p> <p>Document date riparian easement is completed and when site potential forest is established</p>	2015–19	PWB has worked since 2011 to purchase the Miller Quarry property. The property has lead contamination, which the sellers are unwilling to address. PWB is unable to purchase the property and will discuss the impacts to the measure's projected benefits with NMFS.

Offsite Measures–Compliance

#	Measure	Measurable Habitat Objective	Compliance Monitoring	HCP Years	Status
H-24	Salmon 2 Miller Quarry Restoration	Establish riparian forest of >70% site potential trees (by canopy cover) for approximately 40 acres (with 100-foot buffer widths) within 15 years of acquisition	Document purchase of the site in annual report Complete an aerial photograph analysis or site survey to determine whether planting is needed Repeat the analysis every five years for the term of the HCP to verify that initial planting has succeeded and/or if replanting is warranted Document date riparian easement is completed and when site potential forest is established	2015–19	See Measure H-23. PWB cannot acquire, or restore the Miller Quarry property. PWB will discuss measure with NMFS.

Water Rights

F-5	Cedar Creek Purchase Water Rights	During HCP Years 1-10, purchase approximately 50% of the current surface water rights that affect summer flows	Document the rights purchased and the estimated amount of additional flow for fish	2010–19	Measure cannot be completed due to unwilling seller. PWB will discuss with NMFS.
-----	-----------------------------------	--	--	---------	--

Fish Passage

P-2	Alder 1 Fish Passage	Provide year-round upstream and downstream passage for steelhead	Document passage conditions compared with NMFS design criteria once every three years after project implementation	2010–14	Measure was completed in 2013.
-----	----------------------	--	--	---------	--------------------------------

Offsite Measures–Compliance					
#	Measure	Measurable Habitat Objective	Compliance Monitoring	HCP Years	Status
P-3	Alder 1A Fish Passage	Provide upstream and downstream passage for native fish during the months of water diversion operation	Same as above	2010–14	Measure was completed in 2014.
P-4	Cedar Creek 1 Fish Passage	Provide up to \$3.7 million dollars to fund fish passage improvements on Cedar Creek.	Same as above	2010–14	Measure was completed in 2014.
Carcass Placement					
H-25	Salmon 2 Carcass Placement	Place 1,800 salmon carcasses in one season	Document number of carcasses, release sites, and year of implementation	2015–19	Measure was completed in the Zigzag and upper Sandy Rivers in 2013. Change authorized by NMFS, December 3, 2013 (see Appendix H, Item 8 in the 2013 report). Measure was completed early.
H-29	Zigzag 1A, 1B, and 1C Carcass Placement	Place 1,800 salmon carcasses in one season	Same as above	2020–24	Measure was completed in the Zigzag and upper Sandy Rivers in 2014. Change authorized by NMFS, December 3, 2013 (see Appendix H, Item 8 in the 2013 report). Measure was completed early.
Large Wood					
H-3	Little Sandy 1 and 2 LW Placement	Place 50 key pieces of LW and achieve 80% of predicted woody debris levels within 15 years of placement	Monitor number of pieces of wood in the stream as described in HCP Appendix F	2015–19	Measure was completed in 2014, earlier than specified in the HCP.

Offsite Measures–Compliance					
#	Measure	Measurable Habitat Objective	Compliance Monitoring	HCP Years	Status
H-4	Sandy 2 Log Jams	Place 2 engineered log jams and other large wood in reach Sandy 2, totaling 530 pieces. Increase off-channel habitat by 8,164 square feet. 80% of predicted woody debris levels will be attained within 15 years of placement.	Same as above	2015–19	Construction was begun in 2017 and will be completed in 2018. Measure incorporates benefit increases to offset those of canceled Measure H-9. Change authorized by NMFS, April 14, 2015 (see Appendix H, Item 10 in the 2015 report).
H-5	Gordon 1A and 1B LW Placement	Place 300 key pieces of LW in reaches Gordon 1A and 1B and achieve 80% of predicted woody debris levels within 15 years of placement An additional 65 key pieces of LW will be placed in reaches Gordon 1A and 1B to compensate for the wood that was not placed in Boulder 0 and 1.	Same as above	2010–14	Measure was completed in 2013.
H-6	Trout 1A LW Placement	Place 25 key pieces of LW and achieve 80% of predicted woody debris levels within 15 years of placement	Same as above	2010–14	Measure was completed in 2013.

Offsite Measures–Compliance					
#	Measure	Measurable Habitat Objective	Compliance Monitoring	HCP Years	Status
H-7	Trout 2A LW Placement	Place 20 key pieces of LW in reach Trout 2A and achieve 80% of predicted woody debris levels within 15 years of placement	Same as above	2010–14	Measure will not be implemented. Large wood placements planned for this measure have been added to Trout 1A LW Placement project instead. Change authorized by NMFS, August 16, 2011 (see Appendix F, Item 2 in the 2011 report) and March 15, 2012 (see Appendix G, Item 4 in the 2012 report).
H-17	Cedar 2 and 3 LW Placement	Place 600 key pieces of LW in reaches Cedar 2 and 3 and achieve 80% of predicted woody debris levels within 15 years of placement	Same as above	2015–19	Measure was completed in 2016. Only 470 pieces of LW were placed because of limited landowner permissions.
H-26	Boulder 0 and 1 LW Placement	Place 65 key pieces of LW in reaches Boulder 0 and 1 and achieve 80% of predicted woody debris levels within 15 years of placement	Same as above	2010–14	Measure will not be implemented. Large wood placements planned for this measure have been added to Gordon 1A and 1B LW Placement instead. Change authorized by NMFS, August 16, 2011 (see Appendix F, Item 2 in the 2011 report).
Channel Restoration					
H-8	Sandy 1 Reestablishment of River Mouth	Create one additional mile of stream by reconnecting with original river mouth	Document reestablishment of the historical Sandy River mouth	2015–19	The measure was completed in 2013, approximately five years ahead of schedule.

Offsite Measures–Compliance					
#	Measure	Measurable Habitat Objective	Compliance Monitoring	HCP Years	Status
H-9	Sandy 1 Channel Reconstruction	Open one-third river miles of side-channel habitat Place 25 logs in side channel	Tag all side-channel logs at the time of placement for later identification Once every three years, resurvey the stream to document seasonal flooding of the side-channel habitat and determine how many pieces of LW are still within the side channel	2015–19	Measure will not be implemented. Large wood placements planned for this measure have been added to Measure H-4 Sandy 2 Log Jams instead. Change authorized by NMFS, April 14, 2015 (see Appendix H, Item 10 in the 2015 compliance report).
H-10	Sandy 1 Turtle Survey and Relocation	Avoid direct impacts to western painted turtles and northwestern pond turtles	Document surveys of potential turtle habitat. Document all turtle relocations (species, number, locations, and dates) Note: Measure H-10 is only necessary for projects conducted in the Sandy River delta.	2015–19	Measure was completed in 2013 in conjunction with Measure H-8.
H-27	Zigzag 1A Channel Redesign	Maintain one-third mile of floodplain habitat for steelhead, coho, and spring Chinook Place 25 pieces of LW in reaches Zigzag 1A and 1B	Tag all pieces of LW at the time of placement for later identification Once every three years, resurvey the stream to determine how many pieces of LW are still within the side channel	2020–24	
Terrestrial Wildlife Habitat Conservation					
W-1	Minimize Impacts to Spotted Owls	Avoid disturbance of active nesting habitat	Survey protocols for owls, eagles, and fishers have not yet been determined Protocols will be available within six months of the start of the HCP term	2010–59	Ongoing measure. Measure was in full compliance in 2017.

Offsite Measures–Compliance

#	Measure	Measurable Habitat Objective	Compliance Monitoring	HCP Years	Status
W-2	Minimize Impacts to Bald Eagles	Avoid disturbance of active winter night roosts or nests	Survey protocols for owls, eagles, and fishers have not yet been determined Protocols will be available within six months of the start of the HCP term	2010–59	Ongoing measure. Measure was in full compliance in 2017.
W-3	Minimize Impacts to Fishers	Avoid disturbance of fisher habitat	Survey protocols for owls, eagles, and fishers have not yet been determined Protocols will be available within six months of the start of the HCP term	2010–59	Ongoing measure. Measure was in full compliance in 2017.

Monitoring for Clean Water Act Section 401 Certification

Topic	Monitoring Protocol & Analysis	Results Reporting	Duration	Status and Report Location
Monitoring for CWA Section 401 Certification	Monitor for five required water-quality parameters	Include with annual compliance report	For the first 5 years of operation of the modified Bull Run Dam 2 Tower	Baseline data collection period was August 2012–December 2013. Monitoring will continue through 2019, or as determined by ODEQ. See Appendix B.

Offsite Measures—Effectiveness					
#	Measure	Measurable Habitat Objective	Effectiveness Monitoring	HCP Years	Status
Large Wood					
H-5	Gordon 1A and 1B LW Placement	Achieve 80% of predicted increase in pieces of LW within 15 years of implementation	Conduct habitat surveys per monitoring protocol	2010–14	Measure was completed in 2013. Effectiveness monitoring will continue through 2025. See Appendix A.
H-6	Trout 1A LW Placement	Achieve 80% of predicted increase in pieces of LW within 15 years of implementation	Conduct habitat surveys per monitoring protocol	2010–14	Measure was completed in 2013. Effectiveness monitoring will continue through 2025. See Appendix A.
H-7	Trout 2A LW Placement	Achieve 80% of predicted increase in pieces of LW within 15 years of implementation	Conduct habitat surveys per monitoring protocol	2010–14	Measure will not be implemented and associated effectiveness monitoring has been cancelled. Change approved by NMFS March 15, 2012 (see Appendix G, Item 4 in the 2012 report.)
H-3	Little Sandy 1 and 2 LW Placement	<p>Achieve 80% of predicted increase in pieces of LW within 15 years of implementation</p> <p>Achieve 80% of predicted increase in backwater pools, pools, and pool-tail habitat within 15 years of implementation</p> <p>Achieve 80% of predicted increase in percentage of total habitat that is large-cobble riffles, within 15 years of implementation</p>	Conduct habitat surveys per monitoring protocol	2015–19	Measure was completed in 2014. Effectiveness monitoring will continue through 2027.

Offsite Measures—Effectiveness					
#	Measure	Measurable Habitat Objective	Effectiveness Monitoring	HCP Years	Status
H-26	Boulder 0 and 1 LW Placement	Achieve 80% of predicted increase in pieces of LW within 15 years of implementation.	Conduct habitat surveys per monitoring protocol	2010–15	Measure will not be implemented and associated effectiveness monitoring has been cancelled. Change authorized by NMFS, August 16, 2011 (see Appendix F, Item 2 in the 2011 report).
H-4	Sandy 2 Log Jam Placements	Achieve 80% of predicted increase in pieces of LW within 15 years of implementation. Achieve 80% of predicted increase in off-channel habitat within 15 years of implementation.	Conduct habitat surveys per monitoring protocol	2015–19	Measure was in full compliance in 2017. Effectiveness monitoring was initiated in 2015 and will continue through 2031.

Offsite Measures—Effectiveness

#	Measure	Measurable Habitat Objective	Effectiveness Monitoring	HCP Years	Status
H-17	Cedar 2 and 3 LW Placement	Achieve 80% of predicted increase in pieces of LW within 15 years of implementation Achieve 80% of predicted increase in percentage of off-channel, beaver pond and pool habitat within 15 years of implementation	Conduct habitat surveys per monitoring protocol	2015–19	Measure completed in 2016. Effectiveness monitoring was initiated in 2014 and will continue through 2029.

Channel Restoration

H-9	Sandy 1 Channel Reconstruction	Achieve 80% of predicted increase in percentage of off-channel habitat within 15 years of implementation	Every three years, resurvey the site to determine whether the gradient control structure is maintaining flow in the side channel and the river	2015–19	Measure will not be implemented and associated effective monitoring has been cancelled. Fish production anticipated from this measure will be offset by enhanced habitat restoration efforts in Sandy 2. Change authorized by NMFS, April 14, 2015 (see Appendix H, Item 10, in the 2015 compliance report).
-----	---------------------------------------	--	--	---------	--

Offsite Measures—Effectiveness					
#	Measure	Measurable Habitat Objective	Effectiveness Monitoring	HCP Years	Status
H-24	Salmon 2 Miller Quarry Restoration	Achieve 80% of predicted improvements in off-channel habitat within 15 years of implementation	Once every three years after measure implementation, survey opened floodplain area and side channels	2020–24	
H-27	Zigzag 1A Channel Design	Achieve 80% of predicted habitat improvements within 15 years of implementation	Conduct habitat surveys per monitoring protocol	2020–24	
H-30	Habitat Fund	The City will provide money to create a Habitat Fund of \$9 million to contribute to large-scale partnership projects and to implement additional projects for adaptive management, if necessary	Determined through measure effectiveness monitoring	2010–59	Ongoing measure. Measure was in full compliance in 2017.

Research				
Topic	Research Protocol & Analysis	Results Reporting	HCP Years	Status and Report Location
Spawning Gravel Placement	Change in gravel from baseline each year, trends over time, using t-tests & linear regression	HCP Years 6 and 12	2010–59	Measure was in full compliance in 2017. See Appendix C.
Spawning Gravel Scour	Change in bed elevation, depth of scour, percentage of redds with significant scour	Monitoring starts HCP Year 5; reporting in Year 2016	2015–19	Measure was in full compliance in 2017. See Appendix G.

Research				
Topic	Research Protocol & Analysis	Results Reporting	HCP Years	Status and Report Location
Total Dissolved Gas	Exceedence of 110% TDG saturation, rate of TDG dissipation downstream of monitoring. Regression analysis, possibly modeling.	Include with annual compliance report	2010–59	Measure was in full compliance in 2017. See Appendix D.
BR Adult Chinook Population	Survey, sampling, linear regression	Include with annual compliance report	2010–59	Measure was in full compliance in 2017. See Appendix E.
Sandy River Basin Smolt Monitoring	Mark recapture study, various analyses methods	Include with annual compliance report	2010–59	Measure was in full compliance in 2017. See Appendix F.

Appendixes

- A. Effectiveness Monitoring for Offsite In-Channel Conservation Measures
- B. Monitoring Results for Certification According to Section 401 of the Clean Water Act
- C. Lower Bull Run River Spawning Gravel Research
- D. Total Dissolved Gases in the Bull Run River
- E. Lower Bull Run River Adult Chinook Population
- F. Sandy River Basin Smolt Monitoring
- G. Lower Bull Run River Spawning Gravel Scour Research
- H. Western Toad Monitoring for Reservoir Operations Measure R-3
- I. Correspondence on Measures

Appendix A

Bull Run HCP Effectiveness Monitoring Report

Effectiveness Monitoring for Offsite In-Channel Conservation Measures

April 2018

Burke Strobel

City of Portland Water Bureau



Contents

1. Summary.....	1
2. Introduction	1
3. Measurable Objectives.....	2
4. Key Questions and Hypothesis	4
5. Monitoring Design.....	4
5.1 Study Design	4
5.2 Spatial Scale.....	5
5.3 Replication/Duration.....	5
5.4 Variables.....	5
5.5 Sampling Scheme.....	6
6. Analysis	7
6.1 Data Storage	7
6.2 Hypothesis Testing	7
7. Adaptive Management.....	8
8. 2017 Results.....	8
9. Discussion	10
10. Works Cited	12

Tables

Table 1. Attributes and Measurable Habitat Objectives in Reaches Affected by In-Channel Measures and Surveyed in 2017.....	3
Table 2. Paired Treatment and Control Reaches in Streams Surveyed in 2017	5
Table 3. Comparison of Values for Various Habitat Attributes in the Sandy River Derived from the EDT Database and 2017 Survey Results	8
Table 4. Comparison of Values for Various Habitat Attributes ^a in Cedar Creek Derived from the EDT Database and 2017 Survey Results.....	9

1. Summary

The City of Portland Water Bureau (PWB) was in full compliance with its Habitat Conservation Plan obligations in 2017 with regard to effectiveness monitoring for offsite in-channel conservation measures. Fish habitat surveys were conducted for two offsite measures—H-4, Sandy 1 and 2 Log Jams, and H-17, Cedar 2 and 3 Large Wood Placement.

This appendix summarizes the results of the 2017 surveys. The data collected in 2017 for H-4, Sandy 2 Log Jams (formerly titled Sandy 1 and 2 Log Jams), contribute to information about baseline conditions, with which the post-treatment conditions of this stream will be compared. This was the first year of post-treatment monitoring in Cedar Creek. Implementation of H-4, Sandy 2 Log Jams, was initiated in the summer of 2017, but was not completed. Post-treatment monitoring for this measure will not begin until 2019.

2. Introduction

PWB committed through its Bull Run Water Supply Habitat Conservation Plan (HCP; Portland Water Bureau 2008) to implement a number of in-channel fish habitat enhancement measures at offsite locations. Offsite locations are those not in the Bull Run watershed, but at other Sandy River basin streams. These include various tributaries in the basin, portions of the main stem of the Sandy River, and the Little Sandy River. In-channel measures are being completed within the normal high-flow channel of a stream. In-channel measures do not include efforts to improve the riparian zone.

Associated with each offsite in-channel measure are one or more measurable habitat objectives. The effectiveness of PWB's efforts to improve fish habitat at these offsite locations is being evaluated by measuring the habitat attributes associated with these objectives and determining how closely the habitat attributes approach or surpass the value of the respective objective.

In 2017, baseline data and post-treatment data were collected in streams. Baseline data were collected in the Sandy River. Post-treatment data were collected for Cedar Creek.

This appendix describes the effectiveness monitoring protocols and results to-date for the in-channel measures completed or to be conducted in the Sandy River and Cedar Creek. These measures involve placing large wood and creating log jams to influence stream morphological features such as pools and riffles and to accumulate spawning gravel.

3. Measurable Objectives

The offsite in-channel measures discussed in Chapter 7 of the HCP and their predicted effects on habitat attributes have been evaluated using the Ecosystem Diagnostic and Treatment (EDT) model (City of Portland and Mobrand Biometrics 2004). The anticipated benefits of these measures are summarized by reach and ranked by the predicted net change in the attributes' respective metrics listed in Table 1. The net attribute changes in Table 1 include only those benefits expected to be derived from the proposed in-channel restoration projects. Other measures, such as riparian easements, may occur in, and have benefits for, the same reaches, but these benefits are expected to occur over time scales that are longer than the time scales for the offsite in-channel measures. The benefits of other measures are not part of the scope of this research.

The anticipated benefits from H-4, Sandy 2 Log Jams have been changed from what was originally reported in the HCP. The scope of Measure H-4 has been changed to include the restoration work in Sandy 2 and to include the expected fish production benefits originally attributed to HCP measure H-9, Sandy 1 Channel Reconstruction. The original measure planned for Sandy 1 and 2 anticipated increasing large wood in Sandy 2 by 70 percent. The current measure scope calls for increasing large wood by 39 percent, but also anticipates creating off-channel habitat and improving riparian function. Riparian function is not evaluated by the City's Effectiveness Monitoring Program.

The anticipated benefits from H-17 Cedar Creek Large Wood Placement also have been reduced from what was originally reported in the HCP. Permission could not be obtained to work along large portions of the Cedar Creek channel. The available length of stream channel was insufficient to accommodate the number of wood pieces originally planned for placement. The original measure planned to increase large wood in Cedar 3 by 67%. The modified measure anticipates increasing large wood by 32%. The benefits anticipated for Cedar 2 remain unchanged.

The net changes predicted in Table 1 represent measurable habitat objectives created for each individual reach. The monitoring objective is to document how effectively the offsite in-channel measures accomplish measurable habitat objectives. PWB's working hypothesis for effectiveness monitoring of these measures is that at least 80 percent of the projected changes in the key habitat attributes (pre-project versus post-project conditions) will occur in each affected stream reach.

PWB has committed to a performance level of 80 percent of projected changes (instead of 100 percent) because there will be a high degree of natural variation year to year and site to site. The natural variation will be further compounded by the error associated with measuring habitat variables in the field. Given this high level of variation, it would not be possible to statistically detect a difference between a 100 percent change in a habitat variable and a much smaller change. PWB chose 80 percent as a minimum performance standard. If that level of habitat response is not met, additional actions may

be required, and PWB will follow the adaptive management program described in Chapter 9 of the HCP.

Table 1. Attributes and Measurable Habitat Objectives in Reaches Affected by In-Channel Measures and Surveyed in 2017^{a,b}

Attribute	Measurable Habitat Objective (80% of Net Change in Metric)		Reach
	Metric	Net Change	
Large Woody Debris	Number of pieces per channel width	39%	Sandy 2
Off-Channel Habitat	Percentage of reach (by surface area) that comprises off-channel habitat	1%	
Large Woody Debris	Number of pieces per channel width	100%	Cedar 2
Large Woody Debris	Number of pieces per channel width	32%	Cedar 3
Beaver Ponds	Percentage of reach (by surface area) that comprises beaver ponds	39%	
Pool Habitat	Percentage of reach (by surface area) that comprises pool habitat	25%	

^aSource: EDT model run (10/20/2005) for current and historical status of attributes and expected values after implementation of individual measures.

^bAppendix E of the HCP, Offsite Habitat Effects Tables, provides the list of all attributes, habitat objectives, and reaches that may be affected by the HCP measures.

4. Key Questions and Hypothesis

One key question and its related null hypothesis (H_0) will be answered by the offsite monitoring protocol:

Question: Did the implementation of the restoration projects result in the changes to the monitored habitat attributes that were predicted by the EDT assessment?

H_0 : The difference between the mean of baseline values and the mean of post-treatment values in treatment reaches will not be significantly less than the difference predicted by the EDT assessment.

In order to make this comparison, the baseline values in the EDT model will be updated by collecting at least two years of pre-treatment data on all the habitat attributes that are predicted to significantly change (summarized in Table 1). The differences in habitat conditions between the actual pre-treatment and post-treatment data will be used to determine whether the projected EDT fish benefits, as expressed in the HCP, are realized.

The comparison of the observed changes in monitored habitat attributes to measurable habitat objectives will be analyzed both numerically and statistically (using a 95 percent level of confidence). The numeric test will simply determine whether the mean of post-treatment values is at least 80 percent of the target values. The measurable habitat objective for each offsite, in-channel measure response variable was set at 80 percent of the projected change to account for the fact that each variable is expected to show a large degree of variation. The statistical test will assign a level of confidence to each of the pre-treatment and post-treatment values and determine the power of the statistical test to detect significant shortfalls. Having a level of confidence associated with each value will be helpful during the adaptive management process, should any post-treatment value fall short of the measurable habitat objective.

5. Monitoring Design

5.1 Study Design

PWB uses a Before-After with Control-Impact (BACI) study design to monitor the effects of the HCP offsite, in-stream mitigation projects (Roni et al. 2005). Control reaches upstream of the treated reaches will be surveyed, in addition to the treated reaches, as indicated in Table 2. Control reaches will be entire upstream reaches delineated for EDT or one mile in length, whichever is less, to minimize survey effort and yet provide a representative length of stream. In cases in which a treated reach is very long (more than five miles) and the treatment is restricted to the lower portion of the reach, the upstream portion of the same reach will serve as a control. This approach is used because the further upstream a control reach is, the less representative it probably

is of the habitat in which treatment occurred. PWB will use attribute values for the entire EDT reach (including the control reach segment) as the treatment reach values and just use attribute values from the control reach segment as the respective control reach values.

Table 2. Paired Treatment and Control Reaches in Streams Surveyed in 2017

Watershed	Treated Reaches	Control Reaches
Lower Sandy River ^a	Sandy 2	Sandy 2 (upper 4 miles)
Middle Sandy River	Cedar 2	Cedar 4
	Cedar 3	Cedar 4

^aThe upstream-most four miles of Sandy 2 serve as the control reach for the rest of Sandy 2.

5.2 Spatial Scale

The measureable habitat objectives (in Table 1) are reach-scale objectives. The survey protocol is to collect data at both the habitat-unit and reach scales, but all the data are used to derive reach-scale assessments of habitat condition. Reaches vary in length, so all attribute values are normalized by either channel length or surface area.

5.3 Replication/Duration

Most habitat attributes are naturally variable from year to year. For example, if wood is added to a reach but high flows do not occur the following winter, there may be no resultant formation of pools. In other years, winter high flows may fill in some pools and create new ones elsewhere. For this reason, before (baseline) and after (post-treatment) data will be replicated over time.

Surveys are conducted in the summer or early fall when flows are low and the stream channels are most navigable. Two to three pre-treatment surveys and five post-treatment surveys are conducted. Pre-treatment surveys will be conducted annually prior to treatment. Post-treatment surveys are conducted at three-year intervals beginning the year after treatment and continuing for 12 additional years, for a total of five post-treatment surveys.

5.4 Variables

The habitat attributes used by EDT to evaluate restoration alternatives are derived from the data types summarized below. All data types are information collected during stream surveys. However, not all attributes are used to evaluate the effectiveness of the offsite in-channel measures.

- Reach-scale data
 - Active channel (bankfull)¹ width (feet)
 - Gradient (percent)
 - Total surface area of off-channel habitat (estimated visually, in square feet)
- Habitat unit-scale data
 - Habitat type (pool, backwater pool, beaver pond, glide, small-cobble riffle, large-cobble riffle)
 - Average length (feet)
 - Average width (feet)
 - Amount of pool tail-out habitat (data collected in pools only; percentage of total surface area that is at the downstream end of the pool and flowing with velocities comparable to those of neighboring glides and riffles)
 - In-channel wood (number of pieces greater than 1 foot in diameter and greater than 7 feet long in the active channel of the habitat unit)
 - Fine sediment in spawning habitat types (percentage surface area of gravel patches in small-cobble riffles, pool tail-outs, glides)
 - Embeddedness in spawning habitat types (percent of the vertical dimension of surface cobbles and large gravel that is buried in fine sediment in gravel patches in small-cobble riffles, pool tail-outs, glides)

These data enable PWB to evaluate how well it has met most of the measurable habitat objectives summarized in Table 1. The percentage of fine sediment in spawning gravels may show too much in-reach variability to allow the detection of the anticipated change.

5.5 Sampling Scheme

Habitat attributes in both treatment and control reaches are monitored using a modified Hankin and Reeves-type stratified systematic inventory of stream channel characteristics (Hankin and Reeves 1988).

Hankin and Reeves-type protocols involve two main sources of error. PWB adjusts its protocols to reduce these sources of error. The first source of error stems from the strategy of estimating habitat dimensions throughout a reach and then using a subset of measurements to correct the estimates. These corrections are associated with a range of variability, which decreases confidence in the final result. To maximize the statistical power of the monitoring data analysis, given the small sample size of pre-treatment data, all habitat unit dimensions are measured. The second source of error is measurement error, which can accumulate over the length of a reach. PWB monuments survey

¹ The active channel, or bankfull channel, is the portion of the channel where flows occur often enough to prevent the establishment of vegetation, generally corresponding to a break in the slope of the bank.

reaches at specific intervals to allow for standardization of lengths between years, unless natural landmarks are identified to serve a similar purpose.

6. Analysis

6.1 Data Storage

Monitoring data collected during the HCP are maintained by PWB in Microsoft® Excel spreadsheets. Summary data will be added to the Sandy River EDT database. The data will be made available to the National Marine Fisheries Service, U.S. Fish and Wildlife Service, Oregon Department of Fish and Wildlife, and other regulatory agencies (Services) for review at any time and will be extensively discussed during the HCP Year-20 check-in meeting of PWB with the services. Following quality assurance/quality control procedures and review and approval by PWB and the Services, the data will be made available to the StreamNet Library (through the Columbia River Inter-Tribal Fish Commission [CRITFC] technical reports), Oregon Department of Fish and Wildlife AIP (<http://oregonstate.edu/Dept/ODFW/freshwater/inventory/index.htm>), and the U.S. Forest Service Natural Resource Information System (NRIS) Water Module databases. Each of these databases was consulted extensively in the Sandy River Basin EDT analysis. Appropriate treatment- and control-reach data that are already in these databases will be used to bolster the sample size of the pre-treatment habitat attributes. Pre-existing data will not be used if the habitat in the respective streams has since been modified by restoration activities other than the planned HCP offsite in-channel measures.

6.2 Hypothesis Testing

Both the numeric and statistical evaluation of the hypothesis for the monitoring plan key question suggest a fundamental comparison between baseline and post-treatment data on a reach-by-reach, attribute-by-attribute basis. Control reaches will be employed to subtract out variation due to large-scale effects outside of PWB's control. An example of how this will occur is given below (T=Treatment reach value, C=Control reach value):

$$\left. \begin{array}{l} T_{\text{before1}} - C_{\text{before1}} \\ T_{\text{before2}} - C_{\text{before2}} \end{array} \right\} \text{ mean vs. mean } \left\{ \begin{array}{l} T_{\text{after1}} - C_{\text{after1}} \\ T_{\text{after2}} - C_{\text{after2}} \\ T_{\text{after3}} - C_{\text{after3}} \\ T_{\text{after4}} - C_{\text{after4}} \\ T_{\text{after5}} - C_{\text{after5}} \end{array} \right.$$

The numeric comparison of the means of pre-treatment and post-treatment data will determine whether or not the post-treatment mean is equal to or greater than 80 percent of the measurable habitat objective. For statistical comparisons, t-tests will be performed on the differences between treatment reach and control reach habitat attribute values, with a 95 percent level of confidence.

7. Adaptive Management

If data indicate that the effectiveness monitoring protocol null hypotheses should not be rejected, and if the new EDT results indicate that the predicted changes to freshwater productivity are less than originally described for PWB's offsite in-channel conservation measures, PWB will follow the adaptive management process described in Chapter 9 of the HCP.

8. 2017 Results

Tables 3 and 4 summarize the results for offsite in-stream measure effectiveness monitoring surveys conducted in 2017 in the Sandy River and Cedar Creek, respectively. The tables also compare survey results with the values for the current condition of the same habitat attributes in the EDT database. The control reach for Sandy 2 was expanded in 2017 to include the upper four miles, rather than the upper one mile. The Sandy River is large enough that one mile did not capture a range of habitat variation that is representative of this reach. The control reach has been adjusted accordingly for the 2015 and 2016 survey data.

Table 3. Comparison of Values for Various Habitat Attributes^a in the Sandy River Derived from the EDT Database and 2017 Survey Results

Attribute	Treatment Reach		Control Reach ^c	
	Sandy 2 Reach		Sandy 2 Upper Reach	
	EDT Current	2017 Survey	EDT Current	2017 Survey
Large Wood (pieces/CW) ^b	6.5	7.2	6.5	4.0
Backwater Pools	2.4%	0.2%	2.4%	0.8%
Beaver Ponds	0.0%	0.02%	0.0%	0.0%
Pools	13.9%	28.5%	13.9%	26.0%
Pool Tails	2.8%	3.6%	2.8%	0.4%
Small-Cobble Riffles	34.8%	18.3%	34.8%	4.7%
Large-Cobble Riffles	34.8%	28.9%	34.8%	46.8%
Glides	11.1%	20.4%	11.1%	21.4%
Off-Channel Habitat	3.0%	0.03%	3.0%	0.0%
Percent Fines	14.5%	17.6%	14.5%	7.7%
Embeddedness	37.5%	38.4%	37.5%	31.5%

^aThe selected attributes are expected to respond to HCP in-stream conservation measures.

Table 3. Comparison of Values for Various Habitat Attributes^a in the Sandy River Derived from the EDT Database and 2017 Survey Results

Attribute	Treatment Reach		Control Reach ^c	
	Sandy 2 Reach		Sandy 2 Upper Reach	
	EDT Current	2017 Survey	EDT Current	2017 Survey

^bLarge wood is given as a standardized metric (pieces of wood per average high-flow channel width [CW].)

^cControl reach for Sandy 2 was expanded in 2017 to include the upper four miles of the reach rather than the upper mile.

Table 4. Comparison of Values for Various Habitat Attributes^a in Cedar Creek Derived from the EDT Database and 2017 Survey Results

Attribute	Treatment Reaches				Control Reach	
	Cedar 2 Reach		Cedar 3 Reach		Cedar 4 Reach	
	EDT Current	2017 Survey	EDT Current	2017 Survey	EDT Current	2017 Survey
Large Wood (pieces/CW) ^b	1.5	1.6	1.5	3.8	3.0	2.6
Backwater Pools	14.0%	0.0%	7.0%	0.2%	2.0%	0.0%
Beaver Ponds	1.0%	0.5%	6.0%	0.0%	0.0%	0.0%
Pools	14.0%	28.2%	21.0%	24.6%	19.0%	11.1%
Pool Tails	3.0%	2.2%	4.0%	2.2%	3.0%	0.8%
Small-Cobble Riffles	25.0%	10.2%	24.0%	1.5%	28.0%	0.3%
Large-Cobble Riffles	35.0%	58.9%	33.0%	71.6%	50.0%	87.7%
Glides	0.0%	0.0%	6.0%	0.0%	4.0%	0.0%
Off-Channel Habitat	8.0%	0.0%	15.0%	0.0%	0.0%	0.0%
Percent Fines	14.5%	3.1%	8.5%	4.1%	8.5%	3.7%
Embeddedness	0.0%	20.4%	0.0%	46.0%	0.0%	40.0%

^aThe selected attributes are expected to respond to HCP in-stream conservation measures.

^bLarge wood is given as a standardized metric (pieces of wood per average high-flow channel width [CW]).

Table 5 summarizes the averages of baseline values, standard deviations, and post-treatment targets for the habitat attributes that have measurable habitat objectives in each treatment reach. Control reaches are not included because they do not have measurable habitat objectives. The number of baseline survey years that are incorporated into each baseline average and the number of post-treatment survey years incorporated into each post-treatment average is given in respective order in parentheses in the Reach column, separated by a comma.

Table 5. Baseline Averages, Post-Treatment Targets, and Post-Treatment Averages for Habitat Attributes with Measurable Habitat Objectives in Streams Surveyed in 2017^{a,b}

Attribute	Baseline Average	Standard Deviation	Post-Treatment Target	Post-Treatment Average ^c	Reach
Large Woody Debris (pieces/CW)	7.33	0.48	9.00	NA	Sandy 2 (n=1,0)
Off-Channel Habitat	0.03%	0.00%	3.04%	NA	
Large Woody Debris (pieces/CW)	2.04	0.34	3.00	1.57	Cedar 2 (n=2,0)
Large Woody Debris (pieces/CW)	2.10	0.82	2.50	3.77	Cedar 3 (n=2,0)
Beaver Ponds	0.00%	0.00%	7.89%	0.00%	
Pool Habitat	27.12%	2.35%	26.31%	24.58%	

^aSource: EDT model run (10/20/2005) for current and historical status of attributes and expected values after implementation of individual measures.

^bAppendix E of the HCP, Offsite Habitat Effects Tables, provides the list of all attributes, habitat objectives, and reaches that may be affected by the HCP measures.

^cNA takes the place of a post-treatment average if the project has not yet been implemented.

9. Discussion

The results presented in Tables 3, 4, and 5 of this report contribute to the baseline average of values and begins a record of post-treatment values for the respective monitored habitat attributes. Measure H-17 (Cedar 2 and 3 Large Wood Placement) was implemented in 2016, so the habitat attribute data collected in this stream in 2017 are post-treatment measurements. Further post-treatment data will be collected in Cedar Creek in 2020, 2023, 2026, and 2029. The bureau will begin collecting post-treatment data on the Sandy River in 2019.

The comparison of baseline values to the current condition values in the EDT database will help determine whether more restoration is needed than was assumed during the development of the HCP. The comparison of the averages of post-treatment values for habitat attributes to the averages of baseline values in each treatment reach and with the respective averages in control reaches will determine whether PWB has met its restoration targets in those streams and whether additional efforts are necessary.

10. Works Cited

- City of Portland. 2004. Development and Application of the EDT Database and Model for the Sandy River Basin. Prepared with assistance from Mobrand Biometrics, Inc. Portland, Oregon.
- Hankin, David G., and Gordon H. Reeves. 1988. Estimating total fish abundance and total habitat area in small streams based on visual estimation methods. *Can. J. Fish. Aquat. Sci.* 45:834-844.
- Portland Water Bureau. 2008. Bull Run Water Supply Habitat Conservation Plan for the Issuance of a Permit to Allow Incidental Take of Threatened and Endangered Species. Portland, Oregon.
- Roni, Philip, Andrew H. Fayram, and Michael A. Miller. 2006. Monitoring and evaluating instream habitat enhancement. Pages 209-236 in *Monitoring Stream and Watershed Restoration* (P. Roni, ed.). American Fisheries Society. Bethesda, Maryland.

Appendix B

Bull Run HCP Monitoring Report

Monitoring Results for Certification According to Section 401 of the Clean Water Act

February 2018

Kristin Anderson

City of Portland Water Bureau



Contents

1. Summary 1

2. Introduction 1

3. Monitoring Design..... 3

 3.1 Parameters..... 3

 3.1.1 Nuisance Phytoplankton Growth and the Creation of Taste, Odors, and
 Toxic Conditions 3

 3.1.2 Dissolved Oxygen 3

 3.1.3 pH Levels..... 3

 3.1.4 Temperature..... 3

 3.2 Sampling..... 4

 3.3 Map of Sampling Sites 5

4. Analysis 6

5. Results 6

 5.1.1 Nuisance Phytoplankton Growth and the Creation of Taste, Odors, and
 Toxic Conditions 7

 5.1.2 Dissolved Oxygen 7

 5.1.3 pH Levels..... 8

 5.1.4 Temperature..... 8

6. Conclusions 8

7. Works Cited 8

Exhibit A. Raw Data 9

1. Summary

The City modified its Bull Run Dam 2 water intake towers per the commitments described in the Bull Run Water Supply Habitat Conservation Plan (HCP) Measure T-2. As part of the conditions from the Federal Energy Regulatory Commission that oversees the associated Portland Hydroelectric Project, the City must monitor and report on the impacts of the Dam 2 Tower project to the Oregon Department of Environmental Quality (DEQ). DEQ has issued a Section 401 certification under the Clean Water Act. The certification requirements describe the conditions the City must meet (Oregon Department of Environmental Quality 2012). The 401 conditions require the City to report on five water-quality parameters: 1) nuisance phytoplankton growth, 2) the creation of taste, odors, and toxic conditions, 3) dissolved oxygen levels, 4) pH levels, and 5) temperature.

This report is produced annually, as part of the HCP compliance report. Baseline water quality sampling occurred from 2009 to 2013. Baseline conditions are those that existed before construction and operation of the Dam 2 tower. The City will be monitoring the five water quality parameters for five years, 2014–2018. Initial monitoring started after the completion of the Dam 2 Tower project. The monitoring data will be compared to pre-construction and operation conditions (baseline conditions) to document changes in water quality due to the modifications to the Dam 2 tower, or Dam 2 operations.

This report includes results from the 2017 water quality monitoring efforts (see Exhibit A). For nuisance phytoplankton growth and taste, odors, and toxic conditions, the City tracked nutrient conditions and did not observe any increasing trends compared to baseline conditions. Observations of dissolved oxygen and pH were within the range observed in baseline conditions, with the exception of one dissolved oxygen measurement at the base of the reservoir. The results section of this appendix includes a discussion of water quality criteria for reservoirs as described in the Oregon Administrative Rules and how Bull Run Reservoir 2 results comply with these criteria.

2. Introduction

As part of the HCP, the City of Portland is implementing its Temperature Management Plan for the Lower Bull Run River to fulfill requirements of the Clean Water Act (City of Portland 2008). The Temperature Management Plan describes the background, scientific basis for, baseline conditions, and implementation plan for HCP Measure T-2. The intent of HCP Measure T-2—Post-infrastructure Temperature Management—is to better control the temperature of water that PWB releases from the reservoir for fish in the lower Bull Run River. The measure requires that PWB design, permit, and complete a project to modify water intake towers at Dam 2 to allow taking water from the

reservoir at different levels. For the Dam 2 Tower Improvement Project, the north intake tower was modified to have multi-level gates for taking water from Reservoir 2.

Conducting this project affects the operation of the Portland Hydroelectric Project (PHP) Powerhouse 2. Because of the proposed modifications to the Dam 2 infrastructure, the City completed a non-capacity license amendment process with the Federal Energy Regulatory Commission (FERC). As part of that licensing process, the Oregon Department of Environmental Quality (ODEQ) reviewed the impacts of the Dam 2 Tower project on certain water-quality parameters that have the potential to be affected by the operation of the modified north intake tower. ODEQ approved a 401 certification for the Dam 2 Tower Project and issued certification conditions to the City in 2012.

Section 401 of the CWA requires certification that the discharge water from a proposed action, such as work on the intake towers, will comply with water-quality standards in Oregon. The five water-quality parameters identified in the 401 certification that have the potential to be affected by work in Bull Run Reservoir 2 are listed in Table 1 with the Oregon Administrative Rule (OAR) number and the OAR description of the potential impact.

Table 1. Water Quality Parameters to Monitor for CWA Section 401 Certification

Water Quality Parameter	Oregon Administrative Rule	Potential Impact
Nuisance Phytoplankton Growth	OAR 340-041-0019	Changes in reservoir circulation may lead to changes in nutrient concentrations, which in turn may lead to algal blooms.
Creation of Taste, Odors, Toxic Conditions	OAR 340-041-007(12)	Taste and odor or toxic conditions can occur from nuisance algal blooms.
Dissolved Oxygen	OAR 340-041-0016	Changes in water circulation in reservoir may alter dissolved oxygen concentration, especially at depth with change in residence time deep in reservoir; algal bloom respiration and decay may also consume dissolved oxygen.
pH	OAR 340-041-0021	Algal blooms may cause spikes in pH values.
Temperature	OAR 340-041-0028	Changes in withdrawal depth may result in temperature changes downstream.

The initial monitoring from 2009 to 2013 provided baseline results. The monitoring results in subsequent years are compared with the baseline data.

3. Monitoring Design

Monitoring for the five parameters was conducted as specified in Table 2 (on page 5) when conditions were safe to do so.

3.1 Parameters

3.1.1 Nuisance Phytoplankton Growth and the Creation of Taste, Odors, and Toxic Conditions

The purpose of this monitoring is to determine whether operation of the new intake structure will contribute to the formation of nuisance or toxic algal blooms in Reservoir 2. In 2017, the City completed monthly sampling of nutrient concentrations in Bull Run Reservoir 2. Nutrient samples were analyzed for nitrate (NO_3^-), nitrite (NO_2^-), total nitrogen (N), reactive phosphorus (PO_4^-), and total phosphorus (P). See Section 3.2 for a description of the sampling methods for these parameters.

3.1.2 Dissolved Oxygen

Dissolved oxygen was monitored upstream and downstream of Bull Run Dam 2 in 2017. This monitoring fulfills two objectives:

- To determine whether operation of the new intake structure contributes to changes in dissolved oxygen concentrations within the reservoir
- To determine whether operation of the new intake structure provides the level of oxygen saturation established by Oregon DEQ in the Clean Water Act Section 401 Certification Conditions (Oregon Department of Environmental Quality 2012).

Monitoring for reservoir dissolved oxygen concentrations consisted of biweekly dissolved oxygen measurements in Bull Run Reservoir 2. Monitoring for lower Bull Run River flow consisted of biweekly dissolved oxygen measurements in the lower Bull Run River downstream of Reservoir 2. A station for this monitoring has been established at the bridge over the Bull Run River immediately below Headworks (Headworks Bridge). See Section 3.2 for a description of the sampling methods for this parameter.

3.1.3 pH Levels

Compliance with the pH parameter was monitored through biweekly pH measurements in Bull Run Reservoir 2. See Section 3.2 for a description of the sampling methods for this parameter.

3.1.4 Temperature

Compliance with the temperature parameter was monitored upstream and downstream of Bull Run Dam 2. This monitoring fulfills two objectives:

- Provide information on how operation of the new intake affects stratification in Reservoir 2
- Determine how the daily maximum temperature in the lower Bull Run River is affected by operation of the new intake tower

Monitoring for stratification consisted of biweekly temperature measurements in Bull Run Reservoir 2. Monitoring the daily maximum temperature measurements at Larson's Bridge in the lower Bull Run River was already being conducted as part of compliance for HCP Measure T-1 Pre-Infrastructure Temperature Management. For HCP Measure T-2, Post-Infrastructure Temperature Management, the bureau continues to report on temperatures in the lower Bull Run River at Larson's Bridge for the period required for 401 Certification.

3.2 Sampling

Reservoir water sampling was conducted from a boat at the deepest part of Reservoir 2, denoted as Station 60-1. Grab samples for nutrients were collected with a Kemmerer sampler at discrete depths beginning at three meters above the reservoir bottom, continuing up at intervals in the water column and ending with a sample at a depth of one meter.

Measurements of dissolved oxygen, pH, and temperature were collected *in situ* in a vertical profile using a multiparameter probe that logs the data as they are collected. During the baseline monitoring period, a weight was suspended three meters below the sampling device to determine reservoir depth. Investigators interpreted that the action of the weight hitting the bottom of the reservoir caused some sediment to be stirred up, resulting in lower-than-expected dissolved oxygen concentrations. Late in 2013, reservoir sampling for dissolved oxygen included using a depth finder to determine reservoir depth. Samples at the Headworks Bridge for downstream dissolved oxygen measurements were collected by a multiparameter probe lowered from the bridge into the river.

Temperature measurements at Larson's Bridge were made by the U.S. Geological Survey (USGS) using a temperature probe placed in the river. Data were stored at 15-minute intervals on a data logger on-site and telemetered hourly via satellite to the USGS data center, from which they were made available on the Internet. The 15-minute data are considered provisional and are used by the USGS to determine daily mean, minimum, and maximum temperatures, which are published annually as approved data.

Table 2 summarizes the sampling methods, locations, and baseline sampling periods by parameter.

Table 2. Sampling Methods, Locations, and Baseline Periods for Section 401 Water Quality Parameters

Water Quality Parameter	Sampling Method	Sampling Location	Baseline Sampling Period
Nuisance Phytoplankton Growth	Monthly nutrient samples at specific depths	Reservoir 2 Station 60-1	January 2009 – December 2013
Creation of Taste, Odors, Toxic Conditions	Monthly nutrient samples at specific depths	Reservoir 2 Station 60-1	January 2009 – December 2013
Dissolved Oxygen	Biweekly <i>in situ</i> vertical profiles	Reservoir 2 Station 60-1	January 2009 – December 2013
	Biweekly multiparameter probe lowered from bridge	Headworks Bridge	August 2012 – December 2013
pH	Biweekly <i>in situ</i> vertical profiles	Reservoir 2 Station 60-1	January 2009 – December 2013
Temperature	Biweekly <i>in situ</i> vertical profiles	Reservoir 2 Station 60-1	January 2009 – December 2013
	15-minute monitoring with on-site data logger	USGS Station 14140020 at Larson's Bridge	N/A ^a

^aTemperature data are continually collected at this location.

3.3 Map of Sampling Sites

**Figure 1. Sampling Sites for Monitoring**

4. Analysis

Data for each parameter were analyzed by PWB staff. Reservoir nutrient concentrations were calculated at each sample depth for each nutrient. Reservoir dissolved oxygen concentration and saturation levels, temperatures, and pH levels for the entire reservoir profile were recorded. In the lower Bull Run River, dissolved oxygen concentration and saturation levels and temperatures were recorded for readings taken at Headworks Bridge. Temperature data at Larson's Bridge are available online at the USGS website, http://waterdata.usgs.gov/or/nwis/dv/?site_no=14140020&agency_cd=USGS&referred_module=sw.

5. Results

Data from 2017 were compared to the 2009–2013 baseline results (see Table 2 for the baseline sampling periods). As anticipated with the infrastructure change, stronger stratification occurred in the reservoir, creating more defined zones of water temperature and other water quality parameters within the vertical profile of Reservoir 2. However, nearly all water quality parameters monitored for the Section 401 certification still were within the ranges observed during the baseline monitoring period, with the exception of one dissolved oxygen measurement that was below the lowest value observed during the baseline period. Thermal stratification occurs each year in the reservoir, with a defined epilimnion, metalimnion, and hypolimnion.¹ Dissolved oxygen measurements outside of the baseline range are limited to the hypolimnion and in 2017 were observed only at the bottom-most sampling depth on October 3. In all observations from 2014 through 2017 in which dissolved oxygen at the base of the reservoir was lower than baseline conditions, 95% or more of the reservoir still had favorable conditions for cold-water fish.

Exhibit A includes raw data from the 2017 monitoring effort in Reservoir 2 and at the Headworks Bridge site. Temperature data for the lower Bull Run River from USGS Station 14140020 at Larson's Bridge are available from the USGS at the following website: http://waterdata.usgs.gov/or/nwis/dv/?site_no=14140020&agency_cd=USGS&referred_module=sw.

¹ The epilimnion is the uppermost, warm layer of a water body; the metalimnion (also referred to as the thermocline) is the middle layer defined by its rapidly decreasing temperature with depth; and the hypolimnion is the bottom, cold layer of a water body. These layers typically develop in the spring and persist through early to mid-fall.

5.1.1 Nuisance Phytoplankton Growth and the Creation of Taste, Odors, and Toxic Conditions

For nuisance phytoplankton growth and the potential creation of taste, odors, and toxic conditions, the City tracked nutrient concentrations to determine whether there were increasing trends compared to baseline condition levels. In 2017, nutrient results showed no observable increasing trends. Reactive phosphorus ranged from <0.003 mg/L to 0.004 mg/L, and total phosphorus was <0.01 mg/L. Nitrite was <0.005 mg/L, nitrate ranged from <0.01 mg/L to 0.073 mg/L, and total nitrogen from <0.05mg/L to 0.15 mg/L.

Table A-1 shows nutrient monitoring results for 2017. Samples were often collected and analyzed at a frequency greater than the required frequency.

5.1.2 Dissolved Oxygen

Dissolved oxygen concentrations downstream of Dam 2 were at or above values observed in the baseline monitoring period. Sampling in 2017 showed dissolved oxygen saturation values of 99.4–105 percent at the Headworks Bridge. Baseline sampling in 2012–2013 showed dissolved oxygen saturation values of 94.5–103 percent at the Headworks Bridge. Table A-2 shows results of dissolved oxygen monitoring at the Headworks Bridge.

In the 2013 compliance report, the lowest values of dissolved oxygen that were observed in Bull Run Reservoir 2 were questionable due to the monitoring practice. Yet with a change in method to using a depth finder rather than a weight to determine the reservoir depth, low dissolved oxygen values were still observed at the base of the reservoir. This changes the interpretation of the lowest dissolved oxygen values observed from 2009 to 2013; it now appears that low dissolved oxygen values occur naturally without sediment disturbance.

The monitoring results from 2017 show, overall, high levels of dissolved oxygen. Of 754 total observations of dissolved oxygen in Reservoir 2 in 2017, five observations showed dissolved oxygen concentrations lower than 6 mg/L. Dissolved oxygen concentrations lower than 6 mg/L were observed in the bottom 4 meters of the reservoir from September 19 through October 3. These values ranged from 5.0 mg/L to 5.8 mg/L. The lowest observed value during the baseline monitoring period from 2009–2013 was 5.2 mg/L.² Dissolved oxygen concentrations below 5.2 mg/L were observed in the bottom-most sample of the reservoir on October 3. Table A-3 includes dissolved oxygen results from Reservoir 2.

² One observed value of 2.5 mg/L during the baseline monitoring period was later discarded due to lack of confidence in the results.

5.1.3 pH Levels

The range of pH observed in 2017 is within the range observed in the baseline monitoring period. Results ranged from pH 6.5 to 7.5. It is notable that many instances of pH less than 6.5 were observed in the baseline-monitoring period. The lowest observed pH value during the baseline monitoring period from 2009–2013 was 5.8. Table A-3 includes results for pH observed in Reservoir 2 during the 2017 monitoring period.

5.1.4 Temperature

Table A-3 also includes temperature measurements taken during profiling of Reservoir 2 during the 2017 monitoring period. As expected, thermal stratification was observed to change seasonally. Figure A-1 shows the thermal stratification throughout 2017.

6. Conclusions

With the exception of one low dissolved oxygen observation at the base of Reservoir 2 in early October, monitoring in 2017 showed results within ranges observed in the baseline conditions. Continued monitoring will provide results that can be compared with the baseline conditions to look for changes relative to pre-project conditions.³

7. Works Cited

City of Portland. 2008. Bull Run Water Supply Habitat Conservation Plan For the Issuance of A Permit to Allow Incidental Take of Threatened and Endangered Species. Appendix G. Temperature Management Plan for the Lower Bull Run River. Portland, Oregon. Available at www.portlandoregon.gov/water/46157.

Oregon Department of Environmental Quality. 2012. Clean Water Act Section 401 Certification Conditions for the City of Portland's Bull Run Reservoir Hydroelectric Project (FERC No. 2821), Sandy River Basin, Clackamas County, Oregon. Available online at www.oregon.gov/deq/wq/wqpermits/Pages/Section-401-Hydropower.aspx.

³ This is true for all parameters except temperatures in the lower Bull Run River, which will be monitored under HCP Measure T-2, Post-Infrastructure Temperature Management.

Figure A-1. Bull Run Reservoir 2 temperature profiles 2017.

