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# Memo

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| Date: | April 18, 2011, Revised July 12, 2011 | Job No: | 124985 |

**Subject: PLOAD Model Refinement for the Spokane River Watershed**

## 1 Introduction

This technical memorandum presents the refinement of the Spokane River watershed PLOAD model application and the resulting products. The process for the refinement included defining the Spokane River specific watershed basins and land uses in the model, converting the available data for comparison to the model prediction, and refining the model export coefficients. The PLOAD model application to the Spokane River watershed provides an estimation of the total phosphorus from land uses representing nonpoint sources (NPS).

## 2 Background

The purpose of the PLOAD model application is to provide a watershed scale model to use as a screening tool for nonpoint source total phosphorus loads from land uses (**Figure 1**). The methods for applying the PLOAD model to the Spokane River watershed were described in the technical memorandum "Proposed Methods for PLOAD Model Calibration and Products" (HDR, 2010). The construction of the PLOAD model was presented in the technical memorandum "Test Application of PLOAD Model" (HDR, 2010).

## 3 Objective

The purpose of this technical memorandum is to document the refined PLOAD model application including comparison to watershed data and adjustment of export coefficients.

## 4 PLOAD

PLOAD is a simplified, GIS-based model used to calculate pollutant loads for watersheds (EPA, 2001). PLOAD functions within the Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) interface framework to generate annual phosphorus loads using phosphorus export coefficients. The model was designed to be a screening tool for watershed management projects. Inputs to the model include watershed geographic parameters, land use types, and pollutant loading rate tables.

PLOAD provides total phosphorus yields from sub-basins providing a means for a relatively simple prioritization of areas with greater loads or loading intensity. PLOAD uses export coefficients which integrate the processes to provide a land use based, nonpoint source load, based on annual aerial loadings. For the watershed, there were available data to support the application of the model and this tool matched schedule and budget constraints. Additionally, PLOAD includes a BMP tool for comparison of pre-management with post-management scenarios.

### *4.1 PLOAD Model and Result Limitations*

PLOAD does have some limitations, however. The model is not site specific, there is potential bias in refining export coefficients to annual loadings, groundwater and point source impacts that are not explicitly included in the model framework, and fate and transport in the stream network are not represented. The resulting refined export coefficients are representative of each land use for the entire watershed. Export coefficients for at a subbasin or local scale may potentially be different.

An underlying limitation of a model is that it is only a representation of actual physical processes, and is only a representation of reality. The PLOAD model uses an export coefficient that integrates the representation of nonpoint source load from land uses in the subbasin. This is an underlying assumption of the model, providing a simplified mathematical representation. Appropriate caution and expertise should be used in applying the results beyond the scale or intention as developed and described in this technical memorandum and supporting documentation.

## 5 Comparison Data

Phosphorus data collected from monitoring conducted in the watershed were compiled in the Spokane NPS database. However, the concentrations in the phosphorus database are from discrete grab samples, whereas the PLOAD model predicts an annual load. A method was developed to translate the watershed data to be comparable for comparison with the predictions generated by the PLOAD model.

### *5.1 Monitoring Data Translation*

The following steps were completed to estimate a target range of annual loads for the PLOAD model based on sampling data in the Spokane NPS database (database). The database includes in-stream water quality samples from stations located throughout the watershed. (Construction and content of the Spokane NPS database is described in previous memoranda.)

The database was filtered to select for samples with both total phosphorus concentration and flow data collected on the same date. This provides the ability to estimate the load from monitoring data. Only data collected after January 1, 1990 were used in the analysis. Data from before this period are not representative of modern land use development and practices. These two criteria reduced the dataset from 1862 to 256 stations (locations).

These stations were then sorted into three groups: strong, weak, and random to reflect the temporal consistency of the phosphorus and flow monitoring data. The strong group consisted of data with at least monthly samples of flow and total phosphorus for an entire year. There are 44 stations in the strong group. The weak group consisted of data with samples from every month but from different years. There are 54 stations in the weak group. The random data were not used in the analysis because there was an insufficient distribution of data to estimate annual loads. The 98 stations in the strong and weak categories are shown in **Figure 2**.

For the strong group, data were assumed to be log normally distributed and a statistical method was applied to estimate the potential range of phosphorus loadings represented by the data. A log normal distribution using the t-test was completed on the loads for each year of data for each station. “The most commonly-used transformation in water resources is the logarithm. Logs of water discharge, hydraulic conductivity, or concentration are often taken before statistical analyses are performed” (USGS, 2002). The statistics were calculated using a software package within Excel. The results include the 95-percent confidence interval which was used to estimate the low and high range of the annual mean load.

Four stations in the strong group have nearly consistent monthly records from 1991 through 2007. These four stations are along the mainstem of the Spokane River. The yearly load was compared to the median load and annual flow to determine the normalized load for each year. This was done using a ratio of the yearly flow to median flow to adjust loads from any type of water year, high flows or low flows, to a typical annual load.

For data from the strong group, the yearly load was normalized from high and low flow years for comparison with the PLOAD model which estimates mean annual loads. This allowed for the comparison of in-stream data from multiple years of various conditions. The normalization is the inverse of the percent of the yearly load to the median load and then adjusted based on the preceding year flow and the overall period of record using best professional judgment (**Figure 3**). The normalization was then used to estimate mean annual loads from each of the yearly loads.

The mean of the low and high range was used as the target value for comparison to the predicted annual load from PLOAD.

The dataset with less temporal consistency in phosphorus and flow monitoring were assigned to the weak group and a different approach was required. Monthly loads were calculated using the data. These monthly loads were adjusted for flow conditions by using a ratio computed from the monthly loads in the strong group. The adjusted monthly loads were summed to estimate the annual load for each location. A low and high range was then estimated from the annual load. The percent differences between the median monthly load and the low and high loads in the strong group were calculated for each station. The median difference of all locations was calculated. This median difference was used to compute the low and high range of annual load estimates for the weak group.

### *5.2 Alignment of Stations to Sub-Subbasins*

The sub-subbasins in PLOAD that impact the strong and weak group data stations, as shown on **Figure 2**, were identified. These were identified by examining the stream network within the basin and the station location in GIS. Loads from these sub-subbasins were summed and compared to loading estimates from the strong and weak data groups at the sample locations. However, few of the stations are located at the terminus of the basin. The relative location of the station in the basin was used to determine if the basin that the station is located in was included in the sum of the upstream basins. Summing the loads is an assumption that ignores fate and transport in the stream network. However, regardless of changes between the dissolved, particulate, or organic phosphorus fractions, total phosphorus is being measured and compared.

Potential issues that would skew the assumption are point source loadings, deposition and uptake by root aquatic vegetation, and groundwater losses/gains. Point sources could cause the monitoring station to have a greater phosphorus load than the sum of the upstream nonpoint source contribution. Deposition and uptake by rooted aquatic vegetation could cause an under-estimation of the upstream nonpoint source load. Groundwater influences could skew the timing and magnitude of the monitoring station data relative to nonpoint source loads.

### *5.3 Historically Reported Loads*

The average, median, and high/low ranges from historically reported loads were computed. A summary of these loads is shown in **Table 1**. These were compared to the annual load estimates using the data from NPS Database and the statistical analyses. The historically reported loads are similar to the NPS Database estimated loads. The loads were converted to export coefficients by dividing by the subbasin area and the computed export coefficients are shown in **Figure 4**. Computed export coefficients from both the historically reported and NPS Database loads divided by the corresponding area provide targets for the PLOAD export coefficients (see Section 7.2 and **Figures 6** through **13**).

**Table 1. Spokane River Watershed Historically Reported Loads**

| Subbasin | Load (lbs/yr) | | | |
|---|---|---|---|---|
| | Average | Low | High | Median |
| Coeur d'Alene River above the Lake[1] | 71,694 | 24,030 | 119,490 | 74,075 |
| Hangman Creek[2] | 140,087 | 21,535 | 415,370 | 95,995 |
| Little Spokane River[3] | 45,220 | n/a | n/a | n/a |
| Spokane River out of Coeur d'Alene Lake[1] | 82,497 | 54,675 | 114,640 | 70,989 |
| St. Joe River[1] | 149,958 | 77,823 | 326,284 | 99,428 |

[1]2008 USGS Coeur d'Alene Lake Report - USGS. 2008. Coeur d'Alene Lake, Idaho: Insights gained from limnological studies of 1991-92 and 2004-06. Scientific investigations report 2008-5168
[2]unpublished Washington Department of Ecology data from Joe Joy
[3]2008 WSU TMDL Report - Barber, Michael, Tom Cichosz, Shulin Chen, Yuzhou Luo, Goubin Fu, and Abbas Al-Omari. 2007. Total maximum daily load technical report for the Little Spokane River: Data collection, analysis, and recommendations. December 2007

## 6 Land Use Based Phosphorus Export Coefficients

The major land uses in the Spokane River watershed and brief descriptions of the land use categories are shown in **Table 2**. For these land uses, literature values for phosphorus export coefficients are summarized in **Table 3**. These literature values provided the range of potential refinement for the export coefficients in the PLOAD model of the Spokane River watershed.

The land use data are from 2001 (USGS, 2001) and represent the entire watershed. The default phosphorus export coefficients (ECs) in PLOAD suggest that some of the highest export values are from urban areas. The Spokane River water quality data being used to check the ECs were collected watershed wide from 1990 through 2008. Previously completed surface water linear trend analysis did not indicate any changes in surface water total phosphorus concentrations in the larger subbasins between 1990 and 2008. The model represents mean annual loads, not annual loads for each year with the associated changes in land uses. The analysis will be used as a screening tool of nonpoint source loadings across the entire watershed. The relative comparison between land use loadings and sub-subbasin loadings are expected to be similar with and without land use updates for the rapid growth areas. This is anticipated because a majority of the rapid growth occurred in sub-subbasins with existing urban land uses. The current analysis is not intended to examine how loadings changed for a single area or basin over time. This would be an interesting analysis and could be completed by using a different land use layer in PLOAD, but is beyond the current objectives and scope of the project. Such an analysis could be beneficial for a single entity, such as a city, to track impacts of land use changes and integrate in the effects of nonpoint source management actions.

**Table 2. Major Spokane River Watershed Land Use Categories**

| Land Use | Description |
|---|---|
| Urban or Built-Up Land | Areas of intensive use with much of the land covered by structures or otherwise impervious not falling in other urban categories |
| Residential | Low to high density areas with housing |
| Commercial and Service | Areas of commercial products and services such as business districts and shopping areas |
| Other Urban | Undeveloped or parks and other urban areas that are generally pervious |
| Cropland and Pasture | Areas used for crops and pasture generally discerned from imagery and agricultural statistics |
| Herbaceous Range Land | Areas dominated by naturally occurring grasses and forbs |
| Shrub and Brush Range Land | Typical shrub occurrences found in arid and semiarid regions characterized by xerophytic vegetative types like sagebrush |
| Deciduous Forest Land | Areas having a predominance of trees that lose their leaves at the end of the frost-free season |
| Evergreen Forest Land | Areas having a predominance of trees that remain green throughout the year |

**Table 3. Summarized Range of Literature Reported Phosphorus Export Coefficients**

| Land Use | TP (lbs/ac/yr) | | | References |
|---|---|---|---|---|
| | Lowest | Median | Highest | |
| Urban or Built-up Land | 0.06 | 0.40 | 5.56 | 1,2,3,5,6,7,8,9 |
| Residential | 0.01 | 0.49 | 1.97 | 1,2,4,6,9 |
| Commercial and Service | 0.09 | 1.81 | 6.78 | 1,2,3,6,9 |
| Other Urban | 0.17 | 0.18 | 0.80 | 1,6 |
| Cropland and Pasture | 0.02 | 0.50 | 16.6 | 1,2,3,4,6,7,8,9 |
| Other Agricultural Land | 0.50 | 0.71 | 0.92 | 2 |
| Herbaceous Range Land | 0.04 | 0.25 | 0.87 | 1,3,6 |
| Shrub and Brush Land | 0.05 | 0.18 | 0.87 | 3,6,7 |
| Deciduous Forest Land | 0.01 | 0.13 | 0.99 | 1,2,3,4,6,7,8 |
| Evergreen Forest Land | 0.01 | 0.08 | 0.99 | 1,2,3,6,7,8 |
| Mixed Forest Land | 0.01 | 0.18 | 0.99 | 1,2,3,6,7 |
| Forested Wetland | 0.02 | 0.17 | 0.66 | 1,2,9 |
| Non-forested Wetland | 0.01 | 0.11 | 0.22 | 1,2 |

References:
[1]Alberta, 2006
[2]EPA, 2001
[3]NY, 2007
[4]MDEP, 2000
[5]Rast, 1983
[6]St. Croix, 2009
[7]TIAER, 1999
[8]USACE, 2004
[9]USGS, 2008

# 7 PLOAD

The PLOAD model application integrates land uses, export coefficients, and watershed water quality data to create the basis for a phosphorus export load calculation. The PLOAD model uses a single export coefficient for each land use and generates a single total annual phosphorus load for each sub-subbasin. A range of values for the export coefficients, water quality data, and PLOAD results were considered in this analysis.

## *7.1 Phosphorus Export Coefficients*

A range of phosphorus export coefficients based on the literature review were used as constraints in selecting phosphorus export coefficients used in the PLOAD model. In **Figure 5** land uses are shown on the horizontal scale and the export coefficient values are shown on the vertical scale. Based on the literature review (**Table 3**), the median total phosphorus export coefficient is shown in **Figure 5**, as an open triangle for each land use category. The range of the export coefficients is shown by the vertical bars. The median of the export coefficients used in the PLOAD model are shown in **Figure 5,** as a solid square.

The selection of the export coefficients included testing the range literature values and narrowing the ranges to be within the target ranges set by the Spokane River water quality data. Basins with dominant land uses restricted the ranges for some export coefficients. For example, the St. Joe subbasin is predominantly evergreen forest. Alternatively, the Hangman Creek subbasin has a dominant cropland land use. Additional factors include the Little Spokane subbasin which has the most target data points and integrates numerous land uses.

This process was then enhanced by using a mathematical approach to narrow the selection of the export coefficients. The 'Solver' tool in Excel was used to refine the export coefficients (Appendix A). The 'target' was to minimize the difference between the observed loads and the PLOAD model predicted loads. Export coefficients were allowed to vary within the constraints of the literature values. There were 17 export coefficients for the land uses meaning there were 34 constraints, greater than the minimum of the range and less than maximum of the range. Additionally there were 20 constraints that the PLOAD model predicted loads and export coefficients for the subbasins were within the low and high ranges and/or 10-percent of the median values for the loads and export coefficients.

