Appendix E: Detailed surface water analysis

- Spokane River nonpoint source analysis project, Phase 1 surface water total phosphorus data analysis
Phase 1 Study
June 2009

Prepared by:
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Spokane River Non-Point Source Analysis Project  
Phase 1 Surface Water Total Phosphorus Data Analysis

Introduction
The following discussion presents the results of the Phase 1 surface water analysis of the Spokane River watershed total phosphorus dataset. The total phosphorus studies, credibility and relevance review, database creation, and Phase 1 groundwater analyses are described in separate documents (Geo, 2008a; Geo, 2008b). The non-point source phosphorus analysis is one of many activities related to the Spokane River Dissolved Oxygen Total Maximum Daily Load (TMDL). The ultimate goal of the non-point source analysis project is to identify and prioritize locations for non-point phosphorus reductions activities such as best management practice (BMP) implementation projects.

The Washington State Department of Ecology has stated “Phosphorus and other nutrients and organic matter have polluted the Spokane River, causing it to violate water-quality standards. These pollutants deplete dissolved oxygen in the river and Lake Spokane. To address the problem, a cleanup plan, also known as a total maximum daily load (TMDL), will set allocations for how much of the pollutants (such as phosphorus and ammonia) each of the major dischargers and other sources will be allowed to discharge at very low levels. The amounts will be set to protect water quality and bring the river into compliance with state water-quality standards and the federal Clean Water Act” (Ecology, 2009).

Approach to Phase 1 Surface Water Analysis
This analysis includes technical approaches completed for select locations in the Spokane River watershed. The analyses and locations were limited in Phase 1 to meet multiple objectives including the following:

1. Provide a basis for prioritizing and selecting more detailed approaches for Phase 2 analyses
2. Summarize phosphorus concentrations and loads from a large area (approximately 6,580 square mile watershed)
3. Summarize phosphorus concentrations and loads from a large dataset (approximately 15,000 data points)
4. Meet Phase 1 schedule constraints; and provide a relatively rapid assessment of the data
5. Meet Phase 1 budget constraints

The locations selected for the Phase 1 surface water analysis were downstream points in the subbasins and intermediate locations along the mainstem of the Spokane River. The analyses generally used data from the vicinity of the following six locations, as shown in Figure 1.

1. Spokane River at Lake Coeur d’Alene (downstream of Lake Coeur d’Alene)
2. Spokane River at Stateline (the border between Idaho and Washington separating the Upper Spokane subbasins)
3. Spokane River at Spokane
4. Spokane River at Long Lake headwaters (downstream of Nine Mile Dam and upstream of the confluence with the Little Spokane River)
5. Hangman Creek at Spokane River
6. Little Spokane River at Spokane River
These locations were selected as generally recognized reference points within the Spokane River watershed. As such, various agencies have also selected these locations or similar locations for water quantity (flow) and water quality monitoring. Those single point monitoring stations may coincide within the selected locations as the selected locations were examined more broadly than one single point. Data from the non-point source database from multiple sampling points within the vicinity of the selected locations were examined.

The analyses selected for the Phase 1 surface water study were those that could be completed relatively rapidly, with minimal intermediate data computational steps, and provide a basis for a simple and straightforward presentation. The results provide insights into changes in phosphorus concentration and/or loads both temporally and spatially. Comparisons of the graphs indicate where and when the greatest total phosphorus loads occur. The six analyses selected for the Phase 1 surface water study are as follows:

1. Times Series Plots
2. Data Charts
3. Average Monthly Phosphorus Loadings
   a. Average Monthly Phosphorus Loadings by Year
4. Average Monthly Phosphorus Loadings for 2001
   a. Average Monthly Phosphorus Loading by Flows
5. Average Seasonal Phosphorus Concentrations and Loadings
6. Land Use to Phosphorus Correlation

This combination of selected locations and analyses allows for initial observations about the dataset to be made, along with questions and hypotheses to be posed about the cause and effect relationships that may be occurring. These questions and hypotheses will be useful for prioritizing and selecting the Phase 2 analyses. The Phase 2 analyses may include some of the same analytical approaches used in Phase 1, but in new locations and with additional techniques including those previously identified such as: stream segment analysis, load analysis by subbasin or sub-subbasin, and episodic or event-based loading analysis (HDR, 2009).

Presented in the sections below are the surface water analyses selected for Phase 1. Each section begins with a description of the objectives that were identified as part of the options analysis. The process used for the analysis and observations from the results are then presented followed by tables and figures. Additional text and/or tables and figures are then presented for simple follow-up analysis for initial basic questions about the results. More complex questions were deferred to the more detailed analysis that can be completed in Phase 2.

**Summary of Phase 1 Surface Water Data Analysis**

A review of the Phase 1 surface water analyses is useful to make observations about where and when concentrations and loads of phosphorus are higher or lower, trends over space and time, when and where data are available and not available and other inferences about phosphorus movement through the watershed. A summary of observations from the Phase 1 surface water analyses include the following:
Hangman Creek has the greatest total phosphorus concentrations and the greatest maximum and average total phosphorus loads (Table 1.1 and Figure 1.5).

- The greatest phosphorus concentrations appear to be correlated with population, e.g., the communities of Rockford, Fairfield, Tekoa, and Spangle. Higher phosphorus concentrations appear to correlate to large agricultural areas including middle California Creek, the reach between Latah and Waverly, near the confluence of Rattler Run Creek with Hangman Creek, and Little Hangman Creek and the area along the Stateline. Lower phosphorus concentrations appear to correspond with forestry and conservation program land uses (Figure 6.1). (The land covers are defined in Section 6.)

- May is the month with generally the greatest total phosphorus loads throughout most of the watershed (Figures 3.1 through 3.6).

- Total phosphorus loads are greater than the Spokane River TMDL current loads in May and June for Spokane River at Stateline (Figure 4.1), February, March and April for Hangman Creek at Spokane River (Figure 4.2) and February, March, June and December for Little Spokane River at Spokane River (Figure 4.3) (Ecology, 2008).