Reservoir 2 Temperature Profiles

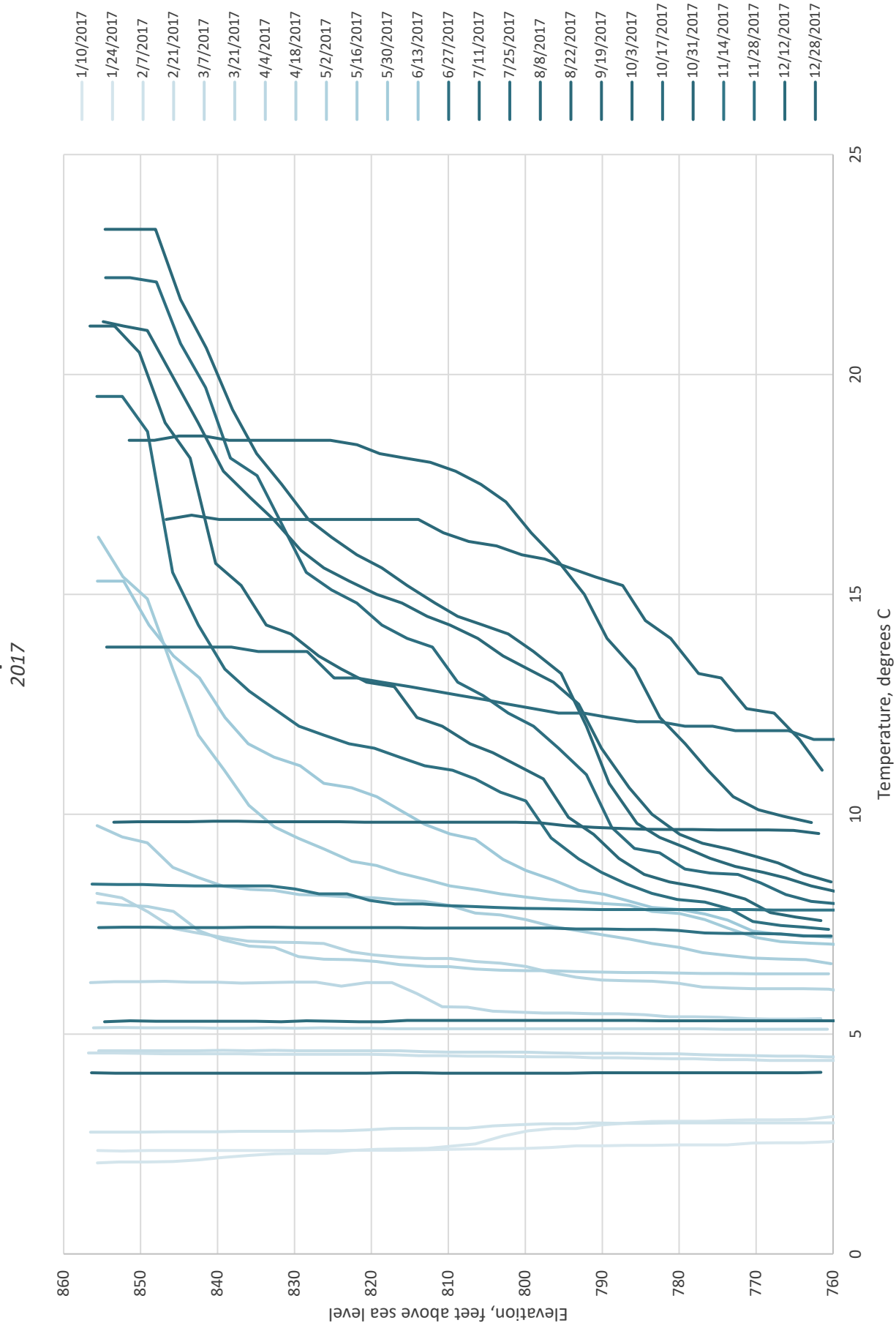


Table A-1. Reservoir 2 Nutrient Monitoring at Station 60-1 for Reactive Phosphorus, Total Phosphorus, Nitrite, Nitrate, and Total Nitrogen^a

Sample Depth M	Elevation ft MSL	PO ₄ mg/L	Total P mg/L	NO ₂ mg/L	NO ₃ mg/L	Total N mg/L
1/10/2017						
1	855.6	<0.003	<0.01	<0.005	0.046	0.09
6	839.3	<0.003	<0.01	<0.005	0.048	0.09
15	809.8	<0.003	<0.01	<0.005	0.048	0.09
22	786.8	<0.003	<0.01	<0.005	0.048	0.09
30	760.6	<0.003	<0.01	<0.005	0.048	0.09
1/24/2017						
1	855.6	<0.003	<0.01	<0.005	0.050	0.09
6	839.1	<0.003	<0.01	<0.005	0.050	0.09
15	809.8	<0.003	<0.01	<0.005	0.052	0.09
22	786.5	<0.003	<0.01	<0.005	0.048	0.09
31	757.3	<0.003	<0.01	<0.005	0.048	0.08
2/7/2017						
1	856.5	<0.003	<0.01	<0.005	0.053	0.09
6	840.3	0.004	<0.01	<0.005	0.052	0.09
15	810.8	<0.003	<0.01	<0.005	0.049	0.09
22	787.8	<0.003	<0.01	<0.005	0.052	0.09
31	758.3	<0.003	<0.01	<0.005	0.054	0.09
2/21/2017						
1	856.8	<0.003	<0.01	<0.005	0.049	0.08
6	840.4	<0.003	<0.01	<0.005	0.052	0.08
15	810.6	<0.003	<0.01	<0.005	0.053	0.08
22	787.9	<0.003	<0.01	<0.005	0.054	0.08
31	758.4	<0.003	<0.01	<0.005	0.054	0.08
3/7/2017						
1	855.5	<0.003	<0.01	<0.005	0.045	0.07
6	839.3	<0.003	<0.01	<0.005	0.046	0.08
15	809.8	<0.003	<0.01	<0.005	0.045	0.07
22	786.8	<0.003	<0.01	<0.005	0.046	0.07
31	757.3	<0.003	<0.01	<0.005	0.046	0.07
3/21/2017						
1	855.7	0.003	<0.01	<0.005	0.038	0.08
6	839.3	<0.003	<0.01	<0.005	0.037	0.07
15	809.5	<0.003	<0.01	<0.005	0.037	0.07
22	786.8	<0.003	<0.01	<0.005	0.037	0.07
30	760.3	<0.003	<0.01	<0.005	0.039	0.07
4/4/2017						
1	856.5	<0.003	<0.01	<0.005	0.017	0.07
6	840.2	<0.003	<0.01	<0.005	0.016	0.06
15	810.8	<0.003	<0.01	<0.005	0.020	0.05
22	787.8	<0.003	<0.01	<0.005	0.026	0.06
30	761.6	<0.003	<0.01	<0.005	0.027	0.06

Sample Depth M	Elevation ft MSL	PO ₄ mg/L	Total P mg/L	NO ₂ mg/L	NO ₃ mg/L	Total N mg/L
4/18/2017						
1	855.7	<0.003	<0.01	<0.005	<0.010	0.06
6	839.3	<0.003	<0.01	<0.005	0.011	0.06
15	809.8	<0.003	<0.01	<0.005	0.012	0.05
22	786.8	<0.003	<0.01	<0.005	0.014	<0.05
31	757.3	<0.003	<0.01	<0.005	0.015	0.05
5/2/2017						
1	855.6	<0.003	<0.01	<0.005	<0.010	0.06
6	839.3	<0.003	<0.01	<0.005	0.013	0.06
15	809.8	<0.003	<0.01	<0.005	0.016	0.05
22	786.8	<0.003	<0.01	<0.005	0.018	0.06
30	760.6	<0.003	<0.01	<0.005	0.017	0.05
5/16/2017						
1	855.7	<0.003	<0.01	<0.005	<0.010	0.05
6	839.2	<0.003	<0.01	<0.005	<0.010	0.06
15	809.8	<0.003	<0.01	<0.005	<0.010	0.05
22	786.5	<0.003	<0.01	<0.005	<0.010	<0.05
30	760.3	<0.003	<0.01	<0.005	0.022	0.06
5/30/2017						
1	855.5	<0.003	<0.01	<0.005	<0.010	<0.05
6	839.1	<0.003	<0.01	<0.005	<0.010	<0.05
15	809.8	<0.003	<0.01	<0.005	<0.010	0.05
22	786.5	<0.003	<0.01	<0.005	0.011	0.05
30	760.6	<0.003	<0.01	<0.005	0.019	0.06
6/13/2017						
1	855.6	<0.003	<0.01	<0.005	<0.010	0.07
6	839	<0.003	<0.01	<0.005	<0.010	0.05
15	809.8	<0.003	<0.01	<0.005	<0.010	<0.05
22	786.8	<0.003	<0.01	<0.005	0.025	0.09
30	760.3	<0.003	<0.01	<0.005	0.026	0.07
6/27/2017						
1	855.7	<0.003	<0.01	<0.005	<0.010	0.08
6	839.1	<0.003	<0.01	<0.005	<0.010	0.07
15	809.5	<0.003	<0.01	<0.005	<0.010	<0.05
22	786.8	<0.003	<0.01	<0.005	<0.010	0.05
30	760.6	<0.003	<0.01	<0.005	0.026	0.07
7/11/2017						
1	856.6	<0.003	<0.01	<0.005	<0.010	0.06
6	840.3	<0.003	<0.01	<0.005	<0.010	0.06
15	810.8	<0.003	<0.01	<0.005	<0.010	0.06
22	787.8	<0.003	<0.01	<0.005	<0.010	<0.05
30	761.6	<0.003	<0.01	<0.005	0.027	0.07

Sample Depth M	Elevation ft MSL	PO ₄ mg/L	Total P mg/L	NO ₂ mg/L	NO ₃ mg/L	Total N mg/L
7/25/2017						
1	854.6	<0.003	<0.01	<0.005	<0.010	0.06
6	838.3	<0.003	<0.01	<0.005	<0.010	0.06
14	812.1	<0.003	<0.01	<0.005	<0.010	0.05
22	785.8	<0.003	<0.01	<0.005	<0.010	<0.05
8/8/2017						
1	854.6	<0.003	<0.01	<0.005	<0.010	0.06
6	838.1	<0.003	<0.01	<0.005	<0.010	0.06
14	811.8	<0.003	<0.01	<0.005	<0.010	0.05
22	785.5	<0.003	<0.01	<0.005	<0.010	<0.05
30	759.6	0.004	<0.01	<0.005	0.025	0.06
8/22/2017						
1	854.9	<0.003	<0.01	<0.005	<0.010	0.07
6	839.3	<0.003	<0.01	<0.005	<0.010	0.06
15	809.8	<0.003	<0.01	<0.005	0.015	0.07
22	786.5	<0.003	<0.01	<0.005	0.012	0.05
30	760.3	<0.003	<0.01	<0.005	0.026	0.06
9/19/2017						
1	851.5	<0.003	<0.01	<0.005	<0.010	0.07
5	838.5	<0.003	<0.01	<0.005	<0.010	0.08
13	812.4	<0.003	<0.01	<0.005	0.016	0.09
21	785.8	<0.003	<0.01	<0.005	0.025	0.08
28	762.8	<0.003	<0.01	<0.005	0.031	0.08
10/3/2017						
1	846.7	<0.003	<0.01	<0.005	0.012	0.08
3	839.8	<0.003	<0.01	<0.005	0.013	0.09
12	810.6	<0.003	<0.01	<0.005	0.013	0.08
19	787.4	<0.003	<0.01	<0.005	0.050	0.12
27	761.4	<0.003	<0.01	<0.005	0.035	0.12
10/17/2017						
1	854.4	<0.003	<0.01	<0.005	0.038	0.11
6	838.2	<0.003	<0.01	<0.005	0.039	0.10
14	811.8	<0.003	<0.01	<0.005	0.049	0.11
22	785.5	<0.003	<0.01	<0.005	0.059	0.13
31	756.3	<0.003	<0.01	<0.005	0.068	0.14
10/31/2017						
1	853.5	<0.003	<0.01	<0.005	0.072	0.15
5	840.5	<0.003	<0.01	<0.005	0.072	0.14
14	810.8	0.003	<0.01	<0.005	0.073	0.14
21	788.1	<0.003	<0.01	<0.005	0.071	0.14
29	761.9	<0.003	<0.01	<0.005	0.072	0.15

Sample Depth	Elevation	PO ₄	Total P	NO ₂	NO ₃	Total N
M	ft MSL	mg/L	mg/L	mg/L	mg/L	mg/L
11/14/2017						
1	856.3	<0.003	<0.01	<0.005	0.058	0.13
6	839.8	<0.003	<0.01	<0.005	0.058	0.14
15	810.4	<0.003	<0.01	<0.005	0.059	0.12
22	787.4	<0.003	<0.01	<0.005	0.058	0.12
31	757.9	<0.003	<0.01	<0.005	0.058	0.12
11/28/2017						
1	855.5	0.003	<0.01	<0.005	0.044	0.11
6	839.3	0.004	<0.01	<0.005	0.044	0.10
15	809.8	<0.003	<0.01	<0.005	0.045	0.10
22	786.8	0.003	<0.01	<0.005	0.046	0.11
30	760.3	0.004	<0.01	<0.005	0.047	0.10
12/12/2017						
1	854.7	<0.003	<0.01	<0.005	0.039	0.09
6	838.3	<0.003	<0.01	<0.005	0.039	0.08
14	812.1	<0.003	<0.01	<0.005	0.039	0.08
21	788.8	<0.003	<0.01	<0.005	0.039	0.08
30	759.6	<0.003	<0.01	<0.005	0.040	0.09

^am is meters, ft MSL is feet above mean sea level, mg/L is milligrams per liter, PO₄ is reactive phosphorus, Total P is total phosphorus, NO₂ is nitrite, NO₃ is nitrate, Total N is total nitrogen

Table A-2. Headworks Bridge Data for Dissolved Oxygen (DO) and Temperature^a

Date	Depth m	DO concentration mg/L	DO saturation %	Temperature °C
1/10/2017	0.29	13.3	102.0	2.6
1/24/2017	0.57	13.7	103.0	2.5
2/7/2017	0.20	13.4	103.0	2.9
2/21/2017	0.34	13.2	104.0	4.6
3/7/2017	0.11	12.8	102.0	4.7
3/21/2017	0.27	12.8	104.0	5.3
4/4/2017	0.16	12.4	103.0	6.3
4/18/2017	0.73	12.0	101.0	7.1
5/2/2017	0.24	12.3	103.0	7.1
5/16/2017	0.13	11.7	103.0	8.2
5/31/2017	0.12	11.5	105.0	10.0
6/13/2017	1.53	11.1	103.0	11.0
6/27/2017	1.16	10.6	101.0	12.3
7/11/2017	1.38	11.5	103.0	9.2
7/25/2017	1.35	11.2	101.0	9.9
8/8/2017	0.86	9.7	99.4	15.2
8/22/2017	1.23	11.1	101.0	10.2
9/19/2017	1.58	11.1	102.0	10.7
10/3/2017	1.62	10.3	102.0	14.2
10/17/2017	0.22	10.8	103.0	12.3
10/31/2017	0.74	11.3	102.0	9.9
11/14/2017	0.19	12.1	105.0	8.1
11/28/2017	0.93	12.0	103.0	7.5
12/12/2017	0.32	13.0	104.0	5.4
12/28/2017	0.06	13.1	102.0	4.2

^am is meters, mg/L is milligrams per liter, °C is degrees Celsius

On 9/5/2017, sampling was cancelled due to the proximity of the Eagle Creek Fire to the Bull Run watershed.

Table A-3. Reservoir 2 Profile Data at Station 60-1 for Dissolved Oxygen (DO), Temperature, and pH^a

Sample Depth	Elevation	DO concentration	DO saturation	Temperature	pH
m	ft MSL	mg/L	%	°C	
1/10/2017					
1	855.6	12.9	97.9	2.4	7.1
2	852.4	12.9	97.9	2.3	7.1
3	849.0	12.9	98.0	2.4	7.1
4	845.8	12.9	98.0	2.4	7.1
5	842.6	12.9	98.0	2.4	7.1
6	839.3	12.9	97.9	2.4	7.1
7	836.0	12.9	97.9	2.4	7.1
8	832.8	12.9	97.9	2.4	7.1
9	829.4	12.9	97.9	2.4	7.0
10	826.2	12.9	97.9	2.4	7.1
11	822.9	12.9	97.9	2.4	7.0
12	819.6	12.9	97.9	2.4	7.0
13	816.3	12.9	97.9	2.4	7.0
14	813.1	12.9	98.0	2.4	7.0
15	809.8	12.9	98.0	2.4	7.0
16	806.5	12.9	97.9	2.4	7.0
17	803.2	12.9	97.9	2.4	7.0
18	799.9	12.8	97.9	2.4	7.0
19	796.7	12.8	97.9	2.4	7.0
20	793.4	12.8	97.8	2.5	7.0
21	790.1	12.8	97.8	2.5	7.0
22	786.8	12.8	97.8	2.5	7.0
23	783.5	12.8	97.8	2.5	7.0
24	780.3	12.8	97.8	2.5	7.0
25	777.0	12.8	97.7	2.5	7.0
26	773.7	12.8	97.7	2.5	7.0
27	770.4	12.8	97.7	2.5	7.0
28	767.1	12.8	97.6	2.5	7.0
29	763.9	12.8	97.6	2.5	7.0
30	760.6	12.8	97.6	2.6	7.0
31	757.3	12.7	97.4	2.6	6.8
1/24/2017					
1	855.6	13.1	97.4	2.1	7.0
2	852.8	13.1	97.5	2.1	7.0
3	849.2	13.1	97.4	2.1	7.0
4	845.8	13.1	97.4	2.1	7.0
5	842.5	13.1	97.5	2.1	7.0
6	839.1	13.1	97.6	2.2	7.0
7	835.9	13.1	97.6	2.2	7.0
8	832.6	13.1	97.7	2.3	7.0
9	829.4	13.1	97.7	2.3	7.0
10	825.9	13.1	97.7	2.3	7.0

Sample Depth	Elevation	DO concentration	DO saturation	Temperature	pH
m	ft MSL	mg/L	%	°C	
11	822.6	13.1	97.8	2.4	7.0
12	819.3	13.1	97.9	2.4	7.0
13	816.3	13.1	97.9	2.4	7.0
14	812.7	13.1	97.8	2.4	7.0
15	809.8	13.1	97.9	2.5	7.0
16	806.5	13.0	98.0	2.5	7.0
17	802.9	13.0	97.7	2.7	7.0
18	799.6	12.9	97.8	2.8	7.0
19	796.3	12.9	97.8	2.9	7.0
20	793.4	12.9	97.8	2.9	7.0
21	790.1	12.9	97.7	2.9	7.0
22	786.5	12.8	97.7	3.0	7.0
23	783.5	12.8	97.6	3.0	7.0
24	779.9	12.8	97.6	3.0	7.0
25	776.7	12.8	97.6	3.0	7.0
26	773.7	12.8	97.6	3.0	7.0
27	770.4	12.8	97.6	3.1	7.0
28	767.1	12.8	97.6	3.1	7.0
29	763.5	12.8	97.4	3.1	7.0
30	760.2	12.8	97.3	3.1	7.0
31	757.3	12.8	97.4	3.1	7.0
2/7/2017					
1	856.5	12.9	99.7	2.8	7.0
2	853.2	12.9	99.7	2.8	7.0
3	850.1	12.9	99.6	2.8	6.9
4	846.6	12.9	99.5	2.8	6.9
5	843.5	12.9	99.4	2.8	6.9
6	840.3	12.9	99.4	2.8	6.9
7	837.0	12.9	99.3	2.8	6.9
8	833.6	12.9	99.3	2.8	6.9
9	830.4	12.8	99.1	2.8	6.9
10	827.2	12.8	99.0	2.8	6.9
11	823.9	12.8	99.0	2.8	6.9
12	820.6	12.8	99.0	2.8	6.9
13	817.3	12.8	98.9	2.9	6.9
14	814.1	12.8	98.8	2.9	6.9
15	810.8	12.8	98.7	2.9	6.9
16	807.5	12.8	98.7	2.9	6.9
17	804.2	12.7	98.5	2.9	6.9
18	800.9	12.7	98.5	2.9	6.9
19	797.7	12.7	98.4	3.0	6.9
20	794.4	12.7	98.3	3.0	6.9
21	791.1	12.7	98.2	3.0	6.9
22	787.8	12.6	98.1	3.0	6.9
23	784.5	12.6	98.1	3.0	6.9

Sample Depth	Elevation	DO concentration	DO saturation	Temperature	pH
m	ft MSL	mg/L	%	°C	
24	781.3	12.6	97.9	3.0	6.9
25	777.7	12.6	97.8	3.0	6.9
26	774.7	12.6	97.8	3.0	6.8
27	771.4	12.6	97.7	3.0	6.8
28	767.8	12.6	97.6	3.0	6.8
29	764.9	12.6	97.6	3.0	6.8
30	761.6	12.6	97.5	3.0	6.8
31	758.3	12.6	97.4	3.0	6.8
2/21/2017					
1	856.8	12.8	102.0	4.6	7.5
2	853.4	12.8	102.0	4.6	7.5
3	850.2	12.8	102.0	4.6	7.4
4	846.9	12.8	102.0	4.6	7.4
5	843.5	12.8	103.0	4.6	7.4
6	840.3	12.8	103.0	4.6	7.4
7	836.9	12.8	103.0	4.6	7.4
8	833.8	12.8	103.0	4.5	7.4
9	830.4	12.8	102.0	4.5	7.4
10	827.3	12.8	103.0	4.5	7.4
11	824.0	12.8	103.0	4.5	7.4
12	820.4	12.8	103.0	4.5	7.4
13	817.1	12.8	103.0	4.5	7.4
14	813.8	12.8	103.0	4.5	7.4
15	810.6	12.8	103.0	4.5	7.4
16	807.6	12.8	103.0	4.5	7.4
17	804.3	12.8	103.0	4.5	7.4
18	800.7	12.8	103.0	4.5	7.4
19	797.8	12.8	103.0	4.5	7.4
20	794.2	12.8	103.0	4.5	7.4
21	791.2	12.8	103.0	4.5	7.4
22	787.9	12.8	102.0	4.5	7.3
23	784.6	12.8	102.0	4.5	7.3
24	781.0	12.8	102.0	4.4	7.3
25	778.1	12.8	102.0	4.4	7.3
26	774.8	12.8	102.0	4.4	7.3
27	771.2	12.8	102.0	4.4	7.3
28	768.2	12.8	102.0	4.4	7.3
29	764.6	12.8	102.0	4.4	7.3
30	761.7	12.8	102.0	4.4	7.3
31	758.4	12.8	102.0	4.4	7.3
3/7/2017					
1	855.5	12.6	100.0	4.6	7.4
2	852.4	12.6	100.0	4.6	7.3
3	849.2	12.6	100.0	4.6	7.2
4	845.9	12.6	100.0	4.6	7.2

Sample Depth	Elevation	DO concentration	DO saturation	Temperature	pH
m	ft MSL	mg/L	%	°C	
5	842.6	12.6	100.0	4.6	7.2
6	839.3	12.6	100.0	4.6	7.2
7	836.0	12.6	99.9	4.6	7.1
8	832.7	12.5	99.8	4.6	7.1
9	829.4	12.5	99.7	4.6	7.1
10	826.2	12.5	99.6	4.6	7.1
11	822.9	12.5	99.5	4.6	7.1
12	819.6	12.5	99.4	4.6	7.1
13	816.3	12.5	99.3	4.6	7.0
14	813.1	12.5	99.2	4.6	7.0
15	809.8	12.4	99.0	4.6	7.0
16	806.5	12.4	98.9	4.6	7.0
17	803.2	12.4	98.9	4.6	7.0
18	799.9	12.4	98.7	4.6	7.0
19	796.7	12.4	98.6	4.6	7.0
20	793.4	12.4	98.4	4.6	7.0
21	790.1	12.4	98.4	4.6	7.0
22	786.8	12.4	98.3	4.6	7.0
23	783.5	12.4	98.2	4.6	7.0
24	780.3	12.3	98.1	4.6	7.0
25	777.0	12.3	97.8	4.5	7.0
26	773.7	12.3	97.7	4.5	7.0
27	770.1	12.3	97.6	4.5	7.0
28	767.1	12.3	97.4	4.5	7.0
29	763.9	12.3	97.3	4.5	7.0
30	760.6	12.2	97.2	4.5	7.0
31	757.3	12.2	97.1	4.5	7.0
3/21/2017					
1	855.7	12.7	104.0	5.1	7.0
2	852.3	12.7	104.0	5.2	7.0
3	848.9	12.7	104.0	5.1	7.0
4	845.7	12.7	104.0	5.1	7.0
5	842.5	12.7	104.0	5.1	7.0
6	839.3	12.7	104.0	5.1	7.0
7	835.9	12.8	104.0	5.1	7.0
8	832.6	12.7	104.0	5.1	7.0
9	829.2	12.7	104.0	5.1	7.0
10	825.9	12.7	104.0	5.1	7.0
11	822.6	12.7	104.0	5.1	7.0
12	819.6	12.7	104.0	5.1	7.0
13	816.3	12.7	104.0	5.1	7.0
14	812.7	12.7	104.0	5.1	7.0
15	809.5	12.7	104.0	5.1	7.0
16	806.2	12.8	104.0	5.1	6.9
17	802.9	12.7	104.0	5.1	6.9

Sample Depth	Elevation	DO concentration	DO saturation	Temperature	pH
m	ft MSL	mg/L	%	°C	
18	799.6	12.7	104.0	5.1	6.9
19	796.3	12.7	104.0	5.1	6.9
20	793.4	12.7	104.0	5.1	6.9
21	790.1	12.8	104.0	5.1	6.9
22	786.8	12.7	104.0	5.1	6.9
23	783.5	12.7	104.0	5.1	6.9
24	779.9	12.7	104.0	5.1	6.9
25	777.0	12.7	104.0	5.1	6.9
26	773.7	12.7	104.0	5.1	6.9
27	770.1	12.7	104.0	5.1	6.9
28	767.1	12.7	104.0	5.1	6.9
29	763.9	12.7	104.0	5.1	6.9
30	760.2	12.7	104.0	5.1	6.9
4/4/2017					
1	856.5	12.6	105.0	6.2	6.8
2	853.4	12.6	105.0	6.2	6.8
3	850.1	12.6	105.0	6.2	6.8
4	846.8	12.7	105.0	6.2	6.8
5	843.5	12.6	105.0	6.2	6.8
6	840.2	12.6	105.0	6.2	6.8
7	836.9	12.6	105.0	6.2	6.8
8	833.7	12.6	105.0	6.2	6.8
9	830.5	12.6	105.0	6.2	6.8
10	827.2	12.6	105.0	6.2	6.8
11	823.9	12.6	105.0	6.1	6.8
12	820.6	12.6	105.0	6.2	6.8
13	817.3	12.6	105.0	6.2	6.8
14	814.1	12.7	104.0	5.9	6.8
15	810.8	12.6	103.0	5.6	6.8
16	807.5	12.7	104.0	5.6	6.8
17	804.2	12.7	103.0	5.5	6.8
18	800.9	12.6	103.0	5.5	6.8
19	797.7	12.6	103.0	5.5	6.8
20	794.4	12.6	103.0	5.5	6.8
21	791.1	12.7	103.0	5.5	6.8
22	787.8	12.7	103.0	5.5	6.8
23	784.5	12.7	103.0	5.4	6.8
24	781.3	12.7	103.0	5.4	6.8
25	778.0	12.7	103.0	5.4	6.8
26	774.7	12.7	103.0	5.4	6.8
27	771.1	12.7	103.0	5.4	6.8
28	768.1	12.7	103.0	5.3	6.8
29	764.9	12.7	103.0	5.3	6.8
30	761.6	12.7	103.0	5.4	6.8

Sample Depth m	Elevation ft MSL	DO concentration mg/L	DO saturation %	Temperature °C	pH
4/18/2017					
1	855.7	11.6	102.0	8.2	7.1
2	852.4	11.7	102.0	8.1	7.1
3	849.0	11.7	101.0	7.8	7.1
4	845.7	11.8	101.0	7.4	7.1
5	842.6	11.9	101.0	7.3	7.1
6	839.3	11.8	101.0	7.2	7.1
7	836.0	11.8	101.0	7.1	7.1
8	832.7	11.8	101.0	7.1	7.1
9	829.3	11.8	100.0	7.1	7.1
10	826.2	11.8	100.0	7.1	7.1
11	822.6	11.8	100.0	6.9	7.1
12	819.6	11.8	99.8	6.8	7.1
13	816.3	11.8	99.6	6.8	7.1
14	813.1	11.8	99.5	6.7	7.1
15	809.8	11.8	99.4	6.7	7.1
16	806.5	11.8	99.0	6.7	7.0
17	803.2	11.8	98.9	6.6	7.0
18	799.9	11.8	98.7	6.5	7.0
19	796.7	11.8	98.3	6.4	7.0
20	793.4	11.8	97.9	6.3	7.0
21	790.1	11.7	97.5	6.2	7.0
22	786.8	11.7	97.3	6.2	7.0
23	783.5	11.7	97.2	6.2	7.0
24	780.3	11.7	97.1	6.2	7.0
25	777.0	11.7	96.6	6.1	7.0
26	773.7	11.7	96.5	6.1	7.0
27	770.4	11.6	96.3	6.0	7.0
28	767.1	11.6	96.2	6.0	7.0
29	763.9	11.6	96.1	6.0	7.0
30	760.6	11.6	96.1	6.0	7.0
31	757.3	11.6	95.4	5.9	7.0
5/2/2017					
1	855.6	12.3	106.0	8.0	6.9
2	852.3	12.3	106.0	7.9	6.9
3	849.1	12.2	106.0	7.9	6.9
4	845.7	12.3	105.0	7.8	6.9
5	842.4	12.3	104.0	7.4	6.9
6	839.3	12.3	104.0	7.1	6.9
7	835.9	12.3	104.0	7.0	6.9
8	832.6	12.3	104.0	7.0	6.9
9	829.5	12.3	103.0	6.8	6.9
10	826.2	12.4	103.0	6.7	6.9
11	822.6	12.4	103.0	6.7	6.9

Sample Depth	Elevation	DO concentration	DO saturation	Temperature	pH
m	ft MSL	mg/L	%	°C	
12	819.3	12.3	103.0	6.7	6.9
13	816.3	12.3	103.0	6.6	6.9
14	812.7	12.3	103.0	6.5	6.9
15	809.8	12.3	103.0	6.5	6.9
16	806.5	12.3	102.0	6.5	6.9
17	803.2	12.3	102.0	6.5	6.9
18	799.9	12.3	102.0	6.4	6.9
19	796.7	12.3	102.0	6.4	6.9
20	793.4	12.3	102.0	6.4	6.9
21	790.1	12.3	102.0	6.4	6.9
22	786.8	12.3	102.0	6.4	6.9
23	783.5	12.3	102.0	6.4	6.9
24	780.3	12.3	102.0	6.4	6.9
25	777.0	12.3	102.0	6.4	6.9
26	773.7	12.3	102.0	6.4	6.9
27	770.1	12.2	101.0	6.4	6.9
28	767.1	12.2	101.0	6.4	6.9
29	763.5	12.2	102.0	6.4	6.9
30	760.6	12.2	102.0	6.4	6.9
5/16/2017					
1	855.7	11.7	108.0	9.7	7.3
2	852.4	11.8	107.0	9.5	7.3
3	849.1	11.9	108.0	9.4	7.2
4	845.8	12.0	107.0	8.8	7.2
5	842.5	12.0	106.0	8.6	7.2
6	839.2	12.0	106.0	8.4	7.2
7	835.7	12.0	106.0	8.3	7.2
8	832.7	11.9	106.0	8.3	7.1
9	829.4	11.9	105.0	8.2	7.1
10	826.2	11.9	105.0	8.2	7.1
11	822.9	11.9	104.0	8.1	7.1
12	819.6	11.8	104.0	8.1	7.1
13	816.3	11.8	104.0	8.1	7.1
14	813.1	11.8	104.0	8.0	7.1
15	809.8	11.8	104.0	7.9	7.1
16	806.5	12.1	105.0	7.8	7.1
17	803.2	12.0	105.0	7.7	7.1
18	799.9	12.0	104.0	7.6	7.1
19	796.3	12.0	104.0	7.4	7.1
20	793.4	12.0	104.0	7.4	7.1
21	789.8	12.0	103.0	7.3	7.0
22	786.5	11.9	102.0	7.2	7.0
23	783.5	11.8	101.0	7.1	7.0
24	779.9	11.7	99.9	7.0	7.0
25	777.0	11.7	99.8	6.9	7.0

Sample Depth	Elevation	DO concentration	DO saturation	Temperature	pH
m	ft MSL	mg/L	%	°C	
26	773.7	11.7	99.7	6.8	7.0
27	770.4	11.6	98.9	6.7	7.0
28	767.1	11.6	98.6	6.7	7.0
29	763.5	11.5	98.2	6.7	7.0
30	760.2	11.4	96.3	6.6	7.0
5/30/2017					
1	855.5	10.1	106.0	16.3	6.9
2	852.3	10.5	108.0	15.4	6.9
3	849.1	10.6	108.0	14.9	6.9
4	845.8	10.9	107.0	13.3	6.9
5	842.5	11.1	105.0	11.8	6.9
6	839.1	11.4	106.0	11.0	6.9
7	835.9	11.6	106.0	10.2	6.9
8	832.6	11.6	105.0	9.7	6.9
9	829.5	11.6	104.0	9.5	6.9
10	826.2	11.6	104.0	9.2	6.9
11	822.6	11.5	102.0	8.9	6.9
12	819.3	11.6	102.0	8.8	6.9
13	816.3	11.6	102.0	8.7	6.9
14	812.7	11.5	101.0	8.5	6.9
15	809.8	11.5	101.0	8.4	6.9
16	806.2	11.5	101.0	8.3	6.9
17	803.2	11.5	100.0	8.2	6.9
18	799.6	11.4	99.7	8.1	6.9
19	796.7	11.5	99.6	8.1	6.9
20	793.4	11.5	99.6	8.0	6.8
21	790.1	11.4	99.1	8.0	6.8
22	786.5	11.4	99.0	7.9	6.8
23	783.5	11.3	97.8	7.8	6.8
24	779.9	11.3	97.4	7.7	6.8
25	776.7	11.1	95.2	7.6	6.8
26	773.7	11.0	93.8	7.4	6.8
27	770.1	10.7	91.3	7.2	6.8
28	766.8	10.5	89.4	7.1	6.8
29	763.5	10.5	88.7	7.1	6.8
30	760.6	10.4	88.4	7.1	6.8
31	757.0	10.2	86.8	7.0	6.8
6/13/2017					
1	855.6	10.1	103.0	15.3	7.2
2	852.2	10.1	103.0	15.3	7.2
3	848.9	10.6	106.0	14.3	7.2
4	845.7	10.8	106.0	13.6	7.2
5	842.3	10.9	106.0	13.1	7.2
6	839.0	10.8	103.0	12.2	7.1
7	836.0	11.1	104.0	11.6	7.1

Sample Depth	Elevation	DO concentration	DO saturation	Temperature	pH
m	ft MSL	mg/L	%	°C	
8	832.7	11.1	104.0	11.3	7.1
9	829.3	11.1	104.0	11.1	7.0
10	826.2	11.2	103.0	10.7	7.0
11	822.6	11.3	104.0	10.6	7.0
12	819.3	11.4	104.0	10.4	6.9
13	816.3	11.4	104.0	10.1	6.9
14	813.1	11.2	101.0	9.8	6.9
15	809.8	11.3	101.0	9.6	6.9
16	806.5	11.2	101.0	9.4	6.9
17	802.9	11.2	99.3	9.0	6.8
18	799.9	11.2	98.2	8.7	6.8
19	796.3	11.2	98.0	8.5	6.8
20	793.1	11.4	98.8	8.3	6.8
21	789.8	11.4	98.8	8.2	6.8
22	786.8	11.4	98.8	8.0	6.8
23	783.5	11.2	96.9	7.9	6.8
24	779.9	11.0	94.3	7.8	6.7
25	776.7	10.8	92.8	7.7	6.7
26	773.7	10.6	90.7	7.6	6.6
27	770.4	10.2	86.7	7.3	6.6
28	767.1	10.1	85.6	7.3	6.6
29	763.9	9.9	83.9	7.2	6.6
30	760.2	9.7	81.8	7.2	6.5
6/27/2017					
1	855.7	9.4	105.0	19.5	7.3
2	852.4	9.4	105.0	19.5	7.3
3	849.1	9.8	108.0	18.7	7.3
4	845.8	10.4	107.0	15.5	7.3
5	842.5	10.7	107.0	14.3	7.2
6	839.1	10.7	105.0	13.3	7.2
7	835.9	10.8	104.0	12.8	7.1
8	832.7	10.7	103.0	12.4	7.1
9	829.4	10.6	101.0	12.0	7.1
10	826.2	10.6	101.0	11.8	7.0
11	822.9	10.7	101.0	11.6	7.0
12	819.6	10.7	100.0	11.5	7.0
13	816.3	10.7	100.0	11.3	7.0
14	813.1	10.7	99.6	11.1	7.0
15	809.5	10.7	99.4	11.0	6.9
16	806.5	10.6	98.7	10.8	6.9
17	803.2	10.6	97.6	10.5	6.9
18	799.9	10.5	96.2	10.3	6.9
19	796.7	10.4	93.4	9.5	6.8
20	793.1	10.3	91.5	9.0	6.8
21	790.1	10.6	93.6	8.7	6.8

Sample Depth	Elevation	DO concentration	DO saturation	Temperature	pH
m	ft MSL	mg/L	%	°C	
22	786.8	10.5	92.3	8.4	6.7
23	783.5	10.5	91.5	8.2	6.7
24	780.3	10.1	87.5	8.1	6.6
25	776.7	10.1	87.4	8.0	6.6
26	773.4	10.1	86.8	7.8	6.6
27	770.4	9.4	80.7	7.6	6.6
28	766.8	9.3	79.9	7.5	6.5
29	763.9	9.2	78.2	7.4	6.5
30	760.6	9.0	76.4	7.4	6.5
7/11/2017					
1	856.6	8.8	101.0	21.1	7.3
2	853.4	8.8	101.0	21.1	7.3
3	850.2	9.2	105.0	20.5	7.3
4	846.8	9.6	106.0	18.9	7.3
5	843.6	9.7	106.0	18.1	7.3
6	840.2	10.4	107.0	15.7	7.3
7	836.9	10.2	105.0	15.2	7.3
8	833.7	10.7	107.0	14.3	7.3
9	830.5	10.5	105.0	14.1	7.3
10	826.9	10.4	102.0	13.6	7.3
11	823.9	10.3	101.0	13.3	7.3
12	820.6	10.3	100.0	13.0	7.3
13	817.0	10.2	99.4	12.9	7.3
14	814.1	10.4	99.7	12.2	7.3
15	810.8	10.4	98.6	12.0	7.2
16	807.2	10.3	97.4	11.6	7.2
17	804.2	10.3	96.6	11.4	7.2
18	800.9	10.2	95.1	11.1	7.2
19	797.7	10.2	94.4	10.8	7.2
20	794.4	10.0	90.7	9.9	7.2
21	791.1	10.1	90.6	9.5	7.2
22	787.8	10.1	89.7	9.0	7.2
23	784.5	9.9	87.2	8.6	7.2
24	781.3	9.6	83.9	8.5	7.1
25	777.7	9.6	83.9	8.4	7.1
26	774.7	9.7	84.3	8.2	7.0
27	771.4	9.3	80.6	8.1	7.0
28	768.1	9.0	77.2	7.8	7.0
29	764.9	8.6	73.9	7.7	6.9
30	761.6	8.2	70.2	7.6	6.9
7/25/2017					
1	854.6	8.8	104.0	22.2	7.3
2	851.4	8.8	104.0	22.2	7.3
3	847.9	8.8	104.0	22.1	7.3
4	844.8	9.2	106.0	20.7	7.3

Sample Depth	Elevation	DO concentration	DO saturation	Temperature	pH
m	ft MSL	mg/L	%	°C	
5	841.6	9.5	107.0	19.7	7.3
6	838.3	10.0	109.0	18.1	7.3
7	834.9	9.9	107.0	17.7	7.3
8	831.7	10.3	108.0	16.6	7.3
9	828.5	10.6	109.0	15.5	7.3
10	825.2	10.3	105.0	15.1	7.3
11	821.9	10.2	103.0	14.8	7.3
12	818.6	10.2	103.0	14.3	7.3
13	815.3	10.1	101.0	14.0	7.3
14	812.1	10.0	99.2	13.8	7.2
15	808.8	9.9	96.2	13.0	7.2
16	805.5	9.6	93.5	12.7	7.2
17	802.2	9.8	93.9	12.3	7.2
18	798.9	9.9	94.5	12.0	7.2
19	795.7	9.9	93.1	11.5	7.2
20	792.1	9.8	91.2	10.9	7.2
21	788.8	9.6	87.2	9.7	7.1
22	785.8	9.6	86.2	9.2	7.1
23	782.5	9.5	84.6	9.1	7.1
24	779.3	8.9	79.0	8.8	7.0
25	776.0	8.9	78.5	8.7	7.0
26	772.4	8.9	78.3	8.6	7.0
27	769.4	8.9	78.5	8.4	7.0
28	766.1	8.6	75.0	8.2	6.9
29	762.9	8.3	71.9	8.0	6.9
30	759.2	7.9	68.7	8.0	6.9
31	756.3	7.2	62.3	7.9	6.7
8/8/2017					
1	854.6	8.5	103.0	23.3	7.5
2	851.3	8.5	103.0	23.3	7.5
3	848.1	8.5	103.0	23.3	7.4
4	844.8	9.2	108.0	21.7	7.4
5	841.5	9.4	108.0	20.6	7.4
6	838.1	9.9	110.0	19.2	7.4
7	834.9	10.0	109.0	18.2	7.4
8	831.7	9.9	106.0	17.5	7.3
9	828.2	10.1	107.0	16.7	7.3
10	825.2	9.9	104.0	16.3	7.2
11	821.9	9.8	102.0	15.9	7.2
12	818.6	9.7	100.0	15.6	7.2
13	815.3	9.7	99.1	15.2	7.2
14	811.7	9.6	97.3	14.8	7.2
15	808.8	9.5	96.1	14.5	7.1
16	805.5	9.6	96.2	14.3	7.1
17	802.2	9.6	95.9	14.1	7.1

Sample Depth	Elevation	DO concentration	DO saturation	Temperature	pH
m	ft MSL	mg/L	%	°C	
18	798.9	9.6	94.9	13.7	7.1
19	795.3	9.2	90.0	13.2	7.1
20	792.1	9.0	86.2	12.0	7.1
21	789.1	9.3	85.9	10.7	7.0
22	785.5	9.2	83.7	9.8	7.0
23	782.5	8.7	78.6	9.5	7.0
24	779.3	7.8	69.8	9.2	6.9
25	776.0	7.9	70.3	9.0	6.8
26	772.7	7.9	70.2	8.8	6.8
27	769.1	7.8	68.8	8.7	6.8
28	766.1	7.7	68.2	8.6	6.8
29	762.9	7.4	64.7	8.4	6.7
30	759.6	7.0	61.2	8.2	6.7
8/22/2017					
1	854.9	9.1	105.0	21.2	7.4
2	852.2	9.1	104.0	21.1	7.4
3	849.1	9.1	104.0	21.0	7.4
4	845.6	9.7	108.0	19.9	7.4
5	842.5	9.6	107.0	18.9	7.4
6	839.2	10.1	109.0	17.8	7.3
7	835.7	9.9	105.0	17.2	7.3
8	832.7	9.5	100.0	16.7	7.3
9	829.2	9.2	95.4	16.0	7.2
10	826.2	9.4	96.7	15.6	7.2
11	822.9	9.2	94.3	15.3	7.1
12	819.3	9.4	95.5	15.0	7.1
13	816.0	9.3	94.8	14.8	7.1
14	812.7	9.5	96.0	14.5	7.1
15	809.8	9.6	96.5	14.3	7.1
16	806.2	9.9	98.1	14.0	7.1
17	802.9	9.7	96.2	13.6	7.1
18	799.6	9.7	95.5	13.3	7.0
19	796.3	9.7	94.4	13.0	7.0
20	793.1	9.3	89.4	12.5	7.0
21	790.1	8.6	80.9	11.5	7.0
22	786.5	8.8	81.0	10.6	7.0
23	783.5	8.9	80.8	10.0	7.0
24	779.9	8.0	71.8	9.5	6.9
25	777.0	7.6	68.5	9.3	6.9
26	773.4	7.2	64.3	9.2	6.9
27	770.1	6.8	60.4	9.0	6.9
28	767.1	6.7	59.3	8.9	6.8
29	763.9	6.7	58.6	8.6	6.8
30	760.2	6.1	53.5	8.5	6.8

Sample Depth m	Elevation ft MSL	DO concentration mg/L	DO saturation %	Temperature °C	pH
9/19/2017					
1	851.5	9.0	99.4	18.5	7.3
2	848.2	9.0	99.3	18.5	7.3
3	845.0	9.0	99.3	18.6	7.3
4	841.8	9.0	99.3	18.6	7.3
5	838.5	9.0	99.1	18.5	7.3
6	835.2	9.0	98.8	18.5	7.3
7	831.9	8.9	98.6	18.5	7.3
8	828.5	8.9	98.5	18.5	7.3
9	825.3	8.9	97.9	18.5	7.3
10	821.9	8.6	94.8	18.4	7.3
11	818.9	8.5	93.0	18.2	7.3
12	815.6	8.4	92.0	18.1	7.3
13	812.3	8.3	90.0	18.0	7.3
14	809.1	8.2	88.7	17.8	7.3
15	805.8	8.5	91.5	17.5	7.2
16	802.5	8.4	89.6	17.1	7.2
17	799.2	8.4	88.5	16.4	7.2
18	795.9	8.5	89.0	15.8	7.3
19	792.3	8.2	83.9	15.0	7.2
20	789.4	8.4	84.5	14.0	7.3
21	785.8	8.6	85.0	13.3	7.2
22	782.5	8.3	80.0	12.2	7.2
23	779.2	7.7	73.4	11.6	7.2
24	776.3	7.1	67.0	11.0	7.2
25	773.0	6.4	59.6	10.4	7.2
26	769.7	6.0	54.7	10.1	7.1
27	766.4	5.8	53.0	10.0	7.1
28	762.8	5.6	51.3	9.8	7.1
10/3/2017					
1	846.7	9.2	96.7	16.7	7.2
2	843.4	9.2	96.6	16.8	7.2
3	839.8	9.2	96.5	16.7	7.2
4	836.7	9.2	96.5	16.7	7.2
5	833.5	9.2	96.4	16.7	7.2
6	830.2	9.2	96.4	16.7	7.2
7	826.9	9.2	96.3	16.7	7.2
8	823.7	9.2	96.1	16.7	7.2
9	820.3	9.1	95.9	16.7	7.2
10	816.9	9.1	95.9	16.7	7.2
11	813.9	9.1	95.7	16.7	7.2
12	810.6	8.8	92.0	16.4	7.2
13	807.3	8.7	90.6	16.2	7.2
14	803.7	8.7	90.3	16.1	7.2

Sample Depth	Elevation	DO concentration	DO saturation	Temperature	pH
m	ft MSL	mg/L	%	°C	
15	800.5	8.6	88.9	15.9	7.2
16	797.5	8.5	87.7	15.8	7.2
17	794.2	8.6	87.7	15.6	7.2
18	790.9	8.4	85.7	15.4	7.1
19	787.3	8.4	84.9	15.2	7.1
20	784.4	7.8	78.2	14.4	7.1
21	781.1	7.6	75.1	14.0	7.0
22	777.5	7.7	75.4	13.2	7.0
23	774.5	7.7	75.2	13.1	7.0
24	771.3	6.3	60.4	12.4	6.8
25	767.7	6.3	59.9	12.3	6.8
26	764.4	5.7	53.8	11.7	6.8
27	761.4	5.0	46.0	11.0	6.7
10/17/2017					
1	854.4	9.5	94.1	13.8	7.2
2	851.2	9.5	94.0	13.8	7.2
3	847.9	9.5	94.0	13.8	7.2
4	844.7	9.5	93.9	13.8	7.2
5	841.6	9.5	94.0	13.8	7.2
6	838.2	9.5	93.8	13.8	7.2
7	834.7	9.5	93.6	13.7	7.1
8	831.8	9.5	93.6	13.7	7.1
9	828.3	9.5	93.5	13.7	7.1
10	824.9	9.5	92.7	13.1	7.1
11	821.9	9.5	92.5	13.1	7.1
12	818.6	9.6	92.9	13.0	7.1
13	815.0	9.5	92.1	12.9	7.1
14	811.7	9.5	91.9	12.8	7.1
15	808.5	9.5	91.9	12.7	7.1
16	805.2	9.6	92.6	12.6	7.1
17	802.2	9.7	93.2	12.5	7.1
18	798.9	9.7	93.1	12.4	7.0
19	795.7	9.8	93.5	12.3	7.0
20	792.4	9.8	93.6	12.3	7.0
21	789.1	9.8	93.5	12.2	7.0
22	785.5	9.8	93.4	12.1	7.0
23	782.5	9.8	93.6	12.1	7.0
24	779.3	9.9	93.6	12.0	7.0
25	775.7	9.9	93.6	12.0	7.0
26	772.7	9.9	93.8	11.9	7.0
27	769.1	9.9	93.8	11.9	7.0
28	765.8	9.9	93.6	11.9	7.0
29	762.5	9.9	93.5	11.7	7.0
30	759.6	9.9	93.7	11.7	7.0
31	756.3	9.9	93.6	11.7	7.0

Sample Depth m	Elevation ft MSL	DO concentration mg/L	DO saturation %	Temperature °C	pH
10/31/2017					
1	853.5	11.0	99.8	9.8	7.0
2	850.4	11.0	99.8	9.8	7.0
3	847.0	11.0	99.6	9.8	7.0
4	843.8	11.0	99.6	9.8	7.0
5	840.5	11.0	99.5	9.8	7.0
6	837.3	11.0	99.5	9.8	7.1
7	834.0	11.0	99.3	9.8	7.0
8	830.6	11.0	99.3	9.8	7.0
9	827.3	11.0	99.1	9.8	7.1
10	824.2	10.9	99.1	9.8	7.1
11	820.9	10.9	98.9	9.8	7.0
12	817.6	10.9	98.8	9.8	7.0
13	814.0	10.9	98.8	9.8	7.0
14	810.7	10.9	98.6	9.8	7.0
15	807.8	10.9	98.6	9.8	7.0
16	804.2	10.9	98.5	9.8	7.0
17	801.2	10.9	98.4	9.8	7.0
18	797.9	10.9	98.3	9.8	7.0
19	794.7	10.9	98.1	9.7	7.0
20	791.1	10.9	98.0	9.7	7.0
21	788.1	10.8	97.9	9.7	7.0
22	784.5	10.8	97.8	9.7	7.0
23	781.5	10.8	97.6	9.7	7.0
24	778.3	10.8	97.5	9.7	7.0
25	775.0	10.8	97.4	9.6	7.0
26	771.7	10.8	97.4	9.6	7.0
27	768.4	10.8	97.3	9.6	7.0
28	765.1	10.8	97.2	9.6	7.0
29	761.9	10.8	96.8	9.6	7.0
11/14/2017					
1	856.3	11.2	97.6	8.4	7.1
2	853.0	11.2	97.4	8.4	7.1
3	849.7	11.2	97.5	8.4	7.1
4	846.3	11.2	97.4	8.4	7.1
5	843.0	11.2	97.4	8.4	7.1
6	839.8	11.2	97.4	8.4	7.1
7	836.5	11.2	97.4	8.4	7.1
8	833.2	11.2	97.3	8.4	7.0
9	830.0	11.2	97.1	8.3	7.0
10	826.8	11.2	97.0	8.2	7.0
11	823.2	11.2	97.1	8.2	7.0
12	820.2	11.2	96.9	8.0	7.0
13	816.9	11.2	96.8	8.0	7.0

Sample Depth	Elevation	DO concentration	DO saturation	Temperature	pH
m	ft MSL	mg/L	%	°C	
14	813.3	11.2	96.9	8.0	7.0
15	810.4	11.2	97.0	7.9	7.0
16	806.8	11.3	97.2	7.9	7.0
17	803.8	11.3	97.3	7.9	7.0
18	800.2	11.3	97.4	7.9	7.0
19	797.3	11.3	97.5	7.9	7.0
20	794.0	11.3	97.5	7.8	7.0
21	790.4	11.3	97.5	7.8	7.0
22	787.4	11.3	97.5	7.8	7.0
23	784.1	11.3	97.5	7.8	6.9
24	780.9	11.3	97.5	7.8	6.9
25	777.6	11.3	97.6	7.8	6.9
26	774.3	11.3	97.4	7.8	6.9
27	771.0	11.3	97.5	7.8	6.9
28	767.7	11.3	97.5	7.8	6.9
29	764.1	11.3	97.5	7.8	6.9
30	761.2	11.3	97.5	7.8	6.9
31	757.9	11.3	97.6	7.8	6.9
11/28/2017					
1	855.5	12.1	104.0	7.4	7.0
2	852.3	12.1	104.0	7.4	7.0
3	849.1	12.1	104.0	7.4	7.0
4	845.8	12.1	103.0	7.4	7.0
5	842.6	12.1	103.0	7.4	7.0
6	839.2	12.1	103.0	7.4	7.0
7	835.7	12.1	103.0	7.4	7.0
8	832.8	12.0	103.0	7.4	7.0
9	829.3	12.0	103.0	7.4	7.0
10	826.2	12.0	103.0	7.4	7.0
11	822.9	12.0	103.0	7.4	7.0
12	819.6	12.0	103.0	7.4	7.0
13	816.3	12.0	103.0	7.4	7.0
14	813.1	12.0	102.0	7.4	7.0
15	809.8	12.0	102.0	7.4	7.0
16	806.5	12.0	102.0	7.4	7.0
17	803.2	12.0	102.0	7.4	7.0
18	799.9	11.9	102.0	7.4	7.0
19	796.7	11.9	102.0	7.4	7.0
20	793.4	11.9	102.0	7.4	7.0
21	790.1	11.9	102.0	7.4	7.0
22	786.8	11.9	102.0	7.4	7.0
23	783.2	11.9	102.0	7.4	7.0
24	780.3	11.9	102.0	7.4	7.0
25	776.7	11.9	101.0	7.3	7.0
26	773.7	11.9	101.0	7.3	7.0

Sample Depth	Elevation	DO concentration	DO saturation	Temperature	pH
m	ft MSL	mg/L	%	°C	
27	770.4	11.9	101.0	7.3	7.0
28	766.8	11.9	101.0	7.3	7.0
29	763.9	11.8	101.0	7.2	7.0
30	760.2	11.8	101.0	7.2	7.0
12/12/2017					
1	854.7	12.4	98.9	5.3	7.1
2	851.3	12.4	98.9	5.3	7.1
3	848.0	12.4	98.9	5.3	7.1
4	844.9	12.4	98.9	5.3	7.1
5	841.5	12.4	98.9	5.3	7.0
6	838.3	12.4	98.9	5.3	7.0
7	835.0	12.4	98.9	5.3	7.0
8	831.7	12.4	98.9	5.3	7.0
9	828.4	12.4	98.9	5.3	7.0
10	824.9	12.4	98.9	5.3	7.0
11	821.6	12.4	98.9	5.3	7.0
12	818.6	12.4	98.8	5.3	7.0
13	815.3	12.4	98.9	5.3	7.0
14	812.1	12.4	98.8	5.3	7.0
15	808.5	12.4	98.8	5.3	7.0
16	805.2	12.4	98.8	5.3	7.0
17	802.2	12.4	98.9	5.3	7.0
18	798.6	12.4	98.8	5.3	7.0
19	795.3	12.4	98.8	5.3	7.0
20	792.1	12.4	98.8	5.3	7.0
21	788.8	12.4	98.7	5.3	7.0
22	785.8	12.4	98.7	5.3	7.0
23	782.5	12.3	98.7	5.3	6.9
24	779.3	12.4	98.8	5.3	7.0
25	775.7	12.3	98.7	5.3	7.0
26	772.4	12.3	98.6	5.3	7.0
27	769.4	12.3	98.6	5.3	7.0
28	766.1	12.3	98.6	5.3	6.9
29	762.5	12.3	98.6	5.3	6.9
30	759.6	12.3	98.6	5.3	6.9
12/28/2017					
1	856.4	12.4	97.4	4.1	7.1
2	853.3	12.4	97.3	4.1	7.1
3	850.0	12.4	97.2	4.1	7.1
4	846.8	12.4	97.1	4.1	7.1
5	843.5	12.4	97.0	4.1	7.1
6	840.0	12.4	96.9	4.1	7.1
7	837.0	12.4	96.9	4.1	7.1
8	833.7	12.4	96.8	4.1	7.1
9	830.4	12.4	96.6	4.1	7.1

Sample Depth	Elevation	DO concentration	DO saturation	Temperature	pH
m	ft MSL	mg/L	%	°C	
10	827.2	12.3	96.5	4.1	7.1
11	823.9	12.3	96.4	4.1	7.1
12	820.6	12.3	96.3	4.1	7.1
13	817.3	12.3	96.1	4.1	7.1
14	814.1	12.3	96.0	4.1	7.1
15	810.8	12.3	95.9	4.1	7.1
16	807.5	12.2	95.8	4.1	7.1
17	804.2	12.2	95.8	4.1	7.1
18	800.9	12.2	95.7	4.1	7.1
19	797.3	12.2	95.7	4.1	7.1
20	794.4	12.2	95.5	4.1	7.1
21	791.1	12.2	95.4	4.1	7.1
22	787.8	12.2	95.3	4.1	7.1
23	784.5	12.2	95.2	4.1	7.1
24	781.3	12.2	95.2	4.1	7.1
25	778.0	12.2	95.1	4.1	7.1
26	774.7	12.1	95.0	4.1	7.1
27	771.1	12.1	94.9	4.1	7.1
28	767.8	12.1	94.8	4.1	7.1
29	764.5	12.1	94.7	4.1	7.1
30	761.6	12.1	94.5	4.1	7.1

^am is meters, ft MSL is feet above mean sea level, mg/L is milligrams per liter, °C is degrees Celsius

On 9/5/2017, sampling was cancelled due to the proximity of the Eagle Creek Fire to the Bull Run watershed.

