IDAHO DEPARTMENT OF
WATER RESOURCES

Summary of lower Camas Creek Seepage Surveys

Open File Report

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Contents

Figures

Tables

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Introduction

The Camas Prairie is a 740 mi^2 intermountain basin in south-central Idaho ranging in elevation from 4,799 ft to 10,075 feet. The basin is bounded by the Soldier Mountains to the north, the Bennett Mountains to the south, and the South Fork Boise River divide to the west. Basin-wide mean annual precipitation is 16.8 in and mean annual temperature is 42.4°F. Camas Creek drains the basin as it flows east into the Big Wood River at Magic Reservoir. Mean annual flow, peak flow, and low flow at the Camas Creek near Blaine gage (USGS 13141500) since 1991 is 118 ft^3/s, 1,469 ft^3/s, and 2.26 ft^3/s, respectively.

Alluvial sediments, lake sediments, and Snake River Group basalts host the aquifer system, which Young (1978) and Walton (1962) characterized as an unconfined aquifer overlying an upper and lower confined system. A shallow unconfined layer within valley-fill sediments about 40 feet thick overlies clays inter-bedded with sands and silts. Below this is an extensive clay layer that creates confining conditions for the upper artesian aquifer within alluvial sediments and the lower artesian aquifer within fractures, voids, and interflows of basalt. Camas Creek incises into the basalt aquifer about seven miles upstream of Magic Reservoir, at which point the aquifer discharges to the stream.

Purpose

The purpose of this report is to summarize six seepage surveys conducted by IDWR since fall 2017 in the lower reach of Camas Creek upstream of the Magic Reservoir pool. The surveys were designed to quantify groundwater/surface-water interaction between Camas Creek and the aquifer and to measure additional inflows from tributaries or groundwater past the USGS stream gage near Blaine (USGS 13141500). The extent of the seepage surveys is limited by backwater from Magic Reservoir, which extends into the lower reach of Camas Creek. Additional aquifer discharge may occur to the backwater in lower Camas Creek and directly to Magic Reservoir.

Methods

Streamflow measurements were taken during six seepage surveys on lower Camas Creek: November 1, 2017, November 15, 2018, November 4, 2019, November 2, 2020, March 23, 2021, and November 23, 2021. Most survey dates were selected to occur after irrigation season during base-flow conditions at the gage. One survey was selected to capture seepage during spring runoff prior to irrigation season. Measurement sites were selected based on accessibility, likelihood of there being measurable flow, and repeatability. Throughout the course of the surveys, tributaries were measured at different points as appropriate access to a given site was discovered. Figure 1 shows the location of measurement sites in the Camas Prairie. Location CC4 is coincident with the USGS gage.