### *7.2 Comparison to Data Load Estimates*

The model coefficients are shown in **Table 4** along with comparisons to the constraints. The observed and model results are compared by subbasin and station as shown in **Figures 6** through **13**. The stations and stream names are shown on the horizontal scale and the total phosphorus load or export coefficient is shown on the vertical scale. The water quality data targets are shown as an open circle with the range shown by the vertical bars. The PLOAD results are shown as a solid square. The model sub-subbasin results were summed to the station location. Additionally, the load or export coefficient for the subbasin is shown at the far right.

For the Spokane River station downstream of all of the point sources, the point source load was estimated and subtracted from the in-stream water quality data estimate to achieve an adjusted target for comparison. The point source load was estimated as 0.054 lbs/acre/yr based on the flow rate and concentration from the major dischargers. With this adjustment the PLOAD export and load results match well to the data (**Figure 6**).

No other attempts to "correct" of modify the subbasin loads to account for sources other than nonpoint source were added to the graphs. Estimates of the groundwater loading contribution were estimated. These are show in Appendix B for relative comparison.

Export coefficients for urban land within the Spokane area have been estimated as part of previous studies (Appendix C). The values are within the ranges shown in **Table 3**. However, it was decided to not further constrain the model with this narrower range of urban export coefficients. While the export coefficient calculated for urban land in the PLOAD model are lower than from previous studies, the sensitivity analysis suggests a narrow range for many of the export coefficients including the urban land uses. This suggests there are a sufficient number of constraints with the export coefficient ranges, database estimated loads and export coefficients, and variations between the subbasins. The differences may be a result of scale with PLOAD using watershed scale land uses that may integrate more diverse urban land uses than the previous studies which may have had a small scale and used only the most urban/developed areas.

For the Upper Spokane River, the PLOAD export results are higher than the data but no adjustment has been made to the data for the Idaho point source discharges (**Figure 7**). The

PLOAD load results are similar to the data. The reported values shown are for the upstream portion instead of the downstream for this subbasin.

For the Lake Coeur d'Alene subbasin, the model export results are generally higher than the data but the loads are similar (**Figure 8**). The higher estimate may be due to the unknown influence of Coeur d'Alene Lake.

For the Upper and South Fork Coeur d'Alene subbasins, the model export and loads results vary greater and less than the data (**Figure 9**). Higher data points may be influenced by the communities in the Silver Valley along the South Fork Coeur d'Alene River. The solid circles for the data represent weaker data and were given a lower priority for comparison.

Export from the St. Joe subbasin (**Figure 10**) is generally greater than the data estimates, but the loads are generally similar. Again, there are some potential influences from communities and land use activities.

The Hangman Creek subbasin shows significant variation in the water quality data, potentially due to a variety of influences (**Figure 11**). This variation could be from any number of factors including date of sampling, location, purpose, quality control, objective of study, detection limits, etc. The PLOAD export and loads are generally less than the data.

The Little Spokane subbasin contains the most water quality data points for comparison (**Figure 12** and **Figure 13**). This is also the most complex basin with the greatest variation in land use, suburban influences, and other watershed activities. **Figure 12** includes the stations from the strong data group, considered more reliable estimates than those shown in **Figure 13** which are stations with less frequent data.

**Table 4. Summarized Range of Model Phosphorus Export Coefficients**

| Land Use | Total Phosphorus Export (lbs/ac/yr) | | |
|---|---|---|---|
| | Lower Constraint | Refined | Upper Constraint |
| Evergreen Forest Land | 0.01 | 0.08 | 0.99 |
| Cropland and Pasture | 0.02 | 0.31 | 16.59 |
| Herbaceous Range Land | 0.04 | 0.04 | 0.87 |
| Shrub and Brush Land | 0.05 | 0.05 | 0.87 |
| Non-forested Wetland | 0.01 | 0.01 | 0.66 |
| Deciduous Forest Land | 0.01 | 0.01 | 20 |
| Forested Wetland | 0.01 | 0.02 | 0.66 |
| Mixed Forest Land | 0.01 | 0.01 | 20 |
| Urban or Built-up Land | 0.06 | 0.06 | 5.56 |
| Other Urban | 0.17 | 0.17 | 0.80 |
| Residential | 0.01 | 0.01 | 1.97 |
| Other Agricultural Land | 0.50 | 0.50 | 0.92 |
| Commercial and Service | 0.09 | 0.20 | 6.78 |
| Barren Land | 0.06 | 0.50 | 0.78 |
| | | | |
| **Subbasin** | **Total Phosphorus (lbs/ac/yr)** | | |
| | **Lower Constraint** | **Refined** | **Upper Constraint** |
| Hangman | 86,396 | 86,395 | 105,595 |
| Little Spokane | 40,698 | 43,779 | 49,742 |
| St. Joe | 89,486 | 89,486 | 109,371 |
| Upper Coeur d’Alene | 66,668 | 62,105 | 81,483 |
| Coeur d’Alene Lake out | 63,890 | 92,483 | 78,088 |
| | | | |
| **Subbain** | **Total Phosphorus Export (lbs/ac/yr)** | | |
| | **Lower Constraint** | **Refined** | **Upper Constraint** |
| Hangman | 0.19 | 0.20 | 0.23 |
| Little Spokane | 0.07 | 0.10 | 0.09 |
| St. Joe | 0.08 | 0.08 | 0.09 |
| Upper Coeur d’Alene | 0.09 | 0.08 | 0.11 |
| Coeur d’Alene Lake out | 0.03 | 0.04 | 0.03 |

The results are presented spatially in **Figures 14 and 15**. The model results indicated that the highest loads per area are in the Hangman Creek subbasin, Lower Spokane River subbasin, and along Deadman Creek. The highest loads follow a similar pattern with higher loads along the Spokane River corridor. This is similar to previous results that suggested loads nearest the river should have a higher priority. The next highest model results are areas around the Spokane River corridor and especially in the Little Spokane River subbasin. These areas generally have a higher mix of land uses. The combination of these land uses results in the higher loading. Loading in the middle of the range are mostly from areas with mixes of agricultural and range land uses and small suburban areas. The majority of this area is the middle of Hangman Creek subbasin through the agricultural areas around the lower portion of Lake Coeur d’Alene and into the Silver Valley along the South Fork Coeur d'Alene River. The lowest loadings were the rural mostly forested areas around the northern and eastern portion of the watershed.

### *7.3 Sensitivity Analysis*

Three methods to test the sensitivity of the PLOAD model to the refined export coefficients (as shown in **Table 4)** were performed. These were:

1. Target variation with manual adjustment of export coefficients
2. Summary table (**Table 5**) variations with adjustment of export coefficients
3. Export coefficient range with similar results

#### *7.3.1 Target Variation with Manual Adjustment of Export Coefficients*

The refined export coefficients (**Table 4**) were manually adjusted, individually increased and decreased, and the target was recalculated. The target was the difference between the observed loads and the PLOAD model predicted loads (see Section 7.1). The difference between the target and the result from each adjustment was calculated. A twenty percent increase and decrease change in the export coefficient is shown in **Figure 16**. A 0.05 increase and decrease change in the export coefficient is shown in **Figure 17**.

The target varied the most with the change in the evergreen forest export coefficient followed by the cropland and pasture and shrubland and brush export coefficients. Changing the other export coefficients resulted less variation in the target. This was as expected result since forest land is the most common and cropland and pasture have the highest export coefficient.

#### *7.3.2 Summary Table Variations with Adjustments of Export Coefficients*

The refined export coefficients (**Table 4**) were individually increased and decreased by twenty percent and the subbasin yield and export calculated. The difference between the summary table results (**Table 5 –** last two rows) and the results from each adjustment was calculated. The results as percent difference are shown in **Table 6**.

The land uses with the greatest variation to changing the export coefficients are as follows:

- Evergreen forest in all subbasins
- Cropland and pasture in all subbasins except the South Fork and Upper Coeur d'Alene River and St. Joe River
- Shrub and brush in South Fork Coeur d'Alene River and St. Joe
- Other urban and urban or built-up in the Upper Spokane River, WA

#### *7.3.3 Export Coefficient Range with Similar Results*

The loads were set at similar values (1- and 5- percent different from the results since the model is a linear equation) and the export coefficients were then calculated to equal these similar load values. The load results for both the subbasins and watershed were used. The minimum change in export coefficient from the subbasin and watershed results were selected as the range for the export coefficients. The ranges of coefficients for results within 1- and 5-percent are shown in **Table 7**. Mixed forest, deciduous forest, and barren land have the greatest ranges; and thus, the least confidence in the selected value. Mixed forest has the greatest range as four subbasins have little or no mixed forest land use.

There are four urban land uses.  The export coefficient for commercial and service range from plus or minus 0.03 at 1-percent and plus or minus 0.17 at 5-percent with all the constraints considering all the subbasins.  Other urban and residential has about half the range of commercial and service while urban or built-up has about a quarter of the range.  If only individual subbasins are considered, the range is much greater for subbasins with small percentages of urban land uses such as the Upper Coeur d'Alene River and St. Joe subbasins.  The Upper Spokane River, WA subbasin has the most urban land use and drives the selection of the urban export coefficients.  The selection of the export coefficients for all land uses assumes a single value is representative of each land use across the watershed.

## 8 Summary/Conclusion

This technical memorandum presents the application and refinement of the Spokane River watershed PLOAD model application and the resulting products.  A summary of the land use percentages by subbasin, export coefficients, and land use and subbasin yields of nonpoint source phosphorus are show in **Table 5**.  The PLOAD model application is within the target watershed comparison data using export coefficients within literature ranges.  The model provides a screening level tool for the comparison of nonpoint sources across the Spokane River watershed.  The results provide a guide for future prioritization of areas for additional monitoring, studies, and BMP implementation.  The model may also be used to evaluate alternative BMP implementation programs.

**Table 5. Summary of Land Use Percentages by Subbasin, Export Coefficients, and Land Use and Subbasin Yields**

| Percent of Area | Subbasin | | | | | | | | | | Watershed | Phosphorus Export Coefficient (lb/ac/yr) | Land Use Yield (lbs/yr) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Land Uses | Coeur d'Alene Lake | Hangman Creek | Little Spokane River | Lower Spokane River | Pend Oreille Lake SW | South Fork Coeur d'Alene River | St. Joe River | Upper Coeur d'Alene River | Upper Spokane River, ID | Upper Spokane River, WA | | | |
| Barren Land | 0% | 0% | 0% | 0% | 0% | 0.7% | 0% | 0% | 0% | 0% | 0% | 0.50 | 824 |
| Commercial and Service | 0% | 0.1% | 0.1% | 0.2% | 0% | 0.1% | 0% | 0% | 0.2% | 2.3% | 0.1% | 0.20 | 1,113 |
| Cropland and Pasture | 4.2% | 50.7% | 8.7% | 22.5% | 0.15 | 0% | 0.6% | 0% | 5.9% | 3.6% | 8.9% | 0.31 | 110,764 |
| Deciduous Forest Land | 0.2% | 0.1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0.1% | 0.01 | 22 |
| Evergreen Forest Land | 62.5% | 26.2% | 57.1% | 24.3% | 83.2% | 73.7% | 73.2% | 93.6% | 60.7% | 34.5% | 63.7% | 0.08 | 205,205 |
| Forested Wetland | 1.1% | 0.1% | 0.2% | 0.2% | 0.4% | 0.1% | 0.2% | 0.2% | 0.3% | 0% | 0.3% | 0.02 | 233 |
| Herbaceous Range Land | 2.8% | 6.4% | 10.6% | 12.2% | 3.4% | 1.3% | 0.9% | 0.2% | 6.1% | 8.0% | 4.0% | 0.04 | 6,385 |
| Lakes | 7.8% | 0.1% | 0.6% | 2.5% | 1.2% | 0% | 0.3% | 0% | 2.2% | 1.2% | 1.3% | n/a | n/a |
| Mixed Forest Land | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0.01 | 7 |
| Nonforested Wetland | 0.9% | 0.5% | 1.0% | 0.4% | 0.9% | 0.2% | 0.6% | 0.7% | 0.4% | 1.4% | 0.6% | 0.01 | 261 |
| Other Agricultural Land | 0.3% | 0.1% | 1.0% | 0.2% | 0.4% | 0% | 0% | 0% | 0.7% | 0.6% | 0.3% | 0.50 | 5,276 |
| Other Urban | 1.0% | 3.9% | 1.9% | 3.4% | 0.6% | 0.5% | 0.3% | 0.1% | 2.7% | 6.5% | 1.5% | 0.17 | 10,099 |
| Perennial Snow or Ice | 0% | 0% | 0% | 0% | 0.1% | 0% | 0% | 0% | 0% | 0% | 0% | n/a | n/a |
| Residential | 0.5% | 0.6% | 1.3% | 2.5% | 0% | 0.8% | 0% | 0% | 2.0% | 9.6% | 0.9% | 0.01 | 357 |
| Shrub and Brush Range Land | 17.1% | 9.2% | 14.2% | 27.7% | 8.4% | 21.5% | 23.5% | 5.1% | 12.6% | 15.9% | 16.2% | 0.05 | 32,538 |
| Streams and Canals | 0.3% | 0% | 0% | 0.25 | 0% | 0.1% | 0.2% | 0% | 0.3% | 0.2% | 1.1% | n/a | n/a |
| Urban or Built-up Land | 1.1% | 2.1% | 3.0% | 3.8% | 1.3% | 0.8% | 0.2% | 0% | 5.9% | 17% | 2.0% | 0.06 | 4,721 |
| Subbasin Export (lbs/ac/yr) | 0.07 | 0.19 | 0.09 | 0.12 | 0.08 | 0.08 | 0.07 | 0.08 | 0.09 | 0.08 | 0.09 | n/a | n/a |
| Subbasin Yield (lbs/yr) | 32,502 | 85,902 | 43,044 | 25,661 | 12,722 | 14,508 | 86,706 | 44,743 | 21,324 | 10,692 | 377,805 | n/a | n/a |