Appendix C

Bull Run HCP Research Report

Lower Bull Run River Spawning Gravel Research

April 2018

Burke Strobel

City of Portland Water Bureau



Contents

1. Summary	1
2. Introduction	1
3. Research Objective	2
4. Key Questions and Hypotheses.....	2
4.1 Area of Spawning Gravel.....	2
4.2 Trend over Time	3
4.3 Reach-Level Effective Spawning Gravel	3
4.4 Distribution of Spawning Gravel	4
5. Methods.....	4
5.1 Gravel Estimates per Seasonal Flow	4
5.1.1 Steelhead Spawning Gravel.....	5
5.1.2 Spring Chinook Spawning Gravel.....	5
5.1.3 Fall Chinook Spawning Gravel	5
5.2 Spatial Scale.....	6
5.3 Replication/Duration	6
5.4 Variables.....	6
5.5 Sampling Scheme	7
6. Analysis	8
7. Results	8
7.1 Area of Spawning Gravel.....	9
7.1.1 Steelhead	9
7.1.2 Spring Chinook	9
7.1.3 Fall Chinook.....	10
7.2 Trend over Time	10
7.3 Distribution of Spawning Gravel	12
7.3.1 Steelhead	12
7.3.2 Chinook	14

8. Summary and Discussion.....	16
9. Works Cited	18

Tables

Table 1. Combined Surface Area of Steelhead Spawning Gravel Patches in the Lower Bull Run River, 2017.....	9
Table 2. Combined Surface Area of Spring Chinook Spawning Gravel Patches in the Lower Bull Run River, 2017	9
Table 3. Combined Surface Area of Fall Chinook Spawning Gravel Patches in the Lower Bull Run River, 2017.....	10

Figures

Figure 1. Comparison of HEC-RAS Model River Stage Results with USGS Stage/Discharge Curve Values	8
Figure 2. Trends in the Surface Area of Steelhead Spawning Gravel Wetted at 30 cfs and 1,480 cfs in Post-Treatment Years. Baseline Surface Areas are Indicated.....	11
Figure 3. Trends in the Surface Area of Chinook Spawning Gravel Wetted at 30 cfs and 1,480 cfs in Post-Treatment Years. Baseline Surface Areas are Indicated.....	11
Figure 4. Longitudinal Distribution of Steelhead Spawning-Size Gravel Patches in the Lower Bull Run River in 2017 at 30 cfs and 1,480 cfs Compared to 2016.....	12
Figure 5. Longitudinal Distribution of Steelhead Spawning-Size Gravel Patches in the Lower Bull Run River Through a) Years of High Additions (2010–2014) Compared to the Baseline Average, and b) Years of Reduced Additions (2015–2017) at 30 cfs	13
Figure 6. Longitudinal Distribution of Steelhead Spawning-Size Gravel Patches in the Lower Bull Run River Through a) Years of High Additions (2010–2014) Compared to the Baseline Average, and b) Years of Reduced Additions (2015–2017) at 1,480 cfs	13
Figure 7. Increase in the Surface Area of Steelhead Spawning-Size Gravel Patches in 2017 above the Baseline Average for Various Flows Compared to Past Years	14
Figure 8. Longitudinal Distribution of Chinook Spawning-Size Gravel Patches in the Lower Bull Run River in 2017 at 30 cfs and 1,480 cfs Compared to 2016.....	15

Figure 9. Longitudinal Distribution of Chinook Spawning-Size Gravel Patches in the Lower Bull Run River Through a) Years of High Additions (2010–2014) Compared to the Baseline Average, and b) Years of Reduced Additions (2015–2017) at 30 cfs 15

Figure 10. Longitudinal Distribution of Chinook Spawning-Size Gravel Patches in the Lower Bull Run River Through a) Years of High Additions (2010–2014) Compared to the Baseline Average, and b) Years of Reduced Additions (2015–2017) at 1,480 cfs 16

Figure 11. Increase in the Surface Area of Chinook Spawning-Size Gravel Patches in 2017 above the Baseline Average for Various Flows Compared to Past Years 16

Figure 12. Comparison of Longitudinal Distribution of Chinook and Steelhead Spawning-Size Gravel Patches in the Lower Bull Run River in 2017 at 30 cfs and 1,480 cfs..... 17

1. Summary

The City of Portland Water Bureau (PWB) was in full compliance with its Habitat Conservation Plan obligations in 2017 with regard to lower Bull Run River spawning gravel research. A survey of gravel patches of sufficient area and with adequately sized substrate for Chinook salmon and steelhead spawning was conducted from the mouth of the Bull Run River (RM 0) to the former site of the Dam 2 spillway plunge pool rock weir (river mile [RM] 5.8).

The combined surface area of adequately sized spawning gravel patches was significantly higher than the baseline average for steelhead and for Chinook at all flows. The surface area of spawning gravel in 2017 was within the range of what had been observed in all previous years (2010–2016) at all locations and flows and nearly identical to what it was in 2016. The largest accumulations of gravel were in the river channel immediately downstream of Larson’s Bridge. This appendix summarizes the results of this study.

2. Introduction

The availability of appropriate gravel patches can limit the productivity of salmonid populations within a given stream. The dams on the Bull Run River block the downstream movement of streambed substrates. These obstructions have contributed over time to a net loss of spawning gravel patches in the lower Bull Run River, as gravel is washed away and then not replaced.¹

Under the conditions of the Bull Run Water Supply Habitat Conservation Plan (HCP; Portland Water Bureau 2008), PWB adds gravel annually to the lower Bull Run River to supplement naturally occurring spawning gravel. A total of 600 cubic yards of adequately sized gravel was added to the lower Bull Run River in 2017 to benefit spawning salmonids. This was the eighth treatment year. In years 2010–2014, 1,200 cubic yards of gravel was added annually to the Bull Run River. This amount was decreased to 600 cubic yards in 2015. In future years, for the duration of the HCP term, the amount of spawning gravel added to the Bull Run River will be 600 cubic yards. This appendix describes the methods and protocols for monitoring the effectiveness of this effort to increase the surface area of spawning gravel in the lower Bull Run River and provides a summary of the findings for 2017.

¹ More information on the role of gravel in spawning is available in Chapter 8 and Appendix E of the HCP.

3. Research Objective

PWB identified a measurable habitat objective for the spawning gravel placement conservation measure (H-1) detailed in HCP Chapters 7 and 9. PWB is supplying spawning gravel in amounts equivalent to, or exceeding, natural supply rates. PWB augmented spawning gravel in the lower Bull Run River with a total of 1,200 cubic yards of gravel annually for the first five years of HCP implementation. This amount roughly doubled the estimated natural recruitment rate of gravel in the absence of reservoirs (calculations and estimates summarized in CH2M HILL 2003) and was intended to accelerate the accumulation of gravel in the lower Bull Run River.

After five years (in 2015), the rate of gravel supplementation was decreased to 600 cubic yards annually for the remainder of the HCP, the estimated natural recruitment rate in the absence of upstream reservoirs. PWB, however, cannot predict how the gravel will be distributed or how quickly it will be moved downstream. There is no information on how much gravel was in the lower Bull Run channel and how it varied from year to year before construction of the first Bull Run dam blocked its recruitment from the upper river in 1923.

The objective of the Bull Run River spawning gravel research is to measure the surface area of patches of gravel suitable for spawning steelhead and Chinook in the lower Bull Run River. Gravel that is suitable for steelhead spawning is defined as particle sizes between 0.01 feet (0.12 inches) and 0.4 feet (4.8 inches) in diameter. Gravel that is suitable for Chinook spawning is defined as particle sizes between 0.01 feet (0.12 inches) and 0.5 feet (6 inches) diameter. Effective spawning gravel patches are patches that experience adequate depth and flow throughout the egg and alevin incubation period. Separate estimates will be generated for steelhead and Chinook. PWB will quantify the surface area of all patches that have substrate in suitable size ranges. (The surface area of the subset of the patches that would be effective for spawning may also be analyzed in the future.)

4. Key Questions and Hypotheses

The key questions and related null hypotheses (H_0) to be answered by the Bull Run River spawning gravel research are described below.

4.1 Area of Spawning Gravel

Question 1: What is the summed surface area of gravel patches suitable for steelhead and Chinook spawning in the lower Bull Run River and has it significantly increased from pre-supplementation values?

H₀: The summed surface area of spawning gravel patches in each post-supplementation year will not be significantly greater than the mean of pre-supplementation years (one-sample t-test, $\alpha=0.05$).

The pre-supplementation years that will be used for the analysis are 2007, 2008, and 2009. Gravel data were also collected by PWB in 1997, 1999, and 2001. The data from these surveys were not included in the baseline averages, because they were collected using different protocols, with conclusions based on different flow assumptions. The comparison will only use gravel patches between the Dam 2 spillway plunge pool at RM 5.8 and the Portland General Electric (PGE) Bull Run Powerhouse at RM 1.5 because the 2007 survey data do not cover the river downstream of this point.

4.2 Trend over Time

Question 2: What is the trend in the summed surface area of spawning gravel patches and the effective spawning area for each reach?

H₀: The summed surface area of spawning gravel patches in post-supplementation years will not show a significant increase over time ($\alpha=0.05$).

H₀: The summed surface area of effective spawning gravel patches at various flow combinations in post-supplementation years will not show a significant increase over time ($\alpha=0.05$).

4.3 Reach-Level Effective Spawning Gravel

Although the HCP calls for determining the quantity of effective spawning gravel, this objective has proven to be impractical. Determining the effective spawning area for each reach requires information on water surface elevation and water velocity for each gravel patch through time.

The following HCP key question and hypothesis were not addressed:

Question 3: What is the effective spawning area of each reach at various combinations of flows and at the flows actually observed during steelhead incubation in the lower Bull Run River?

H₀: The summed effective spawning area at various flow combinations in each post-supplementation year will not be significantly greater than the mean of pre-supplementation years (one-sample t-test, $\alpha=0.05$).

The total of the areas of gravel that meet the depth and water velocity criteria for both spawning and incubation of steelhead and Chinook (summarized in Appendix F, Table F-5, of the HCP) during the respective time periods are used to determine the “effective spawning area” of each reach (R2 Resource Consultants 1998). These variables, however, will change continuously through time as they are the sum of current and future conditions for each point in space and time.

If a method for accurately estimating depth and water velocity through time for each gravel patch is devised, an analysis of effective spawning gravel may be attempted in the future.

4.4 Distribution of Spawning Gravel

Although there were no key questions or hypotheses identified in the HCP regarding how gravel will be moved naturally by flows over time in the Bull Run channel, understanding how the longitudinal and lateral distribution of gravel patches changes over time will be useful to evaluate the effectiveness of this measure. The following questions will be investigated. There are no associated null hypotheses:

Question 4: What is the longitudinal distribution of the surface area of gravel patches and how does it change from year to year?

Question 5: Where in the channel laterally (as described in terms of being wetted at specific flows²) does gravel accumulate and how does the lateral distribution change from year to year?

5. Methods

5.1 Gravel Estimates per Seasonal Flow

The design of the lower Bull Run River spawning gravel research involved the use of surveys of spawning gravel surface areas to create a snapshot of the distribution of spawning gravel at a particular point in time. Predicted relationships between stage and flow were developed for multiple points along the lower Bull Run River using Hydrologic Engineering Center's River Analysis System (HEC-RAS).³ These relationships were then used to estimate the amount of spawning gravel that would be wetted at each flow. Although not all wetted gravel patches would have the proper depth, velocity, or degree of turbulence for spawning, it was assumed throughout the subsequent analyses that the change in overall surface area of gravel can serve as a predictor of the surface area of the subset of that gravel that can be used for spawning.

² Gravel patches that are located laterally further to the edge of the active channel require a higher flow to become wetted.

³ HEC-RAS is a software package developed by the U.S. Army Corps of Engineers for predicting the behavior of flowing channels using one-dimensional hydraulic modeling.

5.1.1 Steelhead Spawning Gravel

The amount of **steelhead spawning gravel** was estimated for the following peak steelhead spawning time (March, April, and May) flows:

- **1,405 cfs:** 10 percent average exceedence flow
- **614 cfs:** 50 percent average exceedence flow
- **120 cfs:** The lowest allowed flow under the HCP measure for minimum flows (actual flows may be higher)

5.1.2 Spring Chinook Spawning Gravel

The amount of **spring Chinook spawning gravel** was estimated for the following peak spring Chinook spawning time (September and October) flows:

- **358 cfs:** 10 percent average exceedence flow
- **77 cfs:** 50 percent average exceedence flow
- **30 cfs:** The lowest allowed flow under the HCP measure for minimum flows (actual flows may be higher)

5.1.3 Fall Chinook Spawning Gravel

The amount of **fall Chinook spawning gravel** was estimated for the following peak fall Chinook spawning time (October and November) flows:

- **1,480 cfs:** 10 percent average exceedence flow
- **77 cfs :** 50 percent average exceedence flow
- **30 cfs:** The lowest allowed flow under the HCP measure for minimum flows (actual flows may be higher)

Calculating the amount of spawning gravel at the 10 percent and 50 percent exceedence flows, as well as at the minimum allowable flow for each species' peak spawning period, allows for comparisons in the amount of spawning gravel across flows and across years. The amount of gravel wetted at the minimum allowable flow represents the minimum amount of gravel that would be available to each species. The amount of gravel wetted at the 10 percent and 50 percent exceedence flows indicates how far up the margins of the channel gravel accumulates and how much gravel remains available for spawning. This combined information can be used to evaluate the effectiveness of the HCP gravel placement effort at increasing the amount of spawning gravel for steelhead and spring and fall Chinook.

5.2 Spatial Scale

Surveys were used to determine the amount and quality of spawning gravel at various flows within the lower Bull Run River from the mouth (RM 0.0) to the Reservoir 2

spillway plunge pool (RM 5.8). Results are applicable only to the lower Bull Run River and have a reach-scale resolution.

5.3 Replication/Duration

Surveys are conducted once per year in the late spring/early summer or early fall in conjunction with adult Chinook surveys. The surveys occur after high flows associated with winter and spring storms have ceased and spawning gravel patches have stabilized, representing the amount of gravel available to steelhead and later to Chinook spawners for that year. There is no spatial replication; the entire channel is surveyed.

Three pre-treatment surveys were conducted in 2007, 2008, and 2009. These surveys form the baseline against which individual post-treatment years will be compared. One post-treatment survey was conducted each year during HCP Years 2–6, while the maximum amount of gravel supplementation (1,200 cubic yards) occurred. This represents the period of time when gravel was expected to accumulate most rapidly in the lower Bull Run River. The final year of maximum gravel supplementation was 2014.

After gravel supplementation was reduced in Year 6 (2015) of the HCP (to the maintenance level of 600 cubic yards), gravel surveys were conducted once per year and will be continued for a total of five years at the lower treatment level, HCP Years 7–11. During this phase, gravel supplementation is primarily intended to maintain gravel deposits in the lower Bull Run River, and surveys are designed to allow for an analysis powerful enough to detect negative trends in the surface area of spawning gravel.

Provided that gravel supplementation at maintenance levels does not result in a rapid negative trend during HCP Years 7–11, the frequency of gravel surveys will be reduced to once every five years for the duration of the HCP.

5.4 Variables

The following variables were measured for each gravel patch:

Longitudinal Location. Location relative to the beginning of the reach, measured with a hand-held global positioning system (GPS) device

Lateral Location. Location within the channel—in the center of the channel, in the channel margin, or above the channel margin (outside the wetted area but within the active channel)

Retention Feature. Feature that acts on the current to allow gravel deposition: pool-tail, boulder, bedrock, large wood, and/or slow margins

Patch Size. Surface area of patch (square feet), calculated as total length multiplied by average width

Depth or Elevation. For submerged patches, depth of the center of the patch below the water surface; for gravel patches above the water surface, elevation of the center of the patch above the water surface

Embeddedness. The visually estimated percentage of the vertical dimension of surface substrates between 1.8 inches and 4 inches intermediate axis (roughly golf-ball size to softball size) that is surrounded by silt and sand. Average of 10 particles per patch of varying sizes. The percentage of total embeddedness is calculated as

$$\% \text{Total Embedded} = [(\% \text{Embedded large particles} / 100) * (100 - \% \text{ fines})] + [\% \text{ fines}] / 100$$

(Embeddedness procedures are reviewed in Sylte and Fischenich 2002).

Percentage of Fines. Estimated surface area of patch covered by silt and sand (not a thin film over other obvious surface substrates)

Upper and Lower 10th Percentile of Substrate Size. The sizes of particles corresponding to the upper and lower 10th percentile for each gravel patch were visually estimated. Particle size reflects the intermediate axis of the particle, or the axis that controls the particle's passage through a sieve

5.5 Sampling Scheme

Sampling protocols were slightly altered from those described in Appendix F of the HCP.

The lower Bull Run River was divided into a total of 16 segments, each one 2,000 feet in length. These smaller divisions will provide for greater resolution when tracking the dispersal of gravel through time than the original six reaches proposed in the HCP.

Segments were surveyed from upstream to downstream.

The 2017 survey was conducted at a discharge flow that varied between 25 cfs and 53 cfs, as measured at U.S. Geological Survey (USGS) Gage No. 14140000.

Patches of gravel suitable for spawning steelhead and/or Chinook were identified along the length of the channel. Patches of spawning gravel were defined as being equal to or greater than 9 square feet, lying within the active channel and composed of substrates between 0.01 and 0.5 feet in diameter along their intermediate axis for Chinook and between 0.01 and 0.4 feet in diameter for steelhead.

A HEC-RAS model was developed for the lower Bull Run River using cross-sections taken from Light Detection and Ranging (LiDAR)⁴ data. The model was calibrated using

⁴ LiDAR is a method of determining surface topography using reflected returns from a downward-pointed laser mounted on an aircraft. LiDAR has a resolution of 3 feet squared.

actual stage-discharge relationships from USGS Gage No. 14140000, as shown in Figure 1. The depth at each gravel patch at various flow levels was determined using stage-discharge relationships developed for each 2,000-foot river segment.

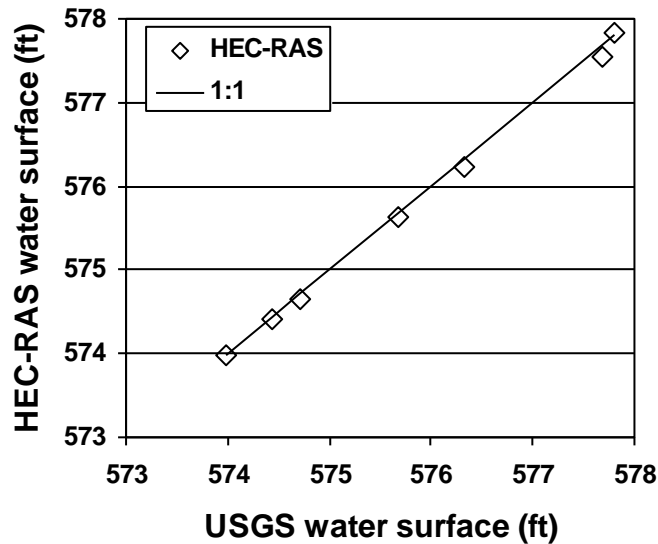


Figure 1. Comparison of HEC-RAS Model River Stage Results with USGS Stage/Discharge Curve Values

6. Analysis

Data Storage. Data are stored in Microsoft® Excel spreadsheets managed by the City of Portland Water Bureau.

Hypothesis Testing. The hypotheses relating each year's measured surface area of gravel to the mean of pre-gravel supplementation years were evaluated using one-tailed, one-sample t-tests ($\alpha=0.05$).

7. Results

A total of 370 gravel patches with substrate sizes suitable for spawning Chinook were identified within the active channel in 2017, with a total of 43,762 square feet of combined surface area. Of these, 345 patches also had substrate sizes suitable for spawning steelhead, with a total of 39,450 square feet of combined surface area.

7.1 Area of Spawning Gravel

7.1.1 Steelhead

There was more combined surface area of gravel patches with substrate sizes suitable for spawning steelhead in 2017 than the baseline average at all flows. This difference was statistically significant at all flows evaluated (one-sample, one-tailed t-test, $\alpha=0.05$, $df=2$). The combined surface area, baseline average, standard deviation, and significance for each flow are summarized in Table 1.

Table 1. Combined Surface Area of Steelhead Spawning Gravel Patches in the Lower Bull Run River, 2017

	120 cfs	614 cfs	1,405 cfs
2017 Survey Results	23,777 ft ²	32,441 ft ²	36,557 ft ²
Baseline Average	5,159 ft ²	8,373 ft ²	12,532 ft ²
Baseline Standard Deviation	2,396 ft ²	4,723 ft ²	5,708 ft ²
Significantly Greater than Baseline?	Yes	Yes	Yes

7.1.2 Spring Chinook

In 2017, there was significantly more combined surface area of gravel patches with substrate sizes suitable for spawning spring Chinook than the baseline average at all flows (one-sample, one-tailed t-test, $\alpha=0.05$, $df=2$). The combined surface area, baseline average, standard deviation, and significance for each flow are summarized in Table 2.

Table 2. Combined Surface Area of Spring Chinook Spawning Gravel Patches in the Lower Bull Run River, 2017

	30 cfs	77 cfs	358 cfs
2017 Survey Results	20,871 ft ²	24,649 ft ²	28,984 ft ²
Baseline Average	4,621 ft ²	4,994 ft ²	7,941 ft ²
Baseline Standard Deviation	1,578 ft ²	1,506 ft ²	3,294 ft ²
Significantly Greater than Baseline?	Yes	Yes	Yes

7.1.3 Fall Chinook

In 2017, there was significantly more combined surface area of gravel patches with substrate sizes suitable for spawning fall Chinook than the baseline average at all flows (one-sample, one-tailed t-test, $\alpha=0.95$, $df=2$). The combined surface area, baseline average, standard deviation, and significance for each flow are summarized in Table 3.

Table 3. Combined Surface Area of Fall Chinook Spawning Gravel Patches in the Lower Bull Run River, 2017

	30 cfs	77 cfs	1,480 cfs
2017 Survey Results	20,871 ft ²	24,649 ft ²	40,010 ft ²
Baseline Average	4,621 ft ²	4,994 ft ²	13,912 ft ²
Baseline Standard Deviation	1,578 ft ²	1,506 ft ²	5,134 ft ²
Significantly Greater than Baseline?	Yes	Yes	Yes

7.2 Trend over Time

The increase in gravel surface area over time in post-supplementation years has been statistically significant. Seven years of post-supplementation data on gravel surface area have been collected, which is adequate to begin to evaluate whether gravel surface area shows an increasing or decreasing trend over time. Despite the high degree of variability that can be attributed to varying river flows from year to year, the increase in the surface area of spawning gravel patches above baseline levels has continued to a point where it is extremely unlikely to be due to chance (Figures 2 and 3). The statistical significance of each trend in Figures 2 and 3 is indicated by the *p* value. Decreasing *p* values indicate increasing statistical significance, where 95 percent confidence equates with $p=0.05$).

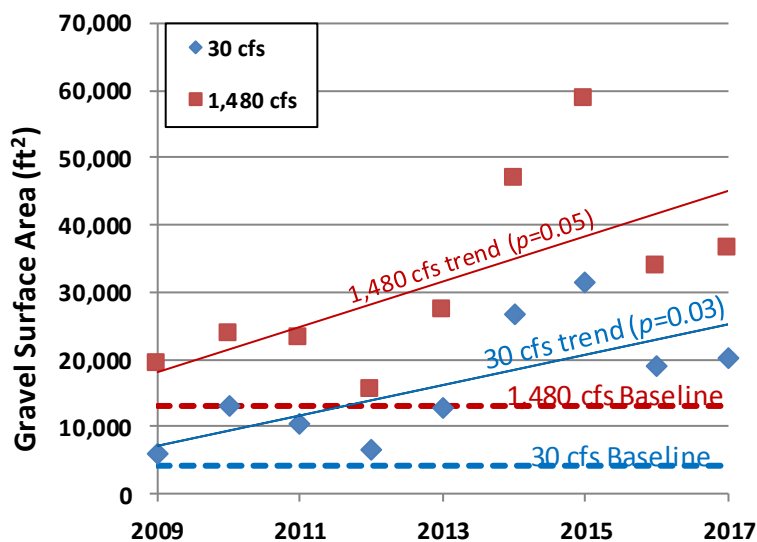


Figure 2. Trends in the Surface Area of Steelhead Spawning Gravel Wetted at 30 cfs and 1,480 cfs in Post-Treatment Years. Baseline Surface Areas are Indicated.

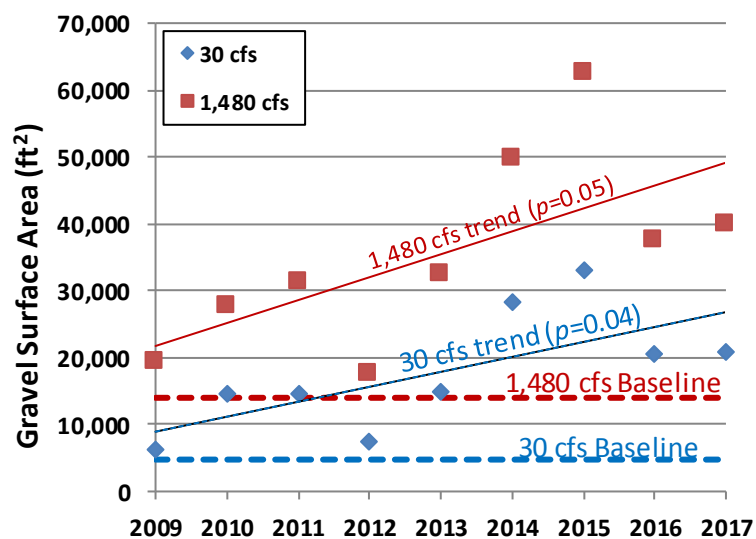


Figure 3. Trends in the Surface Area of Chinook Spawning Gravel Wetted at 30 cfs and 1,480 cfs in Post-Treatment Years. Baseline Surface Areas are Indicated

7.3 Distribution of Spawning Gravel

7.3.1 Steelhead

In 2017, large accumulations of steelhead spawning gravel were observed immediately downstream of Larson's Bridge, as in previous years (Figure 4). Other accumulations were observed in the river segment between the Southside Bridge and Larson's Bridge. Steelhead gravel accumulations continued to be elevated above baseline levels in the lower 1.5 miles of the river channel (mouth to the Bull Run Powerhouse). This, combined with past years' data, suggests that gravel that has been placed into the Bull Run River channel since 2010 has, in part, moved to the lowest portions of the river and has possibly been passing out of the river since 2014. Figures 5 and 6 compare the longitudinal distribution of steelhead spawning gravel in 2017 with previous post-treatment years and the baseline at flows that bracket the range of flows being evaluated.

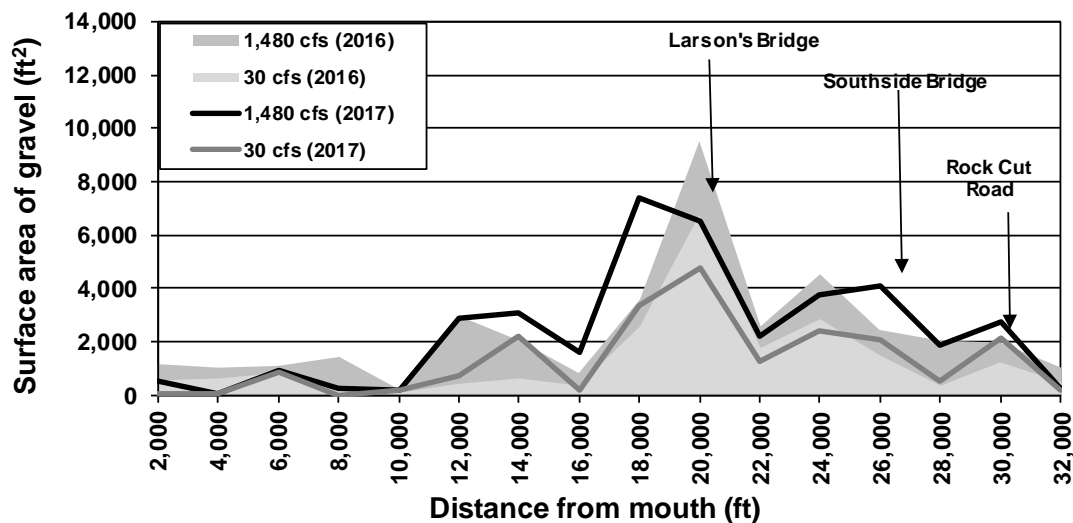


Figure 4. Longitudinal Distribution of Steelhead Spawning-Size Gravel Patches in the Lower Bull Run River in 2017 at 30 cfs and 1,480 cfs Compared to 2016

The largest observed increases in gravel over the baseline occurred in the portion of the channel wetted at relatively low flows (i.e., 120 cfs and less), as shown in Figure 7. The observed increases in the total surface area of steelhead spawning gravel above the baseline in 2017 were in the middle of the range of what was observed in previous years at all flows. The surface area of steelhead gravel wetted at the lowest flows (120 cfs and less) was between four and five times the baseline levels.

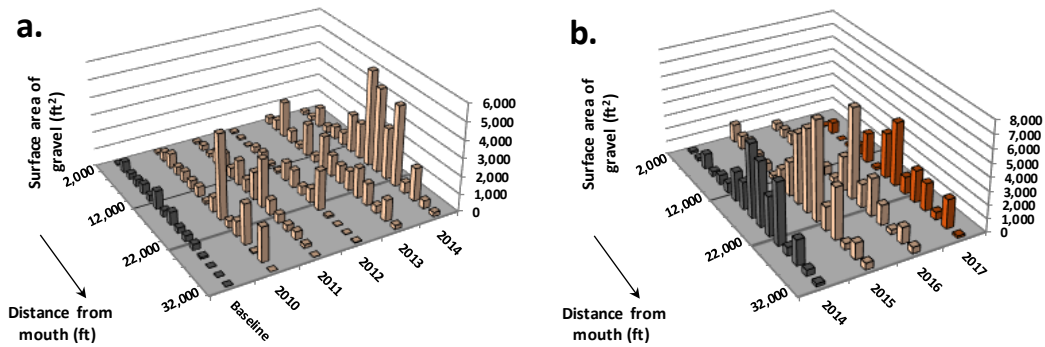


Figure 5. Longitudinal Distribution of Steelhead Spawning-Size Gravel Patches in the Lower Bull Run River Through a) Years of High Additions (2010–2014) Compared to the Baseline Average, and b) Years of Reduced Additions (2015–2017) at 30 cfs

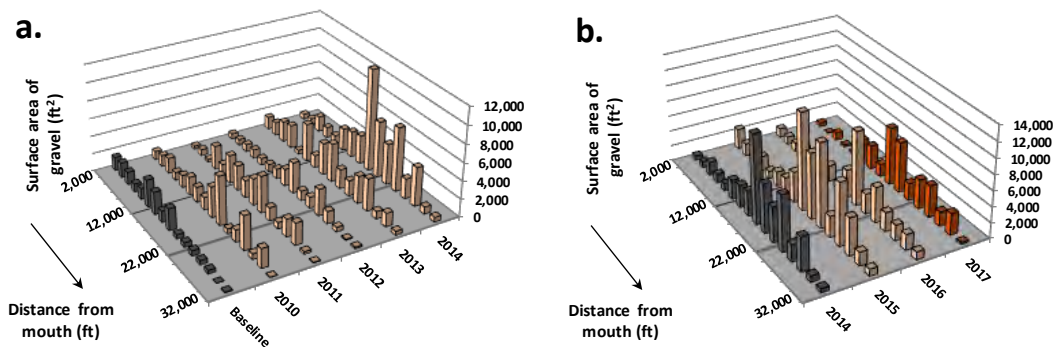


Figure 6. Longitudinal Distribution of Steelhead Spawning-Size Gravel Patches in the Lower Bull Run River Through a) Years of High Additions (2010–2014) Compared to the Baseline Average, and b) Years of Reduced Additions (2015–2017) at 1,480 cfs

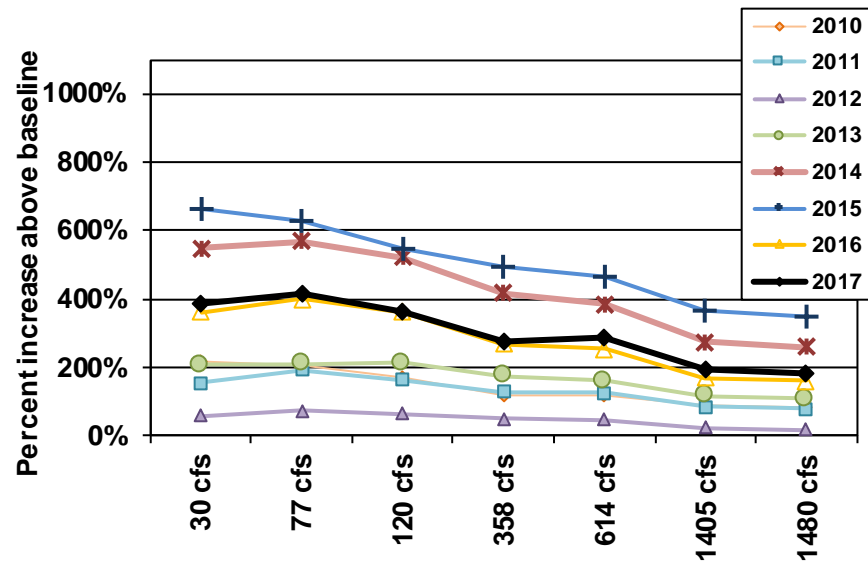


Figure 7. Increase in the Surface Area of Steelhead Spawning-Size Gravel Patches in 2017 above the Baseline Average for Various Flows Compared to Past Years

7.3.2 Chinook

In 2017, large accumulations of Chinook spawning gravel were observed immediately downstream of Larson's Bridge, as in previous years (Figure 8). Other accumulations were observed in the river segment between the Southside Bridge and Larson's Bridge. Chinook gravel accumulations continued to be elevated above baseline levels in the lower 1.5 miles of the river channel (mouth to the Bull Run Powerhouse), as with steelhead gravel. This suggests that gravel that has been placed into the Bull Run River channel since 2010 has, in part, moved to the lowest portions of the river and has possibly been passing out of the river since 2014. Figures 9 and 10 compare the longitudinal distribution of Chinook spawning gravel in 2017 with previous post-treatment years and the baseline at flows that bracket the range of flows being evaluated.

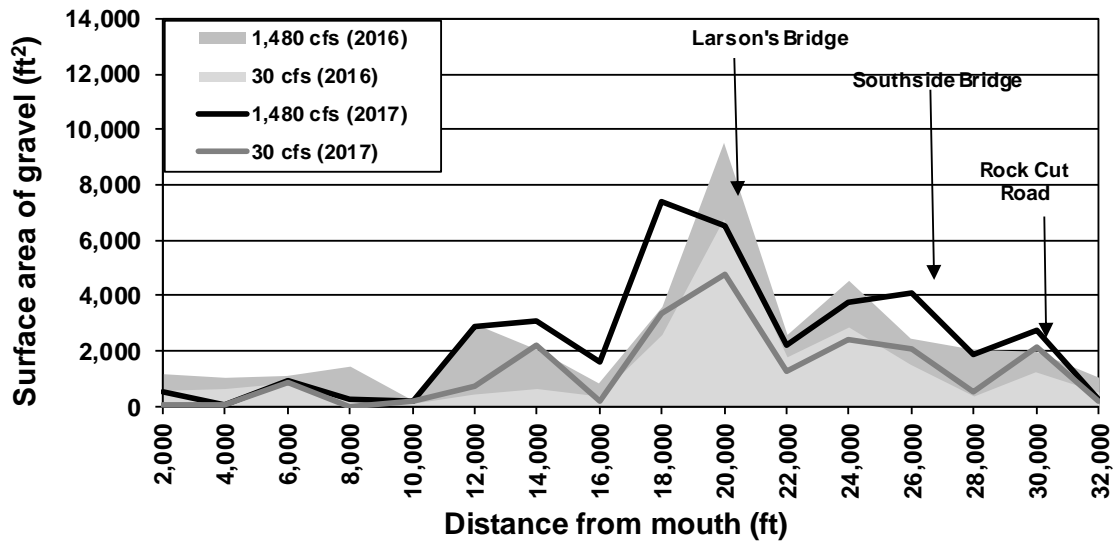


Figure 8. Longitudinal Distribution of Chinook Spawning-Size Gravel Patches in the Lower Bull Run River in 2017 at 30 cfs and 1,480 cfs Compared to 2016

The largest observed increases in gravel over the baseline occurred in the portion of the channel wetted at relatively low flows (i.e., 120 cfs and less), as shown in Figure 11. The observed increases in the total surface area of Chinook spawning gravel in 2017 above the baseline were in the middle of the range of what was observed in previous years at all flows. The surface area of Chinook gravel wetted at the lowest flows (30 cfs) was four to five times the baseline levels.

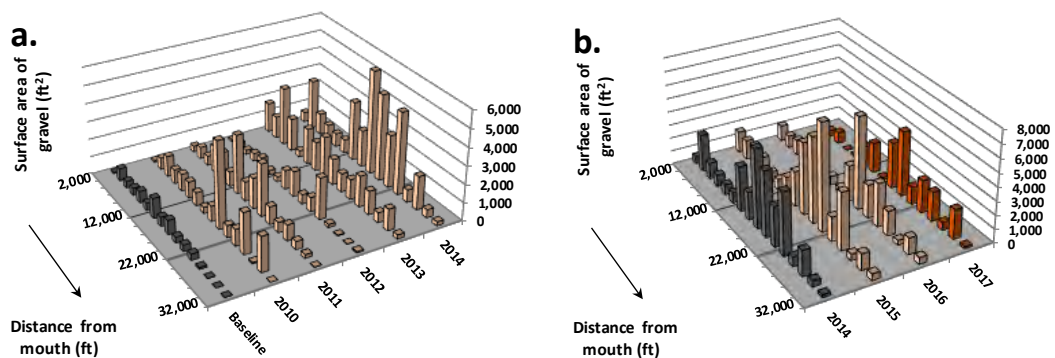


Figure 9. Longitudinal Distribution of Chinook Spawning-Size Gravel Patches in the Lower Bull Run River Through a) Years of High Additions (2010–2014) Compared to the Baseline Average, and b) Years of Reduced Additions (2015–2017) at 30 cfs

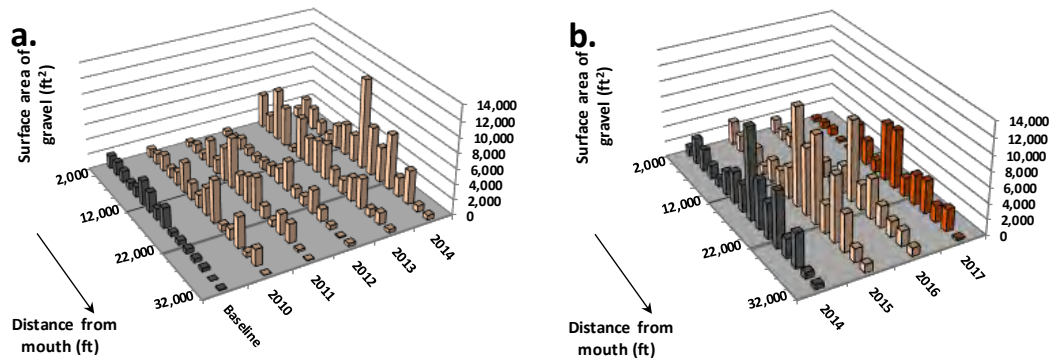


Figure 10. Longitudinal Distribution of Chinook Spawning-Size Gravel Patches in the Lower Bull Run River Through a) Years of High Additions (2010–2014) Compared to the Baseline Average, and b) Years of Reduced Additions (2015–2017) at 1,480 cfs

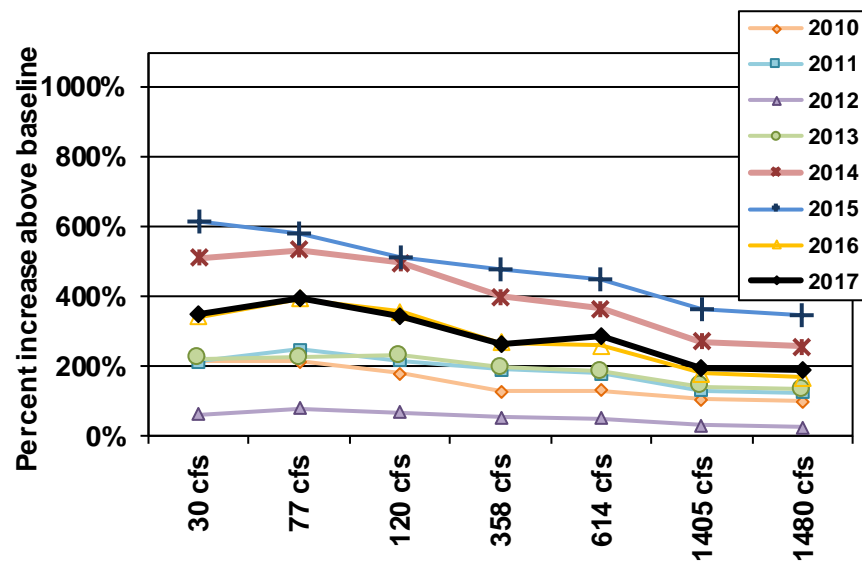


Figure 11. Increase in the Surface Area of Chinook Spawning-Size Gravel Patches in 2017 above the Baseline Average for Various Flows Compared to Past Years

8. Summary and Discussion

The total surface area of spawning-sized gravel was significantly greater in 2017 than in baseline years at all flows for both steelhead and Chinook at a 95 percent level of statistical confidence. The total surface area of spawning gravel in 2017 was about the same as in 2016, but both years were less than in 2014 and 2015. Gravel was concentrated in portions of the Bull Run River immediately downstream of the

Southside Bridge and Larson's Bridge gravel placement sites, with the largest accumulations downstream of Larson's Bridge. Gravel accumulations in the lowest 1.5 miles of the river were also greater than in baseline years, though less than in 2016. Fluctuations in gravel accumulations in the lower 1.5 miles of the river, observed since 2013, may suggest that gravel placed since 2010 has worked its way to the furthest downstream portions of the Bull Run River and may have been passing out of the river since 2014, at least.

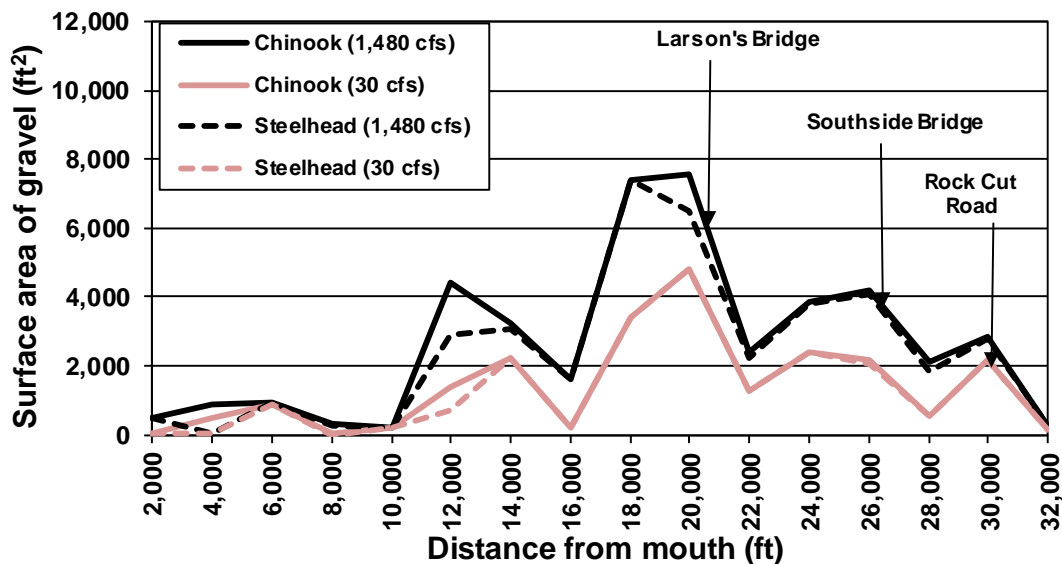


Figure 12. Comparison of Longitudinal Distribution of Chinook and Steelhead Spawning-Size Gravel Patches in the Lower Bull Run River in 2017 at 30 cfs and 1,480 cfs

The largest percentage increases in the surface area of gravel have occurred in the parts of the river that are wetted at relatively low flows. Over half of the total surface area of gravel patches was wetted at flows of 30 cfs at most locations along the lower Bull Run River channel (Figure 12). The surface area of gravel in this part of the channel was four to five times the baseline levels.

The large decrease in spawning surface area observed in 2016 and 2017 from the levels observed in 2014 and 2015 could be attributable to either the decreased rate of gravel supplementation or the mobilization of gravel into the bottoms of deep pools. The rate of gravel supplementation was decreased from 1,200 cubic yards to 600 cubic yards per year after 2014. The 2016 and 2017 gravel surveys occurred after two and three years of the lower rate. The 2015 survey, however, observed record accumulations of gravel, despite being conducted after the first year at the lower rate of supplementation. It was suggested in 2012, after a peak flow of 9,330 resulted in decreased spawning gravel surface area, that relatively low and relatively high peak flows might result in larger observed gravel surface areas than peak flows of intermediate magnitude. Low peak flows might fail to

fully mobilize recently introduced gravel. Intermediate peak flows might mobilize gravel into deep pools with slow water. High peak flows might be capable of remobilizing gravel that has accumulated in pool bottoms. The peak flow experienced by the lower Bull Run River during the winter previous to the 2016 gravel survey was 10,400 cfs—an intermediate magnitude—supporting the above 2012 assumptions. The peak flow experienced by the lower Bull Run River in the previous winter, however, was 6,830 cfs, suggesting that the total quantity of spawning gravel in the lower Bull Run River has, in fact, decreased with the lower rates of gravel supplementation.

9. Works Cited

- CH2M HILL. 2003. Lower Bull Run River Bedload Rate Approximations, Technical Memorandum to Steve Kucas, Portland Bureau of Water Works. February 20, 2003. Portland, Oregon.
- R2 Resource Consultants. 1998. Spawning Gravel Survey of the Lower Bull Run River, Oregon. Revised draft report, prepared for the Portland Bureau of Water Works. May 27, 1998. Portland, Oregon.
- Portland Water Bureau. 2008. Bull Run Water Supply Habitat Conservation Plan for the Issuance of a Permit to Allow Incidental Take of Threatened and Endangered Species. Portland, Oregon.
- Sylte, Traci, and Craig Fischenich. 2002. Techniques for Measuring Substrate Embeddedness. EURPP Technical Notes Collection (ERDC TN-EMRPP-SR-36). U.S. Development Center, Vicksburg, Mississippi.

Appendix D

Bull Run HCP Research Report

Total Dissolved Gases in the Bull Run River

April 2018

Burke Strobel

City of Portland Water Bureau



Contents

1. Summary	1
2. Introduction.....	1
3. Research Objectives.....	2
4. Key Questions and Hypotheses	3
5. Monitoring Design	3
5.1 Sites.....	3
5.2 Spatial Scale.....	7
5.3 Replication/Duration.....	7
5.4 Parameters.....	7
5.5 Sampling.....	8
6. Analysis	8
7. Results	8
7.1 Data Collected.....	8
7.2 TDG/Spillway Flow Relationships.....	9
7.3 Effects of Hydropower Water on TDG	11
7.4 Downstream Dissipation of Elevated TDG	14
8. Conclusions.....	16
9. Works Cited.....	17
Exhibit A. TDG Data Associated with Bull Run Dams 2 and 1	18

Tables

Table 1. TDG Monitoring Sites, Associated Structure, and Purpose of Measuring	5
Table 2. Flow Ranges and Number of Replicates per Flow Range for Sampling TDG	6
Table 3. Flow Range for Each Structure and Number of TDG Measurements Yet to be Collected	8
Table 4. Average Distances Downstream at which Various Elevated TDG Levels Are Predicted to Dissipate to 110 Percent	15

Figures

Figure 1. Locations of TDG Monitoring Sites Associated with Dam 2 ^a	4
Figure 2. Locations of TDG Monitoring Sites Associated with Dam 1	4
Figure 3. Relationship of TDG Percent Saturation to Flow over the Dam 2 Spillway (TDG-1L) After Rock Weir Removal Compared to Relationship After Rock Weir Removal.....	10
Figure 4. Relationship of TDG Percent Saturation to Flow over the Dam 1 Spillway (TDG-11).....	11
Figure 5. TDG Meter—in Use Since 2012—below the Dam 2 Spillway	12
Figure 6. Relationship of TDG Percent Saturation to the Combined Flow of the Dam 2 Spillway and Powerhouse 2 After Rock Weir Removal Compared to Before Rock Weir Removal	13
Figure 7. Relationship of TDG Percent Saturation to Combined Flow of the Dam 1 Spillway and Powerhouse 1	14
Figure 8. Dissipation of TDG Downstream of the Site of the Rock Weir at the Dam 2 Spillway Plunge Pool on Four Dates	15

1. Summary

The City of Portland Water Bureau (PWB) was in full compliance with its Habitat Conservation Plan (HCP; Portland Water Bureau 2008) obligations with regard to total dissolved gas (TDG) monitoring in the Bull Run River in 2017. No additional TDG data were collected in 2017 because the Bull Run River flows were not in the desired range for monitoring.

PWB has measured TDG levels in the Bull Run River since 2005. On two occasions at one site and on one occasion at a second site, PWB has measured TDG levels in excess of 110 percent at river flows below the 10-year, 7-day average flood (7Q10) flow. The measurements, however, were made in water which had passed over a spillway and represented only a portion of the total flow in the river at the time. On all of these occasions, the remaining flow had lower TDG levels and the combined flow had a calculated TDG level below 110 percent.

