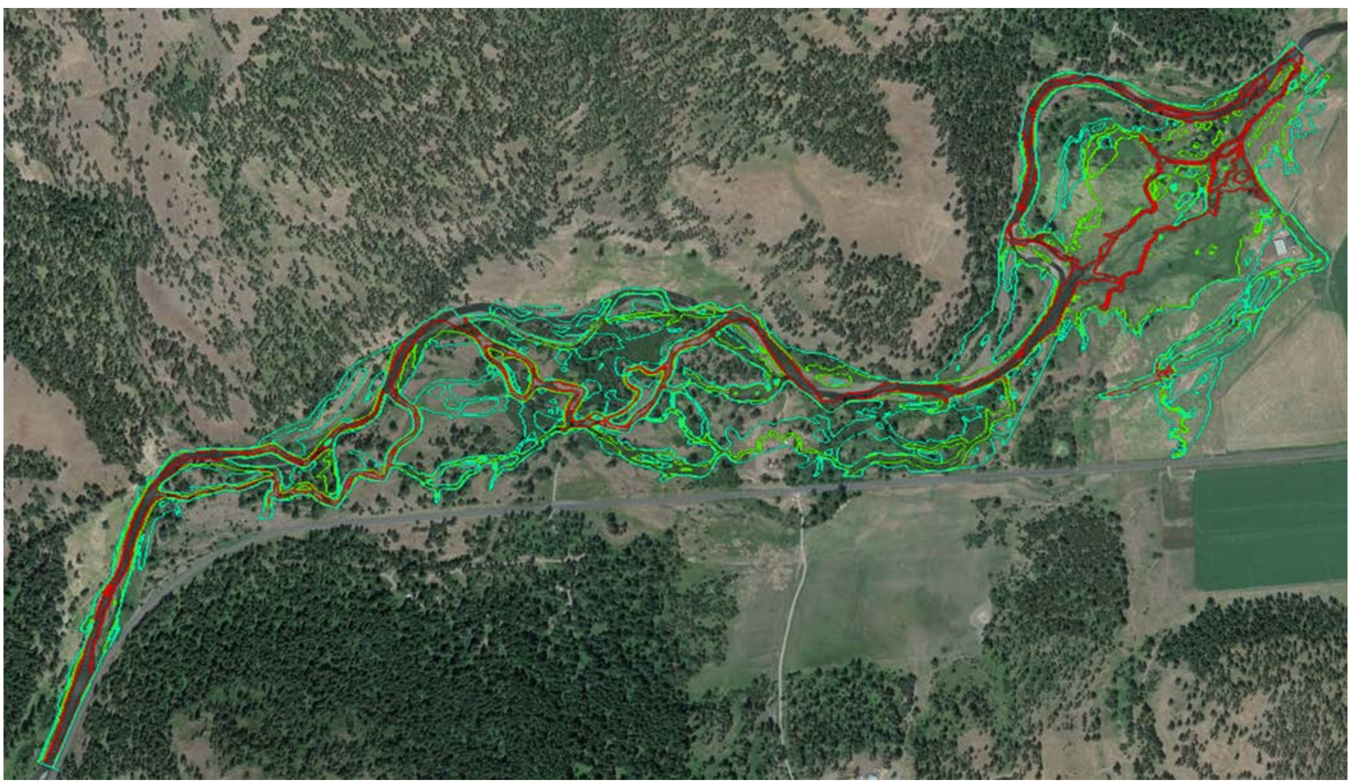
River Restoration Freeboard Design Requirements

Science and Technology Program
Research and Development Office
Final Report ST-2020-1798
Hydraulics Laboratory Technical Memorandum PAP-1192



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14. ABSTRACT
Data from water surface elevation and atmospheric loggers at Bird Track Springs restoration project on the Grande Ronde River in La Grande, Oregon was compared to the numerical model performed by Ubing (2018) for a low flow rate, March median flow rate, winter high flow rate, 1.25-, and two 50-year storms that happened during the winter and spring runoff season from 2019 to 2020. The numerical model performed extremely well when compared to observed water surface elevation data recorded by the loggers, underestimating the water surface elevation by an average of 0.7 ft. The area of the largest deviation from the observed data was under the lowest discharge conditions and the winter high flow. Some portions of the main channel that were anticipated to be dry continued to have flow during this dry period. However, this may be due to pooling on-site, or changes to the bed-forms following large flow events as opposed to connected flow. Additionally, the winter high flow storm selected for comparison between the model and on-site data may have been incorrect for this assessment. Removing these events, the average difference in water surface elevation falls to 0.6 ft.

