Endangered Species Act Analysis Model Comparison Study: Comparing HI-RUN and SELDM for use in Washington State Department of Transportation Biological Assessments

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Endangered Species Act Analysis Model Comparison Study

Comparing HI-RUN and SELDM for use in Washington State Department of Transportation Biological Assessments

by

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16. ABSTRACT

This study compares the HI-RUN and SELDM models for use in WSDOT biological assessments for western Washington highway projects. Current WSDOT policy and an interagency agreed upon analytical approach require the use of HI-RUN in these assessments, which are completed in order to comply with Section 7 of the Endangered Species Act. SELDM is a model developed by the USGS and FHWA which could possibly be used in biological assessment analysis. This study was completed to determine the feasibility and cost benefits of use of either model for biological assessments in western Washington projects. The study consists of three primary components; comparison of model results, comparison of model usability, and comparison of costs and benefits of each model. The comparison demonstrates that SELDM provides similar assessment results to HI-RUN and that with preliminary steps as detailed in the study, both models were found to be similarly usable. Ongoing maintenance costs were also found to be similar, but implementation costs related to use of SELDM within current policy requirements was found to be prohibitive. The recommendation of these findings is for continued use of the HI-RUN model, with the condition that further analysis be completed if policy conditions were to change. Additionally, it is recommended that WSDOT investigate other possible needs and situations where the SELDM model would be beneficial.

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Contents

Abbreviations

BA	biological assessment
BMP	best management practice
cf	cubic feet
cfs	cubic feet per second
cfsm	cubic feet per second per square mile
DCu	dissolved copper
DZn	dissolved zinc
ESA	Endangered Species Act
FHWA	Federal Highway Administration
HI-RUN	Highway Runoff Dilution and Loading Model
HRDB	Highway-Runoff Database
mg/L	milligram per liter
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NURP	Nationwide Urban Runoff Program
NWISWeb	National Water Information System Web
SELDM	Stochastic Empirical Loading and Dilution Model
SSC	suspended sediment concentration
TAC	technical advisory committee
TCu	total copper
TDA	threshold discharge area
TP	total phosphorus
TSS	total suspended solids
TZn	total zinc
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UU	University of Utah Department of Civil and Environmental Engineering
WSDOT	Washington State Department of Transportation

Executive Summary

This study compares the Stochastic Empirical Loading and Dilution Model (SELDM) to the Highway Runoff Dilution and Loading Model (HI-RUN) for use in evaluating the effects of stormwater in biological assessments (BAs) for Washington State Department of Transportation (WSDOT) highway projects occurring in western Washington. These BAs are conducted in order to comply with Section 7 of the Endangered Species Act (ESA), which requires evaluation of the potential impacts to listed species for any project with a federal nexus. A memorandum of agreement (MOA) between WSDOT, the Federal Highway Administration (FHWA), the US Fish and Wildlife Service (USFWS), and the National Marine Fisheries Service (NMFS) documents the current approach for stormwater effects analysis in BAs, which includes use of the HI-RUN model.

HI-RUN was developed in 2008 specifically for conducting stormwater effects analysis as part of a WSDOT BA for western Washington projects. The model is the culmination of a WSDOT project, "Analyzing Stormwater Effects on ESA Listed Species", that was completed in collaboration with FHWS, NMFS, and USFWS. HI-RUN is a stochastic model that compares a baseline, or existing conditions, to the proposed project conditions. The model has two subroutines, loading and dilution, which are used to analyze five water quality parameters including total suspended solids (TSS), total copper (TCu), dissolved copper (DCu), total zinc (TZn), and dissolved zinc (DZn). Empirical data from monitoring in western Washington was used in the model for characterization of stormwater runoff and best management practice (BMP) outflow. The model was designed for use at the planning stage of a project and was not designed to be a design tool or general stormwater effects analysis tool.

SELDM, which was released in 2013, was developed by the United States Geological Survey (USGS) in cooperation with the Federal Highway Administration (FHWA) for use in planning level analysis. It is a stochastic model in which Monte Carlo methods are used in combination with empirically derived data. The model can be used to assess the impacts of highway stormwater runoff on receiving waters and the mitigation potential of BMPs. SELDM is populated with national data sets for precipitation and stream flows. The model is designed for user flexibility so that local data can be used to characterize runoff and BMP treatment ability. Complete model output results are provided so that the user can perform a range of analysis possibilities.

Three activities were conducted as part of this study:

1. Comparison of model results using two western Washington sites: In this task both models were used to perform analysis on two case study sites in western Washington. Output values for concentration and load were compared using the independent t-test. Percent exceedance and dilution analysis output were compared qualitatively.

2. Study model usability: To assess usability four students were employed to model a simple theoretical scenario. Three areas of usability were assessed; efficiency, the ability of each model to reproduce output matching the control set from that model, and satisfaction.
3. Determine the costs of maintaining and using the models: In this task information regarding the ongoing maintenance costs associated with each model was compared and the cost to implement SELDM was explored.

This report describes the methods used for these activities, as well as their results.

Several important limitations of this study should be noted. (1) This study does not provide a general evaluation of either model, but rather a context specific comparison. (2) This study does not provide an evaluation of methods used in WSDOT's current BA analytical approach. (3) The context and design of this study contain inherent bias in that the HI-RUN model was used as the basis of comparison for SELDM. HI-RUN was created and is used exclusively for western Washington BAs. SELDM was created for national use over a broad scope of stormwater effects analysis possibilities, and therefore is not tailored to specifically meet the needs of western Washington BAs.

Comparison of SELDM results to HI-RUN results

SELDM model results were compared to HI-RUN model results for two western Washington sites. The first site consists of improvements to two intersections in Lynden, WA, with proposed impervious surfaces totaling 2.9 acres. The second site consists of multiple interchange improvements along I-5 and I-205 in Clark County, WA, with proposed impervious surfaces totaling 82.4 acres.

Five water quality parameters were assessed: TSS, TCu, DCu, TZn, and DZn. Median concentrations and associated percent exceedance and annual loads and associated percent exceedance, between existing and proposed conditions, were evaluated for each of the five parameters. In addition, downstream distance to the biological effects threshold was evaluated in HI-RUN and downstream concentration at the outfall was evaluated in SELDM.

In order to quantitatively compare output between the models, SELDM was customized with the same runoff quality and stormwater best management practice (BMP) treatment ability characterization data used in HI-RUN. This data set consists of empirical data from 13 WSDOT monitoring sites. Output from SELDM was compiled and analyzed using a spreadsheet tool in order to compare with HI-RUN output, which is provided in summary tables.

The concentration and load values estimated by each model were found to be statistically different. However, the concentration values were found to be practically the same; both models produced values within the 95% confidence interval of WSDOT monitoring values. Most importantly, the percent exceedance values estimated through use of both models provided a similar assessment of concentration and load in the comparison of proposed to existing conditions. Additionally, though a quantitative comparison was not possible for the dilution components due to the different methods employed and output types produced by each model, each model provided a similar assessment of effects to ESA species. In summary, the SELDM results for both sites predicted a similar assessment of risk as the results from HI-RUN, even though the majority of output was found to be statistically different.

Usability of SELDM and HI-RUN

Four students were employed to simulate a theoretical scenario using each model. The customized version of SELDM from task one was provided to the student modelers. In addition, a spreadsheet tool was provided to the students which compiled SELDM output in a manner similar to the output tables produced by HI-RUN. Three attributes of usability were assessed; efficiency, the ability of each model to reproduce output matching the control set from that model, and satisfaction. The time students spent in completing the task was used to evaluate efficiency, the output they obtained from each model was compared to a control set created for each model to test whether the user was able to replicate output, and user ratings of each model were used to evaluate satisfaction.

The models were found to be similarly useable; SELDM was found to be more efficient, while HI-RUN was found to have higher user satisfaction ratings. Although the models were found to be similarly usable, it should be noted that SELDM does not provide one piece of information currently required for Western Washington BA analysis: SELDM does not compute the downstream distance to the biological effects threshold.

Costs of Maintaining and Using SELDM and HI-RUN

Costs were developed for the use of each model in BAs for western Washington projects. Ongoing maintenance costs for both models include the cost to update the models with current monitoring data as required by the MOA and costs to provide annual training to individuals that will conduct BAs. The cost to implement SELDM for use under current WSDOT policy was investigated. Specifically four areas were considered; the initial customization, policy change requirements, a recommended add-on tool, and initial training for all individuals currently qualified to conduct BAs. Cost data on the development of HI-RUN, model updates, and annual training were obtained from WSDOT and Herrera, Inc. (the consulting company that built HI-RUN). Information regarding training plans and materials for SELDM were obtained from the USGS/FWHA. It was found that ongoing maintenance costs would be the same for both models ($6,300). Although SELDM is a model that is free for public use, the initial implementation costs for its use for western Washington BAs would be a minimum of $23,000, excluding the policy change and add-on tool costs. The policy change required would include a revision of the current MOA and accepted analytical approach to accept SELDM modeling and results in place of HI-RUN. The recommended add-on tool would compile and summarize SELDM output, providing the results required for western Washington BAs including the estimate of distance downstream from the discharge at which the biological effects threshold concentration is met. Because this study was conducted within the context of the current WSDOT policy, this result would change under several policy change scenarios.

Summary and Conclusions

This study demonstrates that SELDM provides risk assessment results similar to HI-RUN for the two case studies evaluated. The usability of SELDM was found to be similar to HI-RUN, with SELDM scoring higher than HI-RUN in the efficiency category. Ongoing maintenance costs for SELDM were found to be the same as those of HI-RUN. However, implementation costs associated with the replacement of HI-RUN with SELDM are estimated to be substantial. Although SELDM provides similar risk assessment results to HI-RUN and was found to be equally usable to HI-RUN, the cost of implementing SELDM dictates the recommendation that WSDOT continue to use HI-RUN for BAs in western Washington. This recommendation is based on the current BA policies, therefore further study on the use of SELDM under alternative BA policies is recommended. Evaluation of the use of SELDM for other WSDOT modeling needs is also recommended.

Introduction

This project stems from a Washington State Department of Transportation (WSDOT) need for an evaluation of two different computer models relative to use in biological assessments (BAs) for Endangered Species Act (ESA) Section 7 consultations. The evaluation of the cost and benefits of these two models is the goal of the ESA Analysis Model Comparison project. In this study four tasks were performed by University of Utah Department of Civil and Environmental Engineering (UU) research staff in order to assist WSDOT in obtaining the necessary information to make this evaluation. This report outlines the research methods used and the results obtained in the first three tasks, which are: comparison of models results using two western Washington sites, study model usability, and determine the cost and benefit of maintaining and using the models. The fourth task completed in this study was a final web seminar with the WSDOT appointed technical advisory committee and other interested parties to summarize the results of the study.

The two models being compared in this study are the Highway Runoff Dilution and Loading Model (HI-RUN) and the Stochastic Empirical Loading and Dilution Model (SELDM). HI-RUN is a planning level model developed specifically for use by WSDOT in BAs for western Washington projects. SELDM is a new model that has just been developed by the United States Geological Survey (USGS) in cooperation with the Federal Highway Administration (FHWA) for use in planning level analysis to assess the impacts to receiving waters from highway stormwater runoff. The two models possess many similarities; both use stochastic methods, calculate pollutant concentrations and loads, and analyze the effect of runoff on receiving waters. Due to the possibility that both HI-RUN and SELDM could be similarly used in preparation of BAs, WSDOT has initiated this study to compare the costs and benefits associated with the use of each model.

It is important to note that this project specifically evaluated HI-RUN and SELDM for use in western Washington BAs. The comparison completed was context specific, not a general comparison or evaluation of either HI-RUN or SELDM. Additionally this project and report is not meant to provide an assessment of the underlying methods used by either model or an assessment of WSDOT's currently accepted analytical approach and related policy for BAs. Use of HI-RUN is currently required in western Washington BAs. HI-RUN was designed and built specifically for this purpose. Under current policy HI-RUN methods, parameters assessed, and output types are part of the standardized approach used for a BA. SELDM was designed and built for a much broader spatial area and purpose of use. SELDM was not custom built for Western Washington BAs or designed to fit within current BA policy requirements. These facts make bias towards HI-RUN inherent in this project. Certain steps were taken during this project to attempt to correct for some of the inherent bias; however these steps did not change the scope of the project. This scope is focused on use of either model for BAs under current policy requirements.

It is also important to note that some steps taken in modeling with SELDM deviate from instruction for use of the model provided by the USGS and FHWA. Therefore details provided in this report regarding modeling in SELDM do not in any way represent a guide for use of the model. This note specifically relates to modeling of the case studies included in task one of this study. SELDM was used to replicate modeling currently completed using HI-RUN and output from SELDM was used to generate output types similar to what is provided by HI-RUN as required for analysis in BAs for Western Washington projects. This was not done because HI-RUN was found to be a superior model. Again, this study did not assess the ability of either model to accurately estimate actual environmental conditions or attempt to judge the methods used in either model. Instead the attempt to match HI-RUN methods is solely because the model represents current WSDOT practice. Because the goal was to generate comparable output between the models, some of the parameters selected in SELDM and methods used to mimic methods employed by HI-RUN would not be recommended in practice. Specifically this refers to the selection of runoff coefficient statistics and the method used to remove variability in upstream concentrations in order to mimic the constant upstream concentrations used in HI-RUN. These instances are further detailed in the Task 1 section of this report.

Background

WSDOT Biological Assessments

Section 7 of the 1973 Endangered Species Act (ESA) requires that federal agencies "insure that any action authorized, funded, or carried out by such agency is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat of such species" (ESA, 2003). In order to comply with Section 7 requirements, a BA must be completed on any WSDOT project with a federal nexus. This includes projects which receive any federal funds, projects that are located on federal lands, and projects that require either a federal permit or U.S. Army Corps of Engineers permit. A BA is done "to evaluate the potential effects of a proposed project on listed and proposed wildlife, fish and plant species and designated or proposed critical habitats that are likely to occur in the vicinity of the project" (WSDOT, 2013a, p 3.2). Listed species are any species of wildlife, fish, or plant that has been listed as endangered or threatened under Section 4 of the Endangered Species Act. While proposed species are those which are proposed to be listed as threatened or endangered under the ESA. Critical habitats are specific geographic areas that possess physical or biological features that are essential to the conservation of listed species. They may be designated as critical habitat under ESA or proposed to be designated. Listed species are under the jurisdiction of either the National Marine Fisheries Service (NMFS) or the United States Fish and Wildlife Service (USFWS). NMFS is also commonly referred to as NOAA Fisheries and together, NMFS and USFWS are referred to as the "Services" in WSDOT BA literature and in this report.

One component of a WSDOT BA is the analysis of the effects of stormwater and stormwater best management practices (BMPs). All components of a WSDOT BA are well defined in the Biological Assessment Preparation Manual (WSDOT, 2013a). Chapter 17 of the manual outlines the methodology for analysis of stormwater effects. This guidance relates specifically to the potential impacts of stormwater runoff on ESA species. Prior to this analysis projects are designed and BMPs are selected and sized according to guidance provided in the WSDOT Highway Runoff Manual. The Highway Runoff Manual is used to evaluate and design projects to meet federal and state water quality standards (WSDOT, 2011a). A BA provides additional analysis specifically as to the potential effects of the project on ESA species and habitat. A BA is not meant to provide a complete assessment of the potential adverse effects from stormwater runoff for a project. Stormwater analysis is not required in all BAs. Depending on the project and location this component of a BA may be omitted (i.e., lack of species or habitat in project extent or lack of new impervious surface in project design).

This project and report is concerned with computer modeling that is completed in a WSDOT BA as part of the analysis of stormwater effects. Chapter 17 of the Biological Assessment Preparation Manual includes ten steps. Step six includes two components; analysis of the effects of changes in flow and analysis of the effects of changes in water quality (WSDOT, 2013a). This step is further divided between eastern and western Washington, with distinct guidance for each geographic area. The western Washington analytical process, as detailed in the manual, entails modeling in HI-RUN and analysis using the output from the model (WSDOT, 2013a). Because the goal of this project is to compare and evaluate HI-RUN and SELDM, the guidance provided in step six of Chapter 17 provides the context for this project. This report does not provide a general assessment of either model, but instead an evaluation of both models for use within this context.

The methodology presented in the Biological Assessment Preparation Manual, and used in the HI-RUN model is the synthesis of a multi-agency working group, which consisted of representatives from WSDOT, the Federal Highway Administration (FHWA), the National Marine Fisheries Service (NMFS), and the United States Fish and Wildlife Service (USFWS). Herrera Environmental Consultants were contracted to facilitate this project and provide technical guidance. The goal of the project, titled "Analyzing Stormwater Effects on ESA Listed Species", was "to develop an approach for determining the effect of stormwater from highway projects on ESA listed species" (WSDOT, 2006). The project included two primary components, phases 2 and 3. Phase 1 - scoping, was simply the estimate of project costs. Phase 2 - compile and review best available scientific and commercial information, was a literature review. Phase 3 - analytical approach, was the method development. Throughout the project a series of meetings were held in order to ensure buy-in from all agencies for the analytical approach that was to be developed. The products of phase 2 of the project were four white papers regarding stormwater runoff in western Washington and the impact to ESA species (specifically salmonids). These white papers include: Untreated Highway Runoff in Western Washington

(Herrera, 2007a), BMP Effectiveness Assessment for Highway Runoff in Western Washington (Geosyntec, 2008), Potential Effects of Highway Runoff on Priority Fish Species in Western Washington (Pacific EcoRisk, 2007), and Recent Analytical Approaches for Evaluation of Stormwater Quality Impacts (Herrera, 2007b). The product of phase 3, developed using the findings of the white papers and consensus of the involved agencies, was the HI-RUN model. On February 16, 2009 a Memorandum of Agreement (MOA) between the four agencies was signed committing the agencies to use of the common analytic approach developed for the BA analysis of all future projects which occurred in western Washington. The MOA specifies that as of August 16, 2009 the HI-RUN model would be used to analyze the potential effects of stormwater in a BA. The full text of the MOA is included in this report as Appendix A. Table 1 provides a timeline of this process.

Table 1: Timeline for Development of Current Analytic Approach

Date	Event
October 18, 2006	Project Start Date
May 16, 2007	White Paper by Herrera, “Untreated Highway Runoff in Western Washington”
March, 2008 *	White Paper by Geosyntec, “BMP Effectiveness Assessment for Highway Runoff in Western Washington”
December 2007	White Paper by Pacific EcoRisk, “Potential Effects of Highway Runoff on Priority Fish Species in Western Washington”
December 2007	White Paper by Herrera, “ Recent Analytical Approaches for Evaluation of Stormwater Quality Impacts”
2008	HI-RUN (Version 1)
January 7, 2009	HI-RUN Documentation by Herrera, “Highway Runoff Dilution and Loading Model Documentation – Analysis of Highway Stormwater Water Quality Effects for Endangered Species Act Consultations”
February 16, 2009	MOA between FHWA, NMFS, USFWS, and WSDOT
August 16, 2009	Required start date for using approach from MOA (includes using HI-RUN)
January, 2011	HI-RUN User’s Guide (Current Version)
May, 2011	Release of New Version of HI-RUN (Current Version)

*NOTE: Draft version in 2007, prior to Pacific EcoRisk White Paper

The need for the WSDOT, FHWA, NMFS, and USFWS working group, the creation of HI-RUN, and the signing of the MOA, were a consequence of inadequacies in BAs prior to these actions. HI-RUN was created to provide a method for analysis of the effects of stormwater runoff and the associated pollutant loads on ESA species as part of a “mutually acceptable approach” (Herrera, 2009). This differs from previous analysis, which did not follow a standard method and generally provided only a qualitative assessment (Herrera, 2007b). Although it was noted that the HI-RUN model had several limitations due to the complexity of the processes being assessed, it was agreed by the four agencies to provide a workable solution to the problem; this problem being a need to assess the potential of harm to ESA listed species resulting from construction of a planned transportation project (Herrera, 2009).

WSDOT BAs are completed by the assigned project biologist. This may be either a consultant biologist or a WSDOT employed biologist (WSDOT, 2013a). In order to be authorized to complete a BA a biologist must first complete the qualification process administered by WSDOT. This process ensures that even when an assessment is completed by an individual other than a WSDOT employee the resulting assessment will comply with current policy and regulatory requirements, and reflect WSDOT quality standards. This point is stated and repeated several times in the Biological Assessment Preparation Manual. The manual states that BAs must be consistent with current agency policy and practice, and that BAs that are not consistent with agency policies and practices, or that do not meet WSDOT quality standards, will be considered deficient (WSDOT, 2013a).

The comparison of HI-RUN and SELDM documented in this report was completed within the context of current WSDOT policy as presented here. Because it is difficult to anticipate future regulatory requirements and potential policy changes, this was the only feasible way to complete this comparison. Additionally, given the history and current direction provided for WSDOT BAs it was decided that an evaluation of the two models within the context of current policy requirements would best assist WSDOT in their decision making process.

HI-RUN

The HI-RUN model was created by Herrera Environmental Consultants, Inc. for WSDOT as an analysis tool specifically for western Washington BAs. It was not built to be a design tool or a general stormwater analysis tool. The model components and methods were developed under guidance from WSDOT, FHWA, USFWS and NMFS as part of the collaboration that led to the signing of the 2009 MOA. While it was agreed by these agencies that the use of HI-RUN would address identified shortcomings of western Washington BAs, limitations of the model were noted. Specifically it was noted that site specific variables that affect quantity and quality of runoff were not incorporated (i.e. site location, traffic volume, antecedent dry period) and that a small data set was used for water quality and BMP treatment characterization. Users are cautioned to be aware of the limitations and to realize the intent of HI-RUN, which is to “provide a general assessment of the risk of potential effects on ESA-listed species due to highway runoff" (Herrera, 2009, p. 3). Because HI-RUN was meant to be a tool that could assess the impact of highway runoff on ESA listed aquatic species during the planning stage of a project, it essential that the model be able to function with a limited amount of data. From this limited data the model needed to produce probabilities of loadings and concentrations of various water quality parameters from the untreated or treated runoff and the resultant effect on receiving waters. The model output could then be used in the assessment of risk to aquatic species of interest.

HI-RUN is a stochastic model which uses a risk based approach in order to predict the probability of occurrence rather than a fixed worst case estimate. The model uses probability distributions for input variables and a Monte Carlo simulation method. The water quality parameters analyzed by HI-RUN include total suspended solids (TSS), total copper (TCu), dissolved copper (DCu), total zinc (TZn), and dissolved zinc (DZn). The model compares a baseline, or existing, condition to proposed conditions. The comparison occurs at the Threshold Discharge Area (TDA) level. TDAs are an onsite area draining to a single natural discharge location or multiple natural discharge locations that combine within ¼ mile downstream. In HI-RUN up to five TDAs can be compared at a time. HI-RUN has two subroutines that provide output data specifically required for WSDOT BAs.

The first subroutine in HI-RUN is "Loading". Output provided by this subroutine includes concentration and annual load estimates for each of the quality parameters over a range of probabilities at the outfall from the TDA. These values are provided for baseline and proposed conditions. The model also provides a percent exceed value, which represents the probability of the concentration and load values of the proposed conditions exceeding those of the existing conditions. This value is critical in BAs; it is used to confirm that proposed conditions will not cause a significant increase in pollutant loading. The percent exceed value is also used to determine whether additional modeling using the second subroutine of the model is required.

The second subroutine in HI-RUN is "Dilution". This component provides an evaluation of the DCu and DZn concentrations after dilution in the receiving stream or river. Output is provided in the form of a downstream distance required to meet the site specific biological effects threshold. This threshold is defined as the background, or upstream, concentration of DCu and DZn plus either 0.0056 or 0.002 mg/L respectively. The downstream distance is used to determine the potential for "take". Take, as defined in the ESA, is "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect" a listed species (ESA, 2003, p. 3). The Services definition of harm includes degradation of habitat (WSDOT, 2013a). Therefore in the case of aquatic species take is often estimated as the space and time the species' habitat is negatively affected. A take analysis for a WSDOT BA should define the "amount of a species' habitat likely to be lost as a result of the proposed project" (WSDOT, 2013, p. 3.32). The output from the dilution component of HI-RUN is used by the project biologist to quantify the extent and timing of any degraded, or lost, habitat resulting from a proposed project.

SELDM

SELDM was developed jointly by the FHWA and the United States Geological Survey (USGS) as an update to the FHWA highway runoff quality model from 1990 (Granato, 2012a). As with HI-RUN, the intent of SELDM is a planning level model that can be used with limited amounts of project data. The model uses current data to evaluate the effects of stormwater runoff on receiving waters by simulating stormwater runoff volumes, concentrations, and loads. Monte Carlo methods are used in combination with empirically derived data. SELDM can be used to determine the possibility of exceeding water quality limits downstream and compare scenarios with or without structural BMPs. The model can also be used for lake loading analysis. Complete modeling results are provided in text output files which can then be utilized to obtain the comparison results required.

SELDM uses national data sets for highway runoff concentrations, precipitation, stream flows, runoff coefficients, and upstream water concentrations. However, it is built as a database application so that user flexibility is available as to the level of detail and site specificity desired, allowing user provided data and statistics to be input in lieu of pre-populated model values. The model can be customized with local data for any number of water quality parameters and any number of user defined BMPs.

The version of SELDM used in this study was SELDM 1.0.0, with customization as detailed in this report. The unmodified version of the model includes highway runoff water quality characterization for total suspended solids (TSS) using national FHWA data from 1990 and for ten constituents using Massachusetts data from 2009. The unmodified version includes one stormwater best management practice (BMP) that provides flow reduction and suspended sediment concentration (SSC) treatment. In applied use additional region or use specific water quality constituents and BMPs can be added as needed. For this study the source for regional information was the WSDOT data set used in the creation of HI-RUN. Depending on WSDOT use and timing this may not be the best regional data source available for populating SELDM. The SELDM manual provides sources, such as the Highway Runoff Database (HRDB) and the USGS National Water Information System Web (NWISWeb), from which users can obtain the statistics necessary to populate SELDM (Granato, 2013a). However, in the context of this project use of the same data set used to create HI-RUN provided the best way to compare output and usability of HI-RUN and SELDM.

Comparison of HI-RUN & SELDM

The methods used by computer simulation models can be defined under the following classifications; stochastic or deterministic, conceptual or empirical, distributed or lumped, event or continuous, and planning, design, or operational (Zoppou, 2001). When considered among the substantial number of simulation models available for analysis of urban stormwater runoff and the resultant impact on receiving waters, HI-RUN and SELDM are very similar. Both are planning level, lumped models that can be used with limited information during the developmental stages of a project. Both models are stochastic and use Monte Carlo methods to generate storm event characteristics and runoff pollutant concentration values based on empirical data. HI-RUN and SELDM both use long term precipitation records to generate a series of event based runoff producing storms rather than perform a continuous simulation. Additionally both models are specifically tailored to the analysis of highway projects, the associated runoff and the potential negative impacts to receiving waters from pollutants contained in the runoff, and examination of the potential for mitigation by BMPs. HI-RUN and SELDM are free to users; both models are available online for anyone to download at no cost. Documentation and instruction materials are also available for free for both models.

Aside from these similarities, there are some significant differences between HI-RUN and SELDM. Most significant is the fact that HI-RUN was specifically developed for use in BAs for projects in western Washington and is used only for this purpose. At the time Herrera Environmental Consultants, Inc. was contracted to build HI-RUN, no analysis tools (including SELDM) existed that could be used for BAs. The cost to build HI-RUN, not including the costs associated with development of training materials, costs of the white papers that led to the analytical approach used in the model, or administrative overhead, was $88,613 (WSDOT, 2006). SELDM was developed by the USGS and FHWA. SELDM was designed and created to be applicable nationwide for more general assessments of highway projects and stormwater runoff. SELDM was not designed to provide information specifically required for evaluation of the effects of stormwater on ESA species for highway projects in western Washington. Federal funds were used to pay the costs related to development and creation of SELDM and additional resources would be required to modify its output to meet the current needs for BAs in western Washington.

There are other differences between HI-RUN and SELDM. HI-RUN has a set number of water quality parameters available for analysis and a set number and type of BMP treatment options. SELDM was built with the potential for user customization and can be modified to assess any number of quality parameters. Users can also create any number and type of flow reduction and quality treatment BMPs. HI-RUN is pre-populated with annual runoff volume statistics, storm duration statistics, and monthly discharge statistics. SELDM uses model contained national precipitation data to internally generate all storm event characteristics and runoff volumes using Monte Carlo methods. HI-RUN calculates a downstream distance to the point where a biological threshold concentration is met using a set value for upstream concentration. SELDM calculates a downstream concentration based on the combination of upstream concentrations and flow volumes combined with highway runoff or BMP outflow concentrations and volumes. In this calculation the runoff from the contributing upstream basin in factored into the dilution analysis. HI-RUN does not consider increased stormflow volumes in dilution determinations, but instead uses set user entered monthly flow parameters. Lastly, each model is built on different software operating platforms; HI-RUN uses Microsoft Excel and SELDM users Microsoft Access. Table

2 provides a summary comparison of HI-RUN and SELDM. Table 3 provides of summary for each model of stochastic variables and processes that use Monte Carlo methods.

Table 2: Summary Comparison of HI-RUN and SELDM

	HI-RUN	SELDM
	Overview	
Purpose / Intent	A tool for determining risk to ESA listed aquatic species due to stormwater runoff from planned highway projects, used to compare existing and proposed conditions	An updated version of the FHWA's highway runoff quality planning model, used to assess the potential effects of runoff on receiving waters and assess the potential mitigation possibilities associated with implementation of BMPs
Basic Methodology	Estimate concentration and load at end-of-pipe using Monte Carlo methods, estimate concentration in receiving water after dilution, compare two scenarios in each simulations (existing & proposed)	Simulate storm flows, concentrations, and loads in runoff with and without BMPs to determine pollutant loading to receiving waters, calculate annual and storm specific values for one specified scenario in each model run
	Methods/Model Processes	
Precipitation	Indirectly used to select runoff statistics by geographical regions	User can select rain zone average, ecoregion average, selected station(s) average (all three using NOAA data), or user defined statistics
Runoff	Statistics for annual volume runoff and BMP outflow at either 0, 20, 40, 60, or 80% reduction, and statistics for monthly averages for discharge rates and discharge duration determined by use of the WSDOT MGSFlood model with prototype 1-acre impervious basins, Monte Carlo methods use lognormal distribution for discharge and duration and normal distribution for annual volume	Runoff coefficient specified by user as either user defined statistics, SELDM statistics (which use KTRLine method), or Schueler Trimmed NURP statistics, precipitation regime selected is used in combination with selected runoff coefficient statistics to generate storm event runoff volumes, durations, and times between storm midpoints

Water Quality – Runoff	Parameters Available: DCu, TCu, DZn, TZn, and TSS, characterized using local data for untreated and treated runoff from 13 monitored Western Washington BMP sites from 2005-2008, Monte Carlo Methods generate random numbers using set statistics and a lognormal distribution	Parameters Available: Preloaded with TP and TSS, user can add additional as needed, preloaded values from the HRDB, additional parameters can be characterized with user's own data sets or from HRDB using specified statistics and choice of distribution, parameters can be modeled as random or dependent
BMP Treatment	BMP outflow concentrations characterized using statistics for the treated runoff from the 13 monitored Western Washington BMP sites, five BMP volume reduction options: 0, 20, 40, 60, or 80%	One pre-loaded BMP option available, user defined BMPs can provide volume reduction, concentration reduction, and hydrograph extension using either a trapezoidal, triangular, or uniform distribution for the ratio
Stream flow	Site specific monthly average data entered into model by using stream depth, stream velocity, and channel width	User can select pre-storm discharge statistics by ecoregion average, selected station(s) average (both calculated using USGS data), or create user-defined statistics
Water Quality – Receiving	User entered set upstream concentration value for DCu and DZn	User defined using statistics and data set distribution to generate stochastic values, parameters can be modeled as random, transport curve, or dependent
Dilution	Downstream distance to point where mixed concentration meet biological threshold (background concentration plus either 0.002 (DCu) or 0.0056 (DZn) mg/L) calculated using RIVPLUM6 mixing model	Discharge volume available for mixing calculated using pre-storm discharge, upstream basin storm runoff, and highway site and upstream basin hydrograph recession factors, dilution factor calculated and downstream concentration after mixing
Model Output	Summary excel spreadsheets and probability tables with concentration and load for baseline and proposed scenarios, summary excel spreadsheets and probability tables for distance downstream to meet biological threshold for baseline and proposed scenarios	Up to ten tab-delimited text output files with run documentation, precipitation output, prestorm-stream flow, stormflow, dilution-factors, highway runoff quality, upstream runoff quality, downstream runoff quality, lake analysis, and annual summary

Table 3: Stochastic Variables & Model Processes that Use Monte Carlo Simulation

	HI-RUN	SELDM
Number of Storm Events		X
Precipitation Volume		X
Storm Event Duration	X	X
Runoff Coefficients		X
Runoff Volume	X	X
Runoff Concentrations	X	X
Highway Site Discharge Rate	X	X
BMP Volume Reduction	X	X
BMP Outflow Concentrations	X	X
Stream flow		X
Upstream Concentrations		X

Chapter 1 - Task 1: Comparison of Model Results Using Two Western Washington Sites

Research Methods

The first task completed by the UU research staff in the ESA Analysis Model Comparison project was to perform a comparison of data output provided by each model for matching data input. In order to provide a meaningful comparison of the output provided by HI-RUN and SELDM, site specific data from two case study sites in western Washington were entered into each model and the output recorded. Each subarea from the two case study sites was modeled in both HI-RUN and SELDM 15 times. The multiple simulation runs were necessary because both HI-RUN and SELDM are stochastic models with model generated input variability. The case studies were selected by the WSDOT appointed technical advisory committee (TAC) and the required site specific data were provided to the UU research staff by WSDOT.

In this comparison HI-RUN was used as the baseline. SELDM was used to emulate the output type and values provided by HI-RUN. This does not reflect any judgment by WSDOT, the UU research staff, or any others as to the validity or quality of either model, nor is this meant to suggest that HI-RUN methods and output was found to be superior to SELDM methods and output. HI-RUN was used as a baseline because of current regulatory requirements in Western Washington. As stated the 2009 assessment method agreed upon by WSDOT, FHWA, NMFS, and USFWS requires the use of HI-RUN. Therefore current BA method uses output type as provided by this model. In order to quantitatively compare model output, modeling in SELDM was completed in a specific manner that may not reflect the USGS or FHWA recommended use of this model. Therefore the methods used in this comparison should not be interpreted as a user's guide for SELDM.

Step #1 – Determining Case Study Details

For HI-RUN, the data required for modeling includes case study location and site specific information including area and treatment method for both existing and proposed conditions. The months of interest and the water quality parameters to be analyzed must be specified. Appendix B provides a HI-RUN Case Study Details form listing required data which is a modified version of the forms included in the HI-RUN user's manual, listing only the required values for this comparison study.

For SELDM, the data required for modeling includes all items as specified for HI-RUN with the exception of months of interest. Additional data required includes the site latitude and longitude coordinates and upstream basin characteristics. The SELDM Case Study Details form in Appendix B, which is again a modified version of the forms included in the HI-RUN user's manual, lists required data. Case study details were provided to the UU research staff by WSDOT. The forms in Appendix B were used by UU research staff to compile the required data. Completed forms from Appendix B were reviewed by WSDOT in order to confirm correct understanding of case study details.

Step #2 – Modeling Case Studies in HI-RUN

Data from each of the two case studies were entered into the HI-RUN model and 15 simulation runs of the model were executed and the output saved. The HI-RUN model provides the option to save a complete file of results from each run of the model. These files were saved and used for data compilation in Step #3.

The HI-RUN model has two subroutines. The first deals with loading at the outfall from the threshold discharge area (TDA). TDA, as defined in the WSDOT highway runoff manual, is "an on-site area draining to a single natural discharge location or multiple natural discharge locations that combine within ¼ mile downstream" (WSDOT, 2011). The second HI-RUN subroutine deals with the resultant dilution effect on the receiving waterway. In actual assessment situations a project may not require modeling in the dilution component of HI-RUN. This occurs when the results of the loading component indicate a percent exceed for DZn of less than 0.45 and water quality indicators, as defined by WSDOT, show that the receiving water body is properly functioning. Additional information including the rationale behind the use of DZn as an indicator and selection of the percent exceed threshold values can be found in the HI-RUN Model User's Guide (Herrera, 2011). For this project both model components were utilized when the necessary information was provided, even in cases where the DZn percent exceed was less than 0.45.