PWB's TDG monitoring has been affected by modifications of water infrastructure associated with the implementation of another HCP measure. The relationship between TDG levels and spill at the Dam 2 spillway has changed since the removal of a rock weir at the spillway plunge pool tailout. TDG levels of water from the Diversion Pool have also increased since removal of the rock weir. PWB will continue monitoring to describe these changes.

This appendix summarizes the results to date of PWB's TDG monitoring in the Bull Run River.

2. Introduction

The level of total dissolved gas is the sum of the partial pressures of all gases, including water vapor, dissolved in a volume of water. Elevated levels of TDG in water can have various negative impacts on fish, such as the formation of gas bubbles in tissues and the vascular system (gas bubble disease) and over-inflation of the air bladder. Extremely high levels of TDG or long exposure times can lead to immediate or delayed mortality.

Oregon's Water Quality Standards, as enforced by the Oregon Department of Environmental Quality (ODEQ), state that the concentration of TDG relative to local barometric pressure should not exceed 110 percent of saturation [OAR 340-041-0031]. An exception is made when stream flows at a given sampling site exceed the 10-year, 7-day average flood (7Q10), defined as the yearly peak 7-day rolling average high flow that has an average recurrence interval of 10 years.

In 2005, PWB initiated a monitoring plan to check TDG levels associated with the water facilities in the Bull Run Watershed. The plan, developed in consultation with ODEQ, identified sites at risk of elevated TDG levels and established a sampling regime specific

to each sampling site, with a set number of data to be collected. Many of these data had already been collected prior to 2012.

The TDG sampling plan developed by PWB has been altered from what was described in the HCP due to two infrastructure modifications in the Bull Run Watershed. These modifications were necessary to comply with another measure in the PWB's HCP—Measure T-2, Post-Infrastructure Temperature Management—and include 1) the removal of a rock weir at river mile (RM) 5.8, completed in 2011, and 2) the installation of a multiple-level intake on one of the Dam 2 intake towers, completed in 2014.

Removal of the rock weir has altered the usefulness of certain TDG monitoring sites and may have changed TDG levels under certain flows. The rock weir slowed the passage of water through the Dam 2 spillway plunge pool. Its removal allows cool water to quickly flow downstream with less warming than before, to the benefit of salmon and trout. In the absence of the rock weir, however, spillway water with high TDG levels and Powerhouse 2 water with lower TDG levels, which meet in the plunge pool, have less opportunity to mix before flowing downstream. As a result, certain TDG sites, selected to monitor fully mixed water, are no longer useful. In addition, without the rock weir, spillway water plunges additional feet to the lowered pool surface. This could change TDG levels at the base of the spillway from what they would have been with the rock weir.

Modifications to the intake tower could lead to a change in TDG levels in water coming from the Diversion Pool. Water that passes from the intake tower through Powerhouse 2 into the Diversion Pool has relatively low TDG levels. This relatively low-TDG water mixes with water from the spillway, decreasing the higher TDG levels of the spillway water. TDG levels entering the Diversion Pool from Powerhouse 2 may have been altered, however, by modification of the intake tower. TDG levels for the water from the Diversion Pool may have been further altered by the removal of the rock weir, which changed the water surface elevation and velocity through the spillway plunge pool. TDG levels greater than 110 percent at flows less than the 7Q10 flow could result.

Alterations have been made to the TDG monitoring plan to accommodate these changing conditions in the Bull Run River. These alterations are described in the 2011 Annual Compliance Report (Portland Water Bureau 2012). This appendix describes results to date for monitoring TDG levels in the lower Bull Run River.

3. Research Objectives

The TDG research results are being used to determine whether there are locations in the lower Bull Run Watershed with elevated concentrations of TDG. The sites are monitored across a range of flows.

4. Key Questions and Hypotheses

There are three key questions to be answered by this TDG monitoring plan. Two of the questions have a null hypothesis (H_0) that will be tested with the monitoring protocol; the third question will be addressed by field observation. The questions are as follows:

Question 1: Do any of the monitoring sites exceed the ODEQ standard of 110 percent saturation of TDG?

H_0 : At each monitoring site, the observed TDG concentration will not exceed 110 percent of saturation within any range of flow, as defined in Table F-7 of the HCP, unless the flow exceeds the 7Q10 for the lower Bull Run River.

Question 2: At sites where TDG levels exceeding 110 percent are observed, are there flow ranges associated with excessive TDG levels?

H_0 : At each site with observed TDG levels in excess of 110 percent, there is no relationship between amount of flow and measured levels of TDG.

Question 3: How quickly do elevated levels of TDG dissipate downstream when they are observed?

This key question does not have an associated null hypothesis. It involves the collection of information to assist in the adaptive management process.

5. Monitoring Design

5.1 Sites

PWB, in conjunction with ODEQ staff, identified all watershed structures associated with City operations that could cause elevated levels of TDG. These structures include the spillways, valves, and turbines in which air bubbles could be brought under sufficient pressure to cause their dissolution in water beyond the level of saturation.

Monitoring locations were established to monitor the effects of each specific structure on TDG levels, or to provide information on the persistence of TDG downstream. The monitoring sites, the associated structures that increase the risk of elevated TDG concentrations, and the purposes of measuring each site are summarized in Table 1. Additional sites are also monitored to provide information on the effects of water mixing from various sources and the effects of downstream dissipation on elevated TDG levels. All locations of monitoring sites are shown in Figures 1 and 2.

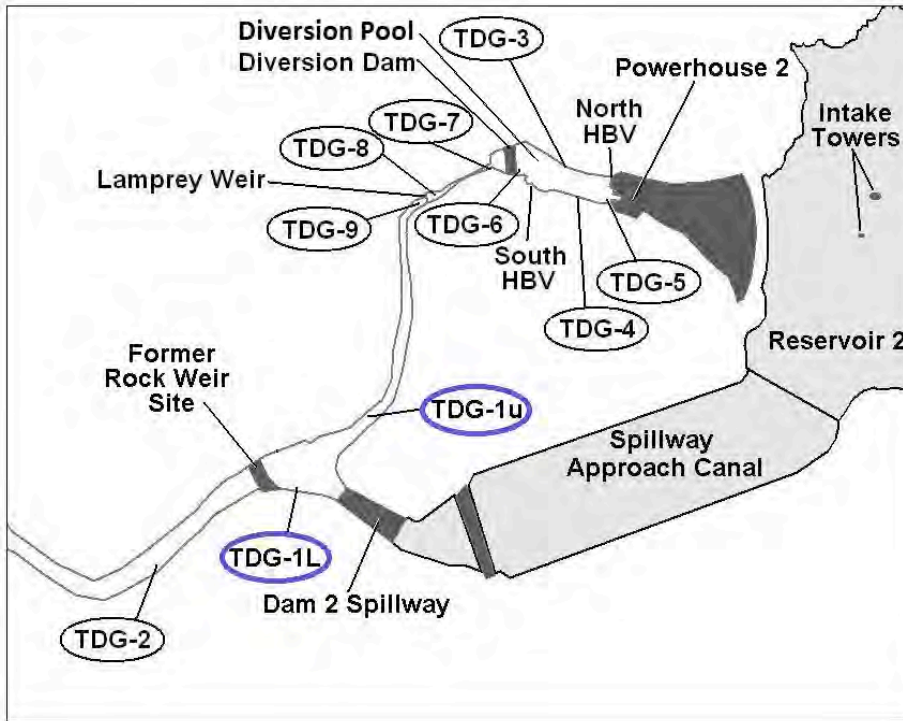


Figure 1. Locations of TDG Monitoring Sites Associated with Dam 2^a

^aMonitoring sites TDG-1L and TDG-1u were added in 2011 to replace sites TDG-1 and TDG-1a.

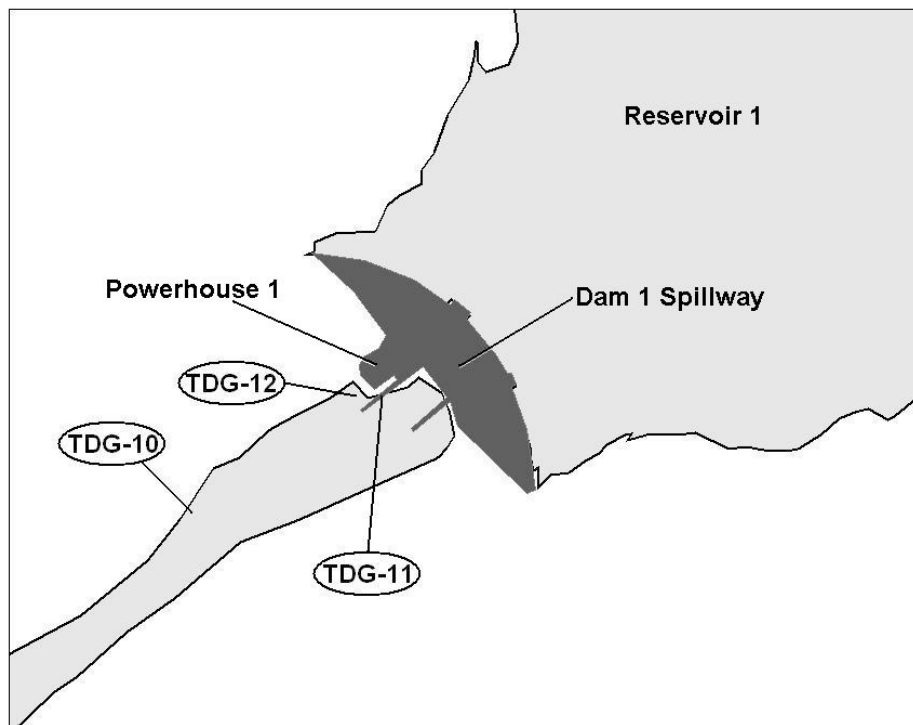


Figure 2. Locations of TDG Monitoring Sites Associated with Dam 1

Two sites listed in Table 1, TDG-1L and TDG-1u, are monitored in tandem and used to calculate a TDG value for mixed water from both the Dam 2 spillway and the Diversion Pool (Powerhouse 2 flow and Howell-Bunger valve flow). The TDG level of mixed flows was originally monitored at site TDG-1a, located immediately downstream of the Dam 2 spillway plunge pool rock weir. After the removal of the rock weir, however, there was no longer an adequate site where fully mixed flows could be monitored before elevated TDG levels had a chance to dissipate. The City replaced TDG-1a by monitoring the two sources of water that mix in the plunge pool and using their relative contribution to calculate a combined-flow TDG value.

Table 1. TDG Monitoring Sites, Associated Structure, and Purpose of Measuring

Monitoring Site	Associated Structure	Purpose
TDG-1L, TDG-1u ^a	Dam 2 Spillway	Structure Effects
TDG-2	Dam 2 Spillway	Downstream Effects
TDG-3	South Howell-Bunger Valve	Structure Effects
TDG-4	North Howell-Bunger Valve	Structure Effects
TDG-5	Powerhouse 2	Structure Effects
TDG-6	Diversion Dam	Structure Effects (Upstream Value)
	Powerhouse 2	Downstream Effects
TDG-7	Diversion Dam	Structure Effects (Downstream Value)
TDG-8	Lamprey Weir	Structure Effects (Upstream Value)
	Diversion Dam	Downstream Effects
TDG-9	Lamprey Weir	Structure Effects (Downstream Value)
TDG-10	Dam 1 Spillway	Downstream Effects
	Powerhouse 1	Downstream Effects
TDG-11	Dam 1 Spillway	Structure Effects
TDG-12	Powerhouse 1	Structure Effects

^aTDG-1L and TDG-1u sites were added in 2011; TDG-1 and TDG-1a are no longer monitored.

Each site has a unique span of possible flows, associated with its longitudinal position along the Bull Run River and its function as a part of the City's water and hydroelectric facilities. Flows passing through each of the two powerhouses are measured by flow sensors in the penstocks and are constrained by the minimum flows required to run the

turbines and the maximum flows that the turbines can accommodate. Flows passing over each dam's spillway are estimated by employing stage/discharge rating curves established for each spillway. The flows are constrained only by the range of natural variability in the Bull Run River as modified by the water diversions and withdrawals by PWB.

For most of the structures, the historical span of flows was divided into three equal parts or flow ranges. Each flow range will be sampled with replication. The ranges of flows for each structure in cubic feet per second (cfs) and the number of replicates for sampling are identified in Table 2. Sites located downstream of structures are for the purpose of monitoring the persistence of TDG concentrations and will be sampled on the same day as the associated upstream sites (for example, TDG-10 is downstream of TDG-11, the Dam 1 Spillway, and TDG 12, Powerhouse 1).

Table 2. Flow Ranges and Number of Replicates per Flow Range for Sampling TDG

Structure	Flow Ranges (cfs)	Number of Replicates
Dam 2 Spillway	1,700–6,900	5
	6,900–12,000	5
	12,000–17,200	5
Powerhouse 2	210–700	5
	700–1,200	5
	1,200–1,700	5
South HB Valve ^a	While operating	5
North HB Valve ^a	While operating	5
Diversion Dam	Whenever Powerhouse 2 or HB valve readings are taken	15 to 20
Lamprey Weir	Whenever Powerhouse 2 or HB valve readings are taken	15 to 20
Dam 1 Spillway	2,000–5,500	5
	5,500–8,900	5
	8,900–12,400	5
Powerhouse 1	800–1,200	5
	1,200–1,600	5
	1,600–2,000	5

^aHB =Howell-Bunger

Two Howell-Bunger (HB) valves at Reservoir 2 provide a route for releasing water that bypasses the hydroelectric turbines and the spillway. The HB valves dissipate energy associated with the head pressure behind the dam. Monitoring sites have been located at

the outlet of each HB valve. No range of flows has been established for the HB valves. Each site will be sampled several times when the respective valve is in operation.

The 7Q10 for the lower Bull Run River was calculated from historical records from January 1, 1940, to June 30, 2015; it is currently estimated to be 5,638 cfs. The 7Q10 for the Dam 1 spillway was calculated from historical records from January 1, 1976 to December 31, 2013; it is currently estimated to be 4,461 cfs. When flows of these magnitudes occur or are exceeded, sampling will continue; however, the ODEQ standard of 110 percent saturation for TDG will not apply. PWB will update the 7Q10 flow amounts in all future years when new data are collected.

5.2 Spatial Scale

All data collected on TDG are site-specific. Downstream sites have been included to determine the spatial extent of elevated TDG exposure.

5.3 Replication/Duration

Each site will be monitored until the full set of ranges, as defined in Table 2, has been adequately sampled. Each site will be sampled five times within each flow range; some sampling has already been conducted. The sites associated with the Diversion Pool dam next to the Headworks facility and the lamprey weir will be sampled as often as possible when the Powerhouse 2 sites are sampled. Downstream sites will be sampled as often as possible when the associated upstream sites are sampled. The HB valve sites will be sampled five times each during valve operation.

Monitoring at all sites associated with the Dam 2 spillway plunge pool was reinitiated after the removal of the rock weir. Once the relationship of TDG percent saturation for each site and set of variables has been established, further monitoring will rely on tracking the environmental variables, such as water temperature and flow, rather than sampling TDG.

5.4 Parameters

On each sampling occasion, the following information is recorded:

- TDG percent saturation
- Water temperature
- Date and time of day
- Flow at the respective structure (e.g., spillway or powerhouse)

5.5 Sampling

TDG percent saturation and water temperature are measured using a Point Four Systems PT4 Tracker Total Dissolved Gas Pressure (TDGP) meter. Flow at the time of measurement is obtained from data gathered at PWB's water facilities by staff.

6. Analysis

Linear regression is used to explore the relationship between TDG levels and flow at each of the dam spillways. In those instances in which the 110 percent TDG criterion is exceeded, a regression model is developed that predicts the conditions under which TDG concentrations might exceed 110 percent at each site. In the future, nonlinear multiple regression may be used to try to use water temperature as a covariate to better model the relationship between flow and TDG concentrations.

The dissipation of elevated TDG concentrations downstream of their sources will be characterized and evaluated across levels of flow using Analysis of Covariance (ANCOVA) of log-transformed data.

7. Results

7.1 Data Collected

No TDG data were collected in the Bull Run River in 2017. Table 3 summarizes the structures in the lower Bull Run River that are being monitored for TDG and the number of data points that remain to be collected for various flows. The remaining number of replicates for the Dam 2 spillway reflects the fact that monitoring for this structure was reinitiated in 2011 following the removal of the rock weir. All TDG data collected to date are summarized in Exhibit A at the end of this report.

Table 3. Flow Range for Each Structure and Number of TDG Measurements Yet to be Collected

Structure	Flow Ranges (cfs)	Remaining Number of Replicates
Dam 2 Spillway	1,700–6,900	0
	6,900–12,000	4
	12,000–17,200	5
Powerhouse 2	210–700	4
	700–1,200	5
	1,200–1,700	0
South HB Valve	While operating	0

Table 3. Flow Range for Each Structure and Number of TDG Measurements Yet to be Collected

Structure	Flow Ranges (cfs)	Remaining Number of Replicates
North HB Valve	While operating	3
Diversion Dam	Whenever Powerhouse 2 or HB valve readings are taken	3
Lamprey Weir	Whenever Powerhouse 2 or HB valve readings are taken	1
Dam 1 Spillway	2,000–5,500	0
	5,500–8,900	5
	8,900–12,400	4
Powerhouse 1	800–1,200	5
	1,200–1,600	5
	1,600–2,000	0

^aHB=Howell-Bunger

TDG levels of greater than 110 percent saturation have been measured at three of the monitoring sites illustrated in Figures 1 and 2 in the last nine years, when the total flow of the river was greater than the 7Q10 flow: the Dam 2 spillway on the left bank (TDG-1L), downstream of TDG-1L (TDG-2), and the Dam 1 spillway (TDG-11).

There is the potential for TDG levels to be greater than 110 percent saturation even if the flows are less than the 7Q10 amount. If the total river flow were under the 7Q10 flow for the sites and all flow went over the spillways at either Dam 1 or 2, the levels could be greater than 110 percent. The highest TDG level observed at these sites during spillway flows less than the 7Q10 flow has been 114 percent. On all of these occasions, however, a portion of the total flow of the river had passed through the Dam 1 and Dam 2 powerhouses and the combined flows are calculated to have had TDG levels less than 110 percent.

Subsection 7.2 describes the spillway flow at which the 110 percent threshold is predicted to be exceeded in relationship to the 7Q10 flows for each spillway. Subsection 7.3 describes the calculated effects of mixing of spillway flows and powerhouse flows on TDG levels in the Bull Run River.

7.2 TDG/Spillway Flow Relationships

Because TDG saturation greater than 110 percent has been measured at two of the locations listed in Table 2, the spillways associated with Dam 1 and Dam 2, PWB studied the relationship between spillway flows and TDG levels. At the Dam 2 spillway, there was a relationship ($R^2=0.81$) between flow over the Dam 2 spillway and TDG mea-

surements at the foot of the spillway (TDG-1L). After the rock weir was removed, that relationship changed. At the Dam 1 spillway, there is no clear relationship between TDG saturation and spillway flow.

After the removal of the rock weir below the Dam 2 spillway, the threshold of 110 percent TDG saturation was predicted to be exceeded at TDG-1L at a spill of approximately 2,616 cfs, as shown in Figure 3. This left a range of flows between 2,616 and 5,689 cfs for which this site had the potential for being in violation of ODEQ's TDG standards if all of the Bull Run flow were to pass over the spillway. This range of flows is larger than it was prior to the removal of the rock weir, when this site had the potential to be in violation of TDG standards between 3,740 cfs and 5,702 cfs. The TDG level at TDG-1L is predicted to be 113 percent at the 7Q10 flow if all of that flow is passing over the spillway and none of it is passing through Powerhouse 2 or the Howell-Bunger valves into the Diversion Pool.

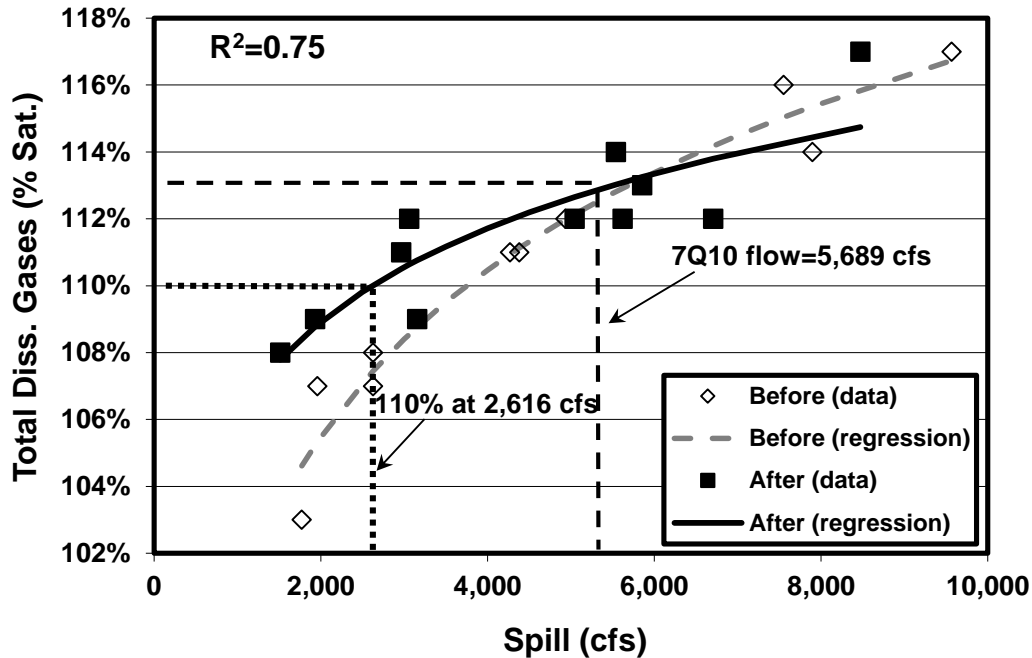


Figure 3. Relationship of TDG Percent Saturation to Flow over the Dam 2 Spillway (TDG-1L) After Rock Weir Removal Compared to Relationship After Rock Weir Removal

Figure 4 illustrates the observed effects of Dam 1 spillway flows on measured TDG values. There is no apparent relationship between flow over the Dam 1 spillway and TDG measurements. TDG values in excess of 110 percent saturation have been measured twice in the Dam 1 spillway, at spillway flows of 2,177 cfs and 2,804 cfs. Spillway flows much higher than these (e.g., 10,158 cfs), however, resulted in TDG measurements below 110 percent. The large variation in TDG measurements at this site could result from the extreme water turbulence in the Dam 1 spillway, making it difficult to obtain a reliable measurement.

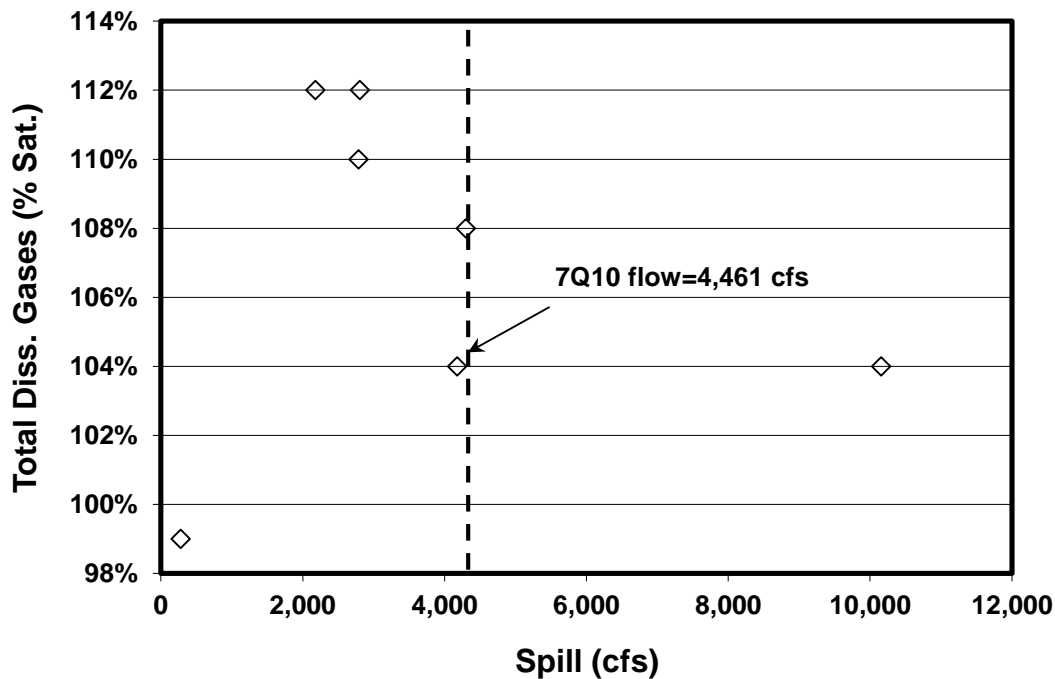


Figure 4. Relationship of TDG Percent Saturation to Flow over the Dam 1 Spillway (TDG-11)

7.3 Effects of Hydropower Water on TDG

The flows from Powerhouse 2, with their lower TDG levels, are expected to reduce the overall TDG level of the flow when combined with Dam 2 spillway flows, similar to what has occurred under previous conditions. Even though TDG levels have exceeded 110 percent at two Bull Run structures, monitoring data indicate that normal water supply operations prior to removal of the rock weir probably had reduced those concentrations through the mixing of powerhouse and spillway water at flows below the 7Q10.

The diluting effect of the water from Powerhouse 2 appears to have changed since the removal of the rock weir. The Bull Run Dam 2 powerhouse diverts a maximum of 1,700 cfs for electricity generation. Typically, this powerhouse has operated at close to maximum capacity when flows in the Bull Run River are high enough to allow it. Prior to rock weir removal, the diverted water downstream of Powerhouse 2 had an average TDG level of 103 percent saturation just before it mixed with water from the Dam 2 spillway. This diverted water had modified the TDG/flow relationships discussed in Section 7.2 and brought the calculated combined TDG level down to below 110 percent at the 7Q10 flow. Since the removal of the rock weir, however, the diverted water downstream of Powerhouse 2 has had an average TDG level of 105.3 percent saturation just before it mixed with water from the Dam 2 spillway. When Powerhouse 2 is operating at full capacity, the water that is diverted is now calculated to decrease the

TDG level of the combined flow (powerhouse + spillway) to 110.1 percent saturation at the 7Q10 flow, as shown in Figure 4. The TDG level of the combined flow is predicted to exceed 110 percent saturation above 5,636 cfs. This leaves a narrow window of flows between 5,636 cfs and 5,689 cfs when the 110 percent TDG saturation threshold could theoretically be exceeded below the 7Q10 flow. TDG levels are predicted to be 110.1 percent at the 7Q10 flow, with dilution.

The reason for the observed increase in TDG levels in water from the Diversion Pool is unclear. The City began using a new TDG meter in 2012, but the new meter has measured values similar to the old meter (Figure 5) at locations where there have been no infrastructure changes, such as the Dam 1 Powerhouse (TDG-12). Upstream structures such as the lamprey weir have also shown no corresponding TDG level increase. It is possible that the removal of the rock weir has inadvertently increased TDG levels in water originating from the Diversion Pool by lowering the water surface of the spillway plunge pool. The accompanying increase in the plunge of water from a cascade immediately upstream of TDG-1u and increased velocity of water from that location to where it joins the water from the Dam 2 spillway may have increased TDG levels slightly and reduced the opportunity for off-gassing.

The relationship between combined TDG levels and combined flows might change if the TDG level of flows from Powerhouse 2 change further under current conditions with a modified intake tower. There have been only two measurements of TDG at TDG-1u while the Dam 2 Powerhouse was in operation after the modification of the intake tower. These measurements are insufficient to determine whether the intake tower modifications will have an effect on the water from the Diversion Pool. The relationship illustrated in Figure 6 will also change if Powerhouse 2 is operated at less than maximum capacity.



Figure 5. TDG Meter—in Use Since 2012—below the Dam 2 Spillway.

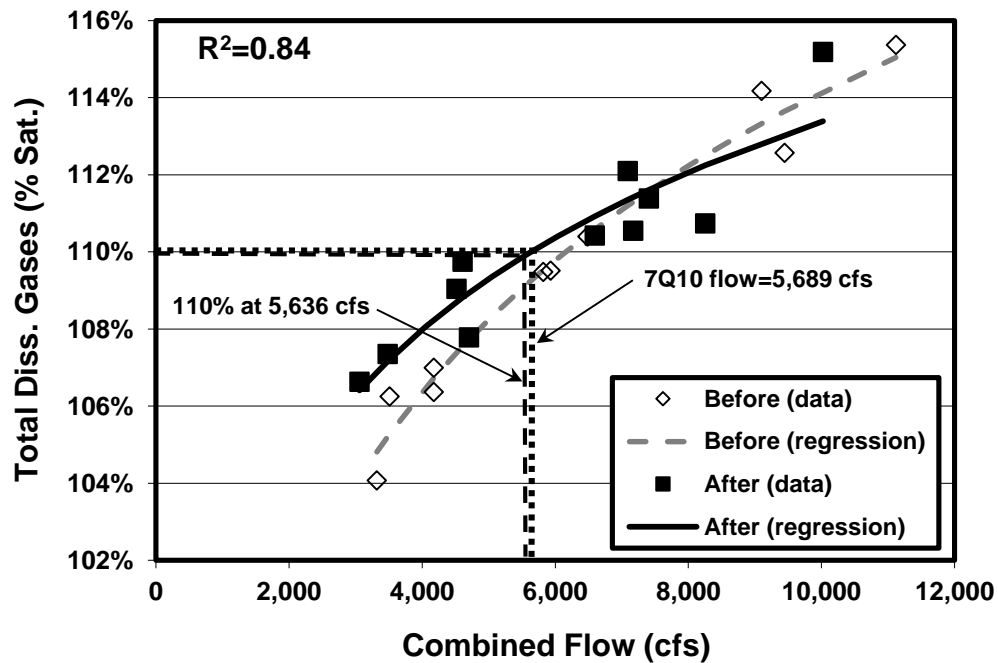


Figure 6. Relationship of TDG Percent Saturation to the Combined Flow of the Dam 2 Spillway and Powerhouse 2 After Rock Weir Removal Compared to Before Rock Weir Removal

The Bull Run Dam 1 powerhouse generally diverts a maximum of 2,300 cfs for electricity generation. Typically, this powerhouse operates at close to maximum capacity when flows in the Bull Run River are high enough to allow it. Diverted water in the tailrace of Powerhouse 1 has an average TDG level of 108 percent saturation. This diverted water modifies the TDG/flow relationships discussed in Section 7.2. When Powerhouse 1 is operating at full capacity, the calculated TDG levels of the combined powerhouse and spillway flows do not show any relationship to amount of flow, but no TDG levels above 110 percent have occurred below the 7Q10 flow for the site, according to calculations, as indicated in Figure 7.

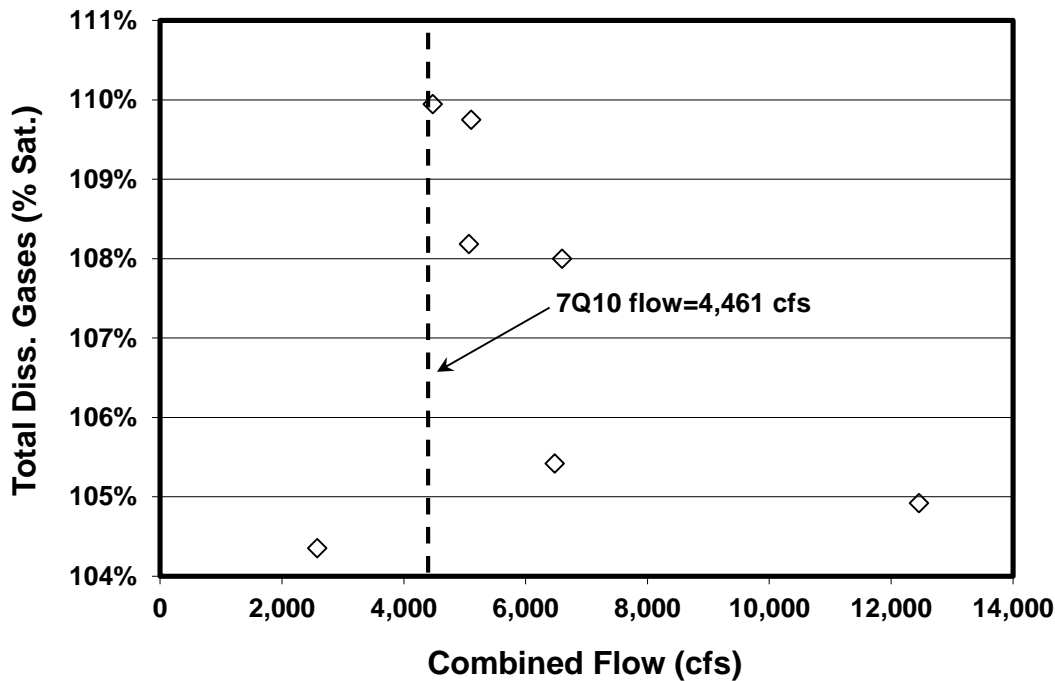


Figure 7. Relationship of TDG Percent Saturation to Combined Flow of the Dam 1 Spillway and Powerhouse 1

PWB does not have a good site to measure the TDG levels of fully mixed water at either the Dam 1 or the Dam 2 spillways, so in 2012, PWB started using data from both spillways and both powerhouse inputs to calculate the TDG of the combined flows. For Dam 1, the flows from the spillway and Powerhouse 1 do not appear to be fully mixed at TDG-10. An island in the middle of the river channel downstream of the Dam 1 spillway pool allows the flow from Powerhouse 1 and the adjacent spillway to remain separate until significant off-gassing is expected to have occurred. For the Dam 2 spillway, in the absence of the rock weir, flows from Powerhouse 2 and the spillway do not appear to mix fully until they have moved further downstream than TDG-2 and some off-gassing has occurred.

Because of these complications, PWB believes that the most meaningful way of estimating the initial TDG of the combined flows at both sites is to calculate TDG using the discharge amount and respective TDG measurements from each powerhouse and each spillway, just before they combine.

7.4 Downstream Dissipation of Elevated TDG

Under the terms of the HCP, PWB monitors the dissipation of TDG levels downstream of the Dam 2 spillway and rock weir structure due to off-gassing. PWB will continue to

monitor dissipation rates for various flows above and below the 7Q10 flow to establish rates that can be applied to flows approximately equal to the 7Q10 flow level.

To date, downstream dissipation of TDG levels has been monitored at six flow levels—15,508 cfs (11/7/2006), 6,631 cfs (2/16/2007), 6,097 cfs (12/3/2007), 11,315 cfs (11/13/2008), 6,151 cfs (11/20/2012), and 10,172 cfs (12/2/2013). All of the monitored flows were above the 7Q10 flow for the lower Bull Run River. Two of the monitoring occasions occurred after the removal of the rock weir.

The natural log of TDG percent saturation above equilibrium (i.e., TDG percent saturation minus 100 percent) initially decreased roughly linearly with distance, as depicted in Figure 8. Table 4 summarizes the average distances downstream at which various elevated TDG levels are predicted to dissipate to 110 percent.

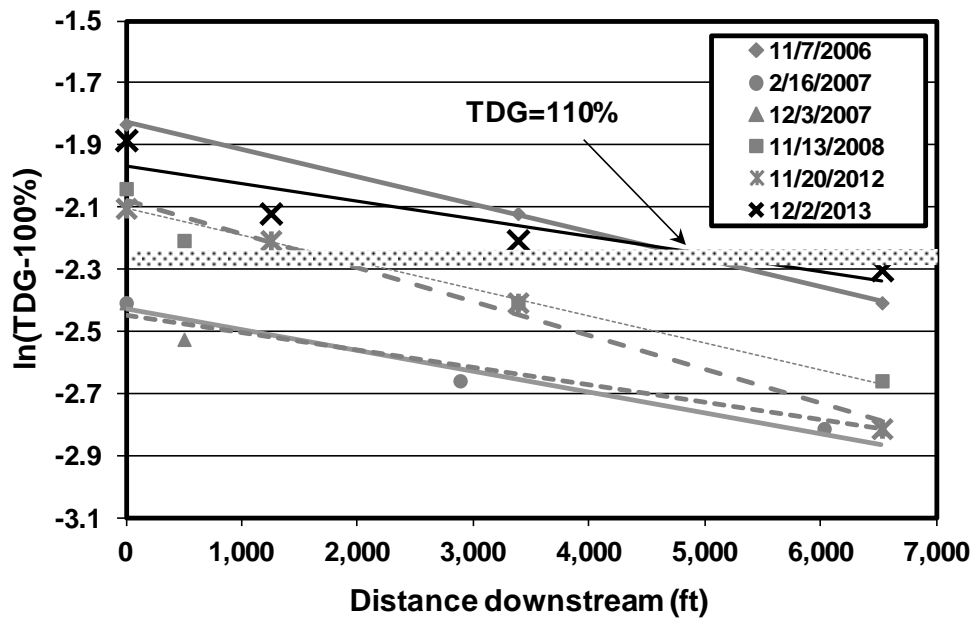


Figure 8. Dissipation of TDG Downstream of the Site of the Rock Weir at the Dam 2 Spillway Plunge Pool on Four Dates

Table 4. Average Distances Downstream at which Various Elevated TDG Levels Are Predicted to Dissipate to 110 Percent

Initial TDG Saturation	Approximate Distance Downstream at which TDG Dissipates to 110%
115%	4,624 feet
114%	3,732 feet
113%	2,774 feet
112%	1,739 feet
111%	613 feet

PWB will continue to monitor the dissipation of TDG levels downstream of the Dam 2 spillway. Future monitoring will focus on lower Bull Run River flows below the 7Q10 level.

8. Conclusions

The monitoring conclusions are organized based on the key questions presented in Section 4.

1. Do any of the monitoring sites exceed the ODEQ standard of 110 percent saturation of TDG?

No TDG data were collected in 2017. TDG levels exceeded 110 percent locally at one site on two occasions and at another site on one occasion, but the combined flow over the spillway and in the river was above the 7Q10 flow.

2. At sites where elevated TDG levels exceeding 110 percent are observed, are there flow ranges associated with excessive TDG levels?

Under current conditions, after removal of the rock weir, TDG levels are predicted to exceed 110 percent at the base of the Dam 2 spillway at a spillway flow above 2,616 cfs.

TDG levels downstream of the spillways are reduced by mixing with water from the powerhouses, which has lower TDG levels than water from the spillways. During normal high-flow conditions in the winter and spring, water is diverted from Reservoirs 1 and 2 and routed through the powerhouses at the base of each dam. If the total river flow is greater than the capacity of the powerhouses, the additional flow goes over the spillways. TDG levels at the Dam 1 and 2 spillway sites are normally reduced by mixing with powerhouse flows downstream of both the Dam 1 and 2 spillways. TDG levels in the water from Powerhouse 2 appear to have increased slightly after the removal of the rock weir, decreasing the diluting benefits of mixing powerhouse with spillway flows. After removal of the rock weir, and with anticipated mixing from Powerhouse 2, TDG levels immediately downstream of the Dam 2 spillway are now calculated to exceed 110 percent at a total river flow of 5,636 cfs.

The TDG levels at the Dam 2 spillway could be slightly higher than 110 percent under flows slightly lower than the 7Q10. This could occur if spillway flows were between 5,636 cfs and the 7Q10 flow of 5,689 cfs and no water was passed through the Diversion Pool. At the 7Q10 flow, TDG levels are predicted to be 110.1 percent.

There is no apparent relationship between spillway flow and TDG levels at the base of the Dam 1 spillway. TDG levels have exceeded 110 percent saturation at the base of the Dam 1 at flows of 2,177 cfs and 2,804 cfs, but higher flows than these have had lower measured levels of TDG.

3. How quickly do elevated levels of TDG dissipate downstream when they are observed?

If the TDG level is 111 to 115 percent of saturation below the site of the Dam 2 spillway plunge pool rock weir, it dissipates to less than 110 percent at between 613 and 4,624 feet downstream. As of the end of 2017, TDG saturation in excess of 110 percent has not been measured below the Dam 2 spillway plunge pool at total river flows below the 7Q10 flow for the site.

9. Works Cited

Portland Water Bureau. 2008. Bull Run Water Supply Habitat Conservation Plan for the Issuance of a Permit to Allow Incidental Take of Threatened and Endangered Species. Portland, Oregon.

Portland Water Bureau. 2012. Bull Run Water Supply Habitat Conservation Plan Annual Compliance Report 2011—Year 2, Final. Portland, Oregon.

Exhibit A. TDG Data Associated with Bull Run Dams 2 and 1

Table A-1. Total Dissolved Gases (TDG) Data Associated with Bull Run Dam 2

Date	Monitoring Site	Percent Saturation	Spillway Flow ^a (cfs)	Powerhouse or HBV ^b Flow (cfs)
1/18/2005	TDG-1	107%	1,959	1,695
1/18/2005	TDG-1	108%	2,624	1,695
12/28/2005	TDG-1	111%	4,380	1,690
1/10/2006	TDG-1	116%	7,550	1,690
11/14/2006	TDG-1	103%	1,770	1,714
12/14/2006	TDG-1	107%	2,624	1,700
2/16/2007	TDG-1	112%	4,932	1,699
12/3/2007	TDG-1	111%	4268	1,690
11/13/2008	TDG-1	114%	7,897	1,560
11/13/2008	TDG-1	117%	9,568	1,560
11/23/2011	TDG-1	105%	2,042	1,585
12/29/2011	TDG-1	111%	3,274	1,596
12/14/2006	TDG-1L	111%	4,346	1,700
2/16/2007	TDG-1L	113%	5,464	1,684
12/3/2007	TDG-1L	111%	3,855	1,710
11/13/2008	TDG-1L	120%	10,611	1,560
11/23/2011	TDG-1L	108%	2,042	1,585
1/19/2012	TDG-1L	112%	3,718	1566
3/16/2012	TDG-1L	111%	3,616	1583
3/30/2012	TDG-1L	112%	6,418	1560
3/31/2012	TDG-1L	109%	2,504	1587
10/29/2012	TDG-1L	112%	5,816	100 (HBV)
11/20/2012	TDG-1L	114%	5,541	510 (HBV)
12/4/2012	TDG-1L	109%	3,155	530 (HBV)
12/2/2013	TDG-1L	117%	8,472	1,700
11/18/2015	TDG-1L	113%	5,855	620 (HBV)
12/9/2015	TDG-1L	112%	6,705	1,503
12/28/2005	TDG-1a	109%	4,380	1,690

Table A-1. Total Dissolved Gases (TDG) Data Associated with Bull Run Dam 2

Date	Monitoring Site	Percent Saturation	Spillway Flow^a (cfs)	Powerhouse or HBV^b Flow (cfs)
11/7/2006	TDG-1a	116%	14,160	1,645
11/14/2006	TDG-1a	102%	1,717	1,714
12/14/2006	TDG-1a	103%	2,746	1,700
2/16/2007	TDG-1a	107%	4,932	1,699
12/3/2007	TDG-1a	109%	4,397	1,700
11/13/2008	TDG-1a	113%	7,766	1,560
11/13/2008	TDG-1a	114%	9,755	1,560
11/23/2011	TDG-1a	104%	1,959	1,585
12/29/2011	TDG-1a	109%	3,274	1,596
12/14/2006	TDG-1u	102%		1,700
2/16/2007	TDG-1u	103%		1,699
12/3/2007	TDG-1u	103%		1,700
11/13/2008	TDG-1u	104%		1,560
11/23/2011	TDG-1u	105%		1,596
3/16/2012	TDG-1u	107%		1,583
3/30/2012	TDG-1u	105%		1,560
3/31/2012	TDG-1u	104%		1,587
10/29/2012	TDG-1u	105%		100 (HBV)
11/20/2012	TDG-1u	106%		510 (HBV)
12/4/2012	TDG-1u	106%		530 (HBV)
12/2/2013	TDG-1u	107%		1,700
11/18/2015	TDG-1u	102%		620 (HBV)
12/9/2015	TDG-1u	104%		1,525
1/18/2005	TDG-2	104%	2,444	1,695
11/7/2006	TDG-2	112%	12,155	1,645
11/14/2006	TDG-2	101%	1,797	1,714
12/14/2006	TDG-2	104%	4,046	1,700
2/16/2007	TDG-2	109%	5,464	1,684
12/3/2007	TDG-2	108%	3,924	1,720
11/13/2008	TDG-2	115%	10,323	1,560
11/23/2011	TDG-2	105%	1,932	1,596

Table A-1. Total Dissolved Gases (TDG) Data Associated with Bull Run Dam 2

Date	Monitoring Site	Percent Saturation	Spillway Flow^a (cfs)	Powerhouse or HBV^b Flow (cfs)
1/19/2012	TDG-2	112%	3,873	1566
10/29/2012	TDG-2	114%	5,698	100 (HBV)
11/20/2012	TDG-2	114%	5,503	510 (HBV)
12/4/2012	TDG-2	107%	3,219	530 (HBV)
12/2/2013	TDG-2	115%	8,161	1,700
11/18/2015	TDG-2	109%	5,737	620 (HBV)
12/9/2015	TDG-2	111%	6,623	1,503
2/3/2005	TDG-3	103%		113 (HBV)
3/25/2008	TDG-3	103%		282 (HBV)
7/2/2008	TDG-3	106%		700 (HBV)
11/20/2012	TDG-3	105%		510 (HBV)
11/18/2015	TDG-3	103%		620 (HBV)
2/3/2005	TDG-4	102%		118 (HBV)
7/2/2008	TDG-4	107%		1,300 (HBV)
12/29/2004	TDG-5	102%		409
12/28/2005	TDG-5	102%		1,690
11/14/2006	TDG-5	100%		1,714
2/16/2007	TDG-5	101%		1,681
12/3/2007	TDG-5	100%		1,700
7/2/2008	TDG-5	109%		1,200
7/2/2008	TDG-5	108%		1,300
7/2/2008	TDG-5	108%		1,700
7/2/2008	TDG-5	108%		1,750
3/16/2012	TDG-5	106%		1,583
3/30/2012	TDG-5	104%		1,560
3/31/2012	TDG-5	106%		1,587
12/2/2013	TDG-5	106%		1,700
5/19/2005	TDG-6	104%		1,725
12/28/2005	TDG-6	102%		1,690
11/14/2006	TDG-6	100%		1,714
2/16/2007	TDG-6	101%		1,681

Table A-1. Total Dissolved Gases (TDG) Data Associated with Bull Run Dam 2

Date	Monitoring Site	Percent Saturation	Spillway Flow^a (cfs)	Powerhouse or HBV^b Flow (cfs)
7/2/2008	TDG-6	107%		2,000 (HBV)
7/2/2008	TDG-6	108%		1,820
3/16/2012	TDG-6	107%		1,583
3/30/2012	TDG-6	106%		1,560
3/31/2012	TDG-6	105%		1,587
11/20/2012	TDG-6	106%		510 (HBV)
12/2/2013	TDG-6	106%		1,700
5/19/2005	TDG-7	104%		1,725
11/14/2006	TDG-7	102%		1,714
7/2/2008	TDG-7	106%		1,820
3/16/2012	TDG-7	106%		1,583
3/30/2012	TDG-7	104%		1,560
3/31/2012	TDG-7	104%		1,587
11/20/2012	TDG-7	104%		510 (HBV)
12/2/2012	TDG-7	106%		1,700
12/28/2005	TDG-8	103%		1,690
11/14/2006	TDG-8	101%		1,714
2/16/2007	TDG-8	102%		1,681
12/3/2007	TDG-8	102%		1,700
7/2/2008	TDG-8	105%		2,000 (HBV)
3/16/2012	TDG-8	106%		1,583
3/30/2012	TDG-8	106%		1,560
3/31/2012	TDG-8	105%		1,587
10/29/2012	TDG-8	103%		100
11/20/2012	TDG-8	104%		510 (HBV)
12/2/2013	TDG-8	106%		1,700
11/18/2015	TDG-8	102%		620 (HBV)
12/9/2015	TDG-8	104%		1,515
11/14/2006	TDG-9	100%		1,714
2/16/2007	TDG-9	103%		1,699
12/3/2007	TDG-9	104%		1,700

Table A-1. Total Dissolved Gases (TDG) Data Associated with Bull Run Dam 2

Date	Monitoring Site	Percent Saturation	Spillway Flow^a (cfs)	Powerhouse or HBV^b Flow (cfs)
3/16/2012	TDG-9	106%		1,583
3/30/2012	TDG-9	105%		1,560
3/31/2012	TDG-9	104%		1,587
10/29/2012	TDG-9	103%		100
11/20/2012	TDG-9	104%		510 (HBV)
12/2/2013	TDG-9	107%		1,700
11/18/2015	TDG-9	102%		620 (HBV)
12/9/2015	TDG-9	104%		1,525

^aBlank space indicates that spillway flows are not applicable to this monitoring site.

^bHBV: Howell Bunger valve. If flow refers to HBV flow, then datum is labeled with (HBV).

Table A-2. Total Dissolved Gases (TDG) Data Associated with Bull Run Dam 1

Date	Monitoring Site	Percent Saturation	Spillway Flow (cfs)	Powerhouse Flow (cfs)
1/18/2005	TDG-10	104%	2,000	2,000
12/28/2005	TDG-10	108%	2,340	2,250
1/10/2006	TDG-10	109%	4,801	2,250
11/7/2006	TDG-10	109%	9,851	2,200
2/16/2007	TDG-10	107%	2,042	2,200
12/3/2007	TDG-10	107%	2,834	2,200
11/13/2008	TDG-10	108%	4,111	2,560
3/16/2012	TDG-10	108%	1,059	2,562
12/2/2013	TDG-10	105%	2,909	2,200
11/18/2015	TDG-10	107%	4,178	0
11/7/2006	TDG-11	104%	10,158	2,200
11/14/2006	TDG-11	99%	278	2,200
2/16/2007	TDG-11	112%	2,177	2,200
12/3/2007	TDG-11	112%	2,804	2,200
11/13/2008	TDG-11	108%	4,300	2,560
12/2/2013	TDG-11	110%	2,769	2,200
11/18/2015	TDG-11	104%	4,178	0

Table A-2. Total Dissolved Gases (TDG) Data Associated with Bull Run Dam 1

Date	Monitoring Site	Percent Saturation	Spillway Flow (cfs)	Powerhouse Flow (cfs)
1/4/2005	TDG-12	103%	0	1,385
12/28/2005	TDG-12	108%	2,145	2,250
11/7/2006	TDG-12	109%	9,667	2,200
11/14/2006	TDG-12	105%	278	2,200
2/16/2007	TDG-12	108%	2,062	2,200
12/3/2007	TDG-12	107%	2,822	2,200
11/13/2008	TDG-12	108%	4,286	2,560
3/16/2012	TDG-12	107%	1,059	2,562
12/2/2013	TDG-12	105%	3,004	2,200

Appendix E

Bull Run HCP Research Report

**Lower Bull Run River Adult
Chinook Population**

April 2018

Burke Strobel

City of Portland Water Bureau



Contents

1. Summary	1
2. Introduction.....	1
3. Research Objectives.....	3
4. Key Questions and Hypotheses	3
5. Methods.....	5
5.1 Spatial Scale.....	5
5.2 Replication/Duration.....	6
5.3 Parameters.....	6
5.4 Sampling.....	7
6. Analysis	9
7. Results and Discussion	10
7.1 Surveys	10
7.2 Live Adults.....	10
7.2.1 Peak Counts and Minimum Escapement Estimates	10
7.2.2 Timing.....	14
7.3 Redds.....	15
7.3.1 Cumulative Count	15
7.3.2 Timing.....	15
7.4 Carcasses.....	16
7.4.1 Hatchery Fish.....	16
7.4.2 Sex Ratio.....	17
7.4.3 Prespawning Mortality.....	18
8. Findings and Conclusions	20
9. Works Cited.....	21

Tables

Table 1. Summary Statistics for Chinook Spawning Runs in the Lower Bull Run River, 2007–2017 ^a	11
Table 2. Timing of Adult Chinook Peak Counts, Highest Minimum Escapement Estimate, and Peak Redd Count, 2007–2017	14
Table 3. Peak 7DADM and Corresponding Observed Prespawning Mortality, 2006–2017	19

Figures

Figure 1. Surveyors Walk Both River Banks Looking for Live Fish, Redds, and Carcasses such as this Female Chinook Salmon.....	8
Figure 2. Bull Run River Discharge Above and Below the Little Sandy Confluence and Dates of Chinook Spawning Surveys in 2017.	10
Figure 3. Chinook Salmon Peak Counts for All Years when Surveys Were Conducted....	12
Figure 4. Relationship of Peak Counts of Adult Chinook in the Lower Bull Run River with Estimated Run Size of Spring Chinook in the Upper Sandy River Basin, Before and After the Removal of Marmot Dam	13
Figure 5. Environmental Variables ^a that May Be Useful in Explaining Chinook Salmon Run Timing in the Lower Bull Run River in 2017.....	15
Figure 6. Comparison of the Timing of the Presence of Adult Chinook Salmon and the Construction of Redds in 2017	16
Figure 7. Estimated Percent Hatchery Spring Chinook Adults Spawning in the Bull Run River Over Time, based on Carcass Recoveries. The Number of Carcasses Incorporated into Each Estimate is Given Above the Respective Column.....	17
Figure 8. Relationship between Peak Seven-Day Average Daily Maximum Stream Temperature (7DADM) and Prespawning Mortality in the Lower Bull Run River, 2006–2017.	19

1. Summary

The City of Portland Water Bureau (PWB) was in full compliance with its Bull Run Water Supply Habitat Conservation Plan (HCP; Portland Water Bureau 2008) obligations in 2017 regarding lower Bull Run River adult Chinook salmon population research. A snorkel survey of holding adult Chinook salmon was conducted in mid-July, and weekly walking surveys of spawning and holding Chinook salmon (spawning surveys) were conducted from the end of September through early December. The snorkeled portion of the lower Bull Run River includes the lower river from its mouth to Larson's Falls (river mile [RM] 3.7). The portion of the river surveyed while walking includes the entire lower river from its mouth to the base of the Bull Run diversion dam at Headworks (river mile [RM] 6.0). In 2017, spawning surveys could not be conducted on seven occasions because of fire restrictions or high flows. The peak adult Chinook count, minimum escapement¹, and cumulative redd count in 2017 were in the middle of the range of what has been observed in past years. This year's seven missed surveys may have also contributed to a lower minimum escapement estimate and cumulative redd count.