- Monthly total phosphorus loads decrease between Lake Coeur d’Alene and Stateline (Figure 3.1 and 3.2).

- During the lower flow months of September and August, there appears to be different loading mechanisms occurring between Lake Coeur d’Alene and Stateline than between Stateline and Spokane (Figure 3.1, 3.2, and 3.3). The September loads for Stateline and Spokane are the second lowest of their twelve monthly loads; whereas, the September load for Coeur d’Alene is the sixth greatest. The August loads for Stateline and Spokane are the lowest of their twelve monthly loads and less than 90 lbs/day; whereas the August load for Coeur d’Alene is the third lowest but 226 lbs/day.

Considerations for Further Data Analysis

The following questions and hypotheses are for further exploration, potentially as part of Phase 2 detailed analysis:

- Why are the loadings different in the subbasins, e.g., especially Hangman Creek and Little Spokane River compared to areas along the Spokane River?
  - Why are the loadings different in timing and magnitude?
  - What are the mechanisms for the delivery of total phosphorus loads and transport in these subbasins?

- What is occurring with the loading between Lake Coeur d’Alene and Stateline?
  - What is the groundwater influence?
  - What are the phosphorus processing, growth, and phosphorus uptake dynamics by algae in this reach?
  - What is the influence from stormwater?

- What are the delivery mechanisms for total phosphorus and how do they relate to the time of year and flow patterns?

- Soil chemistry is a source and factor in the mobility of phosphorus.
  - What is the characteristic of the soils in the watershed?
  - How does the soil type relate to the total phosphorus concentration in the runoff?
  - Continue the examination of land use and add NRCS soil types and characteristics.

- How has historical land use impacted the phosphorus loads today?
Historic land use practices may have left legacy phosphorus concentrations not reflected in the current land use.

Potentially examine historical land use coverages and/or aerial photographs for each decade.

- USGS flow data were compared to flow data associated with the total phosphorus concentrations that were in the studies entered into the database. Ecology graphs generated as part of the Hangman Creek study were compared to total phosphorus values in the database.
  - Consider if additional comparisons are useful and how the information would be used going forward.

- Consider expanding septic system phosphorus loading analysis to other areas.
  - What programs can be implemented to address the impact of on-site septic systems?
  - What are the impacts of on-site septic systems throughout the watershed? Where are the greatest densities, oldest systems, nearest to the groundwater table, greatest loadings?

- Consider how city and county development plans may be considered in future phases.
  - How will development projects be consistent with non-point source phosphorus control?
  - Examine development within the subbasins, especially Hangman Creek.

Citations


Geo. 2008b. GeoEngineers Memorandum, Subject: Database Structure and Data Entry Specifications, Spokane County Bi-State Nonpoint Source Phosphorus Study, Phase 1, November 18, 2008.

1. TIMES SERIES PLOTS OF FLOW, PHOSPHORUS CONCENTRATIONS AND LOADS

Objective
The time series plots provide an overview of the dataset values for flow, phosphorus concentrations and loads. The Phase 1 locations selected for scatter plot graphs are the Spokane River at Lake Coeur d’Alene, Spokane River at Stateline, Spokane River at Spokane, Spokane River at Long Lake headwaters, Hangman Creek at Spokane River, and Little Spokane River at Spokane River.

Linkage to TMDL
The time series provide a basic comparison of computed loads to load allocations (LAs) and waste load allocations (WLAs).

Results
Plots of the total phosphorus load, concentration and flow from 1990 through 2008 for the selected locations are shown in Figures 1.1 through 1.6. (These figures have the y-axis scale set to the maximum value at the monitoring location to best show the data range and trends. Figures with the y-axis set the same for all graphs for comparison between monitoring locations are shown in Figures 1.1Scale through 1.6Scale in Appendix A. Additionally the Figures in the appendix include data from before 1990 that are not shown in the graphs. Earlier data from the same station are used for the trend lines. No statistics or validity of the trend lines was completed; the trend lines are only for general reference. Some of the stations only have data from before 1990 are not shown in the graph and only the legend.) All surface water monitoring locations within the vicinity of the selected sites were examined (identified using the GIS maps of the monitoring locations and by the station location codes shown in the legends of the figures). Only paired data, i.e., dates with both flow and total phosphorus concentrations are shown and used for the analysis. The loads were calculated as the flow multiplied by the concentrations. The data are summarized in Table 1.1 and the following highlights summarize observations from this analysis:

- Data from the Spokane River at Lake Coeur d’Alene are only from the 2000’s.
  - The data trends indicate loads, concentrations, and flows are increasing.
  - The sampling location at the outlet of Lake Coeur d’Alene changed in 2006.
- Data from the Spokane River at Stateline are from throughout the period of interest (1990 to 2008).
  - The data trends indicate loads, concentrations, and flows are decreasing.
  - Comparing Lake Coeur d’Alene to Stateline, both the average and median loads for the period of record increase by about 60 percent (Table 1.1).
  - The dataset includes samples from high runoff in the spring of 1997. These few high values during spring runoff may skew analyses if included.
- Few data exist from Spokane River at Spokane. The data are mostly from the late 1990s.
  - The data trends are not clearly increasing or decreasing; however, there are few data points to clearly establish any trend.
  - Comparing Stateline to Spokane, the loads and concentrations are similar.
- There are only five data points from Spokane River at Long Lake headwaters (Nine Mile) and these are from middle 2007.
• There is insufficient data to evaluate trends at Long Lake headwaters or differences from Spokane upstream.

• Data from Hangman Creek at Spokane River are from throughout the period of interest.
  o The data trend shows loads are steady (not clearly increasing or decreasing) although concentrations are decreasing.
  o Concentrations are five, or more, times greater than concentrations in the Spokane River.
  o Loads are usually about a tenth of the load in the Spokane River with the exception of occasional high loads that are ten, or more, times greater than loads in the Spokane River.

• Data from the Little Spokane River at Spokane River are from throughout the period of interest.
  o The data trend shows loads are steady (not clearly increasing or decreasing) although concentrations are decreasing.
  o Concentrations are about 2 to 3 times greater than concentrations in the Spokane River.
  o Loads are usually about a third of the load in the Spokane River with the exception of occasional high loads that are double or more the loads in the Spokane River.