Each HI-RUN subroutine must be run separately and the output results are provided separately. Output from the HI-RUN loading component includes load and concentration for the specified quality parameters. These values are given for maximum, 75th percentile, median, 25th percentile, and minimum. Also a percent exceed value comparing existing conditions to the proposed conditions is provided. Output from the HI-RUN dilution component includes distance downstream where concentration meets biological effects threshold for DCu and DZn for selected months of interest, for both existing conditions and proposed conditions. These thresholds are an increase over the receiving water's background concentration of 0.002 mg/L for DCu and 0.0056 mg/L for DZn. If the distance output value provided by the model is < 1 (less than 1 foot), the concentration at the outfall is less than the receiving water background concentration plus either 0.002 or 0.0056. Any value other than < 1 indicates the approximate distance from the outfall at which the threshold concentration occurs.

Step #3 – Compiling Data Output from HI-RUN

Output data from HI-RUN for the 15 simulations of each case study was compiled to create a data set for comparison with SELDM. As stated, the need for multiple runs is due to the stochastic quality of the model. The output values compiled and included in the data set from the HI-RUN loading component include load and concentration median and percent exceed values for each quality parameter for baseline and proposed conditions. For the dilution component the distance values for each quality parameter and month selected, for baseline and proposed conditions, were compiled. These values were tabulated for each case study using an Excel spreadsheet.

The sample mean and 95% confidence interval values were determined for each set of variables in the 15 simulation data set. The mean was calculated using Equation 1. The 95% confidence interval was calculated using the sample mean and sample standard deviation (see Equations 2 and 3).

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \qquad \text{Equation 1}$$

$$s = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2} \qquad \text{Equation 2}$$

$$CI = \left[\bar{x} + \left(t\alpha_{/2}\frac{s}{\sqrt{n}}\right)\right] - \left[\bar{x} + \left(t\alpha_{/2}\frac{s}{\sqrt{n}}\right)\right] \qquad \text{Equation 3}$$

Where:

$\bar{x} = sample\ mean$
$n = number\ of\ samples$
$x_i = each\ sample$
$s = sample\ standard\ deviation$
$CI = confidence\ interval\ spread$
$t\propto_{/2} = t - distribution\ value$

Because this is a small data set, t-distribution values were used in calculating the confidence interval (see Appendix C for table of t-distribution values). A test was used to determine if 15 runs provided a sufficient size data set. This test required the 95% confidence interval value to be no greater than 10% of the mean. If this was not true for either case study, an additional run of the model would have been completed and the process repeated until the 95% confidence interval value was no greater than 10% of the mean. See Appendix D for an example of the data compilation spreadsheet that includes cells to perform this sample size test.

Step #4 – Modeling Case Studies in SELDM

Data from each of the two case studies were entered into SELDM and 15 simulation runs of the model were executed and the output saved. In SELDM a simulation can be completed using a new or previously generated set of random numbers. Random numbers are generated from a master seed value; a user can select either "Use the existing value" or "Generate a new value" for the master seed. For each simulation in this analysis the Master Random Seed Option of "Generate a new value" was selected. This option prompts SELDM to use a new set of random numbers for each simulation and produces stochastic output. The existing value option can be used in sensitivity analysis and comparison of different treatment options for scenarios.

SELDM must be run individually for baseline (existing) and proposed analysis. However, unlike HI-RUN, SELDM does not have different loading and dilution subroutines so both types of analysis are completed in one simulation. Results are provided in nine separate text files, including files with data on user input parameters, pre-storm stream flow, precipitation events, storm-flow, highway runoff quality, annual highway runoff, upstream runoff quality, downstream runoff quality, and dilution factors. The complete output files were used for data compilation in Step #5.

SELDM allows the user to select the quality parameters to be analyzed and also allows the user to specify the BMP characteristics. Water quality parameters are selected for highway runoff and upstream watershed runoff and can be of three types: random, dependent, or transport curve. SELDM is pre-populated with statistics for two water quality parameters, TSS and TP. SELDM is also pre-populated with statistics for one BMP type; a non-specific flow reduction and SSC treatment BMP.

For this study the random option for generating water quality data was used. The random option uses sample statistics from monitoring studies, which is also the method used in HI-RUN. The data set used to determine highway runoff and BMP discharge quality characteristics for HI-RUN was provided by WSDOT and used to generate parameter statistics for SELDM. The runoff water quality data input includes all parameters currently available for concentration and loading analysis in HI-RUN; TSS, TCu, DCu, TZn, and DZn. The water quality parameters for the upstream basin include the two parameters used in the dilution component of HI-RUN; DCu and DZn. Detailed information regarding the analysis of the data set and values obtained and used to populate SELDM is provided in the results.

SELDM and HI-RUN differ in the manner in which BMPs can be applied to a scenario. SELDM can be used to compare sites with or without treatment via BMPs. HI-RUN can be used to compare sites with, without, or with partial treatment via BMPs. For this comparison, WSDOT case study sites that received partial treatment via BMPs were divided according to whether the area receives BMP treatment, and if so by what type of BMP. Each subarea of the site was run individually in SELDM and the output for all subareas compiled for comparison with HI-RUN output.

The receiving water components of HI-RUN and SELDM use different approaches and methods and therefore provide different outputs. In order to assess the results of the two models a comparison was made between the downstream concentrations as calculated by SELDM with the concentration values that can be estimated from determination of the biological effects threshold value and the downstream distance calculated by HI-RUN.

Step #5 – Compiling Data Output from SELDM

As with Step #3, output data from SELDM for the 15 simulation runs of each case study were compiled to create a data set for comparison with HI-RUN. The output values compiled include concentration and load for the five water quality parameters: TSS, TCu, DCu, TZn, and DZn. The downstream concentration for DCu and DZn was also included in the data set for comparison with the HI-RUN. The values for each case study were tabulated using an Excel spreadsheet.

The sample mean and 95% confidence interval values were determined for the data set, using Equations 1, 2, and 3 and the t-distribution values (Appendix C). The sample size test comparing the 95% confidence interval to 10% of the mean, as previously detailed, was used to confirm a sufficient data set size. See Appendix D for an example of the data compilation spreadsheet.

Step #6 – Confirming t-Test Primary Conditions for HI-RUN and SELDM

Once valid data sets were obtained a comparison was made between the outputs from HI-RUN and SELDM. The concentration and load values from the data sets were compared using an independent t-test. The t-test analysis was used to determine whether the model results from HI-RUN and SELDM for each of the two case studies were statistically different. An independent t-test is used to determine whether the mean values of two independent sample sets have a significant statistical difference. A null hypothesis and alternate hypothesis are defined and the test will validate or disprove these hypotheses. For this comparison the null hypothesis was defined as the mean of the SELDM data set being statistically identical to the mean of the HI-RUN data set. The alternate hypothesis was defined as the mean of each model being statistically different.

A t-test is valid under three primary conditions; one, that the sample sets are independent, two, that both sample sets are normally distributed and three, that the variances for each sample set are not statistically different. The first condition is true of the two sample sets for this project because they are generated by distinct models. The second condition is satisfied under the Central Limit Theorem which states that the distribution of the sample mean of a moderately large sample set is approximately normally distributed. This holds true even when the sample mean is from data which is not normally distributed. The third condition for using t-test analysis, that the variances are not statistically different, was tested for confirmation using an F-test.

The F-test examines the ratio of the variance from the two independent sample sets to determine if the value is statistically close to 1. Variance is equal to the standard deviation squared (s^2). The null hypothesis is that the ratio (*F*) is equal to 1. The alternative hypothesis is that *F* does not equal 1. If the null hypothesis is confirmed the values are concluded to be statistically identical. The *F* value was calculated using Equation 4. The degrees of freedom (*df*), which are used in determining the upper and lower bounds for *F*, were calculated using Equation 5.

$$F = {(s_2)^2}/{(s_1)^2} \quad \text{Equation 4}$$

$$df = n - 1 \quad \text{Equation 5}$$

Where:

$F = Ratio\ of\ Variance$
$df = degrees\ of\ freedom$
$s_1 = sample\ standard\ deviation$ from HI-RUN
$s_2 = sample\ standard\ deviation$ from SELDM
$n = number\ of\ samples$

The upper bound for *F* was read from the F-distribution chart (see Appendix E) using the row for df_1 and the column for df_2. The lower bound for *F* was read from the F-distribution chart using the inverse of the value found using the column for df_1 and the row for df_2. See Appendix F for a sample spreadsheet that was used for this analysis. If the F-test alternative hypothesis was concluded, which means that the variances were found to be statistically different, an alternative form of the t-test was performed (see Equation 8).

Step #7 – Performing t-Test on Data Sets from HI-RUN and SELDM

The t-test was performed based on the results of the F-test. As stated, the null hypothesis for the t-test is that there is no statistically significant difference between the mean values of the data sets from HI-RUN and SELDM; thus the mean from SELDM is statistically identical to the mean from HI-RUN. For this test the calculated t value (t_c) obtained in Equation 6 is compared to the two-tailed t value from the t distribution table in Appendix C. In order to perform Equation 6, Equation 7 must first be completed. Equation 7 is used to determine the pooled variance for the two data sets. This equation is used when the F-test concludes the variances are equal. When data sets are determined to have unequal variances, Equations 8 is used to calculate t_c.

$$t_c = \bar{x}_2 - \bar{x}_1 \Bigg/ \sqrt{\frac{(s_p)^2}{n_1} + \frac{(s_p)^2}{n_2}}$$ Equation 6

$$(s_p)^2 = \frac{(df_2(s_2)^2) + (df_1(s_1)^2)}{df_2 + df_1}$$ Equation 7

$$t_c = \bar{x}_2 - \bar{x}_1 \Bigg/ \sqrt{\frac{(s_1)^2}{n_1} + \frac{(s_2)^2}{n_2}}$$ Equation 8

Where:

$t_c = calculated\ t\ test\ value$
$\bar{x}_1 = sample\ mean$ from HI-RUN
$\bar{x}_2 = sample\ mean$ from SELDM
$s_p = pooled\ sample\ standard\ deviation$
$s_1 = sample\ standard\ deviation$ from HI-RUN
$s_2 = sample\ standard\ deviation$ from SELDM
$n_1 = number\ of\ samples$ from HI-RUN
$n_2 = number\ of\ samples$ from SELDM
$df_1 = degrees\ of\ freedom$ for HI-RUN
$df_2 = degrees\ of\ freedom$ for SELDM

Once the t_c value from equation 6 or 8 was determined it was compared to the t values from the distribution table in Appendix C. For this test a significance level of 0.05 was used. The degrees of freedom used with the table are the total of df_1 and df_2 if equation 6 was used or the lesser of df_1 or df_2 if equation 8 was used. When the absolute value of t_c was greater than the table value of t, the alternative hypothesis was accepted, which indicated that the HI-RUN and SELDM model results were statistically different. When the absolute value of t_c was less than the table value of t, the null hypothesis was accepted, which indicated that the HI-RUN and SELDM model results were not statistically different. See Appendix F for a sample spreadsheet used for this analysis.

Step #8 – Results Validation using Statistical Analysis Software

Stata, a data analysis and statistical software program, was used to validate the results obtained for the sample size test; specifically checks were made to confirm the calculated mean, standard deviation, and 95% confidence interval for the HI-RUN and SELDM data sets. Stata was also used to validate the t-test results obtained using the method outlined in Step #7.

Step #9 – Performing Wilcoxon Rank-Sum test on Data Sets

The Wilcoxon rank-sum test, also referred to as the Mann-Whitney test or Wilcoxon-Mann-Whitney test, was also used to compare the concentration and load output values from each model (Helsel & Hirsch, 2002). This statistical test was used in addition to the t-test in order to provide verification of the t-test results. The Wilcoxon rank-sum test is used to determine whether one of the two independent data sets tends to produce larger values than the other. This test does not require that the data sets be normally distributed, which is a primary condition of the t-test. The data sets can follow any distribution and the test can even be used to compare data sets with different distributions (Helsel & Hirsch, 2002). The null hypothesis for this test is that the probability of any HI-RUN values being greater than any SELDM values is equal to 0.5. If the null hypothesis is found true then the data sets are shown to be statistically equal (Helsel & Hirsch, 2002). Stata was used to perform the Wilcoxon rank-sum test for both case studies.

Modeling

The two case studies were modeled in HI-RUN and SELDM, and the output from each model was compiled, as outlined in steps #2 through #5 of the methods. Detailed information for both case studies, which are actual WSDOT projects in western Washington, was provided by WSDOT. BAs, which include HI-RUN modeling, were completed previously for both projects. UU research staff was provided the BA reports in addition to other documentation for each project to facilitate the transfer of project details required to complete this task. A summary of each case study follows.

Case Study 1 Summary

Case Study 1 is located in the City of Lynden, WA. The improvements for this project consist of the construction of roundabouts at two intersections; the first being the junction of State Route (SR) 546 and Depot Road and the second being the junction of SR 546 and Bender Road (Northwest Region Environmental Services, 2011). The planned construction will increase impervious surface area by 0.10 acres and improve the stormwater drainage system along with other upgrades. Stormwater runoff at each of the intersections drains to separate unnamed tributaries of Fishtrap Creek, which is a tributary to the Nooksack River. Each intersection is defined in the BA report as a separate TDA.

For this study each of the TDAs, hereafter referred to as Bender Road and Depot Road, were modeled separately in HI-RUN in both the Loading and Dilution components. The Puget East 52 precipitation time series was used, as this was deemed the appropriate precipitation record for the case study location per the region map included in HI-RUN. All five water quality parameters and all months were selected for analysis in the loading component. In the dilution component, both DCu and DZn were modeled for all months of the year. Table 4 provides a summary of key model input values. Appendix G provides a completed HI-RUN case study details form with numerical values acquired from the WSDOT provided documentation and used in the HI-RUN model. The output obtained from 15 runs of the model was compiled to create a data set (Appendix H).

Table 4: Case Study 1, Summary of Model Input Values

	Bender Road TDA 1	Depot Road TDA 1
Baseline Conditions, Treatment Type		
None	1.5 acres	1.3 acres
Proposed Conditions, Treatment Type		
None	0.8 acres	0.7 acres
Basic, 0% infiltration	0.7 acres	0.7 acres
Background Concentration		
Copper – Dissolved (mg/L)	0.026	0
Zinc – Dissolved (mg/L)	0.009	0.003
HI-RUN Precipitation Time Series	Puget East 52	
SELDM Annual Precipitation (average of 3 stations)	51.36	
Water Quality Parameters Analyzed	TSS, TCu, DCu, TZn, DZn	

Each of the two TDAs, Bender Road and Depot Road, were also modeled separately in SELDM. Under baseline (pre-project) conditions neither TDA received any form of BMP treatment; therefore only one site per TDA was modeled. Under proposed (post-project) conditions a portion of each TDA received BMP treatment, therefore modeling was completed for two sites per TDA, one with BMP treatment and one without. The output for the two sites was combined and proportionally adjusted where necessary (i.e. concentrations) to create a data set for the proposed TDA. Preloaded regional precipitation and stream flow statistics provided in SELDM were used, however they were specifically selected in order to reasonably replicate the precipitation and stream flow statistics used in HI-RUN. Washington specific water quality and BMP treatment characteristics were entered in SELDM for this project. Details regarding precipitation and stream flow selections and water quality characterization are provided in the SELDM customization section of this report.

Some information required for modeling in SELDM is not required for HI-RUN, and therefore was not included in the case study information provided by WSDOT. This includes site latitude and longitude, certain highway site characteristics, and upstream basin characteristics. The latitude and longitude for Case Study 1 was determined using Google Earth. Instructions regarding the determination of required highway site characteristics, including drainage length, mean basin slope, impervious fraction, and basin development factor are provided in the SELDM documentation Appendix 2. This instruction in combination with the provided case study information and Google Earth was used to determine the required values. The upstream basin area was determined through the use of the USGS online tool StreamStats (www.streamstats.usgs.gov), which can be used to delineation the watershed area for a specific stream location. Additional necessary upstream basin values were again determined through use of the SELDM documentation and Google Earth. Table 4 provides a summary of model input values. Appendix G provides a completed SELDM case study details form with numerical values used in the SELDM model. The output obtained from the 15 runs of the model was compiled to create a data set (see Appendix H).

Case Study 2 Summary

Case Study 2 is located in Clark County, WA. The improvements for this project consist of upgrades to I-5 and I-205 in the Salmon Creek area including the construction of new interchanges, removal and construction of on-ramps and off-ramps, construction of new lanes, and improvements to adjacent local roadways (Haffie, 2008). The planned construction will increase impervious surface by 14.5 acres and at the same time increase the total area which receives treatment from 19 % to 60%. Stormwater runoff at the project site drains to four receiving waters: Whipple Creek, a tributary of Whipple Creek, Rockwell Creek, and Salmon Creek. The BA lists a total of nine TDAs within this project site and groups the designated areas into three drainage basins based on the creek to which they drain.

The three drainage basins, thereafter referred to as Whipple Creek Basin, Salmon Creek Basin, and Rockwell Creek Basin, were modeled separately in HI-RUN, with the various TDAs set as subbasins. Whipple Creek Basin consists of four TDAs which were combined for the loading component. For the dilution component required information was provided for two of the four TDAs, which were therefore modeled. Salmon Creek Basin consists of two TDAs which were combined for the loading component. For the dilution component required information was provided for one TDA, which was modeled. Rockwell Creek Basin consists of three TDAs which were combined for the loading component. For the dilution component no TDAs were modeled as this wasn’t warranted per the completed analysis and therefore the required inputs were not provided. For all three drainage basins the Vancouver 44 precipitation time series was used and all five water quality parameters and all months were selected for analysis is the loading component. In the dilution component, both DCu and DZn were modeled for the months for which the necessary information was provided; this includes January to March and September to October for all TDAs assessed. Table 5 provides a summary of key model input values. Appendix I provides a completed HI-RUN case study details form with all numerical values acquired from the WSDOT provided documentation and used in the HI-RUN model. The output obtained from the 15 runs of the model was compiled to create a data set (Appendix J).

Table 5: Case Study 2, Summary of Model Input Values

	Whipple Creek Basin			
	TDA 1	TDA 2	TDA 3	TDA CC5
Baseline Conditions, Treatment Type				
None	5.61 acres	11.53 acres	6.56 acres	0.75 acres
Basic, 0% infiltration	0.64 acres			1.12 acres
Proposed Conditions, Treatment Type				
None	5.61 acres	10.93 acres	5.22 acres	
Basic, 0% infiltration	0.64 acres			2.38 acres
Enhanced, 60% infiltration		1.8 acres	2.24 acres	
Background Concentration				
Copper – Dissolved (mg/L)	0.00152 (Jan to Mar)		0.00154 (Sept to Oct)	
Zinc – Dissolved (mg/L)	0.0047 (Jan to Mar)		0.0042 (Sept to Oct)	

	Salmon Creek Basin	
	TDA 5	TDA6
Baseline Conditions, Treatment Type		
None	6.26 acres	4.54 acres
Basic, 0% infiltration	0.93 acres	0.55 acres
Proposed Conditions, Treatment Type		
None	3.42 acres	4.34 acres
Basic, 0% infiltration	0.93 acres	0.63 acres
Enhanced, 60% infiltration	4.08 acres	0.22 acres
Background Concentration		
Copper – Dissolved (mg/L)	0.00153 (Jan to Mar)	0.00155 (Sept to Oct)
Zinc – Dissolved (mg/L)	0.0047 (Jan to Mar)	0.0043 (Sept to Oct)

	Rockwell Creek Basin		
	TDA 4	TDA CC6	TDA CC7
Baseline Conditions, Treatment Type			
None	14.46 acres	2.74 acres	2.26 acres
Basic, 0% infiltration	8.85 acres		1.14 acres
Proposed Conditions, Treatment Type			
None	3.01 acres		
Basic, 0% infiltration	18.89 acres	3.89 acres	4.47 acres
Enhanced, 60% infiltration	9.76 acres		
HI-RUN Precipitation Time Series	Vancouver 44		
SELDM Annual Precipitation (average of 2 stations)	43.22		
Water Quality Parameters Analyzed	TSS, TCu, DCu, TZn, DZn		

Each of the three drainage basins was entered as a separate project in SELDM. Each of the TDAs within the three basins (9 TDAs in total) was modeled separately. The TDAs were sub-divided into separate sites for modeling when necessary due to partial treatment by BMPs. For example, TDA 1 baseline was modeled as 2 sites; one 5.61 acre site with no treatment and one 0.64 acre site with BMP treatment. TDA 4 proposed was modeled as 3 sites; one 3.01 acres site with no treatment, one 18.89 acres site with BMP treatment with zero infiltration, and one 9.76 acre site with BMP treatment with 60% infiltration. For each sub-divided area the output was combined and proportionally adjusted where necessary to create a data set for the TDA. Preloaded regional precipitation and stream flow statistics provided in SELDM were used, however they were specifically selected in order to reasonably replicate the precipitation and stream flow statistics used in HI-RUN. Washington specific water quality and BMP treatment characteristics were entered in SELDM for this project. Details regarding precipitation and stream flow selections and water quality characterization are provided in the SELDM customization section of this report.

Similar to Case Study 1, some of the necessary inputs for SELDM were not provided in the documentation received from WSDOT because they are not necessary for modeling in HI-RUN. The SELDM documentation in combination with Google Earth was again used to determine site latitude and longitude, certain highway site characteristics, and upstream basin characteristics. StreamStats was not used to define the upstream basins for this case study because the results obtained through the use of this tool were decided to produce an unrealistically large upstream contributing basin considered the urbanization of the area. Due to a lack of local expertise and in order to obtain more conservative results, one square mile upstream basins were modeled for Salmon Creek and Whipple Creek and a 0.25 square mile upstream basin was modeled for the Tributary to Whipple Creek. This was not seen to be a significant factor in the comparison of output from the two models due to the fact that HI-RUN does not account for the added dilution effects from upstream runoff and only considers the dilution effects from the stream flows. Table 5 provides a summary of key model input values. Appendix I provides a completed SELDM case study details form with numerical values used in the SELDM model. The output obtained from the 15 runs of the model was compiled to create a data set (Appendix J).

SELDM Customization & Parameter Selection

HI-RUN was created specifically for western Washington while SELDM was designed to be nationally applicable with the potential for customization with area and task specific data. In order to enable SELDM to provide the output that would be necessary to complete a western Washington BA and could be compared with output provided by HI-RUN, data that is both area specific for western Washington and task specific for BAs was added to the SELDM database. This includes the five water quality parameters that were determined to be significant for Washington State BAs and are currently used in HI-RUN; TSS, TCu, DCu, TZn, and DZn. The statistics used to characterize these water quality parameters in both highway runoff and BMP effluent are from the data set used to populate HI-RUN, which is referred to in this report as the

WSDOT data set. In addition the BMP treatment parameters were defined in SELDM using statistics from this same data set. Appendix K provides complete details regarding the pre-processing of the data set, the values used to populate SELDM, and analysis that was done to verify the accuracy of values and methods used.

SELDM is pre-populated with hourly precipitation statistics computed from data from 2,610 National Weather Service (NWS) monitoring stations. These data are used within the model in combination with the site runoff coefficient to generate runoff volumes. Site latitude and longitude are entered in SELDM. From these coordinates SELDM provides options for selection of precipitation statistics; rain zone average or median (based on the 15 EPA Rain Zones), ecoregion average or median (based on the 182 EPA Ecoregions of North America), selected station average or median, or user-defined. For this model comparison study, proximate stations were selected in order to create an equivalent to the annual volume of the precipitation time series selected for HI-RUN. For case study 1 the HI-RUN precipitation series selected was Puget East 52, which has an annual average of 52 inches of precipitation. In SELDM the selected stations average option was used to create an average of three stations (NOAA Station ID numbers 455786, 453160, and 452157) with an annual average of 51.36 inches. For case study 2 the HI-RUN precipitation series selected was Vancouver 44, which has an annual average of 44 inches of precipitation. In SELDM the selected stations average option was used to create an average of 2 stations (NOAA Station ID numbers 352348 and 351222) with an annual average of 43.22 inches.

SELDM is pre-populated with prestorm stream flow statistics computed from data from 2783 USGS stream gages. Runoff from the upstream basin is added to the prestorm stream flow in order to determine the total stream volume available for mixing and dilution. From the user entered latitude and longitude coordinates SELDM provides options for selection of stream flow statistics; ecoregion average or median (based on the 182 EPA Ecoregions of North America), selected station average or median, or user-defined. For Case Study 1 the selected station average option was used. The case study details provided by WSDOT included monthly stream flow characteristics that were used in HI-RUN. The lowest monthly average was 1.08 cubic feet per second (cfs) and the highest was 15.3 cfs. In SELDM statistics for three proximate streams were selected to create a selected station average. The cubic feet per second per mile average of these three stream flows was 1.975, which is 8.73 cfs when adjusted for the specified upstream basin of 4.42 square miles. For Case Study 2 the user-defined and selected station average options were used. For the Salmon River, which is the largest river at this case study site, information was obtained from the USGS National Water Information System Web (NWISWeb) and processed for use in SELDM. Two tools created specifically for this purpose were used to do this; these tools are Get National Water Information System Streamflow (Q) files (GNWISQ) and Streamflow (Q) Statistics (QSTATS). From this analysis an average daily mean stream flow of 131.09 cfsm with a standard deviation of 161.97 and skew of 2.447 was obtained and used to create user defined statistics in SELDM. For Whipple Creek and the tributary to Whipple Creek the selected station average option was used. For these two creeks, the lowest monthly stream flow average used in HI-RUN was 0.40 cfs and the highest was 2 cfs. For Whipple Creek, statistics for two proximate creeks were selected to create a selected station average. The cfsm average of these two stream flows was 2.985 and the cfsm median was 1.179 (2.985 cfs and 1.179 cfs when adjusted for the specified upstream basin of 1 square mile). For the tributary to Whipple Creek one station with a daily mean stream flow average of 8.208 cfsm and median of 4.524 cfsm (2.052 cfs and 1.131 cfs when adjusted for the 0.25 acre upstream basin) was selected.

To characterize the upstream receiving water concentrations in SELDM a user can select one of three methods; upstream random, upstream transport curve, or upstream dependent. For the purpose of comparison with HI-RUN output, which uses a fixed upstream concentration value as specified by the user, the upstream random method was used. The background concentration value used in HI-RUN was set as the average. The standard deviation and skew were set to zero which removed all variation and therefore represented the entered average as a fixed value. In doing this the SELDM model was manipulated to remove the stochastic nature of this variable. This is clearly not the intended use of SELDM. It is also not a recommendation of how the model should be used in practice. This simplification was done only to provide a comparison with HI-RUN. The upstream concentration values used for DCu and DZn are provided in Table 4 and Table 5. The seasonal concentration values for Whipple Creek Basin and Salmon Creek Basin were averaged to create an annual value.

SELDM provides four options to calculate runoff coefficient statistics; three regression equations and a user defined option. Two equations, labeled SELDM Highway Sites and SELDM Upstream Basin, were developed specifically for SELDM in 2009 and 2010. The other equation, labeled Schueler Trimmed NURP, is based on Schueler's 1987 analysis of the Nationwide Urban Runoff Program (NURP) data. According to the SELDM documentation this equation is "provided for comparison with results from other studies or with average calculations developed by using Schueler's "Simple Method"" (Granato, 2013a, p. 28). In HI-RUN a user does not select a runoff coefficient because runoff volumes are not calculated within the HI-RUN program. Through selection of a precipitation series the user selects runoff volume statistics. The runoff volume statistics in HI-RUN were determined through pre-processing of Washington State precipitation data using MGSFlood, which is a WSDOT continuous hydrological simulation model. Therefore in order to determine which SELDM runoff coefficient equation would best replicate highway runoff volumes from HI-RUN eight trial runs were completed. In these trial runs a 100% impervious one acre site was modeled using the precipitation definition generated for Case Study 1, which is comparable to the HI-RUN Puget East 52 series (51.36 inches and 52 inches respective annual averages). The two highway site equations, SELDM Highway Sites and Schueler Trimmed NURP were used. The results were compared with the annual runoff volume used in HI-RUN for the Puget East 52 series, which is 163,711 cubic feet (cf). Runoff values are not included in HI-RUN output but can be found in a hidden Excel spreadsheet within the program titled "Annual_Runoff_Volume". This spreadsheet provides the runoff statistics (average and standard deviation) used within HI-RUN to perform computations. From the analysis it was decided that the Schueler Trimmed NURP option would be used. A summary of the analysis is provided in Table 6. It is important to note that while use of the Schueler equation was considered the best option for this comparison, in practice the newer SELDM Highway Sites equation or the user defined option would provide more realistic estimates of runoff volumes.

Table 6: Summary of Analysis to Determine Best Runoff Coefficient Equation

	"SELDM Highway Sites" Annual Highway Runoff Volume (cf)	"Schueler Trimmed Nurp" Annual Highway Runoff Volume (cf)
Trial 1	155,269	164,077
Trial 2	155,654	164,846
Trial 3	158,038	163,923
Trial 4	154,923	167,000
Trial 5	158,731	170,231
Trial 6	159,385	167,000
Trial 7	154,231	170,231
Trial 8	157,346	166,269
Average (SELDM)	156,697	166,173
Average (HI-RUN)	163,711	163,711
Percent Difference	-4.28%	1.48%

Results

Output obtained from modeling was compared as per steps #6 through #9 in the methods. The output from each model for the two case studies was compiled as per Steps #3 and #5 in the methods. The compilation and analysis forms are included in Appendix H and Appendix J. Using the sample size test outlined in Steps #3 and #5, which tests to see if the 95% confidence interval value is no greater than 10% of the mean, it was confirmed that 15 runs created a sufficient sample set for all subareas of both case studies. The values calculated for this test are included on the compilation forms in Appendix H and Appendix J.

Statistical Comparison of Concentration & Load Values

The output values for load and concentration from the 15 runs of each model were compared using an independent t-test. As stated in the methods, there are three primary conditions under which this test is valid; data sets must be independent, data must be normally distributed, and the variances of each data set must be statistically equal. Conditions one and two are addressed in the methods. To meet condition three, an F-test was completed on the concentration and load values from all sample sets for each of the five water quality parameters. The results of the F-test indicated that in all cases the variances were statistically different and the alternative form of the t-test (Equation 8) was required. Appendix L provides a sample of completed F-test forms. The t-test was completed using Equation 8 for unequal variances, again on the concentration and load values of all sample sets for each of the five water quality parameters. The t-test showed the majority of the concentration output values to be statistically different and all of the load output values to be statistically different. In most cases the null hypothesis, that there is no statistically significant difference between the mean values of the sample sets, was not found to be true. Table 7 and Table 8 provide a summary of this analysis where "equal" denotes that the output sample set was found to be statistically equal and "different" denotes that the output sample set was found to be statistically unequal. Appendix M provides a sample of completed t-test forms.

Stata, a statistical analysis software program, was used to confirm the validity of the tests performed using the excel spreadsheets created specifically for this project. The ttest application was used and the all results found previously were verified to be correct. Samples of t-test results from Stata are included in Appendix N. To read this output the "Pr (|T |> |t|) = value" must be observed. If this value is greater than 0.05, indicating a two-tailed significance level of 0.05, the test shows the data set to be equal. A value of less than 0.05 indicates that the data set is not equal. Appendix O provides a detailed summary of probability values (p-values) obtained performing tests in Stata.

The Wilcoxon rank-sum test was also used to compare the data sets in order to confirm that the results of the t-test were not biased. This was a concern because the t-test is valid only when all three conditions as stated in the methods are met, including that the data set be normally distributed. The Wilcoxon rank-sum test is used often used in lieu of t-test when there is uncertainty as to the distribution of the data set. This is because the test is not conditional on a normal distribution. The Stata program was used to perform these tests. Samples of test results from Stata are included in Appendix P. To read the output from this test the "Prob > |z| = value" must be observed. If this value is greater than 0.05, indicating a two-tailed significance level of 0.05, the test shows the data set to be equal. A value of less than 0.05 indicates that the data set is not equal. Appendix Q provides a detailed summary of probability values (p-values) obtained performing tests is Stata. In all but one case this test agreed with the results of the t-test. Table 7 and Table 8 provide a summary of these results.

Table 7: Summary of Results from Statistical Analysis of Concentration Output

	Baseline TSS	Proposed TSS	Baseline TCu	Proposed TCu	Baseline DCu	Proposed DCu	Baseline TZn	Proposed DZn	Baseline DZn	Proposed DZn
Case Study 1										
Bender Road	Different	Different	Different	Different	Different	Different	Different	Different	Different	Different
Depot Road	Different	Different	Different	Different	Different	Different	Different	Different	Different	Different
Case Study 2										
Rockwell Creek TDA4	Different	Different	Different	Different	Different	Different	Different	Different	Different	Different
Rockwell Creek TDA CC6	Different	Different	Equal	T-D/ W-E	Different	Different	Different	Different	Different	Equal
Rockwell Creek TDA CC7	Different	Different	Equal	Equal	Different	Different	Different	Different	Different	Equal
Salmon Creek TDA 5	Different	Different	Different	Different	Different	Different	Different	Different	Different	Different
Salmon Creek TDA 6	Different	Different	Equal	Different	Different	Different	Different	Different	Different	Equal
Whipple Creek TDA 1	Different	Different	Different	Different	Different	Different	Different	Different	Different	Different
Whipple Creek TDA 2	Different	Different	Different	Different	Different	Different	Different	Different	Different	Different
Whipple Creek TDA 3	Different	Different	Equal	Different	Different	Different	Different	Different	Different	Different
Whipple Creek TDA CC5	Different	Different	Different	Different	Different	Different	Different	Different	Different	Equal

NOTE: Different denotes that the median values from the 15 trials were found to be statistically different in both tests.
Equal denotes that the median values from the 15 trials were found to be statistically equal in both tests.
If the tests did not agree, T-D / W-E denotes t-test found different and Wilcoxon rank-sum test found equal.

Table 8: Summary of Results from Statistical Analysis of Load Output

	Baseline TSS	Proposed TSS	Baseline TCu	Proposed TCu	Baseline DCu	Proposed DCu	Baseline TZn	Proposed DZn	Baseline DZn	Proposed DZn
Case Study 1										
Bender Road	Different	Different	Different	Different	Different	Different	Different	Different	Different	Different
Depot Road	Different	Different	Different	Different	Different	Different	Different	Different	Different	Different
Case Study 2										
Rockwell Creek	Different	Different	Different	Different	Different	Different	Different	Different	Different	Different
Salmon Creek	Different	Different	Different	Different	Different	Different	Different	Different	Different	Different
Whipple Creek	Different	Different	Different	Different	Different	Different	Different	Different	Different	Different

NOTE: Different denotes that the median values from the 15 trials were found to be statistically different in both tests.

Discussion of Comparison Results for Concentration

For the majority of cases the statistical tests used found the concentration values output by each model to be statistically different, even though both models were populated with statistics from the WSDOT data set. This is likely due to the methods used to calculate the random numbers required to perform the Monte Carlo simulations and the methods used to create a distribution of values for each of the water quality parameters, although in theory both models are meant to produce the same range of values. In addition, the high number of computations performed by each model for each parameter (1,000 for HI-RUN and from 1,800 to 2,000 for SELDM) produced similar median concentrations per each of the 15 simulation runs; which results in little variation, small standard deviations, and high sensitivity to statistical tests.

However, the fact that the concentrations values calculated by HI-RUN and SELDM were found to be statistically different is not necessarily significant for practice. Considering the goal and use for which the models are intended it is more important that the output from the models be comparable to the values in the original WSDOT data set used to populate the models. In order to determine the relationship between model output and the empirical values from the WSDOT data set, a comparison was made using the Case Study 1 concentration values produced by each model. These values were compared to the 95% confidence interval of each parameter in the WSDOT data set. Table 9 provides the concentration mean, median, geometric mean, and 95% confidence interval about the geometric mean for each parameter. The interval about the geometric mean was used because the data was previously found to be lognormal distributed, and therefore best represented by the geometric mean. The interval values in Table 9 for untreated and treated were weighted according to the untreated/treated proportion of each site to create 95% confidence intervals for each case study subarea. Figures 1 through 10 show the confidence interval limits and the concentration values from each simulation run. The majority of values from both models were within the 95% confidence interval. The exceptions are likely due to two conditions. One, output values provided by HI-RUN are rounded to three decimal places which causes the values to appear closer than actual to the limits. Two, there was a discrepancy between the treated TSS concentration values in the WSDOT data set used for this study and the data set used to populate HI-RUN, which is detailed in Appendix K. It is assumed that if both conditions were corrected all values produced by both models would fall within the 95% confidence interval of the empirical data.