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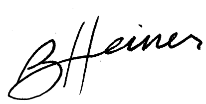

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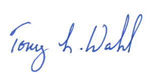

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Acronyms and Abbreviations

Reclamation	Bureau of Reclamation
CTUIR	Confederated Tribes of the Umatilla Indian Reservation
Cfs	cubic feet per second, unit of discharge
S&T	Bureau of Reclamation Science and Technology Program

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Executive Summary

The Bureau of Reclamation (Reclamation) has been actively designing and implementing river restoration projects to meet the requirements of the Biological Opinion for the Federal Columbia River Power System. The design process for these projects is extensive with many concepts and numerical models assessed before reaching the final design. Several of these projects were completed in recent years. An example of one of these projects is Bird Track Springs which was completed in winter of 2019 and is located along the Grande Ronde River in La Grande, Oregon. This approximately 5-mile long site includes the addition of pool-riffle complexes throughout the main channel of the stream, construction of side channels with alcoves, large woody debris structures, and opening the floodplain for added storage. After construction was completed, fifteen water surface level loggers and one atmospheric logger were installed at key locations throughout the site. The goal of this project is to compare the recorded water surface elevation data to those predicted by the pre-construction numerical model to verify the accuracy of these models.

Data from the loggers was compared to the SRH-2D final numerical model performed by Ubing (2018) for a low flow rate, March median flow rate, winter high flow rate, 1.25-, and two 50-year storms that happened during the winter and spring runoff season from 2019 to 2020. The numerical model performed extremely well when compared to observed water surface elevation data recorded by the loggers, underestimating the water surface elevation by an average of 0.7 ft. The area of the largest deviation from the observed data was under the lowest discharge conditions and the winter high flow. Some portions of the main channel that were anticipated to be dry continued to have flow during this dry period. However, this may be due to pooling on-site, or changes to the bed-forms following large flow events as opposed to connected flow. Additionally, the winter high flow storm selected for comparison between the model and on-site data may have been incorrect for this assessment. Removing these events, the average difference in water surface elevation falls to 0.6 ft.

As the loggers are still deployed and recording on-site, future benefits could be obtained by comparing this data to the numerical model over multiple years. Furthermore, post-construction discharge data has not yet been compiled by the Snake River Area Office. Additional analysis using this discharge data is also recommended to more closely compare data at the specific logger locations instead of solely downstream at the site via the numerical model. This future work has been submitted as an S&T proposal for the upcoming three fiscal years.

1. Introduction

The Bureau of Reclamation (Reclamation) is one of three action agencies required to help reduce the impact of the Federal Columbia River Power System (FCRPS) on 13 species of salmon and steelhead listed under the Endangered Species Act. The FCRPS Biological Opinion includes language to improve the spawning and rearing habitats, provide better access to this habitat, and enhance in-stream flows. Reclamation has been actively involved in designing habitat improvement projects through the River Systems and Restoration group in the Columbia-Pacific Northwest Region. Over the past several years many projects have been successfully constructed, typically through non-government-issued contracts, to meet the Biological Opinion requirements. Constructed projects undergo an extensive design process including evaluating many concepts and numerical models for each project completed by Reclamation; however, the sites very rarely undergo post-construction analysis to verify the accuracy of the numerical models used during design.

One completed project is Bird Track Springs, located along the Grande Ronde River in La Grande, Oregon. Restoration of this site included adding pool-riffle complexes throughout the main channel of the stream, construction of side channels with alcoves, large woody debris structures, and opening the floodplain for added storage. Construction was completed in winter of 2019 (Figure 1). Shortly after construction was complete, fifteen water surface level loggers and one atmospheric logger were installed at various locations throughout the site. These loggers recorded temperature and pressure throughout the winter and spring thaw. The goal of this project is to verify the accuracy of these models by comparing the recorded water surface elevations to those predicted by the numerical model.

