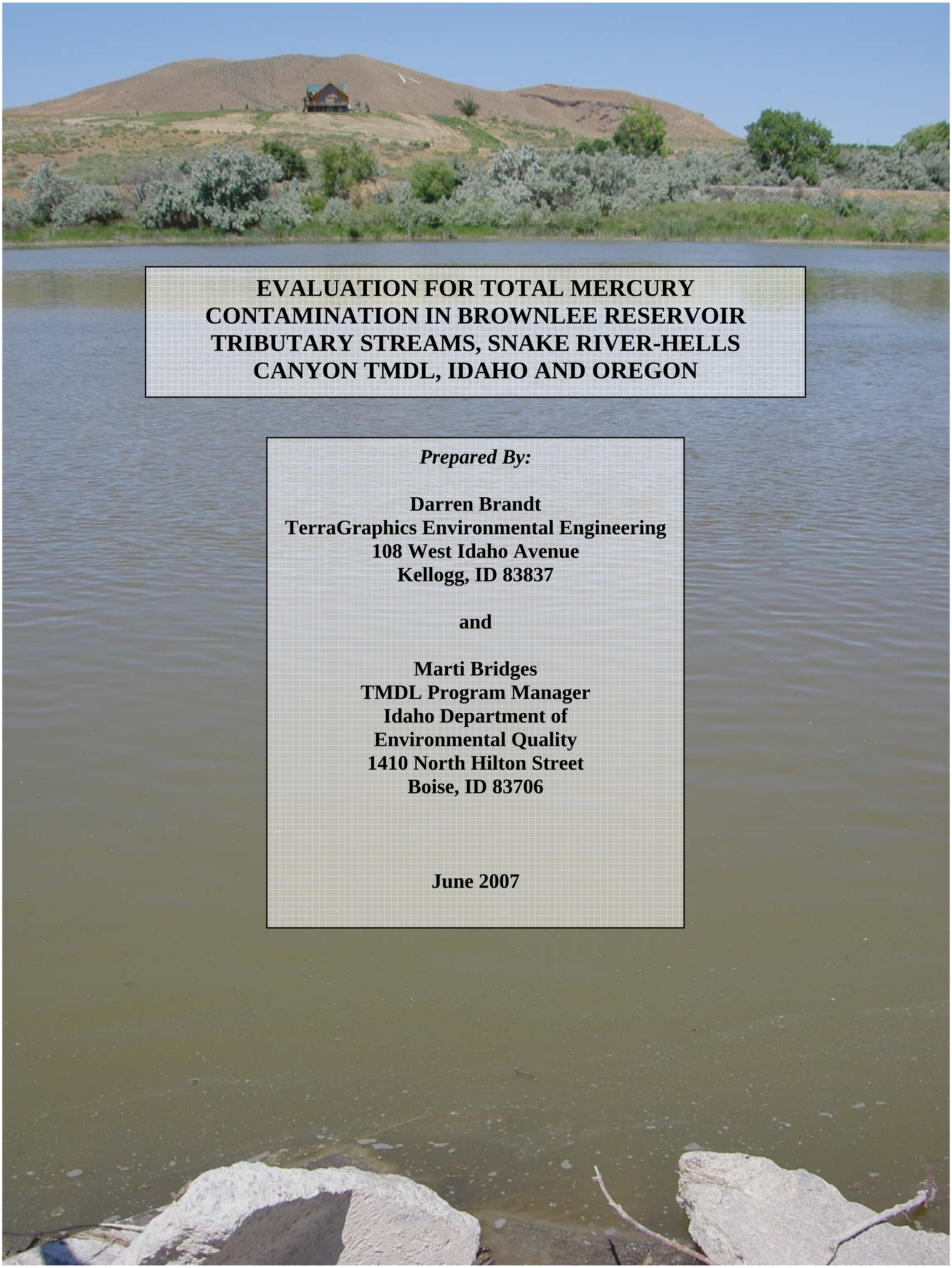

EVALUATION FOR TOTAL MERCURY CONTAMINATION IN BROWNLEE RESERVOIR TRIBUTARY STREAMS, SNAKE RIVER-HELLS CANYON TMDL, IDAHO AND OREGON

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SECTION 1.0 INTRODUCTION

TerraGraphics Environmental Engineering, Inc. (TerraGraphics) was contracted by the Idaho Department of Environmental Quality (IDEQ) to collect unfiltered surface water samples from river locations tributary to Brownlee Reservoir and the Snake River located in southwestern Idaho and eastern Oregon. The subsequent analysis of samples for mercury by Brooks Rand Trace Metals Analysis and Products (Brooks Rand) is intended to be used as a portion of the data required for a possible mercury total maximum daily load (TMDL) for selected water bodies. TerraGraphics collected samples according to U.S. Environmental Protection Agency (USEPA) Method 1669: "Sampling Ambient Water for Trace Metals at EPA Water Quality Criteria Levels" (USEPA 1996). Mercury concentration results were used along with river discharge estimates to approximate mercury loading to the Snake River-Hells Canyon complex. This document summarizes TerraGraphics' sampling efforts as well as the sampling results and calculations related to mercury loading to the Snake River-Hells Canyon complex.