The snorkel survey conducted in July followed protocols modified from the survey protocol described in the HCP. This additional survey was necessary to evaluate efforts by the Oregon Department of Fish and Wildlife (ODFW) to use an adult fish weir and trap near the mouth of the river to prevent adult hatchery Chinook from entering the lower Bull Run River. The modified survey protocols included snorkeling large portions of the river to better count adults holding in deep pools and to attempt to determine whether live fish had clipped or intact adipose fins. A large number of adult hatchery Chinook were observed during the snorkel survey, probably indicating that hatchery adult Chinook were able to enter the lower Bull Run River before the ODFW weir was installed in June. A second snorkel survey could not be conducted to confirm if fish were able to pass the weir over the course of the summer. Large numbers of sexually mature two-year-old Chinook, called "mini-jacks," which had been observed in the Bull Run River in 2015 and 2016, were not observed in 2017.

2. Introduction

This section describes the results of surveys of spawning Chinook salmon adults and redds in the lower Bull Run River. Both spring and fall runs of Chinook salmon spawn in the lower Bull Run River.

Various agencies have conducted surveys of Chinook adults and redds in the Sandy River Basin since the 1980s. ODFW has conducted surveys of spring Chinook adults and redds

¹ Escapement is the number of fish that avoid or escape all harvest and return to spawn in their home streams.

in the Sandy River Basin by boat and on foot from 1996 to the present, and surveys on foot of fall Chinook adults and redds in index reaches in the lower Sandy River Basin from 1984 to the present. These surveys, however, have not included the lower Bull Run River. ODFW conducted weekly surveys of spawning spring and fall Chinook salmon and redds in the lower Bull Run River (RM 0–RM 5.8) in 1997. PWB continued weekly surveys from RM 1.5 to RM 5.8 in 1998 and 1999. An index reach of the lower Bull Run River (RM 1.5–RM 3.7) was surveyed by PWB in 2005 and 2006. This index reach was expanded to include RM 0–RM 3.7 for surveys conducted from 2007 to 2009 and further expanded to include RM 0–RM 6.0 for all subsequent survey years.

For HCP Years 1–20 (2010–2029), PWB will annually count spawning Chinook salmon and redds in the lower Bull Run River. The lower Bull Run River Chinook population research is designed to provide biologists with meaningful data within a 20-year time frame to evaluate the long-term trend in adult Chinook abundance for the Bull Run. The Bull Run data could then be used with information gathered by other agencies to determine the status of federally listed Sandy River Chinook populations.

In addition to meeting its HCP obligations, PWB added a new monitoring consideration in 2013, which it retained in 2017. This new consideration assesses the effects of an ODFW program, begun in 2011, to acclimate and release hatchery Chinook smolts in the lower Bull Run River. Adult Chinook belonging to those acclimated cohorts began returning to the Bull Run River in 2013. PWB was concerned that many adult hatchery Chinook might begin returning to the Bull Run River. The percentage of hatchery spring Chinook adults on the spawning grounds in the upper Sandy Basin is considered to be acceptable if it is below 10 percent (ODFW 2011). A large return of hatchery fish could quickly exceed that threshold in the Bull Run River, undermining the City’s restoration efforts. ODFW began installing a river channel-spanning weir near the mouth of the Bull Run River in 2013 to remove hatchery Chinook adults while allowing wild Chinook adults to enter the river. The weir was also installed in early June 2017. Spawning survey protocols were adjusted in 2017 to evaluate ODFW’s efforts to prevent adult hatchery Chinook from entering the Bull Run River.

PWB also assessed prespawning mortality of spring Chinook salmon in 2017. Hot, dry weather conditions such as those experienced in the Bull Run Watershed in recent years can heat streams. Warm stream temperatures can result in an increase in mortality among adult salmon before they have had the chance to spawn. PWB wishes to determine whether prespawning mortality in the Bull Run River is related to stream temperatures.

3. Research Objectives

In 2017 and continuing through HCP Year 20, PWB will conduct annual counts of spawning Chinook salmon and redds in the lower Bull Run River from RM 0–RM 6.0.

The objectives of the lower Bull Run River Chinook population research are to

- document use of the lower Bull Run River by spring and fall Chinook salmon.
- contribute to ODFW’s annual assessment of spring Chinook in the Sandy River Basin.

4. Key Questions and Hypotheses

The key questions to be answered by the research are the following:

- How many Chinook salmon adults enter the Bull Run River to spawn each year? This key question does not have an associated null hypothesis (H_0).
- How many Chinook salmon redds are built in the Bull Run River each year? This key question has been added since PWB’s adoption of the HCP and does not have an associated null hypothesis.
- What is the long-term trend (20 years) in spawning Chinook salmon abundance?
 H_0 : The abundance of spawning Chinook salmon will not change significantly over the long term (20 years, $\alpha=0.05$, $\beta=0.20$).
- What is the timing (range of dates and peak date) of adult Chinook presence and redd creation in the lower Bull Run River? This key question does not have an associated null hypothesis.
- What percentage of the spawning Chinook salmon are of hatchery origin?² This key question does not have an associated null hypothesis.

Three additional key questions—to be answered by the lower Bull Run River adult Chinook population research—were pursued in 2017:

- What percentage of spring Chinook salmon holding in the Bull Run River while the ODFW weir is in operation are of hatchery origin? This key question does not have an associated null hypothesis.[it is “otolith”

² The protocols followed by PWB provide the proportion of carcasses found with clipped adipose fins. The proportion of unclipped carcasses that are of hatchery origin will be provided by ODFW analysis of otoliths. Otoliths are tiny bones that form a portion of a fish’s inner ear. A fish lays down new bone material on the otolith’s edge as it grows, forming bands that record the fish’s growth rate over time. ODFW thermally “marks” otoliths in hatchery Chinook by exposing juvenile fish to varying water temperatures. Because fish growth increases in warm water and decreases in cold water, characteristic banding patterns are created, which provide an indication of fish origin (Schroeder et al. 2005).

- What percentage of spawning spring Chinook salmon are of hatchery origin? Spring Chinook represent only a portion of the Chinook adults observed in the lower Bull Run River and are expected to have a different hatchery proportion than the aggregate population of both spring Chinook and fall Chinook. This key question does not have an associated null hypothesis.
- What was the rate of prespawning mortality in 2017 for spring Chinook salmon, and is there a relationship between the yearly maximum 7-day average of daily maximum stream temperature in the Bull Run River and observed prespawning mortality? This key question does not have an associated null hypothesis.

In past annual compliance reports, there was an additional key question that was not investigated in 2017. In past years the following key question was addressed:

Does the number of adipose-clipped spring Chinook in the Bull Run River increase while the ODFW weir is in operation?

PWB's survey efforts cannot address this question so it was deleted from this report.

The City also collects otolith,² tissue, and scale samples from adult carcasses found in the lower Bull Run River. The City sends the samples to ODFW to assist in ODFW's assessment of spring Chinook in the Sandy River Basin. In return, PWB will receive information from ODFW at a future date about the proportion of unclipped Chinook salmon that are of hatchery origin, the relative number of spring and fall Chinook salmon in the lower Bull Run River, and the proportion of Chinook adults showing aspects of various life history types.³ The compilation of this information, however, depends on analyses conducted by ODFW and is therefore not reflected in the key questions.

The City conducts surveys throughout the spawning season for both spring Chinook and fall Chinook, but several of the statistics associated with the key questions and hypotheses apply primarily to spring Chinook. The spring Chinook run in the Bull Run River generally tapers off by the end of October, at about the time the fall Chinook run is beginning. There is undoubtedly overlap between the two runs, although the degree of overlap has not been quantified. ODFW uses October 31 as a cutoff date to distinguish between the two runs in the Bull Run River. The dates for peak counts consistently occur before October 31 and, for this reason, reflect the spring Chinook run. Other statistics, such as cumulative redd count and percentage of hatchery fish, are influenced to varying degrees by the inclusion of fall Chinook.

³ A Chinook salmon's life history type is defined by when, where, and how it lives over the course of its lifetime. This includes the number of years that it spent in freshwater and in saltwater before returning to freshwater to spawn.

5. Methods

The study design for the lower Bull Run River Chinook population research uses weekly surveys to count live Chinook adults, Chinook salmon carcasses, and newly created redds. The surveys are coordinated with operators at the City's Headworks facility and the Portland General Electric (PGE) powerhouses at Bull Run Dam 1 and Dam 2. During surveys, operators maintain flows of 100 cubic feet per second (cfs) or less above the Little Sandy confluence as often as possible. This is the level of flow necessary for safety and for accurate counts. No surveys are conducted if flows of 300 cfs or less cannot be maintained. The HCP allows for departures from minimum flow criteria in the lower Bull Run River (Measures F-1 and F-2) to make Chinook spawning surveys possible.

5.1 Spatial Scale

The lower Bull Run River was divided into the following reaches to provide greater spatial resolution of counts than a simple count of the entire river would provide and to reflect the reaches used in previous surveys for comparison:

Reach 1: The confluence of the Bull Run River with the Sandy River to the upstream end of the large pool adjacent to the Bull Run PGE Powerhouse (RM 0–RM 1.5)

Reach 2: The upstream end of the large pool adjacent to the Bull Run PGE Powerhouse to Bowman's Bridge (RM 1.5–RM 2.3)

Reach 3: Bowman's Bridge to the upstream end of the pool at the confluence with the Little Sandy River (RM 2.3–RM 2.8)

Reach 4: The upstream end of the Little Sandy River confluence pool to the upstream end of the pool at Larson's Bridge (RM 2.8–RM 3.7)

Reach 5: The upstream end of the pool at Larson's Bridge to the Road 14 bridge (RM 3.7–RM 4.8)

Reach 6: The Road 14 bridge to the Headworks diversion dam (RM 4.8—RM 6.0)

These reaches correspond to those used for the HCP Chinook spawning gravel research (see Appendix C, Lower Bull Run River Spawning Gravel Research), with the exception that spawning gravel research is not conducted between RM 5.8 and RM 6.0. Reaches 2, 3, and 4 are also the reaches used in previous Chinook spawning surveys conducted by ODFW and PWB. Reach 4 also corresponds to one of ODFW's probabilistic, randomly selected reaches for the Sandy River Basin steelhead and coho spawning surveys and snorkel surveys. Reaches 5 and 6 were not believed to be used by spawning Chinook salmon prior to 2011. These reaches were surveyed twice in 2010 to confirm whether they were being used; one spawning coho salmon was observed. Based on this result, starting in 2011, Reaches 5 and 6 were surveyed every week after October 1. They were

not surveyed earlier in the year because low summer flows make it very unlikely that salmon would be able to pass Larson's Falls at RM 3.7.⁴

Adult and redd abundance and timing information is summarized at the reach scale. The percentage of hatchery fish is summarized at the scale of the entire lower Bull Run River.

5.2 Replication/Duration

The City is committed to funding the Chinook population research in the lower Bull Run River for the first 20 years of the HCP. Annual surveys of spawning Chinook salmon and redds are conducted.

Weekly surveys in 2017 were conducted from mid-August through mid-December. Three weeks were missed because of fire restrictions and four weeks were missed because of high flows. One additional snorkel survey was conducted in July. There was no spatial replication because the entire channel was surveyed.

5.3 Parameters

The following information and samples were collected during each survey.

- Live Adults
 - Number of adults and number of jacks
 - Species
 - Reach
 - Additional behavioral information (e.g., spawning, defending a redd)
- Carcasses
 - Species
 - Reach
 - Length (both total length from the snout-tip to the fork of the tail and the middle-of-eye-to-posterior-scale (MEPS) length, in centimeters)
 - Sex
 - ◆ If a female, whether it died before spawning
 - Presence of adipose fin
 - ◆ If no adipose fin, whether it has coded-wire tags (CWT). If CWT were present, researchers collected the snout

⁴ Flows generally begin increasing with the autumn rains in October, making it possible, though difficult, for salmon to pass Larson's Falls.

- ◆ If an adipose fin was present, researchers collected
 - an otolith sample (for ODFW determination of hatchery origin)
 - a tissue sample (for National Marine Fisheries Service distinction of spring from fall Chinook)
 - a scale sample (for ODFW determination of age and life history)
- Additional information (e.g., whether the individual appeared to be eaten by scavengers or was found in the riparian zone)
- Redds
 - Reach
 - Species (researchers assumed the individual was Chinook unless another species was seen creating or defending it)
 - Size (length x width, in square feet)
 - Substrate size range (visual estimate of the range from approximately the 10th to the 90th percentile of substrate sizes, in inches)⁵
 - Channel feature retaining the gravel patch (e.g., whether the redd is behind a boulder or bedrock, a pool-tail or riffle margin)
 - Evidence of superimposition over a previous redd
- Environmental data
 - Weather (description)
 - Water clarity/visibility
 - Flow (determined from U.S. Geological Survey [USGS] Gage No. 14140000)

5.4 Sampling

Sampling methods have been altered slightly from those proposed in the HCP. The City intended to conduct spawning surveys by walking the river channel in flows of up to 150 cfs. This was regarded as the maximum flow that would still allow for safe navigation by surveyors on foot, wearing waders. Between flows of 150 and 500 cfs, PWB intended to survey while floating the river with kayaks. An initial trial run with kayaks conducted by PWB before 2010 at 400 cfs, however, convinced PWB that this method would not produce reliable data and was not a safe survey approach.

⁵ Substrate sizes are discussed in the HCP, Appendix F. The HCP is available at www.portlandonline.com/water/46157.

Instead, surveys were conducted by two observers walking downstream on each side of the channel (Figure 1). Between flows of 150 and 400 cfs (which included contributions from the Little Sandy River), surveyors wore dry suits and life vests. This enabled them to safely swim through otherwise impassable areas. If the combined flows of the Bull Run River and Little Sandy River could not be maintained below 400 cfs, surveys were cancelled.

Live adults and jacks were counted and their locations recorded. Any carcasses that were found with an intact tail were counted. All carcasses that could be retrieved were measured and their sex was recorded. Females were opened to check for eggs, which would determine whether they died before spawning. All carcasses were checked for the presence of an adipose fin. All carcasses with adipose fins found before October 31 (corresponding to an approximate date used by ODFW to distinguish between spring and fall Chinook—ODFW has an interest only in samples collected from the earlier, spring-run fish—were sampled for otoliths, tissue, and scales. After October 31, tissue samples were only collected from Chinook carcasses with adipose fins.

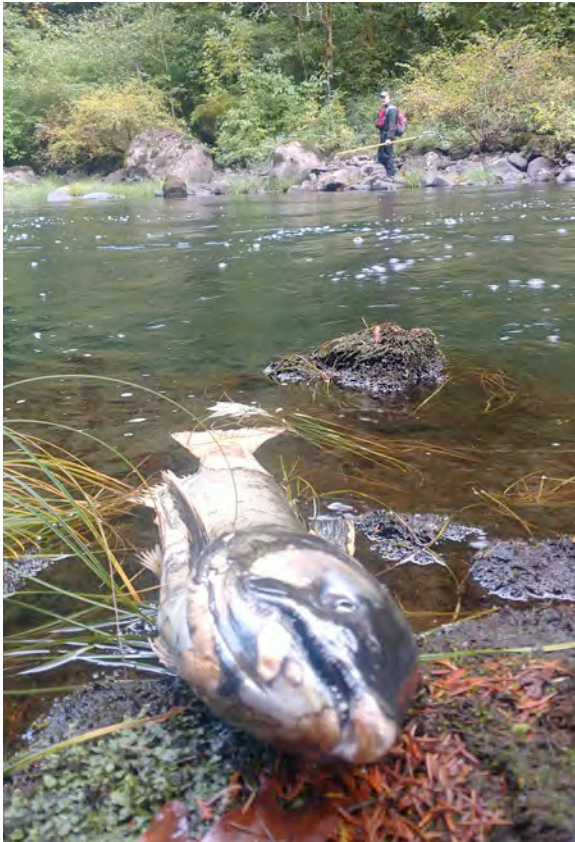


Figure 1. Surveyors Walk Both River Banks Looking for Live Fish, Redds, and Carcasses such as this Female Chinook Salmon.

ODFW also conducted several independent surveys of adults and carcasses on portions the lower Bull Run River in September and October of 2017. ODFW carcass counts and carcass data were added to PWB data for the nearest PWB survey date.

Redds were counted and their locations recorded. The approximate surface area of each redd and the size of its substrate were visually estimated. Once these and other data had been collected, each redd was marked with a flag with the date attached to the bank adjacent to the redd. The following week, if there were no signs of adult fish that could still be building the redd, a painted rock comparable in size to those comprising the redd was placed on the redd. The painted rock helped distinguish new redds from old ones. Painted rocks from previous surveys that had been dislodged or buried indicated that further spawning activity had occurred at that location. The

flag on the bank aided in confirming the presence of an old redd if the painted rock was missing. If live adults were still observed on or near a redd after two weeks, it was

assumed that a new redd was in the process of being built superimposed on the old redd. No rock was placed, but the bank was flagged. If no adults were observed the following week, a rock was placed at that time and a note of it was made.

One survey was conducted in 2017 following an adjusted protocol to provide data to ODFW personnel to evaluate ODFW's efforts to prevent adult hatchery Chinook from entering the lower Bull Run River. The purpose of the additional survey was to determine whether adult hatchery Chinook had entered the Bull Run River before ODFW installed its weir or despite the weir. Under the modified protocols, as much of the lower Bull Run River as possible (Reaches 1-4) was snorkeled. Snorkelers counted adult Chinook and identified whether each observed fish had a clipped or intact adipose fin or whether the adipose fin status could not be determined. Snorkelers did not look for redds in snorkeled portions of the river. Portions of the river that were too shallow to snorkel effectively were surveyed according to the regular protocols described above. This modified survey was conducted in mid-July.

6. Analysis

Data Storage: Monitoring data collected during the HCP Chinook Population Research were entered by PWB in a Microsoft® Excel spreadsheet and stored with spreadsheets containing data from previous years' surveys.

Hypothesis Testing: The number and timing of Chinook salmon in the lower Bull Run in a given year were compared to the number and timing of Chinook salmon in other years. Individual years were not compared statistically, however, because of the lack of replication.

The trend in peak spawner count (live + dead fish on a given date) and minimum escapement estimate (peak count of live fish on a given date plus cumulative carcass count up to and including that date) was calculated for all surveys to date using linear regression ($\alpha=0.05$).

The percentage of hatchery fish in the lower Bull Run in a given year was compared to the percentage of hatchery fish in other years. Individual years were not compared statistically, however, because of the lack of replication.

The percentage of hatchery fish in the spring Chinook population, as opposed to the percentage of hatchery fish in the aggregate population of spring and fall Chinook, was estimated by applying a cutoff date of November 2 for distinguishing between carcasses that were considered to be spring Chinook (carcasses of fish that could have spawned on or before October 31) or fall Chinook (carcasses of fish that probably spawned in November or later).

7. Results and Discussion

7.1 Surveys

Nine surveys were conducted in 2017 between July 18 and December 12; one followed modified protocols, which included snorkeling, and 8 followed standard protocols (Figure 2). Surveys were cancelled due to fire restrictions on three dates: September 5, 12, and 19, and due to high flows on four dates: October 24 and November 15, 21, and 29. No fish or redds were observed on December 12, so no further surveys were conducted.

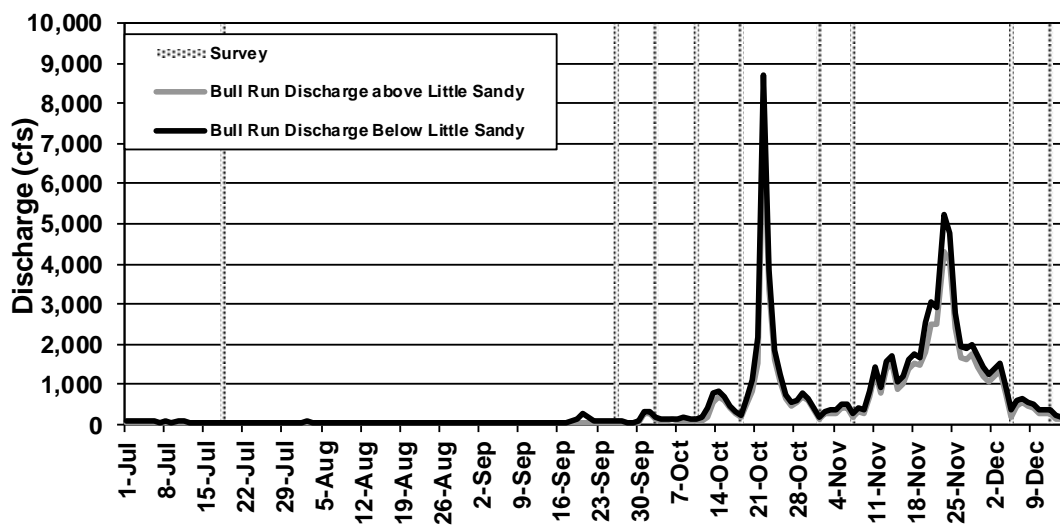


Figure 2. Bull Run River Discharge Above and Below the Little Sandy Confluence and Dates of Chinook Spawning Surveys in 2017.

7.2 Live Adults

7.2.1 Peak Counts and Minimum Escapement Estimates

The peak count and minimum escapement estimate for Chinook salmon in the lower Bull Run River in 2017 were relatively low compared to other years since the removal of Marmot Dam in 2007. A large number of hatchery adult Chinook (127) were observed, however, during a snorkel survey of the lower Bull Run River, conducted on July 18, 2017. These fish either entered the river before the weir was placed or passed the weir once it was in place. PWB suspects that these fish entered the upstream river reaches before the weir was constructed, but does not have empirical evidence to support that assumption. The fish were observed in pools between Bowman's Bridge and Larson's

Bridge (Reaches 3 and 4). The cumulative redd count, however, was in the middle of the range of previous years, as indicated in Table 1.

Table 1. Summary Statistics for Chinook Spawning Runs in the Lower Bull Run River, 2007–2017^a

Year	Peak Count	Minimum Escapement	Cumulative Redd Count	% Hatchery (n) ^b	% Female (n)
2017	24	42	59	77.4% (31)	71.4% (29)
2016 ^c	63	63	59	39.1% (23)	64.0% (25)
2015	37	76	85	27.0% (63)	47.5% (61)
2014	21	37	67	3.7% (27)	37.0% (27)
2013	54	69	124	16.3% (48)	64.6% (47)
2012	30	33	31	60.0% (5)	40.0% (5)
2011	84	99	94	43.1% (72)	54.7% (75)
2010	70	77	43	36.8% (19)	75.0% (16)
2009	61	70	89	11.8% (34)	52.9% (34)
2008	31	38	37	11.5% (26)	73.1% (26)
2007	34	39	62	41.7% (12)	76.9% (13)

^aIncludes peak count, minimum escapement estimate, percent of identifiable carcasses with clipped adipose fins (n=number of carcasses where the state of the adipose fin could be determined), and percent of identifiable carcasses that were female (n=number of carcasses where the sex could be determined).

^bFish with clipped adipose fins. A small portion of unclipped fish may also be of hatchery origin. Determined from carcass data only. On the day of the snorkel survey in 2017 (July 18), 127 live hatchery and 2 wild adult Chinook were observed in the Bull Run River. These fish are not included in the % Hatchery estimate because the survey protocols were not comparable to other dates and other years.

^cPeak Count and Minimum Escapement have been changed from those reported from 2016. The 2016 Compliance Report included the results from snorkel surveys when calculating Peak Count and Minimum Escapement. Snorkel surveys, however, follow different protocols that should not be combined with data collected during walking spawning surveys.

Peak adult counts continue to be lower, on average, than they had been prior to the Marmot Dam removal in 2007 (t-test_{one-tailed}, $p=0.0006$, $df=17$), but with a large amount of variation, as indicated in Figure 3. The average peak count prior to removal was 129 (± 133 95 percent confidence interval). In the years after decommissioning, the average has been 46 (± 89 percent confidence interval). There is no trend in the data observed between 2007 and 2017 ($p=0.60$).

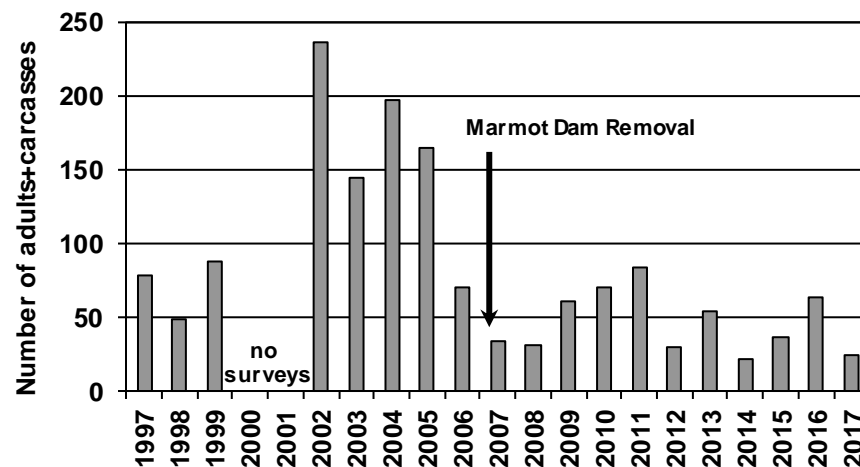


Figure 3. Chinook Salmon Peak Counts for All Years when Surveys Were Conducted

The peak count statistic generally reflects the status of spring Chinook, whereas minimum escapement, cumulative redd count, percent hatchery, and percent female reflect the combined total for spring Chinook and fall Chinook. Dates for peak counts consistently occur in October, at the height of spring Chinook spawning activity and before fall Chinook are believed to be present in the river in significant numbers. For this reason, this statistic can be legitimately compared across years, reflecting spring Chinook populations with little influence from fall Chinook. The minimum escapement estimate, cumulative redd count, and percent of hatchery fish and females, in contrast, can be heavily influenced by the inclusion of fall Chinook and, therefore, should be compared across years with caution. It is difficult to apply a cut-off date to distinguish between spring Chinook and fall Chinook redds and carcasses because of overlap in their run timing at the end of October and early November. In the future, genetic analysis may help to separate these combined statistics.

The relative size of the peak count of spring Chinook in the Bull Run River in 2017 does not necessarily reflect the relative size of the spring Chinook escapement to the Sandy River in general. Since the removal of Marmot dam there has been no correlation between the Bull Run River peak Chinook counts and the Sandy River Basin spring Chinook escapement estimates for the respective years. Prior to the removal of Marmot Dam, adult Chinook counts in the Bull Run River reflected trends in the greater Sandy River Basin.

Marmot Dam diverted Sandy River water to the adjacent Little Sandy River Basin, where it was further diverted by way of Roslyn Lake to the Bull Run River at RM 1.5. Following chemical cues in the water, a portion of adult Chinook salmon intent on returning to their natal streams in the upper Sandy River Basin apparently strayed into the Bull Run River by mistake. During these years, lower Bull Run adult Chinook peak

counts showed a significant positive correlation ($R^2=0.72$, $p=0.008$) with the estimated spring Chinook run size upstream of Marmot Dam (Sandy spring Chinook data 2007 and after from ODFW; Kirk Schroeder and Luke Whitman, pers. comm. Data prior to 2007 from PGE. See Figure 3). After Sandy River water was no longer diverted into the Bull Run River, adult Chinook peak counts declined dramatically and showed no significant correlation with Sandy River spring Chinook counts ($R^2=0.06$, $p=0.85$ for years 2007–2017; see Figures 3 and 4).

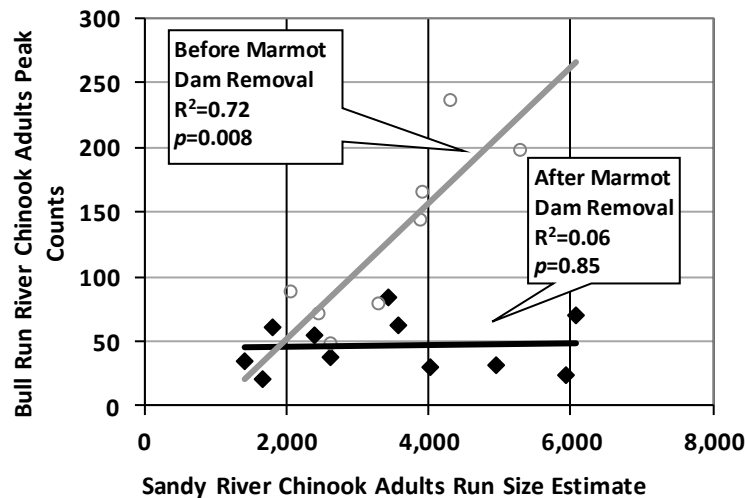


Figure 4. Relationship of Peak Counts of Adult Chinook in the Lower Bull Run River with Estimated Run Size of Spring Chinook in the Upper Sandy River Basin, Before and After the Removal of Marmot Dam

A large number of “mini-jacks” were observed in the Bull Run River in 2015 and 2016 but not in 2017. Jacks are sexually mature male salmon that return one to two years early to the river to spawn. Jacks, which are too small to compete directly with grown adult salmon for opportunities to spawn with adult females, nonetheless are able to contribute genetically to the following generation by “sneak-spawning,” and fertilizing a fraction of other salmon pairs’ eggs at the moment of spawning. Mini-jacks are fish that emigrate as smolts in the spring of a given year and return 4–5 months later as precocious adults.⁶ A number of mini-jacks were captured in the Bull Run River in 2015 and determined to be sexually mature. Mini-jacks are small enough to pass upstream through the ODFW weir and were thought to pose a hatchery introgression risk unmitigated by the weir. No mini-jacks were observed in 2017. The reason for the high incidence of mini-jacks in 2015 and 2016 is unknown but was thought to be related to high water temperatures in the Columbia River.

⁶ ODFW Biologist Todd Alsbury, pers. comm.

7.2.2 Timing

Adult Chinook salmon were observed during walking surveys in the Bull Run River until mid-November, but peaked in early October (Table 2). Two dates, October 3 and October 18, had the same peak redd count.

A large number of mostly hatchery Chinook entered the river early in the year (Figure 5). Only a portion of these fish were accounted for in later counts of live fish and carcasses.

Table 2. Timing of Adult Chinook Peak Counts, Highest Minimum Escapement Estimate, and Peak Redd Count, 2007–2017

Year	Peak Count	Minimum Escapement	Peak Redd Count
2017	Oct. 3	Nov. 1	Oct. 3 & 18
2016	Sep. 20	Sep. 20	Oct. 25
2015	Oct. 27	Nov. 12	Nov. 12
2014	Oct. 28	Oct. 28	Oct. 28
2013	Oct. 23	Nov. 14	Oct. 16
2012	Oct. 24	Oct. 24	Oct. 24
2011	Oct. 5	Nov. 10	Oct. 5
2010	Oct. 20	Oct. 20	Oct. 20
2009	Oct. 21	Oct. 21	Oct. 21
2008	Oct. 22	Oct. 29	Oct. 15 & 22
2007	Oct. 24	Oct. 24	Oct. 18

The effectiveness of the ODFW weir could not be evaluated over the course of the summer in 2017. Only one snorkel survey was conducted after installation of the weir because high fire danger restricted access to the river at the time a second survey was scheduled. Multiple snorkel surveys are necessary to discern if fish pass the weir or if they enter the river before weir installation.

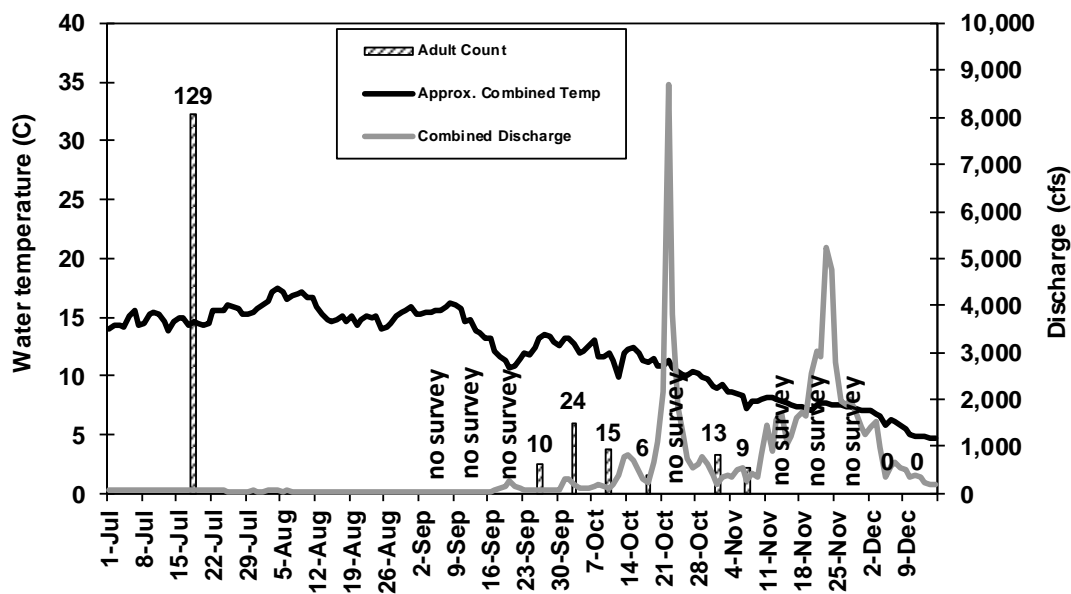


Figure 5. Environmental Variables^a that May Be Useful in Explaining Chinook Salmon Run Timing in the Lower Bull Run River in 2017

^aIncludes the estimated mean daily water temperature near the mouth and discharge near the mouth.

7.3 Redds

7.3.1 Cumulative Count

The cumulative Chinook salmon redd count in the lower Bull Run River was near the middle of the range of years since Marmot Dam was removed in 2007 (Table 1). The cumulative redd count is probably a better measure of spawning activity in the Bull Run River than either peak count or minimum escapement estimate because redds remain visible for weeks after spawning adult Chinook have died and can no longer be observed. Redds that cannot be seen under poor-visibility conditions can also be observed and added to the cumulative total at later dates. It is unclear why the unusually large number of hatchery adult Chinook observed holding in the lower Bull Run River in mid-July did not result in an unusually large number of redds, but many of the adult Chinook are believed to have moved into the Little Sandy and may have spawned there instead of in the Bull Run River.

7.3.2 Timing

Chinook salmon redds were observed in the Bull Run River between September 26 and November 7. The peak number of new redds (14) was observed on two dates, October 3 and October 18. Figure 6 summarizes the timing of redd construction and compares it to

the timing of adults observed in the lower Bull Run River. 5 also includes the cumulative redd count.

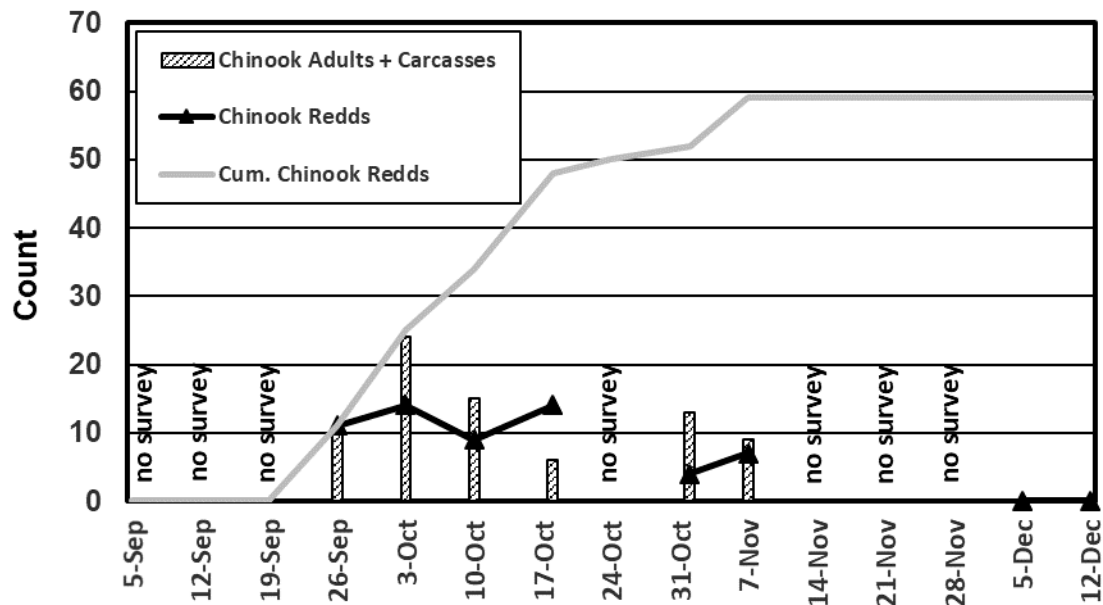


Figure 6. Comparison of the Timing of the Presence of Adult Chinook Salmon and the Construction of Redds in 2017

Redd counts on both September 26 and November 1 may represent the accumulation of more than one week of spawning effort. The September 19 survey and the October 24 survey were cancelled due to fire restrictions and high flows, respectively. The September 26 and November 1 redd counts, therefore, may have consisted of at least two weeks' worth of spawning activity. Some redds may also have been obscured by the movement of gravel by high flows, especially between the October 18 and November 1 surveys.

7.4 Carcasses

7.4.1 Hatchery Fish

The percentage of Chinook carcasses of both spring and fall runs, combined, in the lower Bull Run River that were of hatchery origin was relatively high in 2017 (77.4 percent) based on a sample size of 31 carcasses for which the status of the adipose fin could be determined. The actual percentage of hatchery fish may have been higher than 77.4 percent. During the July 18 snorkel survey, 129 live adult Chinook were observed. Of the individuals for which the status of the adipose fin could be determined, 98 percent were of hatchery origin. Additionally, some Chinook have inadequately clipped adipose fins or their fins grow back. For this reason, ODFW collects otolith samples from spring Chinook salmon carcasses with adipose fins. The percentage of unclipped fish that are of hatchery origin can be determined from the growth structure of these otoliths.

The percentage of unclipped Chinook salmon carcasses that were of hatchery origin in the Bull Run River was not available at the writing of this report.

In 2017, the percentage of hatchery spring Chinook appeared to be the highest it has ever been. The percentage of carcasses considered spring Chinook carcasses in 2017 that were of hatchery origin was 79.3 percent based on a sample size of 21 carcasses. The full Bull Run spawning survey record of percent hatchery fish is summarized in Figure 7.

Most of the large number of hatchery adult Chinook observed on July 18 are believed to have passed upstream of the ODFW weir before its installation on June 29, but PWB does not have empirical data to support that assumption.

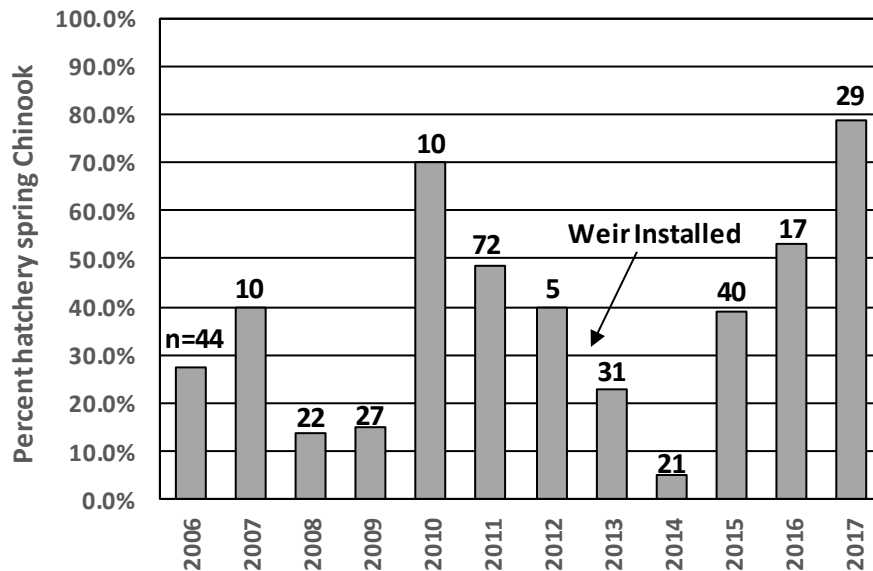


Figure 7. Estimated Percent Hatchery Spring Chinook Adults Spawning in the Bull Run River Over Time, based on Carcass Recoveries. The Number of Carcasses Incorporated into Each Estimate is Given Above the Respective Column.

7.4.2 Sex Ratio

Over two thirds of the Chinook carcasses recovered in 2017 were female. Of the 33 Chinook carcasses observed in the Bull Run River in 2017, 28 were intact enough to determine sex. Of these 28, 20 (71.4 percent) were female.

Females have tended to make up a larger percentage of carcasses recovered in the lower Bull Run River in the past. Their percentage has ranged between 52.9 percent and 76.9 percent in eight out of eleven survey years. The only years when males made up a larger percentage of recovered carcasses were 2015, 2014, and 2012. The reason for the asymmetries observed in the past is unknown. The asymmetries may reflect actual difference between the sexes or differences in the detectability of their carcasses. Females, for instance, appear to remain near their redds for longer periods of time than

males, and may die, on average, in shallower water where they are more readily found by surveyors. Actual differences in sex ratio can arise through differences between the sexes in marine survival, life history differences, or other factors such as gender reversal.

Significant differences in size, which can influence marine survival, were not observed between sexes in the Bull Run watershed in 2017 as they have been in previous years. Female Chinook carcasses had an average middle-of-eye-to-posterior-scale (MEPS) length of 65.8 cm, and male carcasses had an average MEPS length of 66.9 cm.

Life history differences can, in theory, lead to differences in sex ratio if, for example, a significant number of one gender return at a different age than the other. A portion of male Chinook salmon return to spawn after only one year in the ocean. These are called jacks. If a large number of males in a given cohort of Chinook return as jacks, returning adults the following year may show a reduced percentage of males. Large numbers of mini-jacks were observed in the Bull Run River in 2015 and 2016.

Gender reversal, generally male to female, can occur when developing embryos are exposed to high water temperatures or estrogen-imitating chemicals in the environment (Olsen et al. 2006). The possible role of either of these factors in influencing the Chinook salmon sex ratio in the Bull Run River cannot be evaluated with current data.

Given the small number of carcasses typically recovered in the Bull Run River, it is also possible that the biased sex ratios observed in the past few years in the Bull Run River are entirely due to chance.

7.4.3 Prespawning Mortality

No prespawning mortality of spring Chinook salmon was observed in the Bull Run River in 2017. There appears to be a relationship between water temperature and prespawning mortality of spring Chinook salmon in the Bull Run River, whereby prespawning mortality increases when the annual maximum seven-day average of daily maximum stream temperature is above 19.5 °C (Figure 8, Table 3). The annual seven-day average of daily maximum stream temperature is a commonly used statistic for characterizing stream temperatures in an ecologically relevant way. Whereas salmon can endure relatively high water temperatures for short periods of time, the seven-day average of daily maximum stream temperature is a measure of chronic environmental conditions that can affect growth and survival. The last year that a seven-day average of daily maximum stream temperature above 19.5 °C occurred in the lower Bull Run River was 2013. The last year that prespawning mortality was observed in the lower Bull Run River was 2012.

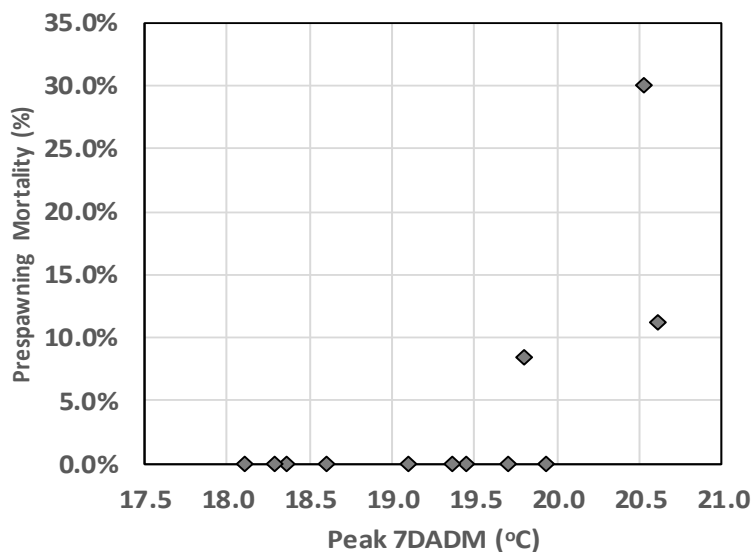


Figure 8. Relationship between Peak Seven-Day Average Daily Maximum Stream Temperature (7DADM) and Prespawning Mortality in the Lower Bull Run River, 2006–2017.

Table 3. Peak 7DADM and Corresponding Observed Prespawning Mortality, 2006–2017

Year	Peak 7DADM (Aug 15-Oct 31; °C)	Prespawning Mortality	Spring Chinook Minimum Escapement Estimate
2006	19.8	8.3%	82
2007	20.5	30.0%	39
2008	18.6	0.0%	38
2009	19.4	0.0%	70
2010	19.7	0.0%	77
2011	19.4	0.0%	85
2012	20.6	11.1%	33
2013	19.9	0.0%	64
2014	18.4	0.0%	37
2015	18.3	0.0%	66
2016	18.1	0.0%	63
2017	19.1	0.0%	42

8. Findings and Conclusions

The findings and conclusions directly address the key questions posed in Section 4.0:

- **How many Chinook salmon adults enter the Bull Run River to spawn each year?**

At least 129 adult Chinook salmon entered the Bull Run River upstream of the ODFW weir to spawn in 2017, based on a snorkel survey. The peak daily count of live adults plus carcasses during walking surveys was 42.

- **How many Chinook salmon redds are built in the Bull Run River each year?**

A total of 59 Chinook redds were identified in the Bull Run River in 2017.

- **What is the long-term trend (20 years) in spawning Chinook salmon abundance?**

The long-term (20-year) trend in spawning Chinook salmon abundance will be calculated in 2028. The number of spawning Chinook salmon in the lower Bull Run River shows no significant trend since the Marmot Dam removal in 2007.

- **What is the timing (range of dates and peak date) of adult Chinook presence and redd creation in the lower Bull Run River?**

Live adult Chinook salmon were observed in the Bull Run River between July 18 and November 7, 2017. The peak date was October 3, 2017. Chinook redds were observed between September 26 and November 7, 2017. The peak dates for redd observation were October 3 and 18.

- **What percentage of the spawning Chinook salmon are of hatchery origin (clipped adipose fin) and what percentage are female?**

In 2017, the percentage of hatchery (clipped adipose fin) fish among the observed Chinook salmon carcasses in which the condition of the adipose fin could be determined was 77.4 percent. The percentage of females among the observed Chinook salmon carcasses in which sex could be determined was 71.4 percent.

- **What percentage of spring Chinook salmon, holding in the Bull Run River while the ODFW weir is in operation, are of hatchery origin?**

A snorkel survey was conducted on July 18. Of the 129 adult Chinook observed while snorkeling, 127 (98.4 percent) were hatchery fish.

- **Is the ODFW weir effective at excluding hatchery spring Chinook from the Bull Run River?**

In 2017, at least 127 hatchery spring Chinook were able to enter the Bull Run River, presumably before the ODFW weir was installed. The ability of fish to pass the

installed weir could not be evaluated in 2017. Only one snorkel survey was conducted because of fire restrictions.

- **What percentage of the spawning spring Chinook salmon are of hatchery origin (clipped adipose fin)?**

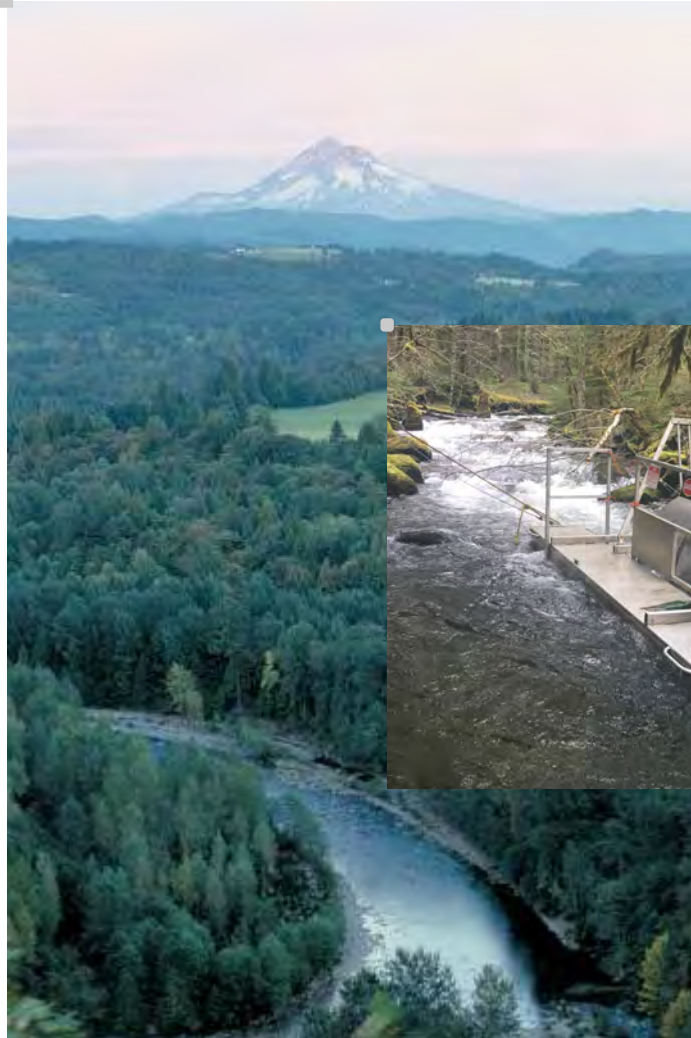
In 2017, the percent of hatchery (clipped adipose fin) fish among the observed Chinook salmon carcasses—for which the condition of the adipose fin could be determined and assuming that only carcasses observed on or before the first survey in November were spring Chinook—was 79.3 percent. This was the highest percentage ever observed in the lower Bull Run River.

- **Was prespawning mortality of spring Chinook salmon observed in 2017? What is the relationship between stream temperature and observed prespawning mortality in the lower Bull Run River?**

No prespawning mortality of spring Chinook salmon was observed in 2017. Prespawning mortality among female Chinook salmon appears to increase above approximately 19.5 °C. Water temperatures of this magnitude last occurred in the lower Bull Run in 2013, although no prespawning mortality was observed that year either.

9. Works Cited

- Olsen, Jeffrey B., Steve J. Miller, Ken Harper, Kevin Van Hatten, Kellie Whitton, James J. Nagler, and John K. Wenburg. "Sex Ratios of Juvenile and Adult Chinook Salmon in the Kuskokwim and Yukon Rivers." *U.S. Fish and Wildlife Service*, 2006.
- Oregon Department of Fish and Wildlife. "Final Hatchery and Genetic Management Plan: Spring Chinook." 2011.
- Portland Water Bureau. "Bull Run Water Supply Habitat Conservation Plan for the Issuance of a Permit to Allow Incidental Take of Threatened and Endangered Species." 2008.
- Schroeder, R. Kirk, Ken R. Kenaston, and Lisa K. Krentz. "Spring Chinook Salmon in the Willamette and Sandy Rivers." Oregon Department of Fish and Wildlife *Fish Research Report F-163-R-10* (2005).