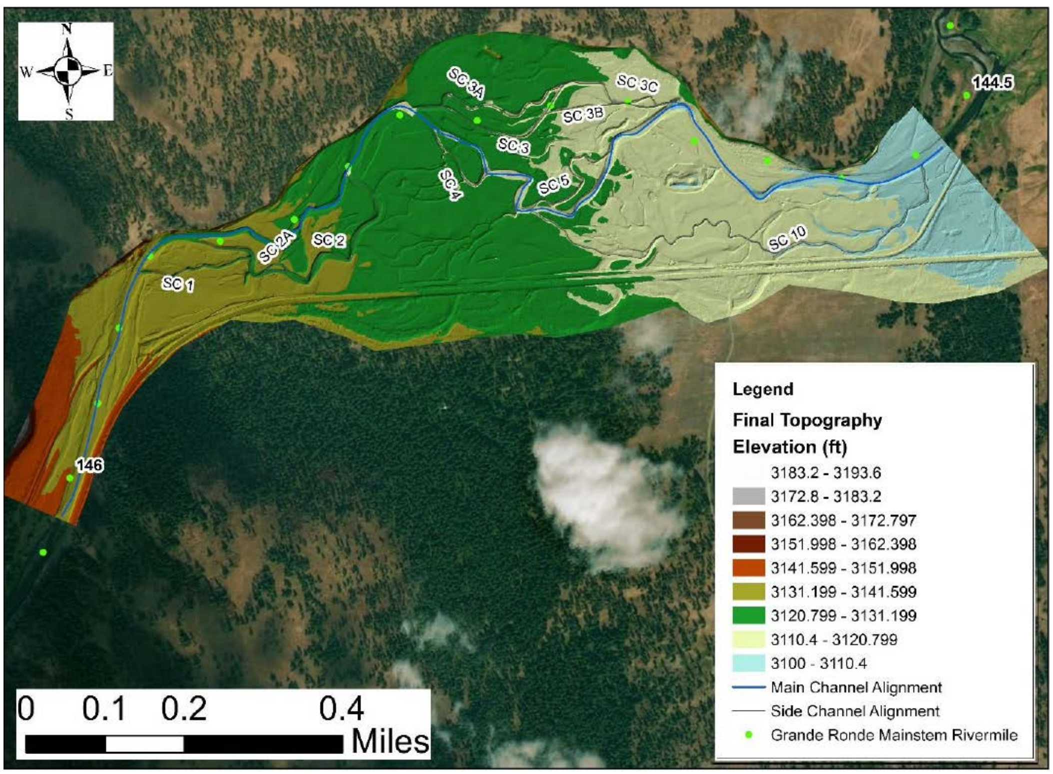

Figure 1 Final design channel reconstruction (Ubing, 2018).

1.1 Project History

In 2018, Reclamation's Technical Service Center (TSC) Sedimentation and River Hydraulics Group was commissioned by the Columbia-Pacific Northwest Regional Office to generate a steady-state two-dimensional SRH-2D (version 2) numerical model of the Grande Ronde River at the Bird Track Springs site. The main objective of this numerical model was to analyze where aquatic habitat enhancements should be located for juvenile Chinook Salmon rearing. The proposed, and subsequently constructed, river restoration design was estimated to increase usable habitat area by 100-140% in summer and 190-920% in winter (Ubing, 2018). The study described herein compares the results of this numerical model to water surface elevations seen in the field at varying flow scenarios. The flood routing is used to compare side channel activation during different flood events. By comparing the side channel activation from real-time data collected via water surface level loggers to outputs from the computational model, this research aims to determine how well the designs and numerical models match actual conditions. Ultimately, this will aid in the design of freeboard on river restoration projects and help designers determine when side channels will activate during the incoming hydrograph.

Construction of the project started in mid-2018, and two main construction phases occurred in the summer of 2018 and the summer of 2019. Since completion in 2019, the site has been monitored by Reclamation's Field and Regional offices in La Grande and Boise, respectively and the Confederated Tribes of the Umatilla Indian Reservation (CTUIR). Additionally, Project ID 20031 "Potential for restoring thermal refuges in rivers for cold-water salmonids" (Ubing, on-going) is monitoring temperatures throughout the complete Bird Track Springs site to evaluate thermal refugia for salmonids.

2. Experimental Setup

In September 2019, members from Reclamation representing the project, Project ID 20031 "Potential for restoring thermal refuges in rivers for cold-water salmonids", and the Reclamation Snake River Area Office visited the Bird Track Springs construction site. The purpose of this field visit was to ascertain the best locations for water surface level loggers. Collaborating with stakeholders, the team identified fifteen water level site locations and one additional site for an atmospheric logger. Sites were selected based on the numerical model mesh (Figure 2) to capture changes in water surface elevation between the main channel and corresponding side channels. Ideally, a logger would be placed in the main channel before a flow split, with an additional logger in each of the flow splits and side channels. This would allow comparison between the channels to see when the side channel activates and becomes fully flowing. Furthermore, loggers at flow splits would help for comparisons with the numerical model to see if the splits were dividing river flow as designed for (Ubing, 2018).