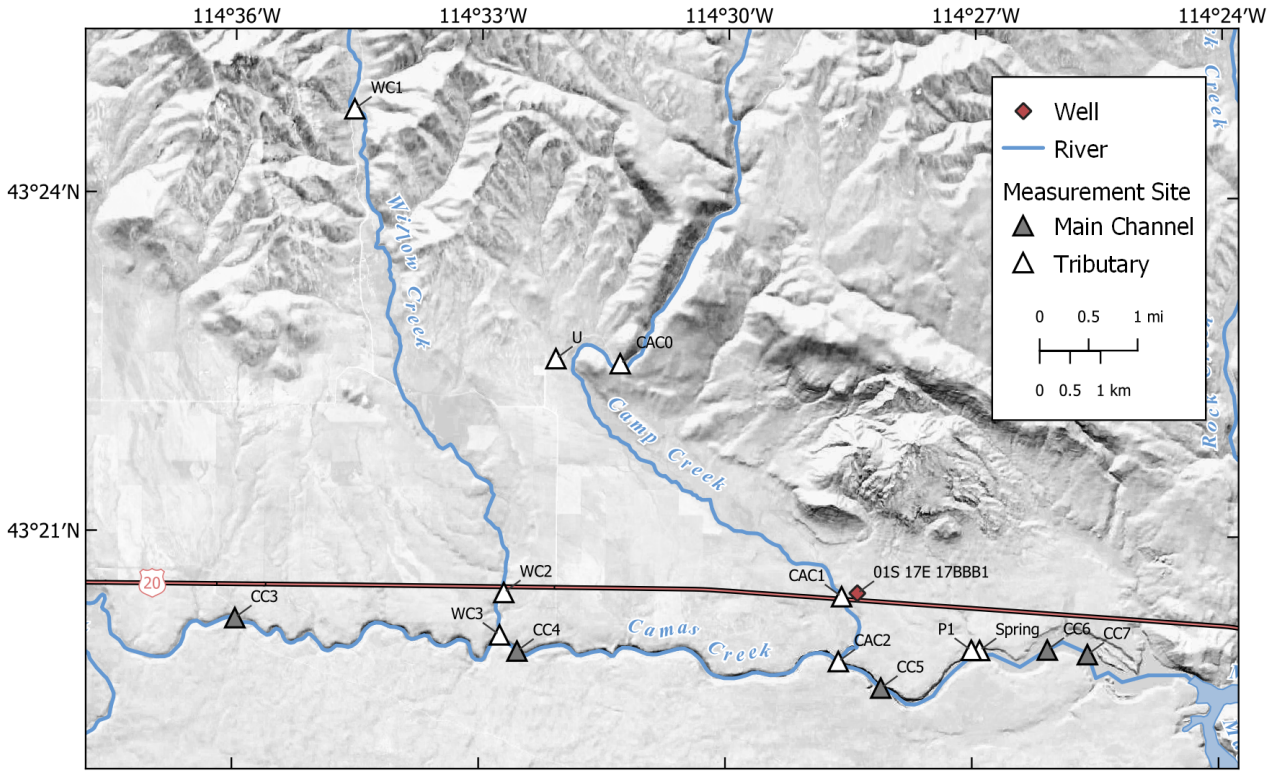

Figure 1. Lower Camas Creek and tributaries showing streamflow measurement sites.

Flow measurements were taken primarily with a YSI Sontek FlowTracker or FlowTracker2 handheld acoustic Doppler velocimeters mounted on a top-setting wading rod. Several measurements at the USGS gage were made with a Teledyne RD Instruments StreamPRO acoustic Doppler current profiler (ADCP). Twenty-five evenly-spaced vertical profiles were measured as allowed by the channel width and at 60% of stream depth at each measured stream cross-section. If 25 measurements could not be made due to stream geometry constraints, measurements were made every 0.3 ft.

River reach gains and losses are calculated as $Q_{seep} = Q_d - I - Q_u + O$, where Q_{seep} is net seepage gain (positive) to the river from groundwater or loss (negative) to groundwater, Q_d is the downstream streamflow, Q_u is the upstream streamflow, I is the sum of all inflows such as tributaries or irrigation returns, and O is the sum of all outflows such as diversions. Evaporation loss is assumed to be negligible.

Each measured streamflow contains a level of due to flow conditions and instrument error. Instrumentation reports error as a percentage of measured flow. This uncertainty can be propagated to the seepage calculation using the equation $s = \sqrt{a^2 + b^2 ... + n^2}$, where a, b, and n are the uncertainty of each measurement in ft^3/s (Wheeler and Eddy-Miller, 2005). Calculated gains or losses less than the propagated uncertainty are considered indistinguishable from noise due to measurement error.

Two to three reaches were measured during the surveys to estimate gains or losses from groundwater throughout those reaches. Macon Flat Bridge to USGS gage contains sites CC3, WC2 or WC3, and CC4. USGS gage to below Camp Creek consists of sites CC4, CAC1 or CAC2, and CC5. Below Camp Creek to Moonstone Landing consists of sites CC5, CC6 and/or CC7 with P1 and Spring measured or inspected only during the most recent survey. Gains from the aquifer may occur in Camas Creek downstream of CC7 including directly into the bottom of Magic Reservoir, but these discharges were not evaluated as part of this study.

Table 1. Seepage survey site inventory for lower Camas Creek. x = flow measured or estimated, o = no flow present during site visit, — = site not measured.