Table 9: WSDOT Data Set Concentration Values - Mean, Median, Geometric Mean, & 95% Confidence Interval

Untreated Runoff					
	Mean (mg/L)	Median (mg/L)	Geometric Mean (mg/L)	95% Confidence Interval about Geometric Mean (mg/L)	
TSS	106.27	60.00	53.72	45.181	63.881
TCu	0.0051	0.0041	0.0039	0.0129	0.0167
DCu	0.0219	0.0158	0.0147	0.0035	0.0043
TZn	0.0423	0.0282	0.0301	0.0783	0.1010
DZn	0.1351	0.0880	0.0889	0.0271	0.0334

Treated Runoff					
	Mean (mg/L)	Median (mg/L)	Geometric Mean (mg/L)	95% Confidence Interval about Geometric Mean (mg/L)	
TSS	12.16	7.40	7.750	6.786	8.734
TCu	0.0036	0.0031	0.0031	0.0045	0.0053
DCu	0.0057	0.0050	0.0049	0.0028	0.0033
TZn	0.0193	0.0158	0.0156	0.0200	0.0244
DZn	0.0279	0.0230	0.0221	0.0142	0.0170

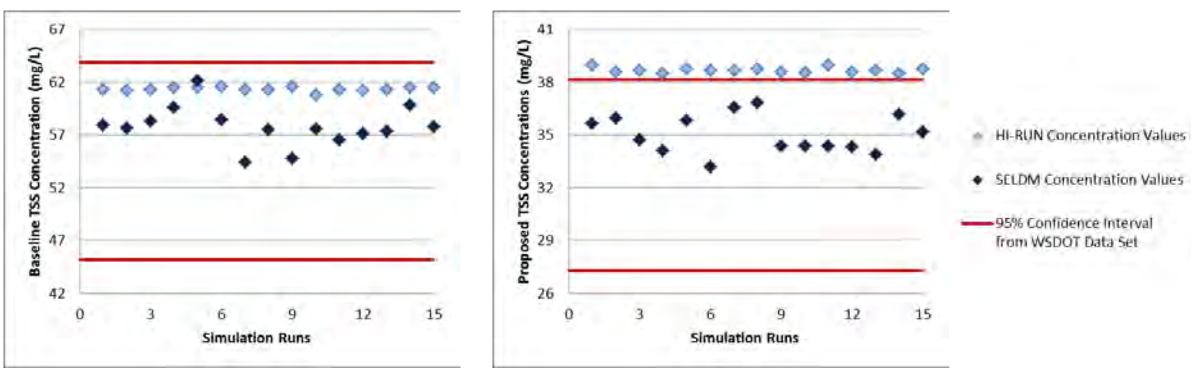

Figure 1: Bender Road TSS Concentration – HI-RUN & SELDM Output Compared to Confidence Limits

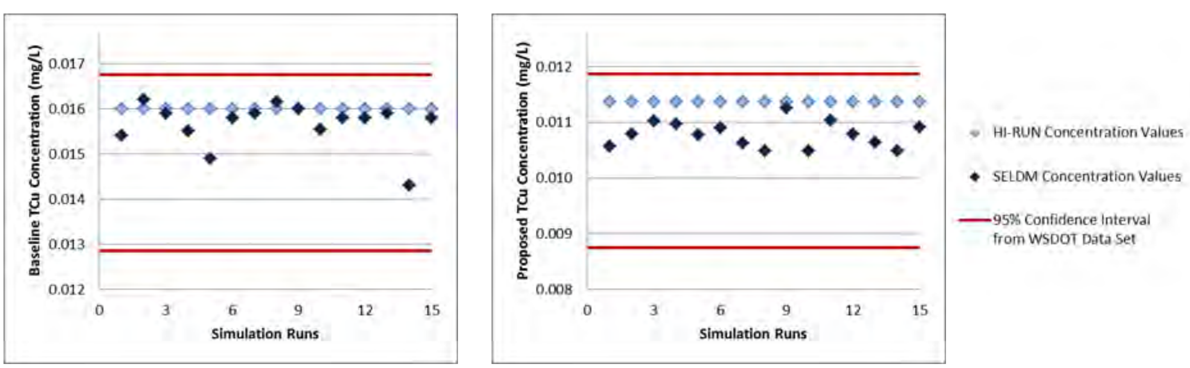

Figure 2: Bender Road TCu Concentration – HI-RUN & SELDM Output Compared to Confidence Limits

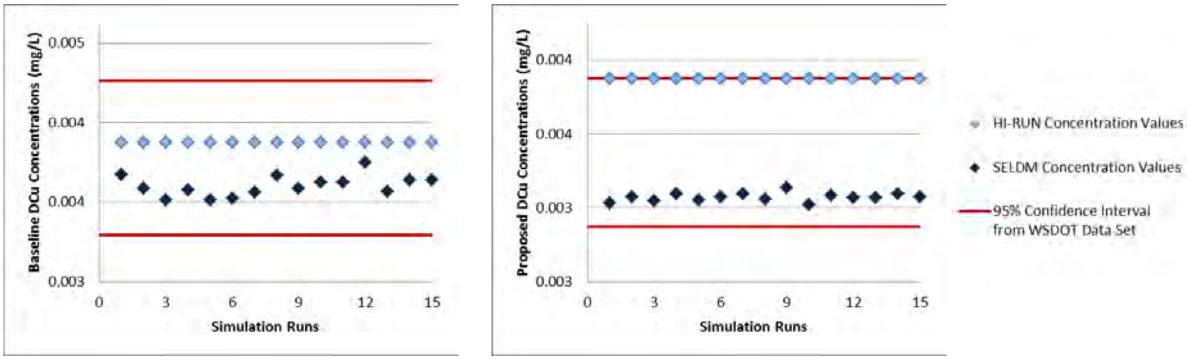

Figure 3: Bender Road DCu Concentration – HI-RUN & SELDM Output Compared to Confidence Limits

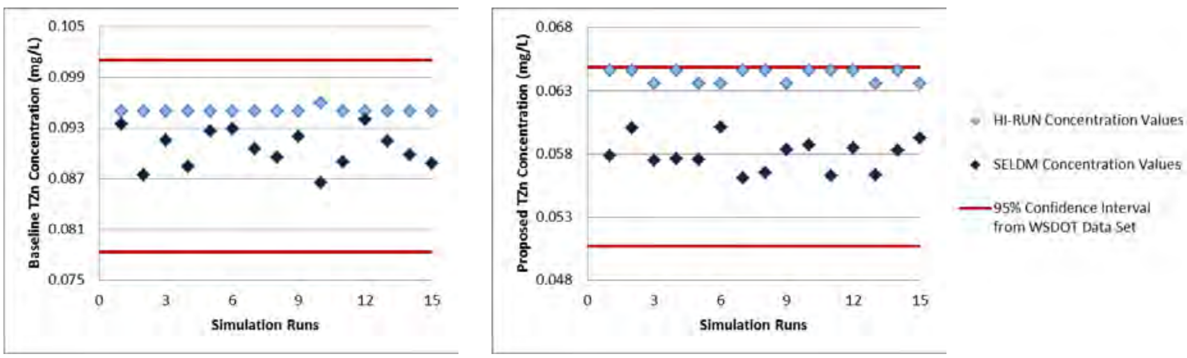

Figure 4: Bender Road TZn Concentration – HI-RUN & SELDM Output Compared to Confidence Limits

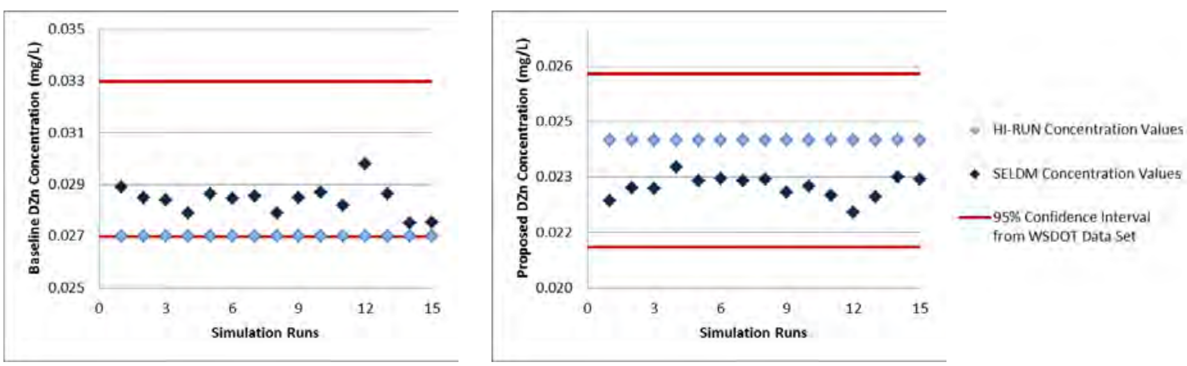

Figure 5: Bender Road DZn Concentration – HI-RUN & SELDM Output Compared to Confidence Limits

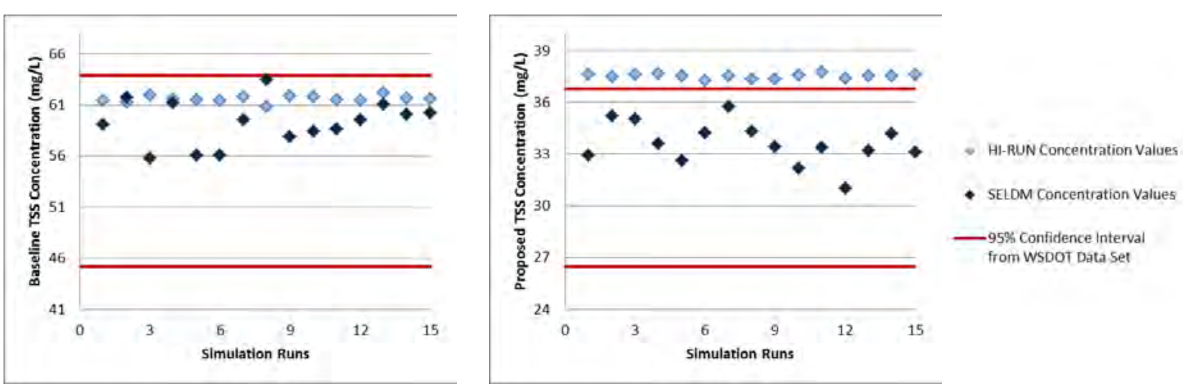

Figure 6: Depot Road TSS Concentration – HI-RUN & SELDM Output Compared to Confidence Limits

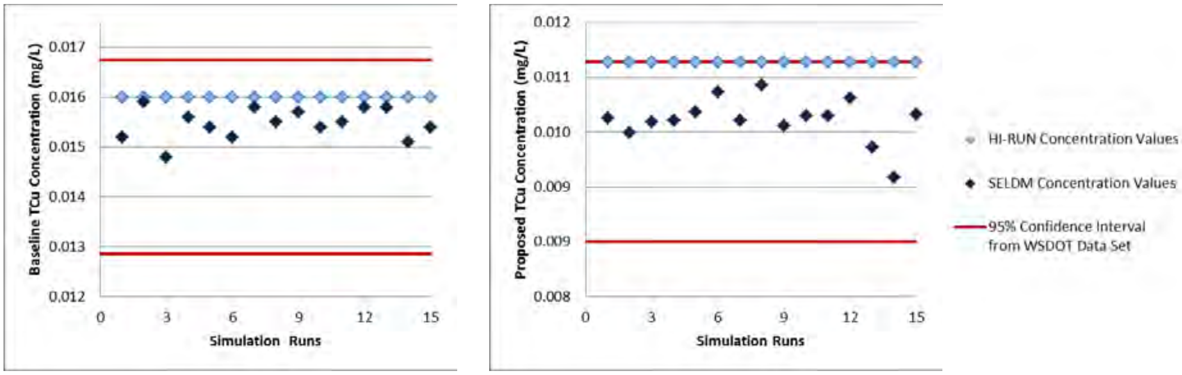

Figure 7: Depot Road TCu Concentration – HI-RUN & SELDM Output Compared to Confidence Limits

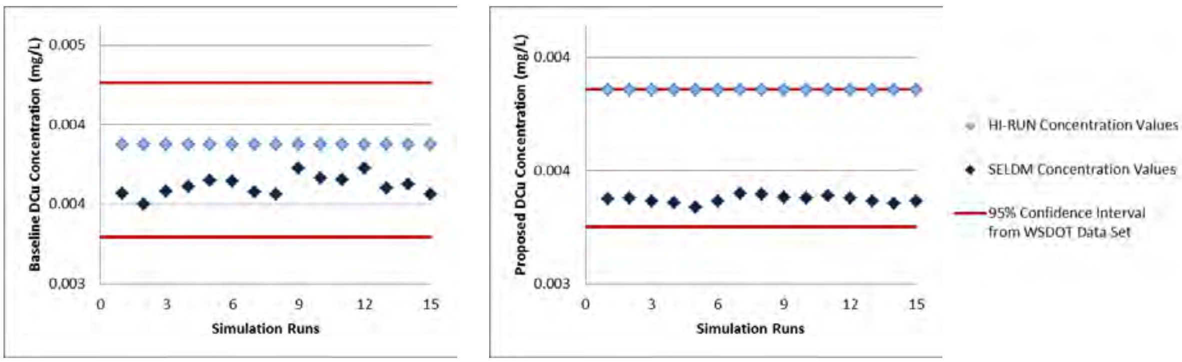

Figure 8: Depot Road DCu Concentration – HI-RUN & SELDM Output Compared to Confidence Limits

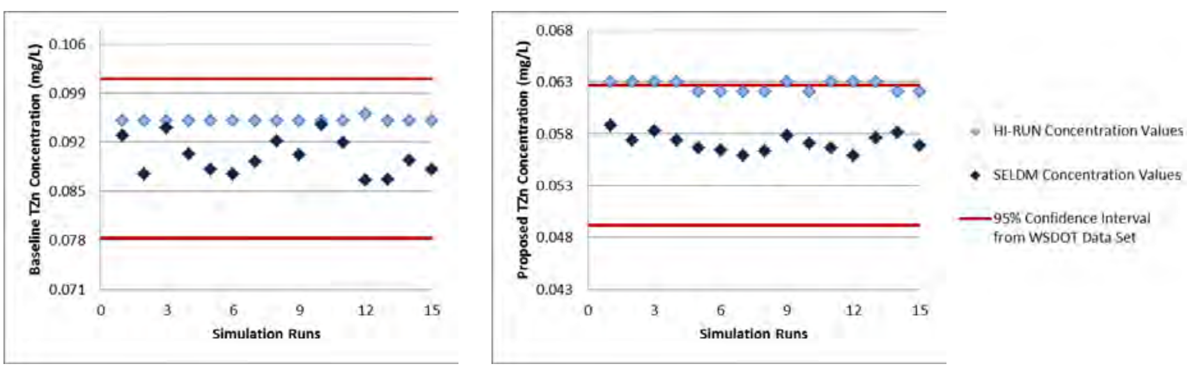

Figure 9: Depot Road TZn Concentration – HI-RUN & SELDM Output Compared to Confidence Limits

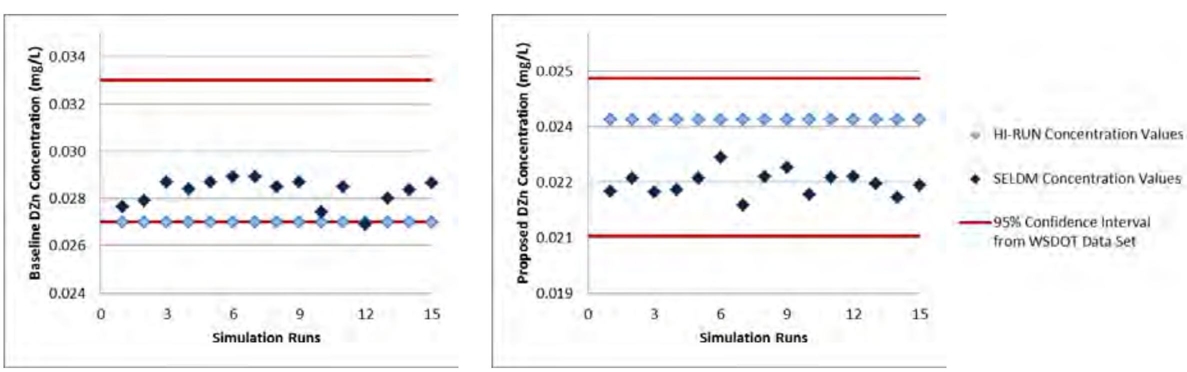

Figure 10: Depot Road DZn Concentration – HI-RUN & SELDM Output Compared to Confidence Limits

Discussion of Comparison Results for Load

For all parameters the load values output by each model were found to be statistically different. As with concentration, this occurred even though both models were populated with water quality statistics from the same data set. Unlike concentration, where differences between model output values were small, the magnitude of the difference in load values computed by the two models was large, with differences as great as 70%. In order to confirm that the annual runoff volume was not a significant factor in the different annual load outputs, a comparison of volumes was made between the two models. In SELDM the annual highway runoff and bmp outflow volumes are provided in the output files. If there is no BMP treatment or if the BMP does not provide volume reduction then the highway runoff and BMP outflow values are the same. Values for both are provided per simulation (per storm) and per year. On the SELDM compilation forms in Appendix H and Appendix J the annual highway runoff and BMP outflow is summarized. HI-RUN does not provide runoff volumes in the model output, however tables in hidden Excel sheets in the model list the annual runoff in terms of BMP outflow for each of the available precipitation time series. If the BMP does not provide volume reduction one value represents highway runoff and BMP outflow. If the BMP does provide volume reduction, values for 20, 40, 60, or 80% reduction represent the reduced volume of BMP outflow. Table 10 provides a comparison of BMP outflow for each case study subarea. HI-RUN values provided are the mean volume for the selected precipitation time series used in HI-RUN, multiplied by the scenario area. SELDM values are the average of the annual volumes from the 15 runs. From this comparison it can be seen that the annual volumes used within each model to perform load calculations are very similar and not capable of producing the degree for variation seen in the load values.

Table 10: Comparison of BMP Outflow Volumes

	HI-RUN		SELDM		Ratio (HI-RUN/SELDM)	
	Baseline (cf)	Proposed (cf)	Baseline (cf)	Proposed (cf)	Baseline	Proposed
Case Study 1						
Bender Road	245,567	245,567	250,034	250,157	0.982	0.982
Depot Road	212,824	229,195	215,635	232,380	0.987	0.986
Case Study 2						
Whipple Creek	3,546,423	3,569,177	3,535,677	3,551,813	1.003	1.005
Salmon Creek	1,661,582	1,491,232	1,654,454	1,488,846	1.004	1.002
Rockwell Creek	3,984,821	4,616,834	3,942,073	4,580,967	1.011	1.008

The variation in concentration and volume, the two variables used to calculate load, was not found to be the reason for the difference between the load values calculated by the models; rather the difference is due to the methods used by each model to compute annual load. In short, HI-

RUN multiplies 1,000 random annual volumes by 1,000 random concentration values to determine 1,000 annual load values. The median of these 1,000 annual load values in provided in the model output. In SELDM a load per storm event is calculated using a random storm event volume multiplied by a random concentration. These individual storm event loads are then summed to produce an annual load value. A more detailed description of the method used by each model follows.

In HI-RUN, the total annual load for each water quality parameter is calculated through a series of steps. These steps, as outlined in the HI-RUN model documentation, are as follows. The first step is the generation of 1,000 concentration values each for either untreated (highway runoff with no BMP treatment), treated by a basic BMP, or treated by an enhanced BMP. This is done via a Monte Carlo simulation using the mean and standard deviation statistics calculated from the WSDOT data set used to characterize each water quality parameter. The data for all five parameters was found to be lognormally distributed and the Monte Carlo simulation uses this distribution to generate the random values. As noted previously, in the current version of HI-RUN the statistics for basic and enhanced BMPs are the same due to insufficient data. The second step accounts for the runoff volume lost due to infiltration when a subarea receives treatment by a volume reduction BMP; this is done by multiplying the acreage of each subarea by 1 minus the infiltration rate of 0, 0.2, 0.4, 0.6, or 0.8. The third step is to generate 1,000 annual runoff per subarea values for each case (untreated, treated via basic BMP, or treated by enhanced BMP, with the various BMP infiltration cases (0, 0.2, 0.4, 0.6, 0.8)). Again this is accomplished via a Monte Carlo simulation using the mean and standard deviation statistics calculated for annual runoff per acre by the MGS Flood model. The annual runoff data was determined to be normally distributed and the random values are generated using this distribution. The 1,000 runoff values are multiplied by the 1,000 concentration values and a conversion factor to determine the load. For simulations with a combination of untreated runoff and runoff treated with BMPs providing varying volume reduction, the individual load values are summed and the model outputs a total load for the simulation. **Step two detailed above seems to provide a double accounting for the volume reduction potential of a BMP, and therefore if HI-RUN actually computes load using this step the model would produce a lower load value.** While this was noted, it was not determined to be a significant factor in the difference in load values, considering the majority of BMP treatment in Case Study 2 was not modeled with volume reduction and in Case Study 1 there was no volume reduction BMP treatment.

As with HI-RUN, SELDM also calculates the total annual load for each water quality parameter through a series of steps. Based on the user selected precipitation data, a number of storm events are determined. This value varies with each run that uses a new value for the Master Random Seed. For the case studies in this analysis the number of storm events varied from 1847 to 1979, which represents between 26 to 29 years of events. Each event is assigned a random volume based on the statistics associated with the user selected precipitation data. A number of random concentration values equal to the number of storm events are generated using the statistics calculated for this study as detailed in Appendix K. The volume is multiplied by the concentration to calculate a load for each event. This is done for highway runoff volume and BMP outflow volume, which may be the same volume as highway runoff or a lesser amount if a volume reduction BMP is modeled. The concentration values used are based on either the statistics for untreated runoff or values for treated BMP runoff as calculated using the ratio of untreated to treated concentration (see Appendix K for more detail regarding these values). The per storm event load values are summed to determine the total annual load and provided as model output. The median annual load for each simulation was calculated from the 26 to 29 annual load values provided by SELDM.

Schueler's Simple Method was used to calculate the load for each case study subarea in order to provide a reference value to compare the different annual loads as calculated by each model (Schueler, 1987). The Simple Method was originally intended for use with data collected in the Nationwide Urban Runoff Program (NURP), but for this analysis concentration values from the WSDOT data set were used. The complete form of Schueler's Simple Method equation used to calculate pollutant load is:

$$L = \frac{(P)(P_j)(R_v)}{12}(C)(A)(2.72) \qquad \text{Equation 9}$$

Where:

$L = storm\ pollutant\ export\ (load)\ in\ lbs$
$P = rainfall\ depth\ over\ the\ desired\ time\ in\ inches$
$P_j = factor\ that\ corrects\ P\ for\ storms\ that\ produce\ no\ runoff$
$R_v = runoff\ coefficient$
$C = flow - weighted\ mean\ concentration\ of\ the\ pollutant\ (mg/L)$
$A = area\ of\ the\ site\ in\ acres$
$NOTE$: $12\ and\ 2.72\ are\ unit\ conversion\ factors$

For this analysis the estimated annual volume of BMP outflow is known so the equation can be simplified; P, P_j, R_v, and A are replace by annual volume (V), a new appropriate unit conversion factor is employed, and the equation becomes:

$$L = (V)(C)(6.2428\ x\ 10^{-5}) \qquad \text{Equation 10}$$

Equation 10 was used to calculate the load for each case study subarea. The BMP outflow volumes from HI-RUN were used for V. For Case Study 1, outflow is 163,711 cf per acre for untreated and treated. For Case Study 2, outflow is 135,308 cf per acre for untreated and treated by BMP with 0% volume reduction, and 53,526 for treated by BMP with 60% volume reduction. For C, calculations were completed using the mean concentration value and the median concentration value from the WSDOT data set for each of the five water quality parameters (Table 42, Appendix K). The results of the Simple Method calculations and the loads calculated by both models are summarized in Table 11 and Table 12. It is evident from this comparison that the method used to calculate load by HI-RUN produces a value similar to the value obtained using the Simple Method and the median concentration value. The method used to calculate load by SELDM produces a value similar to that obtained using the Simple Method and the mean (average) concentration value.

Table 11: Case Study 1, Comparison of Load Values Calculated by Models & Simple Method

Total Suspended Solids	Bender Road		Depot Road	
(lbs)	Baseline	Proposed	Baseline	Proposed
HI-RUN	930	585	805	522
SELDM	1,615	964	1,400	835
Simple Method - Mean	1,630	956	1,412	847
Simple Method - Median	920	544	797	482

Total Copper	Bender Road		Depot Road	
(lbs)	Baseline	Proposed	Baseline	Proposed
HI-RUN	0.235	0.170	0.204	0.150
SELDM	0.338	0.229	0.285	0.204
Simple Method - Mean	0.336	0.220	0.291	0.197
Simple Method - Median	0.242	0.165	0.210	0.149

Dissolved Copper	Bender Road		Depot Road	
(lbs)	Baseline	Proposed	Baseline	Proposed
HI-RUN	0.055	0.056	0.047	0.052
SELDM	0.082	0.070	0.067	0.064
Simple Method - Mean	0.078	0.067	0.068	0.062
Simple Method - Median	0.063	0.056	0.054	0.052

Total Zinc	Bender Road		Depot Road	
(lbs)	Baseline	Proposed	Baseline	Proposed
HI-RUN	1.435	0.979	1.248	0.883
SELDM	2.060	1.364	1.762	1.208
Simple Method - Mean	2.071	1.304	1.795	1.116
Simple Method - Median	1.349	0.884	1.169	0.794

Dissolved Zinc	Bender Road		Depot Road	
(lbs)	Baseline	Proposed	Baseline	Proposed
HI-RUN	0.410	0.360	0.355	0.335
SELDM	0.631	0.518	0.559	0.467
Simple Method - Mean	0.648	0.484	0.562	0.441
Simple Method - Median	0.432	0.344	0.375	0.315

Table 12: Case Study 2, Comparison of Load Values Calculated by Models & Simple Method

Total Suspended Solids (lbs)	Whipple Creek Baseline	Whipple Creek Proposed	Salmon Creek Baseline	Salmon Creek Proposed	Rockwell Creek Baseline	Rockwell Creek Proposed
HI-RUN	12,618	11,456	5,645	4,182	10,962	3,750
SELDM	21,506	19,278	9,568	7,286	18,843	5,969
Simple Method - Mean	22,135	20,013	9,850	7,303	18,500	5,898
Simple Method - Median	12,502	11,317	5,566	4,137	10,487	3,470

Total Copper (lbs)	Whipple Creek Baseline	Whipple Creek Proposed	Salmon Creek Baseline	Salmon Creek Proposed	Rockwell Creek Baseline	Rockwell Creek Proposed
HI-RUN	3.237	3.000	1.465	1.101	3.009	1.700
SELDM	4.510	4.198	2.016	1.574	4.478	2.281
Simple Method - Mean	4.608	4.248	2.069	1.593	4.081	2.055
Simple Method - Median	3.337	3.099	1.504	1.173	3.019	1.716

Dissolved Copper (lbs)	Whipple Creek Baseline	Whipple Creek Proposed	Salmon Creek Baseline	Salmon Creek Proposed	Rockwell Creek Baseline	Rockwell Creek Proposed
HI-RUN	0.791	0.771	0.372	0.304	0.906	0.860
SELDM	1.081	1.066	0.501	0.430	1.376	1.120
Simple Method - Mean	1.107	1.078	0.510	0.433	1.142	1.076
Simple Method - Median	0.893	0.875	0.413	0.354	0.936	0.919

Total Zinc (lbs)	Whipple Creek Baseline	Whipple Creek Proposed	Salmon Creek Baseline	Salmon Creek Proposed	Rockwell Creek Baseline	Rockwell Creek Proposed
HI-RUN	19.687	18.000	8.867	6.653	17.793	8.873
SELDM	27.875	25.406	12.501	9.544	27.050	12.245
Simple Method - Mean	28.317	25.921	12.674	9.624	24.562	10.767
Simple Method - Median	18.517	17.072	8.316	6.402	16.406	8.282

Dissolved Zinc (lbs)	Whipple Creek Baseline	Whipple Creek Proposed	Salmon Creek Baseline	Salmon Creek Proposed	Rockwell Creek Baseline	Rockwell Creek Proposed
HI-RUN	5.775	5.500	2.667	2.100	6.085	4.807
SELDM	8.758	8.400	3.977	3.325	10.060	7.061
Simple Method - Mean	9.023	8.528	4.100	3.304	8.582	6.147
Simple Method - Median	6.059	5.800	2.770	2.284	5.969	4.869

The comparison of load values calculated by each model to the values calculated using the Simple Method indicates that the load estimates produced by SELDM are more accurate. Peer-reviewed literature indicates that mean (average) concentrations should be used in loading calculation (Schueler, 1987, Driscoll et al. 1990, Washington State Department of Ecology, 2009). Schueler (1987) and Department of Ecology (2009) both specify use of mean concentration. The Driscoll et al (1990) design procedure calls for median concentration as an input parameter but provides equations to transform median to mean prior to actual load calculations. In addition to these three sources, WSDOT's Quantitative Procedures for Surface Water Impact Assessments uses a simplified method to calculate pollutant load that is based on the Driscoll et al. method, and therefore uses mean concentration (WSDOT, 2009).

Comparison & Discussion of Percent Exceedance Values

Percent exceedance refers to the percentage of events where the value for proposed conditions exceeds the value for baseline conditions. Output from HI-RUN includes percent exceedance values for load and concentration. Output from SELDM does not include these values but does provide the necessary data to permit a user to determine these values; this includes the per event concentration and per event load. Calculations to determine percent exceedance using the SELDM output values were completed and the results included in the analysis and compilation forms in Appendix H and Appendix J. Tables 13 through 16 provide a summary of percent exceedance values from each model.

Table 13: Case Study 1, Percent Exceedance Values for Load

	TSS	TCu	DCu	TZn	DZn
Bender Road					
HI-RUN	37.5%	38.5%	51.1%	37.0%	46.7%
SELDM	44.1%	46.3%	53.9%	45.4%	50.6%
Depot Road					
HI-RUN	38.3%	40.1%	53.8%	38.3%	48.7%
SELDM	44.3%	47.7%	55.3%	46.2%	52.3%

Table 14: Case Study 1, Percent Exceedance Values for Concentration

	TSS	TCu	DCu	TZn	DZn
Bender Road					
HI-RUN	37.4%	38.1%	51.2%	36.6%	46.5%
SELDM	40.5%	40.9%	49.8%	40.5%	46.1%
Depot Road					
HI-RUN	36.1%	37.0%	50.9%	35.4%	46.0%
SELDM	39.4%	40.2%	49.5%	39.4%	45.9%

Table 15: Case Study 2, Percent Exceedance Values for Load

	TSS	TCu	DCu	TZn	DZn
Whipple Creek					
HI-RUN	47.5%	47.4%	49.4%	47.2%	48.7%
SELDM	46.8%	47.2%	49.7%	46.5%	49.4%
Salmon Creek					
HI-RUN	41.9%	40.4%	42.6%	40.3%	42.7%
SELDM	43.1%	42.3%	43.1%	42.1%	43.1%
Rockwell Creek					
HI-RUN	20.4%	25.6%	47.5%	22.1%	39.9%
SELDM	22.0%	31.9%	50.2%	28.5%	43.9%

Table 16: Case Study 2, Percent Exceedance Values for Concentration

	TSS	TCu	DCu	TZn	DZn
Whipple Creek (TDA 1)					
HI-RUN	49.9%	50.0%	50.0%	50.0%	50.0%
SELDM	45.5%	44.8%	51.2%	44.3%	48.8%
Whipple Creek (TDA 2)					
HI-RUN	48.7%	48.8%	50.3%	48.6%	49.7%
SELDM	47.6%	48.0%	50.7%	47.3%	50.0%%
Whipple Creek (TDA 3)					
HI-RUN	46.8%	46.9%	50.9%	46.8%	49.4%
SELDM	44.7%	44.3%	50.7%	44.1%	48.5%
Whipple Creek (TDA CC5)					
HI-RUN	12.3%	18.4%	40.5%	15.2%	32.9%
SELDM	16.6%	24.8%	51.0%	22.0%	33.1%
Salmon Creek (TDA 5)					
HI-RUN	41.4%	41.9%	51.2%	40.9%	47.9%
SELDM	38.5%	38.6%	48.4%	37.9%	13.8%
Salmon Creek (TDA 6)					
HI-RUN	49.2%	49.3%	50.2%	49.1%	49.8%
SELDM	49.2%	48.4%	50.3%	49.1%	50.3%
Rockwell Creek (TDA 4)					
HI-RUN	21.4%	23.8%	45.0%	20.9%	38.0%
SELDM	24.5%	27.2%	43.3%	25.0%	37.3%
Rockwell Creek (TDA CC6)					
HI-RUN	06.9%	12.4%	42.8%	8.9%	31.4%
SELDM	12.4%	18.8%	38.9%	15.8%	29.6%
Rockwell Creek (TDA CC7)					
HI-RUN	08.7%	14.1%	39.9%	10.8%	30.5%
SELDM	13.1%	20.6%	37.1%	17.4%	29.5%

The percent exceedance value is a critical variable when performing an analysis using HI-RUN. This number determines whether modeling in the dilution component is necessary and is a critical signifier of the potential impacts of the proposed project. Because the goal of a BA is to determine the potential effects a proposed project may have on ESA listed species in comparison to existing conditions, this value is important to note. The percent exceedance value provides a quantitative way to assess the impacts of the changes associated with a project. The HI-RUN model documentation states that because of model limitations the pollutant concentrations produced are less important than the "general assessment of the risk of potential effects" (Herrera, 2009). Statistical comparison of the percent exceedance values was not deemed appropriate as these values are a statistical representation, not a variable. However qualitative assessment found percent exceedance values produced directly by HI-RUN and indirectly through use of SELDM output data, to be very similar. This was the case even for load percent exceedance, where the actual load values varied significantly. This output similarity is important when considering that the primary goal in BA modeling is to determine the risk associated with the proposed conditions in relationship to the existing conditions.

Comparison & Discussion of Downstream Concentration & Dilution Analysis

Comparison of output from HI-RUN and SELDM, related to dilution analysis, was complicated by the different output types provided by each model. HI-RUN uses set monthly flow rate characteristics to determine the stream volume available for dilution. The Washington State Department of Ecology hydraulic mixing model, RIVPLUM6, is incorporated into HI-RUN. This model is used to compute dilution factors; inputs are the user defined streamflow values and discharge rate statistics pre-determined for each precipitation series by use of the MGSFlood model. The dilution factors from RIVPLUM6 are used to compute the distance required for the concentration to be diluted to the biological effects threshold. HI-RUN indirectly accounts for the contribution from upstream basin runoff through the set background concentration value and other set exceedance limits, as outlined in the user's manual, which are used after modeling in the load component to determine whether modeling in the dilution component is required. HI-RUN model output includes the monthly downstream distance, up to 1000 feet, where the biological effects threshold is reached and probability values associated with this distance. HI-RUN output does not include downstream concentration estimates.

SELDM was not designed to calculate mixing distances because of concerns regarding the validity of the methods generally used, including those used in the RIVPLUM6 model (Granato, 2013b). This is not a model deficiency, but rather a design choice. SELDM calculates mixed downstream concentrations at the highway discharge point. Storm event runoff from the upstream basin is added to prestorm stream flow based on timing as specified by user entered hydrograph recession factors. This computation determines the volume available for mixing and dilution. Model output includes upstream and downstream concentrations values, and the computed dilution factors. In addition SELDM output also includes an adverse effect concentration ratio. This ratio can be used to estimate the concentration of concern in the receiving water. Although this ratio was not used during this project, this capability in SELDM could be beneficial and useful to WSDOT in practice. SELDM does provide output that could be used with the RIVPLUM6 model and therefore a mixing distance could be calculated by combination of the models. However the steps necessary to complete this work, which would require an external model to facilitate the calculations, was outside the scope of this project.