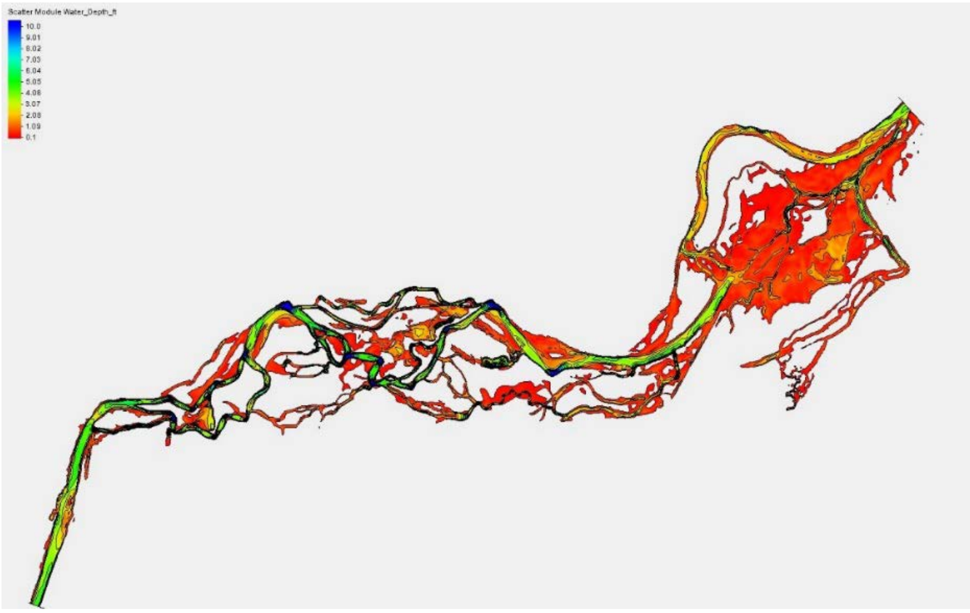

Figure 2 SRH-2D mesh of the Bird Track Spring completed restoration site for the 2-year storm (Ubing, 2018).

After the locations were selected, loggers were installed throughout the site by members of CTUIR (Figure 3). The installation process involved attaching the loggers to the bottom of a rebar pole using metal hose clamps (Figure 4, Figure 5). Once the logger was secured, the logger was surveyed into place with the elevation recorded (Table 1). Data was collected using Onset Hobo 30-foot Titanium Water Level Loggers on 15-minute increments from November 14, 2019 through June 26, 2020. Removal of the loggers occurred in July 2020 when data was offloaded for analysis. Throughout the course of the year, four loggers were lost.