SECTION 2.0 PROJECT PURPOSE

The purpose of this project was to identify the relative importance of tributary sources of mercury-contaminated water entering the Snake River-Hells Canyon complex, and more specifically the Brownlee Reservoir. The results of this work, coupled with fish tissue analysis from other IDEQ efforts, will allow IDEQ to determine if a TMDL is necessary.

2.1 Site Background

Brownlee Reservoir (Snake River RM347 to RM285) is § 303 (d) listed for mercury by the State of Idaho. It is one of several reservoirs in Idaho that have fish consumption advisories issued by the Bureau of Community and Environmental Health (BCEH) based on high levels of mercury in fish tissue. In addition, the State of Oregon has §303(d) listed the mainstem Snake River (RM409 to RM188) for mercury contamination. Fish in Brownlee Reservoir have been found with mercury concentrations exceeding the 0.3 mg/kg wet weight (IDEQ 2006) safe level recommended by the State of Idaho. Little is known about the source of mercury contamination of the reservoir and inflowing water bodies. The Snake River – Hells Canyon Total Maximum Daily Load (SR-HC TMDL) mentions the existence and exploitation of natural mercury deposits and the possible lingering effects of legacy mining in Jordan Creek as potential sources. The consumption of fish is known to be the primary pathway of mercury contamination to most humans. The greatest potential threat is exposure to methyl mercury, a neurotoxin that damages the central nervous system of humans and is the dominant form of mercury in fish (IDEQ 2006).

Numerous studies of lakes and reservoirs have shown that sources of mercury contamination may be from natural, anthropogenic, or a combination of sources. The most common natural sources include erosion from rocks and soils or discharge from geothermal waters such as hot springs. Common anthropogenic sources include discharge or atmospheric emissions from mines, atmospheric emissions from burning of fossil fuels such as coal in power plants, and releases from industrial and medical incinerators. Other sources are legacy mining activities, agricultural fumigants, etc. (IDEQ 2006).

SECTION 3.0 LOCATION DESCRIPTIONS

Samples were collected from the following locations (See Table 3-1 and Figure 3-1):

- In Idaho – mainstem Snake River at RM 409, Boise River, Payette River, Weiser River, Snake River below Brownlee, and Lower Salmon River.
- In Oregon – Owyhee River, Malheur River, Powder River, Imnaha River and Grande Ronde River.

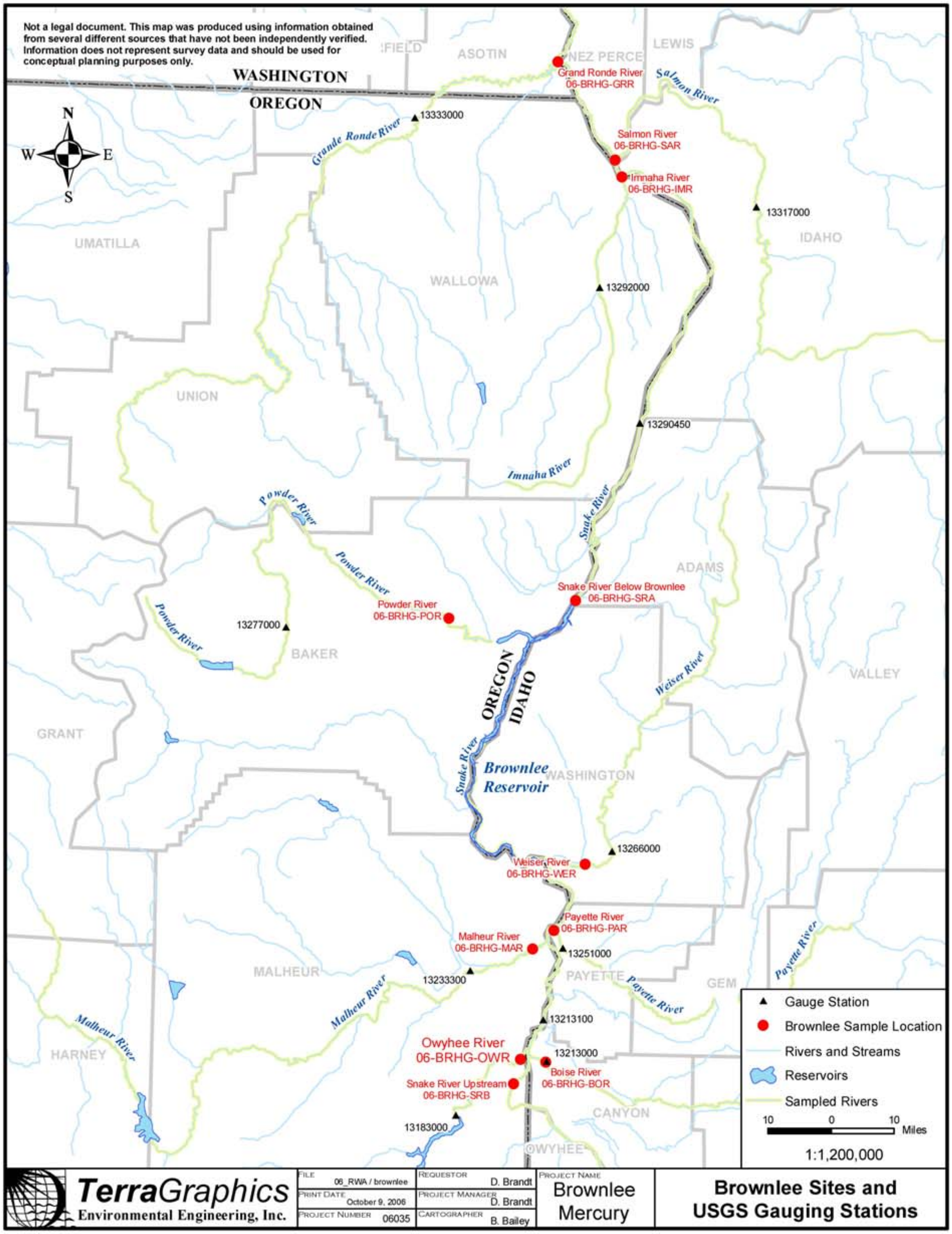
IDEQ hoped to capture basic information on major tributary inputs as well as from a few representative reference rivers. Due to the magnitude of river discharge at the sampling sites, discharge measurements were taken from the nearest USGS gauging station, with the exception of site 06-BRHG-SRBwhere discharge was estimated by the Idaho Power Company (IPC). If the nearest gauging station location was downstream of a confluence that would alter the discharge measurement, then the next most upstream USGS station was used.