The use of a different approach and computational methods in HI-RUN and SELDM to analyze the effect of runoff pollutant concentrations and load on receiving water bodies makes direct comparison of output from each model impossible. However, a qualitative comparison was made between the dilution and downstream concentration output provided by HI-RUN and SELDM. Although HI-RUN output does not provide a downstream concentration value, it does provide a distance downstream at which the biological effects threshold is met. If this distance is less than 1000 feet the user can discern that the concentration is less than the biological effects threshold, which is the background concentration plus either 0.0056 for DCu or 0.002 for DZn, at some point between the outfall and 1000 feet downstream of the outfall. Using this fact a comparison was made between the downstream concentrations as calculated by SELDM and the less than concentration value inferred from the HI-RUN output. A summary of these values is provided in Table 17 and Table 18. From this summary it can be seen that all concentrations values calculated by SELDM are less than the maximum value inferred from the HI-RUN distance output. While a quantitative analysis of these concentration values is not possible, a qualitative assessment shows agreement between the resultant receiving water affects that are read from model outputs. It is important to note that these results are contingent on the non-varying upstream concentration required in the current version of HI-RUN and used for modeling in SELDM in this comparison study. In SELDM the upstream concentration values are designed to be stochastic variables. Modeling upstream concentrations as variable would increase or decrease the downstream concentrations depending on upstream concentration statistics.

Table 17: Case Study 1, Comparison of Downstream Concentration Values

	Dissolved Copper (mg/L)		Dissolved Zinc (mg/L)	
	HI-RUN	SELDM	HI-RUN	SELDM
Bender Road				
Baseline	<0.0316	0.0259	<0.0110 *	0.0091
Proposed	<0.0316	0.0260	<0.0110	0.0090
Depot Road				
Baseline	<0.0056	0.0002	<0.005	0.0031
Proposed	<0.0056	0.0002	<0.005	0.0031

NOTE: *Except for August which had the lowest stream flow rates.

Table 18: Case Study 2, Comparison of Downstream Concentration Values

	Dissolved Copper (mg/L)		Dissolved Zinc (mg/L)	
	HI-RUN	SELDM	HI-RUN	SELDM
Whipple Creek – TDA 2				
Baseline	<0.00713	0.00167	<0.0065	0.00612
Proposed	<0.00713	0.00165	<0.0065	0.00588
Whipple Creek – TDA 3				
Baseline	<0.00713	0.00171	<0.0065	0.00651
Proposed	<0.00713	0.00163	<0.0065	0.00587
Salmon Creek – TDA 5				
Baseline	<0.00714	0.00155	<0.0065	0.00458
Proposed	<0.00714	0.00154	<0.0065	0.00453

Task 1 Summary

The output comparison analysis demonstrated mixed results. The effluent concentration values were found to be statistically different, however further analysis showed that in practice the concentration output values from both HI-RUN and SELDM were effectively the same. This was concluded by comparing the output from both models to the WSDOT monitoring data. The concentration estimates from the models were found to be within the 95% confidence interval of the median concentration values from the monitoring data and therefore determined to be practically the same. In contrast, the load values were found to be both statistically different and practically different. Analysis using the Simple Method (Schuler, 1987) highlighted the extent of this difference. This comparison indicates that SELDM provides a more accurate load estimate than HI-RUN when using mean concentration values as a baseline for comparison. The percent exceedance values from each model were found to be comparable. This indicates that application of output from either model would result is a similar assessment of project risk. The type of output created by each model for use in assessing receiving water effects is different; distance to the biological effects threshold compared to concentration. However a comparison was made using inferred concentration values determined from the HI-RUN distance values and the output was found to be similar. In summary, although the majority of output from HI-RUN and SELDM was statistically different both models provided a similar assessment of risk in analysis of existing and proposed conditions.

Chapter 2 - Task 2: Study Model Usability

Research Methods

The second task completed by the UU research staff in the ESA Analysis Model Comparison project was the evaluation of the usability of both HI-RUN and SELDM. To accomplish this task the UU research staff employed four students to model a simplistic theoretical scenario. The students were unfamiliar with either model and all received the same introductory training. The results from each student's work, including a summary of model output, the time required to complete modeling, and student evaluation of usability, were documented. Key results were compiled in a usability matrix. This chapter provides information regarding the steps taken in completing this task, including details of the theoretical scenario and introductory training, and the findings of the usability evaluation.

It is important to note that the usability assessed in this study relates specifically to the use of either HI-RUN or SELDM in preparing a western Washington BA. Usability of any tool must be assessed in the context of the intended use (Brooke, 1996). In this case the intended use is a WSDOT BA. Therefore the evaluation completed in this study should not be interpreted as a broad assessment of the usability of either model, but instead a context specific analysis.

The version of SELDM used in this task, SELDM 1.0.0, was customized using statistics from the data set used to populate HI-RUN. The customization of SELDM with these regional statistics was completed prior to the start of the usability study and release of the model to the student modelers. This customization was completed as part of Task 1 and is detailed in Chapter 1 of this report (SELDM customization section and Appendix K). The SELDM version used by the student modelers included the five runoff water quality parameters that are available for analysis in HI-RUN (TSS, TCu, DCu, TZn, and DZn) and the two receiving water parameters available in HI-RUN (DCu and DZn). Also five BMP types, to represent each level of infiltration as available in HI-RUN, were included.

Step #1 – Selection of Students to Participate in Task 2

In order for this usability evaluation to be most relevant to WSDOT an attempt was made to select student participants who possess a skill set relevant to the WSDOT staff and consultants who now use HI-RUN and who will in the future use HI-RUN and/or SELDM. According to the WSDOT BA guidance manual, the project biologist is responsible for completing the BA. This includes the use of HI-RUN for determination of the effects of storm water runoff and receiving water impacts, and the related impact to Endangered Species Act (ESA) listed fish. The scope of work for this project called for the employment of three civil engineering graduate students in the evaluation of usability. However, in practice it is biologists that will use the models. Therefore to determine usability as experienced by users with different perspectives and skill sets, two biology students and two civil engineering student were employed as participants in this task.

Step #2 – Basic Training for HI-RUN

The purpose of WSDOT BAs is to ensure that proposed projects comply with ESA requirements and meet WSDOT standards (WSDOT, 2013a). To ensure that individuals preparing these assessments have the proper background and training to complete assessments at WSDOT standards, staff and consultants must participate in a qualification program and afterwards pass an examination. Included in this qualification program is basic training for the HI-RUN model. The PowerPoint presentation used in the qualification program was provided by WSDOT and used as part of the basic training for this task, with attention given to the slides relevant to use and understanding of HI-RUN. The HI-RUN Step-by Step Example which is provided on WSDOT's website was used for hands-on HI-RUN training (WSDOT, 2013c). This example was completed by students under the direction of UU research staff. Many additional HI-RUN training materials are available on the WSDOT website. Selected materials were provided to the student modelers for reference, including the HI-RUN Model User's Guide, HI-RUN User's Input/Output Guide, and HI-RUN Frequently Asked Question/Troubleshooting Guide. Appendix R provides internet link addresses for all of the materials used.

Step #3 – Basic Training for SELDM

SELDM was publically released just prior to the completion of student modeling for this task. Therefore SELDM training materials and methods were still in development by the USGS and FHWA and not available for use in this study. Because of this two sessions were held to provide basic training to student modelers. First, a live WebEx training session conducted by Greg Granato provided information about the theory used in creating SELDM and an introduction to the use and function of the model. Second, hands-on training specific to the use of SELDM for WSDOT BAs was provided by UU research staff. The hands-on training involved the previously referred to HI-RUN Step-by-Step Example. This example project and presentation was modified to be applicable for SELDM. Student modelers completed the example under the direction of UU research staff.

Step #4 – Student Modeling of Theoretical Scenario in HI-RUN and SELDM

To evaluate the usability of HI-RUN and SELDM the students modeled a simplistic theoretical scenario that was created by the UU research staff. Although this scenario contains actual city, street, and creek names from locations in Washington, the scenario is theoretical. The scenario was designed to be realistic in order to obtain an accurate assessment of usability. A brief description of the scenario is provided in Appendix S. This description was provided to student modelers.

In addition to the scenario description students also received instructions and background information regarding the Stormwater Model Comparison Project (Appendix T) and a Stormwater Design Checklist for both HI-RUN and SELDM. The Stormwater Design Checklist is a WSDOT form used to convey project details from the project designer to the biologist responsible for using HI-RUN. This form provides the specific details required for the biologist to complete modeling. An abbreviated version of WSDOT's Stormwater Design Checklist is included in Appendix U with details necessary for HI-RUN modeling. A similar form customized by the UU research staff provides details necessary for SELDM modeling (Appendix U). In practice, the project biologist is responsible for determining what information, such as months of interest or water quality parameters, is needed for the assessment. Because the students in this study were not qualified to make such determinations, this information was provided in the scenario details.

All training materials and scenario information was provided to students electronically, along with the HI-RUN and SELDM models. Some materials were also provided in print, including the scenario description, Stormwater Design Checklists, and evaluation Forms 1, 2, and 3 which are detailed following. Two students, one from engineering and one from biology, were randomly selected to receive training and complete modeling using HI-RUN first. All four students then received SELDM training and completed modeling using SELDM. The two students (one engineering and one biology) who had not yet used HI-RUN then were trained and completed modeling using HI-RUN.

Step #5 – Model Usability Evaluation

Three assessment forms were completed by the student modelers and used by the UU research staff to evaluate usability. Form 1 required a log of time to complete sub-tasks necessary in modeling the scenario. This form also provided space for comments regarding each sub-task. Form 2 was used to report the output results obtained from each model. Form 3, which is the Systems Usability Scale, was used to evaluate each student's opinion of usability (Brooke, 1996). This form was completed after modeling. Blank and completed versions of Forms 1, 2, and 3 are provided in Appendices F through H.

Step #6 – Compilation of Student Assessments in a Usability Matrix

The information obtained from Forms 1, 2, and 3 was used to evaluate the usability of each model by the UU research staff. In this evaluation three usability attributes as established by the International Organization for Standardization (ISO) in publication ISO 9241:11 were considered:

> "1. Effectiveness: How well do the users achieve their goals using the system?
> 2. Efficiency: What resources are consumed in order to achieve their goals?
> 3. Satisfaction: How do the users feel about their use of the system?" (Abran et al, 2003)

According to this standard "software is usable when it allows the user to execute his task effectively, efficiently and with satisfaction in the specified context of use" (ISO, 1998). The effectiveness of a model is generally understood as the ability of the model to accurately model actual conditions. However this task was not evaluating whether users were able to accurate estimate actual environmental conditions through use of either model, but instead whether the users could accurately recreate the output produced in a control set. Therefore the term effectiveness was replaced with the more accurate descriptor, the ability to reproduce control set results.

Information from Form 1 regarding the time to complete sub-tasks was used to determine efficiency. Information from Form 2 regarding the results obtained from each model was used to determine the ability to reproduce control set results. Information from Form 3 regarding the modeler's sense of usability was used to determine satisfaction. A usability matrix was created to compile this information for comparison of the usability of each model.

Results

Student Modelers

As stated, two engineering students and two biology students were hired as modelers for this evaluation. All four were University of Utah students. Details regarding the study emphasis for each student as well as an assigned number for ease of reference are provided in Table 19. Students 1 and 2 completed HI-RUN modeling, then SELDM modeling. Students 3 and 4 completed SELDM modeling, then HI-RUN modeling.

Table 19: Student Modelers Employed

Student	Number	Department	Anticipated Degree
Zachary Magdol	1	Civil & Environmental Engineering	Masters of Science
Duncan Smith	2	Biology	Doctor of Philosophy
Travis Christensen	3	Civil & Environmental Engineering	Masters of Science
Peter Bergeson	4	Biology	Bachelor of Science

Training

For this task the time spent training the student modelers was longer for SELDM than for HI-RUN. HI-RUN training included use of the WSDOT training materials as detailed in step #2. This training took approximately 1.5 hours. SELDM training, including the web seminar hosted by Greg Granato and the work through of the step-by-step example, took approximately 4 hours. It is important to note that neither the HI-RUN nor SELDM training conducted during this study included information on all subjects as required in the BA qualification program. This full training program for new BA authors as currently conducted by WSDOT takes four days. Approximately 3 to 4 hours of this time is used for instruction on the stormwater analysis method. It is also important to note that the SELDM training conducted by Greg Granato included details regarding the purpose and methods associated with the model. While this information is critical to become an expert SELDM user, it is not necessary for basic users, such as those who would use the model in BAs. Observation of the training process by the UU research staff conclude that in practice training for SELDM should take only slightly longer than the training for HI-RUN; it is estimated that HI-RUN comparable SELDM training will take approximately 2.5 hours.

Form 1 - Efficiency

The information provided by the student modelers on Form 1 was used to determine the efficiency of each model. Copies of Form 1, as completed by the student modelers, are provided in Appendix V. The average total time required to complete modeling of the theoretical scenario, as recorded on Form 1, is provided in Table 20. Observation of the student modelers by UU research staff found that these times were generally under reported. The observed time required to complete modeling, for all four students and for both models, was approximately 1 hour. This total observed time includes time used for questions and answers and quick breaks, which partially explains the discrepancy. In addition, the construction of Form 1, with cells for total time per task rather than cells for a start and finish time, further accounts for the under-reporting. The reported times are used in this evaluation because it was decided these times best represent the time requirements per task and best reflect the students' assessment of efficiency.

Table 20: Time Required to Model Scenario

	HI-RUN (minutes)	SELDM (minutes)
Student 1	26	40
Student 2	44	23
Student 3	54	29
Student 4	17	12
Average Recorded Time	35	26

*NOTE: Average observed time was 60 minutes, see above paragraph.

To facilitate an apples to apples comparison in this usability study, student modelers were supplied with a pre-formatted Excel spreadsheet to use for processing the SELDM output. As noted in the background section of this report, SELDM output includes up to ten text output files with complete modeling results. In comparison HI-RUN output includes summary tables specifically tailored to the result requirements of a BA. The decision was made to provide this pre-formatted spreadsheet tool, rather than have the student modelers attempt to use the SELDM output directly to obtain the necessary results. The spreadsheet assisted the student modelers in importing the output text files into Excel and provided formulas to calculate values, such as median annual load, median concentration, and percent exceedance values comparing baseline to proposed conditions. These calculated values are similar to those provided in the HI-RUN output tables. The decision to provide the modelers with this tool was made based on the UU research staff experience using both models during Task 1. It is assumed that if WSDOT were to implement SELDM for standard use in BAs, an add-on tool to compile output and calculate the required values would need to be produced for ease of use and to guarantee consistent results. Consideration was given to this detail in Task 3, which investigates the costs associated with use of each model.

From the student comments provided on Form1 several recurring observations were noted. For HI-RUN, three comments stood out. One, the modelers had difficulty using the map that is provided for selection of a precipitation series. Two, the model run time was long, especially in comparison to SELDM. Three, the output tables were clear and easy to read. For SELDM, three comments stood out. One, training and the completion of a step-by-step example was critical considering the number of options and steps needed to model the scenario. Two, the model run time was quick. Three, the model output was difficult to interpret, even with the use of the provided spreadsheet tool.

Form 2 – Ability to Reproduce Control Set Results

The information provided by the student modelers on Form 2 (Appendix W) was used to determine the how well each user was able to accomplish their goals through use of each model. This was judged by whether the students were able to obtain the correct, or expected, answers through use of the model. Because both models are stochastic, output obtained by each of the four student modelers varied. Also, as determined in Task 1 of this study, output between each model varied. Therefore in order to test if the model output obtained and recorded by each student was correct the values were compared to a control set obtained from each model. Each of the HI-RUN and SELDM control sets consisted of ten runs of the scenario. If the output values obtained by the student modelers were between the minimum and maximum of the control set the output was considered right. Answers outside of this range were considered wrong. Further review of any wrong answers was completed in order to re-categorize any values that were evidently within the correct range but just outside the minimum and maximum of the control set (e.g., TCu load of 1.185 marked wrong because control range was 1.168 to 1.183). This complete analysis is provided in Appendix Y. The right and wrong answers were counted and the results as a percentage are provided in Table 21.

Table 21: Percentage of Correct Results Obtained

	HI-RUN (percent correct)	SELDM (percent correct)
Student 1	100%	41%
Student 2	87%	94%
Student 3	100%	100%
Student 4	81%	65%
Average	92%	75%

Analysis of the wrong answers obtained by Students 2 and 4 in the HI-RUN modeling found that this was the result of two errors. First, the load values were outside of the control range because the student modelers selected a different precipitation time series than was used in modeling the control set. Second, there was an error on the Stormwater Design Checklist provided to all student modelers; the stream depth for February was listed as 0.065 when it should have been 0.65. This error was recognized by Students 1 and 3, who entered the correct value in HI-RUN, but not by Students 2 and 4.

Analysis of the wrong answers obtained by Students 1, 2, and 4 in the SELDM modeling found that this was the result of two known errors and one unknown error. First, the wrong answers obtained by Student 1 were due to incorrect modeling of the BMP; review of the concentration values revealed that no BMP treatment was applied for the proposed conditions. Second, the wrong answers obtained by Student 4 were due to an alteration of the highway runoff concentration characteristics. Students received instructions regarding how to set a constant upstream concentration for DCu and DZn. Student 4 mistakenly adjusted the runoff concentration values for DCu and DZn to match the upstream concentration provided on the Stormwater Design Checklist. Students 2 and 4 obtained unexpected downstream concentrations for DCu; it was not possible to determine the cause of this result.

As stated, the ability to reproduce control set results for each model was evaluated by how well the users achieved their goals using each system. This was judged by whether the student modelers were able to model the scenario and produce model output that matched the control set for that model . However, in practice a user's goals would not be to match a control set, but rather to accurately estimate actual site conditions. A comparison of the ability of either HI-RUN or SELDM to accurately replicate actual environmental site conditions is clearly outside the scope of this project. Therefore any right or wrong answers produced simply show whether the student modelers were able to correctly navigate the model interface and reproduce the expected output. Right or wrong answers do need indicate accuracy of model methods. For example, in Task 1 the load values produced by SELDM were found to best match the load values produced using the Simple Method. In this task, if all load values produced by HI-RUN were judged in this manner, rather than in comparison to the HI-RUN control set, all output would have been found wrong.

Another aspect considered when assessing each model was whether the model could provide all the information required for the intended use. Under current policy requirements it is necessary to determine the downstream distance required for dilution to the biological effects threshold in a western Washington BA. The requirement does not reflect the state of practice in stormwater assessment, but instead relates directly to ESA assessments requirements to determine the "take" of a project. Currently it is not possible to obtain this value using the SELDM model. This is not deficiency of the model, and instead an intentional omission by the designers due to the questionable accuracy of this type of analysis (Granato, 2013b). However, unless the currently accepted methodology for western Washington is modified, this value is necessary to complete an assessment. This is addressed in Task 3 of this report, which considers costs of each model.

Form 3 – Satisfaction

The information provided by the student modelers on Form 3 (Appendix X) was used to determine the satisfaction of the student modelers in regards to each model. Form 3 is the Systems Usability Scale developed by John Brooke. A single score is obtained from this form and is used for comparison of usability. The score of each individual line item is not relevant. The instructions for calculating the overall score are as follows:

> "To calculate the SUS score, first sum the score contributions from each item. Each item's score contribution will range from 0 to 4. For items 1, 3, 5, 7, and 9 the score contribution is the scale position minus 1. For items 2, 4, 6, 8, and 10, the contribution is 5 minus the scale position. Multiply the sum of the scores by 2.5 to obtain the overall value of SU." (Brooke, 1996)

The overall score results calculated are provided in Table 22. Overall scores can range from 0 to 100, with 100 indicating a user assessment of high usability. The average of the four scores for each model was calculated. The score for HI-RUN was higher than the score for SELDM. Individually this was true in 3 of 4 cases. This indicates that the student modelers found HI-RUN more usable than SELDM, or in other words found more satisfaction in using the HI-RUN model. However, the scores were not drastically different and therefore show that in essence the student modelers were relatively satisfied with both HI-RUN and SELDM.

Table 22: Systems Usability Scale Scores

	HI-RUN	SELDM
Student 1	70	43
Student 2	68	55
Student 3	73	83
Student 4	65	55
Average	69	59

The student modelers' satisfaction level with each model is directly related to the context of use. In this study the students used both models to complete the step of BA in which HI-RUN is currently used. Therefore, this assessment is only valid within the context of western Washington BAs. If the models were used to complete a different task, the satisfaction rating might be different. Additionally, the student modeler's experience and expertise level directly relates to the satisfaction rating. In this study the criteria for high satisfaction with each model was mostly related to ease of use and model interface. A more experienced modeler, biologist, or engineer would likely consider other criteria when assessing satisfaction, such as accuracy of output and superiority of model methods.

Usability Matrix

The results from Forms 1, 2, and 3 were combined to create a usability matrix (Table 23). This matrix addresses each evaluation area; efficiency, the ability to reproduce control set results, and satisfaction. For efficiency, the individual time to complete each task and total time required to model the scenario, as recorded by the student modelers, is tabulated. For the ability to reproduce control set results, the percentage of required results for load, concentration, percent exceed, and dilution, are tabulated. These percentages reflect the correct answers, as determined through comparison with the control sets generated for each model. For satisfaction, the average Systems Usability Scale overall score is provided.

Table 23: Usability Matrix

		HI-RUN	SELDM
Efficiency	**Time to Complete Sub Tasks**	Minutes	Minutes
	Review Scenario Details	2	3
	Enter Scenario Details In Model	14	13
	Run Model	11	2
	Review Output	1	4
	Summarize Output	7	5
	Total Time to Complete	35	26
Ability to Reproduce Control Set Results	**Required Results Obtained**	Percent	Percent
	Load	50%	78%
	Concentration	95%	78%
	Percent Exceed	88%	70%
	Dilution	96%	75%
Satisfaction	**Systems Usability Scale Score**	69	59

Task 2 Summary

This purpose of this evaluation was to determine the usability of HI-RUN and SELDM exclusively for use in Western Washington BAs. Therefore two important steps were taken in order to provide an accurate usability comparison between HI-RUN, which was created for the sole purpose of use in BAs, and SELDM, which was created with a much more general purpose. The first step was the customization of SELDM with task specific local characterization data as used in HI-RUN. The second step was to provide the student modelers with a spreadsheet tool for use in compiling and interpreting SELDM output. These steps were considered representative of what would happen in practice should WSDOT adopt SELDM for use in BAs. For the purpose of efficiency, accuracy, and consistency, it is assumed that WSDOT would centrally customize SELDM and the method of interpreting output, rather than allow this to be completed by individual modelers. The results of this task would vary had these two steps not been incorporated.

The usability matrix combines the results obtained comparing the models in terms of efficiency, the ability to reproduce control set results, and satisfaction. As reported by the student modelers SELDM was more efficient. In practice this will likely be true as the model run time is significantly shorter for SELDM than for HI-RUN. For both models, the times to enter data and analyze the results would likely decrease as user familiarity increases. Analysis of output results obtained found that HI-RUN was more able to reproduce control set results. This analysis compared output from each model to a control set from each model, reflecting how well users were able to navigate each model interface in order to produce expected output. Correct answers do not reflect accuracy in terms of actual environmental conditions being modeled. Output produced by each model is clearly subject to any identified model limitations, and therefore is only “correct” in comparison to the control set. Finally, the scores from the Systems Usability Scale were slightly higher in most cases for HI-RUN than for SELDM, indicating that three out of four of the student modelers were more satisfied with HI-RUN. It is acknowledged that this is contingent on the context of use and modelers knowledge level of the process.

Chapter 3 - Task 3: Determine the Costs of Maintaining and Using the Models

Research Methods

The third task completed by the UU research staff in the ESA Analysis Model Comparison project was a cost benefit analysis of maintaining and using both HI-RUN and SELDM. In order to accomplish this task coordination with, and information from, WSDOT, Herrera Environmental Consultants, USGS, and FHWA was required. This task determined the costs associated with the continued use of HI-RUN for BAs and the costs associated with implementation and use of SELDM for BAs. For this study a time period of ten years was considered. Following is an outline of the steps taken in completing this task and the results of this analysis.

Step #1 – Determine Costs Associated with Updating and Maintaining HI-RUN

The first step in this task was to determine the costs associated with updating and maintaining HI-RUN. Although HI-RUN is a relatively new model it was assumed there are currently, or will soon be, necessary model updates in two areas; the water quality characterization of highway runoff and BMP outflow, and the characterization of quality parameters in waters upstream of project sites. The reason for these assumptions as well as the determined validity is detailed in the results.

Step #2 – Determine Costs Associated with Implementation of SELDM

The second step in this task was to determine the costs associated with the implementation of SELDM as part of the BA procedure. This includes costs for customization of SELDM for specific use in Western Washington BAs. It also includes costs associated with policy changes that would be necessary in order for the results produced by SELDM to be accepted by the various involved state and federal regulatory agencies. These implementation costs are separate from initial and ongoing training costs which were addressed in Step #4.

Step #3 – Determine Costs Associated with Updating and Maintaining SELDM

The third step in this task was to determine the costs associated with updating and maintaining SELDM. It was assumed that if SELDM were to be used in BAs update requirements relevant to HI-RUN would apply. It was also assumed that SELDM will be generally updated and maintained by the USGS and FHWA, but that certain updates and associated costs would be the responsibility of WSDOT. The reasons and findings related to these assumptions are detailed in the results.

Step #4 – Determine Training Costs for Both HI-RUN and SELDM

The fourth step in this task was to determine the costs associated with training WSDOT staff and consultants to use either HI-RUN or SELDM. These costs included ongoing training costs associated with the use of HI-RUN and both initial and ongoing training costs associated with the use of SELDM. Information from the results of Task 2 of this study was used in this step.

Step #5 – Compile Costs from Steps #1 through #4

The various costs estimated in Steps #1 through #4 were compiled and compared.

Results

Costs to Update and Maintain HI-RUN

The 2009 memorandum of agreement between WSDOT, FHWA, NMFS, and USFWS, which agrees to the use of HI-RUN for BAs, calls for regular updates of monitoring data used in the model. According to the HI-RUN technical documentation, it was agreed between these four agencies that locally obtained water quality data be used to characterize highway stormwater runoff and BMP outflow (Herrera, 2009). The documentation also states that data "were derived from a relatively small number of monitoring locations and BMP types" (p. 3, Herrera, 2009) and lists this as a limitation of the model. The data set used is from monitoring at eleven BMP sites as required by WSDOT's National Pollution Discharge Elimination System (NPDES) permitting requirements and monitoring at two BMP sites as part of WSDOT special studies. The majority of this monitoring occurred from 2005 to 2008, with one study going back to 2001. Although HI-RUN is programmed for two BMP types, basic and enhanced, limitations of the data set led to both types being characterized with the same statistical parameters.

From statements in the 2009 memorandum and HI-RUN documentation it was assumed that as more monitoring data from additional sites and greater time periods became available, the HI-RUN model would be updated. This assumption was confirmed during a conference call on May 14, 2013 between the UU research staff, WSDOT, and Herrera Environmental Consultants (Herrera). WSDOT and Herrera provided the following information. Currently there is not enough data available to update the model or separately define basic and enhanced BMPs. The estimate of when this will be possible is 1.5 years from May, 2013. Also there is no set schedule for updates. This timing is contingent on decisions regarding what sites are monitored and when the collected data, which must first undergo a separate WSDOT review process, becomes available. Given this, an estimated time of 2 years between updates was provided. To perform updates a new contract with Herrera will be required. The cost for updates will vary depending on the data received, but was estimated at $4,600 (40 hours at $90 per hour plus $1000 in contract fees). This cost estimate includes data processing to confirm data set distribution and calculate the necessary statistical values, the updating of these values in HI-RUN, and documentation of the process which is required in order to satisfy the services as to the legitimacy of the updates. The cost of monitoring to create the data set is not included, as this monitoring is required under NPDES permitting and would be completed regardless.

During the course of this study concern was raised regarding the validity of the data set used to create HI-RUN. Investigation into this concern by WSDOT revealed that one site in the data set, with monitoring prior to 2005, is suspect. Because of this it may be necessary to immediately update the statistics used in HI-RUN to characterize untreated and treated runoff. Therefore this cost estimate is included in this assessment. This cost would be the same as the cost to update the model, which is estimated at $4,600.

The current version of HI-RUN permits the user to enter a single upstream concentration value for DCu and DZn. In the HI-RUN technical documentation detailed steps are provided for the methods used in the model. Step 6 in the "Dilution Analysis Subroutine" is "Conduct Monte Carlo Simulation of Ambient Concentrations" (p. 24). This step refers to a user option for selecting a distribution of upstream concentrations, although in the current version of HI-RUN this option is not available. It was assumed that this option was originally planned but not implemented, and that this option would be implemented in future model updates. However, during the previously referenced May 14, 2013 conference call UU research staff was informed by Herrera that this exclusion was purposeful. Originally there were plans to include a regional or user defined distribution of upstream concentration values and HI-RUN included a stochastic upstream concentration function, however this option was removed. This decision was made by the working group that contributed to the development of HI-RUN (WSDOT, FHWA, NMFS, and USFWS) because of the difficulty in interpreting model output when this function was included. Currently there are no plans to re-add this function to the model in the future. However, this function may be required if policy or procedure were to change. Considering that initially the option was to be included in HI-RUN and that it is an option available in SELDM, costs for updating HI-RUN should be considered a potential maintenance cost.

A cost not included in this study but acknowledged is the cost to update HI-RUN with more current precipitation records. HI-RUN was created such that precipitation records are not directly used by the model. Rather the output obtained from modeling a one-acre impervious site in the WSDOT continuous hydrological simulation model, MGS Flood, was used to characterize stormwater runoff in HI-RUN. This includes monthly statistics for hourly discharge, monthly statistics for discharge durations, and annual statistics for total volume. A HI-RUN user selects a precipitation record and the appropriate runoff statistics are used for analysis. Because HI-RUN is a new model and the records used to create the runoff characteristics are extremely long (MGS Flood uses extended precipitation time series which result in records with lengths greater than 100 years (MGS, 2009)) an update will not be necessary within the ten year period considered for this project. However, when an update is required it will be necessary to re-model the one-acre impervious site in MGS Flood in order to update HI-RUN.

An additional cost not included in this study is the cost to update HI-RUN should this be required due to Microsoft software updates. According to the HI-RUN user's manual, the model was developed using Microsoft Excel 2003. The model was tested and found to work with both 32-bit and 64-bit versions of Microsoft Excel up to the 2013 version. However Microsoft software updates in the future may create problems for user's with newer software versions. This would require updates and changes to HI-RUN. Unfortunately, the associated costs are impossible to determine until this situation occurs.

Costs to Implement SELDM

The first cost associated with implementation of SELDM that was considered in this analysis was the cost to customize the model for use in Western Washington BAs. SELDM was built as a database application in order to provide user flexibility. SELDM can be customized with local data for water quality and with any number of user defined BMPs. Per the technical documentation for HI-RUN there was a general consensus amongst the involved agencies that data for characterization of highway runoff and BMP performance should be obtained from local monitoring studies so that the model results would be representative of actual Western Washington conditions (Herrera, 2009). Therefore if SELDM is to be used in lieu of HI-RUN, SELDM would need to be customized with local data. If implementation of SELDM occurred within the next 1.5 years (prior to the availability of a more current data set) this could be done using the same data set used to create HI-RUN. As part of Task 1 of this study, the customization process has been initiated. However, the methods and values used to customize SELDM would need to be reviewed and validated by WSDOT personnel before the model could be used in practice. This would include a careful review of the relevant sections of Chapter 1 of this report, processing of the WSDOT BMP summary data set used in the creation of HI-RUN in order to obtain the necessary statistics for SELDM, and entry of runoff water quality characterization statistics and BMP volume reduction and treatment statistics into SELDM. The individual completing this work would need to be trained as an expert SELDM user. Based on the time required by the UU research staff in completing this work for Task 1, it is estimated that this will require 50 hours. At $90 per hour the cost estimate for this work is $4,500.

There will also be costs associated with SELDM implementation that relate to policy changes that would be necessary. HI-RUN was developed in coordination between WSDOT, FHWA, NMFS, and USFWS as a "mutually acceptable approach for assessing the potential water quality effects of highway runoff" (Herrera, 2011, p. 1). It was developed for specific use in BAs which are required as part of ESA Section 7 consultations. To modify the currently accepted approach, which accepts output from HI-RUN as proof of a planned project's ability to effectively mitigate possible impacts on ESA species, the agencies would need to accept results from SELDM as providing the same assurance. Such a policy change would have associated costs. Before an estimate cost range can be developed, WSDOT would need to decide to pursue such an effort and meet with the involved agencies to determine how extensive this process would be. Lacking such efforts a review of the costs involved in the Analyzing Stormwater Effects on ESA Listed Species project, as detailed in the WSDOT Biological Assessments section of this report, is provided following in order to demonstrate the possible costs involved.

Per WSDOT records, the total cost of the Analyzing Stormwater Effects on ESA Listed Species was $257,756. This total was paid to Herrera Environmental Consultants, Inc. but includes the costs paid to sub-consultants for two of the white papers. A total of 13 invoices related to this total, from the period December 2006 to March of 2009, were provided by WSDOT to the UU research team for review. From these invoices costs for four different components of this work were summarized. These four components include the cost of the four white papers completed, the cost to build the HI-RUN model, the cost for conducting the workshops necessary to arrive at an accepted approach between the involved agencies, and Herrera's administrative costs. Table 24 provides the detail of these costs. Not included in this total is the cost of WSDOT, FWHA, NMFS, and USFWS personnel hours spent during this process. Through review of the Herrera invoices it was determined that approximately 9 two hour workshops were held during this project. WSDOT estimates that 4 to5 WSDOT employees, 2 FHWA employees, 2 NMFS employees, and 2 USFWS employees attended these workshops. This amounts to a total of 180 to 198 personnel hours spent in meetings.

Table 24: Component Costs for the "Analyzing Stormwater Effect on ESA Listed Species" Project

Project Component	Total
White Papers	$104,083
Build HI-RUN	$88,613
Meetings/Workshops	$58,945
Administration	$18,721
Unallocated Credit (from Phase III)	-$12,606.7

It is assumed that the cost to modify policy to allow SELDM to be used in place of HI-RUN would be much less than that associated with the process that led to the development of HI-RUN and the 2009 MOA. Because there is now a framework of cooperation is in place between the necessary agencies, this type of change should require less time and cost. However, this process would still require meetings with the various agencies to provide the information necessary to gain approval for this policy change. This report, especially the results from Task 1 which compare the output from HI-RUN and SELDM, would be useful in this process.

From Tasks 1 and 2 of this study, another cost associated with implementation of SELDM was identified. Task 1 of this study required investigation into whether all output types provided by HI-RUN can also be provided or calculated using output from SELDM. The results of Task 1 found that a value currently required in BAs cannot be produced using SELDM output; this is the downstream distance required for mixing to meet the biological effects threshold limit. SELDM output does provide the data necessary to obtain the other values required for BAs, such as annual load, median concentrations, and percent exceed values. However unlike HI-RUN a summary of these values is not directly provided in model output. Some data compilation is required and some values must be calculated. In Task 1and 2 of this study this was done using a pre-formatted Excel spreadsheet. Because of these findings from Tasks 1 and 2, the UU research staff recommends the development of a tool to be used with SELDM. An add-on tool could be developed to calculate the required downstream distance and summarize the model output. This would allow the model to be used efficiently and effectively in BAs and provide all the information currently required. The creation of such a tool is beyond the scope of this study, as is the estimation of the cost of such a tool. However this additional cost was considered in this analysis.

Costs to Update and Maintain SELDM

As with HI-RUN, there will be costs to update and maintain SELDM in order to comply with the 2009 memorandum of agreement. Although SELDM will be generally maintained by the USGS and FHWA, updates to the model with customized local statistics, such as characterization of runoff quality and BMP outflow quantity and quality, will be the responsibility of WSDOT.

Other parameters in SELDM, such as precipitation records, stream flow statistics, and runoff coefficient equations, will be updated by the USGS and FHWA if needed. Table 25 provides a list of parameters within SELDM and the party that would be responsible for updating these parameters. According to correspondence from the USGS, the four parameters listed as USGS/FHWA responsibility are from such robust data sets that there will be no need to update within the 10 year time frame considered in this study (Granato, 2013b). The cost estimate to update the other parameters listed as WSDOT responsibility is the same as the cost estimate to update HI-RUN, which is $4,600 every two years. As with HI-RUN, this cost estimate includes data processing, the updating of these values in SELDM, and documentation of the process. Again, the cost of monitoring to create the data set is not included, as this monitoring is required under NPDES permitting and would be completed regardless.