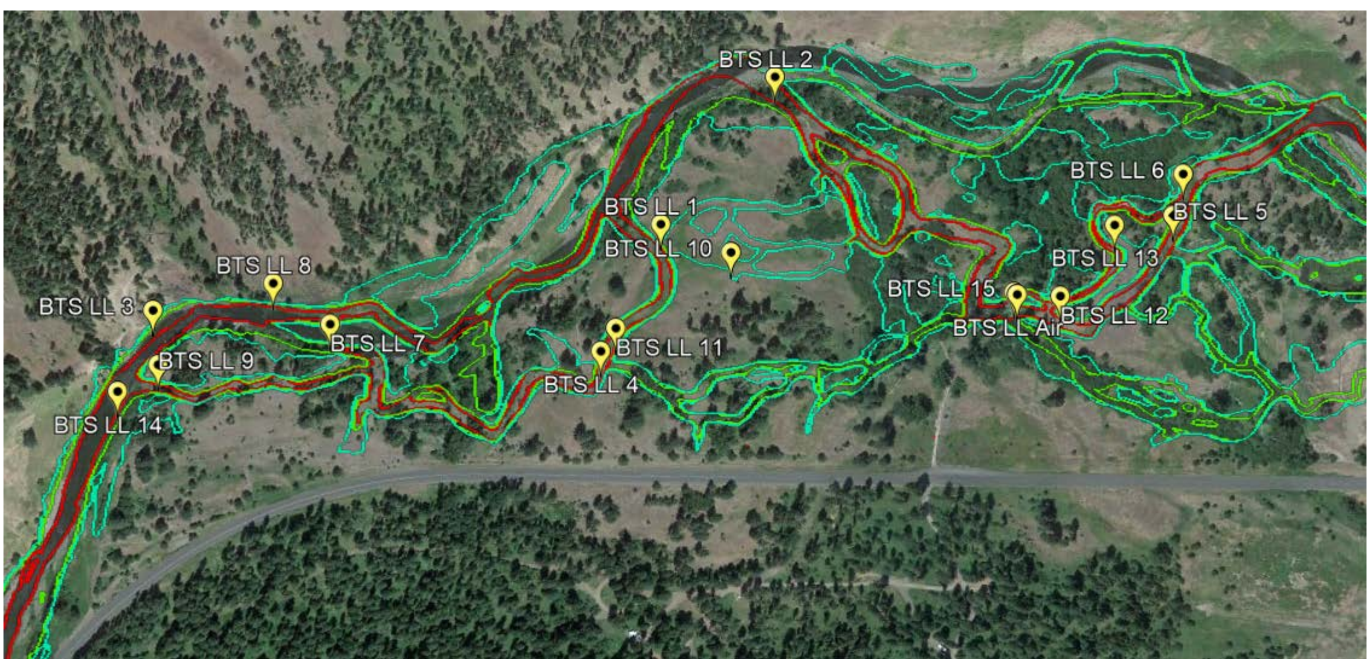

Figure 3 Locations of water surface loggers installed at the site in November 2019.

Table 1 Location of water level loggers (LL) with elevation. Red font denotes loggers that were lost during the year.

Logger	Northing	Easting	Elevation	Description
1	603894.189	8765369.949	3125.76	Main channel, adjacent to side channel 4. Corresponded to LL 10.
2	604372.350	8765679.331	3122.72	Main channel.
3				Main channel, downstream of LL 8 after LL 7 feeds back in
4	603491.070	8765227.124	3126.51	Main channel, downstream of side channel 2. Corresponded to LL 11
5	604024.196	8766927.492	3116.74	Left of flow split with LL 13 and 6.
6	604170.588	8766945.378	3115.97	Upstream of flow split with LL 13 and 5.
7				Main channel, before flow split with LL 8 and 9
8	603629.423	8764221.314	3130.30	Main channel, after flow split with LL 1.
9	603363.579	8763908.776	3133.59	Main channel, downstream of LL 1 after flow split with LL 7.
10	603821.548	8765593.342	3125.39	Side channel 4, corresponding to LL 1
11				Main channel, upstream of side channel 2.
12				In flow split, downstream of LL 5.
13	603995.893	8766743.794	3116.98	Right of flow split with LL 5 and 6.
14	603276.483	8763781.343	3133.30	In main channel after combined flow from LL 7 8 and 9.
15	603763.885	8766448.998	3119.15	Main channel, adjacent to side channel 10.

Figure 4 Logger installation completed by CTUIR in November, 2019 (Kimbro, 2019).

Figure 5 Example of a logger installed at site with rebar (red) protruding above the water surface near center. Logger is located at the bottom of the rebar (Kimbro, 2019).

During the course of the year, the La Grande Field Office and the Columbia-Pacific Northwest Regional Office took discharge measurements throughout the site. At the time of writing, the majority of these efforts have not yet been compiled, however two discharge measurements dated 5/27/2020 were provided for model comparisons (Nielsen, May 27, 2020).

3. Methods

To analyze the accuracy of the numerical model, six representative discharges were selected from the final design for comparison with the deployed water surface loggers (Table 2). When possible, these discharges were related to real-time discharge measurements provided by the Columbia-Pacific Northwest Region of Reclamation (Nielsen, May 27, 2020). Two discharge measurements were taken by the Columbia-Pacific Northwest Region on May 27, 2020 at three different sites. The first resulted in a flow rate of approximately 1,000 cfs, which was compared with the Winter High (983 cfs) design; the second a flow rate of 1,500 cfs was compared to the 1.25-yr storm (1,477 cfs). The rapid decrease in discharge stemmed from the downwards trend following the 50-yr storm on May 25, 2020. For the other discharges, the Low total discharge was compared to the lowest water surface elevations of the dataset (1/15/2020), the March Median to the median for March 2020, and the 50-yr storm to two separate storms. These storms, both referred to as 50-yr flood events by those on-site, occurred on February 2 and May 25 of 2020. While these storms yielded differing water surface elevations, they were both utilized for comparison to assess the range of discharges that can occur at the site.

Table 2 Downstream Model Boundary Discharge Table for Final Design conditions (Ubing, 2018). Rows highlighted in blue were assessed for comparison with water surface elevation loggers.