**Table 6. Sensitivity of Subbasin Yield to Twenty Percent Increase and Decrease in Individual Export Coefficients as Percent Change of Refined Export Coefficient Results**

| Land Uses | Coeur d'Alene Lake | Hangman Creek | Little Spokane River | Lower Spokane River | Pend Oreille Lake SW | South Fork Coeur d'Alene River | St. Joe River | Upper Coeur d'Alene River | Upper Spokane River, ID | Upper Spokane River, WA | Watershed |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Barren Land | 0% | 0% | 0.1% | 0.1% | 0.1% | 4.8% | 0% | 0% | 0.1% | 0.3% | 0.2% |
| Commercial and Service | 0.1% | 0.1% | 0.3% | 0.4% | 0% | 0.4% | 0% | 0% | 0.4% | 5.8% | 0.3% |
| Cropland and Pasture | 13.1% | 81% | 28.6% | 59.3% | 0.6% | 0% | 2.55 | 0% | 20.6% | 13.7% | 29.0% |
| Deciduous Forest Land | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Evergreen Forest Land | 67.9% | 10.8% | 48.2% | 16.5% | 87.0% | 77.7% | 79.7% | 95.9% | 55.3% | 34.5% | 54.5% |
| Forested Wetland | 0.3% | 0% | 0.1% | 0% | 0.1% | 0% | 0% | 0% | 0.1% | 0% | 0.1% |
| Herbaceous Range Land | 1.5% | 1.3% | 4.5% | 4.1% | 1.8% | 0.7% | 0.5% | 0.1% | 2.8% | 4.0% | 1.7% |
| Lakes | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Mixed Forest Land | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Nonforested Wetland | 0.1% | 0% | 0.1% | 0% | 0.1% | 0% | 0.1% | 0.1% | 0% | 0.1% | 0.1% |
| Other Agricultural Land | 1.9% | 0.3% | 5.3% | 0.7% | 2.5% | 0.3% | 0.2% | 0.3% | 4.2% | 3.9% | 1.4% |
| Other Urban | 2.3% | 3.4% | 3.3% | 4.9% | 1.3% | 1.1% | 0.8% | 0.2% | 5.1% | 13.9% | 2.7% |
| Residential | 0.1% | 0% | 0.1% | 0.2% | 0% | 0.1% | 0% | 0% | 0.2% | 1.2% | 0.1% |
| Shrub and Brush Range Land | 11.6% | 2.4% | 7.5% | 11.8% | 5.5% | 14.1% | 16.0% | 3.3% | 7.2% | 10.0% | 8.6% |
| Urban or Built-up Land | 0.9% | 0.7% | 1.9% | 1.9% | 1.0% | 0.7% | 0.1% | 0% | 4.0% | 12.7% | 1.3% |
| Values shown are the (subbasin yield with individual EC+20% – subbasin yield with individual EC-20%) / refined subbasin yield in Table 5 / the total percent change. | | | | | | | | | | | |

**Table 7. Range of Export Coefficients for Similar Results**

| Land Use | Total Phosphorus Export (lbs/ac/yr) | | |
|---|---|---|---|
| | **Refined** | **1% Similar Results** | **5% Similar Result** |
| Evergreen Forest Land | 0.08 | 0.08 | 0.08 |
| Cropland and Pasture | 0.31 | 0.31 | 0.01 - 0.33 |
| Herbaceous Range Land | 0.04 | 0.03 - 0.05 | 0.01 - 0.08 |
| Shrub and Brush Land | 0.05 | 0.05 | 0.03 - 0.07 |
| Non-forested Wetland | 0.01 | 0.07 - 0.09 | 0.01 - 0.41 |
| Deciduous Forest Land | 0.01 | 0.01 - 0.40 | 0.01 1.94 |
| Forested Wetland | 0.02 | 0.01 - 0.08 | 0.01 - 0.34 |
| Mixed Forest Land | 0.01 | 0.01 - 1.65 | 0.01 - 8.21 |
| Urban or Built-up Land | 0.06 | 0.06 | 0.04 - 0.08 |
| Other Urban | 0.17 | 0.16 - 0.18 | 0.11 - 0.23 |
| Residential | 0.01 | 0.01 - 0.02 | 0.01 - 0.05 |
| Other Agricultural Land | 0.50 | 0.41 - 0.59 | 0.03 - 0.97 |
| Commercial and Service | 0.20 | 0.17 - 0.23 | 0.03 - 0.37 |
| Barren Land | 0.50 | 0.4 - 0.6 | 0.01 - 1.02 |

# 9 References

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USGS. 2008. Hydrologic and Water-Quality Characterization and Modeling of the Onodaga Lake Basin, Onondaga County, New York. Scientific Investigation Report 2008-5013. Reston, VA.