Table 3-1 Sampling location, site name and nearest USGS Station Number

Site Name	Description	USGS Station Number	Northing (ft)	Easting (ft)
06-BRHG-BOR	Boise River near Parma	13213000	772615.45	2301903.64
06-BRHG-GRR	Grande Ronde River near SR 129	13333000	1610892.95	2311790.68
06-BRHG-IMR	Imnaha River near Imnaha, OR	13292000	1514139.00	2365917.43
06-BRHG-MAR	Malheur River near Vale, OR	13233300	867541.17	2290787.39
06-BRHG-OWR	Owyhee River below Owyhee Dam	13183000	774756.12	2280505.79
06-BRHG-PAR	Payette River near Payette, ID	13251000	882941.37	2308798.81
06-BRHG-POR	Powder River	13277000	1144685.57	2220736.81
06-BRHG-SAR	Lower Salmon in Idaho	13317000	1528698.68	2359787.87
06-BRHG-SRA	Snake River below Brownlee Reservoir	IPC Brownlee Outflow	1159459.62	2326628.71
06-BRHG-SRB	Snake River upstream of the Boise and Owyhee inflow in Idaho near RM 409[a]	13213100	754553.03	2275095.36
06-BRHG-WER	Weiser River near Weiser	13266000	938438.47	2334860.59

[a] = closest station is downstream of the monitoring site.

Figure 3-1 Sampling Locations and Gauging Stations



SECTION 4.0 FIELD AND LABORATORY METHODS

This was a study of real time inputs from unfiltered water containing suspended sediment from the major tributaries of the Snake River/Brownlee Reservoir system. The river reaches are as follows: mainstem Snake River at RM 409, Boise River, Payette River, Weiser River, and Lower Salmon River in Idaho; Owyhee River, Malheur River, Powder River, Imnaha River, and Grande Ronde River in Oregon. The Imnaha River is useful as a relatively unimpaired reference stream based on GIS analysis and is included because there is no mining/urban influence, few roads, and minimal agricultural influence.

4.1 Surface Water Sampling

Surface water monitoring occurred at 11 locations in tributaries to Brownlee Reservoir and the Snake River (Table 3-1). Field crews collected an unfiltered sample for each surface water location during four sampling events, three in June and one in September 2006. The sampling schedule is shown in Table 4-1. Samples were gathered three times during higher spring runoff periods in June of 2006 and once during base flow in September of 2006.

Table 4-1 Schedule for Surface Water Monitoring

Sampling Start Date	Site(s)	Number of Samples for each event.	Total Samples for each event
June 1-4 June 8-11 June 21-23 September 6-10	06-BRHG-GRR 06-BRHG-SAR 06-BRHG-IMR 06-BRHG-SRA 06-BRHG-BOR 06-BRHG-PAR 06-BRHG-WER 06-BRHG-POR 06-BRHG-SRB 06-BRHG-OWR 06-BRHG-MAR	11 surface water samples + 3 field blanks + 3 field duplicates	17

Water quality sample collection and field processing was conducted using "ultra-clean" protocols that ensure non-contamination at the parts-per-trillion level, as described in USEPA Method 1669 (USEPA 1996). Unfiltered grab water samples were gathered by boat or wading using USEPA 1669 approved methods. Surface water samples were collected through direct immersion of the sample bottle into the water body (Figure 4-1). The bottles used were certified clean from Brooks Rand. Clean sample bottles were double-bagged in polyethylene bags for storage and transportation; the bags were not opened until time of collection.

Sampling consisted of a two-person team. All sampling personnel were trained and certified in low level mercury sampling. One person was designated "Clean hands" and the other was designated “Dirty hands.” All operations involving contact with the sample bottle or transfer of the sample from the sample collection device to the sample bottle were handled by the individual designated as “Clean hands.” “Dirty hands” was responsible for all activities that did not involve direct contact with the sample (Figure 4-2).

