Groundwater-Surface Water Interactions along the Hangman, California, and Rock Creeks, September 30, 2009

Abstract

This data collection effort was required to complete recommendations in the Hangman Creek (WRIA 56) Detailed Implementation Plan. It provides information for developing a better understanding of the surface/groundwater relationships in the mainstem of Hangman Creek and in two major tributaries; Rock and California Creeks. The method utilized was a seepage run. Temperature data was also collected at selected sites for Rock and California Creeks. All study sites were measured on September 30, 2009.

The seepage runs were conducted on the Hangman mainstem, the Rock Creek mainstem and the California Creek mainstem. The study consisted of multiple stream flow measurements on a single day. The location of measurement stations were based upon geomorphologic characteristics, tributary confluences, and available access points.

The mainstem of Hangman Creek consisted of 12 measurements including 4 tributaries. Ten measurements were conducted along Rock Creek including 3 tributaries. California Creek had nine mainstem measurements and no tributaries. Reach lengths varied between 0.6 and 14.2 miles, and flow measurements were taken at each reach break. Five reaches along the Hangman Creek mainstem were gaining reaches and three were losing reaches. The total base flow gain estimated on Hangman Creek mainstem during the seepage run was 5.46 cfs and the flow loss was 0.73 cfs. On Rock Creek, three gaining reaches and one losing reach were identified. The total base flow gain estimated for Rock Creek was 1.42 cfs and the flow loss was 0.09 cfs. California Creek illustrated a complex series of losing (3) and gaining (4) reaches. Total flow gains were estimated at 0.51 cfs and flow losses were 0.18 cfs.

Water temperature data collected during the study averaged 48.9 ºF for Rock Creek and 45.3 ºF for California Creek.

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1.0 Introduction

The Hangman Creek Watershed (Figure 1) is known to have very little surface water during the critical summer flow period (June through September). This situation is exacerbated by the continued proliferation of domestic exempt wells, high summer water use by rural residents, and the over allocation of certificated water rights, permits and claims. Long-term groundwater supply in the basin is questionable and may have impacts to instream flow, future population growth, and ground and surface water quality.

The purpose of this study was to gain insight into the groundwater and surface water interactions within the Hangman Creek Watershed. A "seepage run" was used to gather and evaluate inflows and outflows of groundwater from various water bodies in the watershed. A seepage run consists of multiple stream flow measurements on a stream or creek. Usually, these measurements are taken in a single day and are often conducted during the low flow season for evaluating surface water quantities. A seepage run can identify the different gaining and losing reaches of a stream in order to provide information for water and project management within a basin. Areas where streams are losing surface flow to the ground water system may be zones where the ground water resource is over utilized.

This project, completed by the Spokane County Conservation District in September 2009, fulfilled recommendation R2.a from the Hangman Creek (WRIA 56) Detailed Implementation Plan. Recommendation R2.a endorsed the evaluation the ground water/surface water interactions within the sub-basins of the watershed. This project provides information for developing a better understanding of ground water availability for near stream projects.

1.1 Background

1.1.1 Climate

The Hangman Creek watershed is in a maritime-continental transition climatic zone and has characteristics of both damp coastal weather and more arid interior conditions. In general, the Hangman Creek watershed has an arid climate during the summer months and a mild coastal climate during the winter months. The mouth of Hangman Creek is at an elevation of approximate 1,700 feet. The headwaters are at an elevation of approximately 3,600 feet. Because of the higher headwater elevation, the headwater area experiences an orographic effect that increases the annual average precipitation from less than 18 inches per year at the mouth, to over 40 inches per year in the southeastern headwaters (NRCS, 1999).

1.1.2 Regional Geology

The headwaters of the Hangman Creek watershed begin in mountains formed by the Idaho Batholith. Hangman Creek then flows through the rolling loess hills of the Palouse region and into an area of basalt cliffs and canyons. In reaches below Rock Creek (Figure 1), Hangman Creek flows through sedimentary hills of sand, gravel, and cobbles deposited during the ancestral Glacial Lake Missoula floods.

Bedrock in the lower watershed is mainly Miocene basalt flows with pockets of Tertiary biotite granite and granodiorite (WDNR, 1998). During the Miocene, the basalt flows would periodically dam rivers and form lakes. Material deposited in these lakes formed dense laminated clay and silt deposits that are resistant to erosion. Wind-blown silt (loess) accumulated up to 200 feet over the basalt flows and formed the dune shaped hills.

During the Pleistocene period, lobes from glacial ice sheets blocked several major drainages and produced extensive lakes. The largest of these was Glacial Lake Missoula, which at one time covered over 3,000 square miles. There were up to 40 separate flood events from Glacial Lake Missoula (Waitt, 1980). The floods left major channels in the eastern Washington region, removed loess deposits, and deposited much of the sand, gravel, cobble, and boulders found in the lower reaches of Hangman Creek.