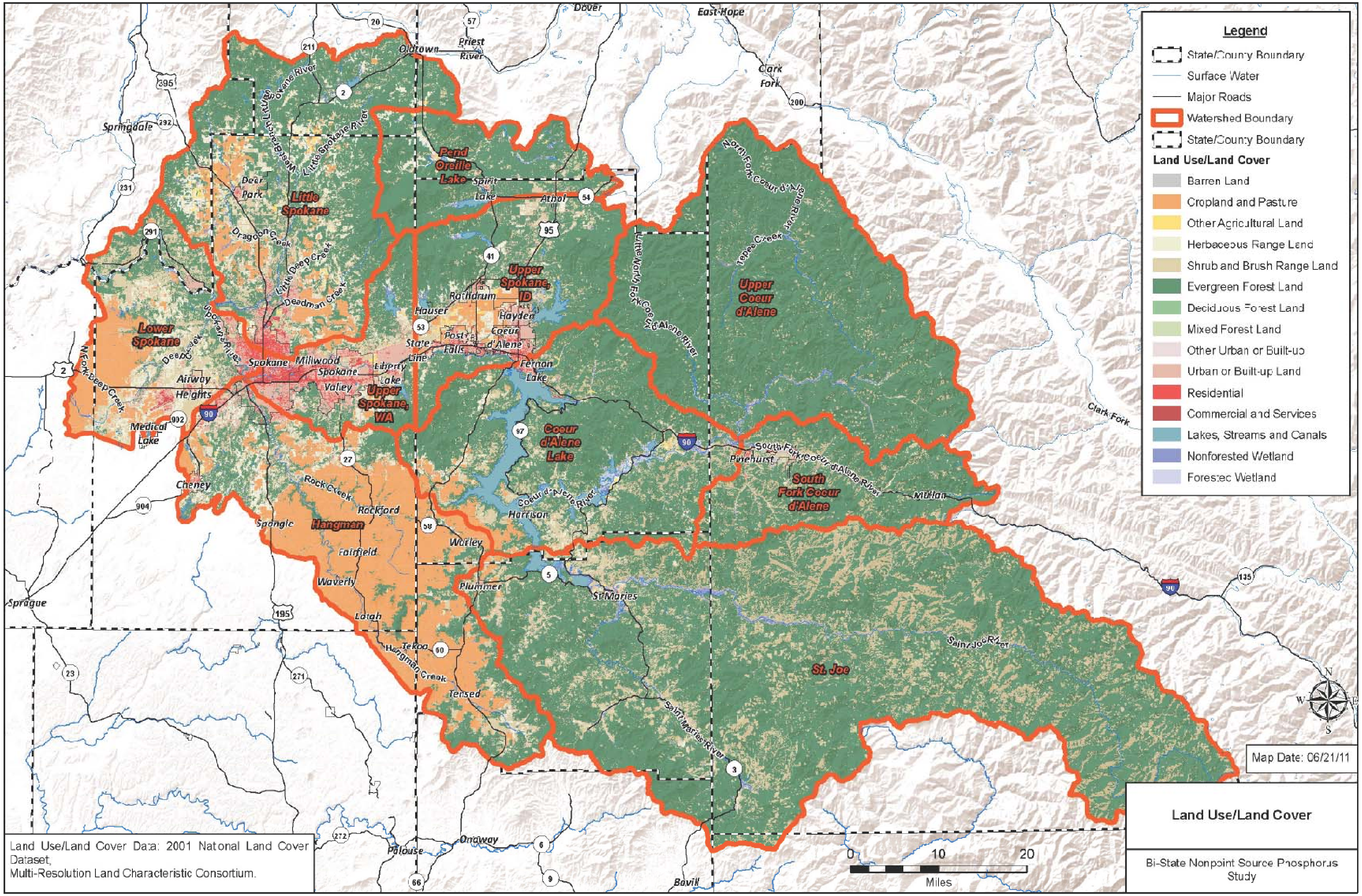



**Figure 1. Spokane River Watershed and Land Uses**

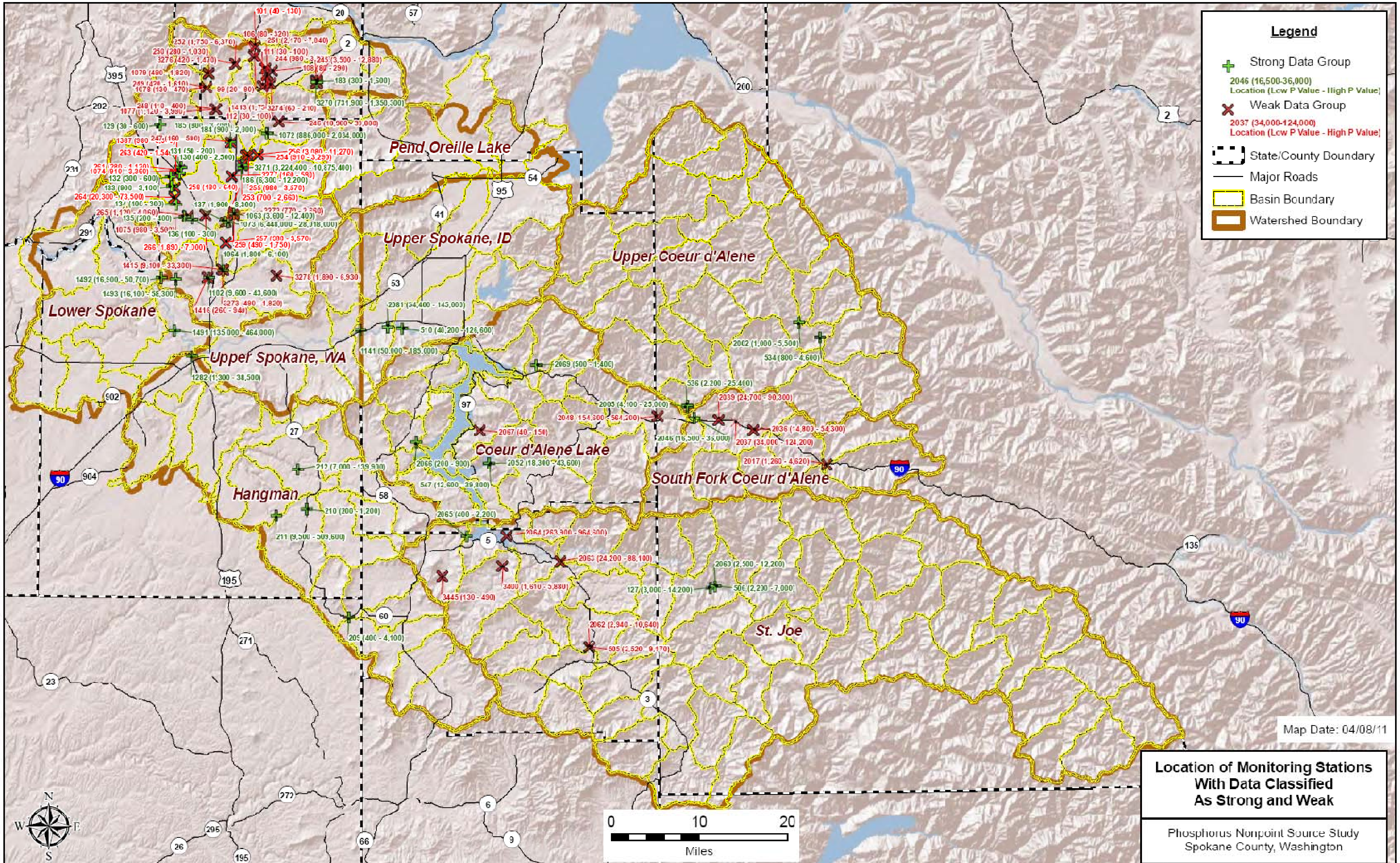



**Figure 2. Location of Monitoring Stations meeting Criteria for PLOAD Model Comparison and Refinement**

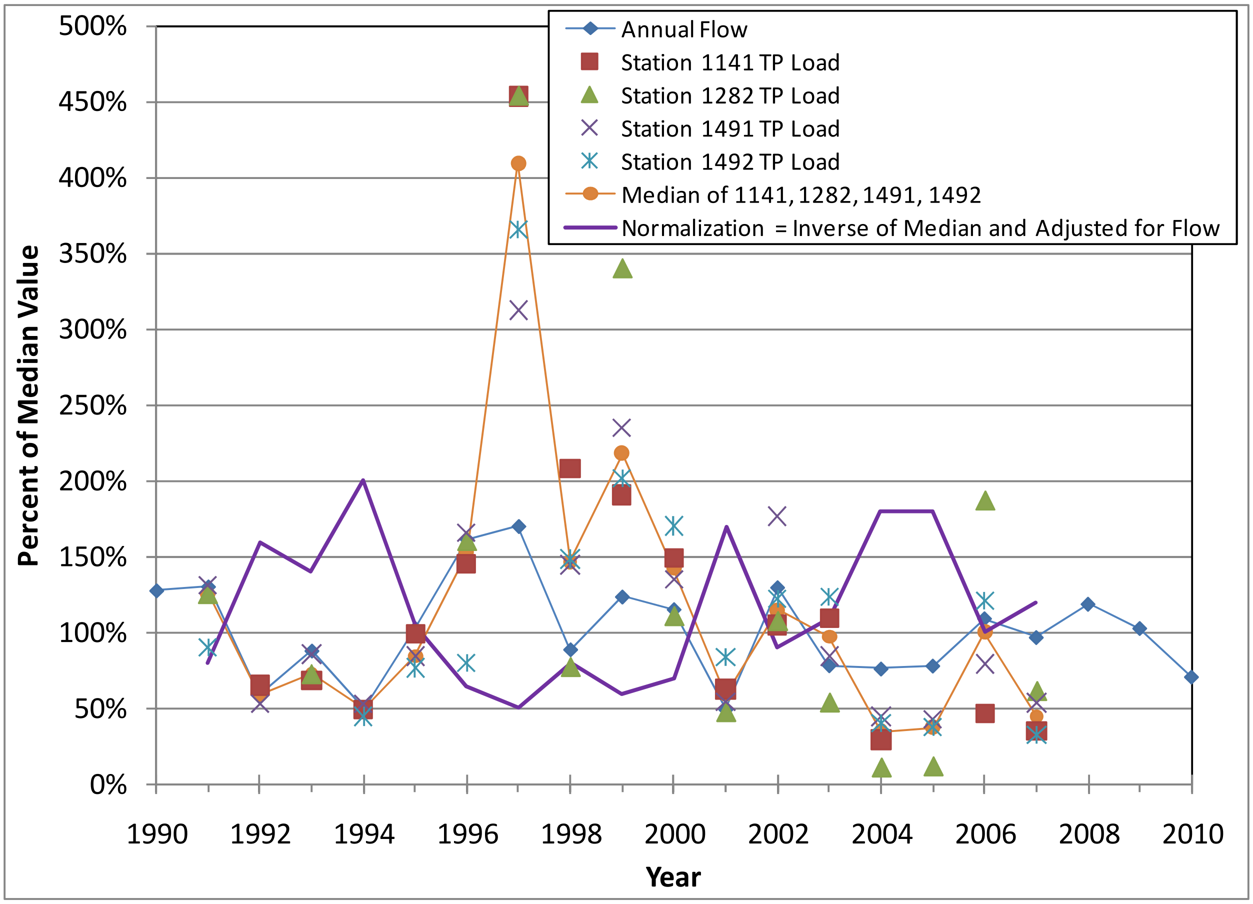



**Figure 3. Yearly Load Normalization**
**(Annual flow adjusted by using a ratio of the yearly flow to median flow.)**

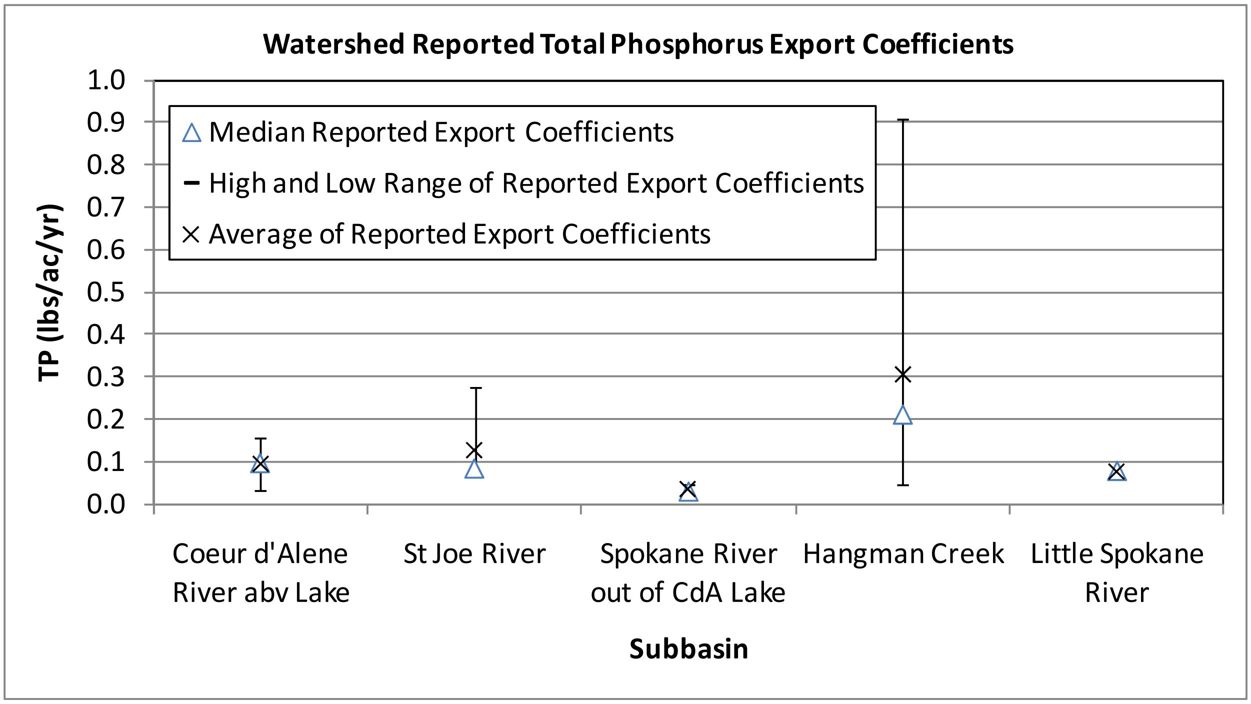



**Figure 4. Historically Reported Loads converted to Export Coefficients**

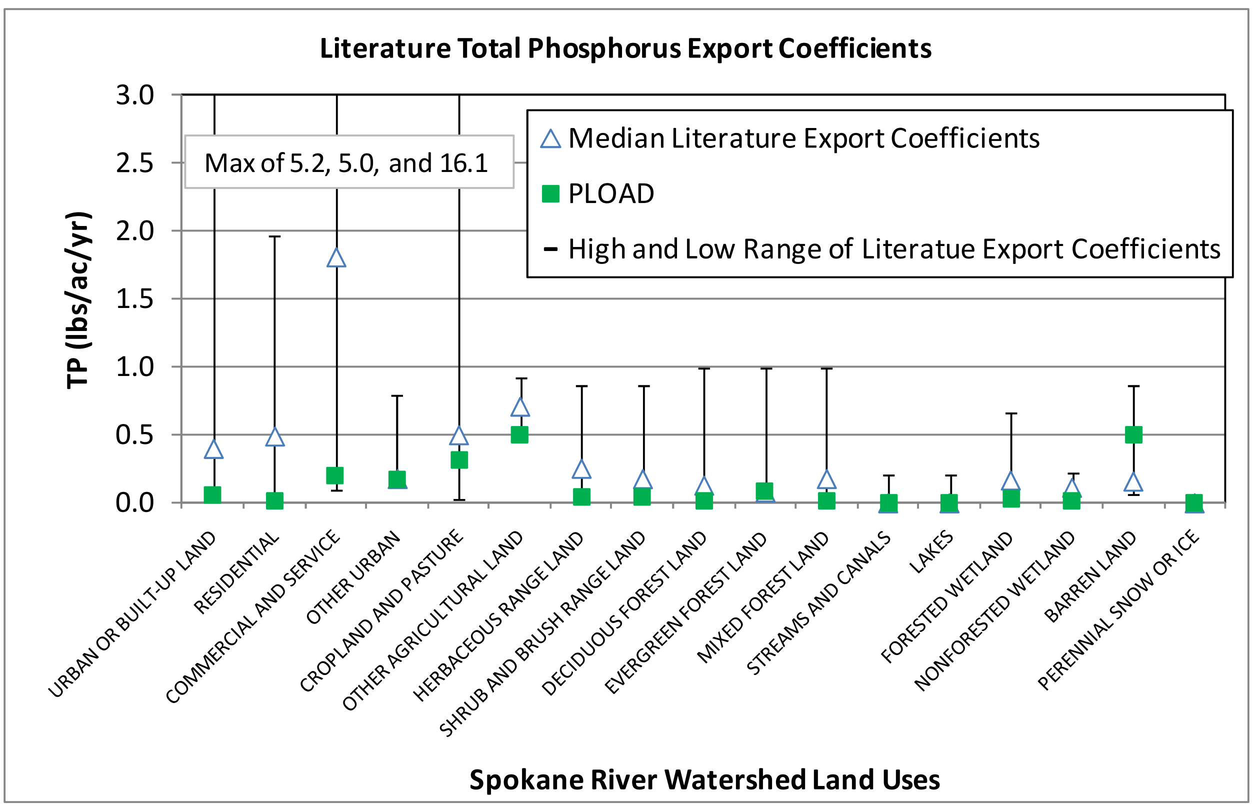
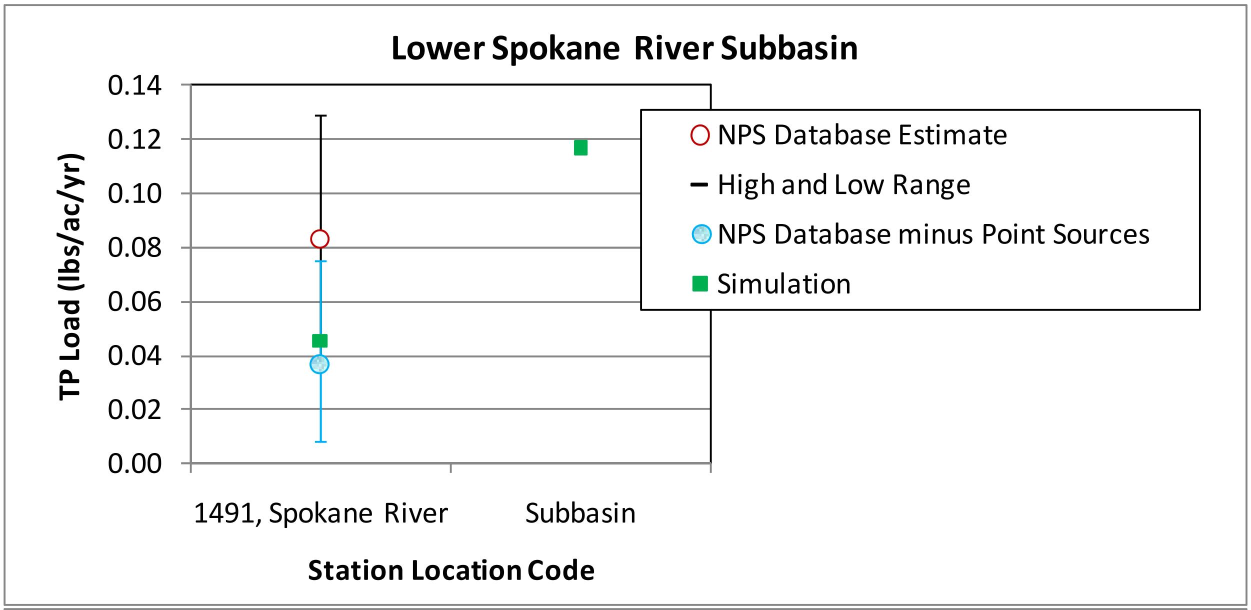



**Figure 5. Total Phosphorus Export Coefficients**
**(Vertical bars show the minimum and maximum range from the PLOAD scenarios and literature review of export coefficients.)**



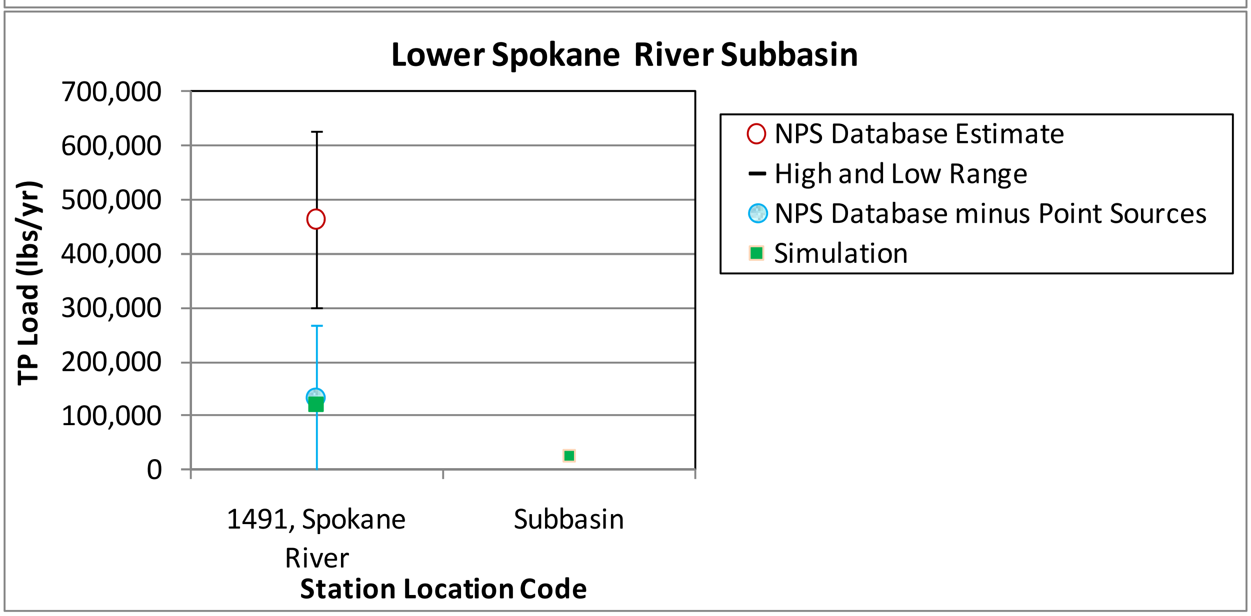
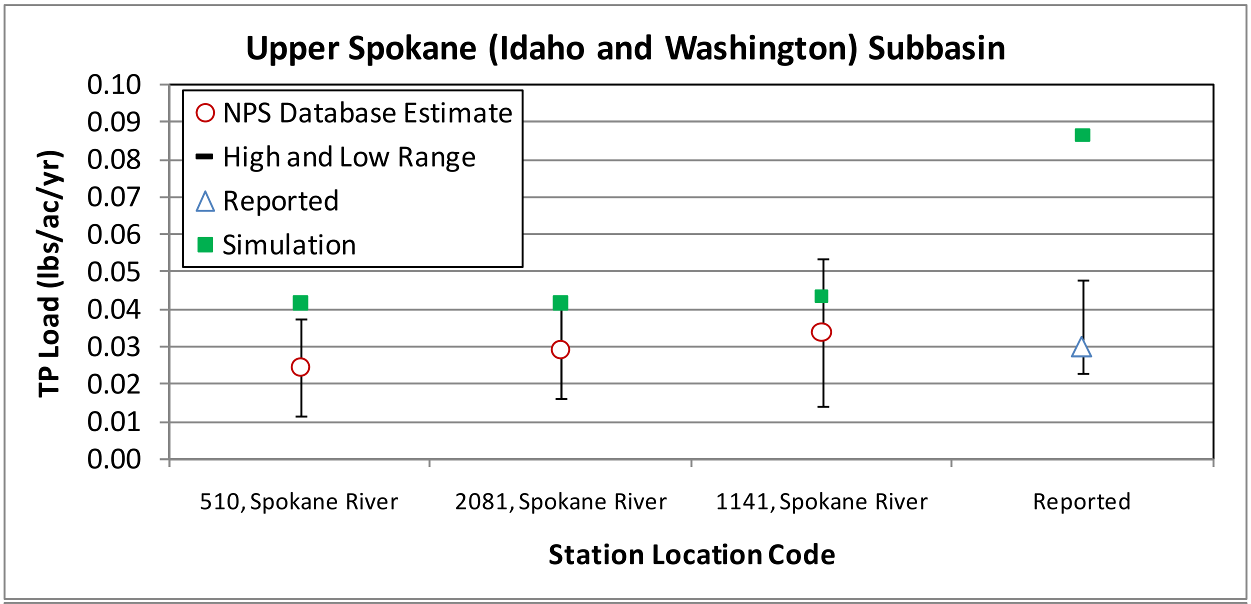