Appendix F. Sandy River Basin Smolt Monitoring 2017

April 2018

Burke Strobel, Portland Water Bureau



Photo (left) of Mount Hood and Sandy River provided by Josh Kling/Western Rivers Conservancy

Photo (right) of the Lost Creek smolt trap provided by the U.S. Forest Service

Contents

1. Summary	1
2. Introduction	2
2.1 Background	2
2.2 Goal and Objectives	3
2.3 Sample Area and Scope	3
2.3.1 Study Area	3
2.3.2 Sample Area	4
3. Methods	6
3.1 Sampling	6
3.1.1 Sampling Schedule	6
3.1.2 Sampling in 2017	8
3.1.3 Data Collection	9
3.1.4 Mark-Recapture Study	10
3.2 Assumptions	11
3.3 Data Analysis	11
3.3.1 Smolt Population Estimation	11
3.3.2 Smolt Fork Lengths	13
3.3.3 Smolt Condition Factors	13
3.3.4 Emigration Dates	13
4. Results	14
4.1 Smolt Population Estimation	14
4.1.1 Trap Efficiencies	14
4.1.2 Subbasin Population Estimates	15
4.1.3 Sandy River Basin Index Area Population Estimates	19
4.1.4 Recolonization of the Little Sandy River	26
4.2 Fork Lengths	27

4.3	Condition Factors	31
4.4	Emigration Dates	32
4.5	Age Distribution	34
5.	Discussion	35
5.1	Smolt Population Estimation	35
5.2	Fork Lengths	37
5.3	Condition Factors	38
5.4	Emigration Dates	38
5.5	Age Distribution	38
6.	Findings, Conclusions, and Recommendations	39
7.	Acknowledgments	40
8.	Works Cited	40
Exhibit A.	All Species and Life Stages Captured at Smolt Traps in the Sandy River Basin in 2016.....	42

Tables

Table 1.	Streams sampled for salmon and steelhead smolts, with sampling category, range of elevations of anadromous reaches, and average gradient	6
Table 2.	Provisional schedule for sampling major tributaries in the Sandy River Basin.....	7
Table 3.	Dates of operation and the number of days traps did not operate in the Sandy River Basin in 2017	9
Table 4.	Trap efficiencies for each site, species, and two-week trap period in 2017	14
Table 5.	Steelhead and coho smolt population estimates and 95% confidence intervals for 2017.....	15
Table 6.	Steelhead and coho smolts per mile and smolts per 1,000 ft ² for 2017	16
Table 7.	Statistics for steelhead subbasin smolt trap population estimates compiled from the Sandy River Basin Index Area, 2009–2017	19
Table 8.	Statistics for coho subbasin smolt trap population estimates compiled from the Sandy River Basin Index Area, 2009–2017	20
Table 9.	Subbasin steelhead smolt population estimates and gap estimates since the inception of the Sandy River Basin Smolt Monitoring Plan	22

Table 10. Subbasin coho smolt population estimates and gap estimates since the inception of the Sandy River Basin Smolt Monitoring Plan	23
Table 11. Sandy River Basin Index Area steelhead and coho smolt population estimates and 95% confidence intervals	24
Table 12. Estimates of freshwater productivity for steelhead in the Sandy River Basin Index Area, 2010–2014.....	25
Table 13. Estimates of freshwater productivity for coho salmon in the Sandy River Basin Index Area, 2010–2015.....	26
Table 14. Steelhead weighted mean fork lengths, weighted standard deviation, and range of fork lengths of steelhead smolts captured in Sandy River Basin smolt traps in 2017	28
Table 15. Coho weighted mean fork lengths, weighted standard deviation, and range of fork lengths of coho smolts captured in Sandy River Basin smolt traps in 2017	30
Table 16. Steelhead smolt weighted mean date of emigration, associated standard deviation, weighted median date of emigration, estimated peak emigration date, and earliest and latest capture dates in Sandy River streams monitored in 2017	32
Table 17. Coho smolt weighted mean date of emigration, associated standard deviation, weighted median date of emigration, estimated peak emigration date, and earliest and latest capture dates in Sandy River streams monitored in 2017	33
Table 18. Steelhead smolt weighted mean age and age distribution for Sandy River streams, 2009–2016.....	34
Table 19. Coho smolt weighted mean age and age distribution for Sandy River streams, 2009–2016	35

Figures

Figure 1. The Gordon Creek smolt trap, with wooden pontoons and frame to deter metal theft	4
Figure 2. Sandy River Basin—Smolt trap sites, streams covered by rotating smolt trap study, and streams receiving glacial runoff.....	5
Figure 3. Adult Pacific Lamprey caught in the Beaver Creek trap.....	8
Figure 4. USFS personnel process fish	10
Figure 5. Steelhead and coho smolt population estimates over time for individual subbasins.....	17

Figure 6. Steelhead and coho smolt population estimates over time for individual subbasins with extended records	18
Figure 7. Average relative contributions of monitored streams to steelhead smolt production in the Sandy River Basin Index Area, 2009–2017	20
Figure 8. Average relative contributions of monitored streams to coho smolt production in the Sandy River Basin Index Area, 2009–2017.....	21
Figure 9. Sandy River Basin Index Area steelhead and coho smolt population estimates and 95% confidence intervals	24
Figure 10. Coho spawners compared to resulting coho smolts in the Sandy River Basin Index Area, spawner years 2007–2015	26
Figure 11. Recolonization of the Little Sandy River by steelhead, coho, and Chinook after the removal of the Little Sandy Dam.....	27
Figure 12. Steelhead smolt fork length frequency distributions for Sandy River Basin traps in 2017 ^a	28
Figure 13. Weighted mean fork lengths of age 2 steelhead smolts for all Sandy River Basin streams and years for which age distribution data and fork length data exist.....	29
Figure 14. Coho smolt fork length frequency distributions for Sandy River Basin traps in 2017.....	30
Figure 15. Steelhead smolt results of Tukey test multiple comparisons of condition factors for Sandy River streams monitored in 2016.....	31
Figure 16. Coho smolt results of Tukey test multiple comparisons of coho smolt condition factors for Sandy River streams monitored in 2017	31
Figure 17. Steelhead smolt cumulative percentage of total emigration from Sandy River streams monitored in 2017. Steepest portions of each curve indicate peak capture periods.....	33
Figure 18. Coho smolt cumulative percentage of total emigration from Sandy River streams monitored in 2017. Steepest portions of each curve indicate peak capture periods.	34

1. Summary

The Portland Water Bureau, the U.S. Forest Service, and the Oregon Department of Fish and Wildlife collaborated in 2017 to continue a long-term study monitoring steelhead and coho smolt production for the Sandy River Basin in Oregon. The study, initiated in 2009, is intended to detect declines or increases in abundance and productivity of smolts at the basin scale and to provide useful data at the tributary scale to guide restoration efforts. The sampling design involves monitoring different sets of tributaries every year. Some tributaries are monitored every year; others are monitored on an irregularly rotating basis. The study is intended to provide basin-scale trends after 20 years.

Smolt numbers, fork length, condition factors, and emigration timing were monitored using rotary smolt traps in nine streams: Lost Creek, Still Creek, Clear Creek, Salmon River, Cedar Creek, Little Sandy River, Bull Run River, Gordon Creek, and Beaver Creek. Population estimates, fork length distributions, and emigration statistics were calculated for steelhead and coho smolts in all nine streams, but condition factor analysis was not conducted on fish from Cedar Creek. The average age of smolts was calculated by aging fish using fish scale samples collected between 2009 and 2016.

Trapping efforts were hampered somewhat in 2017 by a release of hatchery Chinook smolts from an acclimation pond upstream of one trap and high-flow and low-flow periods in several other streams. Trapping challenges did not hinder the generation of population estimates at any site.

Preliminary Sandy River Basin-level population estimates were calculated for each year from 2009 to 2017. Freshwater productivity (smolts per adult) was also estimated, with the help of age data, for steelhead adult year classes 2010 to 2014 and for coho adult year classes 2007 to 2015.

Steelhead and coho smolts from different streams in the Sandy River Basin showed significant differences in weighted mean fork length of smolts. Low-elevation streams had longer smolts of a given age than high-elevation streams, in general.

Steelhead and coho smolts from different streams in the Sandy River Basin also showed significant differences in mean condition factors. Condition factors correlated negatively with fork length for both species, but not to a statistically significant degree.

Steelhead smolts emigrated earlier than coho smolts, on average, in all streams. Coho smolts emigrated from low-elevation streams earlier than from high-elevation streams.

High-elevation streams had a larger proportion of older age steelhead and coho smolts than low-elevation streams. Length-at-age calculations revealed that steelhead smolt fork lengths are shorter on average for a given age in higher-elevation streams than in lower elevation streams, as is seen in coho, but this fact is masked by their older average age.

2. Introduction

2.1 Background

In 2017, the Portland Water Bureau (PWB), the Mt. Hood National Forest (U.S. Forest Service [USFS]), and the Oregon Department of Fish and Wildlife (ODFW) continued collaboration on a long-term study, monitoring steelhead and coho smolt production throughout the Sandy River Basin in Oregon. The Sandy River enters the lower Columbia River just east of Portland, Oregon, and includes several large tributaries—the Bull Run, Salmon, and Zigzag rivers—as well as many smaller tributaries such as Beaver, Cedar, Clear, Gordon, and Lost creeks, and the Clear Fork Sandy River.

Smolt monitoring has been conducted in various Sandy River tributaries in the past. The USFS has monitored smolt production continuously in Still Creek, a tributary of the Zigzag River, since 1989 and sporadically in the Clear Fork Sandy River (Figure 1), Lost Creek, and the Salmon River. The purpose of these efforts originally included monitoring the benefits of stream restoration projects and, more recently, supporting efforts to evaluate the effects of the removal of Marmot Dam in 2007. The USFS also operated a smolt trap on the Little Sandy River in 2007 and 2008, upstream of a diversion dam operated as part of Portland General Electric’s Bull Run Hydroelectric Project. The Portland Water Bureau has operated a smolt trap in the Bull Run River near its mouth since 2008 and assumed the management of the Little Sandy River trap in 2009. Two related factors led to an expansion of salmonid smolt monitoring in the Sandy River Basin, beginning in 2009. The first was the formation of the Sandy River Basin Partners in 1999—a group intended to coordinate the fish and fish habitat management efforts of various agencies and groups. This coordination led to a broadening of the monitoring focus to better correspond with an emerging holistic approach to watershed restoration and to mesh with other programs that collect biological information at a basin scale. The second factor was that PWB created the Bull Run Water Supply Habitat Conservation Plan (HCP; Portland Water Bureau 2008) in 2008 to bring its municipal water supply operations in the Bull Run River into compliance with the Endangered Species Act and the Clean Water Act.¹ Among the many measures detailed in the HCP is a commitment to contribute resources toward smolt monitoring in the Sandy River Basin.

Monitoring smolt production can benefit a number of management efforts on many spatial scales, including viability analyses and adaptive restoration. Given limited resources, however, managers face potential tradeoffs between collecting smolt information that is meaningful at the population scale (that is, enumerating smolts at the mouths of large rivers) and collecting smolt information at a scale that is most meaningful to individual restoration efforts (that is, enumerating smolts in tributaries). The sampling plan adopted by the monitoring subgroup of the Sandy River Basin

¹ To learn more about the HCP, visit <http://www.portlandoregon.gov/water/55040>.

Partners is intended to provide information at both scales in order to maximize the usefulness of the data-collection effort. The sampling plan is summarized in the HCP Appendix F (Portland Water Bureau 2008).

2.2 Goal and Objectives

The goal of the Sandy River smolt monitoring project is to contribute to the viability assessment of salmonid stocks in the Sandy River Basin and support their adaptive management. The objectives of the Sandy River Smolt Monitoring project are to

- collect information to assess the long-term (20-year) trend in steelhead and coho smolt populations for as much of the Sandy River Basin as possible (population scale),
- collect information to assess the long-term (20-year) trend in steelhead and coho smolt populations at the scale of individual tributaries (tributary scale),
- evaluate steelhead and coho smolt production of individual tributaries relative to one another (tributary scale),
- evaluate steelhead and coho smolt physical quality from individual tributaries relative to one another (tributary scale), and
- determine the values of various life-history characteristics at the scale of individual tributaries in the Sandy River Basin (tributary scale).

The proximate objectives each year will be to determine the values for the following variables for each stream that is trapped:

- Smolt population (for every salmonid species possible)
- Mean fork length (by species)
- Mean condition factor ($((\text{weight}/(\text{fork length}^3)) \times 100,000)$)
- Mean date of emigration (by species)

Beginning in 2014, a collaboration between PWB and ODFW provided age information from scale samples collected by PWB and USFS between 2009 and 2016. This information allowed the pursuit of an additional life-history objective:

- Determine the mean age at emigration for steelhead and coho smolts

2.3 Sample Area and Scope

2.3.1 Study Area

The portions of the Sandy River Basin that are accessible to anadromous fish include approximately 190 miles of streams and rivers spanning a wide range of environments from cold, high-elevation, high-gradient streams in wilderness areas to warm, low-

gradient, and tidally influenced streams within the Portland urban growth boundary, as indicated in Figure 2. About 30 percent of these stream miles are influenced by glacial runoff, often with high turbidity (Portland Water Bureau 2008).

2.3.2 Sample Area

Not all of the Sandy River Basin that is accessible to anadromous fish is included in the sample area. Streams selected for smolt sampling total 106 miles, or 56 percent of the total habitat in the Sandy River accessible to anadromous fish. Over 80 percent of the clear water stream miles are included. Clear water streams are streams not influenced by glacial runoff. These are the streams expected to contribute most to total smolt production, due to the suitability of spawning habitat (Suring et al. 2006) and relatively greater primary productivity and ease of locating prey. The remaining clear water streams are generally small, have relatively high gradients, and are not expected to produce a large number of salmon or steelhead smolts. This sample area covers nearly the full range of environmental conditions that salmon and steelhead encounter in the Sandy River Basin and is considered by the Sandy River Basin Partners monitoring group to constitute a representative index for the entire basin for steelhead and coho. It also closely corresponds with the area for which steelhead and coho spawner counts are developed annually by the Oregon Department of Fish and Wildlife (ODFW; Suring et al. 2006, Hutchinson et al. 2007). The sample area covered by the Sandy River Basin



Figure 1. The Gordon Creek smolt trap, with wooden pontoons and frame to deter metal theft

Smolt Monitoring effort is henceforth referred to as the Sandy River Basin Index Area. The products of this effort will eventually be applicable to the entire index area. Information that is collected will be immediately applicable at the scale of individual tributaries.

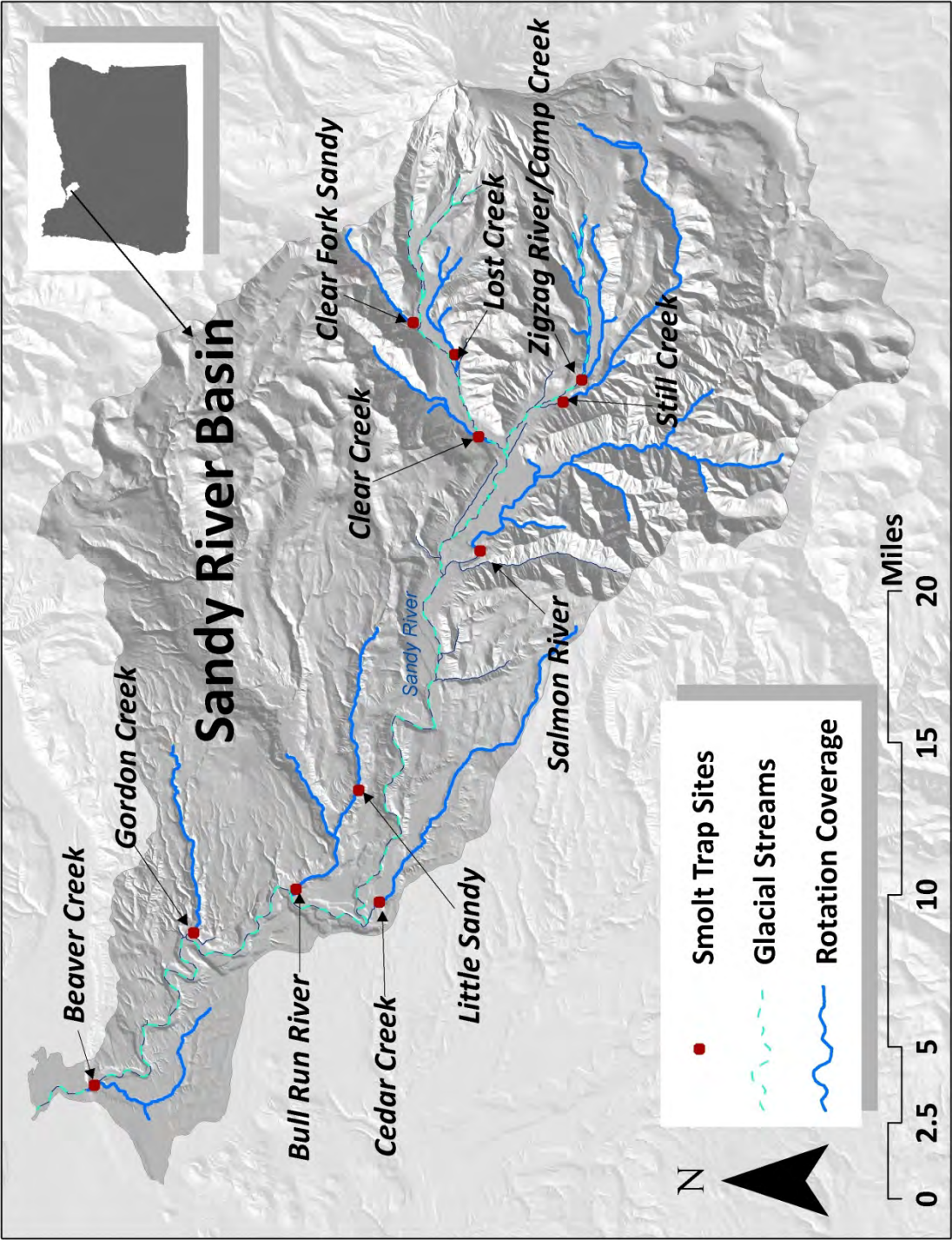


Figure 2. Sandy River Basin—Smolt trap sites, streams covered by rotating smolt trap study, and streams receiving glacial runoff

3. Methods

3.1 Sampling

Juvenile outmigrant (JOM) sampling in the Sandy River Basin is implemented following a carefully coordinated, long-term sampling schedule, using methods that are consistent across geography and time.

3.1.1 Sampling Schedule

Eleven streams were identified by the monitoring subgroup as being feasible and appropriate for operating a smolt trap. These streams are summarized in Table 1.

Table 1. Streams sampled for salmon and steelhead smolts, with sampling category, range of elevations of anadromous reaches, and average gradient

Stream	Miles Used by Anadromous Fish	Sampling Category ^a	Anadromous Elevation Range (feet above mean sea level)	Average Gradient
Bull Run River (without the Little Sandy River)	7.5	Fixed	240–700	1.3%
Little Sandy River	5.9	Fixed	430–1,600	2.9%
Cedar Creek	13.2	Fixed	360–3,240	4.1%
Clear Fork Sandy River	4.3	Rotation	2,130–3,390	5.4%
Lost Creek	4.9	Rotation	1,770–2,660	3.7%
Clear Creek	5.5	Rotation	1,440–2,780	4.6%
Still Creek	8.7	Rotation	1,580–3,120	3.1%
Zigzag River/ Camp Creek	16.4	Rotation	1,840–3,360	4.1%
Salmon River	24.0	Rotation	1,010–1,850	1.2%
Gordon Creek	7.4	Rotation	100–1,630	4.0%
Beaver Creek	7.7	Rotation	20–550	1.3%

^aSampling category: Fixed=sampled annually, Rotation=sampled according to rotating schedule

It is anticipated that at least seven smolt traps will be operated each year. The provisional sampling schedule is summarized in Table 2. Three trap locations are fixed and operated every year, because of additional monitoring needs. The Bull Run River and Little Sandy River are monitored annually to meet specific commitments in the HCP. Cedar Creek has been monitored annually to document recolonization by salmon and steelhead since 2010, when adult salmon and steelhead were again allowed access to historical habitat blocked by the ODFW hatchery at river mile 1.5.

Table 2. Provisional schedule for sampling major tributaries in the Sandy River Basin^a

Year	Cedar Creek	Little Sandy River	Bull Run River	Clear Fork Sandy River	Lost Creek	Clear Creek	Still Creek	Zigzag River/ Camp Creek	Salmon River	Gordon Creek	Beaver Creek
2009		x	x		x	x	x			x	
2010		x	x	x				x	x		x
2011		x	x		x		x	x		x	
2012		x	x				x	x	x		x
2013	x	x	x	x	x				x	x	
2014	x	x	x			x	x	x			x
2015	x	x	x	x	x		x				x
2016	x	x	x			x			x	x	x
2017	x	x	x		x	x			x		
2018	x	x	x		x	x			x		x
2019	x	x	x	x			x	x		x	
2020	x	x	x	x	x	x					x
2021	x	x	x	x		x		x		x	
2022	x	x	x	x			x		x	x	
2023	x	x	x				x		x	x	x
2024	x	x	x	x		x	x		x		
2025	x	x	x		x	x		x		x	
2026	x	x	x	x	x			x			x
2027	x	x	x		x			x		x	x
2028	x	x	x	x		x	x		x		

^aSchedules for years 2009, 2010, 2018, 2019, 2027, and 2028 (shaded gray) are fixed, but the remaining years may be changed to accommodate other monitoring needs as long as all sites scheduled for a given year remain grouped together as a unit.

This smolt monitoring plan extends the reference area of the remaining four traps by rotating them among eight streams according to the following constraints (assuming that Camp Creek and the Zigzag River are combined):

- Each site will be trapped, on average, every other year.

- All sites will be trapped once in the first two years, once in the middle two years and once in the last two years of a 20-year period.

Rotated sites will be trapped according to a schedule that maximizes the pair-wise comparisons between them.

The original provisional smolt trap rotation schedule established in 2009 was adjusted in 2011 to accommodate logistical needs. The group of traps scheduled for 2011 was traded with that scheduled for 2021. The Zigzag River was scheduled to be trapped in 2017, but was cancelled in favor of using limited resources to continue monitoring on Still Creek. Table 2 reflects the new schedule. Additional sites may also be trapped if resources allow. For instance, Still Creek has also been trapped in 2010, 2013, 2016, and 2017 because of the particular value of the resulting data. Since 2016, both Beaver Creek and Gordon Creek have been trapped every year.

3.1.2 Sampling in 2017

Smolt production was monitored in Lost Creek, Still Creek, Clear Creek, Salmon River, Cedar Creek, the Little Sandy River, the Bull Run River, Gordon Creek, and Beaver Creek in 2017. An eight-foot-diameter rotary trap was used on the Bull Run River. Five-foot-diameter rotary screw traps were used on all other streams. Screw traps modified with wooden pontoons and other trap parts were used on Gordon Creek and Beaver Creek to discourage metal theft (Figure 1). A motor was added to the Beaver Creek trap in 2015 to continue trapping despite low stream flows. The Lost Creek, Still Creek, Clear Creek, and Salmon River traps were checked and maintained by USFS Zigzag Ranger District staff and volunteers. ODFW staff checked and maintained the Cedar Creek trap. PWB staff checked and maintained the Little Sandy River, Bull Run River, Gordon Creek, and Beaver Creek traps. All traps were operated seven days per week throughout the season to the maximum extent possible. The periods of operation for each site are summarized in Table 3, together with the number of days that each trap was not in operation due to scheduling, high or low flows, or other considerations.



Figure 3. Adult Pacific Lamprey caught in the Beaver Creek trap

A variety of factors contributed to time periods when traps were not in operation in 2017. High flows and wind storms led to traps being pulled for several days on all streams. Low flows hampered trapping in Beaver Creek. Two days were missed on the

Bull Run River to avoid capturing hatchery Chinook smolts released upstream from an acclimation pond.

The Cedar Creek trap was not checked on weekends. The trap was left fishing, however, and accumulated fish until it was checked on Monday. The weekend days, when the trap was not checked but continued to capture fish, were not treated as down time days (Table 3).

The trapping season ended early in Little Sandy, Bull Run, Gordon Creek, and Beaver Creek because of a lack of smolts.

Table 3. Dates of operation and the number of days traps did not operate in the Sandy River Basin in 2017

Stream^a	Trap In	Trap Out	Down Time (Days)
Lost Creek	April 22	June 23	11
Still Creek	April 5	June 26	14
Clear Creek	April 5	June 23	18
Salmon River	April 6	June 21	19
Cedar Creek	March 24	June 22	1
Little Sandy River	March 14	June 15	13
Bull Run River (without the Little Sandy River)	March 14	June 15	16
Gordon Creek	March 14	June 15	14
Beaver Creek	March 14	June 2	25

^aStreams are presented in order from highest-elevation Lost Creek to lowest-elevation Beaver Creek.

3.1.3 Data Collection

Traps were checked daily and all fish were removed from the trap's live well. Fish were anesthetized using Alka-Seltzer Gold™ (buffered sodium bicarbonate). The following data were collected for most fish:

- Species
- Life-stage (smolt, juvenile, fry, or adults)
- Fork length (mm)
- Weight (g)
- Fin marks given or observed (see Mark-Recapture Study section below)
- Comments (e.g., injuries, pathogens, etc.)

Life stage was determined using external characteristics. Smolts show a general silvering, fading of parr marks, and a darkening of the posterior edge of the caudal fin. Juveniles are small fish but larger than 50 millimeters (mm) that show none of the above smolt

characteristics. Fry are 50 mm or less. At times, and especially early in the season, steelhead smolts were just beginning to develop their characteristics and could be difficult to distinguish from juveniles. In these borderline cases, the following rule-set was applied:

If a steelhead is longer than 130 mm fork length, consider it a smolt unless there are absolutely no signs that smoltification may have begun, in which case consider it a juvenile. If a steelhead is 130 mm or less, consider it a juvenile, unless there are clearly signs of it being a smolt.

Tissue and scale samples were collected from steelhead and coho smolts at all sites. Scale samples were collected from 10 individual fish in each 10-millimeter fork-length increment throughout the fork length range of both steelhead and coho smolts at each trap site. Approximately 50 steelhead and 50 coho tissue samples are collected each year from each monitored trap site.

The ages of sampled fish are determined from scale samples by the ODFW Fish Life History Analysis Project laboratory in Corvallis, Oregon. The ages of smolts sampled between 2009 and 2016 were determined and are incorporated into this report.

3.1.4 Mark-Recapture Study

An ongoing trap efficiency study was conducted throughout the trapping season to determine the proportion of the outmigration that was being captured in the traps. Following a modified mark-recapture protocol, up to 25 smolts of each species at each site each day were given a fin mark specific to the day of the week. Marked fish were subsequently released from

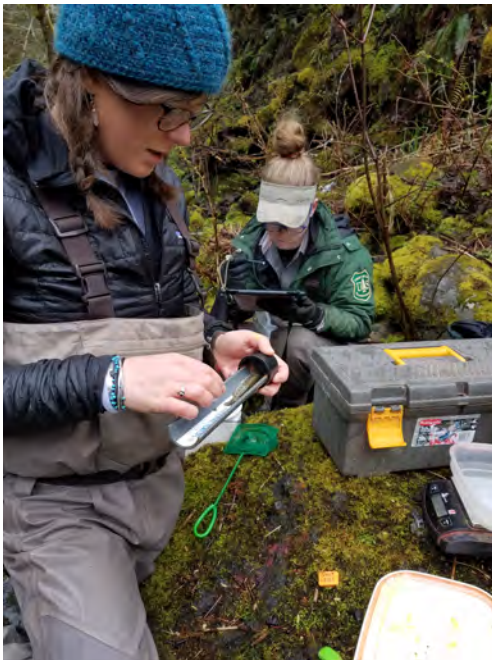


Figure 4. USFS personnel process fish

approximately 0.1 to 1.5 miles upstream of the trap, depending on access to appropriate release sites. Fins were marked either with small clips or injected dye. Captured fish were sorted each day to look for fin marks from previous days' releases.

In deciding to mark fish for the trap efficiency study with only seven specific fin-clip markings—one for each weekday—researchers assumed that all marked fish would travel from the release point to the trap within seven days. An analysis of the recapture data appears to bear this assumption out. Most fish appeared to be recaptured after one to three days, with very few indicating a travel time of four or more days. The consequences of some fish taking more than seven days to travel from the release point to the trap are reduced by pooling adjacent weeks together into two-week mark-recapture periods.

3.2 Assumptions

The mark-recapture procedures are subject to the same limitations inherent to all similar studies. The model assumes the following:

- The target species and life-stages are actively moving downstream (equivalent to the “closed population” requirement of the Peterson estimator, discussed in Volkhardt et al. 2007).
- All fish in a capture period (stratum) of a given species and life stage have equal probability of first-time capture.
- Marking fish does not affect their catchability (that is, they do not suffer mortality between marking and potential recapture).
- Marked and unmarked fish traveling together have an equal probability of recapture (that is, fish do not become “trap-shy” or “trap-happy,” leading to overestimated or underestimated populations, respectively).
- Fish do not lose their marks.
- All recaptured marked fish are recognized.

3.3 Data Analysis

3.3.1 Smolt Population Estimation

Smolt population sizes for individual streams are estimated using Darroch Analysis with Rank Reduction for R (DARR 2.0.2, Bjorkstedt 2010), a program provided by the National Marine Fisheries Service.² DARR 2.0.2 relies on a stratified Peterson estimator for mark-recapture data. Prior to calculation of the estimate, however, time periods are aggregated following rules designed to avoid the pitfalls associated with small populations and low recapture rates.

In the Sandy River Basin, fish total captures (C) and marks (M) are stratified by two-week time periods, to reduce variation associated with flows, water temperature, and changing fish behavior. The associated recaptures (R) are identified by both the time period in which they originated and the time period in which they are recaptured, resulting in a recapture matrix. The Darroch estimator uses the recapture matrix to estimate the number of marked fish passing the trap during a given time period. The total estimate is the sum of the individual time period estimates. Details of the calculation of the total estimate and its variance are fully described in Bjorkstedt (2005).

For the special cases in which all recaptures occur in the same stratum from which they originated (all non-zero values occur along the middle diagonal of the recapture matrix), the Darroch estimator reduces to a simple Peterson estimator (where N refers to population estimate and the subscript s refers to the stratum):

² The program is available on the NMFS site: <http://swfsc.noaa.gov/textblock.aspx?Division=FED&id=3346>.

Stratum estimate (N_s) = $C_s (M_s / R_s)$ (Equation 1)

There were several days at each site when certain smolt traps were not in operation, because of damage, potential damage, or scheduling issues (see Table 3). For these days, the daily smolt output was estimated using a two-week running average of daily population estimates (daily total capture without recaptures \div trap efficiency_{stratum}; with trap efficiency provided by DARR 2.0.2). Only days with actual captures within seven days before and after a particular date were included in the running average of daily population estimates. The variance of down-time estimates was calculated by adding the variances of each daily estimate, which, in turn, was added to the variance provided by DARR to produce 95 percent confidence intervals for each smolt population estimate.

The Sandy River Basin Smolt Monitoring Plan is designed to produce Sandy River Basin-level (index area) smolt populations estimates, population trend estimates, and freshwater productivity estimates (smolts per adult) after 20 years of annual smolt monitoring. Preliminary calculations, however, can be made now. The preliminary calculations illustrate the process of filling gaps in each time series of subbasin estimates and the process of adding individual subbasin population estimates in a given year together to produce a Sandy River Basin-level estimate.

The Sandy River Basin Smolt Monitoring Plan sampling schedule (Table 2) results in gaps that must be filled in each subbasin's time series of population estimates. These gaps were filled, on a demonstration basis in 2017, by using the average and the associated variance of all past population estimates for each respective subbasin. The number used to fill gaps in a given trap's time series of population estimates is henceforth referred to as a "gap estimate." For each year between 2009 and 2017, all subbasin smolt trap estimates and gap estimates were summed by species to calculate Sandy River Basin-level population estimates for steelhead and coho smolts. The variances associated with each smolt trap estimate and each gap estimate were similarly summed by species to calculate a variance for each Sandy River Basin-level population estimate. Gap estimates will be recalculated in the future, once more subbasin estimates are available, to retroactively produce refined Sandy River Basin-level smolt population estimates.

Estimates of the number of adult steelhead and coho spawners in the Sandy River Basin for each parent generation that produced the steelhead and coho smolts monitored in 2009 through 2017 were used to tentatively calculate freshwater productivity (smolts per adult) for as many adult spawner years as possible. Adult steelhead and coho spawner estimates were obtained from the ODFW Oregon Adult Salmonid Inventory & Sampling (OASIS) Program. The adult steelhead and coho spawner estimates correspond to approximately the same geographic reference frame (index area) as the Sandy River Basin Smolt Monitoring Plan.

3.3.2 Smolt Fork Lengths

Weighted average fork lengths for all smolt populations were calculated. Smolt fork lengths for each site were compiled and then weighted by capture stratum using trap efficiency (provided by DARR 2.0.2). If trap efficiency for a given stratum was low, the weights for fish captured in that stratum were weighted more heavily. This prevented strata with few fish but high trap efficiencies, for example, from influencing the average more than strata with many fish but low trap efficiencies. Fork lengths of actual captures were compared among streams using analysis of variance (ANOVA). If the resulting *F* statistic was found to be significant at an α level of 0.05, a Tukey test was applied to all combinations of pairs of streams to determine how average fork lengths of captured fish differed from one another.

3.3.3 Smolt Condition Factors

Condition factors (K) were determined for all steelhead and coho smolts by basin using weights (W) and fork lengths (L) according to the following formula:

$$K = (W/L^3) * 100,000 \quad (\text{Equation 2})$$

Condition factors give an indication of how thin or fat a fish is. Condition factors were compared among basins by statistically testing for differences using ANOVA. If the resulting *F* statistic was found to be significant at an α level of 0.05, a Tukey test was applied to determine how mean condition factors differed from each other. Condition factors were not weighted by capture stratum using trap efficiency because of the analytical complexities involved.

3.3.4 Emigration Dates

Steelhead and coho smolt mean and peak emigration dates were calculated for each site. The mean emigration date was defined as the sum of the product of daily captures corrected for stratum efficiency (C) and the date of capture (D) on any given day (i for days 1-k), divided by the sum of corrected captures using the following formula:

$$\sum_{i=1}^k (CD)_i / \sum_{i=1}^k C_i \quad (\text{Equation 3})$$

The peak emigration date was defined as the day when most fish of a species and condition were estimated to have passed the trap site (daily captures corrected for stratum trap efficiency).

4. Results

4.1 Smolt Population Estimation

4.1.1 Trap Efficiencies

The efficiencies of traps varied across sites and time. Trap efficiencies are summarized in Table 4 for each site and two-week trapping period. Period 1 for each site started the Sunday of the week that trapping began for the respective site (see Table 3 for start dates). Given a certain number of marked fish, the higher the trap efficiency, the more precise the population estimate. A trap efficiency of at least 0.1 and preferably closer to 0.25 is desirable.

Table 4. Trap efficiencies for each site, species, and two-week trap period in 2017

Site ^a	Species	Period						
		1	2	3	4	5	6	7 ^b
Lost Creek	Steelhead	NA	NA	NA	NA	NA	NA	NA
	Coho	0.250	0.250	0.250	0.250	0.250	0.250	0.250
Still Creek	Steelhead	0.434	0.434	0.254	0.254	0.289	0.289	0.289
	Coho	0.337	0.337	0.148	0.357	0.384	0.305	0.339
Clear Creek	Steelhead	0.156	0.156	0.156	0.250	0.191	0.714	0.714
	Coho	0.367	0.367	0.367	0.349	0.553	1.000	1.000
Salmon River	Steelhead	0.048	0.048	0.048	0.088	0.090	0.090	0.090
	Coho	0.188	0.228	0.228	0.433	0.331	0.313	0.313
Cedar Creek	Steelhead	0.356	0.356	0.356	0.356	0.174	0.174	—
	Coho	0.194	0.194	0.194	0.098	0.098	0.098	—
Little Sandy River	Steelhead	0.191	0.191	0.191	0.135	0.155	0.098	—
	Coho	0.176	0.176	0.176	0.222	0.286	0.375	—
Bull Run (without Little Sandy River)	Steelhead	0.017	0.017	0.017	0.017	0.025	0.088	—
	Coho	0.078	0.078	0.078	0.078	0.078	0.133	—
Gordon Creek	Steelhead	0.053	0.053	0.053	0.065	0.065	0.065	—
	Coho	0.222	0.222	0.222	0.250	0.158	0.158	—
Beaver Creek	Steelhead	0.074	0.074	0.074	0.074	0.071	0.071	—
	Coho	0.100	0.100	0.100	0.100	0.100	0.100	—

^aStreams are presented in order from highest-elevation Lost Creek to lowest-elevation Beaver Creek.

^bThere was no seventh two-week trapping period in some stream because those traps were not operated long enough due to low flows, lack of fish, or other factors.

4.1.2 Subbasin Population Estimates

Monitored smolt production was relatively high for steelhead but low for coho in 2017. As has been observed in the past, more steelhead smolts emigrated from the Bull Run River than from all other monitored streams combined. Beaver Creek produced more steelhead smolts than in any previous monitored year (Table 9). Still Creek produced very few, and Lost Creek produced no steelhead smolts in 2017. The Salmon River had the largest coho estimate of any monitored stream, as is summarized in Table 5. All monitored streams except Still Creek had markedly lower coho estimates than 2016, and the Salmon River in 2017 had the lowest coho estimate on record. Cedar Creek had low estimates of both species. Exhibit A summarizes the total captures at all trap sites.

A portion of the emigration of smolts from several streams may have been missed. A small number of steelhead or coho smolts were caught on the first and last days of trapping in Still Creek, Clear Creek, and the Salmon River, and steelhead smolts were caught on the first day of trapping in Gordon Creek. Trapping in each of these streams in 2017 coincided with the period of spring smolt emigration observed in the past, so it is likely that the proportion of the population that was missed was small.

The variances associated with estimates in several streams were large relative to the estimates themselves in 2017. Steelhead estimates tended to be less precise than coho estimates, given similar population sizes, because of lower trap efficiencies for steelhead than for coho (see Table 4). The Bull Run River and Gordon Creek estimates were the least precise for steelhead and the Bull Run River and Lost Creek estimates were least precise for coho. Lack of precision was generally due to a combination of low marking rates due to small population sizes and low trap efficiencies.

Table 5. Steelhead and coho smolt population estimates and 95% confidence intervals for 2017

Stream ^{a,b}	Steelhead		Coho	
	Estimate	95% CI	Estimate	95% CI
Lost Creek	0	NA	48	101%
Still Creek	905	19%	6,191	10%
Clear Creek	1,094	33%	841	15%
Salmon River	12,689	27%	7,859	9%
Cedar Creek	248	58%	868	58%
Little Sandy River	1,762	35%	253	52%
Bull Run River (without Little Sandy)	25,826	60%	733	99%
Gordon Creek	2,186	74%	272	63%
Beaver Creek	2,391	55%	141	74%

^aConfidence intervals are expressed as percentages of the associated estimates.

^bStreams are presented in order from highest-elevation Lost Creek to lowest-elevation Beaver Creek.

Of all streams monitored in 2017, steelhead smolt production per unit of stream length and per unit of surface area was highest in the Bull Run River, as summarized in Table 6. Lost Creek had the lowest steelhead smolt production per unit of length and surface area.

Table 6. Steelhead and coho smolts per mile and smolts per 1,000 ft² for 2017

Streams ^a	Steelhead		Coho	
	Smolts/mile	Smolts/1,000 ft ²	Smolts/mile	Smolts/1,000 ft ²
Lost Creek	0.00	0.00	10.67	0.06
Still Creek	60.74	0.34	848.08	3.49
Clear Creek	214.51	1.32	164.90	1.01
Salmon River	456.44	1.15	299.96	0.72
Cedar Creek	16.87	0.09	59.05	0.31
Little Sandy River	298.64	0.90	42.88	0.13
Bull Run River (without Little Sandy)	3111.57	6.68	88.31	0.19
Gordon Creek	295.41	1.41	37.78	0.18
Beaver Creek	310.52	2.71	18.31	0.16

^aStreams are presented in order from highest-elevation Still Creek to lowest-elevation Beaver Creek.

Of all streams monitored in 2017, both coho smolt production per unit of stream length and coho smolt production per unit of surface area were highest in Still Creek. Clear Creek had the second-highest production of coho smolts per unit of surface area, and the Salmon River had the second-highest production per unit length. Lost Creek had the lowest coho smolt production per unit stream length and surface area.

Some streams have shown significant changes in fish populations over their monitoring record (Figures 5 and 6). Steelhead have increased significantly in the Salmon River, Little Sandy River, and the Bull Run River. Coho have increased significantly in Still Creek. Coho have decreased significantly in Beaver Creek. A trend in numbers with a *p*-value of 0.1 or less was considered significant because of the high amount of variability seen in population estimates across years.

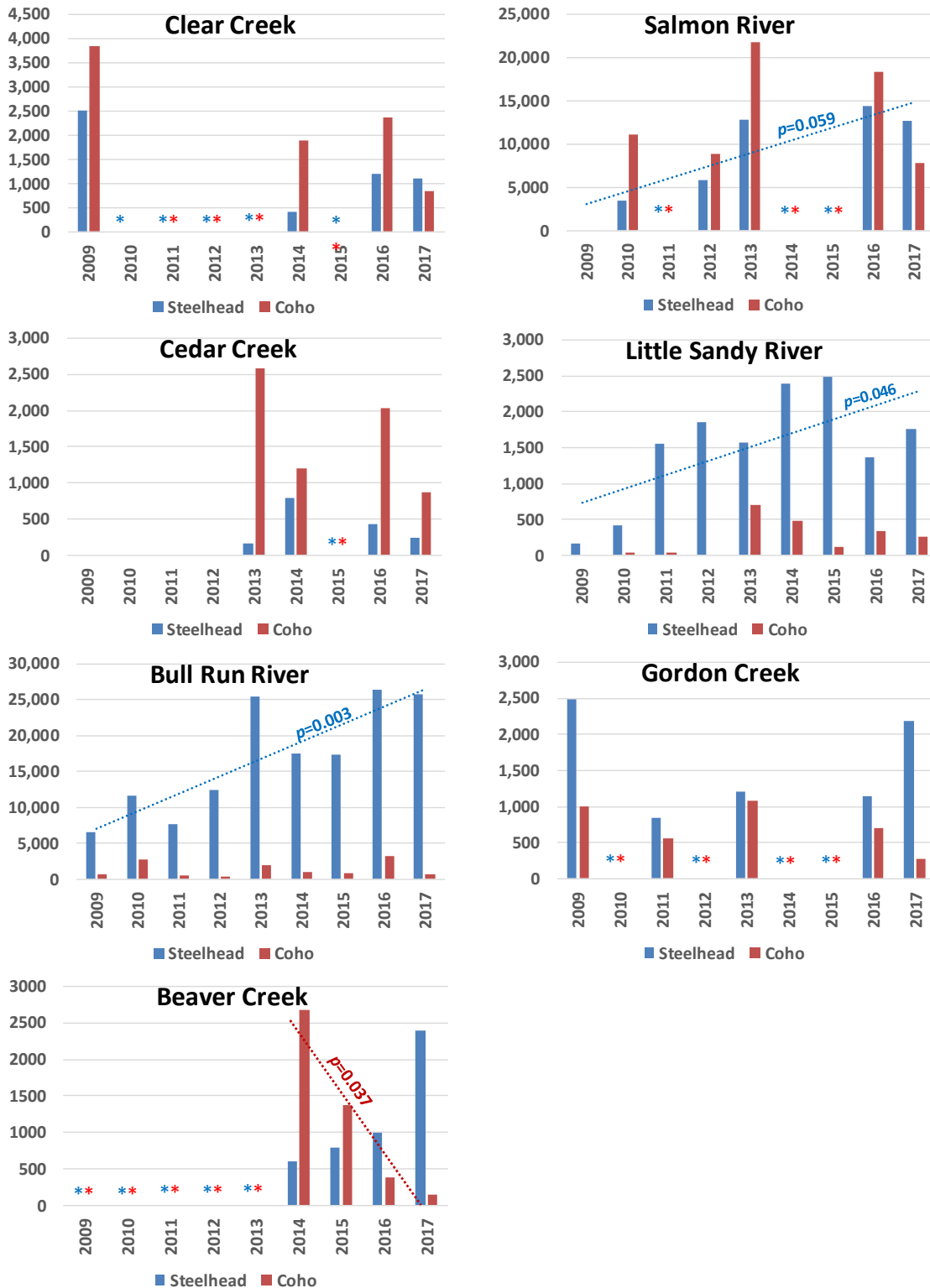


Figure 5. Steelhead and coho smolt population estimates over time for individual subbasins. Statistically significant changes over time are indicated with a trendline and associated p -value. Years with no population estimate are indicated with an asterisk to distinguish them from years with an estimate of zero.

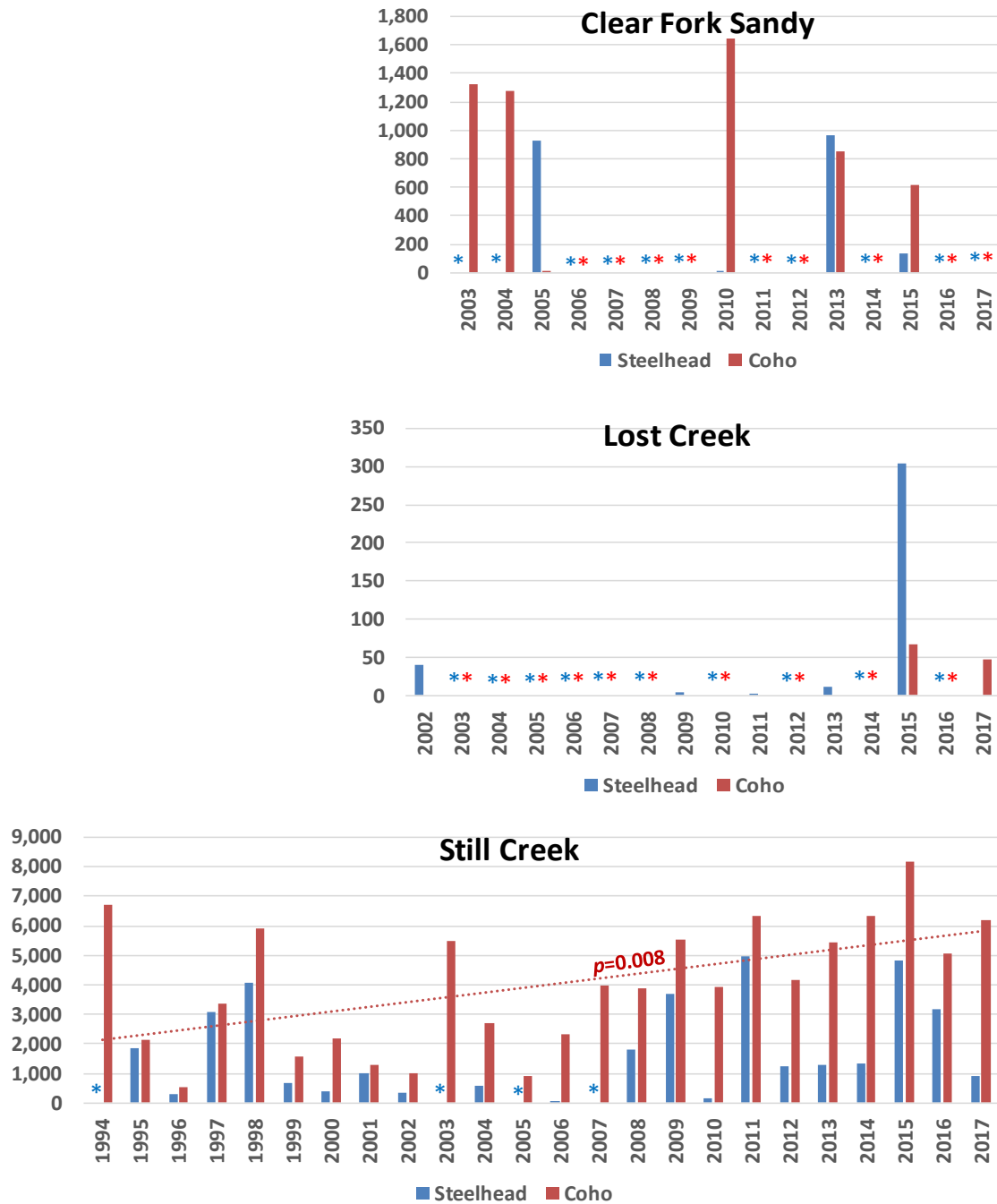


Figure 6. Steelhead and coho smolt population estimates over time for individual subbasins with extended records. Figures are right margin-justified to align trapping years. Statistically significant changes over time are indicated with a trendline and associated p -value. Years with no population estimate are indicated with an asterisk to distinguish them from years with an estimate of zero.

4.1.3 Sandy River Basin Index Area Population Estimates

At least four smolt population estimates were compiled from past trapping efforts in each subbasin. The smolt population estimates were used to create gap estimates. The subbasin

smolt population estimate statistics are summarized in Tables 7, for steelhead, and 8, for coho. The average relative contributions of each of the streams monitored in the Sandy River Basin Index Area are illustrated for steelhead and coho in Figures 7 and 8, respectively.

Table 7. Statistics for steelhead subbasin smolt trap population estimates compiled from the Sandy River Basin Index Area, 2009–2017

	Clear Fork Sandy	Lost Creek	Clear Creek	Zigzag River	Still Creek	Salmon River	Cedar Creek	Little Sandy	Bull Run	Gordon Creek	Beaver Creek ^a
n	4	6	4	4	21	5	4	7	9	5	4
Average	510	61	1,307	8	1,779	9,825	409	1,853	16,781	1,573	1,193
St. Dev.^a	511	120	876	6	1,565	4,878	277	431	7,729	716	814

^aStandard Deviation (St. Dev.) describes the spread of individual subbasin estimates around their average.

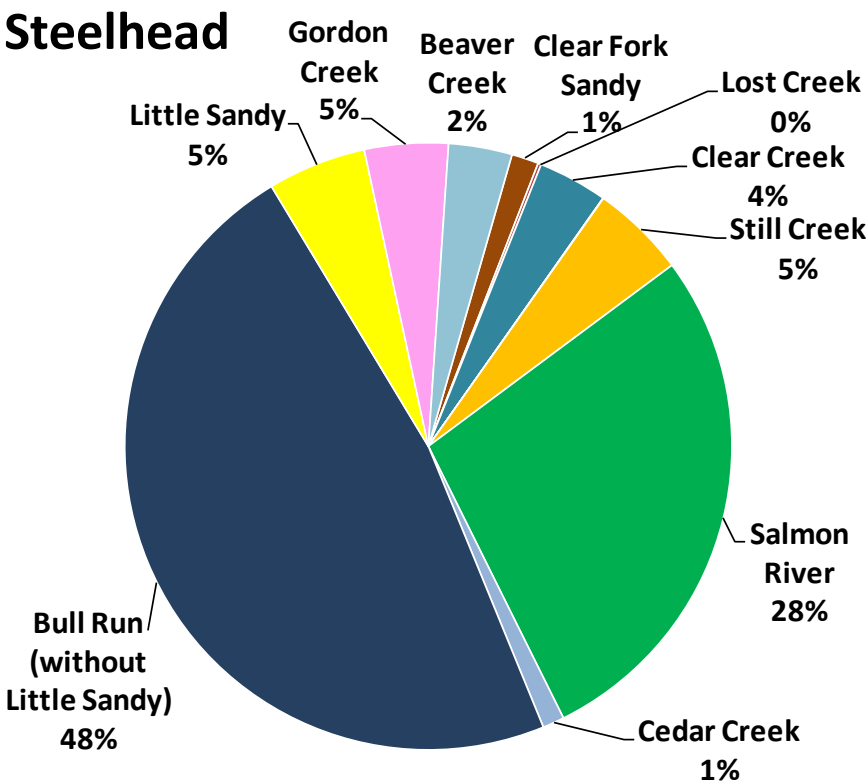


Figure 7. Average relative contributions of monitored streams to steelhead smolt production in the Sandy River Basin Index Area, 2009–2017

Table 8. Statistics for coho subbasin smolt trap population estimates compiled from the Sandy River Basin Index Area, 2009–2017

	Clear Fork Sandy	Lost Creek	Clear Creek	Zigzag River	Still Creek	Salmon River	Cedar Creek	Little Sandy	Bull Run	Gordon Creek	Beaver Creek
n	6	6	4	4	24	5	4	9	9	5	4
Average	953	19	2,237	0	3,960	13,579	1,673	245	1,349	719	1,147
St. Dev. ^a	591	31	1,244	0	2,155	6,144	781	247	1,061	329	1,154

^aStandard Deviation (St. Dev.) describes the spread of individual subbasin estimates around their average.

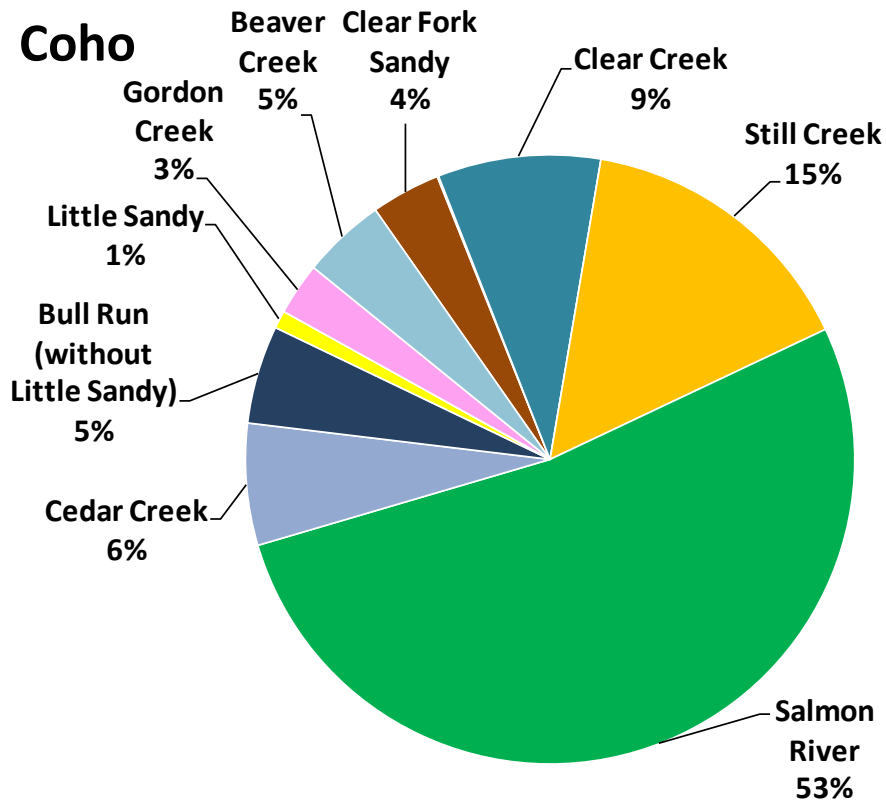


Figure 8. Average relative contributions of monitored streams to coho smolt production in the Sandy River Basin Index Area, 2009–2017

The subbasin steelhead and coho smolt population estimates and demonstrative gap estimates, as well as their 95 percent confidence intervals, are summarized in Tables 9 and 10, respectively, for the eight years of the Sandy River Basin Smolt Monitoring Plan period (2009–2016). Expanded estimates were used for the 2011 subbasin population estimates and for Still Creek and the Salmon River in 2012, when trapping started late enough in the season to miss a significant portion of the smolt emigration. Averages of existing subbasin smolt population estimates (from Tables 7 and 8) were tentatively used as the gap estimates for this initial exercise.