Table 1.1. Summary of Time Series Data

<table>
<thead>
<tr>
<th>Sites</th>
<th>Period and Count</th>
<th>Maximum (lb/day) (mg/L)</th>
<th>Average (lb/day) (mg/L)</th>
<th>Median (lb/day) (mg/L)</th>
<th>90th Percentile (lb/day) (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spokane River at Lake Coeur d’Alene</td>
<td>11/02–11/08 91</td>
<td>2.724 0.015 0.008 0.007</td>
<td>315 0.015 0.008 0.007</td>
<td>137 0.015 0.008 0.007</td>
<td>739 0.013 0.007 0.013</td>
</tr>
<tr>
<td>Spokane River at Stateline</td>
<td>12/90-9/08 217</td>
<td>11,046 0.126 0.014 0.010</td>
<td>512 0.126 0.014 0.010</td>
<td>224 0.126 0.014 0.010</td>
<td>1,048 0.262 0.026 0.026</td>
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<td>Spokane River at Spokane</td>
<td>10/98-4/00 35</td>
<td>1,181 0.016 0.010 0.010</td>
<td>487 0.016 0.010 0.010</td>
<td>395 0.016 0.010 0.010</td>
<td>1,122 0.014 0.014 0.014</td>
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<tr>
<td>Spokane River at Long Lake headwaters</td>
<td>5/07-9/07 5</td>
<td>861 0.022 0.015 0.014</td>
<td>325 0.022 0.015 0.014</td>
<td>202 0.022 0.015 0.014</td>
<td>653 0.021 0.021 0.021</td>
</tr>
<tr>
<td>Hangman Creek at Spokane River</td>
<td>1/90-9/07 205</td>
<td>24,683 1.740 0.095 0.056</td>
<td>506 1.740 0.095 0.056</td>
<td>14 1.740 0.095 0.056</td>
<td>627 0.197 0.055 0.055</td>
</tr>
<tr>
<td>Little Spokane River at Spokane River</td>
<td>1/90-9/07 186</td>
<td>2,381 0.253 0.033 0.027</td>
<td>129 0.253 0.033 0.027</td>
<td>71 0.253 0.033 0.027</td>
<td>255 0.055 0.055 0.055</td>
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</tbody>
</table>
Figure 1.1. Spokane River at Lake Coeur d’Alene Time Series
Figure 1.2. Spokane River at Stateline Time Series
Figure 1.3. Spokane River at Spokane Time Series
Figure 1.4. Spokane River at Long Lake headwaters (Nine Mile) Time Series
Figure 1.5. Hangman Creek at Spokane River Time Series
Figure 1.6. Little Spokane River at Spokane River Time Series
Flows in the phosphorus database were compared to flows from nearby USGS gages as a check. These comparisons are shown in Figures 1.7 through 1.11. For the Spokane River and Hangman Creek locations, the flow in the phosphorus database appears to match well with the USGS gage record. The flow in the Little Spokane River appears to be lower at the end of the time series than during the earlier years. There are two USGS gages on the Little Spokane River near the Spokane River, at Dartford and near Dartford. The earlier flows in the database appear to match the gage near Dartford and when the flows drop, approximately November 2006, the flows appear to match the gage at Dartford. The gage at Dartford is located at river mile 11.4, with a drainage area of 665 square miles. The gage near Dartford is located at river mile 3.9, with a drainage area is 698 square miles.

Figure 1.7. Spokane River at Lake Coeur d’Alene Flow Comparison

Figure 1.8. Spokane River at Stateline Flow Comparison
Figure 1.9. Spokane River at Spokane Flow Comparison

Figure 1.10. Hangman Creek at Spokane River Flow Comparison

Figure 1.11. Little Spokane River at Spokane River Flow Comparison
The differences in flows and loads in the Spokane River between Coeur d'Alene to Stateline and Stateline to Spokane are shown in Figures 1.12 and 1.13, respectively. From Coeur d’Alene to Stateline flows decreased an average of 360 cfs while from Stateline to Spokane flows increased an average of 480 cfs. From Coeur d’Alene to Stateline phosphorus loads decreased an average of 85 lbs/day while from Stateline to Spokane phosphorus loads increased an average of 231 lbs/day for the comparison dataset. The groundwater, withdrawal, and inflow interactions need to be explored further in these reaches to understand why phosphorus concentrations and loadings appear to vary.

![Figure 1.12. Change in Flows and Loads Coeur d’Alene to Stateline](image)

![Figure 1.13. Change in Flows and Loads Stateline to Spokane](image)
2. “DNA” STRIP CHARTS

Objective
The DNA strip charts provide a simple representation of the temporal continuity of the dataset. The Phase 1 DNA charts are for all the monitoring locations in the database.

Linkage to TMDL
The DNA charts show the available data for the TMDL model year 2001.

Results
Plots of when total phosphorus was sampled as recorded in the database are shown in Figure 2.1. The data dates are shown by sample location code, on the y-axis, as assigned in the study database. There are some gaps in the sample location codes (the codes are not continuous) and these are shown as blanks in Figure 2.1. There are 862 locations where phosphorus was sampled. An average of 17 and a median of 8 samples have been collected per location for these 862 locations. Most of the stations only have a few samples. For 292 locations, or about a third of the total locations, only one or two samples have been collected. There are 21 locations with more than 100 samples and of those 10 locations with more than 200 samples. The general location of these 21 locations are provided in Table 2.1 The station location codes for these 10 are 214, 215, 216, 510, 928, 943, 1141, 1282, 1491 and 1492.

Figure 2.1 shows that other than the stations with long records, there were not many other locations sampled during the 1990s. The figure also indicates intensive sampling around the year 2000 as shown by station location codes around 1100 to 1200 and 3000 to 3200. More sampling appears to have been conducted during the 2000s. The figure indicates this as shown by station locations codes around 250 to 400, 950 to 1000, 1050 to 1600, 2150 to 2300, and 3400 to 3450. The mean annual flow for three locations is shown in Table 2.2 for reference.