**Figure 6. Lower Spokane River Subbasin Data versus PLOAD (Export and Load)**



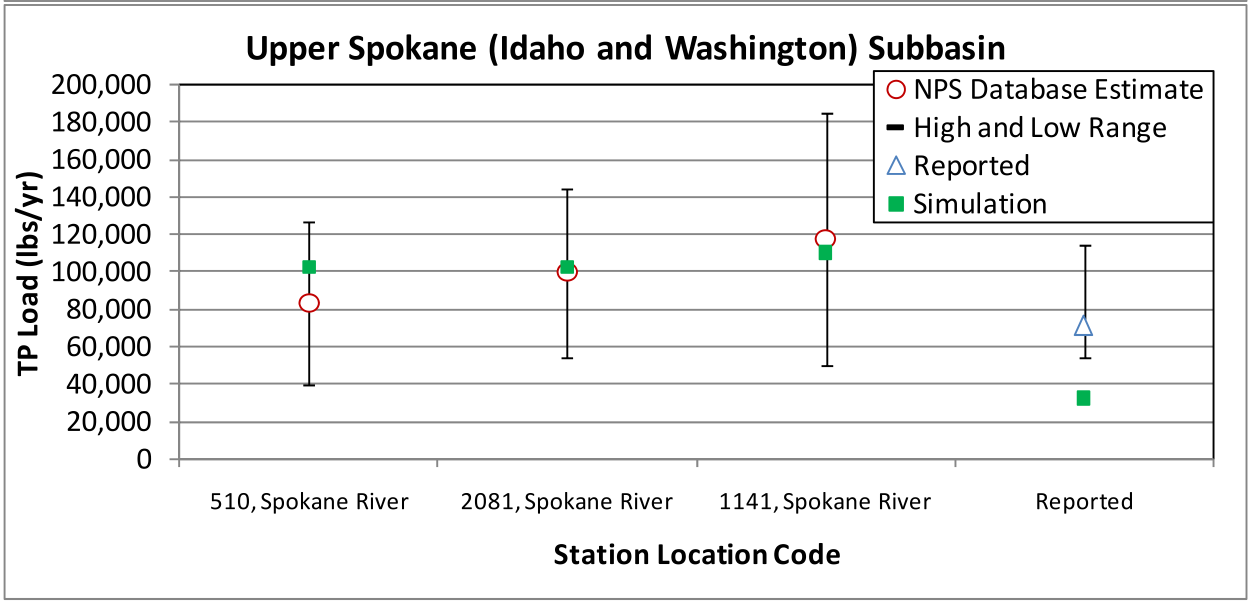




**Figure 7. Upper Spokane River Subbasin Data versus PLOAD (Export and Load) (Reported is for the upstream, not the downstream part of the subbasin)**

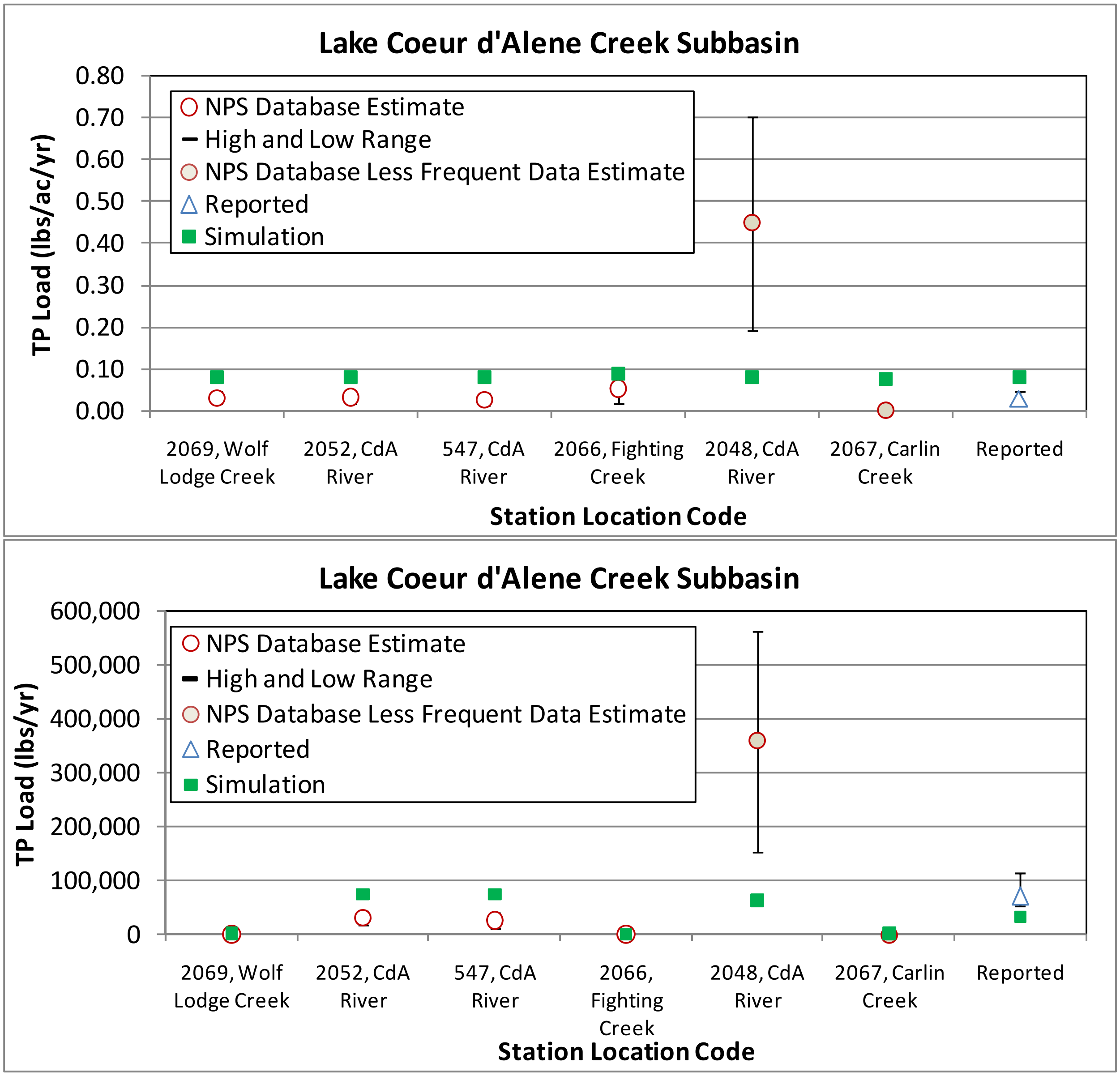



**Figure 8. Lake Coeur d'Alene Subbasin Data versus PLOAD (Export and Load)**

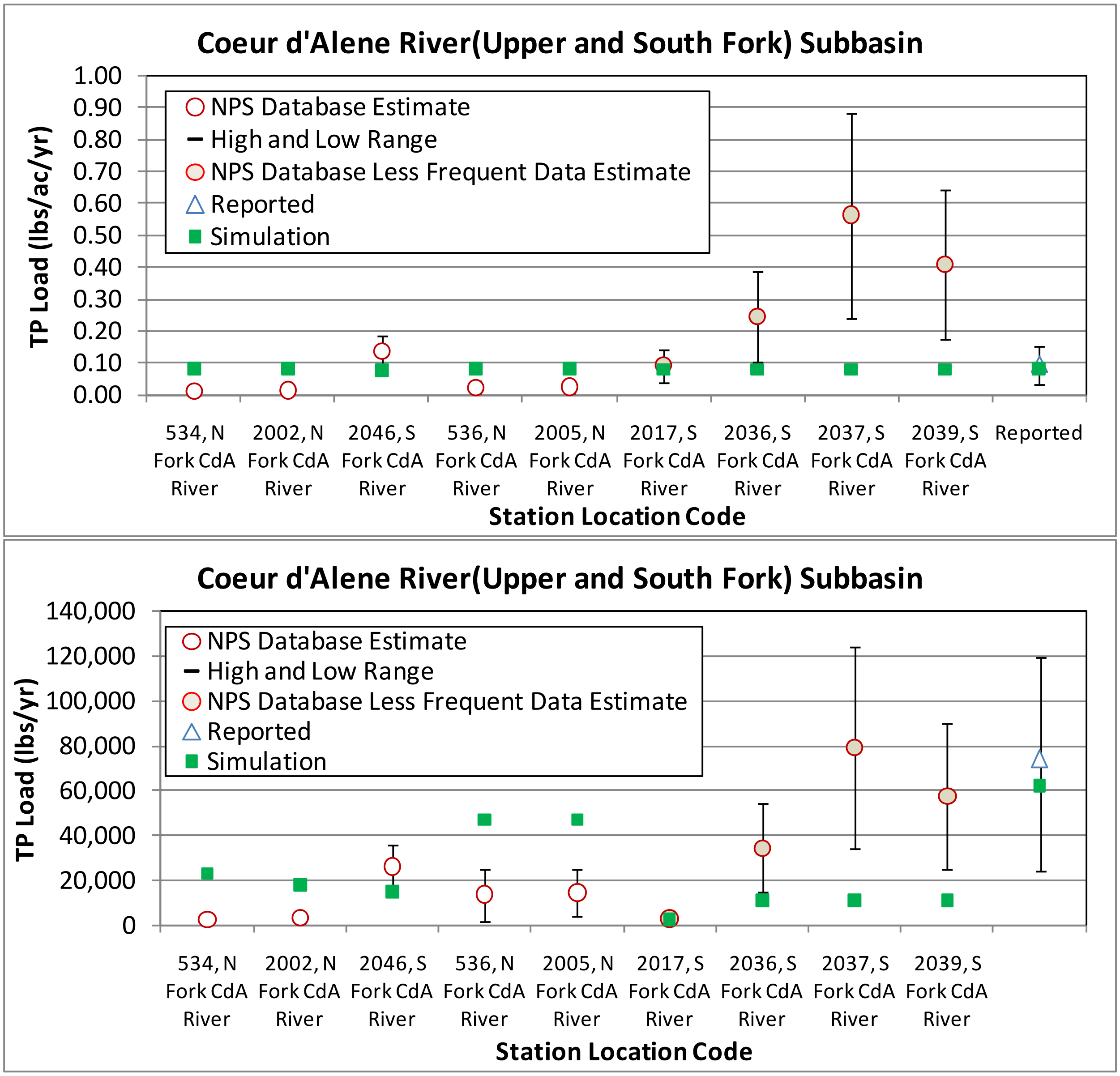



**Figure 9. Coeur d'Alene River Subbasin Data versus PLOAD (Export and Load)**

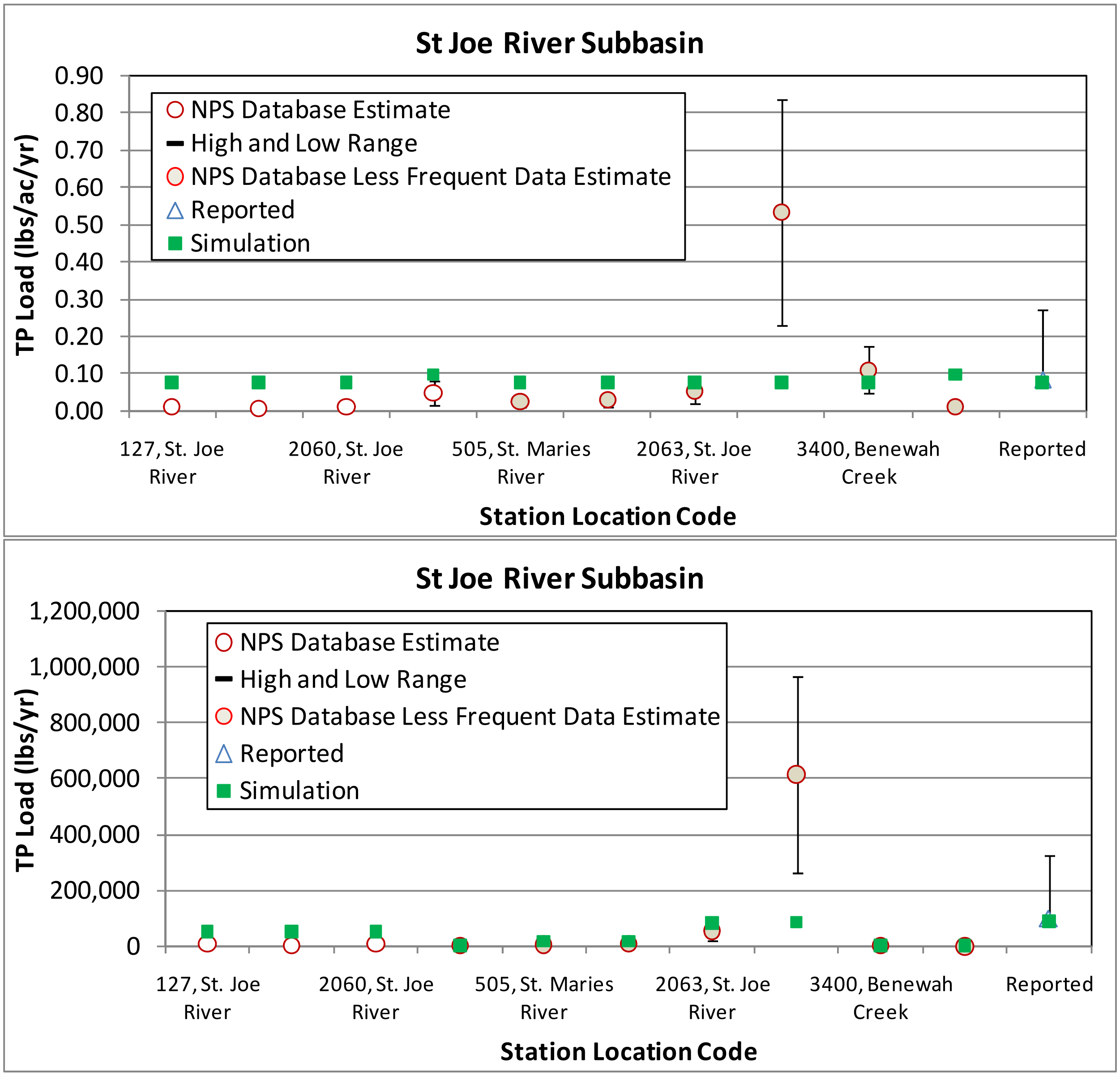
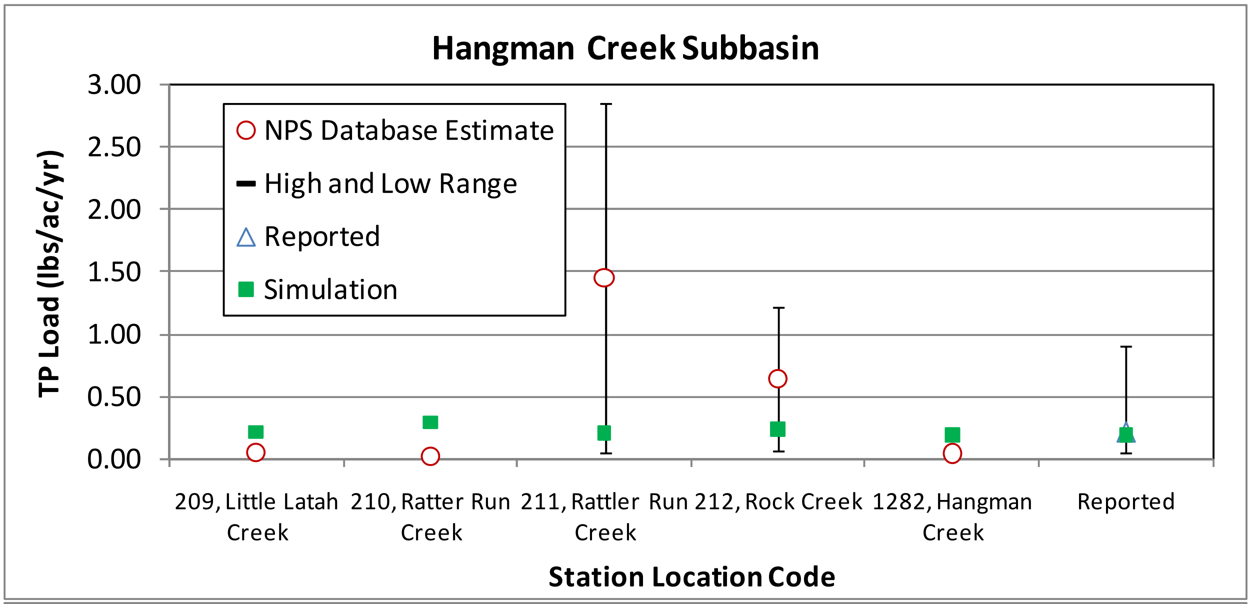