1.1.3 Upper Hangman Creek Sediments

Soils above the Rock Creek – Hangman Creek confluence in the Hangman Creek watershed have formed from a wide variety of materials. The materials include volcanic ash, silty loess, glacial deposits, alluvium deposited by streams, and material weathered from basaltic, granitic, and metamorphic bedrock. In the upper Hangman Creek area, much of the farmed soil is derived from loess deposits. The loess settled in the region approximately 100,000 years ago. The loess deposits are up to 200 feet thick and form dune-like hills. The present day loess deposits are areas where sheet and rill erosion tends to account for almost 90 percent of the soil loss from cropland (USDA, 1978).

1.1.4 Lower Hangman Creek Sediments

The easily erodible stream bank material influences the Hangman Creek flow regime below Duncan (River Mile 18.8). The unconsolidated material generally consists of one or more of three major alluvial deposit types. The deposits are the Latah Formation (lake deposits), Glacial Lake Missoula flood deposits (sand, gravel, and cobbles), and post-Missoula flood alluvium (USDA, 1978).

Hangman Creek
Seepage Run Station Locations

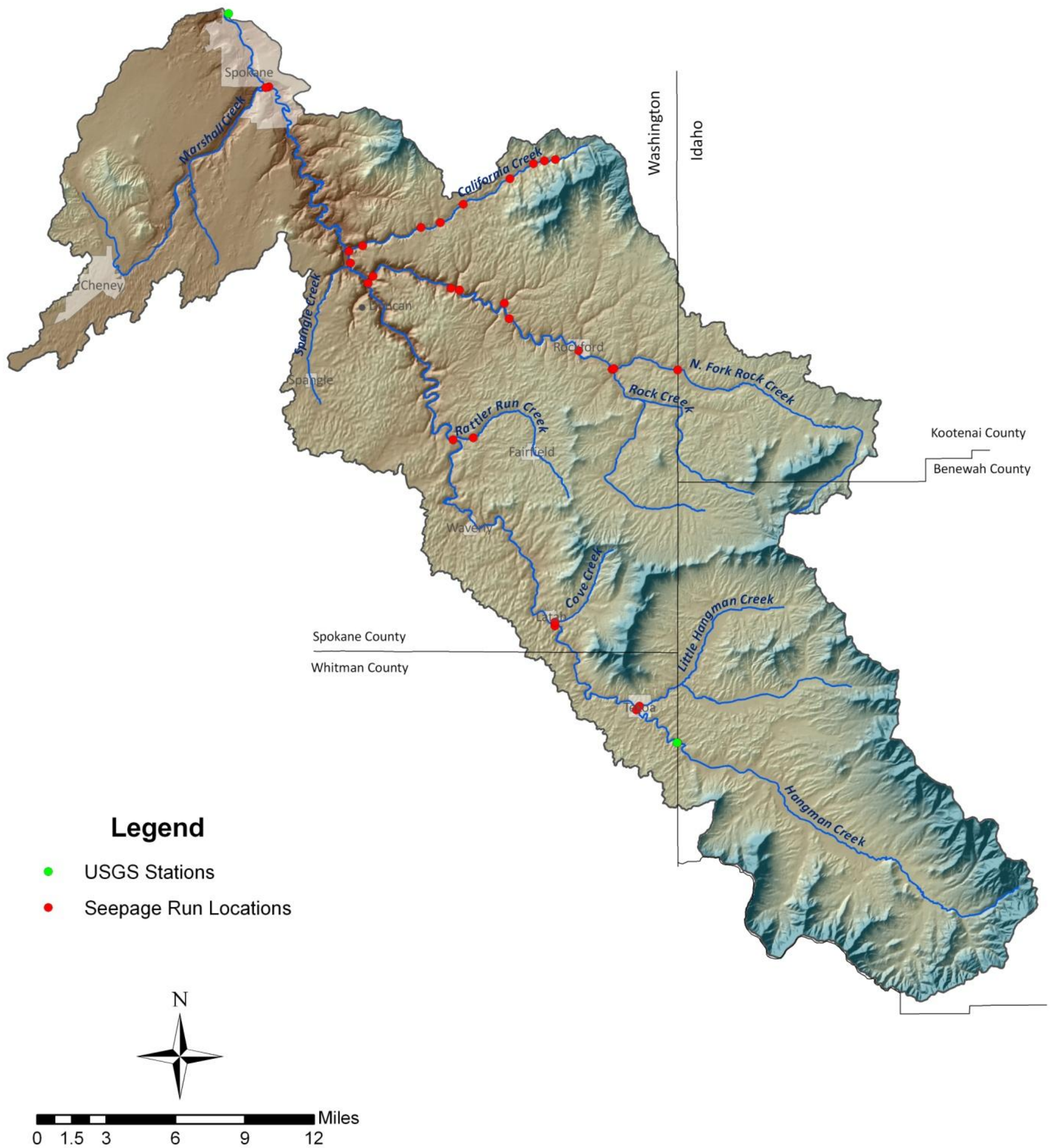

Figure 1: Hangman Creek Watersheds and Measurement Sites

2.0 Methods

2.1 Seepage Run

The purpose of a seepage run is to develop a mass balance on all measurable inflows and outflows. The differences in flow between measurement sites (not attributable to surface inflows or outflows) is the gain from, or the loss to, the ground water system. The mass balance equation used for this analysis is:

Net seepage gain/loss = $(Q_{downstream} – Q_{upstream}) – T + D$ where;

$Q_{downstream}$	= Streamflow measured at the downstream station
$Q_{upstream}$	= Streamflow measured at the upstream station
T	= Inflow from tributaries
D	= Diversions

Flow measurements were made at 31 sites along Hangman, Rock, and California Creeks, and associated tributaries. All sites identified in the Quality Assurance Project Plan (QAPP) were measured (Table 1), with the following exceptions:

1. The measurements at California Creek River Mile 11.5 and Sands Road were added.
2. California Creek at Highway 27 flow was indeterminate, so California Creek at Madison Road was substituted.
3. Stevens Creek along the Hangman Creek mainstem was added.
4. Ochlare Creek along the Rock Creek mainstem was added.
5. Rock Creek sites RC1, RC2, and RC3 were mislabeled. They should be labeled as RC1 – North Fork of Rock Creek at Stateline, RC2 – North Fork of Rock Creek upstream of Chatcolet Road, and RC3 – Rock Creek at Chatcolet Road.

The Spokane County Conservation District (SCCD) conducted the seepage run on September 30, 2009. The SCCD selected discharge measurement stations on the Hangman Creek mainstem (eight) and tributaries (four); Rock Creek mainstem (five) and tributaries (five); and California Creek mainstem (nine). The three general measured components of the seepage run included:

<u>Mainstem flow:</u> A combination of manual flow measurements and local USGS gaging station data were used to populate the flow profiles. All sites were measured on a single day. Cross-sections were modified to meet the measurement requirements for depth and velocity outlined in Rantz and others, 1982.

<u>Tributaries, Distributaries:</u> All known streams and other discharges (i.e. municipal discharges) that provide flow to the creeks were measured as close to its confluence as possible. The discharge measurements were completed during the low flow period and prior to significant rain events. The Hangman Creek hydrograph was relative steady for the weeks prior to the measurements (less than a ten percent increase in flow). The Towns of Rockford and Tekoa were contacted and the discharges to the creek were recorded (Rockford <0.01 cfs; Tekoa 0.19 cfs).

Diversions: No known large scale irrigation or diversions were in operation prior to the measurements. The Hangman Hills Golf Course was contacted and stopped pumping water from the creek the day prior to the seepage run.

2.2 Temperature

Temperature data was collected on Rock and California Creeks. The Sontek YSI Handheld ADV discharge meters recorded the average temperature of the water column during the discharge measurement.

Table 1: Measurement Site Types and Locations from QAPP

Water Body	Site	Type	Location
California Creek	CC1	Main Stem	California Creek at Jons Road
California Creek	CC2	Main Stem	California Creek at Chapman Road
California Creek	CC3	Main Stem	California Creek at Jackson Road
California Creek	CC4	Main Stem	California Creek at Highway 27
California Creek	CC5	Main Stem	California Creek at Dunn Road
California Creek	CC6	Main Stem	California Creek at Elder Road
California Creek	CC7	Main Stem	California Creek at mouth
Rock Creek	RC1	Main Stem	Rock Creek at State Line
Rock Creek	RC2	Main Stem	Rock Creek upstream of Chatcolet Road
Rock Creek	RC3	Tributary	South Fork Rock Creek at Chatcolet Road
Rock Creek	RC4	Main Stem	Rock Creek in Rockford
Rock Creek	RC5	Tributary	Mica Creek in Rockford
Rock Creek	RC6	Main Stem	Rock Creek at Jackson Road
Rock Creek	RC7	Main Stem	Rock Creek up stream of Cottonwood Creek
Rock Creek	RC8	Tributary	Cottonwood Creek at mouth
Rock Creek	RC9	Main Stem	Rock Creek at mouth
Hangman Creek	HC1	Main Stem	USGS Hangman Creek at State Line – rated discharge
Hangman Creek	HC2	Tributary	Little Hangman Creek
Hangman Creek	HC3	Main Stem	Hangman Creek in Tekoa downstream of Little Hangman
Hangman Creek	HC4	Main Stem	Hangman Creek upstream of Latah
Hangman Creek	HC5	Tributary	Cove Creek in Latah
Hangman Creek	HC6	Main Stem	Hangman Creek downstream of Rattler Run
Hangman Creek	HC7	Tributary	Rattler Run Creek
Hangman Creek	HC8	Main Stem	Hangman Creek upstream of Rock Creek
Hangman Creek	HC9	Main Stem	Hangman Creek downstream of Rock Creek
Hangman Creek	HC10	Main Stem	Hangman Creek upstream of Marshall Creek
Hangman Creek	HC11	Tributary	Marshall Creek
Hangman Creek	HC12	Main Stem	USGS station at mouth – rated discharge