Figure 4-1 Trace Metal Grab Sample Technique

Figure 4-2 Clean Hands/Dirty Hands Sample Handling and Clean Sampling Field Clothing

Field blank and duplicate results were examined upon receipt and all Quality Control (QC) objectives were met. This indicates that there was no contamination of the samples during the field sampling portion of this project.

4.2 Laboratory Methods

The samples were analyzed by the USEPA Method 1631 (Table 4-2) for mercury in surface water. TerraGraphics met all holding time requirements for the collected samples.

Table 4-2 Analytical Program Summary

ANALYTE	ANALYTICAL METHOD	METHOD DETECTION LIMIT (ng/L) Brooks Rand	PRACTICAL QUANTITATION LIMIT (ng/L) Brooks Rand
Mercury	EPA Method 1631	0.1	0.25

SECTION 5.0 RESULTS

5.1 Station Mercury Concentrations

Mercury concentrations at the sampling sites and the estimated river discharges are presented in Table 5-1. Grab samples do not represent the entire depth and width of the sample location. In addition, grab samples do not yield long term average concentrations; rather they reflect the concentration at a single point in time and place. Some of the samples may have been collected on the ascending limb of the hydrograph and others may have been collected on the descending limb, which would influence the sample concentration. These results represent an estimate of the concentration and loading for each sampling station. Due to the sampling limitations, care should be used when making management decisions from this data set. The data have high precision but accuracy has not been determined.

Table 5-1 Mercury Concentrations and Loading Results

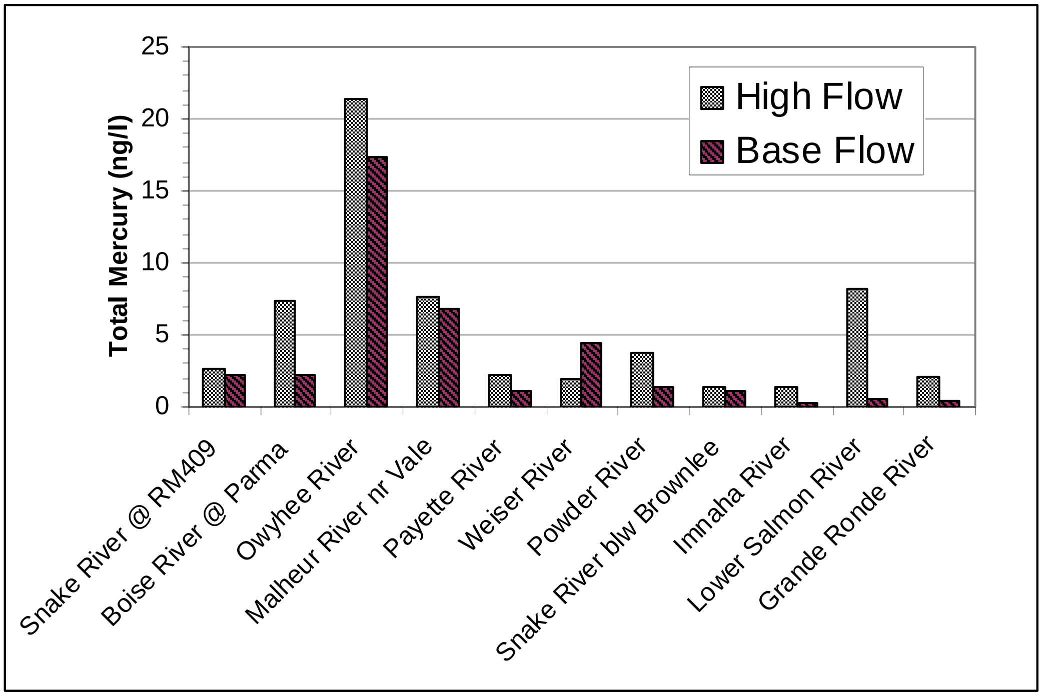
Site Name	Date	Mean Discharge (cfs)	Total Mercury Concentration (ng/L)	Mercury Loading Rate (lbs/day)	Mercury Loading Rate (grams/day)
06-BRHG-BOR	6/1/2006	5,170	6.88	0.192	87.1
	6/8/2006	2,110	9.63	0.109	49.4
	6/21/2006	1,900	5.53	0.057	25.9
	9/6/2006	837	2.2	0.010	4.5
06-BRHG-GRR	6/4/2006	7,680	1.76	0.073	33.1
	6/11/2006	6,330	3.62	0.124	56.2
	6/23/2006	3,540	0.69	0.013	5.9
	9/10/2006	571	0.36	0.001	0.5
06-BRHG-IMR	6/4/2006	1,850	1.87	0.019	8.6
	6/11/2006	1,790	1.74	0.017	7.7
	6/23/2006	1,210	0.73	0.005	2.3
	9/10/2006	114	0.24	0.00015	0.1
06-BRHG-MAR	6/1/2006	386	4.12	0.008	3.6
	6/8/2006	194	11.3	0.012	5.4
	6/21/2006	109	7.37	0.004	1.8
	9/6/2006	184	6.8	0.007	3.2
06-BRHG-OWR	6/1/2006	623	21.3	0.072	32.7
	6/8/2006	282	22.3	0.034	15.4
	6/21/2006	657	20.6	0.073	33.1
	9/6/2006	239	17.3	0.022	10.0
06-BRHG-PAR	6/2/2006	6,440	2.3	0.080	36.3
	6/8/2006	10,000	2.67	0.144	65.3
	6/21/2006	5,680	1.65	0.050	22.7
	9/6/2006	1,180	1.14	0.007	3.2
06-BRHG-POR	6/2[a]	245	3.87	0.005	2.3
	6/9[a]	236	4.69	0.006	2.7
	6/22[a]	213	2.62	0.003	1.4
	9/7[a]	87	1.38	0.001	0.5