Site ID	Site Name	Latitude	Longitude	Survey Date					
				Nov 2017	Nov 2018	Nov 2019	Nov 2020	Mar 2021	Nov 2021
CC2	Camas Creek	43.3166	-114.639	x	—	—	—	—	—
CC3	Camas Creek at Macon Flat Bridge	43.3372	-114.600	x	x	x	x	x	x
CC4	Camas Creek near Blaine ID (Gage)	43.3326	-114.542	x	x	x	x	x	x
CC5	Camas Creek below Camp Creek	43.3274	-114.469	x	x	x	x	—	x
CC6	Camas Creek at Moonstone Landing Upper	43.3332	-114.435	—	x	—	—	x	x
CC7	Camas Creek at Moonstone Landing Lower	43.3326	-114.427	—	—	—	x	—	—
WC1	Upper Willow Creek at bridge	43.4125	-114.576	x	x	—	—	x	—
WC2	Willow Creek at Hwy 20	43.3412	-114.545	x	x	x	x	—	—
WC3	Willow Creek at Confluence	43.3350	-114.546	—	—	—	—	x	x
CAC0	Upper Camp Creek	43.3751	-114.522	—	—	—	—	x	—
CAC1	Camp Creek at Hwy 20	43.3409	-114.477	x	x	x	—	—	—
CAC2	Camp Creek at Confluence	43.3313	-114.477	—	—	—	x	x	x
P1	Poison Creek	43.3331	-114.450	—	—	-	—	—	o
Spring	Unnamed Spring	43.3331	-114.449	—	—	—	—	—	x
U	Spare Creek	43.3758	-114.535	—	—	—	—	x	—

Willow Creek and Camp Creek measurements sometimes included measurement sites located outside of the approximate alluvial boundary of the aquifer system (WC1, U, and CAC0; figure 1) to investigate seepage on those tributaries.

Results from the surveys are described below and in table 2. Figure 2 shows streamflow conditions at the gage during the measurements as well as the measurement at CC4 plotted with the water year hydrograph. Reach gains are mapped in figure 3.

November 2017

Streamflow measurements were made at eight sites on November 1, 2017 on Camas Creek and flowing tributaries between Deer Creek and the Magic Reservoir pool. Daily mean streamflow on November 1, 2017 at the gage was 15.5 ft^3/s. No rain had been recorded nearby and instantaneous readings show small fluctuations from 15.0 to 15.9 ft^3/s during the prior 48 hours (figure 2).

Seepage estimates in CC3-CC4 were less than uncertainty. Gains from groundwater were estimated at 0.79 ± 0.93 ft^3/s with most uncertainty attributable to the measurement at Willow Creek site WC2, which was contributing most flow at CC4. Measured flow at CC4 was 1.3 ft^3/s less than the average daily flow measured by the USGS gage. Using the discharge for the gage could have brought the seepage estimate above uncertainty, though potential gains would have still been below 1 ft^3/s.

Past the gage, CC4-CC5 showed gains from groundwater of 6.90 ± 1.01 ft^3/s. The minor inflow from CAC1 is assumed to be recent groundwater gains and is included in the estimated reach gain.

Discharge on Willow Creek was equal at both the upper and lower measurements on Willow Creek.

November 2018

Seven streamflow measurements made on November 15, 2018 show Camas Creek gaining 7.30 ft^3/s from groundwater from CC3-CC6. Daily mean streamflow at Camas Creek near Blaine was 6.96 ft^3/s and ranged from 6.82 to 7.10 ft^3/s. The instantaneous USGS gage measurement was 1.03 ft^3/s lower than our measurement. CC3-CC4 gained 2.07 ± 0.28 ft^3/s. The measurement at WC2 again showed most flow at CC4 was from Willow Creek. CC4-CC5 gained 3.69 ± 0.21 ft^3/s with 0.23 ± 0.05 ft^3/s of calculated groundwater gains originating in