<table>
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<th>Station Location Code</th>
<th>General Location</th>
<th>Station Location Code</th>
<th>General Location</th>
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<td>Newman Lake</td>
<td>536</td>
<td>Coeur d’Alene River</td>
</tr>
<tr>
<td>215</td>
<td>Newman Lake</td>
<td>547</td>
<td>Lake Coeur d’Alene, Coeur d’Alene River branch</td>
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<tr>
<td>216</td>
<td>Newman Lake</td>
<td>949</td>
<td>Liberty Lake</td>
</tr>
<tr>
<td>510</td>
<td>Spokane River Idaho</td>
<td>953</td>
<td>Liberty Lake</td>
</tr>
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<td>928</td>
<td>Liberty Lake</td>
<td>957</td>
<td>Liberty Lake</td>
</tr>
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<td>943</td>
<td>Liberty Lake</td>
<td>1431</td>
<td>Newman Lake</td>
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<td>1141</td>
<td>Spokane River Stateline</td>
<td>1489</td>
<td>Spokane River below Long Lake Dam</td>
</tr>
<tr>
<td>1282</td>
<td>Hangman Creek</td>
<td>2005</td>
<td>Coeur d’Alene River</td>
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<td>1491</td>
<td>Hangman Creek</td>
<td>2046</td>
<td>South Fork Coeur d’Alene River</td>
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<td>1492</td>
<td>Little Spokane River</td>
<td>2052</td>
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</table>
Figure 2.1a. Surface Water Total Phosphorus Sampling Dates
Figure 2.1b. Surface Water Total Phosphorus Sampling Dates
Figure 2.1c. Surface Water Total Phosphorus Sampling Dates
Figure 2.1d. Surface Water Total Phosphorus Sampling Dates
In Figure 2.1, the data dates are shown by sample location code as assigned in the database. There are some sample location codes without data. These gaps in the graphs were removed by reassigning the codes only for Figure 2.2 to show all the dates on one figure.

The 23 locations with more 100 samples are shown in Figure 2.3. Additionally shown is the location name in the database as provided in the original dataset. The same data are shown in Figure 2.4 with the date scales modified to start at 1990 to focus on the more recent data.

The 96 locations with data from 2001 are shown in Figure 2.5.

The sample dates are shown in Figure 2.6 for the six selected locations Spokane River at Coeur d’Alene, Spokane River at Stateline, Spokane River at Spokane, Spokane River at Long Lake headwaters, Hangman Creek at Spokane River, and Little Spokane River at Spokane River.
Figure 2.2. Surface Water Total Phosphorus Sampling Dates

Note: Station codes are unique for this figure.
Figure 2.3. Surface Water Total Phosphorus Sampling Dates for Locations with more than 100 Samples

Note: Station codes are unique for this figure.
Figure 2.4. Surface Water Total Phosphorus Sampling Dates for Locations with more than 100 Samples starting at 1990

Note: Station codes are unique for this figure.
### Figure 2.5. Surface Water Total Phosphorus Sampling Dates for Locations Sampled in 2001

Note: Station codes are unique for this figure.
Figure 2.6. Surface Water Total Phosphorus Sampling Dates for Selected Locations starting at 1990
Note: Station codes are unique for this figure.
3. AVERAGE MONTHLY PHOSPHORUS LOADINGS

Objective
The average monthly phosphorus loadings provide a simple portrayal of phosphorus loads by month. The Phase 1 locations selected for bar graphs of surface water loads are at Spokane River at Stateline, Spokane River at Spokane, Spokane River at Long Lake headwaters, Hangman Creek at Spokane River, and Little Spokane River at Spokane River.

Linkage to TMDL
The average monthly loads provide a means of comparison to TMDL loads to the Spokane River including the preliminary calculations by Ecology for the Hangman Creek TMDL.

Results
Plots of the average monthly phosphorus load are shown in Figures 3.1 through 3.6. (These figures have the y-axis scale set to the maximum value at the monitoring location to best show the data range and trends. Figures with the y-axis set the same for all graphs for comparison between monitoring locations are shown in Figures 3.1Scale through 3.6Scale in Appendix B.) Monthly data for the period of record were averaged. Three plots are shown of the average monthly phosphorus load: 1) of the monthly load; 2) the monthly load along with the number of samples averaged and the numbers of years with samples for the month both on the second y-axis on the right side of the graph; and 3) the monthly load along with the current and targeted load in the Spokane River TMDL. The current and targeted TMDL loads are from Table 4 and Appendix C of the Spokane River TMDL (Ecology, 2008).

The loads are usually greater during the first half of the year (January through June) than the second half of the year (July through December). The highest loads occur in May in the Spokane River except at Long Lake headwaters where May has one of the lowest loads and January has the highest. As shown in Figure 3.2 the Stateline load is based on data from about 20 years whereas the Long Lake load is only based on data from about 2 years as shown in Figure 3.4. For Hangman Creek the loads are highest in January, March, and May. For the Little Spokane River there are not one or more months that show a higher load.

A comparison of the average monthly phosphorus loads for Hangman Creek to the estimated load from preliminary calculations from Ecology (unpublished analysis, Hangman Creek water quality planning, Joe Joy, Washington State Department of Ecology) is shown in Figure 3.7. The comparison shows some differences during months with higher loads. However, the first data compared from the database are averaged over a different period than the Ecology loads. When the average monthly phosphorus load was computed for the same period as Ecology’s analysis, 1996 through 2005, results are similar to the period of record except for May. The monthly data were then plotted for comparison. The differences appear to be mostly in the peak loads.
Figure 3.1. Average Monthly Phosphorus Load for Spokane River at Lake Coeur d’Alene
Figure 3.2. Average Monthly Phosphorus Load for Spokane River at Stateline
Figure 3.3. Average Monthly Phosphorus Load for Spokane River at Spokane
Figure 3.4. Average Monthly Phosphorus Load for Spokane River at Long Lake headwaters
Figure 3.5. Average Monthly Phosphorus Load for Hangman Creek at Spokane River
Figure 3.6. Average Monthly Phosphorus Load for Little Spokane River at Spokane River
Figure 3.7. Average Monthly Phosphorus Load Hangman Creek Database to Ecology Comparison
Figure 3.8. Average Monthly Phosphorus Load by Year, 2000 and 2001
Figure 3.9. Average Monthly Phosphorus Load by Year, 2002 and 2003
Figure 3.10. Average Monthly Phosphorus Load by Year, 2004 and 2005
Figure 3.11. Average Monthly Phosphorus Load by Year, 2006 and 2007
4. KEY FLOW CHARACTERISTIC AVERAGE MONTHLY PHOSPHORUS LOADINGS