Notes:

1. USGS is United States Geological Survey.

3.0 Results

3.1 Hangman Creek

Historically, seepage runs on Hangman Creek demonstrate that the flow above Duncan is notably less than the flow measured at the mouth; and that a significant portion of the flow is contributed downstream of Marshall Creek (Table 2). In the past, the flows in the upper watershed ranged from 6.7 percent (at Tekoa) to 41.2 percent (at Duncan) of the measured USGS flow at the mouth, Table 2. The measurements on September 30, 2009 followed the same pattern; the flows at Tekoa and Duncan were 4.6 and 45.4 percent, respectively, of the flow at the USGS station at the mouth. The reach based results September 30, 2009 measurements are detailed in Table 3. The ground water/surface water exchange rate varied from -0.20 to 0.19 cfs per mile. Figure 2 shows the gaining (blue) and losing (red) reaches.

3.2 Rock Creek

The North Fork of Rock Creek was dry until the confluence of Rock Creek at Chatcolet Road (Table 4). From Rockford to Jackson Road, Rock Creek was losing flow to the ground water (0.02 cfs per mile). From Jackson Road through the canyon area where the stream gradient increases, the flow increased by 0.18 cfs per mile, Table 5. All tributaries to Rock Creek were dry with the exception of Ochlare Creek (0.05 cfs). The ground water/surface water exchange rate varied from -0.09 to 0.18 cfs per mile.

3.3 California Creek

The headwaters of California Creek fluctuate between gaining and losing reaches, Table 6. From approximately River Mile 6.0 the base flow increases in the steep canyon reach with a maximum flow at Elder Road. From Elder Road to the mouth of California Creek the flow decreased by approximately 12 percent. A larger (59 percent) decrease was observed in flow measurements completed on the lower portion of California Creek in 2002. The ground water/surface water exchange rate varied from -0.11 to 0.17 cfs per mile (Table 7).