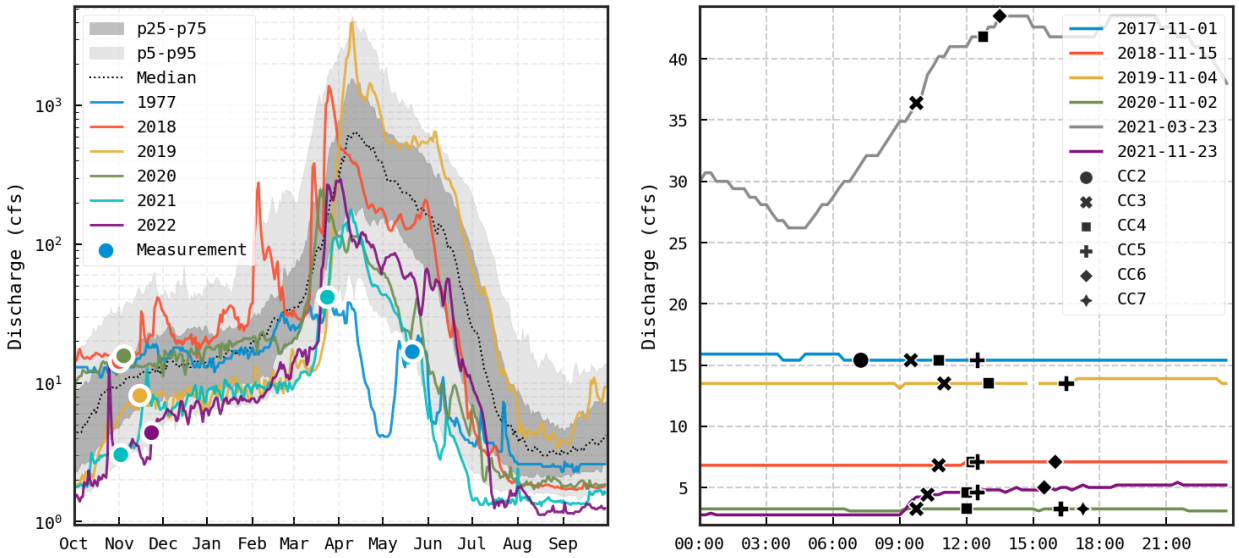

Figure 2. **(Left)** Water year hydrographs of USGS Camas Creek near Blaine gage with points showing measurements made at the gage during seepage surveys. **(Right)** 15-minute streamflow values at Camas Creek near Blaine on days coinciding with seepage surveys. Markers indicate timing of measurements on Camas Creek.

Camp Creek. The pool of Magic Reservoir was lower than the prior year and the measurement at CC6 showed gains above uncertainty in the CC5-CC6 reach of 1.55±0.28 ft^3/s.

Willow Creek measurements again showed equal discharge at the upstream and downstream measurement.

November 2019

Five streamflow measurements were made on November 4, 2019 showing Camas Creek gaining 5.3 ft^3/s from groundwater from CC3-CC5. Daily mean streamflow at Camas Creek near Blaine was 13.2 ft^3/s and ranged between 13.1 to 13.9 ft^3/s. CC3-CC4 gained 2.6±1.34 ft^3/s from groundwater. The measurement at CC4 was 2.5 ft^3/s higher than the daily average gage reading. There were 2.7±1.33 ft^3/s of gains from groundwater in CC4-CC5. Downstream reaches were unable to be measured due to the reservoir stage.

November 2020

Six measurements were made on November 2, 2020. Camas Creek gained 5.86 ft^3/s from CC3-CC7. Water levels in Magic Reservoir were much lower than prior years of seepage surveys and allowed access downstream of the Moonstone boat ramp. Average daily discharge at the gage was 3.22 ft^3/s with instantaneous USGS gage readings ranging between 3.09 to 3.26 ft^3/s. The measurement at CC4 was 0.18 ft^3/s lower than the gage discharge. CC3-CC4 showed a gain of 1.66±0.22 ft^3/s, CC4-CC5 gained 2.18±0.31 ft^3/s, and CC4-CC7 gained 2.02±0.46 ft^3/s. Willow Creek and Camp Creek were at their lowest measured discharges for the seepage surveys; 0.52±0.06 ft^3/s and 0.09±0.03 ft^3/s, respectively

March 2021

Eight measurements on March 23, 2021 on Camas Creek and flowing tributaries were affected by a snowmelt runoff event throughout the day. Uncertainty from the event was undetermined and no estimate of seepage was

made. Average daily discharge at the gage was 37.1 ft^3/s and ranged from 26.2 to 43.5 ft^3/s throughout the day. The instantaneous reading at the USGS gage when CC4 was measured was 41.0 ft^3/s, within 0.5 ft^3/s of our measurement.

An additional measurement on Camp Creek at CAC0, located approximately where Camp Creek flows into the alluvial aquifer boundary, had 3 ft^3/s more flow than at CAC2. No diversions should have occurred between the sites as it was not irrigation season and there are no stockwater diversions between the sites.