Table 25: Summary of SELDM Input Parameters

Input Parameters:	Updated By:
Precipitation Statistics	USGS/FHWA
Highway Site Runoff Coefficient	USGS/FHWA
Upstream Basin Runoff Coefficient	USGS/FHWA
Stream Flow	USGS/FHWA
Highway Site Runoff Quality	WSDOT
Upstream Quality	WSDOT
BMP Treatment Efficiency – Quantity	WSDOT
BMP Treatment Efficiency - Quality	WSDOT

It may be possible for WSDOT to decrease the cost of updating SELDM by submitting the monitoring data set for inclusion in the Highway Runoff Database (HRDB). This database was created by the USGS and FHWA as a data preprocessor for SELDM. Version 1.0 of the database includes monitoring data from 12 Western Washington sites from 2001 to 2005. In general this monitoring data is older than the monitoring data that was used in creating HI-RUN and customizing SELDM in Task 1 of this study, although one site is included in both data sets. Currently plans for updating the HRDB are uncertain (Granato, 2013b). If the HRDB were to be updated, the most economical way for WSDOT to obtain the statistics necessary to populate SELDM would be to submit monitoring data for inclusion in the database. The HRDB provides all necessary data processing so that once a data set is included the necessary statistics can be generated for entry into SELDM.

As with HI-RUN, a cost not included in this study is the cost to update SELDM should this be required due to Microsoft software updates. SELDM is built on a Microsoft Access platform and HI-RUN is built on a Microsoft Excel platform. Unlike HI-RUN, which requires that a user has Microsoft Excel on their computer to run the model, the SELDM installation package includes a run-time version of Access. This allows a user to run SELDM even if they do not have Microsoft Access. This also provides flexibility in that SELDM will not require updating in order to be compatible with updated versions of Access. In addition, were such updates required the associated costs would be the responsibility of USGS and FHWA. Therefore this is not considered a possible future cost to WSDOT, where software updates could result in future costs related to the maintenance of HI-RUN.

Training Costs for HI-RUN

In addition to the costs to update and maintain HI-RUN, there are ongoing costs associated with training staff and consultants to use HI-RUN for the purpose of BAs. As noted in Chapter 2, individuals who conduct BA are qualified by WSDOT in a training program. The well-developed training materials used in this program were provided to the UU research staff by WSDOT for use in Task 2 of this study. Although these materials will need to be updated as updates are made to HI-RUN, these changes will be minimal and the associated costs insignificant to comparison to total training costs. According to WSDOT, current BA training sessions cost an estimated $30,000 to $40,000 per year. WSDOT estimates that 10% of this cost ($3,000 to $4,000 per year) is specifically for HI-RUN training. The high end of this range will be used as the estimate for ongoing training costs in this analysis.

Training Cost for SELDM

Two training costs were considered for SELDM. The first cost was initial model training for all individuals currently qualified to perform BAs. WSDOT estimates that there are currently 100 individuals that would require initial SELDM training. The USGS and FHWA plan to host three different training courses for SELDM: a 1-hour webex, a 4-hour webex, and a three day training course. These courses will be offered at no charge. The SELDM manual, including appendices is also available at no charge. However WSDOT will need to develop training materials specific to use of SELDM in western Washington BAs and host a training course for this same purpose. The incorporation of the free USGS/FHWA provided training will decrease the initial training costs to WSDOT, however due to the specific nature of the intended use there will certainly be additional training requirements.

The incurred cost of HI-RUN training was used to estimate potential training costs for SELDM. According to WSDOT records the initial one day training for the HI-RUN model cost $39,578. This cost included a pre-release workshop with representatives from the services, the development of HI-RUN reference and training materials, the cost for instructors to provide training, and administrative costs. The portion of this total cost that relates to development of reference and training material was $21,354.

It is assumed that SELDM materials can be developed for approximately half the cost of the HI-RUN reference and training material development if WSDOT uses the USGS/FHWA provided training materials and the step-by-step example developed as part of Task 2 of this study. These materials would be inserted in the BA training program currently in use. This cost estimate would also cover related expenses, such as required updates to all BA materials and updates to online resources.

It was estimated by WSDOT during the previously referenced May 14, 2013 conference call that the cost to host a one day training session for SELDM, not including material development, would be $6,000 to $10,000. Therefore initial training for SELDM is estimated at $17,000 to $20,000; $10,000 for material development and $6,000 to $10,000 to the hosting the training. The mid-range of this estimate, $18,500, is used in the summary of costs.

The second training cost considered for SELDM was for ongoing training similar to what currently exists for HI-RUN. This ongoing training would be included in the BA qualification program, in place of HI-RUN training. From Task 2 of this study it was determined that SELDM training took 2.5 hours in comparison to 1.5 hours for HI-RUN training. Using this ratio ongoing SELDM training costs would be slightly higher than HI-RUN costs. However, based on further discussion with WSDOT, and the fact that stormwater effects training is just a small part of the overall BA training program, it was decided that the same estimate value used for ongoing HI-RUN training most accurately represents ongoing SELDM training costs. Therefore the estimate of $4,000 is used in the summary of costs.

Compilation of Costs

The costs estimated in this task were compiled for each model (Table 26). Costs for HI-RUN include updates to the model and training; the ongoing annual cost estimate is $6,300. Costs for SELDM include updates to the model and training, as well as initial implementation costs; the initial cost estimate is $23,000, plus the cost of policy change and the add-on tool. The ongoing annual cost estimate is $6,300.

Table 26: Summary of Costs for HI-RUN and SELDM

	HI-RUN	SELDM
Model Update	$4,600	
Customization		$4,500
Policy Change		unknown
Add-On Tool		unknown
Training		$18,500
Total Initial Costs	**$4,600**	**$23,000 plus policy change and add-on tool cost**
Model Updates	$2,300*	$2,300*
Training	$4,000	$4,000
Total Annual Costs	**$6,300**	**$6,300**

*$4,600 every two years

Task 3 Summary

The result of this task was an estimate of the costs associated with use and maintenance of either HI-RUN or SELDM. Annual ongoing costs for model updates and training will apply to either model. As seen in Table 26 these costs are estimated to be the same. Several costs associated with switching from the use of HI-RUN to SELDM for future WSDOT BAs were investigated. These initial implementation costs associated with SELDM are significant and include the most uncertainty. All costs were summarized for comparison purposes.

Final Discussion

Task 1

In the first task of this study output from HI-RUN and SELDM was compared. The purpose of this comparison was to test if each model could produce similar output. This is significant because HI-RUN modeling is included in the current analytic method required for the assessment of stormwater effects in a western Washington BA. To complete an assessment under current policy requirements output similar to that produced by HI-RUN is required. In this task it was found that in practice each model produced output that would result in a similar assessment of risk, even though the majority of output was found to be statistically different. The one exception to this conclusion is the load values produced. However, the percent exceedance values associated with load were similar between each model. Because it is most important in a BA to determine the increased risk of negative impacts to ESA species from a proposed project, the percent exceedance value, which compares existing and proposed conditions, is of greater importance than the actual load estimate.

In order to obtain output from SELDM that could be quantitatively compared to output from HI-RUN, steps were taken they may not represent the best option for use of the model in practice. Runoff coefficient statistics were selected to best match runoff volume. In practice, these statistics would be selected to best match environmental conditions. Upstream concentrations are modeled as a stochastic variable in SELDM. In HI-RUN, upstream concentrations are constant. For comparison purposes statistics were entered in SELDM to remove the stochastic variability.

Output types produced by HI-RUN can generally be replicated through use of SELDM, except in regards to dilution analysis. HI-RUN output includes a downstream distance to meet the biological effects threshold. This value is used to determine the take of a project. SELDM does not include the ability to calculate a mixing distance. This is not a deficiency of the model and the model includes many other output types that can be used to assess the effects of stormwater on the receiving water. However, under the current WSDOT analytical approach used for BAs a distance calculation is required.

Task 2

In the second task of this study the usability of each model for analysis in western Washington BAs was evaluated. This was not a general usability assessment, but rather a context specific evaluation, which is effectively the only way to assess the usability of any product. Due to the context of use for this study, certain steps were taken to facilitate the comparison. These include the customization of SELDM prior to distribution of the model to the student modelers and provision of the spreadsheet tool to compile and interpret SELDM output. It was assumed that in practice WSDOT would also take similar steps. In this task SELDM and HI-RUN were found to have similar overall usability. SELDM was more efficient, where HI-RUN had a greater user satisfaction rating. A stipulation to the usability assessment was noted. Under current WSDOT policy requirements SELDM can not be used to produce all information required for a BA; SELDM can not be use to replicate the dilution analysis done by HI-RUN that results in a downstream distance value. However, this analysis could be accomplished with SELDM output and an add-on tool using RIVPLUM methods. This fact is accounted for in Task 3 within SELDM implementation costs.

An aspect of usability not assessed in this study that should be considered is the usability of either model given the potential for future policy change. Because HI-RUN was built to be a simple model capable of completing a specific task, it does not include much flexibility. In comparison SELDM was built for a broader purpose and includes the ability for user customization. This fact would affect the evaluation of usability in many possible policy change situations. For example, if the Services were to require analysis of an additional water quality parameter in addition to the five currently included in HI-RUN, the HI-RUN model would need to be updated by Herrera. Because SELDM can be populated with any number of water quality parameters by the user, this update could be made by a WSDOT expert SELDM user. In either case, updated models would then be re-released to the BA qualified authors for use.

Task 3

In the third task of this study the costs of maintaining and using each model were assessed. These costs included the ongoing costs associated with HI-RUN use and the initial and ongoing costs associated with SELDM use. It was found that ongoing costs related to use of either model would be similar. It was also found that initial implementation costs for SELDM are difficult to estimate, but are most likely substantial.

It is important to note that the implementation costs discussed in this study are related to the intended use. SELDM is a free model and can be used by WSDOT at no cost. The implementation costs identified in this study are related to the specific use of SELDM for western Washington BAs. In addition, these costs are only relevant under current policy requirements. If SELDM had been available for use in BAs prior to the signing of the MOA the associated implementation costs would vary significantly. Because there is now a framework under which assessments must be done and an approach that must be followed, the implementation costs are higher.

As with usability the evaluation of costs would change if policy were to change. If a change were made requiring upstream concentrations to be modeled as stochastic variables additional costs to WSDOT would be incurred related to updating HI-RUN. Also, if policy required the analysis of additional water quality parameters costs would be incurred. This is especially true for HI-RUN, where any changes to the model must be completed by Herrera. Modifications to SELDM would also incur costs, but because these modifications can be completed by WSDOT personnel, the costs would likely be less.

Conclusion

Although HI-RUN and SELDM are in many ways similar there are also important differences between the models. HI-RUN was designed and created for western Washington BAs. It was not built to be a general purpose stormwater analysis tool or to be a design tool. HI-RUN was created with a limited scope of purpose and therefore can only be used to complete analysis for BAs for western Washington; the model is not applicable for eastern Washington. HI-RUN includes a set number of water quality parameters and BMP types available for assessment. This cannot be modified by the user. The model includes two components, “Loading” and “Dilution”. Unlike HI-RUN, SELDM was not created specifically for the purpose of western Washington BAs. SELDM was designed as an update to the 1990 FHWA model. It is a planning level model that is designed to be applicable nationwide. SELDM is a complex model with a wide range of analysis possibilities. The model is prepopulated with enough parameters to allow for use during the planning stage of a project when limited data is available, but also allows for user customization so any number of water quality parameters and BMP types can be assessed. Because the model was created for a general purpose of use there are multiple components and method options, many of which were not used or explored in this study.

One possible benefit related to the use of either HI-RUN or SELDM that was not investigated in this study is whether either model is useful to WSDOT for more than analysis of water quality related stormwater effects for western Washington BAs. Due to the design of each model this is more likely possible for SELDM. Many components of SELDM, such as the lake basin analysis option, the ability to model water quality constituents using dependent relationships, and the adverse effect calculation option, were not be used in this study. However these and other model components may be of use to WSDOT in various capacities. For example, the lake basin analysis option may be useful statewide for BAs. Currently HI-RUN cannot be used in analysis of discharges to lakes or estuarine water bodies. Instead a separate model, CORMIX, is recommended for this type of analysis. In addition, because SELDM output includes all modeling results, the data can be used to perform a wide range of analysis. SELDM was designed to allow for user modifications. This model flexibility allows for the tool to be employed for more than just a specific task. Therefore an expert SELDM user may be able to identify other tasks completed by WSDOT where the use of SELDM would generate time and money savings.

This project provides a comparison between HI-RUN and SELDM. The purpose of the comparison was to determine the benefits and costs of using either HI-RUN or SELDM for analysis in the stormwater effects component of a western Washington BA. Because HI-RUN was created specifically for this purpose and SELDM was not, certain steps were taken to facilitate the comparison of these two models for the intended use. As noted in the introduction of this report, the design of the study contains certain inherent bias. This includes the fact that this comparison was completed within the context of the currently accepted analytical approach and policy requirements, which require not only use of HI-RUN but are also based on methods used and the output types provided by this model. This study and report do not provide a general assessment of either model or an assessment of the underlying methods used in either model. Additionally, this report does not provide an assessment of the current analytical approach used by WSDOT in conducting stormwater effects assessment for ESA listed species.

The result of the tasks completed in this study lead to three primary conclusions. First, it was found that both models provide a similar assessment in the analysis of stormwater effects in BAs. Second, with pre-customization of SELDM, provision of the spreadsheet tool to compile and summarize SELDM output, and the noted stipulation regarding the dilution analysis, both models were found to be equally usable in analysis for western Washington BAs. Third, ongoing costs of using each model were found to be similar but initial implementation costs related to use of SELDM for a western Washington BA were found to be significant. Based on this cost of implementation, it is recommended that WSDOT continue using HI-RUN. It should be noted that this recommendation applies under current policy requirements. In the case of a change to the accepted analytical method, due to additions to the scope of the required analysis or revisions to the accepted methodology, the conclusions of this study would change. These facts should be considered and a re-evaluation conducted given changed circumstances. In addition, because SELDM is designed for a broader scope of purpose and includes the ability for user customization, it is recommended that WSDOT further investigate other possible uses of the model.

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Appendix A: Memorandum of Agreement between WSDOT, FHWA, NMFS, and USFWS

The Federal Highway Administration	National Marine Fisheries Service	US Fish and Wildlife Service	WA State Department of Transportation

MEMORANDUM

February 16, 2009

To: Applicable Agency Staff

Re: **Analytic Approach to be used in Assessing Stormwater Effects in Biological Assessments**

The Federal Highway Administration (FHWA), National Marine Fisheries Service (NMFS), US Fish and Wildlife Service (USFWS), and Washington State Department of Transportation (WSDOT) have agreed to use the Hi-Run Model, its user guide and the accompanying stormwater assessment guidance that is included in WSDOT's Biological Assessment Preparation for Transportation Projects document in consultations on western Washington projects with the potential to have stormwater effects on listed species.

This model was developed through an 18-month process that included monthly meetings with key policy and technical staff from the signatory agencies and technical staff from Herrera Environmental Consultants.

All WSDOT projects with Biological Assessments (BAs) submitted 60 days from the date of this agreement are required to use the approach outlined above for analysis of stormwater affects unless the stormwater analysis was started prior to this date. In those cases, the BA can be submitted using the existing stormwater analytic approach.

Local agency projects that have already started preparing project BAs have a six-month "grandfather period" during which the use of this new stormwater analysis method and model is recommended, but will not be required. However, all local agency BAs submitted to NMFS and USFWS for initiating consultation after August 16, 2009, will be required to use the new methodology in analyzing the potential effects of stormwater on ESA-listed species.

WSDOT provided training to WSDOT and local agency staff and consultants on this approach in September, October, and November 2008. Additional training will be provided by WSDOT on a yearly basis. In addition, a DVD from the September training session is available for self study.

The agencies agree to revisit the guidance regularly to determine how well it is working and what, if any, modifications are required, in addition to updating the monitoring data used to determine pollutant levels. The first evaluation will occur one year after implementation.

If you have questions on the approach, please contact WSDOT's Fish and Wildlife Program Manager at (360) 705-7404.

John Grettenberger
CTA Division Manager

Kevin Ward, P.E.
Assistant Division Administrator

U.S. Department of Transportation
Federal Highway Administration

Michael Grady, Branch Chief
WA State Habitat Office

NOAA FISHERIES SERVICE

Megan White, P.E., Director
Environmental Services Office

Washington State
Department of Transportation

Appendix B: Case Study Details Sample Forms

HI-RUN Case Study Details - Sample Form

Location of TDA Case Study: ______________________________

Number of Outfalls for TDA: ______________________________

NOTE: The area contributing to each outfall must be treated as a separate subbasin.

State Route and Milepost of Outfall: ______________________________

Water Quality Parameters to be Analyzed:

Total Suspended Solids	Total Copper	Dissolved Copper	Total Zinc	Dissolved Zinc

Months of Interest:

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

Baseline (i.e., Pre-Project) Stormwater Facilities

Treatment Type	Level of Infiltration	Subbasin 1 Impervious Area (acres)	Subbasin 2 Impervious Area (acres)	Subbasin 3 Impervious Area (acres)	Subbasin 4 Impervious Area (acres)	Subbasin 5 Impervious Area (acres)
Basic	0%					
	20%					
	40%					
	60%					
	80%					
Enhanced	0%					
	20%					
	40%					
	60%					
	80%					
None						
Infiltration BMP	100%					

Proposed (i.e., Post Project) Stormwater Facilities

Treatment Type	Level of Infiltration	Subbasin 1 Impervious Area (acres)	Subbasin 2 Impervious Area (acres)	Subbasin 3 Impervious Area (acres)	Subbasin 4 Impervious Area (acres)	Subbasin 5 Impervious Area (acres)
Basic	0%					
	20%					
	40%					
	60%					
	80%					
Enhanced	0%					
	20%					
	40%					
	60%					
	80%					
None						
Infiltration BMP	100%					
Flow Control (Detention)		Yes / No	Yes / No	Yes / No	Yes / No	Yes / No

Basic Treatment BMPs include Vegetated Filter Strip, Biofiltration Swale, Wet Biofiltration Swale, Continuous Inflow Biofiltration Swale, and Wet Pond.

Enhanced Treatment BMPs include Compost-Amended Vegetated Filter Strip, Media Filter Drain (previously named Ecology Embankment), and Constructed Stormwater Treatment Wetland.

Inputs for Receiving Water Dilution Subroutine

Stormwater Parameter	Background Concentration (mg/L)
Copper - Dissolved	
Zinc - Dissolved	

Drainage Subbasin # NOTE: This section must be completed for each subbasin

Receiving Water Characteristics Downstream from Discharge	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Stream depth (ft)												
Stream velocity (fps)												
Channel width (ft)												
□Stream slope (ft/ft) or □Manning's roughness "n" *(Check one)*												
Discharge distance into receiving waterbody from nearest shoreline												

Drainage Subbasin #

Receiving Water Characteristics	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Stream depth (ft)												
Stream velocity (fps)												
Channel width (ft)												
□Stream slope (ft/ft) or □Manning's roughness "n" *(Check one)*												
Discharge distance into receiving waterbody from nearest shoreline												

Drainage Subbasin #

Receiving Water Characteristics	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Stream depth (ft)												
Stream velocity (fps)												
Channel width (ft)												
□Stream slope (ft/ft) or □Manning's roughness "n" *(Check one)*												
Discharge distance into receiving waterbody from nearest shoreline												

SELDM Case Study Details – Sample Form

Project Name: ____

Project Location: ____

Latitude & Longitude: ____

Baseline (i.e., Pre-Project) Site Characteristics

	Drainage Area (acres)	*Drainage Length (feet)*	*Mean Basin Slope (feet per mile)*	*Impervious Fraction*	*Basin Development Factor*	
Highway Site						
Upstream Basin						

Baseline (i.e., Pre-Project) Stormwater Facilities

BMP Type	*Area Treated (acres)*	*Level of Infiltration*				

Proposed (i.e., Post Project) Site Characteristics

	Drainage Area (acres)	*Drainage Length (feet)*	*Mean Basin Slope (feet per mile)*	*Impervious Fraction*	*Basin Development Factor*	
Highway Site						
Upstream Basin						

Baseline (i.e., Post Project) Stormwater Facilities

BMP Type	*Area Treated (acres)*	*Level of Infiltration*				

Appendix C: Critical Values of the t-Distribution

t Table

cum. prob	$t_{.50}$	$t_{.75}$	$t_{.80}$	$t_{.85}$	$t_{.90}$	$t_{.95}$	$t_{.975}$	$t_{.99}$	$t_{.995}$	$t_{.999}$	$t_{.9995}$
one-tail	0.50	0.25	0.20	0.15	0.10	0.05	0.025	0.01	0.005	0.001	0.0005
two-tails	1.00	0.50	0.40	0.30	0.20	0.10	0.05	0.02	0.01	0.002	0.001
df											
1	0.000	1.000	1.376	1.963	3.078	6.314	12.71	31.82	63.66	318.31	636.62
2	0.000	0.816	1.061	1.386	1.886	2.920	4.303	6.965	9.925	22.327	31.599
3	0.000	0.765	0.978	1.250	1.638	2.353	3.182	4.541	5.841	10.215	12.924
4	0.000	0.741	0.941	1.190	1.533	2.132	2.776	3.747	4.604	7.173	8.610
5	0.000	0.727	0.920	1.156	1.476	2.015	2.571	3.365	4.032	5.893	6.869
6	0.000	0.718	0.906	1.134	1.440	1.943	2.447	3.143	3.707	5.208	5.959
7	0.000	0.711	0.896	1.119	1.415	1.895	2.365	2.998	3.499	4.785	5.408
8	0.000	0.706	0.889	1.108	1.397	1.860	2.306	2.896	3.355	4.501	5.041
9	0.000	0.703	0.883	1.100	1.383	1.833	2.262	2.821	3.250	4.297	4.781
10	0.000	0.700	0.879	1.093	1.372	1.812	2.228	2.764	3.169	4.144	4.587
11	0.000	0.697	0.876	1.088	1.363	1.796	2.201	2.718	3.106	4.025	4.437
12	0.000	0.695	0.873	1.083	1.356	1.782	2.179	2.681	3.055	3.930	4.318
13	0.000	0.694	0.870	1.079	1.350	1.771	2.160	2.650	3.012	3.852	4.221
14	0.000	0.692	0.868	1.076	1.345	1.761	2.145	2.624	2.977	3.787	4.140
15	0.000	0.691	0.866	1.074	1.341	1.753	2.131	2.602	2.947	3.733	4.073
16	0.000	0.690	0.865	1.071	1.337	1.746	2.120	2.583	2.921	3.686	4.015
17	0.000	0.689	0.863	1.069	1.333	1.740	2.110	2.567	2.898	3.646	3.965
18	0.000	0.688	0.862	1.067	1.330	1.734	2.101	2.552	2.878	3.610	3.922
19	0.000	0.688	0.861	1.066	1.328	1.729	2.093	2.539	2.861	3.579	3.883
20	0.000	0.687	0.860	1.064	1.325	1.725	2.086	2.528	2.845	3.552	3.850
21	0.000	0.686	0.859	1.063	1.323	1.721	2.080	2.518	2.831	3.527	3.819
22	0.000	0.686	0.858	1.061	1.321	1.717	2.074	2.508	2.819	3.505	3.792
23	0.000	0.685	0.858	1.060	1.319	1.714	2.069	2.500	2.807	3.485	3.768
24	0.000	0.685	0.857	1.059	1.318	1.711	2.064	2.492	2.797	3.467	3.745
25	0.000	0.684	0.856	1.058	1.316	1.708	2.060	2.485	2.787	3.450	3.725
26	0.000	0.684	0.856	1.058	1.315	1.706	2.056	2.479	2.779	3.435	3.707
27	0.000	0.684	0.855	1.057	1.314	1.703	2.052	2.473	2.771	3.421	3.690
28	0.000	0.683	0.855	1.056	1.313	1.701	2.048	2.467	2.763	3.408	3.674
29	0.000	0.683	0.854	1.055	1.311	1.699	2.045	2.462	2.756	3.396	3.659
30	0.000	0.683	0.854	1.055	1.310	1.697	2.042	2.457	2.750	3.385	3.646
40	0.000	0.681	0.851	1.050	1.303	1.684	2.021	2.423	2.704	3.307	3.551
60	0.000	0.679	0.848	1.045	1.296	1.671	2.000	2.390	2.660	3.232	3.460
80	0.000	0.678	0.846	1.043	1.292	1.664	1.990	2.374	2.639	3.195	3.416
100	0.000	0.677	0.845	1.042	1.290	1.660	1.984	2.364	2.626	3.174	3.390
1000	0.000	0.675	0.842	1.037	1.282	1.646	1.962	2.330	2.581	3.098	3.300
z	0.000	0.674	0.842	1.036	1.282	1.645	1.960	2.326	2.576	3.090	3.291
	0%	50%	60%	70%	80%	90%	95%	98%	99%	99.8%	99.9%
	Confidence Level										

http://www.sjsu.edu/faculty/gerstman/StatPrimer/t-table.pdf

Appendix D: Data Compilation & Analysis Spreadsheet

HI-RUN Data Compilation & Analysis Spreadsheet – Sample Form

Load							Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Test
Baseline TSS	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Proposed TSS	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
TSS	P (exceed)	0.5	0.5	0.5	0.5	0.5	15	0.5	0	0	0.05	PASS
Baseline Total Copper	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Proposed Total Copper	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Total Copper	P (exceed)	0.5	0.5	0.5	0.5	0.5	15	0.5	0	0	0.05	PASS
Baseline Dissolved Copper	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Proposed Dissolved Copper	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	P (exceed)	0.5	0.5	0.5	0.5	0.5	15	0.5	0	0	0.05	PASS
Baseline Total Zinc	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Proposed Total Zinc	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Total Zinc	P (exceed)	0.5	0.5	0.5	0.5	0.5	15	0.5	0	0	0.05	PASS
Baseline Dissolved Zinc	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Proposed Dissolved Zinc	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Zinc	P (exceed)	0.5	0.5	0.5	0.5	0.5	15	0.5	0	0	0.05	PASS

Concentration							Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Test
Baseline TSS	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Proposed TSS	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
TSS	P (exceed)	0.5	0.5	0.5	0.5	0.5	15	0.5	0	0	0.05	PASS
Baseline Total Copper	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Proposed Total Copper	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Total Copper	P (exceed)	0.5	0.5	0.5	0.5	0.5	15	0.5	0	0	0.05	PASS
Baseline Dissolved Copper	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Proposed Dissolved Copper	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	P (exceed)	0.5	0.5	0.5	0.5	0.5	15	0.5	0	0	0.05	PASS
Baseline Total Zinc	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Proposed Total Zinc	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Total Zinc	P (exceed)	0.5	0.5	0.5	0.5	0.5	15	0.5	0	0	0.05	PASS
Baseline Dissolved Zinc	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Proposed Dissolved Zinc	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Zinc	P (exceed)	0.5	0.5	0.5	0.5	0.5	15	0.5	0	0	0.05	PASS

Biological Effect Thresholds							
DCu Threshold	Background Concentration	0.020	Allowable Increase	0.0020		Total	0.0220
DZn Threshold	Background Concentration	0.010	Allowable Increase	0.0056		Total	0.0156

Baseline Distance							Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Test
Dissolved Copper	January	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	February	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Zinc	January	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Zinc	February	1	1	1	1	1	15	1	0	0	0.1	PASS

Proposed Distance							Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Test
Dissolved Copper	January	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	February	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Zinc	January	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Zinc	February	1	1	1	1	1	15	1	0	0	0.1	PASS

SELDM Data Compilation & Analysis Spreadsheet – Sample Form

Highway Load							Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Test
Baseline TSS	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Proposed TSS	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Baseline Total Copper	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Proposed Total Copper	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Baseline Dissolved Copper	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Proposed Dissolved Copper	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Baseline Total Zinc	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Proposed Total Zinc	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Baseline Dissolved Zinc	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Proposed Dissolved Zinc	Median	1	1	1	1	1	15	1	0	0	0.1	PASS

Highway Concentration							Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Test
Baseline TSS	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Proposed TSS	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Baseline Total Copper	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Proposed Total Copper	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Baseline Dissolved Copper	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Proposed Dissolved Copper	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Baseline Total Zinc	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Proposed Total Zinc	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Baseline Dissolved Zinc	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Proposed Dissolved Zinc	Median	1	1	1	1	1	15	1	0	0	0.1	PASS

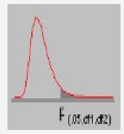
Discharge Load							Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Test
Baseline TSS	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Proposed TSS	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Baseline Total Copper	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Proposed Total Copper	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Baseline Dissolved Copper	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Proposed Dissolved Copper	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Baseline Total Zinc	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Proposed Total Zinc	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Baseline Dissolved Zinc	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Proposed Dissolved Zinc	Median	1	1	1	1	1	15	1	0	0	0.1	PASS

Discharge Concentration							Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Test
Baseline TSS	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Proposed TSS	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Baseline Total Copper	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Proposed Total Copper	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Baseline Dissolved Copper	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Proposed Dissolved Copper	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Baseline Total Zinc	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Proposed Total Zinc	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Baseline Dissolved Zinc	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Proposed Dissolved Zinc	Median	1	1	1	1	1	15	1	0	0	0.1	PASS

Downstream Concentration							Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Test
Dissolved Copper	Median	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Zinc	Median	1	1	1	1	1	15	1	0	0	0.1	PASS

Appendix E: F-distribution Chart

F Table for alpha=.05



df2/df1	1	2	3	4	5	6	7	8	9	10	12	15	20	24	30	40	60	120	INF
1	161.4476	199.5000	215.7073	224.5832	230.1619	233.9860	236.7684	238.8827	240.5433	241.8817	243.9060	245.9499	248.0131	249.0518	250.0951	251.1432	252.1957	253.2529	254.3144
2	18.5128	19.0000	19.1643	19.2468	19.2964	19.3295	19.3532	19.3710	19.3848	19.3959	19.4125	19.4291	19.4458	19.4541	19.4624	19.4707	19.4791	19.4874	19.4957
3	10.1280	9.5521	9.2766	9.1172	9.0135	8.9406	8.8867	8.8452	8.8123	8.7855	8.7446	8.7029	8.6602	8.6385	8.6166	8.5944	8.5720	8.5494	8.5264
4	7.7086	6.9443	6.5914	6.3882	6.2561	6.1631	6.0942	6.0410	5.9988	5.9644	5.9117	5.8578	5.8025	5.7744	5.7459	5.7170	5.6877	5.6581	5.6281
5	6.6079	5.7861	5.4095	5.1922	5.0503	4.9503	4.8759	4.8183	4.7725	4.7351	4.6777	4.6188	4.5581	4.5272	4.4957	4.4638	4.4314	4.3985	4.3650
6	5.9874	5.1433	4.7571	4.5337	4.3874	4.2839	4.2067	4.1468	4.0990	4.0600	3.9999	3.9381	3.8742	3.8415	3.8082	3.7743	3.7398	3.7047	3.6689
7	5.5914	4.7374	4.3468	4.1203	3.9715	3.8660	3.7870	3.7257	3.6767	3.6365	3.5747	3.5107	3.4445	3.4105	3.3758	3.3404	3.3043	3.2674	3.2298
8	5.3177	4.4590	4.0662	3.8379	3.6875	3.5806	3.5005	3.4381	3.3881	3.3472	3.2839	3.2184	3.1503	3.1152	3.0794	3.0428	3.0053	2.9669	2.9276
9	5.1174	4.2565	3.8625	3.6331	3.4817	3.3738	3.2927	3.2296	3.1789	3.1373	3.0729	3.0061	2.9365	2.9005	2.8637	2.8259	2.7872	2.7475	2.7067
10	4.9646	4.1028	3.7083	3.4780	3.3258	3.2172	3.1355	3.0717	3.0204	2.9782	2.9130	2.8450	2.7740	2.7372	2.6996	2.6609	2.6211	2.5801	2.5379
11	4.8443	3.9823	3.5874	3.3567	3.2039	3.0946	3.0123	2.9480	2.8962	2.8536	2.7876	2.7186	2.6464	2.6090	2.5705	2.5309	2.4901	2.4480	2.4045
12	4.7472	3.8853	3.4903	3.2592	3.1059	2.9961	2.9134	2.8486	2.7964	2.7534	2.6866	2.6169	2.5436	2.5055	2.4663	2.4259	2.3842	2.3410	2.2962
13	4.6672	3.8056	3.4105	3.1791	3.0254	2.9153	2.8321	2.7669	2.7144	2.6710	2.6037	2.5331	2.4589	2.4202	2.3803	2.3392	2.2966	2.2524	2.2064
14	4.6001	3.7389	3.3439	3.1122	2.9582	2.8477	2.7642	2.6987	2.6458	2.6022	2.5342	2.4630	2.3879	2.3487	2.3082	2.2664	2.2229	2.1778	2.1307
15	4.5431	3.6823	3.2874	3.0556	2.9013	2.7905	2.7066	2.6408	2.5876	2.5437	2.4753	2.4034	2.3275	2.2878	2.2468	2.2043	2.1601	2.1141	2.0658
16	4.4940	3.6337	3.2389	3.0069	2.8524	2.7413	2.6572	2.5911	2.5377	2.4935	2.4247	2.3522	2.2756	2.2354	2.1938	2.1507	2.1058	2.0589	2.0096
17	4.4513	3.5915	3.1968	2.9647	2.8100	2.6987	2.6143	2.5480	2.4943	2.4499	2.3807	2.3077	2.2304	2.1898	2.1477	2.1040	2.0584	2.0107	1.9604
18	4.4139	3.5546	3.1599	2.9277	2.7729	2.6613	2.5767	2.5102	2.4563	2.4117	2.3421	2.2686	2.1906	2.1497	2.1071	2.0629	2.0166	1.9681	1.9168
19	4.3807	3.5219	3.1274	2.8951	2.7401	2.6283	2.5435	2.4768	2.4227	2.3779	2.3080	2.2341	2.1555	2.1141	2.0712	2.0264	1.9795	1.9302	1.8780
20	4.3512	3.4928	3.0984	2.8661	2.7109	2.5990	2.5140	2.4471	2.3928	2.3479	2.2776	2.2033	2.1242	2.0825	2.0391	1.9938	1.9464	1.8963	1.8432
21	4.3248	3.4668	3.0725	2.8401	2.6848	2.5727	2.4876	2.4205	2.3660	2.3210	2.2504	2.1757	2.0960	2.0540	2.0102	1.9645	1.9165	1.8657	1.8117
22	4.3009	3.4434	3.0491	2.8167	2.6613	2.5491	2.4638	2.3965	2.3419	2.2967	2.2258	2.1508	2.0707	2.0283	1.9842	1.9380	1.8894	1.8380	1.7831
23	4.2793	3.4221	3.0280	2.7955	2.6400	2.5277	2.4422	2.3748	2.3201	2.2747	2.2036	2.1282	2.0476	2.0050	1.9605	1.9139	1.8648	1.8128	1.7570
24	4.2597	3.4028	3.0088	2.7763	2.6207	2.5082	2.4226	2.3551	2.3002	2.2547	2.1834	2.1077	2.0267	1.9838	1.9390	1.8920	1.8424	1.7896	1.7330
25	4.2417	3.3852	2.9912	2.7587	2.6030	2.4904	2.4047	2.3371	2.2821	2.2365	2.1649	2.0889	2.0075	1.9643	1.9192	1.8718	1.8217	1.7684	1.7110
26	4.2252	3.3690	2.9752	2.7426	2.5868	2.4741	2.3883	2.3205	2.2655	2.2197	2.1479	2.0716	1.9898	1.9464	1.9010	1.8533	1.8027	1.7488	1.6906
27	4.2100	3.3541	2.9604	2.7278	2.5719	2.4591	2.3732	2.3053	2.2501	2.2043	2.1323	2.0558	1.9736	1.9299	1.8842	1.8361	1.7851	1.7306	1.6717
28	4.1960	3.3404	2.9467	2.7141	2.5581	2.4453	2.3593	2.2913	2.2360	2.1900	2.1179	2.0411	1.9586	1.9147	1.8687	1.8203	1.7689	1.7138	1.6541
29	4.1830	3.3277	2.9340	2.7014	2.5454	2.4324	2.3463	2.2783	2.2229	2.1768	2.1045	2.0275	1.9446	1.9005	1.8543	1.8055	1.7537	1.6981	1.6376
30	4.1709	3.3158	2.9223	2.6896	2.5336	2.4205	2.3343	2.2662	2.2107	2.1646	2.0921	2.0148	1.9317	1.8874	1.8409	1.7918	1.7396	1.6835	1.6223
40	4.0847	3.2317	2.8387	2.6060	2.4495	2.3359	2.2490	2.1802	2.1240	2.0772	2.0035	1.9245	1.8389	1.7929	1.7444	1.6928	1.6373	1.5766	1.5089
60	4.0012	3.1504	2.7581	2.5252	2.3683	2.2541	2.1665	2.0970	2.0401	1.9926	1.9174	1.8364	1.7480	1.7001	1.6491	1.5943	1.5343	1.4673	1.3893
120	3.9201	3.0718	2.6802	2.4472	2.2899	2.1750	2.0868	2.0164	1.9588	1.9105	1.8337	1.7505	1.6587	1.6084	1.5543	1.4952	1.4290	1.3519	1.2539
inf	3.8415	2.9957	2.6049	2.3719	2.2141	2.0986	2.0096	1.9384	1.8799	1.8307	1.7522	1.6664	1.5705	1.5173	1.4591	1.3940	1.3180	1.2214	1.0000

Appendix F: F-Test and t-Test Spreadsheet Examples

F-Test Spreadsheet Example

Case Study 1
Load
Baseline
Dissolved Zinc

	HI-RUN	SELDM
Number of Runs	15	20
Mean	1.874	2.3235
Standard Deviation	0.235881	0.253466
Variance	0.05564	0.064245

F-TEST	
F	1.154655
df_1	14
df_2	19
F Upper Bound	2.3879
F Lower Bound	0.4476
Result	Pass

t-Test Spreadsheet Example

Case Study 1
Baseline
Load
Dissolved Zinc

	HI-RUN	SELDM
Number of Runs	15	20
Mean	1.874	2.3235
Standard Deviation	0.235881	0.253466
Variance	0.05564	0.064245

T-TEST	
s_p^2	0.060594
t_c	5.346137
df_1	14
df_2	19
t	2.042
Result	Unequal

Appendix G: Case Study 1 Detail Forms

HI-RUN - Case Study Details

Project Name: Case Study 1 - Bender Road Intersection

Location of TDA Case Study: City of Lynden, Whatcom County, Washington State (Puget East 52)

Number of Outfalls for TDA: Two

NOTE: The area contributing to each outfall must be treated as a separate subbasin.