Site Name	Date	Mean Discharge (cfs)	Total Mercury Concentration (ng/L)	Mercury Loading Rate (lbs/day)	Mercury Loading Rate (grams/day)
06-BRHG-SAR	6/4/2006	45,200	12.3	3.00	1,360.8
	6/11/2006	44,500	10	2.40	1,088.6
	6/23/2006	21,500	2.3	0.267	121.1
	9/10/2006	3,670	0.52	0.010	4.5
06-BRHG-SRA	6/2/2006	20,191 [b]	0.97	0.106	48.1
	6/9/2006	26,919 [b]	1.71	0.248	112.5
	6/22/2006	21,344 [b]	1.5	0.173	78.5
	9/7/2006	12,184 [b]	1.15	0.076	34.5
06-BRHG-SRB	6/1/2006	16,100	2.24	0.194	88.0
	6/8/2006	9,550	3.62	0.186	84.4
	6/21/2006	9,410	2.07	0.105	47.6
	9/6/2006	8,370	2.18	0.098	44.5
06-BRHG-WER	6/2/2006	1,970	2.27	0.024	10.9
	6/8/2006	2,200	2.28	0.027	12.2
	6/21/2006	1,070	1.49	0.008	3.6
	9/6/2006	159	4.46	0.004	1.8

[a] = All Powder River gauging stations are inactive. Discharge shown is an average for that day from 1972-1997.
[b] = Calculated outflow by Idaho Power Company

The three June sampling events were chosen to represent the high flow mercury concentrations and the September sampling event is thought to be indicative of base flow mercury concentrations. Base flow mercury concentration results were considerably lower than the mean high flow results for 10 of the 11 monitoring locations. The mercury concentrations on the Weiser River were higher during the base flow sampling event than the mean of the three high flow events. The Weiser River high flow results were comparable to the low flow sampling events on all the other tributaries. The higher concentrations during low flow, when a significant amount of the stream water is from groundwater inflow, may indicate that the source for mercury in the Weiser River is groundwater inflow. This could, however, be an artifact of the small sample size. Additional samples taken at both high and base flow conditions could help determine the source of mercury in the Weiser River.

Figure 5-1 Mercury Concentrations by Station for High Flow and Base Flow Conditions



High flow concentrations are a mean of three events.

The Owyhee River had the maximum mercury concentration from a single sampling event (22.3 ng/L), the highest mean value for the three high flow events (21.4 ng/L) and the highest base flow concentration (17.3 ng/L). All of these values are considerably higher than any of the other monitoring stations sampled in this project. It is also interesting to note that the concentrations were not discharge dependent. The high concentrations existed in both high flow and base flow samples. Field observations noted that the base flow conditions of the rivers exhibited considerably lower turbidity. This observation and the consistency of the mercury concentrations within the Owyhee River indicate that the mercury found in the Owyhee system may be in the dissolved, not particulate form. Review of data collected from other monitoring locations indicates that this supposition may hold true for the Malheur River and the two Snake River sites as well. The Snake River and Owyhee sites are all located downstream from a dam. Since dams act as large settling basins this would seem to lend support to the suggestion that the mercury is predominately in the dissolved form for these locations.

The lowest mercury concentration found during this sampling program was 0.24 ng/L from the Imnaha River (06-BRHG-IMR) on September 10, 2006. It is to be expected that the lowest concentration sample was collected from the Imnaha River since this site was included to represent a relatively unimpaired reference site. The largest reduction in mercury concentrations from the high flow events to the base flow events occurred in the Salmon (94%), Imnaha (83%) and Grande Ronde Rivers (82%). These streams seem to only be influenced at higher flow duration due to other unidentified watershed influences. The turbidity within these rivers was considerably lower in the base flow sampling event than in the high flow events. Following the same logic as the previous paragraph, this drop in total mercury with a commensurate reduction in turbidity would suggest that the mercury found in the Salmon, Imnaha, and Grande Ronde Rivers is in a particulate form.

5.2 Station Loading Results

Mercury loads were calculated for each site location by multiplying the discharge for the nearest USGS gauging station, or other estimated discharge for the site, by the mercury concentration and converting to pounds per day (lb/day) and grams per day (g/day). Mercury loading results for each sampling event are presented in Table 5-1 using both metrics so the lay reader can better understand and interpret the results. The base flow mercury loading rates were consistently lower than the high flow results. The maximum mercury loading rate of 3.00 lb/day (1,361 g/day) was collected from the Lower Salmon River in Idaho (06-BRHG-SAR) on June 4, 2006 and the minimum loading rate of 0.00015 lb/day (0.1 g/day) was collected from the Imnaha River (06-BRHG-IMR) on September 10, 2006.