Snowmelt runoff impacted the survey as temperatures rose through the day. Streamflow increased from 5:00 AM to 1:00 PM with flow at the USGS gage increasing approximately 9 ft^3/s within the 3.5 hours between measurements at CC3 and CC6. The WC3 measurement occurred 2.5 hours after CC4, though most of the streamflow increases at the USGS gage had already occurred prior to those measurement times.

Kinematic wave celerity (wave speed) for typical stream channels ranges from 1 to 1.67 times the mean velocity (Miller, 1984). Mean velocity measured at CC4 was 1.22 ft/s, giving a travel time range of 104-174 minutes for a wave to travel the 2.4 miles between CC4 and CC6. The measurement at CC4 preceded CC6 by 50 minutes and thus it is unlikely that pulse of water from snowmelt had reached CC6 during the measurement time.

November 2021

Eight measurements on November 23, 2021 show overall gains of 1.54±.37 ft^3/s to Camas Creek from CC3-CC6. Average daily discharge at the gage was 4.1 ft^3/s and ranged from 2.7 to 5.4 ft^3/s. CC3-CC4 gained 0.60±.34 ft^3/s, CC4-CC5 lost 1.33±0.43 ft^3/s, and CC5-CC6 gained 2.27±0.46 ft^3/s.

Visual estimates of two new locations were included in this survey. An unknown spring entering from the north side of Camas Creek was estimated at 0.03 ft^3/s and Poison Creek (P1) was visually confirmed to have no flow.

Table 2. Summary of flow measurements, gains/losses, and associated uncertainty for six seepage surveys on lower Camas Creek. Reach gains during the March 23, 2021 are not reported due to high uncertainty caused by a streamflow increase of 9 ft^3/s over the course of the measurement.

Site	Main-stem streamflow (cfs)	Tributary streamflow (cfs)	Streamflow gain (+) or loss(-) (cfs)
		November 1, 2017	
CC3	1.18±0.1		
WC1		12.25±0.27	
WC2		12.29±0.36	
CC4	14.26±0.86		0.79±0.93
CAC1		0.32±0.06	
CC5	21.16±0.53		6.9±1.01
		November 15, 2018	
CC3	0.77±0.03		
WC1		5.25±0.136	
WC2		5.29±0.28	
CC4	8.13±0.60		2.07±0.66
CAC1		0.23±0.05	
CC5	11.82±0.21		3.69±0.64
CC6	13.37±0.19		1.55±0.28

Table 2. Summary of flow measurements, gains/losses, and associated uncertainty for six seepage surveys on lower Camas Creek. Reach gains during the March 23, 2021 are not reported due to high uncertainty caused by a streamflow increase of 9 ft^3/s over the course of the measurement.

Site	Main-stem streamflow (cfs)	Tributary streamflow (cfs)	Streamflow gain (+) or loss(-) (cfs)
		November 4, 2019	
CC3	1.1±0.07		
WC2		12±0.67	
CC4	15.7±1.16		2.6±1.34
CAC1		0.61±0.12	
CC5	18.4±0.64		2.7±1.33
		November 2, 2020	
CC3	0.86±0.05		
WC2		0.52±0.06	
CC4	3.04±0.2		1.66±0.22
CAC2		0.09±0.03	
CC5	5.22±0.23		2.18±0.31
CC7	7.24±0.4		2.02±0.46
		March 23, 2021	
CC3	19±1.39		
WC1		14.76±0.48	
WC3		16.61±1.15	
CC4	41.54±1.2		Not Reported
U		0.24±0.03	
CAC0		3.36±0.21	
CAC2		0.41±0.07	
CC6	34.41±0.93		Not Reported
		November 23, 2021	
CC3	0.61±0.06		
WC3		3.17±0.25	
CC4	4.38±0.23		0.6±0.34
CAC2		0.08±0.08	
CC5	3.05±0.37		-1.33±0.43
P1		0	
Spring		0.03	
CC6	5.32±0.27		2.27±0.46

Discussion

Lower Camas Creek was gaining during the four fall surveys from 2017 to 2021. The November 2021 survey showed seepage loss to the aquifer in subreach CC4-CC5. Fall measurement gains in reach CC3-CC5