**Figure 10. St Joe River Subbasin Data versus PLOAD (Export and Load)**



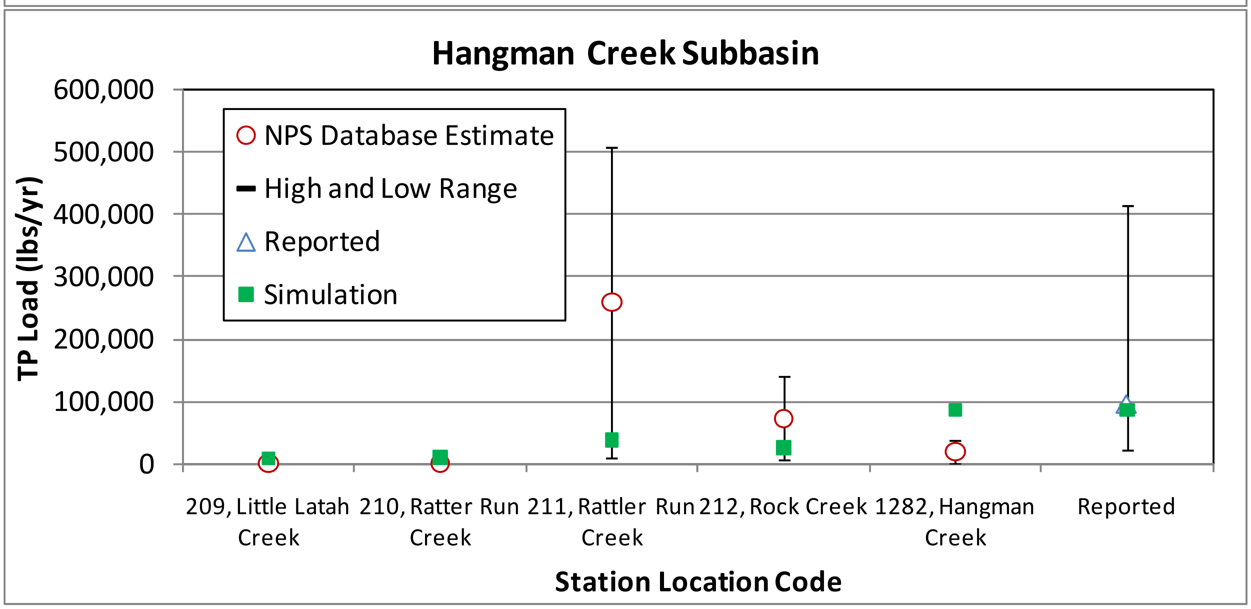




**Figure 11. Hangman Creek Subbasin Data versus PLOAD (Export and Load)**

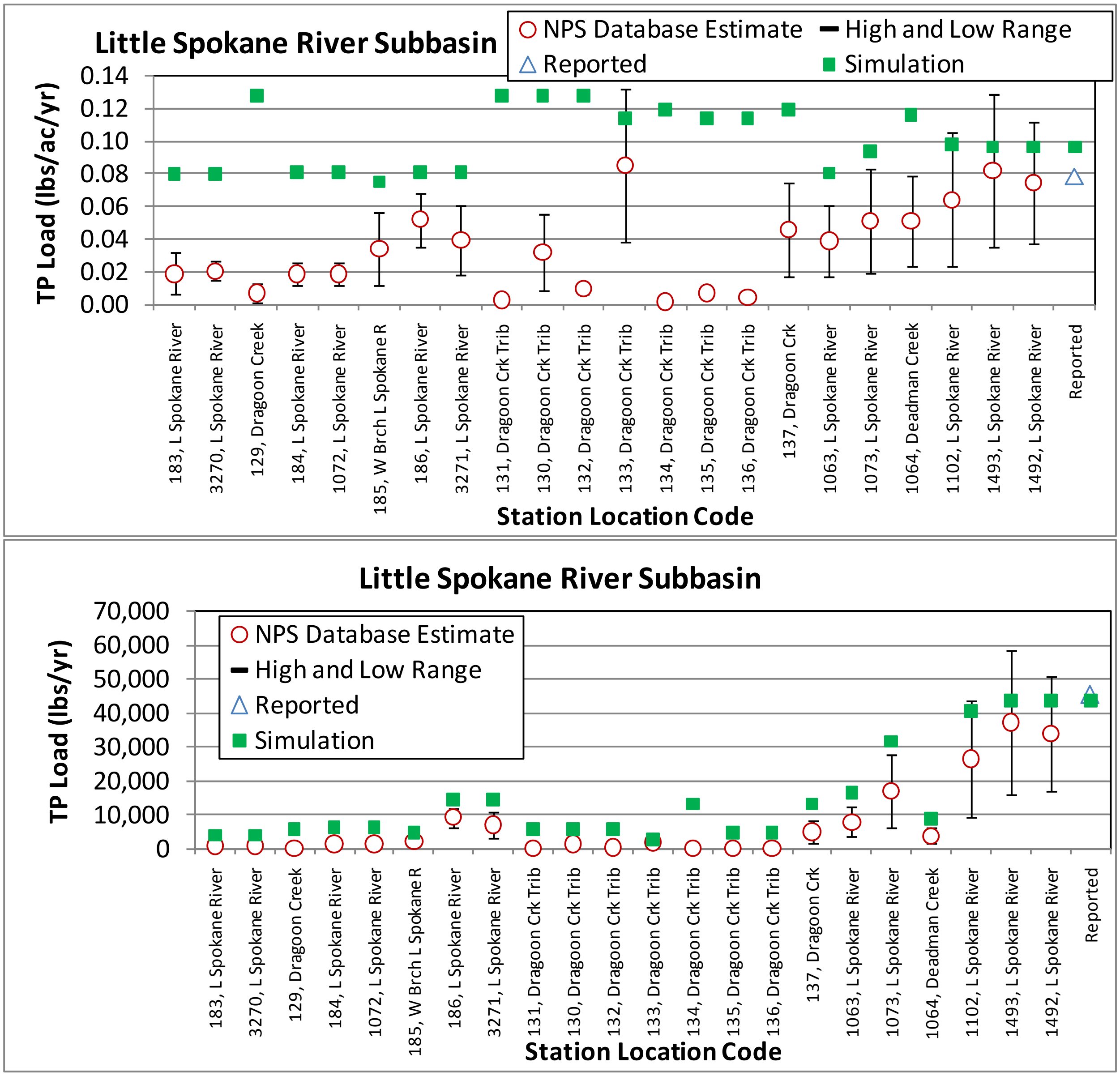
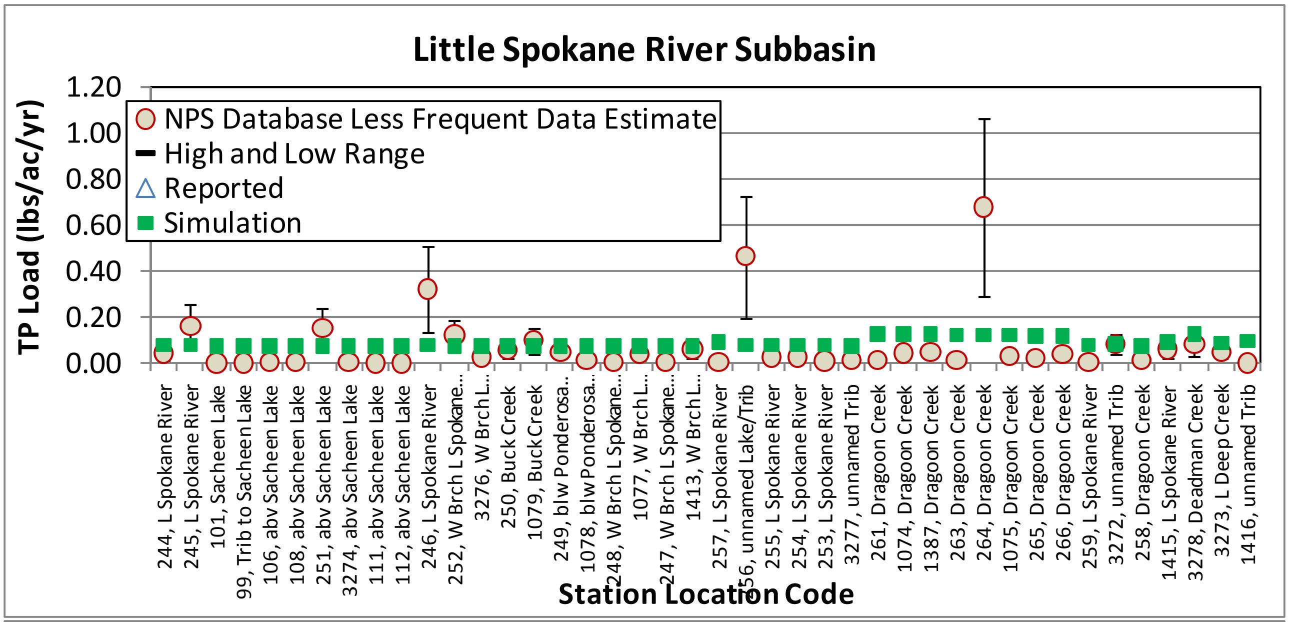