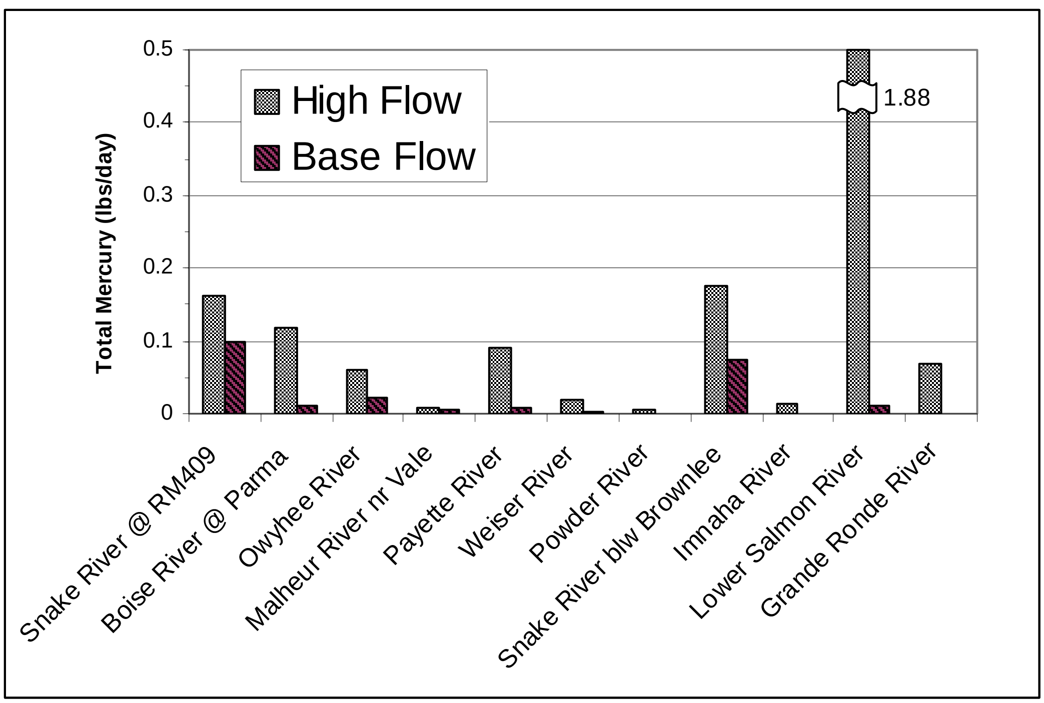
Average high flow loading rates are presented in Table 5-2. The highest average calculated mercury loading rate of 1.89 lb/day (856 g/day) was from the Lower Salmon River in Idaho (06-BRHG-SAR) and the lowest average calculated loading rate of 0.005 lb/day (2.3 g/day) was from the Powder River (06-BRHG-POR).

The loading changes between high flow sampling events and the base flow events exhibit similar characteristics to those of concentration (Figure 5-2). The loading of every site is significantly lower for the base flow event compared to the mean high flow loading. On average, there is a 91% reduction in mercury loading between the high flow and base flow sampling results. The largest percent reductions occur in the Imnaha (99%), Grande Ronde (98%), Salmon (98%), Payette (92%), and Boise (92%) Rivers. The smallest percent reductions occurred in the Malheur (18%), and the lowest Snake River site (39%).

Table 5-2 Average High Flow Mercury Loading Rates

Site Name	Average High Flow Loading Rate (lb/day)	Average High Flow Loading Rate (grams/day)
06-BRHG-BOR	0.119	54.0
06-BRHG-GRR	0.070	31.8
06-BRHG-IMR	0.013	5.9
06-BRHG-MAR	0.008	3.6
06-BRHG-OWR	0.059	26.8
06-BRHG-PAR	0.091	41.3
06-BRHG-POR	0.005	2.3
06-BRHG-SAR	1.887	855.9
06-BRHG-SRA	0.175	79.4
06-BRHG-SRB	0.162	73.5
06-BRHG-WER	0.020	9.1

Figure 5-2 Mercury Loading by Station for High Flow and Base Flow Conditions



High flow loadings are a mean of three events.

5.3 Source and Storage Analysis

One of the goals of this monitoring project was to determine potential sources of mercury loading to Brownlee Reservoir. This is complicated due to the chemical and biological interactions that occur with mercury in aquatic systems. In this report, we have attempted to account for the major water sources entering the Snake River as well as the amount of mercury leaving Brownlee Reservoir via the Snake River by doing a mass balance calculation for mercury. We performed this exercise based on the mean loading under high flow conditions (Figure 5-3) and base flow loadings (Figure 5-4). These calculations do not necessarily indicate how much mercury is being stored in Brownlee Reservoir but can be used to determine if the Snake River and Brownlee Reservoir are acting like sources or sinks of mercury and how significant this may be to developing a TMDL for Brownlee Reservoir.