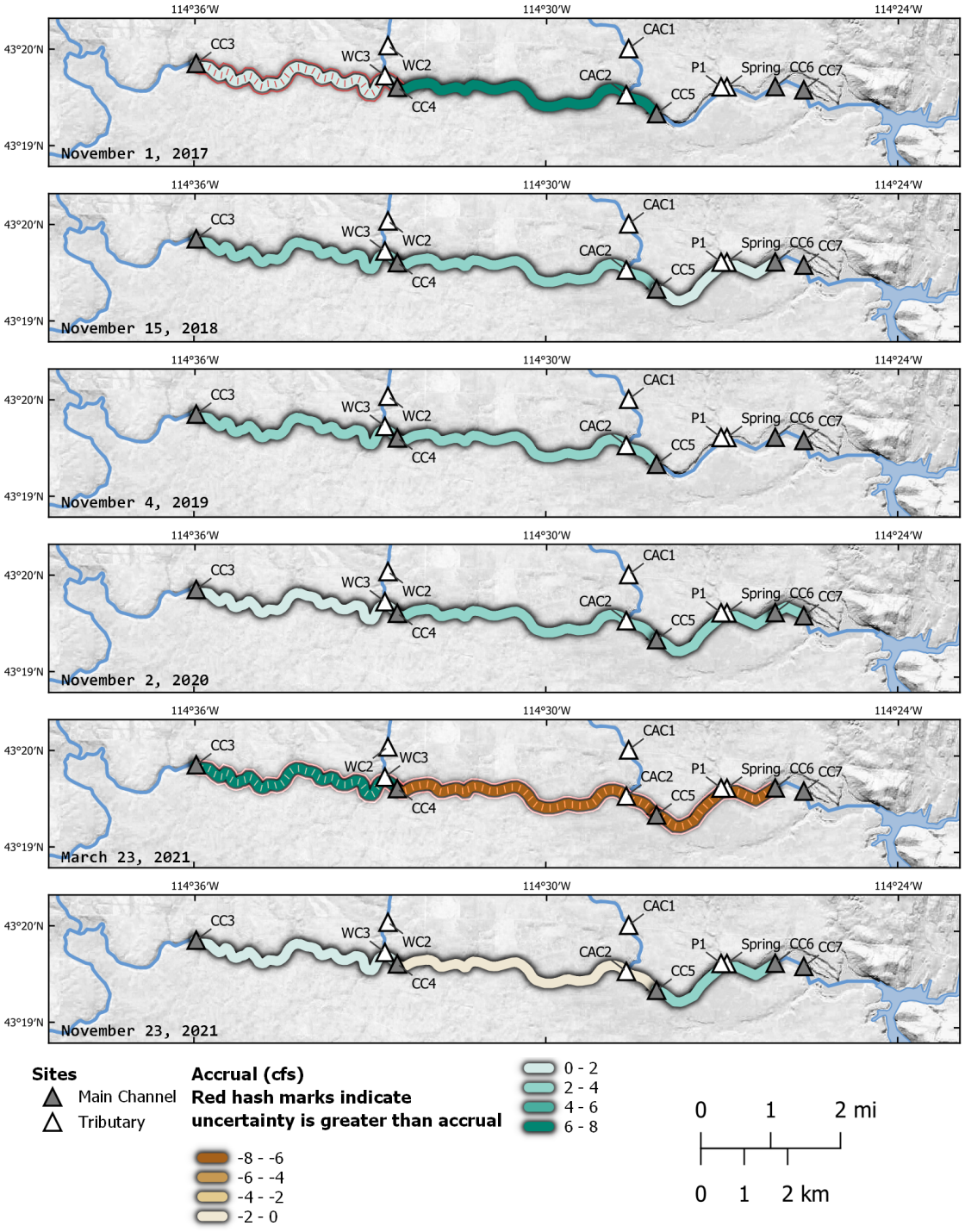

Figure 3. Reach gains during six seepage surveys on lower Camas Creek, south-central Idaho.

monotonically declined from 2017 to 2021 with decreasing gains from 2017 to 2020 followed by net loss to the aquifer in 2021 (figure 4).

An 18 ft^3/s runoff event the day of the March 2021 measurement increased streamflow 9 ft^3/s over the course of the survey and added unquantified uncertainty that precludes interpretation of the measurements. Willow Creek likely contributed most snowmelt runoff. Using a kinematic wave approximation of wave celerity suggests that runoff would not have reached CC6 at the measurement time.