Objective
The monthly phosphorus loadings by flow characteristic provide further disaggregating of averaging by selecting only key flow periods. The Phase 1 locations selected for bar graphs of surface water in 2001 are at Spokane River at Stateline, Spokane River at Spokane, Spokane River at Long Lake headwaters, Hangman Creek at Spokane River, and Little Spokane River at Spokane River.

Linkage to TMDL
The TMDL is based on 2001 flows. Average monthly phosphorus loadings for 2001 provide a direct comparison.

Results
Plots of the monthly phosphorus load are shown in Figures 4.1 through 4.3. Only three of the six locations are shown because the other three locations do not have data for 2001. Two plots are shown of the average monthly phosphorus load: 1) of the monthly load; and 2) the monthly load along with the number of samples averaged (usually one) on the second y-axis on the right side of the graph. The results for 2001 are similar to the results of averaging the dataset.
Figure 4.1. 2001 Monthly Phosphorus Load Spokane River at Stateline
Figure 4.2. 2001 Monthly Phosphorus Load Hangman Creek at Spokane River
Figure 4.3. 2001 Monthly Phosphorus Load Little Spokane River at Spokane River
4.5. KEY FLOW CHARACTERISTIC AVERAGE MONTHLY PHOSPHORUS LOADINGS

Objective
The monthly phosphorus loadings by flow characteristic provide further disaggregating of averages by selecting only key flow periods. The Phase 1 locations selected for bar graphs of loads are at Spokane River at Stateline, Spokane River at Spokane, Spokane River at Long Lake headwaters, Hangman Creek at Spokane River, and Little Spokane River at Spokane River.

Results
Since only three of the six locations had data for loads in 2001, loads were plotted for four flow conditions as shown in Figures 4.4 through 4.9. The top graphs for the Spokane River are shown with a uniform scale that shows all the loads while the bottom graphs for each set have a scale lower than the highest loads but showing the small loads. The average monthly loads are shown for comparison. The four flow conditions are flows below the seven-day minimum, flows less than 90 percent exceed, flows more than 10 percent exceed, and flows within 10 percent of 50 percent exceed. These flow values are from the USGS water data report for Spokane River at Spokane, Hangman Creek at Spokane, and Little Spokane River at Dartford and are shown in Tables 4.1, 4.2 and 4.3, respectively. The database was searched for when samples were collected at these flows. The loads were then graphed as shown in Figures 4.4 through 4.9. These flow ranges may have occurred at other times but phosphorus was not sampled then.

For the Spokane River, when high flow events occurred, the resulting phosphorus loads were high, at a level of 700 lb/day or greater. However, two average flow events still resulted in loads of 2,000 lb/day or greater at Spokane and at Long Lake headwaters. Additionally, even two low flow events resulted in loads of 850 lb/day and greater at Long Lake headwaters. For Hangman Creek, high flows results in high loads, 4 to 8 times the average. The Little Spokane River appears to be less variable in loads over the range of flows, with most of the high flow loads being similar to the average load.

Table 4.1. USGS Flow Statistics Spokane River

<table>
<thead>
<tr>
<th>SUMMARY STATISTICS</th>
<th>Calendar Year 2006</th>
<th>Water Year 2007</th>
<th>Water Years 1891 - 2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual total</td>
<td>2,574,017</td>
<td>2,116,009</td>
<td></td>
</tr>
<tr>
<td>Annual mean</td>
<td>7,052</td>
<td>907</td>
<td></td>
</tr>
<tr>
<td>Highest annual mean</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lowest annual mean</td>
<td>2,508</td>
<td>974</td>
<td></td>
</tr>
<tr>
<td>Highest daily mean</td>
<td>20,600</td>
<td>Apr 19</td>
<td></td>
</tr>
<tr>
<td>Lowest daily mean</td>
<td>601</td>
<td>Sep 4</td>
<td></td>
</tr>
<tr>
<td>Annual seven-day minimum</td>
<td>610</td>
<td>Sep 3</td>
<td></td>
</tr>
<tr>
<td>Annual runoff (ac-ft)</td>
<td>5,106,009</td>
<td>4,276,000</td>
<td>4,084,000</td>
</tr>
<tr>
<td>10 percent exceeds</td>
<td>16,400</td>
<td>13,800</td>
<td>17,000</td>
</tr>
<tr>
<td>50 percent exceeds</td>
<td>6,400</td>
<td>5,220</td>
<td>3,720</td>
</tr>
<tr>
<td>90 percent exceeds</td>
<td>837</td>
<td>700</td>
<td>1,500</td>
</tr>
</tbody>
</table>

Flows in cubic feet per second (cfs)
### Table 4.2. USGS Flow Statistics Hangman Creek
12424000 HANGMAN CREEK AT SPOKANE, WA—Continued