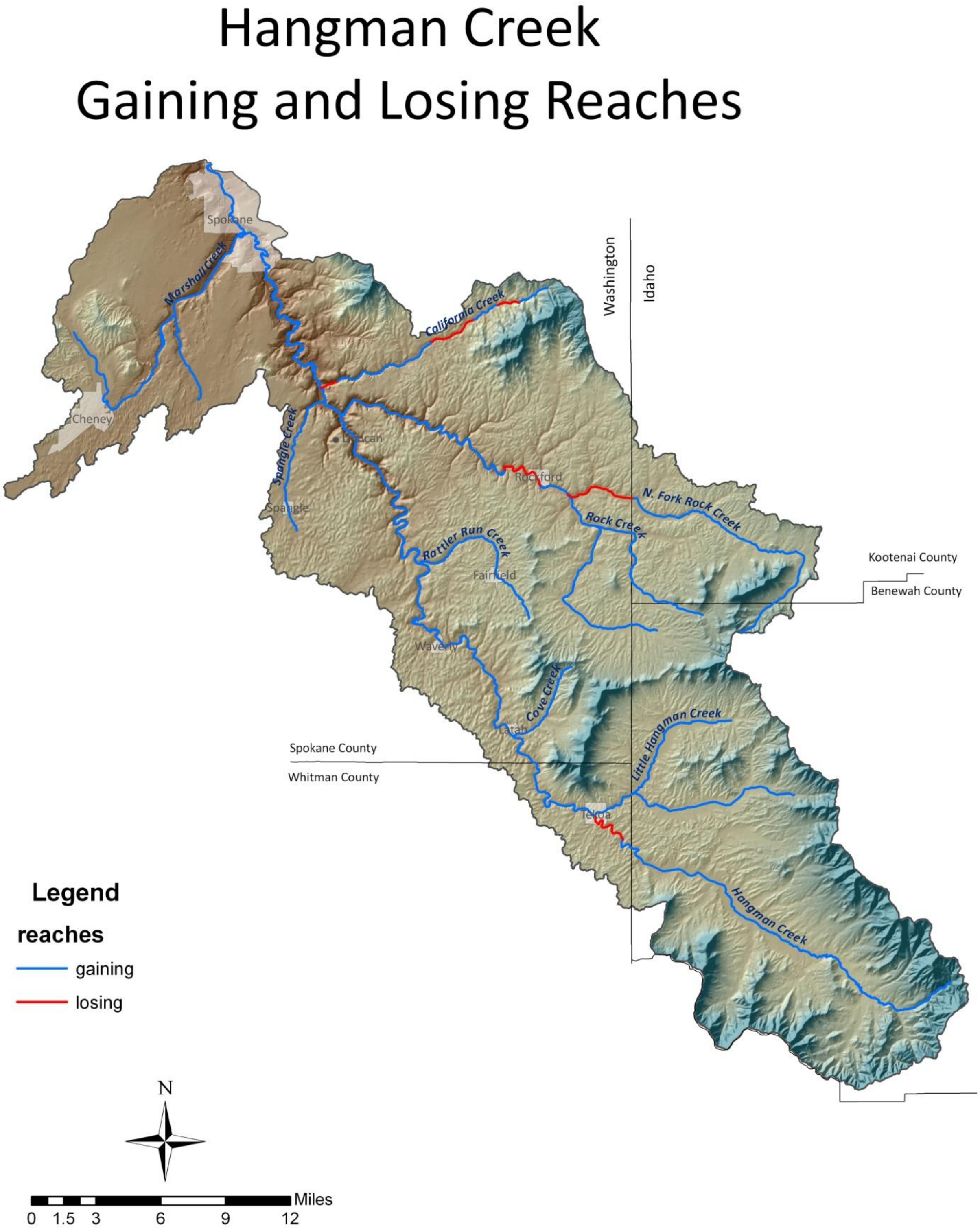

Figure 2: Seepage Run Gaining and Losing Reaches

Table 2: Hangman Creek Discharge Measurement Summary

Description	River Mile	Sept. 6, 2001 Discharge (cfs)	July 18, 2002 Discharge (cfs)	Sept. 4, 2002 Discharge (cfs)	Sept. 30, 2009 Discharge (cfs)
Hangman Creek Stateline	58.4	NM	NM	NM	0.64
Little Hangman Creek	54.9	0.23	0.15	0.16	0.59
Hangman Creek at Tekoa	54.8	0.29	1.48	0.72	0.50
Tekoa WWTF	54.3	NM	NM	NM	0.19
Hangman Creek at Latah	47.3	0.55	2.19	1.21	0.76
Cove Creek at Latah	47.2	0.07	0.18	0.11	0.20
HC at Roberts Road	41.5	0.62	2.99	1.66	NM
Rattler Run Creek	32.9	0.08	0.23	0.15	0.16
HC d/s Rattler Run Creek	32.8	0.59	3.75	1.43	1.81
HC at Kentuck Trails Rd	31.0	NM	3.32	1.10	NM
HC at Keevy Road	29.4	0.35	3.07	0.93	NM
HC u/s of Rock Creek	21.0	1.62	5.62	2.31	3.17
Rock Creek	20.2	0.41	1.33	0.74	1.42
HC at Duncan	18.8	1.77	5.73	2.47	5.00
California Creek	18.3	0.04	0.59	0.12	0.45
Stevens Creek	14.6	NM	NM	NM	0.10
HC d/s Hangman Valley Golf Course	13.5	1.42	7.07	3.72	NM
HC two miles south of Hatch Road	10.2	1.33	8.21	2.80	NM
HC at Yellowstone pipeline	8.8	1.33	8.85	2.40	NM
HC u/s Marshall Creek	4.6	1.20	9.76	3.47	7.49
Marshall Creek	4.5	0.60	0.98	1.74	2.81
USGS gage site	0.8	5.10	14.0	10.0	11.0

Notes:

1. River miles are for main stem Hangman Creek only, and are measured from the mouth of Hangman Creek (RM 0.0) upstream. Measurements are from USGS 7.5 minute topographic maps.
2. No discharge was measured at the USGS sites, the USGS rated flows were used for the station at the mouth and at the state line.
3. Little Hangman Creek discharge was measured at the state line in 2001 and 2002. It was measured at the mouth in 2009.
4. HC is Hangman Creek.
5. WWTF is wastewater treatment facility.
6. u/s is upstream.
7. d/s is downstream.
8. NM is not measured.
9. cfs is cubic feet per second.

Table 3 Hangman Creek Ground Water – Surface Water Interactions by Reach

Reach Location	Reach River Miles	Length (miles)	Ground Water Flow (cfs)	Ground Water Flow Rate (cfs/mile)
Hangman Creek at State Line to Hangman Creek in Tekoa below Little Hangman Creek Confluence	58.4 to 54.8	3.7	-0.73	-0.20
Hangman Creek in Tekoa to Hangman Creek upstream of Cove Creek	54.8 to 47.3	7.4	0.26	0.04
Hangman Creek upstream of Cove Creek to Hangman Creek downstream of Rattle Run Creek	47.3 to 32.8	15.5	0.69	0.04
Hangman Creek downstream of Rattler Run Creek to Hangman Creek upstream of Rock Creek	32.8 to 21.0	9.0	1.36	0.15
Hangman Creek upstream of Rock Creek to Hangman Creek at Duncan	21.0 to 18.8	4.0	0.41	0.10
Hangman Creek at Duncan to Hangman Creek upstream of Marshall Creek	18.8 to 4.6	14.3	1.94	0.14
Hangman Creek upstream of Marshall Creek to Hangman Creek USGS gage near the mouth	4.6 to 0.8	3.7	0.70	0.19

Notes:
1. cfs is cubic feet per second.
2. USGS is U.S. Geological Survey.