Flow Identifier	Total Discharge (ft^3/s)
Low	21
Winter Median	90
March Median	434
Winter High	983
1.05-yr	1,153
1.25-yr	1,477
1.5-yr	1,943
2-yr	2,347
5-yr	3,595
10-yr	4,520
25-yr	4,922
50-yr	6,812
100-yr	7,896

The data collected from the water surface loggers were in units of time, temperature (Fahrenheit), and absolute pressure (psi). In order to get the depth of water, the difference was calculated between the absolute pressure of the logger recording in the water and atmospheric pressure. This pressure differential in psi was converted to a depth of water in feet. This depth was then added to the surveyed elevations of each logger for a water surface elevation.

4. Results and Conclusion

The converted data from the loggers was used to find peaks in depth (Figure 6) and water surface elevation (Figure 7) for comparison to the numerical model. Once these peaks of interest were established, the corresponding water surface elevations from the numerical model (Ubing, 2018) were recorded. The differences in water surface elevations were then calculated (Table 3 and Table 4). The average difference in water surface elevation was -0.7 ft, meaning that the numerical model underestimated the water surface elevation in the channels by 0.7 ft.

The deviation between the numerical model and the observed water surface elevation data was most pronounced on the loggers located in the side channels or the main channel immediately after major flow splits. The numerical model estimated these loggers (2, 5, 8, and 10) to be dry during the low flow event. However, loggers 2 and 5 were registering water up to 0.3 ft. This could be an effect of pooling from previous storms rather than active flow. Logger 8 was correctly dry at this lowest flow event. From the numerical model, logger 10 in side channel 4 was expected to be dry at all events less than a 1.5-yr storm. However, observed water surface elevations at logger 10 indicate water at all flow rates above the low flow event. These differences could be due to design changes implemented during construction that were never modeled.

When Onset Hobo Loggers are exposed to air for prolonged periods of time, the logger can yield unexpected readings such as lower than the elevation the logger was installed at. For example, the water surface elevation for the low flow event on logger 10 reads as lower than the elevation it was installed at, thus implying the logger was exposed to air. In the numerical model, dry flow conditions yielded a water surface elevation of -999. For the sake of comparison, these were assigned to the bottom of the channel elevation and denoted by red font (Table 3 and Table 4).Thus, logger 10 in side channel 4 was correctly assumed to be dry at the low flow events, but quickly refilled for higher discharges. This can also be seen in the main channel for logger 9 at the low flow event. Logger 9 is located downstream of a major flow split in the main channel. This implies that the main channel flow split may not be diverting as much flow as it originally was designed to.

Furthermore, the water surface elevation for the winter high storm event was underestimated by at least 1 ft, an average of 1.2 ft, at all loggers. This difference may be due to the storm selected for comparison as it may not be representative of the winter high flow rate (983 cfs). Excluding the winter high storm and the aforementioned dry readings from the loggers, the average difference in water surface elevation drops to 0.56 ft. Overall, the numerical model appears to be accurate at estimating side channel activation and water depth in the main channel at a variety of flow events. The greatest deviations occurred during the lower flow events due to the potential impacts of pooling around the loggers.