State Route and Milepost of Outfall: SR 546 MP 1.40 to MP 2.10

Water Quality Parameters to be Analyzed:

Total Suspended Solids	Total Copper	Dissolved Copper	Total Zinc	Dissolved Zinc

Months of Interest:

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

Baseline (i.e., Pre-Project) Stormwater Facilities

Treatment Type	Level of Infiltration	TDA 2 Impervious Area (acres)				
Basic	0%					
	20%					
	40%					
	60%					
	80%					
Enhanced	0%					
	20%					
	40%					
	60%					
	80%					
None		1.5				
Infiltration BMP	100%					

Proposed (i.e., Post Project) Stormwater Facilities

Treatment Type	Level of Infiltration	TDA 2 Impervious Area (acres)				
Basic	0%	0.7				
	20%					
	40%					
	60%					
	80%					
Enhanced	0%					
	20%					
	40%					
	60%					
	80%					
None		0.8				
Infiltration BMP	100%					
Flow Control (Detention)		Yes				

Basic Treatment BMPs include Vegetated Filter Strip, Biofiltration Swale, Wet Biofiltration Swale, Continuous Inflow Biofiltration Swale, and Wet Pond.

Enhanced Treatment BMPs include Compost-Amended Vegetated Filter Strip, Media Filter Drain (previously named Ecology Embankment), and Constructed Stormwater Treatment Wetland.

HI-RUN - Case Study Details (continued)

Project Name: Case Study 1 - Bender Road Intersection

Inputs for Receiving Water Dilution Subroutine - Drainage Subbasin TDA 2

Stormwater Parameter	Background Concentration (mg/L)
Copper - Dissolved	0.026
Zinc - Dissolved	0.009

Drainage Subbasin #1

Receiving Water Characteristics Downstream from Discharge	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Stream depth (ft)	0.51	0.41	0.37	0.32	0.24	0.2	0.13	0.1	0.11	0.22	0.38	0.44
Stream velocity (fps)	5	4.4	4.2	3.9	3.2	2.9	2.1	1.8	1.9	3	4.3	4.6
Channel width (ft)	6	6	6	6	6	6	6	6	6	6	6	6
Manning's roughness "n"	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012
Discharge distance into receiving waterbody from nearest shoreline	0	0	0	0	0	0	0	0	0	0	0	0

HI-RUN - Case Study Details

Project Name: Case Study 1 - Depot Road Intersection

Location of TDA Case Study: City of Lynden, Whatcom County, Washington State (Puget East 52)

Number of Outfalls for TDA: Two

NOTE: The area contributing to each outfall must be treated as a separate subbasin.

State Route and Milepost of Outfall: SR 546 MP 1.40 to MP 2.10

Water Quality Parameters to be Analyzed:

Total Suspended Solids	Total Copper	Dissolved Copper	Total Zinc	Dissolved Zinc

Months of Interest:

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

Baseline (i.e., Pre-Project) Stormwater Facilities

Treatment Type	Level of Infiltration	TDA 1 Impervious Area (acres)				
Basic	0%					
	20%					
	40%					
	60%					
	80%					
Enhanced	0%					
	20%					
	40%					
	60%					
	80%					
None		1.3				
Infiltration BMP	100%					

Proposed (i.e., Post Project) Stormwater Facilities

Treatment Type	Level of Infiltration	TDA 1 Impervious Area (acres)				
Basic	0%	0.7				
	20%					
	40%					
	60%					
	80%					
Enhanced	0%					
	20%					
	40%					
	60%					
	80%					
None		0.7				
Infiltration BMP	100%					
Flow Control (Detention)		Yes				

Basic Treatment BMPs include Vegetated Filter Strip, Biofiltration Swale, Wet Biofiltration Swale, Continuous Inflow Biofiltration Swale, and Wet Pond.

Enhanced Treatment BMPs include Compost-Amended Vegetated Filter Strip, Media Filter Drain (previously named Ecology Embankment), and Constructed Stormwater Treatment Wetland.

HI-RUN - Case Study Details

Project Name: Case Study 1 - Depot Road Intersection

Inputs for Receiving Water Dilution Subroutine - Drainage Subbasin TDA 1

Stormwater Parameter	Background Concentration (mg/L)
Copper - Dissolved	0
Zinc - Dissolved	0.003

Drainage Subbasin #1

Receiving Water Characteristics Downstream from Discharge	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Stream depth (ft)	0.51	0.41	0.37	0.32	0.24	0.2	0.13	0.1	0.11	0.22	0.38	0.44
Stream velocity (fps)	5	4.4	4.2	3.9	3.2	2.9	2.1	1.8	1.9	3	4.3	4.6
Channel width (ft)	6	6	6	6	6	6	6	6	6	6	6	6
Manning's roughness "n"	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012
Discharge distance into receiving waterbody from nearest shoreline	0	0	0	0	0	0	0	0	0	0	0	0

SELDM - Case Study Details

Project Name: Case Study 1 – Bender Road Intersection

Project Location: City of Lynden, Whatcom County, Washington State

Latitude & Longitude: 48°57’51.68” N, 122°26’27.83” W

Baseline (i.e., Pre-Project) Site Characteristics

	Drainage Area (acres / square miles)	*Drainage Length (feet)*	*Mean Basin Slope (feet per mile)*	*Impervious Fraction*	*Basin Development Factor*
Highway Site	1.5	100	10	1	6
Upstream Basin	4.42	19000	20	0.05	1

Baseline (i.e., Pre-Project) Stormwater Facilities

BMP Type	*Area Treated (acres)*	*Level of Infiltration*			
None	none				

Proposed (i.e., Post Project) Site Characteristics

	Drainage Area (acres)	*Drainage Length (feet)*	*Mean Basin Slope (feet per mile)*	*Impervious Fraction*	*Basin Development Factor*
Highway Site	1.5	100	10	1	6
Upstream Basin	4.42	19000	20	0.05	1

Baseline (i.e., Post Project) Stormwater Facilities

BMP Type	*Area Treated (acres)*	*Level of Infiltration*			
Basic	0.7	0%			

SELDM Case Study Details

Project Name: Case Study 1 – Depot Road Intersection

Project Location: City of Lynden, Whatcom County, Washington State

Latitude & Longitude: 48°57'53.23" N, 122°27'7.43" W

Baseline (i.e., Pre-Project) Site Characteristics

	Drainage Area (acres / square miles)	*Drainage Length (feet)*	*Mean Basin Slope (feet per mile)*	*Impervious Fraction*	*Basin Development Factor*	
Highway Site	1.3	100	8	1	6	
Upstream Basin	4.42	19000	20	0.05	1	

Baseline (i.e., Pre-Project) Stormwater Facilities

BMP Type	*Area Treated (acres)*	*Level of Infiltration*				
None						

Proposed (i.e., Post Project) Site Characteristics

	Drainage Area (acres)	*Drainage Length (feet)*	*Mean Basin Slope (feet per mile)*	*Impervious Fraction*	*Basin Development Factor*	
Highway Site	1.4	100	8	1	6	
Upstream Basin	4.42	19000	20	0.05	1	

Baseline (i.e., Post Project) Stormwater Facilities

BMP Type	*Area Treated (acres)*	*Level of Infiltration*				
Basic	0.7	0%				

Appendix H: Case Study 1 Compilation and Analysis Forms

Table 27: Case Study 1 (Bender Road) – HI-RUN Output Summary

Load (lbs)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Baseline TSS	Median	924	929	936	929	933	933	925	924	927	932	924	929	936	929	933	15	930	4.190	4.240	92.953	PASS
Proposed TSS	Median	584	587	585	584	584	585	581	581	585	589	584	587	585	584	584	15	585	2.063	2.088	58.460	PASS
TSS	P (exceed)	0.376	0.375	0.373	0.377	0.374	0.375	0.375	0.374	0.377	0.377	0.376	0.375	0.373	0.377	0.374	15	0.375	0.001	0.001	0.038	PASS
Baseline Total Copper	Median	0.236	0.235	0.235	0.235	0.235	0.234	0.236	0.235	0.235	0.235	0.236	0.235	0.235	0.235	0.235	15	0.235	0.001	0.001	0.024	PASS
Proposed Total Copper	Median	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	15	0.170	0.000	0.000	0.017	PASS
Total Copper	P (exceed)	0.387	0.386	0.383	0.383	0.386	0.385	0.383	0.383	0.385	0.385	0.387	0.386	0.383	0.386	0.386	15	0.385	0.002	0.002	0.038	PASS
Baseline Dissolved Copper	Median	0.055	0.055	0.055	0.055	0.054	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.055	0.054	15	0.055	0.000	0.000	0.005	PASS
Proposed Dissolved Copper	Median	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	15	0.056	0.000	0.000	0.006	PASS
Dissolved Copper	P (exceed)	0.510	0.512	0.508	0.511	0.514	0.510	0.512	0.509	0.511	0.512	0.510	0.512	0.508	0.511	0.514	15	0.511	0.002	0.002	0.051	PASS
Baseline Total Zinc	Median	1.440	1.430	1.440	1.440	1.430	1.440	1.440	1.430	1.430	1.430	1.440	1.430	1.440	1.440	1.430	15	1.435	0.005	0.005	0.144	PASS
Proposed Total Zinc	Median	0.980	0.980	0.980	0.980	0.980	0.980	0.980	0.980	0.970	0.980	0.980	0.980	0.980	0.980	0.980	15	0.979	0.003	0.003	0.098	PASS
Total Zinc	P (exceed)	0.369	0.371	0.369	0.368	0.372	0.370	0.371	0.371	0.370	0.369	0.369	0.371	0.369	0.368	0.372	15	0.370	0.001	0.001	0.037	PASS
Baseline Dissolved Zinc	Median	0.408	0.412	0.410	0.410	0.411	0.410	0.409	0.409	0.410	0.409	0.408	0.412	0.410	0.410	0.411	15	0.410	0.001	0.001	0.041	PASS
Proposed Dissolved Zinc	Median	0.360	0.360	0.360	0.360	0.360	0.360	0.360	0.360	0.360	0.360	0.360	0.360	0.360	0.360	0.360	15	0.360	0.000	0.000	0.036	PASS
Dissolved Zinc	P (exceed)	0.468	0.466	0.467	0.467	0.467	0.467	0.466	0.464	0.467	0.465	0.468	0.466	0.467	0.467	0.467	15	0.467	0.001	0.001	0.047	PASS

Concentration (mg/L)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Baseline TSS	Median	61.301	61.205	61.297	61.482	61.473	61.533	61.250	61.294	61.559	60.771	61.301	61.205	61.297	61.482	61.473	15	61.328	0.196	0.198	6.133	PASS
Proposed TSS	Median	38.975	38.586	38.644	38.484	38.765	38.676	38.648	38.749	38.566	38.511	38.975	38.586	38.644	38.480	38.765	15	38.670	0.154	0.156	3.867	PASS
TSS	P (exceed)	0.376	0.375	0.375	0.372	0.373	0.376	0.373	0.376	0.373	0.375	0.376	0.375	0.375	0.372	0.373	15	0.374	0.001	0.002	0.037	PASS
Baseline Total Copper	Median	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	15	0.016	0.000	0.000	0.002	PASS
Proposed Total Copper	Median	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	15	0.011	0.000	0.000	0.001	PASS
Total Copper	P (exceed)	0.381	0.383	0.380	0.381	0.381	0.381	0.382	0.382	0.380	0.381	0.381	0.383	0.380	0.381	0.381	15	0.381	0.001	0.001	0.038	PASS
Baseline Dissolved Copper	Median	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	15	0.004	0.000	0.000	0.000	PASS
Proposed Dissolved Copper	Median	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	15	0.004	0.000	0.000	0.000	PASS
Dissolved Copper	P (exceed)	0.515	0.511	0.510	0.514	0.511	0.513	0.510	0.511	0.511	0.512	0.515	0.511	0.510	0.514	0.511	15	0.512	0.002	0.002	0.051	PASS
Baseline Total Zinc	Median	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.096	0.095	0.095	0.095	0.095	0.095	15	0.095	0.000	0.000	0.010	PASS
Proposed Total Zinc	Median	0.065	0.065	0.064	0.065	0.064	0.064	0.065	0.065	0.064	0.065	0.065	0.065	0.064	0.065	0.064	15	0.065	0.001	0.001	0.006	PASS
Total Zinc	P (exceed)	0.365	0.368	0.363	0.366	0.368	0.367	0.367	0.366	0.368	0.366	0.365	0.368	0.363	0.366	0.368	15	0.366	0.002	0.002	0.037	PASS
Baseline Dissolved Zinc	Median	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	15	0.027	0.000	0.000	0.003	PASS
Proposed Dissolved Zinc	Median	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	15	0.024	0.000	0.000	0.002	PASS
Dissolved Zinc	P (exceed)	0.464	0.465	0.467	0.466	0.465	0.465	0.463	0.463	0.467	0.465	0.464	0.465	0.467	0.466	0.465	15	0.465	0.001	0.001	0.047	PASS

Table 29: Case Study 1 (Bender Road) – HI-RUN Output Summary (continued)

Baseline Distance (feet)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Dissolved Copper	January	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	February	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	March	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	April	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	May	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	June	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	July	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	August	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	September	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	October	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	November	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	December	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Zinc	January	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	15	3	0	0	0.3	PASS
Dissolved Zinc	February	6	6	6	6	6	6	6	6	6	7	6	6	6	6	6	15	6	0	0	0.6	PASS
Dissolved Zinc	March	7	7	7	7	7	7	7	7	8	7	7	7	7	7	7	15	7	0	0	0.7	PASS
Dissolved Zinc	April	9	10	10	10	10	9	10	9	10	9	9	9	9	10	10	15	10	1	1	1.0	PASS
Dissolved Zinc	May	27	26	27	27	26	26	27	27	27	27	27	26	27	27	27	15	27	0	0	2.7	PASS
Dissolved Zinc	June	58	59	58	58	57	57	59	58	58	58	58	59	57	56	58	15	58	1	1	5.8	PASS
Dissolved Zinc	July	300	290	290	290	290	290	300	310	290	290	290	300	290	300	300	15	295	6	6	29.5	PASS
Dissolved Zinc	August	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	15	1000	0	0	100.0	PASS
Dissolved Zinc	September	980	990	960	950	980	970	970	1000	990	990	980	980	970	940	950	15	973	17	17	97.3	PASS
Dissolved Zinc	October	74	75	75	74	75	73	74	73	72	75	73	76	71	72	72	15	74	1	1	7.4	PASS
Dissolved Zinc	November	9	10	9	10	10	9	9	9	9	9	10	9	10	10	9	15	9	1	1	0.9	PASS
Dissolved Zinc	December	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	15	5	0	0	0.5	PASS

Proposed Distance (feet)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Dissolved Copper	January	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	February	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	March	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	April	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	May	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	June	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	July	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	August	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	September	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	October	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	November	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	December	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Zinc	January	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Zinc	February	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	15	2	0	0	0.2	PASS
Dissolved Zinc	March	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	15	3	0	0	0.3	PASS
Dissolved Zinc	April	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	15	3	0	0	0.3	PASS
Dissolved Zinc	May	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	15	9	0	0	0.9	PASS
Dissolved Zinc	June	19	18	19	19	19	19	19	19	19	19	19	19	18	19	19	15	19	0	0	1.9	PASS
Dissolved Zinc	July	100	100	100	100	100	100	100	90	100	100	100	100	100	100	100	15	99	3	3	9.9	PASS
Dissolved Zinc	August	340	340	340	350	340	340	350	350	350	350	340	350	340	340	340	15	344	5	5	34.4	PASS
Dissolved Zinc	September	310	320	320	320	310	310	310	310	310	320	310	310	310	310	320	15	313	5	5	31.3	PASS
Dissolved Zinc	October	24	24	24	24	24	24	24	24	24	24	23	24	24	23	24	15	24	0	0	2.4	PASS
Dissolved Zinc	November	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	15	3	0	0	0.3	PASS
Dissolved Zinc	December	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	15	2	0	0	0.2	PASS

Table 30: Case Study 1 (Bender Road) – SELDM Output Summary

Load (lbs)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Baseline TSS	Median	1610	1705	1515	1590	1630	1650	1455	1510	1505	1740	1720	1625	1685	1725	1555	15	1615	91.133	92.239	161.467	PASS
Proposed TSS	Median	1028	1008	996	903	1066	891	957	972	932	1058	926	896	916	908	1009	15	964	59.770	60.496	96.447	PASS
TSS	P (exceed)	0.451	0.455	0.431	0.418	0.441	0.436	0.464	0.438	0.442	0.443	0.452	0.440	0.439	0.426	0.436	15	0.441	0.011	0.012	0.044	PASS
Baseline Total Copper	Median	0.340	0.330	0.335	0.325	0.322	0.326	0.318	0.366	0.369	0.346	0.347	0.334	0.321	0.339	0.357	15	0.338	0.016	0.016	0.034	PASS
Proposed Total Copper	Median	0.228	0.227	0.220	0.222	0.238	0.231	0.228	0.225	0.233	0.224	0.219	0.243	0.226	0.238	0.228	15	0.229	0.007	0.007	0.023	PASS
Total Copper	P (exceed)	0.461	0.468	0.462	0.461	0.489	0.471	0.455	0.454	0.465	0.444	0.453	0.467	0.464	0.471	0.467	15	0.463	0.010	0.010	0.046	PASS
Baseline Dissolved Copper	Median	0.073	0.076	0.081	0.077	0.075	0.081	0.080	0.079	0.082	0.082	0.078	0.129	0.078	0.080	0.084	15	0.082	0.013	0.013	0.008	FAIL
Proposed Dissolved Copper	Median	0.071	0.067	0.067	0.069	0.071	0.073	0.070	0.070	0.068	0.070	0.071	0.072	0.072	0.068	0.069	15	0.070	0.002	0.002	0.007	PASS
Dissolved Copper	P (exceed)	0.545	0.539	0.537	0.542	0.533	0.551	0.540	0.536	0.540	0.542	0.549	0.521	0.534	0.523	0.554	15	0.539	0.009	0.009	0.054	PASS
Baseline Total Zinc	Median	2.015	1.945	1.960	2.035	2.160	1.960	2.005	2.165	2.220	1.980	2.200	2.025	2.065	2.145	2.025	15	2.060	0.093	0.094	0.206	PASS
Proposed Total Zinc	Median	1.452	1.396	1.449	1.394	1.374	1.383	1.278	1.293	1.328	1.348	1.297	1.474	1.329	1.282	1.383	15	1.364	0.063	0.064	0.136	PASS
Total Zinc	P (exceed)	0.448	0.485	0.462	0.458	0.447	0.442	0.449	0.453	0.452	0.456	0.460	0.438	0.439	0.455	0.467	15	0.454	0.012	0.012	0.045	PASS
Baseline Dissolved Zinc	Median	0.628	0.604	0.625	0.640	0.662	0.652	0.625	0.592	0.641	0.597	0.606	0.668	0.649	0.676	0.605	15	0.631	0.027	0.027	0.063	PASS
Proposed Dissolved Zinc	Median	0.501	0.506	0.535	0.524	0.524	0.519	0.518	0.527	0.489	0.525	0.519	0.542	0.513	0.505	0.527	15	0.518	0.014	0.014	0.052	PASS
Dissolved Zinc	P (exceed)	0.499	0.515	0.502	0.516	0.497	0.516	0.506	0.517	0.485	0.499	0.504	0.513	0.491	0.522	0.511	15	0.506	0.011	0.011	0.051	PASS

Concentration (mg/L)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Baseline TSS	Median	57.900	57.600	58.300	59.600	62.150	58.400	54.400	57.450	54.800	57.550	56.500	57.100	57.350	59.800	57.750	15	57.777	1.889	1.912	5.778	PASS
Proposed TSS	Median	35.659	35.927	34.731	34.083	35.805	33.197	36.577	36.808	34.372	34.345	34.368	34.313	33.883	36.174	35.137	15	35.025	1.075	1.089	3.503	PASS
TSS	P (exceed)	0.407	0.419	0.398	0.402	0.407	0.385	0.426	0.405	0.403	0.412	0.412	0.408	0.410	0.387	0.399	15	0.405	0.011	0.011	0.041	PASS
Baseline Total Copper	Median	0.015	0.016	0.016	0.016	0.015	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.014	0.016	15	0.016	0.000	0.001	0.002	PASS
Proposed Total Copper	Median	0.010	0.011	0.011	0.011	0.011	0.011	0.010	0.010	0.011	0.010	0.011	0.011	0.010	0.010	0.011	15	0.011	0.000	0.000	0.001	PASS
Total Copper	P (exceed)	0.401	0.415	0.399	0.416	0.427	0.412	0.400	0.404	0.412	0.403	0.398	0.409	0.403	0.436	0.406	15	0.409	0.011	0.011	0.041	PASS
Baseline Dissolved Copper	Median	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	15	0.004	0.000	0.000	0.000	PASS
Proposed Dissolved Copper	Median	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	15	0.003	0.000	0.000	0.000	PASS
Dissolved Copper	P (exceed)	0.489	0.487	0.490	0.499	0.499	0.510	0.505	0.505	0.497	0.484	0.502	0.492	0.508	0.498	0.503	15	0.498	0.008	0.008	0.050	PASS
Baseline Total Zinc	Median	0.093	0.087	0.092	0.088	0.093	0.093	0.091	0.090	0.092	0.087	0.089	0.094	0.091	0.090	0.089	15	0.091	0.002	0.002	0.009	PASS
Proposed Total Zinc	Median	0.058	0.060	0.058	0.058	0.058	0.060	0.056	0.057	0.059	0.059	0.057	0.059	0.057	0.059	0.060	15	0.058	0.001	0.001	0.006	PASS
Total Zinc	P (exceed)	0.407	0.419	0.398	0.402	0.407	0.385	0.426	0.405	0.403	0.412	0.412	0.408	0.410	0.387	0.399	15	0.405	0.011	0.011	0.041	PASS
Baseline Dissolved Zinc	Median	0.029	0.029	0.028	0.028	0.029	0.028	0.029	0.028	0.029	0.029	0.028	0.030	0.029	0.028	0.028	15	0.028	0.001	0.001	0.003	PASS
Proposed Dissolved Zinc	Median	0.022	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.022	0.022	0.023	0.023	15	0.023	0.000	0.000	0.002	PASS
Dissolved Zinc	P (exceed)	0.462	0.461	0.456	0.475	0.449	0.454	0.466	0.469	0.449	0.459	0.471	0.434	0.451	0.482	0.479	15	0.461	0.013	0.013	0.046	PASS

Table 28: Case Study 1 (Bender Road) – SELDM Output Summary (continued)

Annual Runoff Volume (cf)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Highway - Baseline	Average	249846	247077	245077	249577	252846	246926	246538	253692	252115	247038	250704	248115	251500	257231	252231	15	250034.3	3305	3345	25003	PASS
Highway - Proposed	Average	251154	246044	249800	245146	252735	252854	249269	254269	248115	251915	256231	248408	245946	251615	248846	15	250156.6	3202	3241	25016	PASS
BMP Outflow - Baseline	Average	249846	247077	245077	249577	252846	246926	246538	253692	252115	247038	250704	248115	251500	257231	252231	15	250034.3	3305	3345	25003	PASS
BMP Outflow - Proposed	Average	251154	246044	249800	245146	252735	252854	249269	254269	248115	251915	256231	248408	245946	251615	248846	15	250156.6	3202	3241	25016	PASS

Upstream Concentration (mg/L)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Dissolved Copper	Median	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	15	0.026	0.000	0.000	0.003	PASS
Dissolved Zinc	Median	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	15	0.009	0.000	0.000	0.001	PASS

Downstream Concentration (mg/L)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Baseline Dissolved Copper	Median	0.0259	0.0259	0.0259	0.0259	0.0259	0.0259	0.0259	0.0259	0.0259	0.0259	0.0259	0.0259	0.0259	0.0259	0.0259	15.0000	0.0259	0.0000	0.0000	0.0026	PASS
Proposed Dissolved Copper	Median	0.0260	0.0260	0.0260	0.0260	0.0260	0.0260	0.0260	0.0260	0.0260	0.0260	0.0260	0.0260	0.0260	0.0260	0.0260	15.0000	0.0260	0.0000	0.0000	0.0026	PASS
Baseline Dissolved Zinc	January	0.0091	0.0091	0.0091	0.0091	0.0091	0.0091	0.0091	0.0091	0.0091	0.0091	0.0091	0.0091	0.0091	0.0091	0.0091	15.0000	0.0091	0.0000	0.0000	0.0009	PASS
Proposed Dissolved Zinc	February	0.0090	0.0090	0.0090	0.0090	0.0090	0.0090	0.0090	0.0090	0.0090	0.0090	0.0090	0.0090	0.0090	0.0090	0.0090	15.0000	0.0090	0.0000	0.0000	0.0009	PASS

Table 29: Case Study 1 (Depot Road) – HI-RUN Output Summary

Load (lbs)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Baseline TSS	Median	806	800	806	804	807	805	815	808	805	799	804	799	799	806	809	15	805	4.362	4.415	80.480	PASS
Proposed TSS	Median	521	521	525	520	522	521	525	523	522	520	521	518	520	523	523	15	522	1.915	1.938	52.167	PASS
TSS	P (exceed)	0.381	0.384	0.386	0.382	0.384	0.385	0.382	0.383	0.385	0.385	0.383	0.382	0.385	0.383	0.381	15.000	0.383	0.002	0.002	0.038	PASS
Baseline Total Copper	Median	0.202	0.203	0.204	0.203	0.204	0.205	0.204	0.203	0.204	0.204	0.202	0.203	0.204	0.204	0.204	15.000	0.204	0.001	0.001	0.020	PASS
Proposed Total Copper	Median	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	15.000	0.150	0.000	0.000	0.015	PASS
Total Copper	P (exceed)	0.400	0.399	0.400	0.403	0.400	0.399	0.401	0.403	0.399	0.401	0.404	0.401	0.400	0.401	0.399	15.000	0.401	0.002	0.002	0.040	PASS
Baseline Dissolved Copper	Median	0.047	0.048	0.048	0.047	0.047	0.048	0.047	0.048	0.047	0.048	0.047	0.048	0.047	0.048	0.047	15.000	0.047	0.001	0.001	0.005	PASS
Proposed Dissolved Copper	Median	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	15.000	0.052	0.000	0.000	0.005	PASS
Dissolved Copper	P (exceed)	0.540	0.536	0.537	0.539	0.541	0.538	0.539	0.538	0.538	0.538	0.539	0.537	0.540	0.538	0.538	15.000	0.538	0.001	0.001	0.054	PASS
Baseline Total Zinc	Median	1.250	1.250	1.250	1.250	1.250	1.250	1.240	1.240	1.250	1.240	1.250	1.250	1.250	1.250	1.250	15.000	1.248	0.004	0.004	0.125	PASS
Proposed Total Zinc	Median	0.880	0.880	0.880	0.890	0.890	0.880	0.890	0.880	0.880	0.880	0.880	0.880	0.880	0.880	0.890	15.000	0.883	0.005	0.005	0.088	PASS
Total Zinc	P (exceed)	0.384	0.383	0.381	0.384	0.384	0.382	0.384	0.384	0.382	0.384	0.383	0.382	0.384	0.382	0.384	15.000	0.383	0.001	0.001	0.038	PASS
Baseline Dissolved Zinc	Median	0.355	0.354	0.353	0.359	0.353	0.355	0.355	0.355	0.352	0.354	0.356	0.355	0.354	0.357	0.355	15.000	0.355	0.002	0.002	0.035	PASS
Proposed Dissolved Zinc	Median	0.340	0.340	0.330	0.340	0.330	0.340	0.330	0.340	0.330	0.340	0.330	0.340	0.330	0.340	0.330	15.000	0.335	0.005	0.005	0.034	PASS
Dissolved Zinc	P (exceed)	0.484	0.487	0.487	0.484	0.489	0.485	0.487	0.486	0.487	0.489	0.487	0.487	0.489	0.484	0.487	15.000	0.487	0.002	0.002	0.049	PASS

Concentration (mg/L)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Baseline TSS	Median	61.398	61.280	61.919	61.590	61.493	61.397	61.828	60.834	61.855	61.782	61.480	61.408	62.160	61.666	61.548	15.000	61.576	0.316	0.320	6.158	PASS
Proposed TSS	Median	37.113	36.990	37.139	37.176	37.024	36.762	37.008	36.828	36.832	37.092	37.232	36.912	37.024	37.036	37.114	15.000	37.019	0.136	0.137	3.702	PASS
TSS	P (exceed)	0.361	0.361	0.362	0.363	0.362	0.359	0.361	0.363	0.360	0.360	0.362	0.361	0.360	0.360	0.364	15.000	0.361	0.001	0.001	0.036	PASS
Baseline Total Copper	Median	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	15.000	0.016	0.000	0.000	0.002	PASS
Proposed Total Copper	Median	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	15.000	0.011	0.000	0.000	0.001	PASS
Total Copper	P (exceed)	0.367	0.371	0.372	0.368	0.369	0.371	0.371	0.371	0.368	0.369	0.368	0.371	0.370	0.370	0.371	15.000	0.370	0.002	0.002	0.037	PASS
Baseline Dissolved Copper	Median	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	15.000	0.004	0.000	0.000	0.000	PASS
Proposed Dissolved Copper	Median	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	15.000	0.004	0.000	0.000	0.000	PASS
Dissolved Copper	P (exceed)	0.509	0.508	0.508	0.511	0.510	0.513	0.508	0.510	0.509	0.511	0.508	0.507	0.507	0.507	0.509	15.000	0.509	0.002	0.002	0.051	PASS
Baseline Total Zinc	Median	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.096	0.095	0.095	0.095	15.000	0.095	0.000	0.000	0.010	PASS
Proposed Total Zinc	Median	0.063	0.063	0.063	0.063	0.062	0.062	0.062	0.062	0.063	0.062	0.063	0.063	0.063	0.062	0.062	15.000	0.063	0.001	0.001	0.006	PASS
Total Zinc	P (exceed)	0.356	0.356	0.355	0.354	0.353	0.354	0.354	0.353	0.355	0.353	0.354	0.353	0.356	0.354	0.353	15.000	0.354	0.001	0.001	0.035	PASS
Baseline Dissolved Zinc	Median	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	15.000	0.027	0.000	0.000	0.003	PASS
Proposed Dissolved Zinc	Median	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	15.000	0.024	0.000	0.000	0.002	PASS
Dissolved Zinc	P (exceed)	0.460	0.458	0.460	0.462	0.466	0.461	0.461	0.461	0.460	0.459	0.459	0.460	0.458	0.461	0.461	15.000	0.460	0.002	0.002	0.046	PASS

Table 31: Case Study 1 (Depot Road) – HI-RUN Output Summary (continued)

Baseline Distance (feet)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Dissolved Copper	January	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0.0	0.1	PASS
Dissolved Copper	February	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0.0	0.1	PASS
Dissolved Copper	March	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0.0	0.1	PASS
Dissolved Copper	April	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0.0	0.1	PASS
Dissolved Copper	May	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	15	3	0	0.0	0.3	PASS
Dissolved Copper	June	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	15	6	0	0.0	0.6	PASS
Dissolved Copper	July	29	28	29	28	28	28	28	28	29	28	28	28	28	29	29	15	28	0	0.5	2.8	PASS
Dissolved Copper	August	100	100	110	100	110	100	110	110	110	110	110	110	110	110	110	15	107	5	4.6	10.7	PASS
Dissolved Copper	September	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	15	100	0	0.0	10.0	PASS
Dissolved Copper	October	7	7	7	7	7	8	8	7	7	8	7	8	7	7	7	15	7	0	0.5	0.7	PASS
Dissolved Copper	November	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0.0	0.1	PASS
Dissolved Copper	December	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0.0	0.1	PASS
Dissolved Zinc	January	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	15	3	0	0.0	0.3	PASS
Dissolved Zinc	February	6	6	5	5	6	6	6	6	6	6	6	6	6	5	5	15	6	0	0.5	0.6	PASS
Dissolved Zinc	March	7	6	6	6	6	6	6	6	6	7	6	7	7	6	6	15	6	0	0.5	0.6	PASS
Dissolved Zinc	April	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	15	8	0	0.0	0.8	PASS
Dissolved Zinc	May	23	24	23	23	23	23	23	23	23	23	24	23	24	23	23	15	23	0	0.4	2.3	PASS
Dissolved Zinc	June	49	51	50	49	51	50	50	49	50	51	52	50	49	50	50	15	50	1	0.9	5.0	PASS
Dissolved Zinc	July	260	250	250	250	250	250	260	260	250	260	260	250	250	260	250	15	254	5	5.1	25.4	PASS
Dissolved Zinc	August	920	930	950	930	910	910	900	940	920	910	920	940	960	940	920	15	927	17	17.0	92.7	PASS
Dissolved Zinc	September	870	840	850	840	860	850	840	830	830	830	850	840	840	830	830	15	842	12	12.2	84.2	PASS
Dissolved Zinc	October	64	63	62	63	63	63	65	63	63	64	63	64	65	64	64	15	64	1	0.8	6.4	PASS
Dissolved Zinc	November	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	15	8	0	0.0	0.8	PASS
Dissolved Zinc	December	5	4	4	5	5	5	5	4	4	4	5	5	4	5	4	15	5	1	0.5	0.5	FAIL

Proposed Distance (feet)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Dissolved Copper	January	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0.0	0.1	PASS
Dissolved Copper	February	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0.0	0.1	PASS
Dissolved Copper	March	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0.0	0.1	PASS
Dissolved Copper	April	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0.0	0.1	PASS
Dissolved Copper	May	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	15	2	0	0.0	0.2	PASS
Dissolved Copper	June	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	15	3	0	0.0	0.3	PASS
Dissolved Copper	July	13	13	13	13	13	13	12	13	13	13	13	13	13	13	13	15	13	0	0.3	1.3	PASS
Dissolved Copper	August	44	45	44	46	45	45	45	45	44	45	45	45	45	45	45	15	45	1	0.5	4.5	PASS
Dissolved Copper	September	41	41	41	41	41	41	40	40	41	41	42	41	40	41	41	15	41	1	0.5	4.1	PASS
Dissolved Copper	October	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	15	4	0	0.0	0.4	PASS
Dissolved Copper	November	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0.0	0.1	PASS
Dissolved Copper	December	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0.0	0.1	PASS
Dissolved Zinc	January	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0.0	0.1	PASS
Dissolved Zinc	February	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	15	2	0	0.0	0.2	PASS
Dissolved Zinc	March	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	15	2	0	0.0	0.2	PASS
Dissolved Zinc	April	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	15	3	0	0.0	0.3	PASS
Dissolved Zinc	May	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	15	8	0	0.0	0.8	PASS
Dissolved Zinc	June	16	17	16	17	16	16	17	17	16	17	17	17	17	16	17	15	17	1	0.5	1.7	PASS
Dissolved Zinc	July	82	81	81	80	81	83	81	81	80	82	82	82	81	81	83	15	81	1	0.9	8.1	PASS
Dissolved Zinc	August	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	15	300	0	0.0	30.0	PASS
Dissolved Zinc	September	280	280	270	280	270	280	270	270	280	280	280	270	280	270	280	15	276	5	5.1	27.6	PASS
Dissolved Zinc	October	21	21	21	21	21	21	21	21	21	21	21	21	21	21	20	15	21	0	0.3	2.1	PASS
Dissolved Zinc	November	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	15	3	0	0.0	0.3	PASS
Dissolved Zinc	December	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	15	2	0	0.0	0.2	PASS