Camp Creek

Flow in lower Camp Creek is assumed to be derived from aquifer discharge and is included in stream gains from groundwater. Camp Creek is intermittent and the upper reaches outside of the alluvial aquifer boundary are often dry in the fall while small amounts of flow are present downstream. Historical USGS measurements of Camp Creek near CAC0 records flows ranging from <0.01 ft^3/s to 5.7 ft^3/s (Young and others, 1978).

A measurement was made during the March 2021 survey at site CAC0 near the boundary with the alluvial fill aquifer to address the assumption during times when the upper reach is flowing. Diversions from Camp Creek should be zero as the survey occurred prior to the start of irrigation season. A difference of 3 ft^3/s between CAC0 and CAC2 may indicate seepage loss, but uncertainty due to snowmelt likely affects these measurements. The upstream measurement was made 1.75 hours after the downstream measurement, and both occurred several hours after the runoff event recorded at the USGS gage. Total loss of surface water in Camp Creek to the aquifer upstream of CAC2 during March 2021 cannot be quantified, though the measurement at CAC2 is the same order of magnitude as prior measurements taken when upper Camp Creek was likely dry.

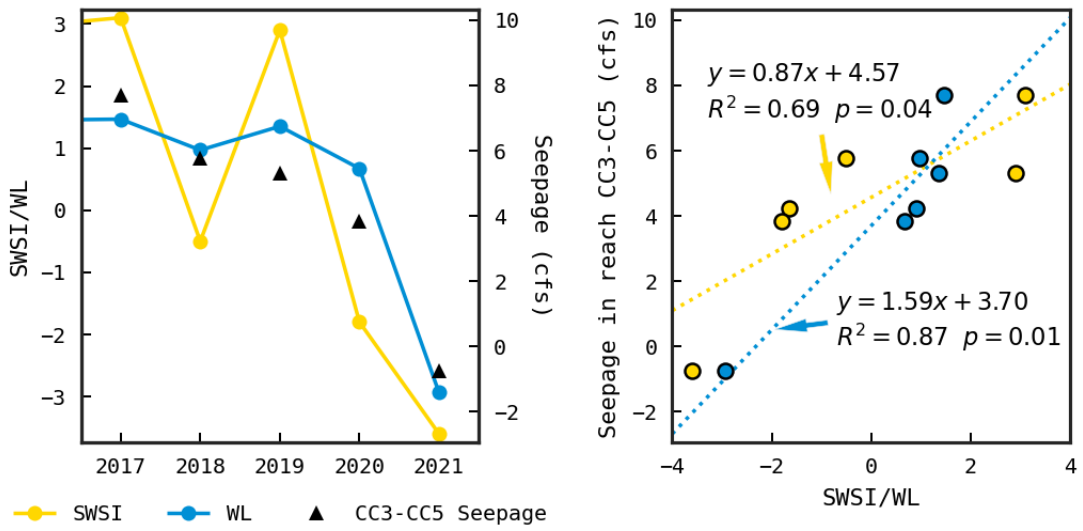

Figure 4. **(Left)** Surface water supply index (SWSI) calculated by the NRCS at Camas Creek near Blaine, normalized water level in 01S 17E 17BBB1, and November survey CC3-CC5 seepage values. 1977 SWSI and seepage in reach CC3-CC5 are not shown. Those values are -1.64 and 4.22 ft^3/s, respectively. Normalized water levels are based on the median monthly value. **(Right)** Correlations of SWSI and normalized 01S 17E 17BBB1 water levels versus measurements of seepage in reach CC3-CC5. The regressions are significant at the 5% significance level.