**Figure 12. Little Spokane River Subbasin Data versus PLOAD (Export and Load)**



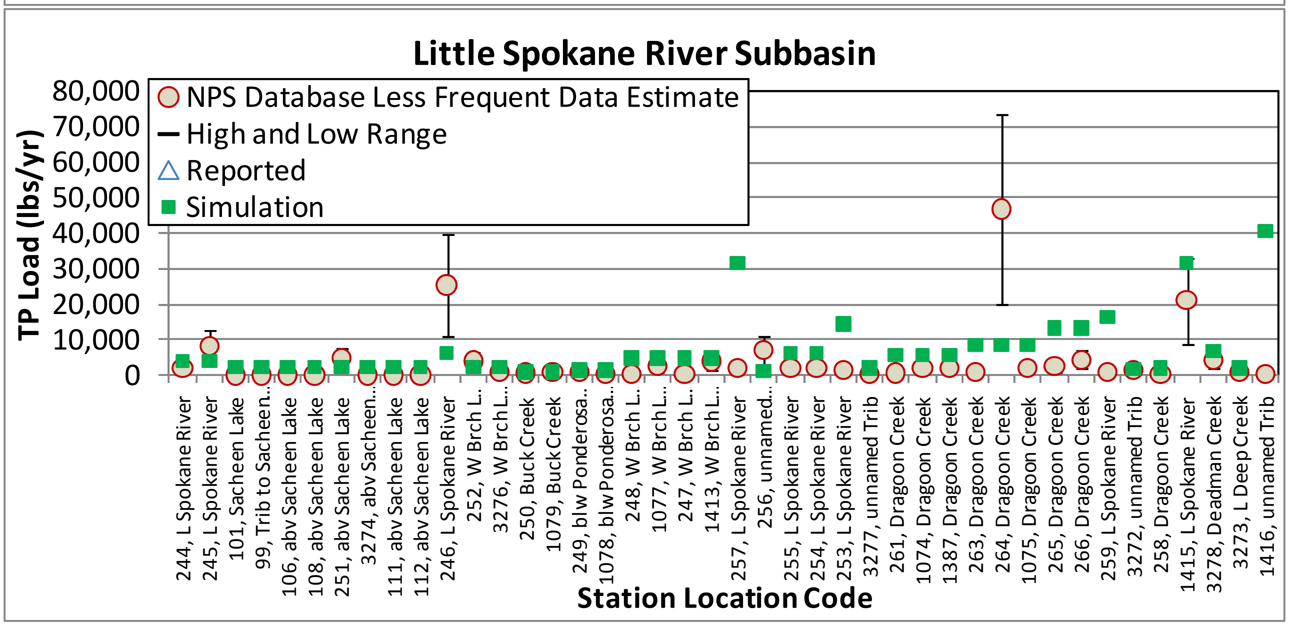




**Figure 13. Little Spokane River Subbasin Data versus PLOAD (Export and Load)**

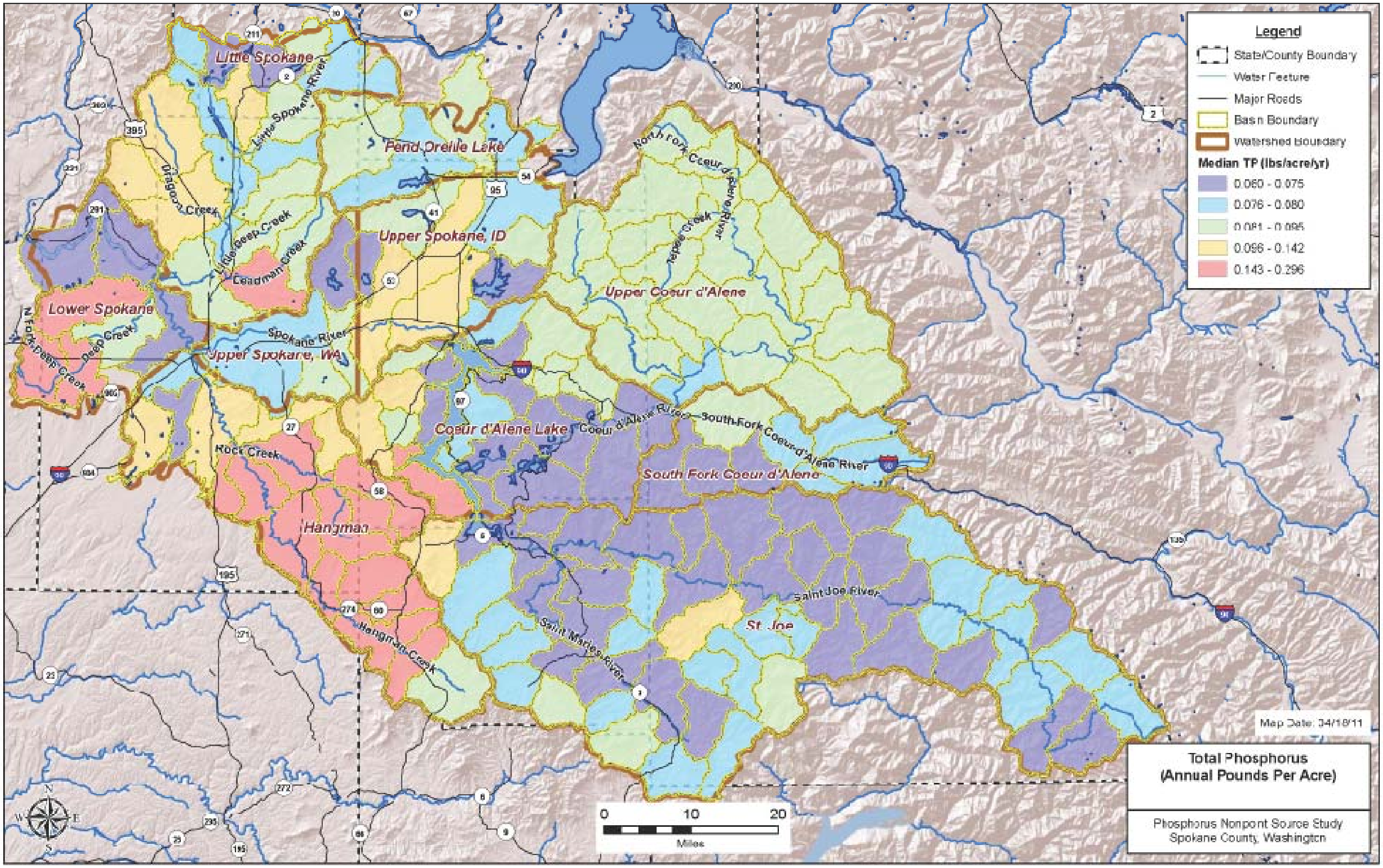



**Figure 14. Spatial Results of PLOAD Model Export Coefficient Results**

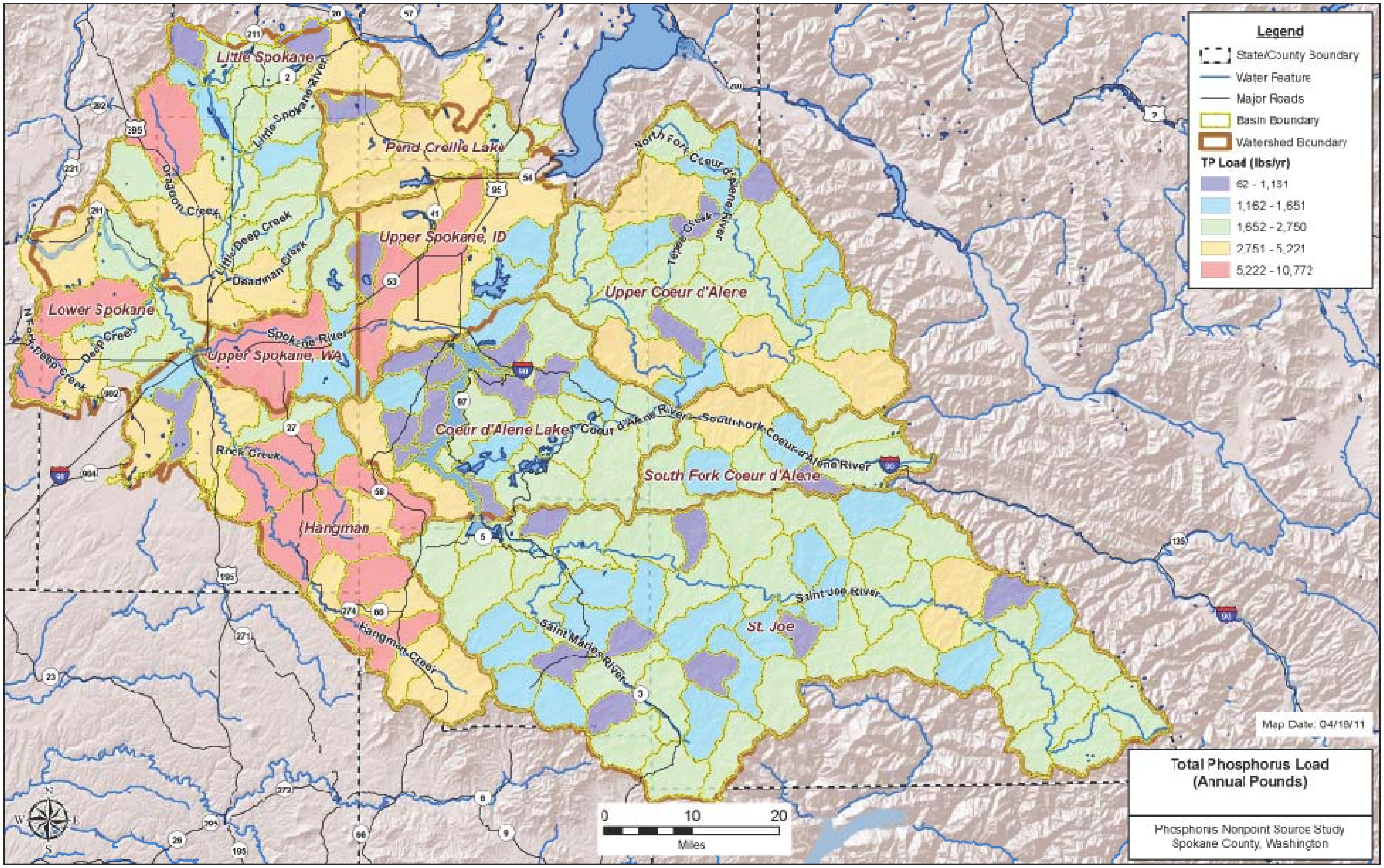



**Figure 15. Spatial Results of PLOAD Model Load Results**

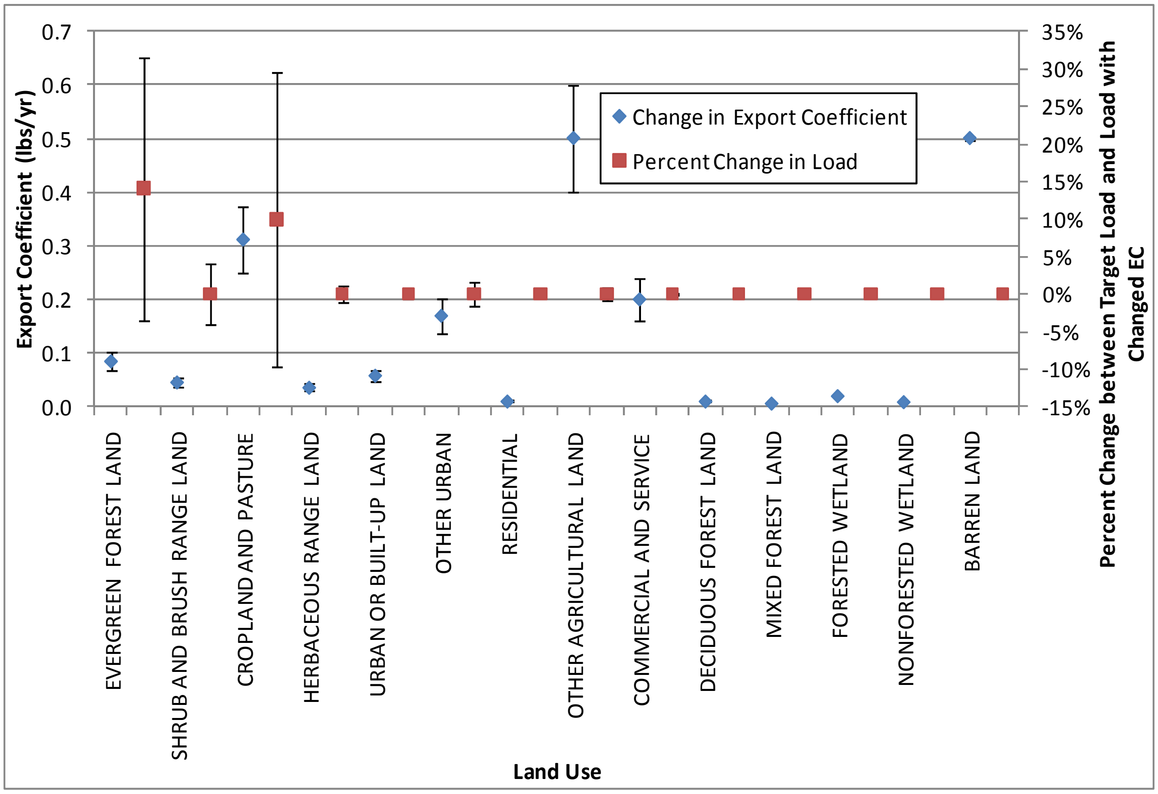



**Figure 16. Twenty Percent Increase and Decrease Change in Export Coefficients**

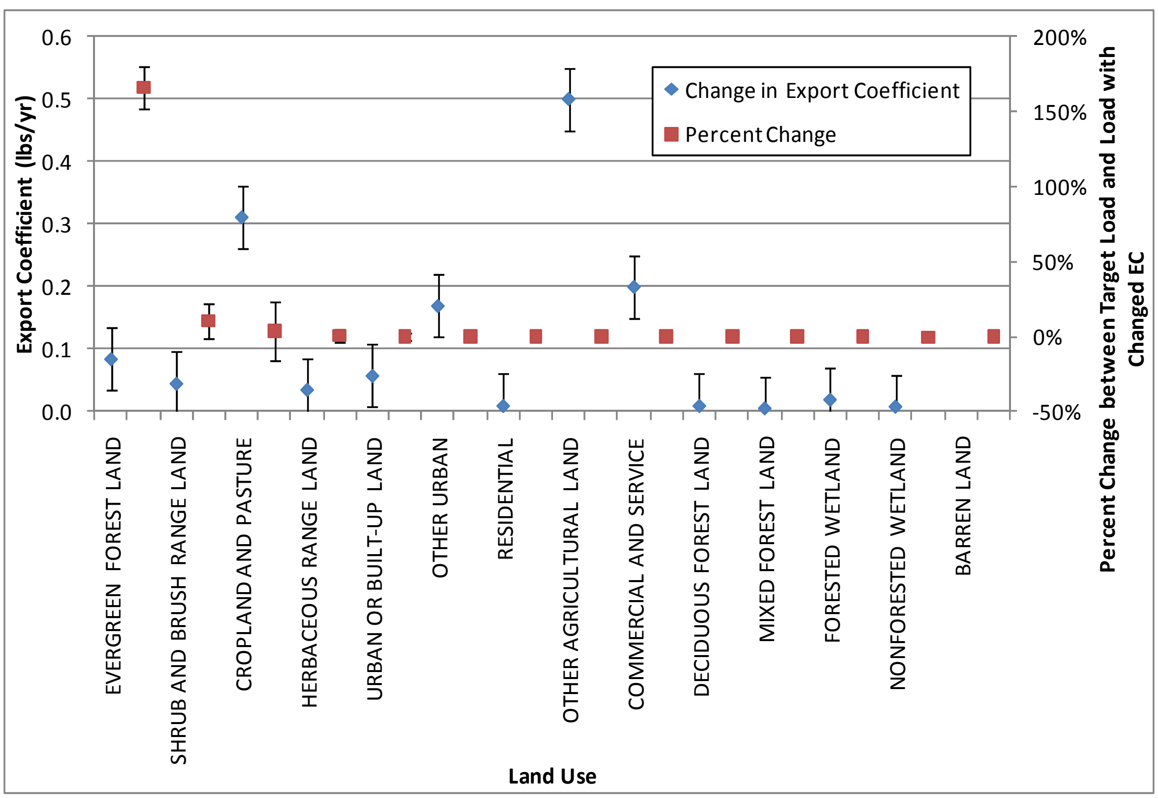



**Figure 17. 0.05 Increase and Decrease Change in Export Coefficients**

## Appendix A

Excel Solver is a powerful application used in a variety of applications including finance, production, distribution, purchasing and scheduling. It is part of the data analysis tools used for what-if analysis--a process of identifying changes in a cell by adjusting related cells. It is method to find the values of certain cells in a worksheet that maximize or minimize a certain objective. The solver tool is known as an optimization model. The model has three parts: the target cell, the changing cells, and the constraints. The target cell represents the objective or goal, i.e., either minimize or maximize the amount in the target cell. Any specification of the changing cells that satisfies the model's constraints is known as a feasible solution. Solver searches all feasible solutions and finds the one that has the "best" target cell value. A model may have no solution, a unique solution, or multiple solutions (potentially an infinite number).

The PLOAD model has a target of minimizing the difference between estimate loads based on data and historical information and the model predicted load. The five locations were Hangman Creek, Little Spokane River, St. Joe River, Coeur d'Alene River above Coeur d'Alene Lake and Spokane River out of Coeur d'Alene Lake.

The changing cells were the export coefficients for 17 land uses, evergreen forest land, shrub and brush range land, cropland and pasture, herbaceous range land, urban or built-up land, other urban, residential, other agricultural land, commercial and service, deciduous forest land, mixed forest land, streams, lakes, forested wetland, nonforested wetland, barren land, and perennial snow or ice. An initial value must be selected for the Solver model to run. Values were selected between the literature ranges and tested for a variety of selections. Initial values that resulted in an overall appropriate solution were used. The median of the literature values (**Table 3**) was used as the first initial values and provided an inappropriate solution, an export coefficient out of range for the land use commercial and service. The resulting values were used with half, quarter and $10^{th}$ of the median value for commercial and service. This solution using the prior results and a $10^{th}$ of the median literature value for commercial and service was selected. The model was also tested using the minimum and maximum of the literature values as initial values.

The model constraints included 34 constraints, greater than the minimum of the range and less than maximum of the range for the export coefficents. Additionally there were 20 constraints that the PLOAD model predicted loads and export coefficients for the subbasins were within the low and high ranges.

Solver options included 2000 iterations and a convergence of 0.00001.

# Appendix B

## Introduction

The PLOAD model constructed for the Spokane River Watershed estimates total phosphorus (TP) loads associated with various land uses. Comparison of these estimated TP loads with TP concentrations observed at various down-gradient stream sampling stations can be used to calibrate the model. However, it is unclear whether dilution or enrichment (with respect to TP) of surface water as a function of baseflow could significantly affect the calibration.

To evaluate the potential impact of groundwater loading on PLOAD calibration, TP loading from groundwater (as a function of contributing surface area) to the Rifle Club Road monitoring station was estimated. Based on the designations of surface water basins and sub-basins presented by HDR (2010), contributions from three primary sub-basins that contribute baseflow to the Rifle Club Road monitoring station were evaluated. These include the Upper Spokane, Hangman and Lower Spokane sub-basins.