Table 9. Subbasin steelhead smolt population estimates and gap estimates since the inception of the Sandy River Basin Smolt Monitoring Plan^a

	Clear Fork Sandy	Lost Creek	Clear Creek	Zigzag River	Still Creek	Salmon River	Cedar Creek	Little Sandy	Bull Run	Gordon Creek	Beaver Creek
2009	510	5	2,514	8	3,709	9,825		160	6,637	2,483	1,193
	196%	na	83%	na	87%	97%		153%	96%	97%	27%
2010	4	61	1,307	5	138	3,419		416	11,701	1,573	1,193
	na	390%	131%	na	102%	77%		56%	149%	91%	27%
2011	510	1	1,307	1	4,958	9,825		1,552	7,750	839	1,193
	196%	na	131%	na	15%	97%		51%	33%	63%	27%
2012	510	61	1,307	13	1,236	5,819		1,856	12,495	1,573	1,193
	196%	390%	131%	na	39%	20%		67%	59%	91%	27%
2013	967	12	1,307	8	1,293	12,755	169	1,569	25,399	1,210	1,193
	51%	55%	131%	na	38%	47%	56%	40%	36%	122%	27%
2014	510	61	418	14	1,341	9,825	791	2,395	17,490	1,573	603
	196%	390%	38%	na	42%	97%	68%	39%	43%	91%	53%
2015	136	304	1,307	8	4,834	9,825	409	2,483	17,341	1,573	785
	73%	63%	131%	149%	38%	97%	133%	36%	24%	91%	34%
2016	510	61	1,201	8	3,192	14,443	426	1,357	26,392	1,150	994
	196%	390%	8%	149%	7%	48%	72%	62%	31%	39%	86%
2017	510	0	1,094	8	905	12,689	248	1,762	25,825	2,185	2,391
	196%	0%	33%	149%	19%	27%	58%	35%	60%	74%	55%

^aShaded cells indicate gap estimates using the best information available.

Table 10. Subbasin coho smolt population estimates and gap estimates since the inception of the Sandy River Basin Smolt Monitoring Plan^a

	Clear Fork Sandy	Lost Creek	Clear Creek	Zigzag River	Still Creek	Salmon River	Cedar Creek	Little Sandy	Bull Run	Gordon Creek	Beaver Creek
2009	953	0	3,838	0	5,528	13,579	0	0	661	994	1,147
	122%	0%	24%	0%	21%	99%		0%	109%	41%	97%
2010	1,646	19	2,237	0	3,911	11,077	0	37	2,708	719	1,147
	51%	310%	109%	0%	12%	53%		50%	68%	90%	97%
2011	953	0	2,237	0	6,325	13,579	0	39	483	557	1,147
	122%	0%	109%	0%	9%	99%		166%	61%	70%	97%
2012	953	19	2,237	0	4,144	8,838	0	0	314	719	1,147
	122%	310%	109%	0%	28%	14%		0%	141%	90%	97%
2013	853	0	2,237	0	5,435	21,721	2,589	706	2,010	1,080	1,147
	29%	0%	109%	0%	12%	18%	44%	35%	57%	50%	97%
2014	953	19	1,902	0	6,322	13,579	1,208	473	1,009	719	2,680
	122%	0%	20%	0%	8%	99%	14%	85%	200%	90%	41%
2015	618	68	2,237	0	8,159	13,579	1,673	116	937	719	1,380
	59%	111%	109%	0%	8%	99%	91%	103%	58%	90%	14%
2016	953	19	2,366	0	5,043	18,399	2,028	332	3,289	694	385
	122%	310%	37%	0%	27%	13%	20%	32%	48%	35%	57%
2017	953	48	841	0	6,191	7,859	868	253	733	272	141
	122%	101%	15%	0%	10%	9%	58%	52%	99%	63%	74%

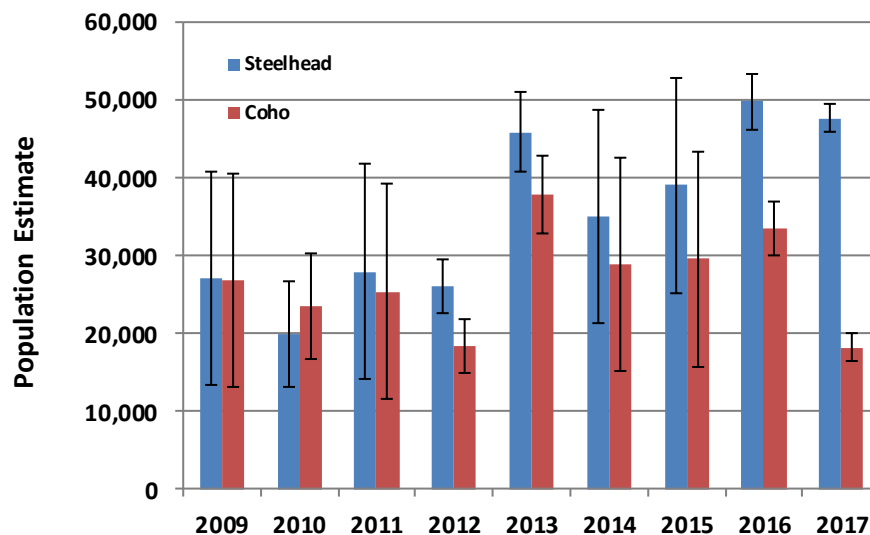
^aShaded cells indicate gap estimates using the best information available.

Preliminary steelhead and coho smolt population estimates for the entire combined index area of the Sandy River Basin are summarized in Table 11 and Figure 9 with their associated 95 percent confidence intervals.

Table 11. Sandy River Basin Index Area steelhead and coho smolt population estimates and 95% confidence intervals^a

Year	Steelhead		Coho	
	Estimate	95% CI	Estimate	95% CI
2009	24,151	54.2%	28,465	48.1%
2010	19,436	91.7%	24,408	28.2%
2011	25,202	43.9%	27,550	50.3%
2012	25,682	31.6%	19,278	18.8%
2013	45,642	24.6%	38,578	13.5%
2014	32,386	40.3%	30,401	45.3%
2015	36,571	32.0%	31,762	43.7%
2016	49,746	21.8%	33,503	10.5%
2017	47,617	33.6%	18,159	9.7%

^aConfidence intervals are expressed as percentages of the associated estimates.

**Figure 9. Sandy River Basin Index Area steelhead and coho smolt population estimates and 95% confidence intervals**

Estimates of freshwater productivity (smolts per adult) for steelhead are presented in Table 12. Estimates of freshwater productivity (smolts per adult) for coho are presented in Table 13. The number of coho smolts are plotted against the number of coho spawners in the parent generation in Figure 10. Also plotted in Figure 10 is a spawner/recruit curve fitted to the Sandy River Basin coho data using the Beverton-Holt model. A spawner/recruit curve describes how the number of recruits (offspring) produced per spawner (parent) changes depending on the number of spawners there are, according to a given model. The Beverton-Holt model, used in this analysis, assumes that the number of recruits is dependent on the density of spawners. The Beverton-Holt equation follows:

$$R = \frac{\alpha S}{(1+S/K)} \quad (\text{Equation 4})$$

where R is the number of recruits, S is the number of spawners, α is a parameter related to the productivity (recruits per spawner) of the population at its maximum (low numbers of spawners) and α and K together describe the maximum production (total number of possible recruits). As the number of spawners becomes very large, the number of recruits (smolts) begins to level off near α/K . No Beverton-Holt spawner/recruit curve was fitted to steelhead data because there are too few data points.

The number of smolts resulting from each parental generation for each species was determined by using age distribution information derived from the reading of scale samples (see Methods) and smolt fork length distribution data from each smolt trap year. Steelhead smolts from a particular parental year class emigrated at age 1, age 2, and age 3 in proportions that varied by stream. Coho smolts are assumed to have emigrated only at ages 2 and 3.³

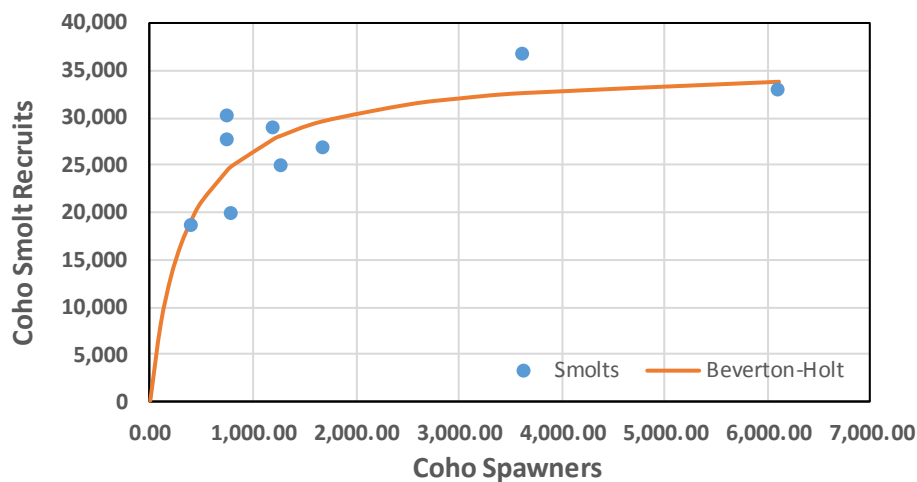
Table 12. Estimates of freshwater productivity for steelhead in the Sandy River Basin Index Area, 2010–2014

Steelhead Spawners		Steelhead Smolts		Freshwater Productivity
Year	Estimate	Year	Estimate	Smolts Per Adult
2010	2,100	2011-13	28,089	13
2011	527	2012-14	41,390	78
2012	391	2013-15	29,339	76
2013	3,767	2014-16	34,185	9
2014	3,344	2015-17	50,144	15

³ According to aging convention, for steelhead, an age 1 smolt is the offspring of adults which spawned the previous spring, approximately 12 months before. For coho, an age 1 smolt is the offspring of adults which spawned the previous fall, approximately 5-6 months before (ODFW 2014).

Table 13. Estimates of freshwater productivity for coho salmon in the Sandy River Basin Index Area, 2010–2015

Coho Spawners		Coho Smolts		Freshwater Productivity
Year	Estimate	Year	Estimate	Smolts Per Adult
2007	753	2009-10	27,887	37
2008	1,277	2010-11	25,152	20
2009	1,677	2011-12	27,081	16
2010	795	2012-13	20,023	25
2011	3,619	2013-14	36,911	10
2012	1,198	2014-15	27,965	23
2013	756	2015-16	28,814	38
2014	6,111	2016-17	31,360	5
2015	401	2017-18	18,772	47

**Figure 10. Coho spawners compared to resulting coho smolts in the Sandy River Basin Index Area, spawner years 2007–2015**

4.1.4 Recolonization of the Little Sandy River

Recolonization of the Little Sandy River by steelhead after the removal of Little Sandy Dam in 2008 appears to have been immediate and sustained (Figure 11). The first year that steelhead smolts were expected to result from the first steelhead adults spawning in the newly reopened portion of the stream was 2011. The Little Sandy 2011 steelhead smolt population was comparable in terms of smolts per unit length and area of stream to other streams of similar size that were never blocked to steelhead, like Gordon Creek or Still Creek. The steelhead smolts observed emigrating from the Little Sandy River in 2009 and 2010—with estimated populations of 160 and 416 fish, respectively—were

evidently primarily fish that had migrated upstream from the lower river past the site of the dam after its removal.

The Little Sandy River produced a moderate number of coho smolts in 2017. This was the eighth year that coho smolts could be expected in the Little Sandy trap, originating from adults that spawned upstream of the trap site after dam removal in 2008. Thus far, the number of coho fry caught in the Little Sandy trap in a given year has served as an effective predictor of the coho smolt estimate the following year.

Spawning by Chinook salmon adults has also been documented to varying degrees in the Little Sandy River since the dam was removed in 2008. This is reflected in the variable presence of Chinook fry in the Little Sandy smolt trap.

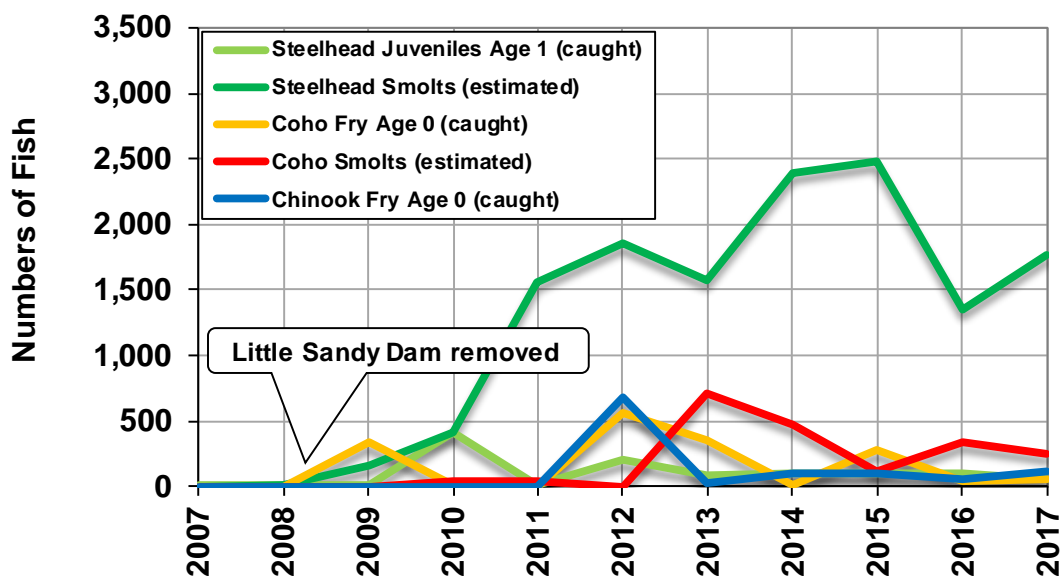


Figure 11. Recolonization of the Little Sandy River by steelhead, coho, and Chinook after the removal of the Little Sandy Dam

4.2 Fork Lengths

Steelhead and coho average fork lengths varied across monitored streams in 2017, as summarized in Tables 14 and 15, respectively. There were significant differences between the mean fork lengths of both steelhead and coho smolts among monitored streams (ANOVA, $\alpha=0.05$, $p<0.001$ for both tests). Steelhead smolts emigrating from the Bull Run River were significantly longer than those emigrating from other monitored streams, as has been observed in previous years. Cedar Creek steelhead smolts were the shortest. Beaver Creek coho smolts were significantly longer, on average, than those from any other stream and showed a distinct bimodal distribution. Lost Creek coho smolts were the shortest.

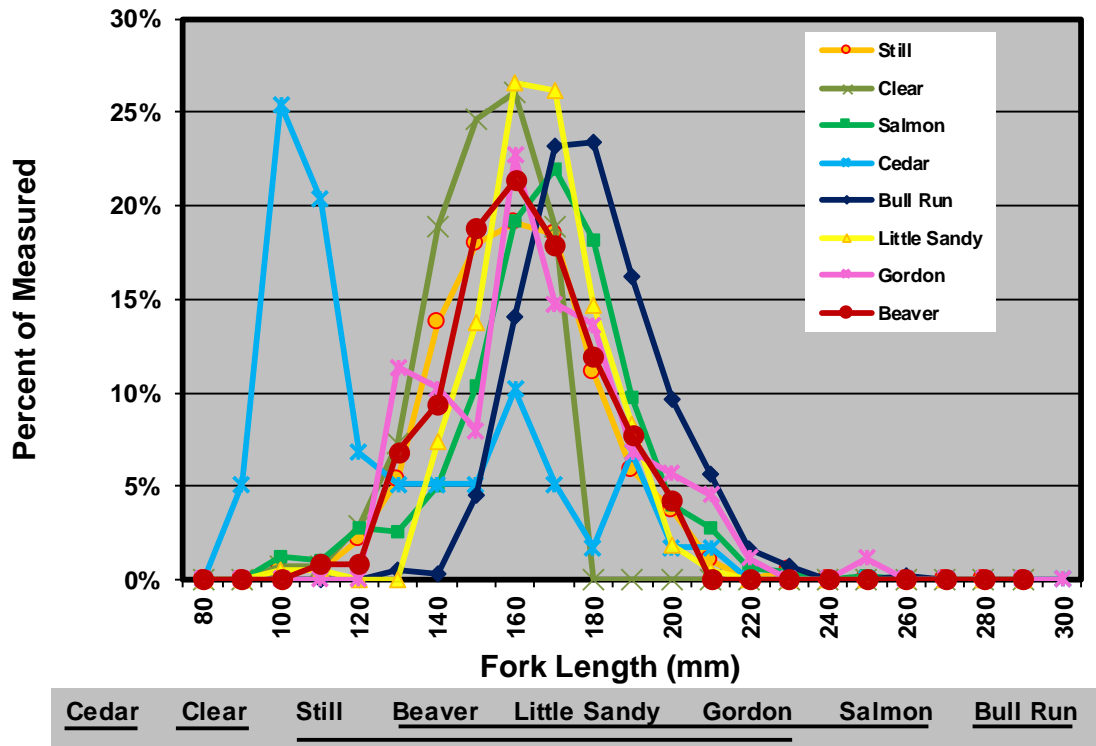
Table 14. Steelhead weighted mean fork lengths, weighted standard deviation, and range of fork lengths of steelhead smolts captured in Sandy River Basin smolt traps in 2017

Streams ^a	n ^b	Weighted		Minimum (mm)	Maximum (mm)
		Mean Fork Length (mm)	St. Dev. (mm)		
Still Creek	189	156	19	100	225
Clear Creek	138	148	14	100	169
Salmon River	474	164	22	95	250
Cedar Creek	59	124	32	85	210
Little Sandy	218	161	16	91	205
Bull Run (without Little Sandy)	599	176	18	125	256
Gordon Creek	88	161	24	121	245
Beaver Creek	117	158	19	109	195

^aStreams are presented in order from highest-elevation Still Creek to lowest-elevation Beaver Creek.

^bn= Number of fish for which fork lengths were determined

Figure 12 shows frequency distributions for steelhead smolt fork lengths. The results of the pair-wise comparisons are summarized below Figure 12.

**Figure 12. Steelhead smolt fork length frequency distributions for Sandy River Basin traps in 2017^a**

^aResults of pair-wise statistical comparisons are presented from left to right, shortest to longest.

In Figure 12, streams that are grouped together by being mutually underlined are not statistically distinguishable from one another at a 95 percent level of significance (e.g., steelhead smolts from Cedar Creek shorter than those from all other streams. Steelhead smolts from Beaver Creek, Little Sandy, and Gordon Creek are not statistically distinguishable from those from Still Creek or the Salmon River, but Salmon River steelhead are significantly longer than Still Creek steelhead).

Smolt age information reveals that different age distributions among streams obscure differences in steelhead growth. Figure 13 compares the weighted mean fork length of age 2 steelhead in all basins and for all years for which adequate age distribution data exists, with 95 percent confidence intervals. Calculations for the weighted mean fork length of age 2 steelhead emigrating in 2017 were made using aging results from 2016 or averages from previous years. Upper-basin steelhead have comparable mean fork lengths to steelhead from lower in the basin. Little Sandy steelhead have been relatively small consistently (see Table 14). These patterns have been partly due to the fact that, in comparison to steelhead emigrating from lower-basin streams, a higher proportion of the steelhead emigrating from upper-basin streams are age 3. Age 3 fish are larger because they have had more time to grow. A large proportion of Beaver Creek steelhead, in contrast, emigrate at age 1. Beaver Creek's complex steelhead fork length distribution and age distribution may also indicate that fish from other streams are entering and over-wintering in the stream.

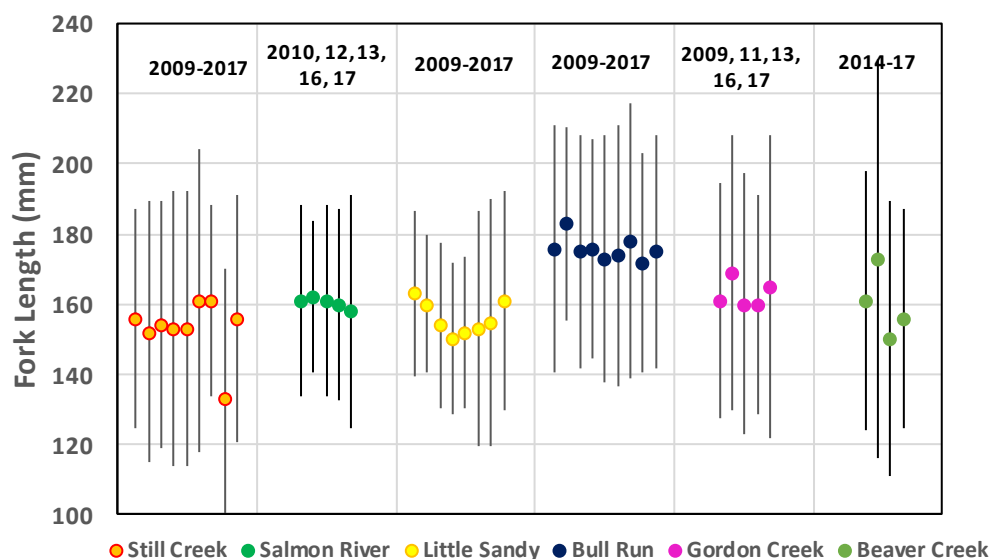


Figure 13. Weighted mean fork lengths of age 2 steelhead smolts for all Sandy River Basin streams and years for which age distribution data and fork length data exist

Table 15. Coho weighted mean fork lengths, weighted standard deviation, and range of fork lengths of coho smolts captured in Sandy River Basin smolt traps in 2017

Streams ^a	n ^b	Weighted		Minimum (mm)	Maximum (mm)
		Mean Fork Length (mm)	St. Dev. (mm)		
Lost Creek	10	100	9	87	116
Still Creek	1085	101	10	62	153
Clear Creek	297	105	14	65	141
Salmon River	1119	111	13	76	178
Cedar Creek	113	118	9	85	145
Little Sandy	49	102	9	84	122
Bull Run (without Little Sandy)	72	116	15	84	182
Gordon Creek	40	109	8	88	124
Beaver Creek	10	129	24	104	168

^aStreams are presented in order from highest-elevation Clear Creek to lowest-elevation Beaver Creek.

^bn= Number of fish for which fork lengths were determined

Figure 14 shows frequency distributions for coho smolt fork lengths. The results of the pair-wise comparisons are summarized below Figure 14.

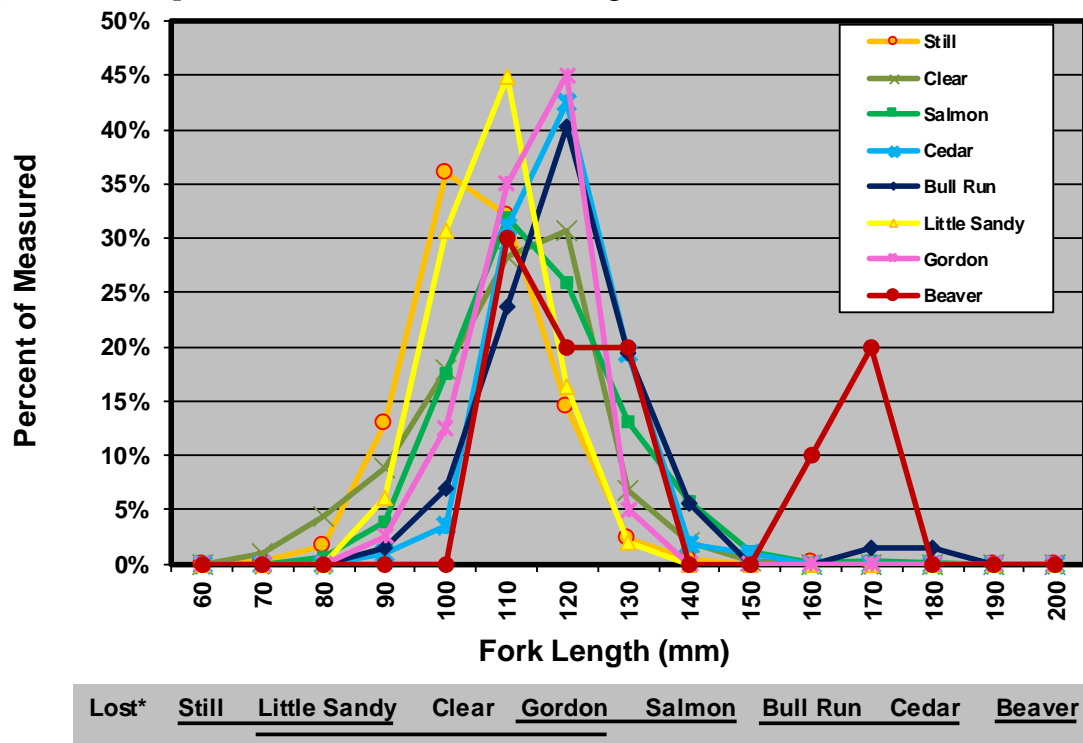


Figure 14. Coho smolt fork length frequency distributions for Sandy River Basin traps in 2017^a. Lost Creek had the shortest coho smolts, but there were too few to characterize a fork length distribution.

^aResults of pair-wise statistical comparisons are presented from left to right, shortest to longest.

In Figure 14, streams that are grouped together by being mutually underlined are not statistically distinguishable from one another at a 95 percent level of significance (e.g., Bull Run coho are statistically indistinguishable from coho from Cedar Creek, but both are significantly longer than coho from the Salmon River. Little Sandy coho are statistically indistinguishable from both Still Creek and Clear Creek coho, but Clear Creek coho are significantly longer than Still Creek coho).

Smolt age information reveals that very few emigrating coho smolts in the Sandy River Basin are older than age 2, though most of those appear to emigrate from upper-basin streams. The proportion of age 2 coho is too small to effect a substantial change to the overall weighted mean fork length of all emigrating coho.

4.3 Condition Factors

There were significant differences (ANOVA, $\alpha=0.05$, $p<0.001$ for both tests) among the condition factors of steelhead and coho among streams monitored in 2017 (Figures 15 and 16). Bull Run steelhead had lower condition factors (were thinner) than steelhead from other streams monitored in 2017 but were statistically indistinguishable from Little Sandy or Beaver Creek steelhead. Still Creek had significantly higher condition factors (were fatter) than steelhead from all other streams monitored in 2017. Bull Run coho also had lower condition factors than coho from other streams monitored in 2017 but could only be statistically distinguished from Clear Creek and Still Creek. Lost Creek coho had the highest condition factors, but were not included in the analysis because of small sample size. Beaver Creek coho are also shown according to rank, but were excluded from analysis because of small sample size. Figures 15 and 16 show the results of Tukey test multiple comparisons of condition factors for these two species across monitored streams. The weights of Cedar Creek steelhead and coho were not measured, so their condition factors were not evaluated relative to the other streams.



Figure 15. Steelhead smolt results of Tukey test multiple comparisons of condition factors for Sandy River streams monitored in 2016



Figure 16. Coho smolt results of Tukey test multiple comparisons of coho smolt condition factors for Sandy River streams monitored in 2017

4.4 Emigration Dates

The weighted mean and peak dates of emigration were earlier in the lowest-elevation streams for steelhead but not coho (Figures 17 and 18). Gordon Creek coho emigrated unusually early in 2017. Coho emigrated from the Little Sandy and Cedar Creek, both mid-elevation streams, later than from other streams in 2017. The weighted mean and median emigration dates for the trapping period are summarized, along with the estimated peak emigration date for the population and the dates of first and last capture, in Tables 16 and 17 for steelhead and coho, respectively.

Table 16. Steelhead smolt weighted mean date of emigration, associated standard deviation, weighted median date of emigration, estimated peak emigration date, and earliest and latest capture dates in Sandy River streams monitored in 2017

Streams ^a	Weighted		Median Emigration (Trapping)	Peak Emigration	Earliest Date	Latest Date
	Mean Emigration (Trapping)	St. Dev.				
Still Creek	5-May	14	4-May	23-Apr	5-Apr	7-Jun
Clear Creek	3-May	16	1-May	24-Apr	5-Apr	16-Jun
Salmon River	1-May	14	29-Apr	19-Apr	6-Apr	19-Jun
Cedar Creek	10-May	15	15-May	15-May	29-Mar	30-May
Little Sandy	8-May	14	12-May	16-May	22-Mar	2-Jun
Bull Run	1-May	14	4-May	4-May	22-Mar	5-Jun
Gordon Creek	16-Apr	18	14-Apr	22-Apr	14-Mar	29-May
Beaver Creek	26-Apr	12	30-Apr	4-May	18-Mar	17-May

^aStreams are presented in order from highest-elevation Still Creek to lowest-elevation Beaver Creek.

Table 17. Coho smolt weighted mean date of emigration, associated standard deviation, weighted median date of emigration, estimated peak emigration date, and earliest and latest capture dates in Sandy River streams monitored in 2017

Streams ^a	Weighted		Median Emigration (Trapping)	Peak Emigration	Earliest Date	Latest Date
	Mean Emigration (Trapping)	St. Dev.				
Lost Creek	18-May	14	25-May	20-May & 26-May	24-Apr	16-Jun
Still Creek	18-May	17	20-May	19-May	5-Apr	26-Jun
Clear Creek	11-May	17	10-May	7-May	5-Apr	23-Jun
Salmon River	8-May	19	6-May	19-Apr	6-Apr	21-Jun
Cedar Creek	1-May	12	4-May	8-May	29-Mar	22-May
Little Sandy	28-Apr	15	27-Apr	16-May	30-Mar	30-May
Bull Run	2-May	17	10-May	19-Apr & 14-May	23-Mar	4-Jun
Gordon Creek	29-Apr	20	8-May	13-May	16-Mar	26-May
Beaver Creek	24-Apr	12	27-Apr	4-May	27-Mar	14-May

^aStreams are presented in order from highest-elevation Lost Creek to lowest-elevation Beaver Creek.

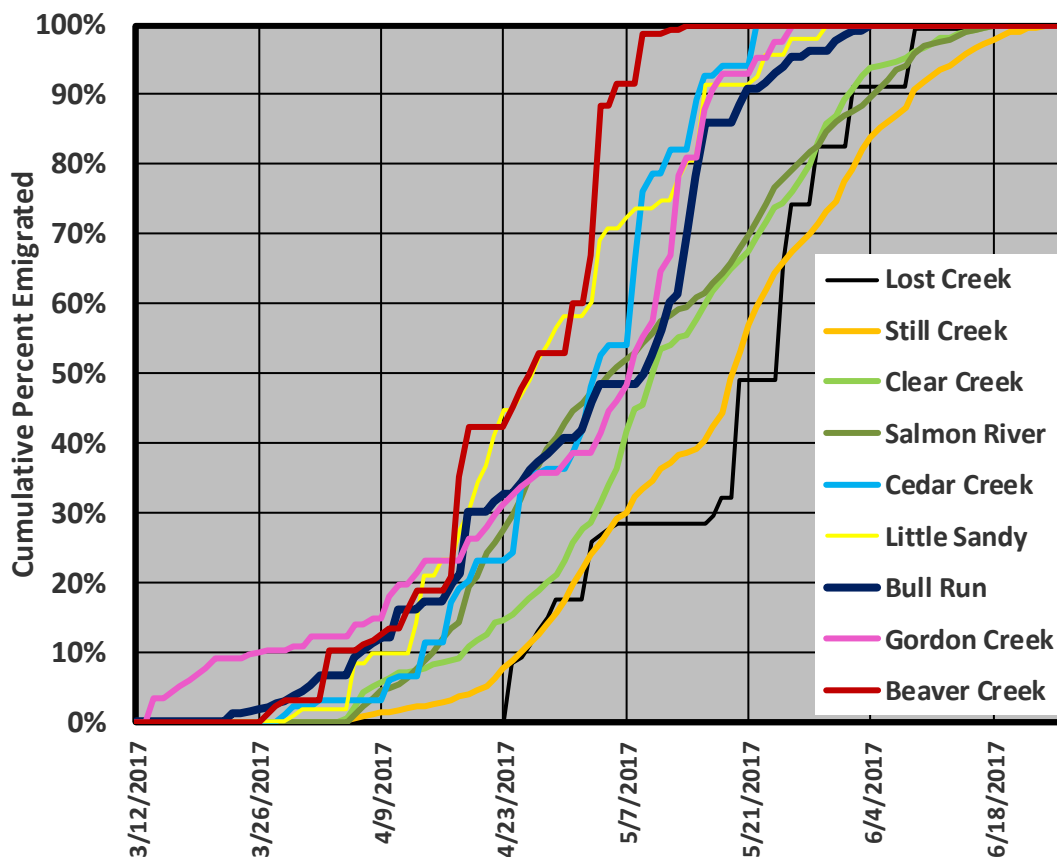


Figure 17. Steelhead smolt cumulative percentage of total emigration from Sandy River streams monitored in 2017. Steepest portions of each curve indicate peak capture periods.

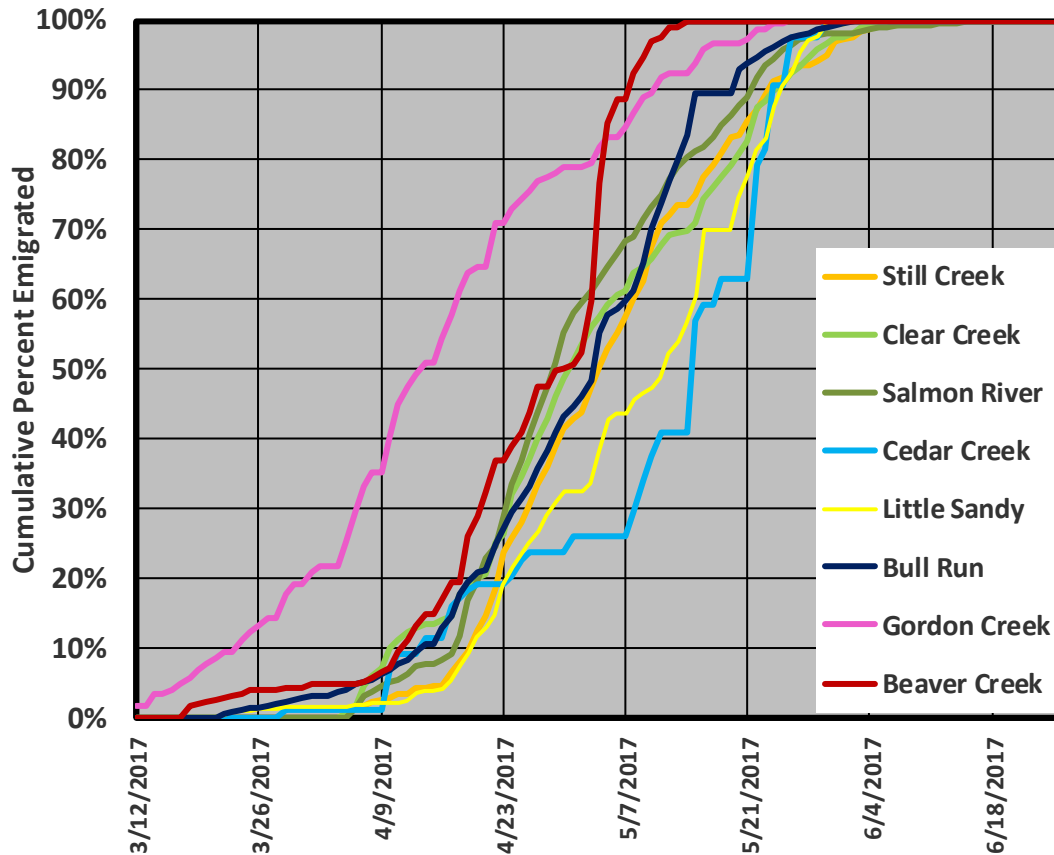


Figure 18. Coho smolt cumulative percentage of total emigration from Sandy River streams monitored in 2017. Steepest portions of each curve indicate peak capture periods.

4.5 Age Distribution

Both steelhead and coho smolts are, on average, slightly older at time of emigration from upper-basin streams than smolts from lower-basin streams. Steelhead and coho smolts from the Little Sandy, however, are, on average, older than expected, given Little Sandy's mid-elevation. Tables 18 and 19 summarize the weighted mean age and age distribution for each stream in the Sandy River Basin Index Area for which adequate age data exist. Age data are averaged across all years of aging data.

Table 18. Steelhead smolt weighted mean age and age distribution for Sandy River streams, 2009–2016

Stream	Weighted Average Age	Age 1	Age 2	Age 3	Age 4
Still Creek	2.36	5.4%	55.2%	37.7%	1.7%
Clear Fork	2.41	0.0%	58.5%	41.5%	0.0%
Clear Creek	2.14	5.2%	76.2%	18.0%	0.5%
Salmon River	2.20	2.5%	75.5%	21.2%	0.8%
Cedar Creek	1.91	9.8%	89.4%	0.9%	0.0%
Little Sandy	2.26	2.7%	68.6%	28.7%	0.0%

Bull Run	2.11	4.5%	79.9%	15.3%	0.3%
Gordon Creek	1.99	20.5%	60.1%	19.4%	0.0%
Beaver Creek	1.37	64.5%	34.1%	1.4%	0.0%

Table 19. Coho smolt weighted mean age and age distribution for Sandy River streams, 2009–2016

Stream	Weighted Average Age	Age 1	Age 2	Age 3	Age 4
Still Creek	2.03	0.3%	96.1%	3.6%	0.0%
Clear Fork	2.00	0.0%	100.0%	0.0%	0.0%
Clear Creek	2.00	2.3%	95.5%	2.2%	0.0%
Salmon River	2.00	0.4%	99.1%	0.5%	0.0%
Little Sandy	2.04	0.1%	95.4%	4.5%	0.0%
Cedar Creek	2.00	0.0%	100.0%	0.0%	0.0%
Bull Run	1.99	0.6%	99.4%	0.0%	0.0%
Gordon Creek	1.97	3.2%	96.8%	0.0%	0.0%
Beaver Creek	1.99	2.5%	95.6%	1.9%	0.0%

5. Discussion

5.1 Smolt Population Estimation

Most steelhead smolt population estimates were relatively high compared to the previous eight years of the Sandy River Basin Smolt Monitoring Program. Most coho smolt estimates, on the other hand, were relatively low. Still Creek was an exception, with a relatively low steelhead estimate and a relatively high coho estimate. The Bull Run River experienced the second highest production of steelhead on record. Beaver Creek had a record high steelhead estimate but unusually low coho estimate.

The low Beaver Creek coho estimate and high steelhead estimate may, as in 2016, be the result of extremely low water conditions in the creek the previous summer and the generally high Sandy River Basin Index Area steelhead smolt emigration, respectively. Beaver Creek experienced extended periods of very low water and high water temperatures in both 2015 and 2016. Conditions were likely near-lethal for cold-water fish like rearing coho except for areas of refuge, such as pools with groundwater inputs. Steelhead smolts may have included fish that originated elsewhere in the Sandy River Basin but overwintered in Beaver Creek. The large number of steelhead emigrating from other streams in the Sandy River Basin may have translated into a larger number of steelhead entering Beaver Creek to overwinter.

The description of smolt production by various streams in the Sandy River Basin could be complicated to an unknown degree by movement of fish between subbasins either before or during the time of smolt emigration. Only one hatchery (adipose-clipped) steelhead smolt was captured in the Bull Run trap on May 27, 2017. This fish would have entered the Bull Run after being released, swimming upstream beyond the Bull Run trap and then being captured on its way back downstream. Although this fish was not included in the Bull Run steelhead population estimate, its presence and the captures of some hatchery steelhead in previous years highlight the possibility of similar behavior in wild fish. When making inferences about the effect of fish habitat conditions on smolt production, studies generally assume that the majority of fish emigrating from monitored streams had their origin in those streams. This is, in part, borne out by observed significant differences in characteristics such as fork lengths and condition factors. A large degree of movement among all streams would tend to equalize these characteristics among streams. Of a total of 757 steelhead marked in tributaries upstream of Bull Run using paint marks, none were recaptured in the Bull Run, Gordon Creek, or Beaver Creek traps, lending further credence to the assumption that such movement between streams is at least not occurring to a significant degree during the spring smolt emigration. Large numbers of hatchery steelhead have been observed straying into the Bull Run River only in 2014, although 37 were also observed in 2015. It is possible that the movements of hatchery steelhead in 2014 and 2015 do not reflect the movements of wild fish. Without further study, however, it cannot be discounted that such movement could occur to some degree and that the differences between the physical characteristics observed between smolts from different streams would have been even larger without it. Movement may also be occurring from the adjacent Sandy River into the Bull Run, for example, to seek refuge from the glacially turbid conditions of the main stem river.

Unequal trap avoidance by different groups of fish is a perennial concern with studies such as this that rely on mark-recapture methodologies. Trap avoidance could have affected the estimation of smolt population sizes in the Sandy River in 2017. If marked individuals become “trap-shy” (i.e., are caught a second time at a rate lower than fish passing the trap for the first time), this results in an inflated population estimate. Steelhead marked at the upstream Little Sandy trap were recaptured at higher rates at the Bull Run trap than steelhead marked at the Bull Run trap in 2017 (6.0 percent compared with 4.1 percent efficiency, respectively, averaged over the season). If this difference reflects “trap-shy” behavior on the part of steelhead that encountered the Bull Run trap rather than reflecting error in the efficiency estimate, it could result in an inflation of the Bull Run estimate. A recalculation of the Bull Run estimate using Little Sandy marks and their recaptures in the Bull Run trap, however, resulted in a similar population estimate (5% smaller).

Large fish of a given species are probably also stronger swimmers than small fish and may have a greater ability to avoid capture when they recognize a trap in their downstream

path. Were this effect to occur equally during the initial capture and subsequent recapture of fish, the result would be an underestimated population size.

Were it to happen during both phases of capture, but more strongly during the recapture phase, the result would vary depending on the strength of the effect, but could result in an inflated estimate. Consequences of this effect are discussed more fully in Strobel 2010. Steelhead marked and recaptured at the Bull Run trap were shorter by 4 mm, on average, than steelhead originally marked. It is unlikely that this small difference would result in different swimming abilities.

The initial estimates of steelhead productivity (smolts per adult) were hampered in 2014 and 2015 by difficulties encountered generating adult steelhead spawner estimates in previous years. No estimates of the number of steelhead spawners in the Sandy River basin was generated in 2008 or 2009. The steelhead spawner estimates in 2011 and 2012 were probably biased toward the low end, due to poor survey conditions (Eric Brown, ODFW, pers. comm., 2013). Confidence in the Sandy River steelhead spawner estimates from 2013 and beyond is higher. Steelhead productivity estimates are also complicated by the fact that an unknown proportion of steelhead smolts may be summer steelhead. For instance, roughly 10 percent of steelhead smolts emigrating from Bull Run in 2012, 2013, and 2014 were summer steelhead (Smith et al. 2015). Although there is some likelihood that summer steelhead redds are being counted during winter steelhead spawner surveys, the extent to which this is happening is unclear.

Steelhead and coho smolt populations for the final Sandy River Basin Index Area, the trends in smolt numbers over time, and Sandy River Basin freshwater productivity (smolts per adult) will be calculated after 20 years of annual smolt monitoring, in 2029. The preliminary calculations made in 2017 and those to be made in future years will improve with the collection of additional data.

5.2 Fork Lengths

The observed differences in fork length distribution for steelhead and coho smolts among Sandy River Basin streams monitored in 2017 mirror the differences observed in other years and may be due to one or both of two factors: (1) how rapidly fish are able to grow in each stream, (which is related to stream productivity), and (2) how long they have had to grow. Steelhead and coho weighted mean fork lengths have shown a correlation with water temperature (Strobel 2012). Steelhead smolts also vary in age from 1 to 4 years (Table 18). Their fork lengths, therefore, can reflect varying growth conditions over multiple years, as well as variations from stream to stream in the average length of time spent growing. Coho smolts also vary in age, though to a much lesser degree (Table 19). Scale samples are collected annually from steelhead and coho smolts for determining the proportions of emigrating smolts of various ages. The continued determination of ages

from these scale samples will provide an improved ability to discern between the effects of growth and age.

5.3 Condition Factors

In 2017, average condition factors for both steelhead and coho smolts were generally negatively related to average fork length, but not at a 95% level of statistical confidence ($p=0.17$ for steelhead, and $p=0.07$ for coho). It is unlikely that lower condition factors in fish reflect, in general, poor rearing conditions throughout the year. If lower condition factors reflected poor rearing conditions, then the low condition factors would tend to correlate with low fork lengths overall, which is not the case. A general negative relationship between condition factor and fork length observed frequently in the past for both coho and steelhead could arise from warmer winter temperatures in low-elevation streams in the months prior to capture. Higher metabolic rates in generally inactive overwintering fish associated with warmer water temperatures could result in greater use of fat stores.

5.4 Emigration Dates

Steelhead smolts generally emigrated earlier from low-elevation streams than from higher-elevation streams. Coho smolts, however, showed no such relationship. A similar pattern has been observed in most previous years for steelhead. The reason for the unusually early emigration timing of coho from Gordon Creek and late timing of coho from the Little Sandy and Cedar Creek in 2017 is unknown. These differences in emigration timing could simply be contingent on environmental conditions (e.g., water temperature warms earlier in the year in the lower basin) or could reflect life-history differences contributing to life-history diversity in the Sandy River Basin.

5.5 Age Distribution

The weighted average age of smolts is probably related to stream elevation by way of water temperature. Higher-elevation streams tend to have colder water temperatures, which slow the metabolic rates of fish. In an environment with plentiful food, growth rates are slower in colder streams. It is likely that the portion of fish that fail to reach a sufficient size by the time of smolt emigration have a survival incentive to remain an additional year to grow larger. Conversely, in warmer, low-elevation streams, fish may grow large enough one year early to confer a survival advantage to individuals that avoid an additional year of risk in the stream environment before seeking the rewards of an ocean migration.

6. Findings, Conclusions, and Recommendations

- Population estimates or approximations could be generated for steelhead in eight streams and coho smolts in nine streams in 2017.
- Steelhead smolt estimates were generally relatively high while coho estimates were relatively low in 2017. Beaver Creek had a record high steelhead but a record low coho smolt estimate. Still Creek alone had a relatively high coho estimate, but had an unusually low steelhead estimate. Cedar Creek had low estimates for both species.
- Estimates of steelhead and coho smolt production were generated for the entire Sandy River Basin Index Area for years 2009–2016. More precise estimates will be generated once additional years of smolt monitoring data are available.
- Estimates of freshwater productivity (smolts per adult) were generated for steelhead for parental years 2010–2014 and for coho for parental years 2007–2015.
- Steelhead and coho smolt fork lengths showed significant differences among monitored streams in the Sandy River Basin in 2017. High-elevation streams produced shorter fish of a given age than low-elevation streams, similar to what has been observed in previous years. An exception was Cedar Creek, a mid-elevation stream, which produced unusually short steelhead smolts in 2017.
- Steelhead and coho smolts from different streams in the Sandy River Basin showed significant differences in the average condition factor in 2017. In general, streams with longer smolts of both species showed lower condition factors.
- Steelhead smolts emigrated earlier from low-elevation streams than from high-elevation streams in 2017. Coho emigration timing did not correlate to stream elevation. Gordon Creek coho emigrated early relative to steelhead from other streams, whereas Little Sandy and Cedar Creek steelhead emigrated relatively late. Steelhead emigrated, on average, earlier than coho in most streams.
- A larger proportion of both steelhead and coho smolts emigrating from upper-basin streams were of older ages than smolts emigrating from lower-basin streams.
- These data represent the ninth installment of a long-term data set that will help both evaluate the viability of Sandy River steelhead and coho and guide the restoration efforts that seek to ensure their continued existence.

7. Acknowledgments

The Sandy River Partners would like to acknowledge the efforts and financial support that made the Sandy River Basin Smolt Monitoring Project possible. In addition to the funds provided by the involved agencies (the Portland Water Bureau, U.S. Forest Service, and Oregon Department of Fish and Wildlife) smolt monitoring efforts were also supported by a grant from Portland General Electric. Special thanks to the dedicated field crews that installed, maintained, and removed the numerous traps and checked them on a daily basis in all weather and desperately low flows. Crew personnel included Steve Schaaf, Jon Mueller, and Trevor Diemer from PWB; Olivia Guthrie, Matthew DeAngelo, Nik Floyd, and Catherine Dillon from USFS; and Ryan Queen, Charles Baker, Dave VanAmburgh, and Jack Rees from ODFW. Additionally, Ben Comfort, Ian Carry, Isabelle Guthrie, John Christiansen, and students from the Timberlake Job Corps contributed countless invaluable volunteer hours to help out with the USFS smolt traps.

Eight years' worth of smolt scale samples were aged by the ODFW Fish Life History Analysis Project in Corvallis, Oregon for this project. We are extremely grateful for their efforts. Thanks also to Eric Brown of the ODFW Oregon Adult Salmonid Inventory and Sampling Project (OASIS) for supplying adult steelhead and coho spawner estimates.

8. Works Cited

- Bjorkstedt, Erik P. 2005. DARR 2.0: Updated Software for Estimating Abundance from Stratified Mark-Recapture Data. NOAA/NMFS technical memorandum. NOAA-TM-NMFS-SWFSC-368.
- Bjorkstedt, Erik P. 2010. DARR 2.0.2: DARR for R code. National Oceanic and Atmospheric Administration. <http://swfsc.noaa.gov/textblock.aspx?Division=FED&id=3346>.
- Hutchinson, Matthew W., Jessica L. Vogt, and Alex Neerman. Winter Steelhead of the Clackamas and Sandy Rivers: Spawning Ground Surveys 2006-2007. Oregon Department of Fish and Wildlife, Salem, Oregon. 2007.
- Portland Water Bureau. Bull Run Water Supply Habitat Conservation Plan for the Issuance of a Permit to Allow Incidental Take of Threatened and Endangered Species. Final Draft. Portland Oregon. 2008.
- Scace, Justin G., Benjamin H. Letcher, and John Noreika. "An Efficient Smolt Trap for Sandy and Debris-Laden Streams." *North American Journal of Fisheries Management*, no. 27 (2007): 1276-86. doi: 10.1577/M07-036.1.

- Smith, Christian, Jennifer Von Bargen, and Kieslana Wing, 2015. Genetic assignment to run of steelhead smolts captured in the Bull Run River. USFWS Abernathy Fish Technology Center. Abernathy, Washington.
- Strobel, Burke. Ecosystem Responses to a Large-Scale Salmon Carcass Enrichment Project. Interim report. Mt. Hood National Forest. Clackamas River Ranger District. Estacada, Oregon. 2004.
- Strobel, Burke. 2014. Sandy River Basin Smolt Monitoring, 2013. Portland Water Bureau. Portland, Oregon.
- Strobel, Burke. 2010. Sandy River Basin Smolt Monitoring, 2009. Portland Water Bureau. Portland, Oregon.
- Suring, Erik J., Eric T. Brown, and Kelly M.S. Moore. 2006. Lower Columbia River Coho Status Report 2002 – 2004: Population Abundance, Distribution, Run Timing, and Hatchery Influence; Report Number OPSW-ODFW-2006-6. Oregon Department of Fish and Wildlife. Salem, Oregon.
- Volkhardt, Gregory C., Steven L. Johnson, Bruce A. Miller, Thomas E. Nickelson, and David E. Seiler. 2007. Rotary Screw Traps and Inclined Plane Screen Traps. Pages 235-66 in D. H. Johnson et al. *Salmonid Field Protocols Handbook: Techniques for Assessing Status and Trends in Salmon and Trout Populations*. American Fisheries Society. Bethesda, Maryland.

Exhibit A. All Species and Life Stages Captured at Smolt Traps in the Sandy River Basin in 2017

	Lost Creek	Still Creek	Clear Creek	Salmon River	Cedar Creek	Little Sandy River	Bull Run River	Gordon Creek	Beaver Creek
Bluegill	0	0	0	0	3	0	0	0	32
Carp	0	0	0	0	0	0	0	0	1
Catfish	0	0	0	0	2	3	0	0	2
Chinook Fry	797	977	115	994	0	134	134	3,643	3,693
Chinook Smolts (Wild)	0	0	0	0	1	0	0	0	0
Chinook Smolts (Hatchery)	0	0	0	0	0	0	4	0	0
Chiselmouth	0	0	0	0	0	0	0	0	10
Coho Fry	0	3	11	16	596	55	5	372	123
Coho Smolts (Wild)	10	1,661	299	1,689	114	50	73	45	10
Coho Smolts (Hatchery)	0	0	0	0	0	0	0	0	1
Cutthroat Juveniles	0	1	0	0	10	0	0	1	0
Cutthroat Smolts	0	2	7	1	4	6	1	7	1
Cutthroat Adults	0	4	0	1	11	7	1	9	0
Longnose Dace	0	13	2	1,383	0	271	786	805	39
Speckled Dace	0	0	0	0	0	0	2	30	491
Banded Killifish	0	0	0	0	0	0	0	0	5
Pacific Lamprey Adult	0	0	0	16	1	2	1	9	3
Lamprey Amocete	0	2	59	32	132	0	2	318	71
Northern Pikeminnow	0	0	0	0	0	0	3	24	191
Oriental Weatherfish	0	0	0	0	0	0	0	0	4
Peamouth	0	0	0	0	0	0	0	0	27
Pumpkinseed	0	0	0	0	0	0	0	0	3

	Lost Creek	Still Creek	Clear Creek	Salmon River	Cedar Creek	Little Sandy River	Bull Run River	Gordon Creek	Beaver Creek
Rainbow Trout	2	6	15	3	0	7	5	0	0
Redside Shiner	0	0	0	0	0	0	0	0	94
Sucker	0	0	0	0	0	1	44	62	5
Sculpin	3	4	15	22	0	1	8	55	137
Steelhead Fry	0	0	0	0	3	131	53	1,699	206
Steelhead Juvenile	3	264	578	340	0	57	75	225	47
Steelhead Smolts (Wild)	0	200	138	501	60	221	597	104	128
Steelhead Smolts (Hatchery)	0	0	0	0	0	0	1	0	0
Steelhead Adult	0	1	6	0	0	2	1	0	0
Whitefish Adult	0	1	11	1	0	0	1	1	0

^aChinook, coho, and steelhead fry were too numerous to identify individually in most streams. Salmonid fry were subsampled.