Table 4: Rock Creek Discharge Measurement Summary

Location	River Mile	Discharge (cfs)	Elevation (feet)
North Fork Rock Creek at Stateline	19.0	0.00	2,480
North Fork Rock Creek u/s of Rock Creek	15.4	0.00	NA
Rock Creek u/s of North Fork of Rock Creek	15.8	0.28	2,410
Rock Creek in Rockford	14.1	0.34	2,355
Mica Creek in Rockford	12.9	0.00	NA
Rock Creek at Jackson Road	8.9	0.25	2,210
Ochlare Creek	8.4	0.05	NA
Rock Creek upstream of Cottonwood Creek	5.1	1.00	2,040
Cottonwood Creek at Mouth	4.9	0.00	NA
Rock Creek at Mouth	0.5	1.42	1,910

Notes:
1. River miles are for main stem Rock Creek, and are measured from the mouth of Rock Creek (RM 0.0) upstream. Measurements are from USGS 7.5 minute topographic maps.
2. cfs is cubic feet per second.
3. u/s is upstream.
4. NA is not applicable.
5. The Rockford WWTF discharged approximately 0.001 cfs to the creek during the measuring period.

Table 5 Rock Creek Ground Water – Surface Water Interactions by Reach

Reach Location	Reach River Miles	Length (miles)	Ground Water Flow (cfs)	Ground Water Flow Rate (cfs/mile)
North Fork Rock Creek at State Line to Rock Creek	19.0 to 15.4	3.8	0.00	0.00
Rock Creek at North Fork confluence to Rock Creek in Rockford	15.4 to 14.1	1.1	0.06	0.06
Rock Creek in Rockford to Rock Creek at Jackson Road	14.1 to 8.9	5.2	-0.09	-0.02
Rock Creek at Jackson Road to Rock Creek at Cottonwood Creek	8.9 to 5.1	3.8	0.70	0.18
Rock Creek at Cottonwood Creek to Rock Creek at the mouth	5.1 to 0.5	4.6	0.47	0.10

Notes:
1. cfs is cubic feet per second.

Table 6: California Creek Discharge Measurement Summary

Location	River Mile	Discharge 2009 (cfs)	Discharge 2002 (cfs)	Elevation (feet)
California Creek at River Mile 11.5	11.5	0.01	NM	2600
California Creek at Jons Road	10.5	0.00	NM	2555
California Creek at Chapman Road	9.9	0.00	NM	2545
California Creek at Jackson Road	8.6	0.11	NM	2530
California Creek at Madison Road	6.2	0.00	NM	2405
California Creek at Sands Road	4.7	0.20	0.15	2320
California Creek at Dunn Road	3.5	0.40	0.31	2250
California Creek at Elder Road	0.7	0.51	0.29	1970
California Creek at Mouth	0.2	0.45	0.12	1900

Notes:
1. River miles are for main stem California Creek, and are measured from the mouth of California Creek (RM 0.0) upstream. Measurements are from USGS 7.5 minute topographic maps.
2. The 2002 measurements are from September 4, 2002. The 2009 measurements are from September 30, 2009.
3. cfs is cubic feet per second.
4. NM is not measured.
5. The 2002 measurement near Elder Road was at approximately River Mile 1.1.

Table 7 California Creek Ground Water – Surface Water Interactions by Reach

Reach Location	Reach River Miles	Length (miles)	Ground Water Flow (cfs)	Ground Water Flow Rate (cfs/mile)
California Creek at River Mile 11.5 to California Creek at Jons Road	11.5 to 10.5	1.0	-0.01	-0.01
California Creek at Jons Road to California Creek at Chapman Road	10.5 to 9.9	0.6	0.00	0.00
California Creek at Chapman Road to California Creek at Jackson Road	9.9 to 8.6	1.3	0.11	0.09
California Creek at Jackson Road to California Creek to Madison Road	8.6 to 6.2	2.4	-0.11	-0.05
California Creek at Madison Road to California Creek at Sands Road	6.2 to 4.7	1.5	0.20	0.13
California Creek at Sands Road to California Creek at Dunn Road	4.7 to 3.5	1.2	0.21	0.17
California Creek at Dunn Road to California Creek at Elder Road	3.5 to 0.7	2.8	0.11	0.04
California Creek at Elder Road to California Creek at the mouth	0.7 to 0.2	0.5	-0.06	-0.12

Notes:

1. cfs is cubic feet per second.

4.0 DISCUSSION

The surface water/ground water connection data provides information for use in a basin wide water balance and hydrologic model. The data collected with this project will be used in the current Hangman Creek Ground Water study. The Hangman Creek Ground Water study is using regional basalt geology, aquifer delineation, and seepage run data to estimate future water availability, land use build-out scenarios, and ground water mining potential. The seepage run hydraulic connectivity data is key in the hydrologic modeling and water balance.