- The Upper Spokane Study Sub-basin consists of 12 Hydrologic Unit Code (HUC) Basins and drains to the Spokane River, between the outlet of Coeur d'Alene Lake and the confluence between Hangman Creek and the Spokane River. The entire Upper Spokane Study Sub-basin is located upstream of the Rifle Club Road monitoring station.

- The Hangman Study Sub-Basin consists of 19 HUC Basins and drains to Hangman Creek, which discharges to the Spokane River. The entire Hangman Study Sub-Basin is also located upstream of the Rifle Club Road monitoring station.

- The Lower Spokane Study Sub-basin includes 7 HUC Basins that are located within the project Study Area. Of these 7 HUC basins, only one (Nine Mile Reservoir) is located upstream of the Rifle Club monitoring station.

## Methodology

TP loading rates from groundwater to the Rifle Club Road monitoring station were calculated by estimating the total TP exchanges (resulting from groundwater/surface water interaction) within the areas of interest and presenting the results as loading rates per unit area. Representative TP concentrations from the Spokane River and Hangman Creek were compiled and calculated to estimate the TP exchange rates.

Selected representative (median) TP concentrations of the Spokane River and Hangman Creek were estimated by GeoEngineers, Inc. (2010). Supplemental representative TP concentrations were estimated to provide coverage for the entire area of interest. These supplemental concentrations are summarized in **Table A-1** and were estimated using the same methodology presented by GeoEngineers, Inc. (2010).

TP exchange rates were then estimated using rates of groundwater/surface water exchange and representative TP concentrations, using the same methodology presented by GeoEngineers, Inc. (2010). The resulting TP exchange rates are presented in **Table A-2**.

The TP loading rates from groundwater that discharges toward the Rifle Club Road monitoring station were then calculated with respect to the areas of interest (**Table A-3**). Note that groundwater sub-basins and basins are assumed to be the same as those defined for surface water drainage.

**Results**

The net TP loading from groundwater that discharges up-gradient of the Rifle Club Road monitoring station from the three upstream sub-basins within the study area (Lower Spokane, Upper Spokane and Hangman) is about 0.024 pounds per acre per year (lbs/ac/yr) (**Table A-3**). The contributing TP loading rates from each of the three sub-basins are about:

- 0.048 lbs/ac/yr from the Upper Spokane;
- 0.0045 lbs/ac/yr from Hangman;
- 0.020 lbs/ac/yr from the Lower Spokane (within the study area).

Within specific portions of the watershed, the TP exchange rates (**Table A-2**) provide enough resolution for TP loading rates to be calculated for selected HUC Basins (**Table A-3**), yielding the following results:

- 0.52 lbs/ac/yr from the Chester Creek-Spokane River basin (within the Upper Spokane);
- 0.023 lbs/ac/yr from the four lowest basins (Hangman Creek, Minnie Creek, Marshal Creek and Stevens-Hangman-Creek) within the Hangman sub-basin;
- 0.15 lbs/ac/yr from the Nine Mile Reservoir-Spokane River (within the Lower Spokane).

The above estimates are intended for comparison to the PLOAD modeling, to assist in evaluating the potential for groundwater/surface water interaction to negatively impact calibration accuracy.

**References:**

GeoEngineeers, Inc. 2010. Technical Memorandum, Groundwater Loading Analysis – Orthophosphate, Bi-State Nonpoint Source Phosphorus Study. File No. 0188-135-01, Report dated November 5, 2010.

HDR. 2010. Test Application of PLOAD Model, Bi-State Nonpoint Source Phosphorus Study. Job No. 124985, Memorandum dated August 9, 2010.

**TABLE A-1 SUPPLEMENTAL TOTAL PHOSPHORUS CONCENTRATIONS**[1]

| Study Sub-basin | Reach | Sampling Location | Median TP Concentration (mg/L) | Number of Samples Collected | Sampling Years |
|---|---|---|---|---|---|
| Upper Spokane | Near Lake Coeur d'Alene to near Post Falls | 140 | 27.8 | 6 | 1984 |
| | | 141 | 27.8 | 6 | 1984 |
| | | 510 | 15.5 | 51 | 1973-1981, 1989, 1991-1992, 1997-2003 |
| | | 2071 | 10.0 | 11 | 1980, 2003-2005 |
| | | 2074 | 120.0 | 3 | 1980 |
| | | 2075 | 50.0 | 3 | 1980 |
| | | 2078 | 40.0 | 3 | 1980 |
| | | 2079 | 40.0 | 2 | 1980 |
| | | 2080 | 60.0 | 2 | 1980 |
| | **Median** | | **20.0** | | |
| | Near Post Falls to near Otis Orchards | 145 | 20.6 | 5 | 1984 |
| | | 511 | 8.0 | 2 | 1999 |
| | | 1131 | 13.0 | 5 | 1999-2000 |
| | | 1141 | 13.0 | 55 | 1971,1973,1977, 1991-2007 |
| | | 2081 | 12.0 | 50 | 1980-1981,1989-2003, 2007 |
| | | 2082 | 9.0 | 4 | 2003, 2008 |
| | | 2083 | 8.0 | 2 | 1999 |
| | | 3590 | 2.0 | 1 | 1992 |
| | **Median** | | **12.0** | | |
| | Near Otis Orchards to Greenacres | 3 | 19.0 | 9 | 1980-1981 |
| | | 1114 | 9.4 | 2 | 2007 |
| | | 1130 | 20.0 | 5 | 1999-2000 |
| | | 1281 | 4210.0 | 4 | 1999-2000 |
| | **Median** | | **20.3** | | |
| | Greenacres to Flora Road | 1114 | 9.4 | 2 | 2007 |
| | | 1130 | 20.0 | 5 | 1999-2000 |
| | | 1262 | - - | - - | - - |
| | **Median** | | **19.0** | | |
| | Below Greene Street to USGS (Spokane) | 161 | 16.3 | 6 | 1984 |
| | | 162 | 16.3 | 6 | 1984 |
| | | 517 | 7.0 | 2 | 1999 |
| | | 1066 | 25.0 | 8 | 1971, 1973 |
| | | 1112 | 4.6 | 2 | 2007 |
| | **Median** | | **16.3** | | |
| Hangman Creek | River Mile 21.0 to Duncan | 224 | 90.0 | 1 | 2004 |
| | | 338 | 90.0 | 1 | 2004 |
| | | 1583 | 90.0 | 1 | 2004 |
| | | 3530 | 111.5 | 4 | 1991 |
| | **Median** | | **98.0** | | |
| | Duncan to d/s of Hangman Creek Golf Course | 375 | 50.5 | 2 | 2004 |
| | | 1590 | 50.5 | 2 | 2004 |
| | **Median** | | **50.5** | | |

[1]The method used to calculate median total phosphorus concentrations is presented by GeoEngineers, Inc. (2010).

**TABLE A-2 TOTAL PHOSPHORUS EXCHANGE**

| Study Sub-basin | Reach | Streamflow Gain (+) or Loss (-) (cfs) | Representative Total Phosphorus Concentration (mg/L) | Total Phosphorus Loading (lbs/day) |
|---|---|---|---|---|
| Upper Spokane | Near Lake Coeur d'Alene to near Post Falls | -291 | 20.0 | -31.4 |
| | Near Post Falls to near Otis Orchards | -191 | 12.0 | -12.4 |
| | Near Otis Orchards to Greenacres | -110 | 20.3 | -12.0 |
| | Greenacres to Flora Road | -14.0 | 19.0 | -1.4 |
| | Flora Road to Centennial Trail Bridge | 360 | See Note 1 | 85.9 |
| | Centennial Trail Bridge to below Green Street | 233 | See Note 1 | 31.1 |
| | Below Green Street to USGS (Spokane) | -112 | 16.3 | -9.8 |
| Total Gain | | | | 117.0 |
| Total Loss | | | | -67.1 |
| **Net Loading** | | | | **49.9** |
| Hangman Creek | River Mile 21.0 to Duncan | -1.0 | 98.0 | -0.5 |
| | Duncan to downstream of Hangman Creek Golf Course | -0.7 | 50.5 | -0.2 |
| | Downstream of Hangman Creek Golf Course to USGS Gage on Hangman Creek | 16.5 | See Note 1 | 6.2 |
| Total Gain | | | | 6.2 |
| Total Loss | | | | -0.7 |
| **Net Loading** | | | | **5.5** |
| Lower Spokane | USGS (Spokane) to T.J. Meenach Bridge | 88.5 | See Note 1 | 6.8 |
| | T.J. Meenach Bridge to Rifle Club Road | 38.0 | See Note 1 | 5.1 |
| Total Gain | | | | 11.9 |
| Total Loss | | | | 0.0 |
| **Net Loading** | | | | **11.9** |

[1]Total phosphorus concentrations and loading were previously calculated by GeoEngineers, Inc. (2010).

cfs = cubic feet per second

mg/L = micrograms per liter

lbs/day = pounds of total phosphorus per day

**TABLE A-3 SUMMARY OF TOTAL PHOSPHORUS LOADING FROM GROUNDWATER**

| Study Sub-basin | HUC Basin | Area[1] (ac) | Total P Loading[2] (lbs/day) | Total P Loading[2] (lbs/ac/yr) |
|---|---|---|---|---|
| Upper Spokane | Total | 378305 | 49.9 | **0.048** |
| | Chester Creek-Spokane River | 75334 | 107.2 | 0.52 |
| | Other HUC basins | 302971 | | |
| Hangman | Total | 447610 | 5.5 | **0.0045** |
| | Hangman Creek | 17372 | | |
| | Minnie Creek | 25555 | | |
| | Marshal Creek | 15483 | | |
| | Stevens Creek-Hangman Creek | 38850 | | |
| | Subtotal of 4 basins above | 97260 | 6.2 | 0.023 |
| | Other HUC basins | 350350 | | |
| Lower Spokane | Total | 580597 | 11.9 | 0.0075 |
| | Nine Mile Reservoir-Spokane River | 29055 | 11.9 | 0.15 |
| | HUC basins in study area | 218452 | 11.9 | **0.020** |
| Sub-basins total | | 1406512 | 67.3 | 0.017 |
| Sub-basins in study area | | 1044367 | 67.3 | **0.024** |

[1]Areas from HDR (2010).

[2]Total phosphorus loading from groundwater, discharging toward the Rifle Club Road station.

ac = acres

lbs/day = pounds of total phosphorus per day

lbs/ac/day = pounds of total phosphorus per acre per day

## Appendix C

The information in Appendix K of the TMDL used to estimate export coefficients from the urban areas covered in the TMDL storm water analysis were compared to the PLOAD export coefficients as a reference (Ecology, 2010). There are several daily phosphorus loads and areas in the TMDL. The following values were calculated from the data for urban phosphorus export 0.24, 0.24, and 0.27 (lb/acre/year). The TMDL Appendix K also references a URS study (1981) that had an urban phosphorus export coefficient of 0.61 (lb/acre/year) calculated for the Spokane area. A comparison of these export coefficients is shown in Figure B-1. The PLOAD model uses four urban/suburban land uses: Other Urban, Urban or Built-up Land, Residential, and Commercial and Service. The median of these is about half the lowest of the Appendix K values.

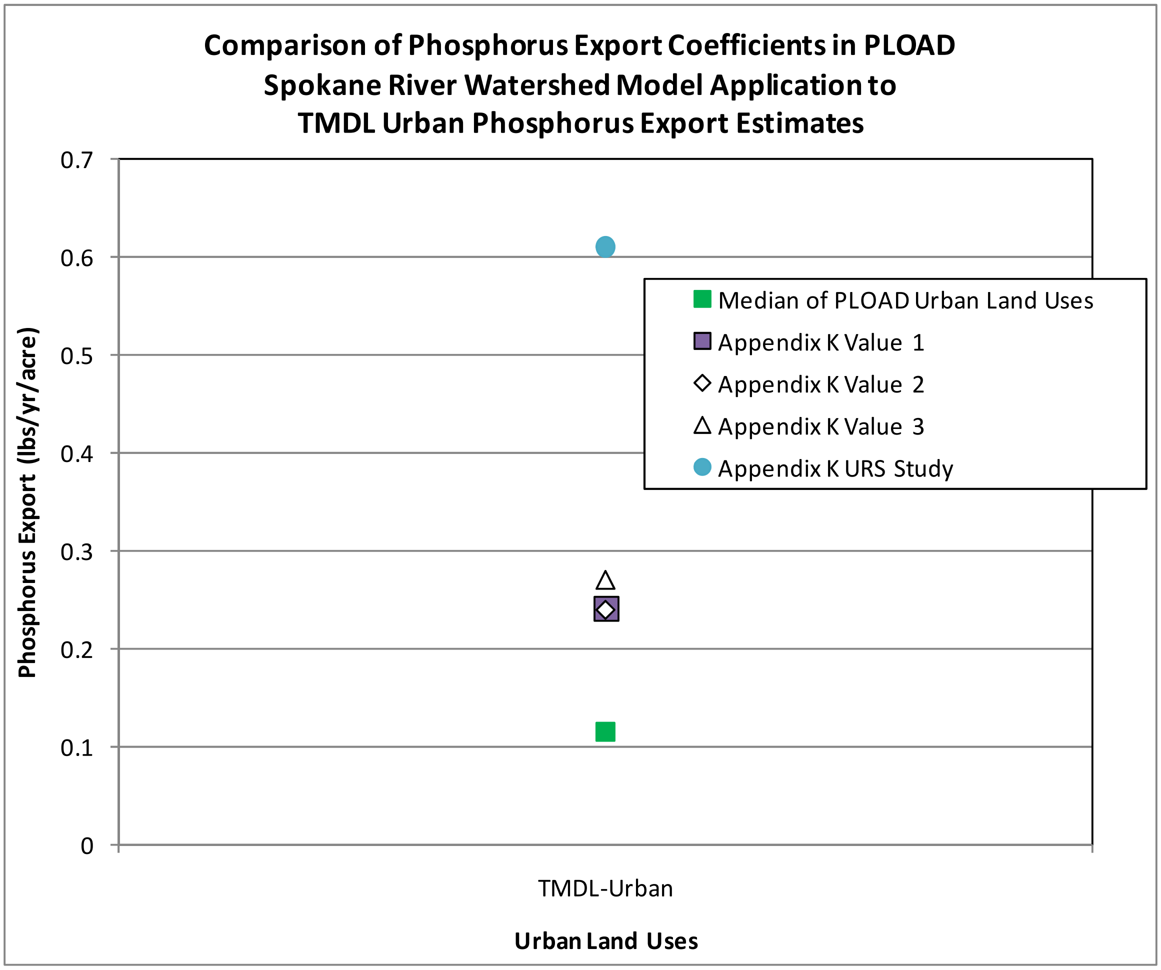



**Figure B-1. Comparison of Phosphorus Export Coefficients**