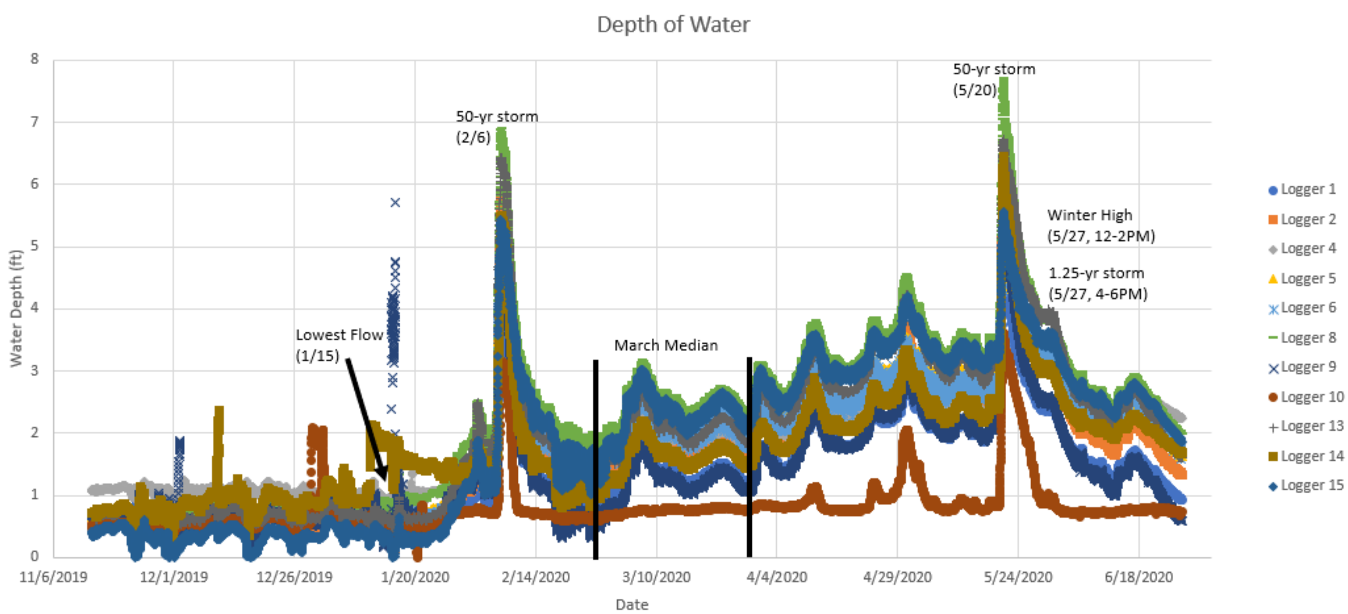

Figure 6 Depth of water above the level loggers at each location throughout the duration of deployment. The March median represents the median over the entire month of March. Though the winter high storm was used for a storm in May, this was due to the similarity in anticipated discharge (983 cfs modeled to 1000 cfs measured in the field). The peak for Level Logger 9 was only a few hours and may be due to a debris strike impacting the logger readings for that day.

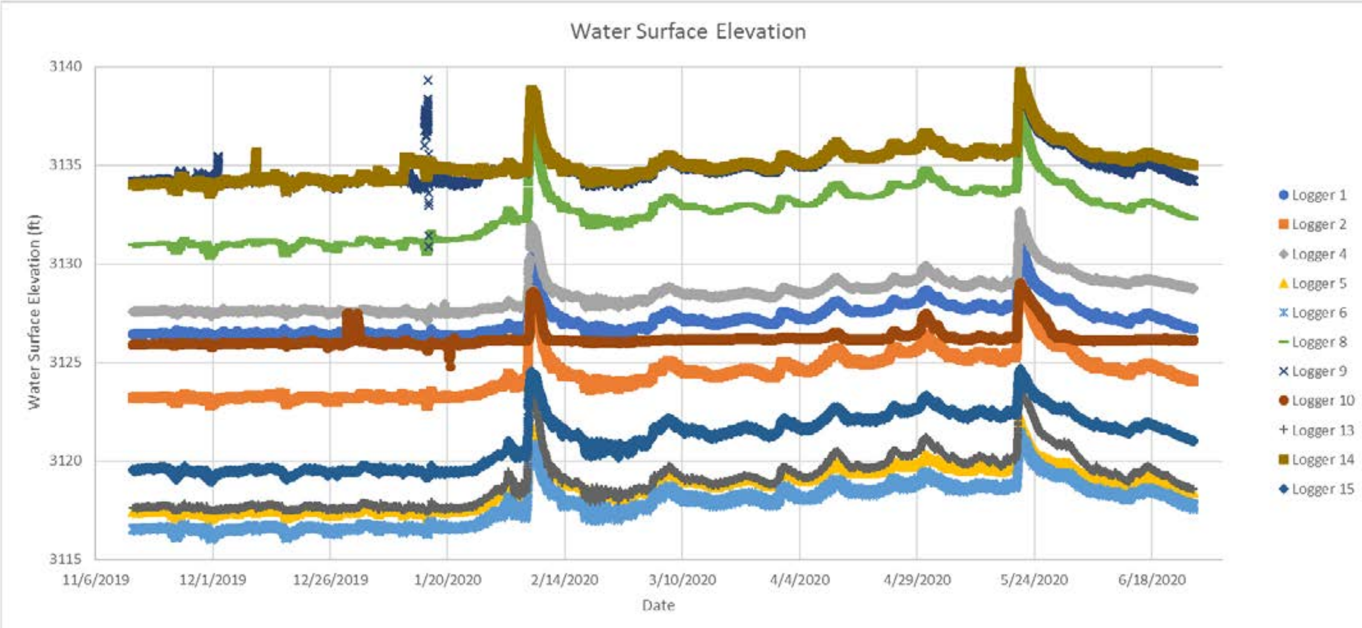

Figure 7 Water surface elevation at each level logger throughout the duration of deployment. The peaks on 2/6 and 5/20 represent the 50-year storm. The peak for Level Logger 9 was only a few hours and may be due to a debris strike impacting the logger readings for that day.