Figure 5-3 Graphical Representation of the Mass Balance Calculation for Total Mercury Under High Flow Conditions

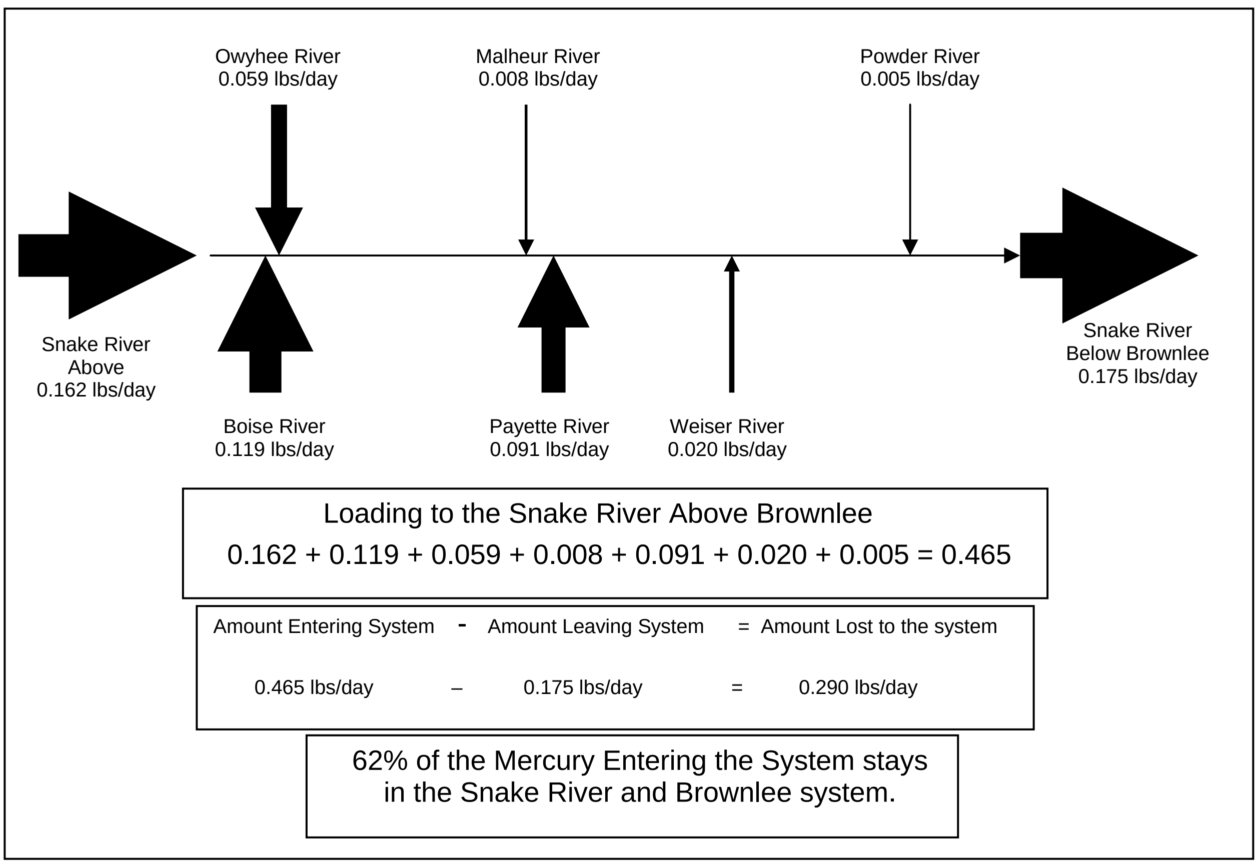
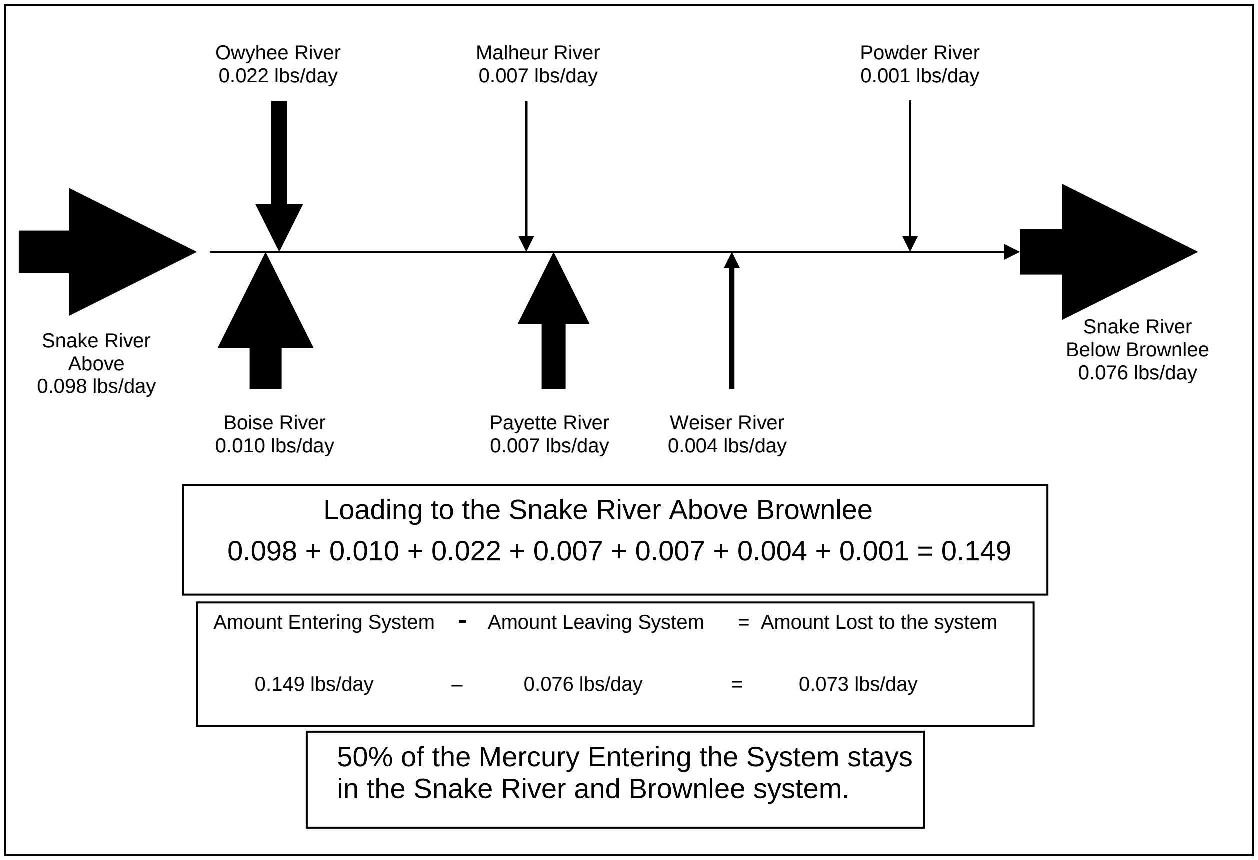