<table>
<thead>
<tr>
<th></th>
<th>Calendar Year 2007</th>
<th>Water Year 2008</th>
<th>Water Years 1948 - 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual total</td>
<td>65,495.7</td>
<td>100,181</td>
<td></td>
</tr>
<tr>
<td>Annual mean</td>
<td>179</td>
<td>274</td>
<td></td>
</tr>
<tr>
<td>Highest annual mean</td>
<td></td>
<td></td>
<td>629</td>
</tr>
<tr>
<td>Lowest annual mean</td>
<td></td>
<td></td>
<td>273</td>
</tr>
<tr>
<td>Highest daily mean</td>
<td>2,950</td>
<td>Jan 4</td>
<td>2,920</td>
</tr>
<tr>
<td>Lowest daily mean</td>
<td>4.9</td>
<td>Aug 13</td>
<td>10</td>
</tr>
<tr>
<td>Annual seven-day minimum</td>
<td>6.2</td>
<td>Aug 9</td>
<td>11</td>
</tr>
<tr>
<td>Annual runoff (ac-ft)</td>
<td>129,900</td>
<td>198,700</td>
<td>166,300</td>
</tr>
<tr>
<td>Annual runoff (cfsm)</td>
<td>0.260</td>
<td>0.397</td>
<td>0.333</td>
</tr>
<tr>
<td>Annual runoff (inches)</td>
<td>3.54</td>
<td>5.41</td>
<td>4.53</td>
</tr>
<tr>
<td>10 percent exceeds</td>
<td>593</td>
<td>851</td>
<td>580</td>
</tr>
<tr>
<td>50 percent exceeds</td>
<td>35</td>
<td>77</td>
<td>43</td>
</tr>
<tr>
<td>90 percent exceeds</td>
<td>9.4</td>
<td>13</td>
<td>8.7</td>
</tr>
</tbody>
</table>

Flows in cubic feet per second (cfs)

### Table 4.3. USGS Flow Statistics Little Spokane
12431000 LITTLE SPOKANE RIVER AT DARTFORD, WA—Continued

<table>
<thead>
<tr>
<th></th>
<th>Calendar Year 2007</th>
<th>Water Year 2008</th>
<th>Water Years 1929 - 2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual total</td>
<td>85,868</td>
<td>113,020</td>
<td></td>
</tr>
<tr>
<td>Annual mean</td>
<td>235</td>
<td>309</td>
<td></td>
</tr>
<tr>
<td>Highest annual mean</td>
<td></td>
<td></td>
<td>626</td>
</tr>
<tr>
<td>Lowest annual mean</td>
<td></td>
<td></td>
<td>128</td>
</tr>
<tr>
<td>Highest daily mean</td>
<td>748</td>
<td>Mar 26</td>
<td>1,330</td>
</tr>
<tr>
<td>Lowest daily mean</td>
<td>88</td>
<td>Aug 18</td>
<td>111</td>
</tr>
<tr>
<td>Annual seven-day minimum</td>
<td>89</td>
<td>Aug 12</td>
<td>113</td>
</tr>
<tr>
<td>Annual runoff (ac-ft)</td>
<td>170,300</td>
<td>224,200</td>
<td>217,100</td>
</tr>
<tr>
<td>Annual runoff (cfsm)</td>
<td>0.354</td>
<td>0.464</td>
<td>0.451</td>
</tr>
<tr>
<td>Annual runoff (inches)</td>
<td>4.80</td>
<td>6.32</td>
<td>6.12</td>
</tr>
<tr>
<td>10 percent exceeds</td>
<td>476</td>
<td>716</td>
<td>608</td>
</tr>
<tr>
<td>50 percent exceeds</td>
<td>185</td>
<td>201</td>
<td>201</td>
</tr>
<tr>
<td>90 percent exceeds</td>
<td>96</td>
<td>128</td>
<td>119</td>
</tr>
</tbody>
</table>

Flows in cubic feet per second (cfs)
Figure 4.4. Loads by Flow for Spokane River at Lake Coeur d'Alene
Figure 4.5. Loads by Flow for Spokane River at Stateline
Figure 4.6. Loads by Flow for Spokane River at Spokane
Figure 4.7. Loads by Flow for Spokane River at Long Lake headwaters (Nine Mile)
Figure 4.8. Loads by Flow for Hangman Creek at Spokane River
Figure 4.9. Loads by Flow for Little Spokane River at Spokane River
5. AVERAGE SEASONAL PHOSPHORUS CONCENTRATIONS AND LOADINGS

Objective
The seasonally averaged loads provide a simple portrayal of phosphorus loads by season. The Phase 1 locations selected for 2001 graphs of loads are at Spokane River at Stateline, Spokane River at Spokane, Spokane River at Long Lake headwaters, Hangman Creek at Spokane River, and Little Spokane River at Spokane River.

Linkage to TMDL
These graphs provide loads for the same seasons and 2001 low flow year as in the TMDL.

Results
Plots of the 2001 phosphorus loads divided between summer and winter seasons are shown in Figures 5.1. Summer is defined as April through October (7 months) and winter is November through March (5 months). This definition is used in the Spokane River TMDL. Only three of the six locations are shown because the other three locations do not have data for 2001. The pie chart labels include the season, load (lb/day), and percentage of the total. For the Spokane River and Little Spokane River the loads are near evenly split between summer and winter. For Hangman Creek, more than 80 percent of the load tends to occur during the winter season.

Using the same summer and winter seasons, the percentage of load of the upstream location to the downstream location is shown in Figures 5.4 and 5.5. The Spokane River at Spokane location was not used because the short record with a few data points skews the results. Thus, the locations Stateline and Long Lake headwaters were used along with Hangman Creek. The Little Spokane River at Spokane River location was not used because a downstream location is not part of this Phase 1 analysis. The loads are separated by groundwater and surface water as shown in Figures 5.6 through 5.8.