The seepage runs for Rock and California Creeks were completed to provide sub-watershed information on the ground water/surface water interactions within the Hangman watershed. Along with the Rock and California Creek measurements, seepage run data were obtained on the Hangman mainstem to compare with historic (2001 and 2002) seepage run data (Table 1). The historic seepage run data for the mainstem show that changes in base flow conditions along reaches can vary seasonally and/or annually. In the Hangman watershed, these annual changes are mostly related to the winter snowpack and spring runoff conditions.

The Hangman Creek seepage run data from 2001 and 2002, when compared to 2009 data, show similar trends, but different magnitudes. This is probably due to the different snowpack conditions preceding summer flows. The June 2001 Washington State Basin Outlook Report (Natural Resources Conservation Service - National Water and Climate Center, June 2001) snowpack estimate for the Spokane River basin was only 13 percent of the average snowpack.

The June 2002 Washington State Basin Outlook Report (Natural Resources Conservation Service - National Water and Climate Center, June 20029) snowpack estimate for the Spokane River basin was 188 percent of the average snowpack, significantly more than in 2001 or 2009. The June 2009 Washington State Basin Outlook Report (Natural Resources Conservation Service - National Water and Climate Center, June 2009) snowpack estimate for the Spokane River basin was 66 percent of the average snowpack, significantly more than in 2001. The Spokane area received record snowfall levels for water year 2009 (October 1, 2008 through September 30, 2009) throughout the county. These snowfall records were more localized than the basin wide snowpack averages reported by the NRCS. The higher snowfall in 2009 compared to 2001 or 2002 is reflected in the seepage run results detailed in this report.

For Hangman Creek, the 2009 flows show that the flow increases around the Rock Creek (River Mile 20.2) and Marshall Creek (River Mile 4.5) confluences (Figure 3). These same increases were seen in 2001 and 2002, but were more pronounced from the Marshall Creek confluence to the mouth of Hangman Creek than the 2009 flows.

Both Rock and California Creeks demonstrate the same basic flow patterns: losing reaches in the headwaters with significant flow increases in the steep canyon reaches (Figures 4 and 5). The surface contribution from springs and tributaries were insignificant for both creeks. California Creek showed a slight loss from the canyon to the mouth where Rock did not. Only California Creek had historic data to compare the 2009 seepage run data with. The 2002 California Creek flows were lower, but showed the same gaining reach through the canyon with the losing reach extending from the canyon outlet to the mouth (Table 4).

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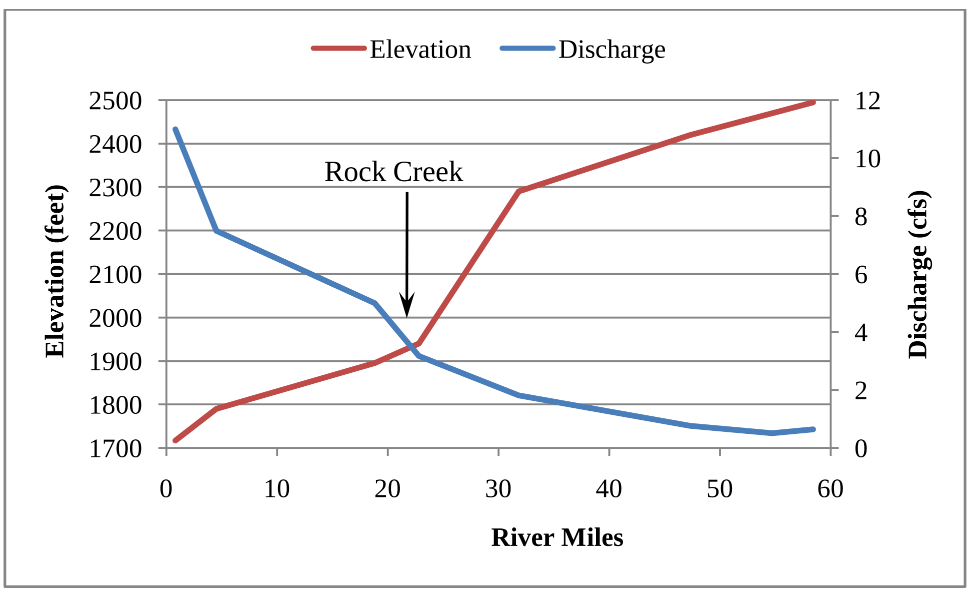