Figure 5-4 Graphical Representation of Mass Balance Calculation for Total Mercury Under Base Flow Conditions



Under both high flow conditions and base flow conditions at least 50% of the total mercury entering the system from upstream sources is lost within the Snake River and/or Brownlee Reservoir. The mass balance calculations were only completed for water inflow and outflow. No air deposition rates were measured or estimated as part of this study.

SECTION 6.0 CONCLUSIONS

The mercury concentrations and loadings determined in this study are relatively low. This study did not attempt to determine the chemical form of the mercury or to determine whether it was dissolved or associated with particulates. We were able to postulate as to whether the mercury was dissolved or particulate but further investigations would be needed to confirm these suppositions. Due to these limitations it is unlikely that one would be able to draw any direct correlations between the loading and concentrations we found in this study to fish tissue concentrations within Brownlee Reservoir. These data can be used to determine likely sources of mercury contamination from Snake River tributaries and can help managers make appropriate recommendations to stakeholders (i.e., sediment control). The data could be analyzed using flow duration curves for the purposes of TMDL analysis and development. Additionally, an aspect of volatilization could be investigated utilizing air temperature and wind speed information from hydro met or similar weather station data.

Mercury concentrations and loading within the Snake River system vary significantly with changes in discharge, and tributary feeder streams. The highest concentrations and largest loadings occur under high flow conditions. This indicates that as a whole, a significant portion of the loading to the system may be in particulate form. There are exceptions to this and for those tributary streams it may be necessary to develop a different set of management practices to reduce overall mercury loading.

Under both high and base flow conditions less than 50% of the mercury entering the Brownlee system leaves in the water column. Compared to other lake studies, this represents a large percent of mercury pass through. In Lake Champlain only 2.6% of the total mercury entering the system was lost via the lake outflow. This means that 97.4% of the inflow loading was either volatilized or sedimented. In the Lake Champlain study the majority of the mercury was volatilized (56.6%) with a significant portion deposited in the lake sediments (40.8%) (Ning et al. 2006). However, it should be noted that reservoirs have fluctuating flows, with periods of wetting and drying that a large lake system is not typically subjected to. Hence, Brownlee Reservoir may be acting as a mercury sink, since it is a man-made reservoir as opposed to a natural lake such as Lake Champlain or Lake Michigan.

The relatively high percentage loss out of the reservoir may be due to the fact we did not measure atmospheric deposition. In Lake Champlain it accounted for 38% of the total mercury load but in Lake Michigan atmospheric deposition accounted for 84% of the total loading to the lake (Hurley et al. 1998). Based on the lack of local sources and small lake surface area versus watershed area, one would expect the contribution from atmospheric deposition to be significantly lower than the Lake Michigan example, but it is still likely to be a significant source that we did not measure. The lack of air deposition rates within the study area is a significant data gap and prevents us from making an estimate of the total mercury entering the Brownlee system.

Another consideration is that by measuring only water within the drainage area, one is significantly underestimating the total mercury being deposited in the basin. According to

USEPA's Report to Congress on the Fate and Transport of Mercury, only a small fraction of the mercury deposited in a basin ever reaches the system's waterways (USEPA 1997).

To further understand the mercury dynamics within the system we recommend that additional sampling occur within the Brownlee system. This should include lake sediment sampling, sampling in bays that are typically watered and dewatered, wetland complexes, upland soil, and both wet and dry air deposition. We would also recommend that the water samples be filtered to determine the dissolved versus particulate contributions to the overall mercury concentrations within Brownlee Reservoir; however, this may not be practical. Filtering of samples for trace levels of mercury can be problematic due to the difficulty in filtering the samples without introducing contamination. Another option may be to deploy a stabilized liquid membrane device (SMLD). This would absorb the dissolved fraction of mercury in the water column. This in conjunction with whole water analysis would allow determination of dissolved versus particulate fractions in these rivers. SMLDs mimic the absorption that would occur in fish tissue but without the biological processes that may excrete some of the mercury from a living organism.

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