![Pie charts showing loads by season for Spokane River at Stateline and 2001 Spokane River at Stateline](image)

Figure 5.1. Loads by Season for Spokane River at Stateline
Figure 5.2. Loads by Season for Hangman Creek at Spokane River

Figure 5.3. Loads by Season for Little Spokane River at Spokane River
Percentage of Load at Stateline Winter (November to March)

- 93% 496 lb/day
- 7% 38 lb/day

Percentage of Load at Stateline Summer (April to October)

- 162% 1237 lb/day
- -62% -474 lb/day

From Upstream at Coeur d'Alene
From the area between Coeur d'Alene and Stateline

Figure 5.4. Percentage of Loading by Season at Stateline

Percentage of Load at Long Lake Headwaters Winter (November to March)

- 74% 4089 lb/day
- 19% 916 lb/day
- 10% 534 lb/day

Percentage of Load at Long Lake Headwaters Summer (April to October)

- 56% 763 lb/day
- 25% 335 lb/day
- 19% 253 lb/day

From Upstream at Stateline
From Hangman Creek
From the area between Stateline and Long Lake

Figure 5.5. Percentage of Loading by Season at Long Lake Headwaters
Figure 5.6. Percentage of Loading by Season at Long Lake Headwaters separated by Groundwater and Surface Water

Figure 5.7. Loads by Season for Hangman Creek at Spokane River separated by Groundwater and Surface Water
Figure 5.8. Loads by Season for Little Spokane River at Spokane River separated by Groundwater and Surface Water
6. LAND USE TO PHOSPHORUS CONCENTRATIONS CORRELATION

Objective
Examine linking land use to phosphorus loads to provide a connection between non-point sources and the TMDL loads. Phosphorus loads may be associated with land uses and the potential best management practices are typically specific to the land use.

Linkage to TMDL
Provide a comparison of classification of land uses in the TMDL and load allocations for non-point sources.

Results
The Hangman Creek subbasin was selected for Phase 1 analysis. Average phosphorus concentrations are shown in Figure 6.1. The comprehensive land use zoning information from the City of Spokane, City of Cheney, Spokane County, and Kootenai County are shown. The USGS land cover data from 2001 is shown for the portion of the subbasin in Whitman and Benewah counties. Major streams from the National Hydrography Dataset (NHD) are shown for the stream network.

The greatest average total phosphorus concentrations appear to be associated with locations of greater densities of people. For example, near the communities of Rockford, Fairfield, Tekoa, and Spangle the average phosphorus concentrations are greater than other areas of the subbasin. The area where Hangman Creek crosses the state line and a suburban area of Spokane also have greater phosphorus concentrations. There are likely higher densities of people, such as residential communities in these areas. While it could be coincidental that the greater concentrations of phosphorus were observed in these location since these are also likely the easiest places to collect water quality samples, there does appear to be potential correlation.

Phosphorus concentrations do not appear to simply increase from upstream to downstream along Hangman Creek. There are greater phosphorus concentrations in some of the tributaries including Rock Creek and the tributaries where Spangle and Rockford are located.

The samples from forested areas generally have lower phosphorus concentrations; whereas, higher phosphorus concentrations are from areas with agricultural and urban/suburban land uses. Higher phosphorus concentrations appear to correlate to large agricultural areas including middle California Creek, the reach between Latah and Waverly, near the confluence of Rattler Run Creek with Hangman Creek, and Little Hangman Creek and the area along the Stateline. The large areas of agriculture with conservation program or other buffers around the creeks appear to generally have greater total phosphorus concentrations.

The reaches of lower Rock Creek and Hangman Creek above the confluence with Rock Creek appear to be surrounded by land uses that are forestry/conservation program. Phosphorus concentrations while not the lowest in the subbasin are on the lower end of the spectrum. It may be worthwhile to further investigate the land use practices in these areas to better understand the relationships with phosphorus loading. The urban growth area promotes on-site septic systems and community drainfields, which are counterproductive to controlling non-point source phosphorus.
Figure 6.1. Average Phosphorus Concentration and USGS Land Cover/Zoning Land Cover with Stream Network for Hangman Creek
Additional definitions for the land covers shown in the legend in Figure 6.1. The land cover information shown in Figure 6.1 and the description of these lands covers is from Spokane County, Building and Planning Maps website (http://www.spokanecounty.org/bp/content.aspx?c=2299) and the USGS Land Cover Institute, LNCD Land Cover (http://landcover.usgs.gov/index.php).

**Barren Land**
Areas characterized by bare rock, gravel, sand, silt, clay, or other earthen material, with little or no "green" vegetation present regardless of its inherent ability to support life. Vegetation, if present, is more widely spaced and scrubby than that in the "green" vegetated categories; lichen cover may be extensive.

**Open Space**
Open space is those areas preserved for parks, recreation, and nature areas.

**Deciduous Forest**
Areas dominated by trees where 75 percent or more of the tree species shed foliage simultaneously in response to seasonal change.

**Open Water**
All areas of open water or permanent ice/snow cover.

**Mixed Forest**
Areas dominated by trees where neither deciduous nor evergreen species represent more than 75 percent of the cover present.

**Shrub/Scrub**
Areas characterized by natural or semi-natural woody vegetation with aerial stems, generally less than 6 meters tall, with individuals or clumps not touching to interlocking. Both evergreen and deciduous species of true shrubs, young trees, and trees or shrubs that are small or stunted because of environmental conditions are included.

**Large Tract Agriculture, Cultivated Crops**
Large Tract Agricultural areas are primarily devoted to grain, legume, and grass seed production. Non-resource-related uses are generally prohibited. Residences will usually be associated with farming operations. Density: 1 dwelling unit per 40 Acres.

**Rural Traditional, Grassland**
Rural lands in this category will include large-lot residential uses and resource-based industries, including ranching, farming, mining and forestry operations. Industrial uses will be limited to industries directly related to, and dependent on, natural resources. New non-resource-related industry would be allowed, provided it meets the requirements for a major industrial development outside the UGA (see policy RL.5.1a and RCW 36.70A.365). Rural-oriented recreational uses will also play a role in this category. Rural clustering would be allowed in this category without bonus density. Density: The density of the Rural Traditional category is 1 dwelling unit per 10 acre.
Rural Conservation
The Rural Conservation category applies to environmentally sensitive areas, including critical areas and wildlife corridors. Criteria to designate boundaries for this category were developed from Spokane County’s Critical Areas program and a study by the University of Washington titled, Wildlife Corridors and Landscape Linkages, An Approach to Biodiversity Planning for Spokane County, Washington. The category will encourage low-impact uses and utilize clustering and/or other open space techniques to protect sensitive areas and preserve open space. Density: The density of the Rural Conservation category is 1 dwelling unit per 20 acres, with a bonus density of 1 dwelling unit per 10 acres for preserving open space and environmentally sensitive areas through clustered housing.