Table 30: Case Study 1 (Depot Road) – SELDM Output Summary

Load (lbs)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Baseline TSS	Median	1440	1420	1405	1270	1255	1475	1405	1570	1360	1345	1450	1370	1510	1395	1335	15	1400	84	85	140	PASS
Proposed TSS	Median	834	804	941	808	797	928	841	785	832	856	873	751	847	805	817	15	835	51	51	83	PASS
TSS	P (exceed)	0.429	0.435	0.458	0.431	0.448	0.464	0.452	0.439	0.461	0.445	0.449	0.423	0.439	0.439	0.436	15	0.443	0.012	0.012	0.044	PASS
Baseline Total Copper	Median	0.279	0.282	0.278	0.286	0.288	0.278	0.304	0.287	0.285	0.297	0.282	0.275	0.293	0.304	0.266	15	0.285	0.010	0.011	0.029	PASS
Proposed Total Copper	Median	0.196	0.192	0.203	0.192	0.199	0.213	0.210	0.216	0.196	0.210	0.205	0.215	0.202	0.203	0.211	15	0.204	0.008	0.008	0.020	PASS
Total Copper	P (exceed)	0.467	0.478	0.479	0.485	0.494	0.497	0.466	0.475	0.465	0.475	0.488	0.480	0.456	0.465	0.488	15	0.477	0.012	0.012	0.048	PASS
Baseline Dissolved Copper	Median	0.067	0.069	0.066	0.070	0.069	0.068	0.068	0.066	0.068	0.063	0.067	0.063	0.071	0.065	0.067	15	0.067	0.002	0.002	0.007	PASS
Proposed Dissolved Copper	Median	0.064	0.061	0.062	0.064	0.064	0.064	0.063	0.068	0.062	0.069	0.060	0.062	0.066	0.065	0.065	15	0.064	0.003	0.003	0.006	PASS
Dissolved Copper	P (exceed)	0.545	0.554	0.546	0.546	0.552	0.573	0.556	0.555	0.546	0.552	0.555	0.556	0.558	0.550	0.551	15	0.553	0.007	0.007	0.055	PASS
Baseline Total Zinc	Median	1.760	1.685	1.795	1.755	1.810	1.795	1.730	1.800	1.780	1.830	1.780	1.675	1.805	1.755	1.670	15	1.762	0.051	0.051	0.176	PASS
Proposed Total Zinc	Median	1.286	1.174	1.266	1.181	1.219	1.178	1.176	1.241	1.260	1.188	1.205	1.143	1.212	1.202	1.193	15	1.208	0.040	0.040	0.121	PASS
Total Zinc	P (exceed)	0.461	0.465	0.438	0.459	0.465	0.472	0.467	0.459	0.459	0.449	0.451	0.468	0.476	0.467	0.469	15	0.462	0.010	0.010	0.046	PASS
Baseline Dissolved Zinc	Median	0.614	0.504	0.545	0.558	0.554	0.600	0.577	0.547	0.581	0.532	0.565	0.555	0.573	0.552	0.535	15	0.559	0.027	0.028	0.056	PASS
Proposed Dissolved Zinc	Median	0.471	0.455	0.443	0.451	0.483	0.477	0.464	0.473	0.476	0.498	0.475	0.466	0.468	0.458	0.455	15	0.467	0.014	0.014	0.047	PASS
Dissolved Zinc	P (exceed)	0.532	0.535	0.515	0.529	0.520	0.515	0.507	0.528	0.524	0.526	0.517	0.527	0.530	0.514	0.529	15	0.523	0.008	0.008	0.052	PASS

Concentration (mg/L)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Baseline TSS	Median	59.100	61.700	55.750	61.200	56.100	56.100	59.500	63.450	57.900	58.400	58.650	59.500	61.050	60.050	60.200	15	59.243	2.194	2.220	5.924	PASS
Proposed TSS	Median	32.445	34.725	34.523	33.093	32.100	33.745	35.255	33.825	32.915	31.663	32.860	30.520	32.680	33.685	32.608	15	33.109	1.232	1.247	3.311	PASS
TSS	P (exceed)	0.374	0.393	0.425	0.389	0.405	0.422	0.400	0.374	0.405	0.393	0.398	0.372	0.383	0.390	0.390	15	0.394	0.016	0.016	0.039	PASS
Baseline Total Copper	Median	0.015	0.016	0.015	0.016	0.015	0.015	0.016	0.016	0.016	0.015	0.016	0.016	0.016	0.015	0.015	15	0.015	0.000	0.000	0.002	PASS
Proposed Total Copper	Median	0.010	0.010	0.010	0.010	0.010	0.011	0.010	0.011	0.010	0.010	0.010	0.011	0.010	0.010	0.010	15	0.010	0.000	0.000	0.001	PASS
Total Copper	P (exceed)	0.389	0.417	0.407	0.399	0.408	0.414	0.387	0.403	0.401	0.414	0.400	0.406	0.378	0.391	0.410	15	0.402	0.011	0.011	0.040	PASS
Baseline Dissolved Copper	Median	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	15	0.004	0.000	0.000	0.000	PASS
Proposed Dissolved Copper	Median	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	15	0.003	0.000	0.000	0.000	PASS
Dissolved Copper	P (exceed)	0.503	0.508	0.498	0.478	0.486	0.499	0.496	0.495	0.493	0.492	0.490	0.498	0.486	0.496	0.499	15	0.495	0.007	0.007	0.049	PASS
Baseline Total Zinc	Median	0.093	0.087	0.094	0.090	0.088	0.087	0.089	0.092	0.090	0.094	0.092	0.087	0.087	0.089	0.088	15	0.090	0.003	0.003	0.009	PASS
Proposed Total Zinc	Median	0.059	0.057	0.058	0.057	0.057	0.056	0.056	0.056	0.058	0.057	0.057	0.056	0.058	0.058	0.057	15	0.057	0.001	0.001	0.006	PASS
Total Zinc	P (exceed)	0.374	0.393	0.425	0.389	0.405	0.422	0.400	0.374	0.405	0.393	0.398	0.372	0.383	0.390	0.390	15	0.394	0.016	0.016	0.039	PASS
Baseline Dissolved Zinc	Median	0.028	0.028	0.029	0.028	0.029	0.029	0.029	0.029	0.029	0.027	0.029	0.027	0.028	0.028	0.029	15	0.028	0.001	0.001	0.003	PASS
Proposed Dissolved Zinc	Median	0.022	0.022	0.022	0.022	0.022	0.023	0.022	0.022	0.023	0.022	0.022	0.022	0.022	0.022	0.022	15	0.022	0.000	0.000	0.002	PASS
Dissolved Zinc	P (exceed)	0.460	0.465	0.450	0.457	0.448	0.460	0.450	0.465	0.448	0.472	0.459	0.468	0.464	0.460	0.452	15	0.459	0.008	0.008	0.046	PASS

Table 32: Case Study 1 (Depot Road) – SELDM Output Summary (continued)

Annual Runoff Volume (cf)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Highway - Baseline	Average	220500	212423	215038	217115	216346	214308	218154	219462	215333	213077	217074	209962	219423	216231	210077	15	215635	3232	3272	21563	PASS
Highway - Proposed	Average	231942	227619	228800	227588	236200	233954	227263	238377	231412	239496	233263	231354	235204	229019	234208	15	232380	3909	3956	23238	PASS
BMP Outflow - Baseline	Average	220500	212423	215038	217115	216346	214308	218154	219462	215333	213077	217074	209962	219423	216231	210077	15	215635	3232	3272	21563	PASS
BMP Outflow - Proposed	Average	231942	227619	228800	227588	236200	233954	227263	238377	231412	239496	233263	231354	235204	229019	234208	15	232380	3909	3956	23238	PASS

Upstream Concentration (mg/L)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Dissolved Copper	Median	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0000	15	0	0	0	0	PASS
Dissolved Zinc	Median	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.0030	15	0.003	0	0	0	PASS

Downstream Concentration (mg/L)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Baseline Dissolved Copper	Median	0.0002	0.0003	0.0003	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0003	0.0002	0.0003	0.0002	0.0003	15	0.0002	0.0000	0.0000	0.0000	PASS
Proposed Dissolved Copper	Median	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	15	0.0002	0.0000	0.0000	0.0000	PASS
Baseline Dissolved Zinc	January	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	15	0.0031	0.0000	0.0000	0.0003	PASS
Proposed Dissolved Zinc	February	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	15	0.0031	0.0000	0.0000	0.0003	PASS

Appendix I: Case Study 2 Detail Forms

HI-RUN - Case Study Details

Project Name: Case Study 2 - Whipple Creek Drainage Basin

Location of TDA Case Study: Salmon Creek Interchange, Clark County, Washington State (Vancouver 44)

Number of Outfalls for TDA: Three

NOTE: The area contributing to each outfall must be treated as a separate subbasin.

State Route and Milepost of Outfall: Salmon Creek Interchange, I-5 at NE 139th Street and I-205 from NE 134th Street

Water Quality Parameters to be Analyzed: Total Suspended Solids | Total Copper | Dissolved Copper | Total Zinc | Dissolved Zinc

Months of Interest: Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec

Baseline (i.e., Pre-Project) Stormwater Facilities

Treatment Type	Level of Infiltration	TDA 1 Impervious Area (acres)	TDA 2 Impervious Area (acres)	TDA 3 Impervious Area (acres)	TDA CC5 Impervious Area (acres)	
Basic	0%	0.64			1.12	
	20%					
	40%					
	60%					
	80%					
Enhanced	0%					
	20%					
	40%					
	60%					
	80%					
None		5.61	11.53	6.56	0.75	
Infiltration BMP	100%					

Proposed (i.e., Post Project) Stormwater Facilities

Treatment Type	Level of Infiltration	TDA 1 Impervious Area (acres)	TDA 2 Impervious Area (acres)	TDA 3 Impervious Area (acres)	TDA CC5 Impervious Area (acres)	
Basic	0%	0.64			2.38	
	20%					
	40%					
	60%					
	80%					
Enhanced	0%					
	20%					
	40%					
	60%		1.8	2.24		
	80%					
None		5.61	10.93	5.22		
Infiltration BMP	100%					
Flow Control (Detention)						

Basic Treatment BMPs include Vegetated Filter Strip, Biofiltration Swale, Wet Biofiltration Swale, Continuous Inflow Biofiltration Swale, and Wet Pond.

Enhanced Treatment BMPs include Compost-Amended Vegetated Filter Strip, Media Filter Drain (previously named Ecology Embankment), and Constructed Stormwater Treatment Wetland.

HI-RUN - Case Study Details

Project Name: Case Study 2 - Whipple Creek Drainage Basin

Inputs for Receiving Water Dilution Subroutine - Drainage Subbasin TDA 2

Stormwater Parameter	Background Concentration (mg/L)
Copper - Dissolved	1.52 (Jan - Mar), 1.54 (Sept - Oct)
Zinc - Dissolved	4.70 (Jan - Mar), 4.2 (Sept - Oct)

Drainage Subbasin #1

Receiving Water Characteristics Downstream from Discharge	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Stream depth (ft)	0.85	0.85	0.85						0.4	0.4		
Stream velocity (fps)	1	1	1						0.67	0.67		
Channel width (ft)	2.35	2.35	2.35						1.87	1.87		
Stream slope (ft/ft)	0.0067	0.0067	0.0067						0.0067	0.0067		
Discharge distance into receiving waterbody from nearest shoreline	0	0	0						0	0		

Inputs for Receiving Water Dilution Subroutine - Drainage Subbasin TDA 3

Stormwater Parameter	Background Concentration (mg/L)
Copper - Dissolved	1.52 (Jan - Mar), 1.54 (Sept - Oct)
Zinc - Dissolved	4.70 (Jan - Mar), 4.2 (Sept - Oct)

Drainage Subbasin #2

Receiving Water Characteristics Downstream from Discharge	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Stream depth (ft)	0.65	0.65	0.65						0.25	0.25		
Stream velocity (fps)	0.97	0.97	0.97						0.58	0.58		
Channel width (ft)	3.01	3.01	3.01						2.76	2.76		
Stream slope (ft/ft)	0.0012	0.0012	0.0012						0.0012	0.0012		
Discharge distance into receiving waterbody from nearest shoreline	0	0	0						0	0		

HI-RUN - Case Study Details

Project Name: Case Study 2 - Salmon Creek Drainage Basin

Location of TDA Case Study: Salmon Creek Interchange, Clark County, Washington State (Vancouver 44)

Number of Outfalls for TDA: One

NOTE: The area contributing to each outfall must be treated as a separate subbasin.

State Route and Milepost of Outfall: Salmon Creek Interchange, I-5 at NE 139th Street and I-205 from NE 134th Street

Water Quality Parameters to be Analyzed:	Total Suspended Solids	Total Copper	Dissolved Copper	Total Zinc	Dissolved Zinc

Months of Interest:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

Baseline (i.e., Pre-Project) Stormwater Facilities

Treatment Type	Level of Infiltration	TDA 5 Impervious Area (acres)	TDA 6 Impervious Area (acres)			
Basic	0%	0.93	0.55			
	20%					
	40%					
	60%					
	80%					
Enhanced	0%					
	20%					
	40%					
	60%					
	80%					
None		6.26	4.54			
Infiltration BMP	100%					

Proposed (i.e., Post Project) Stormwater Facilities

Treatment Type	Level of Infiltration	TDA 5 Impervious Area (acres)	TDA 6 Impervious Area (acres)			
Basic	0%	0.93	0.63			
	20%					
	40%					
	60%					
	80%					
Enhanced	0%					
	20%					
	40%					
	60%	4.08	0.22			
	80%					
None		3.42	4.34			
Infiltration BMP	100%					
Flow Control (Detention)		Yes	Yes			

Basic Treatment BMPs include Vegetated Filter Strip, Biofiltration Swale, Wet Biofiltration Swale, Continuous Inflow Biofiltration Swale, and Wet Pond.

Enhanced Treatment BMPs include Compost-Amended Vegetated Filter Strip, Media Filter Drain (previously named Ecology Embankment), and Constructed Stormwater Treatment Wetland.

HI-RUN - Case Study Details

Project Name: Case Study 2 - Salmon Creek Drainage Basin

Inputs for Receiving Water Dilution Subroutine - Drainage Subbasin TDA 5

Stormwater Parameter	Background Concentration (mg/L)
Copper - Dissolved	1.53 (Jan - Mar), 1.55 (Sept - Oct)
Zinc - Dissolved	4.70 (Jan - Mar), 4.30 (Sept - Oct)

Drainage Subbasin #1

Receiving Water Characteristics Downstream from Discharge	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Stream depth (ft)	1.25	1.25	1.25						0.5	0.5		
Stream velocity (fps)	1.87	1.87	1.87						1.08	1.08		
Channel width (ft)	23.66	23.66	23.66						19.44	19.44		
Stream slope (ft/ft)	0.0056	0.0056	0.0056						0.0056	0.0056		
Discharge distance into receiving waterbody from nearest shoreline	0	0	0						0	0		

HI-RUN Case Study Details

Project Name: Case Study 2 - Rockwell Creek Drainage Basin

Location of TDA Case Study: Salmon Creek Interchange, Clark County, Washington State (Vancouver 44)

Number of Outfalls for TDA: One

NOTE: The area contributing to each outfall must be treated as a separate subbasin.

State Route and Milepost of Outfall: Salmon Creek Interchange, I-5 at NE 139th Street and I-205 from NE 134th Street

Water Quality Parameters to be Analyzed:

Total Suspended Solids	Total Copper	Dissolved Copper	Total Zinc	Dissolved Zinc

Months of Interest:

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

Baseline (i.e., Pre-Project) Stormwater Facilities

Treatment Type	Level of Infiltration	TDA 4 Impervious Area (acres)	TDA CC6 Impervious Area (acres)	TDA CC7 Impervious Area (acres)		
Basic	0%	8.85		1.14		
	20%					
	40%					
	60%					
	80%					
Enhanced	0%					
	20%					
	40%					
	60%					
	80%					
None		14.46	2.74	2.26		
Infiltration BMP	100%					

Proposed (i.e., Post Project) Stormwater Facilities

Treatment Type	Level of Infiltration	TDA 4 Impervious Area (acres)	TDA CC6 Impervious Area (acres)	TDA CC7 Impervious Area (acres)		
Basic	0%	18.89	3.89	4.47		
	20%					
	40%					
	60%					
	80%					
Enhanced	0%					
	20%					
	40%					
	60%	9.76				
	80%					
None		3.01				
Infiltration BMP	100%					
Flow Control (Detention)						

Basic Treatment BMPs include Vegetated Filter Strip, Biofiltration Swale, Wet Biofiltration Swale, Continuous Inflow Biofiltration Swale, and Wet Pond.

Enhanced Treatment BMPs include Compost-Amended Vegetated Filter Strip, Media Filter Drain (previously named Ecology Embankment), and Constructed Stormwater Treatment Wetland.

SELDM Case Study Details

Project Name: Case Study 2 – Whipple Creek Drainage Basin

Project Location: Salmon Creek Interchange, Clark County, Washington State

Latitude & Longitude: 45°44’5.47” N, 122°39’45.74” W

Baseline (i.e., Pre-Project) Site Characteristics

	Drainage Area (acres / square miles)	*Drainage Length (feet)*	*Mean Basin Slope (feet per mile)*	*Impervious Fraction*	*Basin Development Factor*
Highway Site (TDA 1)	6.25	2088	28	1	6
Highway Site (TDA 2)	11.53	4226	95	1	6
Highway Site (TDA 3)	6.56	1594	44	1	6
Highway Site (TDA CC5)	1.87	650	5	1	6
Upstream Basin (TDA 2)	1.00	7700	38	0.1	6
Upstream Basin (TDA 3)	0.25	3000	110	0.3	6

Baseline (i.e., Pre-Project) Stormwater Facilities

BMP Type	*Area Treated (acres)*	*Level of Infiltration*			
Basic (TDA 1)	0.64	0%			
Basic (TDA CC5)	1.12	0%			

Proposed (i.e., Post Project) Site Characteristics

	Drainage Area (acres)	*Drainage Length (feet)*	*Mean Basin Slope (feet per mile)*	*Impervious Fraction*	*Basin Development Factor*
Highway Site (TDA 1)	6.25	2088	28	1	6
Highway Site (TDA 2)	12.73	4226	95	1	6
Highway Site (TDA 3)	7.46	1594	44	1	6
Highway Site (TDA CC5)	2.38	650	5	1	6
Upstream Basin (TDA 2)	1.00	7700	38	0.1	6
Upstream Basin (TDA 3)	0.25	3000	110	0.3	6

Baseline (i.e., Post Project) Stormwater Facilities

BMP Type	*Area Treated (acres)*	*Level of Infiltration*			
Basic (TDA 1)	0.64	0%			
Enhanced (TDA 2)	1.8	60%			
Enhanced (TDA 3)	2.24	60%			
Basic (TDA CC5)	2.38	0%			

SELDM Case Study Details

Project Name: <u>Case Study 2 – Salmon Creek Drainage Basin</u>

Project Location: <u>Salmon Creek Interchange, Clark County, Washington State</u>

Latitude & Longitude: <u>45°42’36.77” N, 122°38’20.20” W</u>

Baseline (i.e., Pre-Project) Site Characteristics

	Drainage Area (acres / square miles)	*Drainage Length (feet)*	*Mean Basin Slope (feet per mile)*	*Impervious Fraction*	*Basin Development Factor*
Highway Site (TDA 5)	7.19	3012	163	1	6
Highway Site (TDA 6)	5.09	1145	45	1	6
Upstream Basin (TDA 5)	1.00	7700	88	0.05	2

Baseline (i.e., Pre-Project) Stormwater Facilities

BMP Type	*Area Treated (acres)*	*Level of Infiltration*			
Basic (TDA 5)	0.93	0%			
Basic (TDA 6)	0.55	0%			

Proposed (i.e., Post Project) Site Characteristics

	Drainage Area (acres)	*Drainage Length (feet)*	*Mean Basin Slope (feet per mile)*	*Impervious Fraction*	*Basin Development Factor*
Highway Site (TDA 5)	8.43	3012	163	1	6
Highway Site (TDA 6)	5.19	1145	45	1	6
Upstream Basin (TDA 5)	1.00	7700	88	0.05	2

Baseline (i.e., Post Project) Stormwater Facilities

BMP Type	*Area Treated (acres)*	*Level of Infiltration*			
Basic (TDA 5)	0.93	0%			
Enhanced (TDA 5)	4.08	60%			
Basic (TDA 6)	0.63	0%			
Enhanced (TDA 6)	0.22	60%			

SELDM Case Study Details

Project Name: <u>Case Study 2 – Rockwell Creek Drainage Basin</u>

Project Location: <u>Salmon Creek Interchange, Clark County, Washington State</u>

Latitude & Longitude: <u>45°43’10.76” N, 122°39’1.13” W</u>

Baseline (i.e., Pre-Project) Site Characteristics

	Drainage Area (acres / square miles)	*Drainage Length (feet)*	*Mean Basin Slope (feet per mile)*	*Impervious Fraction*	*Basin Development Factor*
Highway Site (TDA 4)	23.31	3660	6	1	6
Highway Site (TDA CC6)	2.74	900	6	1	6
Highway Site (TDA CC7)	3.40	1100	33	1	6
Upstream Basin	N/A	N/A	N/A	N/A	N/A

Baseline (i.e., Pre-Project) Stormwater Facilities

BMP Type	*Area Treated (acres)*	*Level of Infiltration*			
Basic (TDA 4)	8.85	0%			
Basic (TDA CC7)	1.14	0%			

Proposed (i.e., Post Project) Site Characteristics

	Drainage Area (acres)	*Drainage Length (feet)*	*Mean Basin Slope (feet per mile)*	*Impervious Fraction*	*Basin Development Factor*
Highway Site (TDA 4)	31.66	3660	6	1	6
Highway Site (TDA CC6)	3.89	900	6	1	6
Highway Site (TDA CC7)	4.47	1100	33	1	6
Upstream Basin	N/A	N/A	N/A	N/A	N/A

Baseline (i.e., Post Project) Stormwater Facilities

BMP Type	*Area Treated (acres)*	*Level of Infiltration*			
Basic (TDA 4)	18.89	0%			
Enhanced (TDA 4)	9.76	60%			
Basic (TDA CC6)	3.89	0%			
Basic (TDA CC7)	4.47	0%			

Table 31: Case Study 2 (Whipple Creek) – HI-RUN Output Summary

Load (lbs)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Baseline TSS	Median	12574	12574	12649	12614	12630	12596	12611	12658	12661	12626	12603	12611	12601	12652	12611	15	12618	27.784	28.121	1261.807	PASS
Proposed TSS	Median	11422	11482	11441	11505	11439	11370	11429	11482	11423	11451	11479	11523	11513	11411	11477	15	11456	42.588	43.104	1145.647	PASS
TSS	P (exceed)	0.477	0.473	0.475	0.475	0.474	0.477	0.476	0.474	0.472	0.475	0.476	0.476	0.476	0.475	0.476	15	0.475	0.001	0.001	0.048	PASS
Baseline Total Copper	Median	3.260	3.230	3.240	3.250	3.240	3.220	3.230	3.250	3.250	3.230	3.220	3.250	3.250	3.240	3.200	15	3.237	0.016	0.016	0.324	PASS
Proposed Total Copper	Median	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	15	3.000	0.000	0.000	0.300	PASS
Total Copper	P (exceed)	0.475	0.473	0.473	0.473	0.478	0.477	0.473	0.471	0.475	0.473	0.473	0.473	0.473	0.473	0.474	15	0.474	0.002	0.002	0.047	PASS
Baseline Dissolved Copper	Median	0.791	0.792	0.794	0.788	0.796	0.793	0.790	0.789	0.790	0.790	0.794	0.792	0.791	0.789	0.788	15	0.791	0.002	0.002	0.079	PASS
Proposed Dissolved Copper	Median	0.770	0.770	0.770	0.770	0.780	0.770	0.770	0.770	0.770	0.770	0.780	0.770	0.770	0.770	0.770	15	0.771	0.004	0.004	0.077	PASS
Dissolved Copper	P (exceed)	0.492	0.493	0.494	0.494	0.495	0.492	0.495	0.495	0.494	0.494	0.494	0.493	0.494	0.494	0.495	15	0.494	0.001	0.001	0.049	PASS
Baseline Total Zinc	Median	19.700	19.600	19.700	19.700	19.700	19.600	19.600	19.700	19.600	19.800	19.700	19.800	19.800	19.600	19.700	15	19.687	0.074	0.075	1.969	PASS
Proposed Total Zinc	Median	18.000	18.000	18.000	18.000	18.000	18.000	18.000	18.000	18.000	18.000	18.000	18.000	18.000	18.000	18.000	15	18.000	0.000	0.000	1.800	PASS
Total Zinc	P (exceed)	0.472	0.472	0.471	0.471	0.472	0.474	0.475	0.471	0.471	0.470	0.471	0.469	0.472	0.471	0.472	15	0.472	0.001	0.001	0.047	PASS
Baseline Dissolved Zinc	Median	5.770	5.750	5.810	5.810	5.810	5.750	5.770	5.770	5.800	5.760	5.760	5.770	5.780	5.770	5.750	15	5.775	0.022	0.022	0.578	PASS
Proposed Dissolved Zinc	Median	5.500	5.500	5.500	5.500	5.500	5.500	5.500	5.500	5.500	5.500	5.500	5.500	5.500	5.500	5.500	15	5.500	0.000	0.000	0.550	PASS
Dissolved Zinc	P (exceed)	0.485	0.486	0.485	0.486	0.486	0.489	0.485	0.488	0.489	0.489	0.486	0.486	0.487	0.489	0.487	15	0.487	0.002	0.002	0.049	PASS

TDA 1 Concentration (mg/L)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Baseline TSS	Median	56.141	57.038	56.539	56.343	56.488	56.305	56.706	56.986	56.813	56.366	56.456	56.575	56.442	56.711	56.467	15	56.558	0.251	0.254	5.656	PASS
Proposed TSS	Median	56.676	56.649	56.546	56.471	56.351	56.674	56.889	56.438	56.614	56.839	56.438	56.222	56.602	56.577	56.509	15	56.566	0.174	0.176	5.657	PASS
TSS	P (exceed)	0.502	0.499	0.500	0.500	0.499	0.500	0.499	0.498	0.499	0.500	0.499	0.496	0.500	0.500	0.501	15	0.499	0.001	0.001	0.050	PASS
Baseline Total Copper	Median	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.014	0.015	0.015	0.015	0.015	0.015	15	0.015	0.000	0.000	0.001	PASS
Proposed Total Copper	Median	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.014	0.015	0.015	0.015	0.015	0.015	0.014	15	0.015	0.000	0.000	0.001	PASS
Total Copper	P (exceed)	0.499	0.499	0.500	0.501	0.500	0.503	0.499	0.504	0.497	0.502	0.496	0.499	0.500	0.500	0.500	15	0.500	0.002	0.002	0.050	PASS
Baseline Dissolved Copper	Median	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	15	0.004	0.000	0.000	0.000	PASS
Proposed Dissolved Copper	Median	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	15	0.004	0.000	0.000	0.000	PASS
Dissolved Copper	P (exceed)	0.500	0.498	0.496	0.500	0.502	0.500	0.500	0.499	0.500	0.500	0.496	0.503	0.501	0.502	0.501	15	0.500	0.002	0.002	0.050	PASS
Baseline Total Zinc	Median	0.088	0.088	0.089	0.088	0.088	0.088	0.088	0.089	0.088	0.088	0.088	0.089	0.088	0.088	0.088	15	0.088	0.000	0.000	0.009	PASS
Proposed Total Zinc	Median	0.088	0.088	0.088	0.088	0.089	0.088	0.089	0.088	0.088	0.088	0.088	0.089	0.088	0.088	0.088	15	0.088	0.000	0.000	0.009	PASS
Total Zinc	P (exceed)	0.498	0.499	0.500	0.501	0.502	0.500	0.501	0.497	0.502	0.500	0.499	0.500	0.503	0.501	0.498	15	0.500	0.002	0.002	0.050	PASS
Baseline Dissolved Zinc	Median	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	15	0.026	0.000	0.000	0.003	PASS
Proposed Dissolved Zinc	Median	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	15	0.026	0.000	0.000	0.003	PASS
Dissolved Zinc	P (exceed)	0.499	0.498	0.501	0.501	0.499	0.499	0.499	0.501	0.499	0.496	0.503	0.501	0.501	0.500	0.500	15	0.500	0.002	0.002	0.050	PASS

Table 33: Case Study 2 (Whipple Creek) – HI-RUN Output Summary (continued)

TDA 2 Concentration (mg/L)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Baseline TSS	Median	61.464	61.649	61.800	61.418	61.713	61.677	61.969	61.435	61.316	61.962	61.735	61.558	61.468	61.558	61.635	15	61.624	0.193	0.195	6.162	PASS
Proposed TSS	Median	58.751	58.198	58.455	58.804	58.495	58.558	58.147	58.199	57.939	58.559	58.622	58.336	58.457	58.350	58.232	15	58.407	0.238	0.241	5.841	PASS
TSS	P (exceed)	0.487	0.486	0.487	0.489	0.486	0.489	0.485	0.486	0.486	0.487	0.488	0.489	0.486	0.487	0.487	15	0.487	0.001	0.001	0.049	PASS
Baseline Total Copper	Median	0.016	0.016	0.016	0.016	0.016	0.016	0.015	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	15	0.016	0.000	0.000	0.002	PASS
Proposed Total Copper	Median	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	15	0.015	0.000	0.000	0.002	PASS
Total Copper	P (exceed)	0.486	0.489	0.489	0.487	0.488	0.486	0.488	0.489	0.486	0.491	0.489	0.491	0.486	0.487	0.487	15	0.488	0.002	0.002	0.049	PASS
Baseline Dissolved Copper	Median	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	15	0.004	0.000	0.000	0.000	PASS
Proposed Dissolved Copper	Median	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	15	0.004	0.000	0.000	0.000	PASS
Dissolved Copper	P (exceed)	0.501	0.503	0.505	0.504	0.505	0.504	0.502	0.504	0.502	0.503	0.506	0.504	0.502	0.502	0.502	15	0.503	0.001	0.001	0.050	PASS
Baseline Total Zinc	Median	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.096	0.095	0.095	0.096	0.095	15	0.095	0.000	0.000	0.010	PASS
Proposed Total Zinc	Median	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.092	0.091	0.091	0.091	0.091	0.091	0.091	15	0.091	0.000	0.000	0.009	PASS
Total Zinc	P (exceed)	0.485	0.486	0.486	0.486	0.483	0.486	0.487	0.486	0.487	0.489	0.487	0.486	0.486	0.484	0.487	15	0.486	0.001	0.001	0.049	PASS
Baseline Dissolved Zinc	Median	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	15	0.027	0.000	0.000	0.003	PASS
Proposed Dissolved Zinc	Median	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	15	0.027	0.000	0.000	0.003	PASS
Dissolved Zinc	P (exceed)	0.496	0.500	0.497	0.498	0.498	0.496	0.499	0.497	0.497	0.497	0.498	0.497	0.495	0.498	0.496	15	0.497	0.001	0.001	0.050	PASS

TDA 3 Concentration (mg/L)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Baseline TSS	Median	61.133	61.755	61.780	61.649	61.498	61.371	61.274	61.606	61.506	61.950	61.273	61.548	61.610	61.611	61.654	15	61.548	0.215	0.218	6.155	PASS
Proposed TSS	Median	54.370	54.199	54.278	54.228	54.400	54.226	54.203	54.332	54.673	54.110	54.280	54.218	54.500	54.464	54.406	15	54.326	0.146	0.147	5.433	PASS
TSS	P (exceed)	0.470	0.467	0.467	0.467	0.469	0.468	0.469	0.467	0.470	0.467	0.469	0.469	0.467	0.467	0.468	15	0.468	0.001	0.001	0.047	PASS
Baseline Total Copper	Median	0.015	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	15	0.016	0.000	0.000	0.002	PASS
Proposed Total Copper	Median	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	15	0.014	0.000	0.000	0.001	PASS
Total Copper	P (exceed)	0.472	0.470	0.469	0.468	0.469	0.470	0.470	0.469	0.468	0.469	0.469	0.465	0.470	0.470	0.471	15	0.469	0.002	0.002	0.047	PASS
Baseline Dissolved Copper	Median	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	15	0.004	0.000	0.000	0.000	PASS
Proposed Dissolved Copper	Median	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	15	0.004	0.000	0.000	0.000	PASS
Dissolved Copper	P (exceed)	0.507	0.507	0.508	0.510	0.510	0.510	0.508	0.511	0.507	0.511	0.511	0.508	0.507	0.510	0.509	15	0.509	0.002	0.002	0.051	PASS
Baseline Total Zinc	Median	0.096	0.095	0.096	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	15	0.095	0.000	0.000	0.010	PASS
Proposed Total Zinc	Median	0.086	0.085	0.085	0.086	0.086	0.086	0.086	0.086	0.086	0.086	0.085	0.086	0.086	0.085	0.086	15	0.086	0.000	0.000	0.009	PASS
Total Zinc	P (exceed)	0.466	0.464	0.462	0.466	0.468	0.510	0.464	0.464	0.465	0.465	0.461	0.469	0.466	0.468	0.467	15	0.468	0.012	0.012	0.047	PASS
Baseline Dissolved Zinc	Median	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	15	0.027	0.000	0.000	0.003	PASS
Proposed Dissolved Zinc	Median	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	15	0.026	0.000	0.000	0.003	PASS
Dissolved Zinc	P (exceed)	0.491	0.496	0.493	0.496	0.495	0.494	0.496	0.492	0.496	0.492	0.493	0.494	0.497	0.493	0.493	15	0.494	0.002	0.002	0.049	PASS

Table 33: Case Study 2 (Whipple Creek) – HI-RUN Output Summary (continued)

TDA CC5 Concentration (mg/L)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Baseline TSS	Median	32.169	32.066	31.921	31.805	32.070	31.948	31.917	31.806	32.039	31.980	31.928	31.845	31.971	32.114	31.991	15	31.971	0.108	0.109	3.197	PASS
Proposed TSS	Median	5.650	5.630	5.695	5.679	5.648	5.670	5.653	5.697	5.661	5.650	5.676	5.706	5.629	5.664	5.665	15	5.665	0.023	0.023	0.566	PASS
TSS	P (exceed)	0.120	0.122	0.123	0.123	0.122	0.123	0.123	0.124	0.122	0.122	0.122	0.124	0.123	0.123	0.123	15	0.123	0.001	0.001	0.012	PASS
Baseline Total Copper	Median	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	15	0.010	0.000	0.000	0.001	PASS
Proposed Total Copper	Median	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	15	0.005	0.000	0.000	0.001	PASS
Total Copper	P (exceed)	0.185	0.183	0.184	0.185	0.185	0.183	0.182	0.184	0.187	0.184	0.185	0.186	0.184	0.185	0.183	15	0.184	0.001	0.001	0.018	PASS
Baseline Dissolved Copper	Median	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	15	0.004	0.000	0.000	0.000	PASS
Proposed Dissolved Copper	Median	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	15	0.003	0.000	0.000	0.000	PASS
Dissolved Copper	P (exceed)	0.404	0.405	0.405	0.405	0.405	0.405	0.407	0.406	0.408	0.404	0.409	0.403	0.405	0.404	0.405	15	0.405	0.002	0.002	0.041	PASS
Baseline Total Zinc	Median	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	15	0.056	0.000	0.000	0.006	PASS
Proposed Total Zinc	Median	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	15	0.023	0.000	0.000	0.002	PASS
Total Zinc	P (exceed)	0.152	0.152	0.153	0.152	0.151	0.150	0.153	0.153	0.151	0.152	0.153	0.151	0.152	0.150	0.153	15	0.152	0.001	0.001	0.015	PASS
Baseline Dissolved Zinc	Median	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	15	0.023	0.000	0.000	0.002	PASS
Proposed Dissolved Zinc	Median	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	15	0.016	0.000	0.000	0.002	PASS
Dissolved Zinc	P (exceed)	0.329	0.327	0.328	0.329	0.330	0.328	0.332	0.331	0.328	0.330	0.326	0.330	0.325	0.328	0.327	15	0.329	0.002	0.002	0.033	PASS