Table 3 The water surface elevations for the numerical model, water loggers, and the difference between the water surface elevation for the low, March median, and winter high conditions. All water surface elevations from the numerical model were taken at the corresponding coordinates of the loggers on-site (Table 1). Red font denotes the model output anticipating the channel as dry.

	Water Surface Elevation in Numerical Model, ft			Water Surface Elevation for Loggers, ft			Difference in Water Surface Elevation, ft		
Logger	**Low**	**March Median**	**Winter High**	**Low**	**March Median**	**Winter High**	**Low**	**March Median**	**Winter High**
1	3125.34	3126.38	3127.27	3125.87	3127.13	3128.34	-0.53	-0.75	-1.06
2	3122.72	3123.77	3124.79	3122.80	3124.51	3126.06	-0.08	-0.73	-1.26
4	3126.69	3127.75	3128.53	3127.12	3128.45	3129.92	-0.43	-0.69	-1.39
5	3116.74	3118.01	3119.00	3117.04	3118.94	3119.98	-0.30	-0.94	-0.98
6	3115.45	3117.28	3118.26	3116.03	3118.09	3119.41	-0.57	-0.80	-1.15
8	3130.30	3132.27	3133.35	3130.30	3132.87	3134.37	0.00	-0.60	-1.02
9	3132.63	3134.10	3135.01	3130.88	3134.87	3136.30	1.75	-0.77	-1.29
10	3125.39	3125.39	3125.39	3124.78	3126.16	3126.62	0.61	-0.77	-1.23
13	3117.11	3118.65	3119.80	3117.44	3119.06	3121.05	-0.33	-0.41	-1.25
14	3132.93	3134.39	3135.37	3133.55	3134.96	3136.47	-0.62	-0.58	-1.10
15	3119.15	3120.35	3121.34	3118.94	3121.53	3122.83	0.21	-1.18	-1.49

Table 4 The water surface elevations for the numerical model, water loggers, and the difference between the water surface elevation for the 1.25-yr and 50-yr flood conditions. The 50-yr flood was compared to two separate storm events on February 2 and May 5 of 2020. All water surface elevations from the numerical model were taken at the corresponding coordinates of the loggers on-site (Table 1). Red font denotes the model output anticipating the channel to be dry, however all channels had water for these storm events.

	Water Surface Elevation in Numerical Model, ft			Water Surface Elevation for Loggers, ft			Difference in Water Surface Elevation, ft		
Logger	**1.25-yr**	**50-yr (2/6)**	**50-yr (5/20)**	**1.25-yr**	**50-yr (2/6)**	**50-yr (5/20)**	**1.25-yr**	**50-yr (2/6)**	**50-yr (5/20)**
1	3127.86	3130.25	3130.25	3128.30	3130.38	3131.12	-0.45	-0.13	-0.86
2	3125.46	3128.10	3128.10	3125.99	3128.63	3129.01	-0.53	-0.53	-0.90
4	3129.11	3132.06	3132.06	3129.88	3131.99	3132.64	-0.77	0.07	-0.58
5	3119.63	3121.85	3121.85	3119.95	3121.80	3122.22	-0.32	0.05	-0.36
6	3118.80	3121.14	3121.14	3119.38	3120.85	3121.48	-0.58	0.28	-0.34
8	3134.04	3137.12	3137.12	3134.31	3137.20	3138.00	-0.28	-0.07	-0.87
9	3135.71	3138.60	3138.60	3136.25	3139.31	3139.12	-0.54	-0.71	-0.52
10	3125.39	3128.19	3128.19	3126.51	3128.53	3129.00	-1.12	-0.34	-0.81
13	3120.52	3122.64	3122.64	3120.99	3123.41	3123.71	-0.47	-0.77	-1.07
14	3136.06	3139.14	3139.14	3136.42	3138.79	3139.74	-0.36	0.35	-0.60
15	3121.95	3123.49	3123.49	3122.79	3124.58	3124.70	-0.84	-1.09	-1.21

5. Recommendations and Future Work

At the time of this report, the dataset containing post-construction discharge measurements had not been compiled by the Snake River Area Office. Therefore, it is recommended to analyze the data with the additional discharge measurements for comparison. Additionally, it would be beneficial to compare the as-built bed elevation to that of the SRH-2D numerical model. This would allow for correction of differences in water surface elevation that come from changes in construction as opposed to flow rates. A proposal was submitted to S&T to continue this work for another three fiscal years. This project would utilize the same water surface loggers as they are still deployed on-site. Therefore, it is highly recommended to revisit this dataset for the upcoming years to assess the side channel changes and the impacts this may have on the reliability of the numerical model over time.

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