Forest Land, Evergreen Forest
Forest land areas are primarily devoted to wood production. Non-resource related uses are generally prohibited. Residences are allowed but will be located on relatively large parcels to minimize conflicts with forestry operations.

Mineral Land
Mineral land areas are primarily devoted to sand, gravel, and rock or clay production. Related products such as concrete, asphalt and brick are also produced. Agriculture and forestry may be conducted on mineral resource lands but residences are generally limited to caretaker residences associated with mining or a related industry.

Community Center
Community Centers are higher intensity mixed-use areas designed to serve two or more neighborhoods. Community Centers will generally serve an area equivalent to a junior high or high school attendance area and may have a mix of uses, including commercial, civic, high-density residential and recreational uses.

Mixed Use
Mixed-use Areas are intended to enhance travel options, encourage development of locally-serving commercial uses, medium-density apartments and offices along transportation corridors identified on the Land Use Plan Map. Mixed-use areas discourage low-intensity, auto-dependent uses and focus on a pedestrian orientation with an emphasis on aesthetics and design.

Regional Commercial
Regional Commercial designates intensive commercial areas intended to attract customers from the County at large and other outlying areas. Regional shopping centers and major commercial areas will be designated with this classification. Residences in conjunction with business and/or multifamily developments may be allowed, with performance standards that ensure compatibility. Small-scale industrial parks may be allowed in this category, provided neighborhood concerns are addressed through a public hearing process.

Urban Growth Area
The Urban Growth Area includes those lands that are considered for growth within a 40-year planning horizon. These areas are given special consideration, such as low-density, large-lot development, so that land uses established in the near future do not preclude their eventual
conversion to urban densities. For example, a 1-acre to 5-acre per lot subdivision pattern in these areas would create parcels that would be difficult to divide to urban densities. Innovative techniques such as residential clustering may be used to allow residential development rights and ensure that these areas will be available in the future. The use of public water systems or community wells is encouraged. Community drain fields may also be appropriate in the Urban Reserve category. Density: The density of the Urban Reserve category is 1 dwelling unit per 20 acres, which may be increased to 1 dwelling unit per 5 acres for clustered housing. Within a cluster subdivision, the remainder lot must be reserved for future urban use. The minimum lot size in a cluster subdivision could be as low as 10,000 sq. ft; the maximum lot size is 1 acre.

**Low Density Residential**
Low Density Residential is a residential category that includes one (1) to, and including, six (6) dwelling units per acre.

**Medium Density Residential**
Medium Density Residential is a residential category that includes greater than six (6) and including fifteen (15) dwelling units per acre.

**High Density Residential**
High Density Residential is a residential category that includes greater than fifteen (15) dwelling units per acre.

**Rural-5**
The Rural Residential-5 category would allow a 1-dwelling-unit-per-5-acre density in areas that have an existing 5-acre or smaller subdivision lot pattern. The provision of public water service may be appropriate for these areas. Rural residential clustering is allowed in this category. Density: The density of the Rural Residential-5 category is 1 dwelling unit per 5 acres.

**Rural Activity Center**
The Rural Activity Center (RAC) category identifies rural residential centers supported with limited commercial and community services. RAC’s consist of compact development with a defined boundary that is readily distinguishable from surrounding undeveloped lands. RAC’s often form at crossroads and develop around some focal point, which may be a general store or post office. Other typical uses might include a church, school, restaurant, gas station, and other small shops. Commercial uses are intended to serve the surrounding rural area or, in some instances, the traveling public. RAC’s must have an identified boundary established on the Comprehensive Plan Map. Density: The maximum residential density in a Rural Activity Center category is 4 dwelling units per acre.

**Light Industrial**
Light Industrial is intended for industrial areas that have a special emphasis and attention given to aesthetics, landscaping and internal and community compatibility. Light Industry areas are comprised of predominantly industrial uses but may incorporate office and commercial uses. Residential uses should be prohibited.
Appendix A – Alternative Figure Scales for Analysis 1

1. TIMES SERIES PLOTS OF FLOW, PHOSPHORUS CONCENTRATIONS AND LOADS

Figures with the y-axis set the same for all graphs for comparison between monitoring locations are shown in Figures 1.1Scale through 1.6Scale. These are the same figures as Figures 1.1 through 1.6 only with the vertical axis set differently. With the scales set the same, it is visually easier to compare the flows, concentrations, and loads in the figures from the different locations in the watershed.
Figure 1.1 Scale. Spokane River at Lake Coeur d’Alene Time Series
Figure 1.2 Scale: Spokane River at Stateline Time Series
Figure 1.3 Scale. Spokane River at Spokane Time Series
Figure 1.4 Scale. Spokane River at Long Lake headwaters (Nine Mile) Time Series
Figure 1.5 Scale. Hangman Creek at Spokane River Time Series
Figure 1.6 Scale. Little Spokane River at Spokane River Time Series
Appendix B – Alternative Figure Scales for Analysis 3

3. AVERAGE MONTHLY PHOSPHORUS LOADINGS

Figures with the y-axis set the same for all graphs for comparison between monitoring locations are shown in Figures 3.1Scale through 3.6Scale. These are the same figures as Figures 3.1 through 3.6 only with the vertical axis set differently. With the scales set the same, it is visually easier to compare the flows, concentrations, and loads in the figures from the different locations in the watershed.

![Figure 3.1Scale](image-url)

**Figure 3.1Scale.** Average Monthly Phosphorus Load for Spokane River at Lake Coeur d’Alene
Figure 3.2 Scale. Average Monthly Phosphorus Load for Spokane River at Stateline
Figure 3.3 Scale. Average Monthly Phosphorus Load for Spokane River at Spokane
Figure 3.4 Scale. Average Monthly Phosphorus Load for Spokane River at Long Lake headwaters.
Figure 3.5 Scale. Average Monthly Phosphorus Load for Hangman Creek at Spokane River
Figure 3.6 Scale. Average Monthly Phosphorus Load for Little Spokane River at Spokane River