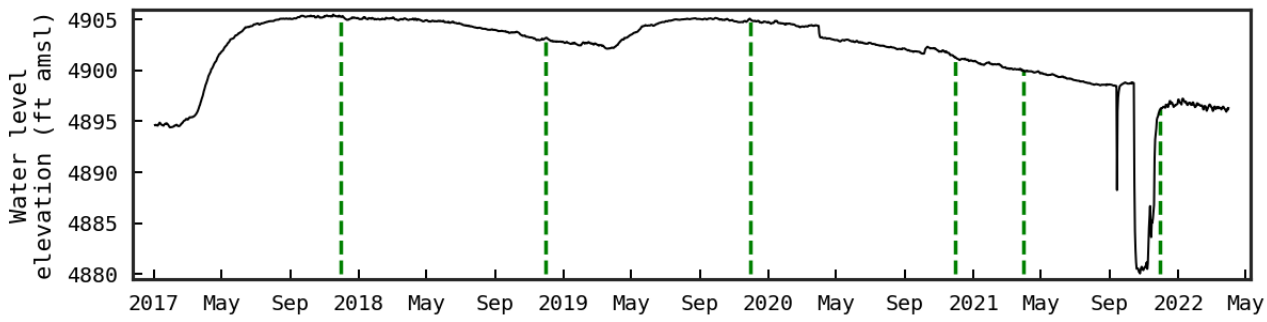

Figure 5. Hydrograph of water levels in well 01S 17E 17BBB1. Dashes mark seepage survey measurement dates. The well was pumped continuously from October 14, 2021 to November 19, 2021.

Tributary runoff and seepage loss

Precipitation in the basin, primarily as winter snowpack, is the largest source of surface runoff to Camas Creek and recharge to the aquifer system via seepage in tributaries. Total seepage losses from streams within the basin are estimated to be 24,000 acre-feet annually or 33 ft^3/s continuously with the seepage rate likely higher during spring runoff (Young and others, 1978). Where a tributary cuts into basalt, there are typically gains from aquifer. Net gains or losses in tributaries during May 1977 USGS seepage survey were +3.0 ft^3/s in Willow Creek, -1.27 ft^3/s in Soldier Creek, and -0.72 ft^3/s in Deer Creek.

Average and median daily peak streamflow since 1991 are 1,469 ft^3/s and 1,015 ft^3/s, respectively, with peaks occurring in late March or early April during snowmelt. The Natural Resource Conservation Service (NRCS) calculates a surface water supply index (SWSI) for Camas Creek that indexes a year's water supply relative to historic supply (NRCS, 2002). Generally, summer streamflow volumes and reservoir carryover are summed and then normalized using non-exceedance probabilities. Summer streamflow from 1991-2021 is the only component in the SWSI calculation for Camas Creek.

Figure 4 shows SWSI values trending lower along with CC3-CC5 seepage. The correlation between SWSI and CC3-CC5 seepage has an R^2 of 0.69 with a slope of 0.87. The plot includes an estimate of the 1977 SWSI value ranked relative to the 1991-2021 record and plotted in relation to the seepage calculated by Young and others (1978) in a nearly equivalent reach. Young and others' seepage survey occurred at the end of May when the hydrograph is usually receding; however, in 1977 there was little runoff and Camas Creek flow conditions were similar to fall base-flow conditions (figure 2). Reach gains in CC3-CC5 are directly proportional to SWSI values at the 5% significance level, which suggests that aquifer discharge to Camas Creek is affected by water supply and irrigation demands.

Relationship with aquifer heads

Aquifer discharge to Camas Creek is head driven and is proportional to differential between aquifer head and stream stage. Well 01S 17E 17BBB1 is approximately 0.7 miles from Camas Creek (see location in figure 1), is completed in basalt, and has a record of water levels that coincide with the seepage surveys (figure 5). Water levels in the well increased 10 feet in response to recharge during winter and spring 2017. Levels slowly declined through the following fall and increased with recharge in spring 2019. Levels have decreased since then. The correlation between monthly median normalized water levels and CC3-CC5 gains has an R^2 of 0.87 with a slope of 1.59 (figure 4).

Summary

The Idaho Department of Water Resources conducted six seepage surveys from November 2017 to November 2021 on lower Camas Creek in south-Central Idaho. Differential gaging was used to calculate gains and losses from the creek. Surveys started in above normal to normal water supply years in 2017 to 2019 and ended in below normal and much below normal years. Lower Camas Creek had gains from groundwater in 2017 to 2020 that varied in each reach. Gains from groundwater past the gage range from 2.7 ft^3/s to 6.9 ft^3/s in those years. In November 2021, Camas Creek had gaining and losing reaches.

Reach CC3-CC5 was measured in the fall surveys and showed declining gains year-to-year that are correlated with water supply and aquifer head.

The results agree with previous studies showing connection between the aquifer and lower Camas Creek (Walton, 1962; Young, 1978). New measurements document stream losses in subreaches of lower Camas Creek that coincide with low aquifer heads following a severe drought in fall 2021.

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