Appendix G

Bull Run HCP Research Report

**Lower Bull Run River
Spawning Gravel Scour
Research**

April 2018

Burke Strobel

City of Portland Water Bureau



Contents

1. Summary	1
2. Introduction	2
3. Research Objective	2
4. Key Questions and Hypotheses.....	2
4.1 Change in Bed Elevation	2
4.2 Depth of Scour	2
4.3 Percentage of Chinook Redds Scoured.....	3
4.4 Scour Depth vs. Discharge.....	3
4.5 Scour Depth vs. Gravel Depth.....	3
5. Methods.....	4
5.1 Research Design.....	4
5.2 Spatial Scale.....	5
5.3 Replication/Duration	5
5.4 Variables.....	5
5.5 Sampling Scheme	6
6. Analysis	7
7. Results	7
7.1 Change in Bed Elevation	7
7.2 Depth of Scour	7
7.3 Percentage of Chinook Redds Scoured.....	8
7.4 Scour Depth vs. Discharge.....	8
7.5 Scour Depth vs. Gravel Depth.....	9
8. Summary and Discussion.....	10
9. Works Cited	12

Figures

Figure 1. Setting a Scour Monitoring Device4

Figure 2. Scour Monitoring Device (right) Next to Pipe and Push Rod (left) used
for Placement4

Figure 3. Scour Monitoring Device Installed in Gravel.....6

Figure 4. Maximum Scour Depths at Seven Chinook Redds Monitored in the
Winter of 2016–20178

Figure 5. Maximum Scour Depths at 23 Gravel Scour Monitoring Devices Placed
in the Winters of 2014–2015 and 2016–20179

Figure 6. Apparent Gravel Depth and Maximum Scour Depths at Gravel Scour
Monitoring Devices Placed in the Winters of 2014–2015 and 2016–201710

1. Summary

The City of Portland Water Bureau (PWB) was in partial compliance with the goals of the Bull Run Water Supply Habitat Conservation Plan in 2017 with regard to spawning gravel scour research in the lower Bull Run River. Seven redds were monitored for gravel scour depth.

Most, but not all objectives of the spawning gravel scour research were met in 2017. Objectives were to measure mean changes in streambed elevation, mean scour depth, and the percentage of redds scoured to the depth of egg deposition. PWB intended to base these statistics on a sample of ten monitored redds. PWB successfully estimated both the mean scour depth and percentage of redds scoured to the depth of egg deposition. Only seven redds were monitored using 14 devices, however, because of the difficulty of maintaining flows low enough to permit installation. At several attempted sites, scour monitoring devices could not be installed deep enough due to shallow underlying bedrock or boulders. Bed elevation at monitored redds was also not measured in 2017 because of the difficulty of transporting the laser level in early winter river flows.

The minimum estimate of mean depth of scour in 2017 was 4.2 inches, with a range of 4.2–9.1 inches. The mean scour depth may have been greater. One monitoring device was scoured down to boulders or bedrock and became dislodged. Although that site was scoured to its maximum extent, the nearby redd may have had thicker gravel deposits and may have been scoured more deeply. Seven scour monitoring devices could not be relocated and may have been completely dislodged or buried by gravel aggradation. Two of seven redds (29 percent) are estimated to have been scoured to the depth of egg deposition and may have been scoured below the maximum depth of egg deposition.

Combined data from 2015 and 2017 indicate that the depth of scour increases generally with the magnitude of river discharge. The large variability of scour depths at any given discharge, however, render the relationship statistically insignificant at the range of discharge monitored to date.

The gravel patches used for spawning by Chinook in the Bull Run River appear to be thin. A total of 31 devices were placed to monitor gravel scour in 2015 and 2017, combined. Of these, seven were at locations where the underlying bedrock or large substrate was shallower than the shallowest depths at which Chinook prefer to bury their eggs. The locations where eggs were actually buried may have been deeper.

Spawning gravel scour studies in both 2015 and 2017 were not able to monitor as many redds as were committed to in the HCP. Scour will be monitored for as many additional winters as necessary to measure the depth of scour at a total of 30 redds.

2. Introduction

The lower Bull Run River experiences high flows during the late fall and winter months, when the Bull Run reservoirs are full and natural high flows exceed the withdrawals of water by the City's facilities. These flows can reach levels that are capable of mobilizing streambed substrates and therefore are a potential cause of mortality to salmonid eggs and alevins residing in the streambed. Flows of 600 cubic feet per second (cfs) and greater—high enough to begin to mobilize some gravels of the size used by spawning Chinook salmon (Carlson 2003)—have occurred every year in the lower Bull Run River for the last 109 years (USGS Gaging Station 14140000, 1908–2015). In the course of HCP negotiations, the National Marine Fisheries Service identified the scouring of Chinook redds to be of particular concern in the lower Bull Run River.

This HCP defines measures to benefit spawning salmon, such as the maintenance of minimum flows in the lower river and the addition of gravel adequately sized for use by spawning salmon (Portland Water Bureau 2008). These efforts can both affect and be affected by the scouring of spawning gravels. This appendix describes sampling methods and protocols for monitoring the effects of high flows on the stability of Chinook salmon redd gravels in the lower Bull Run River and provides a summary of the resultant findings for the winter of 2016–2017. This was the second year that implementation of the spawning gravel scour monitoring protocols described in the HCP was attempted.

3. Research Objective

The objective of this research effort is to measure the effects of high flows on bed elevation and scour depth for a number of sites used by spawning Chinook salmon.

4. Key Questions and Hypotheses

The key questions and related null hypotheses (H_0) to be answered by the Bull Run River spawning gravel scour research are described below.

4.1 Change in Bed Elevation

Question 1: What is the mean change in bed elevation each year and its associated variance at the locations of Chinook salmon redds in the lower Bull Run River?

H_0 : There will be no significant change in bed elevation at the locations of a sample of Chinook salmon redds.

4.2 Depth of Scour

Question 2: What is the mean depth of scour and its associated standard deviation at the locations of Chinook salmon redds in the lower Bull Run River.

H₀: The mean depth of scour will not exceed the assumed upper limit of Chinook egg deposition of 8 inches (Schuett-Hames et al. 1996).

4.3 Percentage of Chinook Redds Scoured

Question 3: What is the percentage of monitored Chinook redds that have significant scour?

H₀: The percentage of scoured Chinook redds will not be more than the 40 percent observed in natural gravel patches (Harvey and Lisle 1999).

The following key questions were added in 2017 and investigated by analyzing combined data from all past gravel scour studies.

4.4 Scour Depth vs. Discharge

Question 4: How does scour depth change with increasing discharge?

H₀: Scour depth will not change with discharge.

4.5 Scour Depth vs. Gravel Depth

Question 5: What is the average depth of scour relative to the depth of gravel?

There is no null hypothesis associated with this key question.

5. Methods

5.1 Research Design

Gravel scour was measured using sliding-bead gravel scour monitoring devices and protocols similar to those described in Nawa and Frissell (1993). These monitoring devices consist of a thin cable attached at one end to a sediment anchor and equipped with some type of stop at the other end. Neutrally buoyant beads are strung on the cable between the sediment anchor and the stop.



Figure 2. Scour Monitoring Device (right) Next to Pipe and Push Rod (left) used for Placement



Figure 1. Setting a Scour Monitoring Device

For the HCP monitoring, the anchor and cable were inserted vertically into the gravel immediately adjacent to a redd as deeply as possible, using a pipe or tube wide enough to accommodate the beads. The insertion pipe or tube was carefully removed so that the beads were buried in a vertical stack in the sediment. Excess cable was left to protrude from the gravel with a marker attached to facilitate its relocation. The number of beads left above the gravel's surface when each scour monitoring device could not be driven deeper was recorded. As gravel was disturbed by high flows, beads were dislodged and slid to the end of the cable at the stop.

The scour monitoring devices were located again in the spring, when river flows had dropped enough to navigate the channel. The locations of monitoring devices were found using detailed descriptions and, if necessary, metal detectors. Once a scour monitoring device was found, the beads at the end of the cable were counted to determine how deep the gravel had been scoured. Scour monitoring devices can be

checked intermittently after storms if flows allow navigation of the river channel. Intermittent visits were not possible in the winter of 2016–2017.

Protocols described in the HCP Appendix F called for measuring bed elevation at each redd site using a laser level and a survey rod with a 5-inch base (DeVries and Goold 1999). This measuring was not done because of the difficulty involved in packing a laser level up the river channel during winter flows.

5.2 Spatial Scale

Chinook redds were monitored in the lower Bull Run River from river mile (RM) 0–3.8. The City surveys this section of the Bull Run River annually for spring and fall Chinook spawning.

5.3 Replication/Duration

Protocols called for ten Chinook redds to be selected per year for monitoring. Based on total redd counts from previous surveys, this amount represents between 10 and 32 percent of the estimated population of Chinook redds.

Monitoring started after HCP Year 5 to allow for five years of gravel placements. The monitoring period covered in this report is from January 4 to July 6, 2017 (the winter of 2016–17). Monitoring will occur during three years between HCP Years 6 and 10. The three years may not be consecutive.

5.4 Variables

The following variables will be measured for each gravel scour monitoring site, if possible:

Bed Elevation (before and after). Surface elevation in inches below the elevation of a benchmark, which will be established nearby at the time of scour monitoring device placement. Bed elevation will be measured as soon as devices are placed and then as soon as possible after the end of March.

Maximum Scour Depth. Depth in inches below the initial bed elevation from which beads were dislodged.

Maximum Flow. The highest discharge that occurred since the previous time a scour monitoring device was checked.

The following variable will be inferred at each gravel scour monitoring site:

Depth of Gravel. Depth of gravel inferred from the depth to which to which gravel scour monitoring device can be driven into the substrate before meeting an unyielding obstruction.

5.5 Sampling Scheme

Chinook redds were identified during Chinook spawning surveys. The lower Bull Run River, from RM 0–3.8, was stratified into reaches based on geomorphic characteristics. These reaches corresponded to those used during Chinook spawning surveys. Protocols called for selecting a total of 10 redds each year for monitoring, with their allocation between reaches corresponding to relative reach length. Within each reach, redds were to be chosen as evenly as possible from each of two general categories: redds created in pool tail-outs, riffle crests, and mid-riffle locations; and redds created in gravel associated with obstructions in the channel (e.g., boulders or bedrock outcrops). These two categories of redd locations were expected to differ in the degree of scour they experienced, with obstructions contributing to more complex flow patterns and turbulence. Redds also had to occur in gravel patches extensive enough to place adjacent scour monitoring devices that were not underlain by shallow bedrock or boulders. In practice, in 2017, redds that were in gravel patches deep enough and wide enough to accommodate adjacent gravel scour monitoring devices were not distributed evenly enough to select with a frequency corresponding to reach length. Selected redds were distributed as broadly along the length of the river channel as possible. In early 2017, high flows also limited access to much of the Bull Run River channel. Flows were decreased artificially for several hours to allow device placement. Under these conditions and limitations, the number of redds that could be monitored was restricted to seven.

Two scour monitoring devices were inserted into the sediment to either side of each active redd to avoid egg mortality associated with monitor placement. The intent was to average the results of the two monitors. For five of the seven monitored redds, however, one of the two devices could not be relocated. The resulting scour values were not an average. Scour monitoring device placements occurred after spawning activity was done to avoid shock to the embryos during what is an especially sensitive stage and to prevent further redd creation from disturbing the placed scour monitoring devices.

The locations of monitored redds and associated scour monitoring devices were recorded. Redd locations were identified for subsequent visits relative to surrounding landmarks using detailed site descriptions.



Figure 3. Scour Monitoring Device Installed in Gravel

Protocols called for measuring bed elevation when the sliding-bead scour monitoring devices were placed and again as soon as possible after Chinook had completed their gravel-rearing life stages (early to mid-May). The monitoring devices, however, were installed after the completion of Chinook spawning surveys, and difficulties with transporting the laser level and tripod through winter flows as well as time constraints prevented the measuring initial bed elevations in 2017. Alternative methods for making bed elevation measurements in the future will be explored.

Scour monitoring devices were not revisited during the winter of 2016–2017. Although the design of the scour monitoring devices permits repeated readings of scour at successively higher flows, it was not possible to revisit devices after device placement in early January and summer low flows in 2017.

6. Analysis

Data Storage. Data are stored in Microsoft® Excel spreadsheets managed by the City of Portland Water Bureau.

Hypothesis Testing. The hypothesis regarding changes in bed elevation will be tested, when data are available, using a paired t-test ($\alpha=0.05$). Mean scour depth will be compared with the estimated 8-inch upper limit for Chinook egg pockets using standard t-tests. The percentage of Chinook redds scoured deeper than 8 inches will simply be compared to the estimate of 40 percent for natural redds in unimpaired streams (Harvey and Lisle 1999).

7. Results

A total of 14 gravel scour monitoring devices were placed at seven redds in the winter of 2016 and 2017. Half of the devices could not be relocated the following summer and yielded no data. One device was found a short distance downstream and was recorded as having scoured to the depth of the device's anchor. The maximum flow the Bull Run River experienced while gravel scour monitoring was underway in 2016–2017 was 6,830 cfs.

7.1 Change in Bed Elevation

Bed elevation at monitored redds was not measured during the winter of 2016–2017.

7.2 Depth of Scour

The mean depth of scour at monitored Chinook redds in 2017 was 6.6 inches, with a standard deviation of 2.1 inches and a range of 4.2 inches to at least 9.1 inches. Mean depth of scour did not exceed the assumed shallow limit of Chinook egg deposition of 8 inches (Schuett-Hames et al. 1996). The scour depth of one location with one of the deepest scours, however, could only be assigned a minimum value. Scour at those

locations had extended at least to the depth of the sediment anchor of the dislodged device but could have been much deeper. Scour depths are summarized in Figure 4.

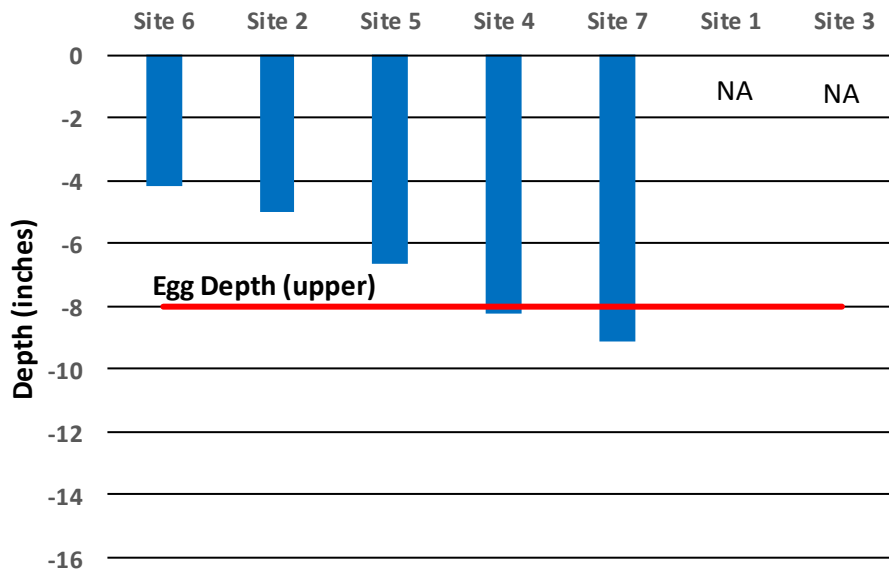


Figure 4. Maximum Scour Depths at Seven Chinook Redds Monitored in the Winter of 2016–2017

7.3 Percentage of Chinook Redds Scoured

Two of five monitored Chinook redds (40 percent) were scoured more deeply than eight inches.

7.4 Scour Depth vs. Discharge

Scour depths observed over two winters increased with maximum experienced discharge. The distribution of depths among monitored devices at each level of discharge was highly variable, but the maximum observed depth increased consistently. The trend in scour depth with discharge, however, was not statistically significant over the range of discharges experienced during the two study years ($p=0.18$) due to the high amount of variability.

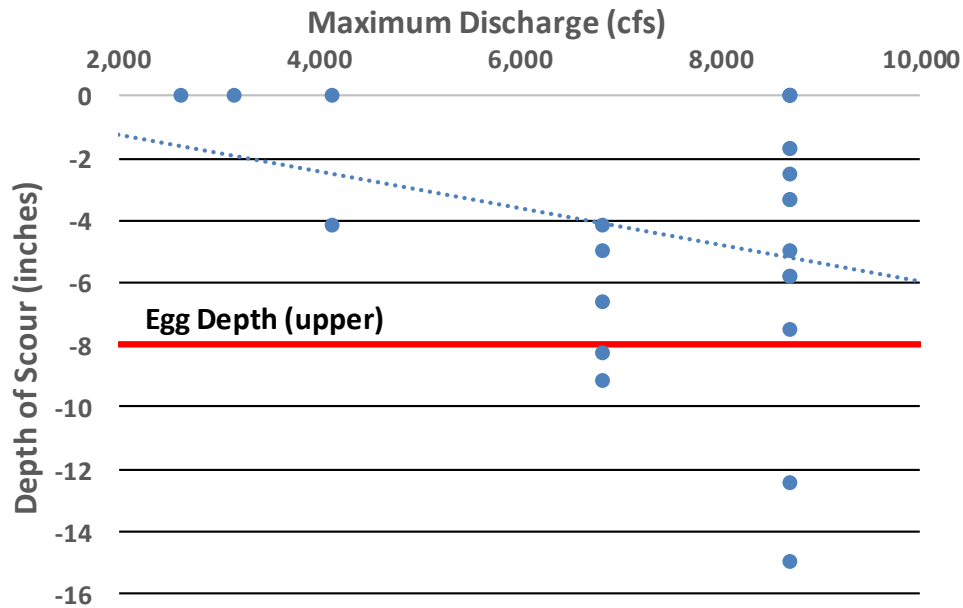


Figure 5. Maximum Scour Depths at 23 Gravel Scour Monitoring Devices Placed in the Winters of 2014–2015 and 2016–2017

7.5 Scour Depth vs. Gravel Depth

Gravel patches used for spawning by Chinook salmon in the Bull Run River tend to be thin. Seven of 23 (30 percent) gravel scour devices placed in the winters of 2014–2015 and 2016–2017 were in gravel that was shallower than the shallowest depths that Chinook prefer to bury their eggs (based on how far scour monitoring devices could be driven into substrate). On average, 46 percent of the available gravel depth was scoured at the flows experienced during the gravel studies.

The complete loss of Chinook redds has been observed during higher flows in the Bull Run River when 100 percent of the available gravel depth was scoured. A flow of 11,800 cfs in 2017 in the Bull Run River resulted in a loss of at least 25 of 48 (48 percent) observed redds where there was a complete removal of gravel down to bedrock or large substrate. A flow of 13,100 cfs in 2013 resulted in an apparent loss of the majority of 123 identified redds.

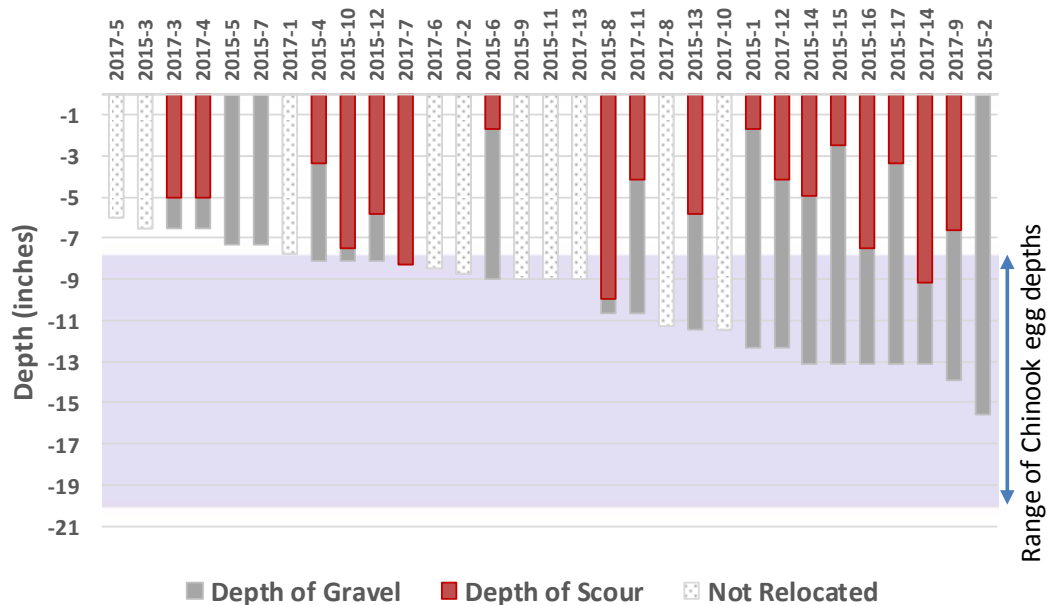


Figure 6. Apparent Gravel Depth and Maximum Scour Depths at Gravel Scour Monitoring Devices Placed in the Winters of 2014–2015 and 2016–2017

8. Summary and Discussion

Forty percent of Chinook redds monitored in 2016–2017 were scoured to a depth likely to threaten deposited salmon eggs (8 inches, Schuett-Hames et al. 1996). A lower percentage of monitored redds were scoured deeper than 8 inches in 2014–2015 despite the Bull Run River experiencing a higher peak discharge in the winter of 2014–2015 than in the winter of 2016–2017. This discrepancy is probably due to chance and the highly variable nature of gravel scour. Qualitative observations of changes in gravel patch size and depth suggest that some gravel patches may suffer high rates of particle turnover, with deep scour and subsequently high re-accumulation of gravel particles. The results of the spawning gravel scour research demonstrate that there is a wide variety of localized scour conditions and that large gravel accumulations do not necessarily indicate ideal spawning opportunities.

The depths to which gravel scour monitoring devices could be driven into the substrate in 2014–2015 and 2016–2017 suggest that even redds that do not experience scour depths greater than 8 inches may still be at risk. Gravel patches appear to be fairly shallow in the Bull Run River, and it is likely that it is difficult for Chinook to bury their eggs as deeply as they would prefer. If redds were buried under less than 8 inches of gravel, then a higher percentage would be affected by the observed degree of scour. To protect deposited eggs, scour monitoring devices were placed adjacent to monitored salmon

redds rather than within the redds. It is possible that the gravel was deeper at the location of egg deposition.

Chinook redds are often subjected to river discharges that are higher than those observed during the two study years and probably experience higher incidences of scour. Observations of redd loss in 2013 and 2017 after much larger flood events showed significant losses of entire gravel patches used for spawning that were scoured to the underlying bedrock (unpublished observations).

Because of the difficulties with meeting all research objectives in the winters of 2014–15 and 2016–2017, PWB will adjust its monitoring objectives for spawning gravel scour research in the Bull Run River. The original intent was to monitor ten redds per year for three years. PWB will instead continue monitoring until gravel scour has been evaluated at a total of 30 redds, which will require more than three years of monitoring. Currently scour has been successfully evaluated at thirteen redds.

9. Works Cited

- Carlson, K. 2003. Estimated Potential of Salmonid Spawning Gravel Scour in the Lower Bull Run River. Technical Memorandum prepared for Steve Kucas, May 28, 2003. 31 pp. Portland, Oregon.
- DeVries, P. and J. Goold. 1999. Leveling rod base required for surveying gravel river bed surface elevations. *Water Resources Research*, Vol. 35: 2877–79.
- Harvey, B.C. and T.E. Lisle. 1999. Scour of Chinook redds on suction dredge tailings. *N Am J Fish Manag* 19: 613–617.
- Nawa, R.K., and C.A. Frissell. 1993. Measuring scour and fill with scour chains and sliding bead monitors. *N. Am. J. Fish. Manage.* 13: 634–9.
- Portland Water Bureau. 2008. Bull Run Water Supply Habitat Conservation Plan for the Issuance of a Permit to Allow Incidental Take of Threatened and Endangered Species. Portland, Oregon.
- Schuett-Hames, D., B. Conrad, A. Peus, and K. Lautz. 1996. Literature Review and Monitoring Recommendations for Salmonid Spawning Gravel Scour. Report No. TFW-AM-9-96-001. Washington Timber, Fish, and Wildlife Monitoring Program. Olympia, Washington.



Appendix H

Bull Run HCP Research Report

Western Toad Monitoring for Reservoir Operations Measure R-3

January 2018

John Deshler

City of Portland Water Bureau



Contents

1. Summary	1
2. Introduction.....	2
3. Objectives.....	2
4. Monitoring Methods	3
5. Analysis	5
6. 2017 Results and Discussion	7
7. Comparison of 2016 and 2017.....	9
8. Approach for 2018.....	11
9. Works Cited	12

Figures

Figure 1. Toad Monitoring Areas.....	6
Figure 2. Western Toad Hatchlings and a Rough-skinned Newt Clinging to Reed Canarygrass at the Area 1 Control Site.....	9

1. Summary

The City of Portland Water Bureau (PWB) was in full compliance with its Habitat Conservation Plan obligations in 2017 regarding reservoir operations measure R-3, Reed Canarygrass Removal. The reed canarygrass was cut and raked off three areas along the north bank of the upper end of Bull Run Reservoir 1 on April 18. In addition, the grass was cut and raked away a second time on September 26 to improve amphibian breeding and rearing habitat for the following year.

Measure R-3 is intended to benefit western toads (*Bufo boreas*) and northern red-legged frogs (*Rana aurora*). Evaluating the effectiveness of PWB's efforts to improve toad and frog breeding habitat in the three areas was not part of the measure. However, in 2016, PWB chose to begin monitoring water temperature and toad breeding site selection to determine whether the measure was having the desired outcomes for toads. This appendix summarizes the results for 2017, the second year of monitoring.

For 2017, the cutting and removal of reed canarygrass did not warm the water for egg and larval development, and there was no difference in water temperature between control and treatment sites. However, the water remained warm ($> 14^{\circ}\text{C}$; range 15°C – 24°C) at the breeding sites throughout the egg and larval development period, so the lack of a treatment effect did not negatively impact toads. Tens of thousands of eggs were laid, and they appeared to develop and hatch quickly—in about 7 days. As the season progressed, hatchlings and tadpoles had sufficiently warm water for development. Ultimately, however, very few tadpoles reached the toadlet stage.

Most eggs were laid at the control site of the eastern area (Area 1 in Figure 1 below). So, in 2017, as in 2016, most eggs were laid where the grass had not been cut and removed. However, it is believed that toads are intentionally selecting areas with the invasive grass. Toads appear to be reusing their historical breeding areas, regardless of the presence of reed canarygrass, because this is (1) where they find warm, shallow, calm, off-channel waters, and (2) where they have gathered annually each spring for communal breeding. Toads have bred at Area 1 since at least the 1980s, and photographic evidence shows little or no reed canarygrass in the area at that time.

Beginning in 2018, PWB plans to treat invasive reed canarygrass more aggressively in all of Area 1 so the habitat at the area that the toads are primarily selecting for communal breeding more closely resembles habitat at other, more productive toad breeding sites on the west slope of the Cascades. While it is not known why toad productivity in the Bull Run Watershed was low in 2017, we believe that more aggressive treatment may improve productivity. The fundamental rationale is that returning the habitat to a condition more like it was prior to reed canarygrass invasion will benefit toads.

Additionally, PWB plans stop cutting and removal of grass at Area 2, where no breeding has been documented. The Area 3 treatment site will continue to be cut. The goals of

monitoring will also change in the 2018 Annual Compliance Report to reflect the new focus on treating Area 1.

2. Introduction

PWB committed through Measure R-3 in its Bull Run Water Supply Habitat Conservation Plan (HCP; Portland Water Bureau 2008) to attempt to improve breeding habitat for western toads (*Bufo boreas*) and northern red-legged frogs (*Rana aurora*) at three designated areas along the north bank of the upper end of Bull Run Reservoir 1. To fulfill the HCP commitment, PWB staff annually cuts and rakes reed canarygrass away from the three areas. While the measure is intended to benefit both amphibian species, the focus of the measure has been on toads because toads are considered uncommon in the Bull Run watershed and breed only at the upper end of Reservoir 1, whereas northern red-legged frogs are common, widespread breeders.

Measure R-3 is based primarily on the premises that (1) toad eggs need warm water to develop properly, and (2) shade from the tall, non-native invasive canarygrass could potentially lower the water temperature where eggs are laid. Cutting and raking away the grass is intended to allow sunlight to penetrate and warm the water so that eggs may develop properly.

In 2016, PWB began investigating whether implementation of the measure was having the desired outcomes for toads, even though evaluating the effectiveness of the measure was not part of the measure.

In the process of attempting to improve breeding habitat for western toads, lessons have been learned, and PWB will be changing the objectives of Measure R-3 in the 2018 HCP Annual Compliance Report.

This appendix describes the monitoring objectives and results for the second year.

3. Objectives

The objectives of western toad monitoring are to determine:

- whether the water is warmer where grass is cut and removed,
- whether toads select treated (cut) sites for egg laying, and, if so, which ones,
- the onset and duration of breeding effort (first and last dates of egg laying),
- the magnitude of the breeding effort (number of breeding adults, points of oviposition), and
- breeding outcomes (did offspring reach the toadlet stage).

An overarching goal of monitoring is to determine how management of the Reservoir 1 water level may affect toad breeding. More specifically, PWB wants to learn whether and how the reservoir could continue to be managed to allow toad breeding to persist

and succeed at the upper end of the reservoir each spring, without interfering with water supply requirements and goals or with the requirements of the HCP.

To achieve these objectives, PWB is engaging in monitoring at the three areas.

4. Monitoring Methods

Toad surveys are conducted in the spring. May is the focal month for surveying because it is the month when breeding adults and eggs have been observed in prior years. In 2017, the monitoring period was April 18 through August 9. Of the eleven field survey days, five were in May. Grass cutting occurred on April 18.

Three areas were surveyed. Each area had a treatment site where grass was cut and removed and an uncut control site. At each treatment and control site, a metal stake was placed in the ground to mark the center of the site. See Figure 1 for the locations of the three areas and the treatment and control sites.

The stakes at Areas 1 and 2 remained at approximately the same locations as in 2016 but were moved slightly in 2017 so that they were at the same elevation. The treatment stake at Area 3 remained at its 2016 position, but the control stake at Area 3 was moved to an area of uncut reed canary grass that was closer to the treatment area.

Water Temperature

At each stake, a temperature sensor was attached to a float such that the sensor was suspended 30-cm below the water's surface, the approximate depth of toad egg laying. The sensors collected water temperature data hourly throughout the monitoring period.

During each field survey day, all three areas were visited, and reed canarygrass height and water depth were measured at the stake of each treatment and control site. Reed canarygrass height was determined by finding the tallest stem within a one-meter radius of the stake. If water was present at the stake, water temperature was collected at a depth of 30-cm.

Toads are known to initiate breeding when the water at their communal breeding sites reaches 14 °C (Marc Hayes, Washington Department of Fish and Wildlife, personal communication). This water temperature threshold is an important indicator of breeding onset and is the minimum temperature needed for egg and larval development. Data from the Bull Run watershed have also shown that toads begin breeding when the water at their preferred breeding areas rises to 14 °C in spring (Portland Water Bureau 2016).

Breeding Site Selection

A site was considered a breeding site if eggs or breeding pairs in amplexus (mating position) were observed there.

Onset, Duration, and Magnitude of Breeding Effort

During each survey, adult toads, pairs in amplexus, new points of egg oviposition, and juvenile toads (tadpoles and toadlets) were counted at each site. Adult male and adult female toads were tallied separately or as “unknown sex” when identification was not possible. The sexes were identified by size (females much larger) and amplexus position (males on top).

The survey conducted at the onset of breeding was the first survey when eggs or pairs in amplexus were found. The duration of breeding began with breeding onset and ended on the last date when new points of oviposition were found.

The magnitude of breeding effort was assessed qualitatively and was based primarily on the number of eggs observed, the number of points of oviposition, and the size (area) of the points of oviposition. The number of observed breeding adults was also a factor.

Breeding Outcomes

Productivity is defined as the number of toadlets produced. Because we are using noninvasive observational methods to detect toadlets, productivity can be described only qualitatively (for example, “none,” “few,” or “many” toadlets produced). The qualitative descriptions are relative to the many thousands of toadlets that are detected dispersing from other regional breeding sites and sometimes historically at Reservoir 1.

The toadlet stage is reached when larval toads absorb their tails and move from the aquatic to the terrestrial environment. Toadlets are often highly conspicuous as they disperse in large numbers from breeding areas into the forest over a period of a few to several days. Toadlet dispersal is the last time that surveys are likely to detect toads during the year.

5. Analysis

Water Temperature

To determine whether water temperature is affected by grass cutting and removal, comparisons of water temperature were made between the treatment and control sites of each area. Pairwise *t*-tests were used to compare water temperatures. Temperatures were only used when ≥ 30 cm of standing water was present at both. The comparisons were based on daytime temperatures collected between May 24 and July 10, the period when the sites were watered, and egg and larval development were known to occur. Daytime temperatures were those taken hourly from 10:00 to 16:00, when solar radiation and shading by uncut grass were most likely to affect water temperature.

Breeding Site Selection

Breeding site selection was examined in the current year and in the prior year to determine whether toads are selecting the same areas each year for breeding and to compare the magnitude of breeding effort at each area.

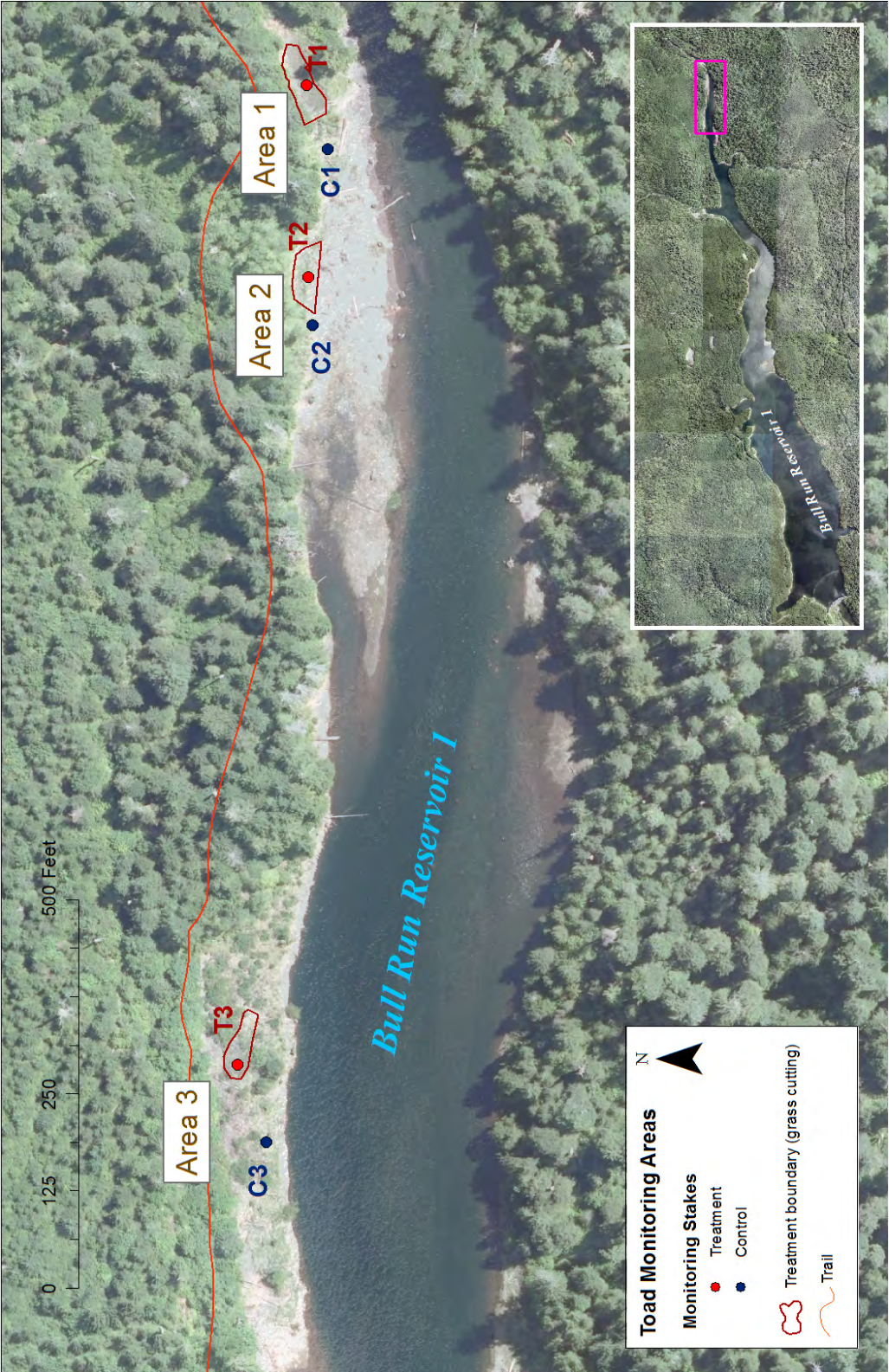


Figure 1. Toad Monitoring Areas

6. 2017 Results and Discussion

Water Temperature

Grass cutting did not appear to affect water temperature at Areas 1 and 2 during the period of egg and larval development. At Area 1, the area where most eggs were laid, the average water temperature at the treatment site was nearly identical to the control site ($s=18.26$ °C and 18.22 °C respectively; $t = 0.2$, $P = 0.421$, $df=546$). At Area 2, the treatment and control site average temperatures were also nearly identical ($\bar{x}=18.57$ °C and 18.74 °C respectively; $t = -1.0$, $P = 0.159$, $df=546$). At Area 3, the control site was seldom wetted, making temperature comparisons there impossible.

During the egg and larval development period, the median daytime water temperature at Area 1 was 18.2 °C. During only two of the 47 days did daytime temperatures fall below 14 °C, indicating that toad eggs and larvae were adequately warmed during their development.

Once the 14 °C temperature threshold was reached and toads began breeding at Area 1, variation in water temperature may not have been a major factor in juvenile development because daytime water temperatures gradually increased, homogenized, and remained warm (> 14 °C), especially at the Area 1 control site where most toads bred. The homogenization of temperatures occurred as the water depth increased from around one foot to more than three feet deep.¹

During the week prior to the onset of breeding, water temperatures at the Area 1 treatment site were higher than at the neighboring control site ($\bar{x}=12.63$ °C vs. 9.78 °C; $t = 5.71$, $P < 0.0001$, $df=96$). This temperature difference may have impacted the initial breeding site selection because water at the Area 1 treatment site was sometimes > 14 °C during that week. By May 25, water temperatures at both the treatment and control sites of Area 1 were > 14 °C and were then similarly warm for the remainder of the spring season. It was unknown whether the grass cutting created this early season temperature difference or whether it was due to other factors.

Breeding Site Selection

Toads laid eggs at two of the treatment sites and one of the control sites. Most eggs were laid at Area 1, the eastern area, and most of the eggs at Area 1 were at the control site, not the treatment site. This year was the second consecutive year that toads primarily used Area 1. No breeding occurred at either the treatment or control site of Area 2 (the

¹ The increased depth was the result of spring inflows and Reservoir 1 level management (i.e., lowering the gates at Dam 1).

central area) or at the control site of Area 3 (the western area). One small point of oviposition was noted at the Area 3 treatment site, presumably from one female.

Although most of the egg laying that occurred at Area 1 was at the control site, the first site used for breeding was the Area 1 treatment site. This site was the first site to reach the 14°C threshold.

Onset, Duration, and Magnitude of Breeding Effort

Toad breeding occurred during a two-week period from May 24 through June 7. The initial pulse of breeding effort was first observed at the Area 1 treatment site on May 24. Five (5) breeding pairs were observed in amplexus, and eggs had begun to be deposited at three points of oviposition. Toads then laid eggs in a broad area at the control site of Area 1. Many thousands of eggs were widely distributed at the control site, presumably from many females. By May 31, the initial, large pulse of breeding effort was complete, and no adults were present at Area 1 despite water temperatures consistently > 16 °C. The last detections of breeding effort, two new points of oviposition, were on June 7.

Breeding Outcomes

Despite seemingly abundant egg and hatchling production in late May and early June, productivity by the toads ultimately was low. By mid- to late June, few tadpoles were found in the area. In early July, no tadpoles were detected anywhere. Then, in mid-July, only three toadlets and a few dozen tadpoles with developing hind legs were discovered near the Area 1 control site.

PWB and U.S. Forest Service staff, in some past years, have observed many thousands of toadlets migrating into the forest at the upper end of Reservoir 1 in late summer (Steve Kucas, Chad Hall, and Charlotte Corkran, personal communications). However, this phenomenon has not been reported by staff for approximately 10 years, and it has not occurred during the two recent years of more intensive toad monitoring. For the past two years, toad productivity appears to have been very low.

In 2017, it appeared that predation of hatchling and larval toads by rough-skinned newts (*Taricha granulosa*) and garter snakes (*Thamnophis* species) may have impacted toad productivity. Rough-skinned newts are abundant at Reservoir 1 and were present during each survey whenever the areas were watered. During the hatchling phase of development in late May and early June, newts with distended abdomens were observed among large groups of hatchling toads but were not seen actively foraging on them (Figure 2). Predation by garter snakes may also have been a factor. Garter snakes were absent during early spring, but were abundant and actively foraging in the water at the toad breeding areas in June and July. During one survey, a garter snake was observed in the water swallowing a juvenile salamander. Fish and predatory birds such as herons were never observed in the toad breeding areas and are not believed to be major predators at these sites.



Figure 2. Western Toad Hatchlings and a Rough-skinned Newt Clinging to Reed Canarygrass at the Area 1 Control Site

7. Comparison of 2016 and 2017

Water Temperature

In both 2016 and 2017, once the water temperatures exceeded the 14 °C threshold and toads bred, the temperatures tended to remain warm during the developmental period regardless of whether the sites were treated (cut) or not. Toad eggs and larvae, therefore, had the potential to be adequately warmed regardless of whether a site was cut or not, as long as the sites remained watered.

In 2016, a slight warming effect (0.6 °C) was detected at the treatment sites of Areas 1 and 2 during the first weeks after breeding began, whereas in 2017 no warming effect was found.

It remains unknown what factors are driving the minor variation in water temperatures at the treatment and control sites in some years, but this potential for minor variation may not be an effect of treatment. For example, the treatment site at Area 1 may be the first to warm simply because it receives slightly more sunlight due to gaps in the neighboring forest canopy.

Although the comparisons of water temperatures at the treatment and control sites are reasonable given the need to comply annually with the requirements of Measure R-3 (cut the grass), the comparisons are confounded because treatment and control sites were not selected randomly and are not identical. Toads had already begun using certain sites for breeding before treatment was started. Treatment sites tend to be at the farthest margins and were chosen based on the known historical presence of toads. The control sites are slightly closer to the main channel of the reservoir and were selected years later based on their proximity to the treatment sites.

Breeding Site Selection

In general, minor variation in water temperature and substantial variation in grass conditions at the control and treatment sites did not appear to have a strong effect on the location of egg deposition in either year. Most eggs in both years were deposited throughout Area 1.

What was clear in both years is that the earliest breeding pairs are selecting Area 1 and that this is the most important breeding area. In 2016, the waters warmed rapidly, and many pairs initiated breeding at the same time throughout the Area 1 treatment and control sites. In 2017, the earliest few pairs used a micro-site (a portion of the Area 1 treatment site) where the water was calmest and the temperature first reached the 14 °C threshold. Within one week, however, egg deposition showed that many other pairs had used a broad area encompassing the treatment and control stakes and laid most eggs where the grass was not cut.

Onset, Duration, and Magnitude of Breeding Effort

Breeding onset in both years was in May, but egg-laying began approximately three weeks earlier in 2016 than in 2017. The timing of breeding onset in both years was consistent with calm, shallow waters at the areas reaching the 14 °C threshold.

In 2016, the duration of breeding was about one week longer than in 2017. Pairs in 2016 were known to have laid eggs from approximately May 3 to May 23, a nearly three-week interval. In 2017, known instances of egg laying were confined to a two-week period. We speculate that the very warm temperatures and large fluctuations in reservoir levels in May of 2016 may have contributed to a longer and more scattered breeding season that year.

More adults and breeding pairs were observed in 2016 than in 2017 (44 adults vs. 17 adults, respectively). However, the difference in the number of adults observed was likely due to the timing of the weekly surveys coinciding with the presence of toads in the water. In 2016, many toads were observed during early surveys, whereas in 2017 it was evident that many pairs arrived, laid eggs, and departed in the interval between the surveys on May 24 and May 31 without being observed. Five pairs were copulating and had begun laying eggs in a single shallow pool on May 24, 2017. Then, on May 31, tens of thousands of eggs in an adjacent area were evidence that many other pairs had also bred.

Qualitatively, the magnitude of the breeding effort in both years seemed similar. Tens of thousands of eggs were deposited at an area of similar size in an initial pulse of breeding effort. In each year, some pairs bred a little later but did not produce nearly as many eggs as in the initial pulse of breeding.

Breeding Outcomes

In 2016, most eggs were known to have desiccated due to reservoir fluctuations. There was no known productivity (toadlets) in 2016.

In 2017, productivity was very low. In May, reservoir levels and water temperatures were adequate, and many thousands of eggs were laid. In June, thousands of hatchlings had developed into free-swimming tadpoles. However, by July, the situation had changed, and detections of tadpoles were few. On July 19, the last date when any toad detections were made, only three larval toads were observed at the water's edge. These individuals were nearing the toadlet stage but had not fully absorbed their tails (see Appendix H cover photo). On that date, only a few dozen other toad tadpoles with hindlimbs were observed in the water.

8. Approach for 2018

Beginning in 2018, PWB plans to shift the focus away from grass cutting to affect water temperature and focus instead on more aggressive treatment of the invasive weed in all of Area 1 (both the control and treatment sites) where toads have concentrated their breeding. The intent of the more aggressive treatment is to make Area 1 more closely resemble habitat similar to other toad breeding sites on the west slope of the Cascades where reed canarygrass has not invaded. Typically, toad breeding sites are nearly devoid of vegetation.

Treatment in 2018 may include cutting (weed-whacking) and removal, hand-pulling, solarization, flooding, or other nontoxic methods that reduce the grass and maintain water quality. Focusing the treatment at Area 1 may improve toad productivity.

Additionally, PWB plans stop cutting and removal of grass at Area 2, where no breeding has been documented during the past two years. The Area 3 treatment site will continue to be cut. The goals of monitoring will also change in 2018 to reflect the new focus on treating Area 1.

Because results from 2016 and 2017 showed that toads focus their breeding efforts at the Area 1 control site where the grass was uncut, and because grass cutting produced no strong effect on water temperature, no future tests of whether the water is warmed by cutting are planned. Water temperatures will continue to be monitored each year at Reservoir 1 and Area 1 to strengthen the correlation between water temperatures at Dam 1 and the breeding areas. Improved understanding of this temperature correlation facilitates the prediction and postdiction of toad-breeding onset and the possibility of successful breeding. In general, when the daily maximum water temperature at Reservoir 1 Dam 1 first reaches approximately 13 °C each spring, the water temperature at Area 1 reaches the 14 °C threshold that initiates toad breeding.

9. Works Cited

- Portland Water Bureau. 2008. Bull Run Water Supply Habitat Conservation Plan for the Issuance of a Permit to Allow Incidental Take of Threatened and Endangered Species. Portland, Oregon.
- Portland Water Bureau. 2017. Bull Run Water Supply Habitat Conservation Plan Annual Compliance Report 2016 – Year 7. Portland, Oregon. 273 pp.

Appendix I

Bull Run HCP Effectiveness Monitoring Report

Correspondence on Measures

April 2018

City of Portland Water Bureau



Appendix I. Correspondence on Measures

Note: Each item refers to two pieces of correspondence: a letter from the Portland Water Bureau (PWB) to the National Marine Fisheries Service (NMFS) and the NMFS response. Letters appearing in previous reports are summarized and appear in gray. If the appendix includes letters relevant to the current compliance year, the letters are summarized and presented in full following the summaries.

Correspondence Summaries from Compliance Reports 2010–2016

Item 1. April 26, 2011, letter from Steve Kucas, PWB, to Ben Meyer, NMFS, proposing to create conservation easements in another subbasin of the Sandy River watershed to replace the benefits of Measure H-22, Boulder 1 Riparian Easement

May 11, 2011, letter from Michael Tehan, NMFS, to Steve Kucas, PWB, authorizing the City to implement conservation easements in Gordon Creek to compensate for Measure H-22

Item 2. July 22, 2011, letter from Steve Kucas, PWB, to Ben Meyer, NMFS, proposing to place large wood pieces in another subbasin of the Sandy River tributary to replace the benefits of Measure H-26, Boulder 0 and 1 LW Placement

August 16, 2011, letter from Ben Meyer for Michael Tehan, NMFS, to Steve Kucas, PWB, authorizing the City to place large wood in Gordon Creek to compensate for Measure H-26

Item 3. August 22, 2011, letter from Steve Kucas, PWB, to Ben Meyer, NMFS, requesting authorization to use riparian easements on lower Bull Run or Sandy River parcels in fulfillment of HCP riparian easement targets

September 16, 2011, letter from Michael Tehan, NMFS, to Steve Kucas, PWB, authorizing the City to purchase some parcels of land on the lower Bull Run or Sandy River and create riparian easements to fulfill HCP easement targets

Item 4. February 14, 2012, letter from Steve Kucas, PWB, to Ben Meyer, NMFS, requesting authorization to increase the number of large wood structures in Trout Creek reach 1A in lieu of adding wood in Trout Creek reach 2A for Measure H-7

March 15, 2012, letter from Michael Tehan, NMFS, to Steve Kucas, PWB, authorizing the City to place additional large wood structures in Trout Creek reach 1A in lieu of placing them in Trout Creek 2A

- Item 5.** December 9, 2011 letter from Steve Kucas, PWB, to Ben Meyer, NMFS, requesting authorization to obtain conservation easements in the Sandy River reach 2 instead of reach 1, establish easements wider than 100 feet wide in the lower Sandy River, and establish conservation easements on lands owned by The Nature Conservancy

January 5, 2012, letter from Michael Tehan, NMFS, to Steve Kucas, PWB, authorizing the City obtain conservation easements in the Sandy River reach 2 in lieu of reach 1, obtain conservation easements in sites wider than 100 feet pending NMFS review and giving priority to parcels on side-channels, and establish conservation easements on lands owned by The Nature Conservancy

- Item 6.** September 18, 2012, letter from Steve Kucas, PWB, to Ben Meyer, NMFS, requesting authorization to obtain conservation easements along the main stem of the Sandy River in lieu of Gordon Creek and establish a long-term 200-foot-wide easement on the Camp Collins property

September 25, 2012, letter from Michael Tehan, NMFS, to Steve Kucas, PWB, authorizing the City to obtain conservation easements along the main stem of the Sandy River in lieu of Gordon Creek and establish a long-term 200-foot-wide easement on the Camp Collins property

- Item 7.** April 2, 2013, letter from Steve Kucas, PWB, to Ben Meyer, NMFS, requesting authorization to discontinue implementation of Measure R-2, Cutthroat Trout Rescue

April 26, 2013, letter from Michael Tehan, NMFS, to Steve Kucas, PWB, authorizing the City to discontinue implementation of Measure R-2, Cutthroat Trout Rescue

- Item 8.** August 6, 2013, letter from Steve Kucas, PWB, to Marc Liverman, NMFS, requesting authorization to fund fish carcass placement in reaches other than those specified in the Habitat Conservation Plan (HCP) for Measures H-25 and H-29

December 3, 2013, letter from Kim W. Kratz, NMFS, to Steve Kucas, PWB, authorizing the City to fund fish carcass placement in reaches other than those specified in the Habitat Conservation Plan (HCP) for Measures H-25 and H-29

- Item 9.** November 18, 2014, letter from David G. Shaff, PWB, to Kim Kratz, NMFS, requesting confirmation that the Habitat Conservation Plan (HCP) Implementing Agreement documents the City's commitment to forgo consumptive use of the Little Sandy River and serves as the Little Sandy Flow Agreement for Measure F-4

December 4, 2014, letter from Kim W. Kratz, NMFS, to David G. Shaff, PWB, confirming that the City has documented its commitment to forgo exercise of its rights and claims to the Little Sandy River and that no additional flow agreement is required for Measure F-4

- Item 10.** March 31, 2015, letter from Steve Kucas, PWB, to Marc Liverman, NMFS, requesting approval to pursue implementing off-channel habitat improvements in the Sandy River, reaches 1 and 2, in lieu of implementing Measure H-9, Sandy 1 Channel Reconstruction

April 14, 2015, letter from Kim W. Kratz, NMFS, to Steve Kucas, PWB, approving the City's proposal to pursue the proposed alternative habitat improvement measures in lieu of implementing Measure H-9

- Item 11.** July 10, 2013, letter from Steve Kucas, PWB, to Ben Meyer, NMFS, requesting approval to shift the location of some of its conservation easement acreage targets to other locations within the Sandy River Basin that provide equal or greater benefits to fish.

July 12, 2013, letter from Michael P. Tehan, NMFS, to Steve Kucas, PWB, approving the City's request to shift some of its conservation easement acreage targets to other locations within the Sandy River Basin and requesting identification of the specific reaches that would be in the new target area.

- Item 12.** March 9, 2016, letter from Steve Kucas to Marc Liverman, NMFS, requesting acquisition of additional conservation easement acreage targets in reaches Sandy 7 and 8 within the Sandy River Basin that provide good benefits to fish.

February 13, 2017, letter from Kim W. Kratz, NMFS, to Steve Kucas, PWB, approving acquisition of conservation easement acreage targets in reaches Sandy 7 and 8