Figure 3: Hangman Creek Discharge and Elevation at Select River Miles

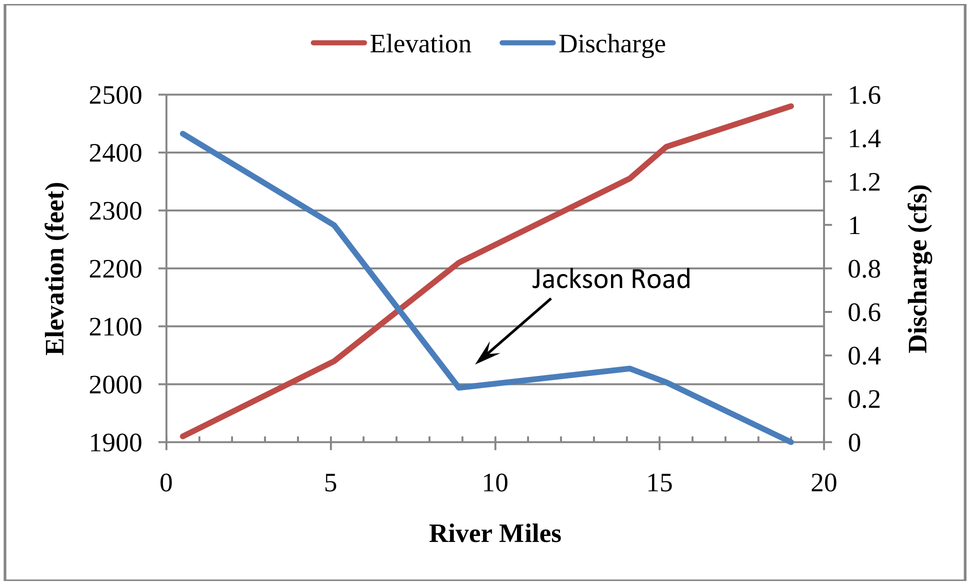

Figure 4: Rock Creek Discharge and Elevation at Select River Miles

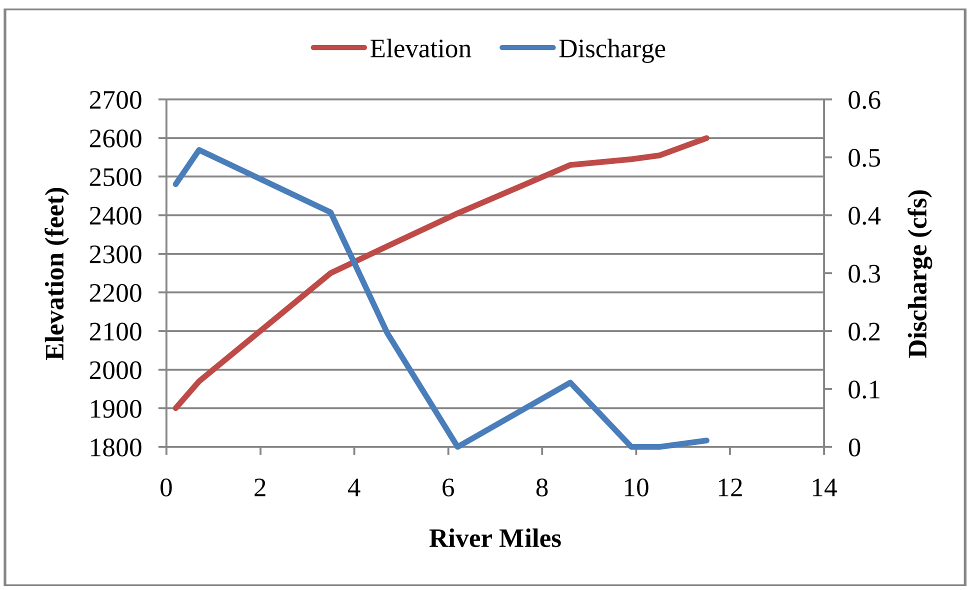

Figure 5: California Creek Discharge and Elevation at Select River Miles

5.0 CONCLUSIONS

Areas of ground water inflow and outflow along Rock, California, and Hangman Creeks were evaluated for use in a basin wide water balance and hydrologic model. Both Rock and California Creeks demonstrate the same basic flow patterns: losing reaches in the headwaters with significant flow increases in the steep canyon reaches.

The North Fork of Rock Creek was dry in upper reaches, with base flow increasing to Rockford. After Rockford, to Jackson Road, Rock Creek flows decreased by 0.09 cfs (26 percent). Through the canyon reach, Rock Creek flows increased by 0.70 cfs (an increase of 280 percent). From the canyon outlet to the mouth, the flows increased by 0.42 cfs (42 percent).

The upper reaches of California Creek varied from dry to 0.11 cfs. To the middle of the canyon reach (Dunn road), the flows increased from 0.20 cfs to 0.40 cfs, an increase of 100 percent. From the middle of the canyon reach to just past the canyon outlet (Elder Road), the flows increased by 0.11 cfs, or 28 percent. From Elder Road to the mouth of California Creek, the flow decreased by 0.06 cfs, or 12 percent. This decrease in California Creek flows just upstream of the mouth were also observed in 2002 (Table 6).

The Hangman Creek mainstem flow measurements for 2009 did not show as significant ground water/surface water interactions as in previous seepage runs. The difference is due mainly to the pre-existing snow pack and spring runoff conditions. The 2009 Hangman Creek low flows were influenced by the record winter snowfall in the watershed; and slow spring runoff allowing significant infiltration to the shallow ground water system.

6.0 REFERENCES

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