TDA 2 Baseline Distance (feet)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Dissolved Copper	January	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	February	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	March	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	September	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	October	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Zinc	January	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Zinc	February	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Zinc	March	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Zinc	September	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Zinc	October	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS

Table 33: Case Study 2 (Whipple Creek) – HI-RUN Output Summary (continued)

TDA 2 Proposed Distance (feet)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Dissolved Copper	January	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	February	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	March	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	September	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	October	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Zinc	January	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Zinc	February	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Zinc	March	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Zinc	September	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Zinc	October	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS

TDA 3 Baseline Distance (feet)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Dissolved Copper	January	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	February	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	March	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	September	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	October	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Zinc	January	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Zinc	February	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Zinc	March	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Zinc	September	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Zinc	October	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS

TDA 3 Proposed Distance (feet)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Dissolved Copper	January	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	February	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	March	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	September	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	October	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Zinc	January	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Zinc	February	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Zinc	March	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Zinc	September	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Zinc	October	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS

Table 32: Case Study 2 (Salmon Creek) – HI-RUN Output Summary

Load (lbs)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Baseline TSS	Median	5631	5648	5627	5681	5642	5647	5637	5650	5676	5623	5641	5637	5617	5625	5687	15	5645	21.377	21.636	564.460	PASS
Proposed TSS	Median	4162	4195	4177	4202	4192	4199	4157	4167	4201	4154	4209	4176	4182	4168	4196	15	4182	17.992	18.210	418.247	PASS
TSS	P (exceed)	0.417	0.420	0.420	0.418	0.421	0.420	0.418	0.418	0.419	0.417	0.421	0.417	0.421	0.419	0.420	15	0.419	0.001	0.002	0.042	PASS
Baseline Total Copper	Median	1.470	1.450	1.470	1.470	1.470	1.470	1.460	1.450	1.470	1.460	1.470	1.470	1.470	1.460	1.460	15	1.465	0.007	0.008	0.146	PASS
Proposed Total Copper	Median	1.110	1.100	1.100	1.100	1.100	1.100	1.100	1.100	1.100	1.100	1.100	1.100	1.100	1.100	1.100	15	1.101	0.003	0.003	0.110	PASS
Total Copper	P (exceed)	0.402	0.405	0.404	0.406	0.407	0.402	0.403	0.406	0.400	0.406	0.403	0.404	0.404	0.407	0.404	15	0.404	0.002	0.002	0.040	PASS
Baseline Dissolved Copper	Median	0.372	0.372	0.373	0.373	0.371	0.372	0.372	0.371	0.370	0.373	0.372	0.371	0.371	0.373	0.371	15	0.372	0.001	0.001	0.037	PASS
Proposed Dissolved Copper	Median	0.310	0.300	0.310	0.310	0.300	0.310	0.300	0.300	0.300	0.310	0.310	0.300	0.300	0.300	0.300	15	0.304	0.005	0.005	0.030	PASS
Dissolved Copper	P (exceed)	0.425	0.427	0.426	0.426	0.426	0.425	0.425	0.428	0.427	0.426	0.427	0.424	0.426	0.426	0.426	15	0.426	0.001	0.001	0.043	PASS
Baseline Total Zinc	Median	8.890	8.880	8.830	8.860	8.860	8.900	8.860	8.890	8.830	8.850	8.870	8.830	8.900	8.880	8.880	15	8.867	0.024	0.025	0.887	PASS
Proposed Total Zinc	Median	6.700	6.700	6.600	6.600	6.700	6.600	6.600	6.700	6.700	6.600	6.600	6.600	6.700	6.700	6.700	15	6.653	0.052	0.052	0.665	PASS
Total Zinc	P (exceed)	0.400	0.404	0.404	0.403	0.405	0.401	0.404	0.403	0.405	0.401	0.405	0.403	0.404	0.402	0.403	15	0.403	0.002	0.002	0.040	PASS
Baseline Dissolved Zinc	Median	2.680	2.660	2.660	2.650	2.680	2.670	2.670	2.670	2.670	2.670	2.640	2.680	2.670	2.660	2.680	15	2.667	0.012	0.012	0.267	PASS
Proposed Dissolved Zinc	Median	2.100	2.100	2.100	2.100	2.100	2.100	2.100	2.100	2.100	2.100	2.100	2.100	2.100	2.100	2.100	15	2.100	0.000	0.000	0.210	PASS
Dissolved Zinc	P (exceed)	0.426	0.428	0.429	0.426	0.427	0.429	0.426	0.428	0.426	0.426	0.426	0.430	0.428	0.429	0.423	15	0.427	0.002	0.002	0.043	PASS

TDA 5 Concentration (mg/L)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Baseline TSS	Median	55.040	55.292	55.124	55.165	55.493	55.598	55.530	55.341	55.174	55.460	55.366	55.497	55.431	55.303	55.323	15	55.342	0.163	0.165	5.534	PASS
Proposed TSS	Median	40.722	40.732	40.657	40.443	40.647	40.599	40.564	40.342	40.861	40.655	40.591	40.579	40.572	40.391	40.324	15	40.579	0.150	0.152	4.058	PASS
TSS	P (exceed)	0.416	0.413	0.415	0.414	0.413	0.413	0.412	0.414	0.418	0.414	0.417	0.412	0.414	0.414	0.414	15	0.414	0.002	0.002	0.041	PASS
Baseline Total Copper	Median	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	15	0.014	0.000	0.000	0.001	PASS
Proposed Total Copper	Median	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	15	0.011	0.000	0.000	0.001	PASS
Total Copper	P (exceed)	0.419	0.417	0.417	0.417	0.419	0.423	0.418	0.422	0.417	0.418	0.419	0.419	0.420	0.420	0.419	15	0.419	0.002	0.002	0.042	PASS
Baseline Dissolved Copper	Median	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	15	0.004	0.000	0.000	0.000	PASS
Proposed Dissolved Copper	Median	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	15	0.004	0.000	0.000	0.000	PASS
Dissolved Copper	P (exceed)	0.510	0.512	0.516	0.510	0.513	0.510	0.512	0.512	0.511	0.513	0.511	0.512	0.514	0.515	0.512	15	0.512	0.002	0.002	0.051	PASS
Baseline Total Zinc	Median	0.087	0.087	0.087	0.087	0.087	0.087	0.086	0.087	0.086	0.087	0.086	0.087	0.087	0.087	0.087	15	0.087	0.000	0.000	0.009	PASS
Proposed Total Zinc	Median	0.067	0.067	0.067	0.067	0.067	0.067	0.067	0.067	0.067	0.067	0.067	0.067	0.067	0.067	0.067	15	0.067	0.000	0.000	0.007	PASS
Total Zinc	P (exceed)	0.408	0.412	0.407	0.408	0.409	0.408	0.409	0.409	0.410	0.410	0.410	0.409	0.410	0.407	0.409	15	0.409	0.001	0.001	0.041	PASS
Baseline Dissolved Zinc	Median	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	15	0.026	0.000	0.000	0.003	PASS
Proposed Dissolved Zinc	Median	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	15	0.024	0.000	0.000	0.002	PASS
Dissolved Zinc	P (exceed)	0.479	0.479	0.478	0.479	0.479	0.480	0.480	0.482	0.478	0.478	0.477	0.480	0.481	0.477	0.477	15	0.479	0.001	0.002	0.048	PASS

Table 34: Case Study 2 (Salmon Creek) – HI-RUN Output Summary (continued)

TDA 6 Concentration (mg/L)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Baseline TSS	Median	56.133	56.275	55.904	56.476	55.992	56.190	56.439	56.293	56.435	56.135	56.680	56.003	55.904	56.287	56.166	15	56.221	0.224	0.227	5.622	PASS
Proposed TSS	Median	54.638	54.568	54.569	54.686	54.574	54.278	54.680	54.445	54.898	54.555	54.670	54.187	54.432	54.496	54.319	15	54.533	0.182	0.184	5.453	PASS
TSS	P (exceed)	0.492	0.492	0.493	0.492	0.494	0.491	0.493	0.492	0.494	0.495	0.491	0.492	0.493	0.491	0.492	15	0.492	0.001	0.001	0.049	PASS
Baseline Total Copper	Median	0.015	0.014	0.015	0.015	0.015	0.015	0.014	0.015	0.014	0.014	0.015	0.014	0.015	0.015	0.015	15	0.015	0.000	0.000	0.001	PASS
Proposed Total Copper	Median	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	15	0.014	0.000	0.000	0.001	PASS
Total Copper	P (exceed)	0.492	0.495	0.491	0.494	0.493	0.494	0.495	0.492	0.492	0.493	0.491	0.493	0.493	0.491	0.492	15	0.493	0.001	0.001	0.049	PASS
Baseline Dissolved Copper	Median	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	15	0.004	0.000	0.000	0.000	PASS
Proposed Dissolved Copper	Median	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	15	0.004	0.000	0.000	0.000	PASS
Dissolved Copper	P (exceed)	0.503	0.501	0.505	0.503	0.502	0.502	0.502	0.501	0.503	0.502	0.500	0.500	0.502	0.501	0.503	15	0.502	0.001	0.001	0.050	PASS
Baseline Total Zinc	Median	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.088	15	0.088	0.000	0.000	0.009	PASS
Proposed Total Zinc	Median	0.086	0.086	0.085	0.086	0.085	0.085	0.086	0.085	0.086	0.086	0.086	0.086	0.085	0.086	0.086	15	0.086	0.000	0.000	0.009	PASS
Total Zinc	P (exceed)	0.494	0.492	0.491	0.491	0.490	0.492	0.491	0.489	0.491	0.491	0.491	0.492	0.491	0.489	0.490	15	0.491	0.001	0.001	0.049	PASS
Baseline Dissolved Zinc	Median	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.027	0.026	0.026	0.026	15	0.026	0.000	0.000	0.003	PASS
Proposed Dissolved Zinc	Median	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	15	0.026	0.000	0.000	0.003	PASS
Dissolved Zinc	P (exceed)	0.499	0.498	0.498	0.499	0.496	0.497	0.498	0.499	0.500	0.498	0.497	0.497	0.497	0.498	0.502	15	0.498	0.001	0.001	0.050	PASS

TDA 5 Baseline Distance (feet)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Dissolved Copper	January	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	February	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	March	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	September	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	October	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Zinc	January	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Zinc	February	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Zinc	March	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Zinc	September	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Zinc	October	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS

TDA 5 Proposed Distance (feet)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Dissolved Copper	January	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	February	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	March	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	September	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Copper	October	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Zinc	January	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Zinc	February	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Zinc	March	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Zinc	September	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS
Dissolved Zinc	October	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15	1	0	0	0.1	PASS

Table 33: Case Study 2 (Rockwell Creek) – HI-RUN Output Summary

Load (lbs)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Baseline TSS	Median	10923	11019	10995	11020	11027	10914	10952	10975	10924	10912	10947	10955	10957	10901	11013	15	10962	43.577	44.106	1096.227	PASS
Proposed TSS	Median	3744	3777	3753	3760	3759	3771	3750	3739	3746	3745	3730	3739	3747	3730	3758	15	3750	13.501	13.665	374.987	PASS
TSS	P (exceed)	0.205	0.203	0.203	0.205	0.202	0.205	0.203	0.204	0.204	0.204	0.202	0.204	0.203	0.205	0.204	15	0.204	0.001	0.001	0.020	PASS
Baseline Total Copper	Median	3.010	3.010	3.010	3.010	3.020	3.020	3.000	3.010	3.010	3.020	2.990	3.020	2.980	3.000	3.020	15	3.009	0.012	0.012	0.301	PASS
Proposed Total Copper	Median	1.700	1.700	1.700	1.700	1.700	1.700	1.700	1.700	1.700	1.700	1.700	1.700	1.700	1.700	1.700	15	1.700	0.000	0.000	0.170	PASS
Total Copper	P (exceed)	0.256	0.256	0.257	0.254	0.254	0.255	0.256	0.257	0.254	0.256	0.254	0.254	0.258	0.257	0.255	15	0.256	0.001	0.001	0.026	PASS
Baseline Dissolved Copper	Median	0.907	0.906	0.905	0.905	0.907	0.907	0.904	0.905	0.905	0.906	0.904	0.907	0.904	0.911	0.906	15	0.906	0.002	0.002	0.091	PASS
Proposed Dissolved Copper	Median	0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860	15	0.860	0.000	0.000	0.086	PASS
Dissolved Copper	P (exceed)	0.473	0.475	0.475	0.475	0.474	0.474	0.476	0.475	0.474	0.474	0.475	0.473	0.478	0.476	0.475	15	0.475	0.001	0.001	0.047	PASS
Baseline Total Zinc	Median	17.800	17.800	17.800	17.900	17.800	17.800	17.700	17.800	17.800	17.800	17.800	17.700	17.800	17.800	17.800	15	17.793	0.046	0.046	1.779	PASS
Proposed Total Zinc	Median	8.900	8.900	8.900	8.800	8.900	8.900	8.900	8.900	8.900	8.900	8.900	8.800	8.800	8.800	8.900	15	8.873	0.046	0.046	0.887	PASS
Total Zinc	P (exceed)	0.221	0.219	0.223	0.218	0.220	0.220	0.223	0.221	0.221	0.221	0.220	0.223	0.220	0.221	0.222	15	0.221	0.001	0.001	0.022	PASS
Baseline Dissolved Zinc	Median	6.070	6.080	6.080	6.090	6.100	6.090	6.110	6.090	6.100	6.080	6.060	6.080	6.090	6.080	6.080	15	6.085	0.012	0.013	0.609	PASS
Proposed Dissolved Zinc	Median	4.800	4.800	4.800	4.800	4.800	4.800	4.900	4.800	4.800	4.800	4.800	4.800	4.800	4.800	4.800	15	4.807	0.026	0.026	0.481	PASS
Dissolved Zinc	P (exceed)	0.397	0.400	0.398	0.399	0.398	0.398	0.398	0.399	0.398	0.401	0.401	0.399	0.400	0.399	0.399	15	0.399	0.001	0.001	0.040	PASS

TDA 4 Concentration (mg/L)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Baseline TSS	Median	43.088	43.337	42.901	43.281	42.586	43.364	42.738	42.814	43.072	42.842	42.910	42.734	42.878	42.812	42.783	15	42.943	0.235	0.238	4.294	PASS
Proposed TSS	Median	16.134	16.230	16.223	16.251	16.235	16.239	16.117	16.289	16.159	16.295	16.215	16.302	16.242	16.258	16.325	15	16.234	0.060	0.061	1.623	PASS
TSS	P (exceed)	0.213	0.211	0.215	0.213	0.215	0.213	0.214	0.217	0.212	0.214	0.213	0.215	0.215	0.215	0.214	15	0.214	0.001	0.002	0.021	PASS
Baseline Total Copper	Median	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	15	0.012	0.000	0.000	0.001	PASS
Proposed Total Copper	Median	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	15	0.007	0.000	0.000	0.001	PASS
Total Copper	P (exceed)	0.237	0.240	0.238	0.238	0.238	0.239	0.238	0.237	0.237	0.236	0.239	0.237	0.235	0.240	0.239	15	0.238	0.001	0.001	0.024	PASS
Baseline Dissolved Copper	Median	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	15	0.004	0.000	0.000	0.000	PASS
Proposed Dissolved Copper	Median	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	15	0.003	0.000	0.000	0.000	PASS
Dissolved Copper	P (exceed)	0.451	0.449	0.452	0.448	0.450	0.451	0.449	0.449	0.451	0.453	0.450	0.449	0.450	0.449	0.447	15	0.450	0.002	0.002	0.045	PASS
Baseline Total Zinc	Median	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070	15	0.070	0.000	0.000	0.007	PASS
Proposed Total Zinc	Median	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	15	0.036	0.000	0.000	0.004	PASS
Total Zinc	P (exceed)	0.210	0.209	0.208	0.206	0.208	0.210	0.208	0.208	0.209	0.209	0.209	0.209	0.210	0.208	0.208	15	0.209	0.001	0.001	0.021	PASS
Baseline Dissolved Zinc	Median	0.025	0.025	0.025	0.024	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	15	0.025	0.000	0.000	0.002	PASS
Proposed Dissolved Zinc	Median	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	15	0.019	0.000	0.000	0.002	PASS
Dissolved Zinc	P (exceed)	0.381	0.380	0.380	0.383	0.380	0.382	0.381	0.380	0.382	0.379	0.378	0.377	0.379	0.379	0.380	15	0.380	0.002	0.002	0.038	PASS

Table 35: Case Study 2 (Rockwell Creek) – HI-RUN Output Summary (continued)

TDA CC6 Concentration (mg/L)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Baseline TSS	Median	61.678	61.624	61.616	61.433	61.421	61.435	61.261	61.735	61.126	61.361	61.962	61.506	61.531	61.643	61.692	15	61.535	0.207	0.210	6.153	PASS
Proposed TSS	Median	5.678	5.651	5.647	5.674	5.691	5.682	5.690	5.711	5.685	5.651	5.697	5.666	5.675	5.681	5.687	15	5.678	0.018	0.018	0.568	PASS
TSS	P (exceed)	0.070	0.069	0.067	0.069	0.069	0.069	0.069	0.069	0.070	0.068	0.068	0.068	0.068	0.069	0.069	15	0.069	0.001	0.001	0.007	PASS
Baseline Total Copper	Median	0.016	0.015	0.016	0.016	0.016	0.012	0.016	0.016	0.016	0.015	0.016	0.015	0.016	0.016	0.016	15	0.016	0.001	0.001	0.002	PASS
Proposed Total Copper	Median	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	15	0.005	0.000	0.000	0.001	PASS
Total Copper	P (exceed)	0.124	0.122	0.125	0.123	0.121	0.123	0.123	0.122	0.124	0.124	0.125	0.124	0.124	0.124	0.126	15	0.124	0.001	0.001	0.012	PASS
Baseline Dissolved Copper	Median	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	15	0.004	0.000	0.000	0.000	PASS
Proposed Dissolved Copper	Median	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	15	0.003	0.000	0.000	0.000	PASS
Dissolved Copper	P (exceed)	0.428	0.429	0.428	0.429	0.431	0.426	0.426	0.429	0.428	0.427	0.430	0.428	0.427	0.427	0.427	15	0.428	0.001	0.001	0.043	PASS
Baseline Total Zinc	Median	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.096	0.095	0.095	15	0.095	0.000	0.000	0.010	PASS
Proposed Total Zinc	Median	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	15	0.023	0.000	0.000	0.002	PASS
Total Zinc	P (exceed)	0.089	0.088	0.088	0.089	0.089	0.089	0.087	0.090	0.088	0.091	0.087	0.090	0.089	0.088	0.089	15	0.089	0.001	0.001	0.009	PASS
Baseline Dissolved Zinc	Median	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	15	0.027	0.000	0.000	0.003	PASS
Proposed Dissolved Zinc	Median	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	15	0.016	0.000	0.000	0.002	PASS
Dissolved Zinc	P (exceed)	0.314	0.313	0.315	0.314	0.312	0.313	0.312	0.315	0.312	0.314	0.315	0.314	0.316	0.315	0.316	15	0.314	0.001	0.001	0.031	PASS

TDA CC7 Concentration (mg/L)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Baseline TSS	Median	45.155	45.122	45.099	45.145	45.179	45.274	45.116	44.898	45.102	45.430	45.296	44.962	45.261	45.093	45.367	15	45.167	0.141	0.143	4.517	PASS
Proposed TSS	Median	5.671	5.693	5.691	5.664	5.674	5.693	5.691	5.660	5.698	5.731	5.686	5.653	5.694	5.686	5.701	15	5.686	0.019	0.020	0.569	PASS
TSS	P (exceed)	0.088	0.087	0.088	0.087	0.086	0.087	0.087	0.087	0.087	0.087	0.088	0.086	0.086	0.088	0.087	15	0.087	0.001	0.001	0.009	PASS
Baseline Total Copper	Median	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	15	0.012	0.000	0.000	0.001	PASS
Proposed Total Copper	Median	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	15	0.005	0.000	0.000	0.001	PASS
Total Copper	P (exceed)	0.139	0.139	0.142	0.141	0.141	0.141	0.141	0.142	0.140	0.140	0.140	0.141	0.140	0.142	0.142	15	0.141	0.001	0.001	0.014	PASS
Baseline Dissolved Copper	Median	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	15	0.004	0.000	0.000	0.000	PASS
Proposed Dissolved Copper	Median	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	15	0.003	0.000	0.000	0.000	PASS
Dissolved Copper	P (exceed)	0.399	0.400	0.400	0.400	0.401	0.400	0.399	0.397	0.399	0.398	0.400	0.398	0.396	0.400	0.398	15	0.399	0.001	0.001	0.040	PASS
Baseline Total Zinc	Median	0.073	0.072	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	15	0.073	0.000	0.000	0.007	PASS
Proposed Total Zinc	Median	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	15	0.023	0.000	0.000	0.002	PASS
Total Zinc	P (exceed)	0.110	0.108	0.109	0.108	0.110	0.108	0.108	0.109	0.107	0.108	0.109	0.108	0.107	0.107	0.108	15	0.108	0.001	0.001	0.011	PASS
Baseline Dissolved Zinc	Median	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	15	0.025	0.000	0.000	0.003	PASS
Proposed Dissolved Zinc	Median	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	15	0.016	0.000	0.000	0.002	PASS
Dissolved Zinc	P (exceed)	0.306	0.307	0.304	0.304	0.305	0.307	0.304	0.305	0.305	0.305	0.303	0.306	0.305	0.305	0.305	15	0.305	0.001	0.001	0.031	PASS

Table 34: Case Study 2 (Whipple Creek) – SELDM Output Summary

Load (lbs)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Baseline TSS	Median	21049	21403	22078	21905	22687	21213	21112	22560	21990	20432	20809	22462	21708	20311	20880	15	21506	761	770	2151	PASS
Proposed TSS	Median	18072	19642	18764	19556	19547	19216	18816	19156	20414	18961	19348	19840	18970	18885	19977	15	19278	578	585	1928	PASS
TSS	P (exceed)	0.463	0.468	0.461	0.466	0.465	0.463	0.478	0.469	0.468	0.478	0.458	0.451	0.475	0.470	0.479	15	0.468	0.008	0.008	0.047	PASS
Baseline Total Copper	Median	4.505	4.542	4.500	4.711	4.727	4.539	4.469	4.482	4.417	4.397	4.473	4.506	4.475	4.336	4.565	15	4.510	0.103	0.105	0.451	PASS
Proposed Total Copper	Median	4.130	4.343	4.121	4.127	4.208	4.234	4.201	4.217	4.249	4.144	4.145	4.420	4.072	4.262	4.093	15	4.198	0.095	0.096	0.420	PASS
Total Copper	P (exceed)	0.464	0.480	0.458	0.465	0.469	0.474	0.500	0.463	0.472	0.474	0.481	0.469	0.472	0.474	0.462	15	0.472	0.010	0.010	0.047	PASS
Baseline Dissolved Copper	Median	1.127	1.111	1.114	1.054	1.080	1.047	1.065	1.057	1.101	1.081	1.056	1.124	1.056	1.081	1.064	15	1.081	0.027	0.028	0.108	PASS
Proposed Dissolved Copper	Median	1.061	1.071	1.037	1.089	1.072	1.068	1.056	1.093	1.076	1.035	1.073	1.057	1.056	1.056	1.094	15	1.066	0.018	0.018	0.107	PASS
Dissolved Copper	P (exceed)	0.489	0.488	0.495	0.490	0.509	0.488	0.492	0.507	0.496	0.496	0.501	0.501	0.508	0.497	0.496	15	0.497	0.007	0.007	0.050	PASS
Baseline Total Zinc	Median	28.831	28.406	27.270	27.958	28.095	27.551	28.552	27.198	27.025	27.220	27.267	28.628	27.909	29.036	27.186	15	27.875	0.684	0.692	2.788	PASS
Proposed Total Zinc	Median	26.379	25.925	24.459	25.612	25.175	24.512	23.942	25.683	26.612	25.610	25.253	27.220	24.661	24.292	25.759	15	25.406	0.924	0.935	2.541	PASS
Total Zinc	P (exceed)	0.451	0.474	0.468	0.464	0.479	0.475	0.446	0.463	0.468	0.466	0.468	0.479	0.465	0.441	0.465	15	0.465	0.011	0.011	0.046	PASS
Baseline Dissolved Zinc	Median	8.620	9.040	8.890	8.820	8.573	8.847	8.907	8.820	9.097	8.793	8.752	8.957	8.247	8.517	8.500	15	8.758	0.228	0.231	0.876	PASS
Proposed Dissolved Zinc	Median	8.244	8.356	8.075	8.480	8.695	8.281	8.607	8.134	8.417	8.612	8.208	8.628	8.602	8.376	8.285	15	8.400	0.197	0.199	0.840	PASS
Dissolved Zinc	P (exceed)	0.489	0.490	0.480	0.503	0.505	0.489	0.501	0.489	0.501	0.500	0.489	0.491	0.510	0.484	0.492	15	0.494	0.009	0.009	0.049	PASS

TDA 1 Concentration (mg/L)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Baseline TSS	Median	51.752	53.164	53.559	53.548	53.015	55.742	55.747	55.393	54.233	51.912	55.765	54.169	53.430	52.794	48.914	15	53.543	1.836	1.859	5.354	PASS
Proposed TSS	Median	50.903	52.632	54.299	55.912	49.524	52.124	52.403	53.472	53.136	54.612	53.963	48.395	54.959	53.514	58.373	15	53.215	2.466	2.496	5.321	PASS
TSS	P (exceed)	0.470	0.462	0.458	0.459	0.458	0.446	0.451	0.460	0.431	0.456	0.459	0.435	0.438	0.463	0.476	15	0.455	0.013	0.013	0.045	PASS
Baseline Total Copper	Median	0.014	0.014	0.015	0.015	0.015	0.014	0.014	0.015	0.015	0.015	0.015	0.015	0.015	0.014	0.015	15	0.015	0.000	0.000	0.001	PASS
Proposed Total Copper	Median	0.014	0.014	0.014	0.015	0.015	0.015	0.015	0.014	0.015	0.015	0.015	0.014	0.014	0.015	0.014	15	0.015	0.000	0.000	0.001	PASS
Total Copper	P (exceed)	0.470	0.460	0.445	0.460	0.445	0.462	0.458	0.439	0.444	0.439	0.434	0.458	0.437	0.447	0.428	15	0.448	0.012	0.012	0.045	PASS
Baseline Dissolved Copper	Median	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	15	0.004	0.000	0.000	0.000	PASS
Proposed Dissolved Copper	Median	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	15	0.004	0.000	0.000	0.000	PASS
Dissolved Copper	P (exceed)	0.500	0.510	0.520	0.511	0.519	0.507	0.507	0.521	0.508	0.517	0.507	0.518	0.521	0.515	0.502	15	0.512	0.007	0.007	0.051	PASS
Baseline Total Zinc	Median	0.084	0.080	0.082	0.082	0.085	0.083	0.086	0.082	0.086	0.088	0.081	0.084	0.084	0.084	0.082	15	0.084	0.002	0.002	0.008	PASS
Proposed Total Zinc	Median	0.081	0.085	0.084	0.084	0.082	0.082	0.079	0.082	0.082	0.081	0.084	0.089	0.080	0.078	0.086	15	0.082	0.003	0.003	0.008	PASS
Total Zinc	P (exceed)	0.444	0.463	0.444	0.451	0.415	0.448	0.414	0.449	0.450	0.440	0.467	0.452	0.441	0.429	0.435	15	0.443	0.015	0.015	0.044	PASS
Baseline Dissolved Zinc	Median	0.028	0.027	0.028	0.028	0.028	0.026	0.026	0.028	0.027	0.028	0.028	0.027	0.027	0.027	0.027	15	0.027	0.001	0.001	0.003	PASS
Proposed Dissolved Zinc	Median	0.027	0.026	0.027	0.028	0.027	0.028	0.027	0.027	0.027	0.028	0.027	0.027	0.027	0.026	0.027	15	0.027	0.001	0.001	0.003	PASS
Dissolved Zinc	P (exceed)	0.467	0.497	0.473	0.501	0.484	0.506	0.502	0.448	0.503	0.497	0.462	0.493	0.493	0.506	0.489	15	0.488	0.018	0.018	0.049	PASS

Table 36: Case Study 2 (Whipple Creek) – SELDM Output Summary (continued)

TDA 2 Concentration (mg/L)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Baseline TSS	Median	56.950	58.900	57.800	57.750	61.500	61.900	58.350	57.400	59.100	54.200	54.200	57.500	58.700	57.000	60.600	15	58.123	2.209	2.236	5.812	PASS
Proposed TSS	Median	51.010	54.289	52.685	49.067	47.493	52.405	53.891	52.196	53.569	49.244	48.591	53.675	52.853	54.784	52.938	15	51.913	2.285	2.313	5.191	PASS
TSS	P (exceed)	0.485	0.479	0.462	0.479	0.463	0.476	0.497	0.467	0.474	0.476	0.473	0.481	0.475	0.479	0.480	15	0.476	0.009	0.009	0.048	PASS
Baseline Total Copper	Median	0.015	0.016	0.016	0.016	0.016	0.015	0.015	0.016	0.015	0.015	0.015	0.017	0.015	0.016	0.016	15	0.016	0.001	0.001	0.002	PASS
Proposed Total Copper	Median	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.015	0.015	0.015	0.014	0.014	0.014	15	0.014	0.000	0.000	0.001	PASS
Total Copper	P (exceed)	0.482	0.481	0.475	0.464	0.487	0.491	0.495	0.469	0.486	0.483	0.481	0.485	0.469	0.484	0.475	15	0.480	0.008	0.009	0.048	PASS
Baseline Dissolved Copper	Median	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	15	0.004	0.000	0.000	0.000	PASS
Proposed Dissolved Copper	Median	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	15	0.004	0.000	0.000	0.000	PASS
Dissolved Copper	P (exceed)	0.508	0.501	0.508	0.506	0.507	0.523	0.510	0.497	0.499	0.504	0.516	0.512	0.512	0.505	0.500	15	0.507	0.007	0.007	0.051	PASS
Baseline Total Zinc	Median	0.089	0.089	0.088	0.090	0.087	0.090	0.094	0.090	0.090	0.094	0.094	0.094	0.089	0.092	0.093	15	0.091	0.002	0.003	0.009	PASS
Proposed Total Zinc	Median	0.077	0.081	0.079	0.078	0.082	0.079	0.078	0.080	0.084	0.081	0.079	0.083	0.081	0.079	0.080	15	0.080	0.002	0.002	0.008	PASS
Total Zinc	P (exceed)	0.458	0.489	0.476	0.483	0.484	0.485	0.445	0.479	0.482	0.466	0.473	0.484	0.471	0.457	0.463	15	0.473	0.013	0.013	0.047	PASS
Baseline Dissolved Zinc	Median	0.028	0.028	0.028	0.027	0.028	0.028	0.028	0.028	0.029	0.028	0.028	0.028	0.027	0.029	0.028	15	0.028	0.000	0.000	0.003	PASS
Proposed Dissolved Zinc	Median	0.027	0.026	0.027	0.027	0.026	0.027	0.027	0.026	0.027	0.027	0.026	0.026	0.027	0.026	0.027	15	0.027	0.000	0.000	0.003	PASS
Dissolved Zinc	P (exceed)	0.490	0.497	0.491	0.510	0.501	0.524	0.493	0.500	0.490	0.515	0.492	0.490	0.514	0.484	0.507	15	0.500	0.012	0.012	0.050	PASS

TDA 3 Concentration (mg/L)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Baseline TSS	Median	59.200	60.350	57.150	56.900	62.600	60.600	54.800	56.300	56.200	54.900	56.900	59.600	58.000	59.800	60.200	15	58.233	2.296	2.324	5.823	PASS
Proposed TSS	Median	45.548	44.379	43.111	42.041	45.275	43.174	42.709	45.207	42.056	43.606	44.800	42.189	43.447	41.575	43.810	15	43.529	1.291	1.307	4.353	PASS
TSS	P (exceed)	0.452	0.433	0.448	0.460	0.438	0.443	0.454	0.447	0.442	0.443	0.470	0.458	0.432	0.433	0.451	15	0.447	0.011	0.011	0.045	PASS
Baseline Total Copper	Median	0.017	0.016	0.016	0.016	0.016	0.016	0.016	0.015	0.017	0.016	0.016	0.016	0.015	0.015	0.015	15	0.016	0.001	0.001	0.002	PASS
Proposed Total Copper	Median	0.013	0.012	0.012	0.013	0.012	0.013	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	15	0.012	0.000	0.000	0.001	PASS
Total Copper	P (exceed)	0.428	0.446	0.449	0.449	0.433	0.444	0.442	0.449	0.438	0.439	0.443	0.466	0.439	0.446	0.435	15	0.443	0.009	0.009	0.044	PASS
Baseline Dissolved Copper	Median	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	15	0.004	0.000	0.000	0.000	PASS
Proposed Dissolved Copper	Median	0.004	0.004	0.003	0.003	0.003	0.003	0.003	0.004	0.003	0.004	0.003	0.004	0.003	0.004	0.004	15	0.004	0.000	0.000	0.000	PASS
Dissolved Copper	P (exceed)	0.508	0.501	0.508	0.506	0.507	0.523	0.510	0.497	0.499	0.504	0.516	0.512	0.512	0.505	0.500	15	0.507	0.007	0.007	0.051	PASS
Baseline Total Zinc	Median	0.094	0.094	0.086	0.092	0.090	0.087	0.089	0.089	0.088	0.095	0.091	0.092	0.090	0.091	0.093	15	0.091	0.003	0.003	0.009	PASS
Proposed Total Zinc	Median	0.071	0.068	0.069	0.071	0.068	0.071	0.068	0.068	0.071	0.075	0.069	0.073	0.070	0.069	0.071	15	0.070	0.002	0.002	0.007	PASS
Total Zinc	P (exceed)	0.432	0.434	0.441	0.449	0.437	0.464	0.428	0.449	0.458	0.449	0.424	0.449	0.440	0.422	0.437	15	0.441	0.012	0.012	0.044	PASS
Baseline Dissolved Zinc	Median	0.028	0.029	0.030	0.028	0.030	0.029	0.027	0.029	0.028	0.029	0.029	0.028	0.029	0.029	0.028	15	0.028	0.001	0.001	0.003	PASS
Proposed Dissolved Zinc	Median	0.024	0.025	0.025	0.025	0.025	0.024	0.025	0.024	0.025	0.025	0.024	0.026	0.024	0.025	0.025	15	0.025	0.000	0.000	0.002	PASS
Dissolved Zinc	P (exceed)	0.483	0.479	0.477	0.496	0.469	0.475	0.503	0.475	0.494	0.489	0.486	0.482	0.483	0.491	0.491	15	0.485	0.009	0.009	0.048	PASS

Table 36: Case Study 2 (Whipple Creek) – SELDM Output Summary (continued)

TDA CC5 Concentration (mg/L)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Baseline TSS	Median	27.034	29.101	27.188	29.249	27.791	27.026	29.222	28.024	28.207	27.562	29.071	26.903	27.673	28.201	27.756	15	28.001	0.830	0.840	2.800	PASS
Proposed TSS	Median	7.780	7.845	7.480	6.635	7.305	6.810	7.320	7.360	7.350	7.400	7.210	7.240	7.790	6.760	7.260	15	7.303	0.359	0.363	0.730	PASS
TSS	P (exceed)	0.178	0.175	0.172	0.141	0.173	0.175	0.152	0.177	0.166	0.160	0.154	0.160	0.177	0.160	0.165	15	0.166	0.011	0.011	0.017	PASS
Baseline Total Copper	Median	0.010	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.010	0.009	0.009	0.009	0.009	15	0.009	0.000	0.000	0.001	PASS
Proposed Total Copper	Median	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	15	0.005	0.000	0.000	0.000	PASS
Total Copper	P (exceed)	0.242	0.269	0.265	0.260	0.235	0.258	0.263	0.251	0.245	0.224	0.243	0.237	0.263	0.239	0.230	15	0.248	0.014	0.014	0.025	PASS
Baseline Dissolved Copper	Median	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	15	0.003	0.000	0.000	0.000	PASS
Proposed Dissolved Copper	Median	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	15	0.003	0.000	0.000	0.000	PASS
Dissolved Copper	P (exceed)	0.506	0.520	0.516	0.512	0.520	0.510	0.509	0.516	0.502	0.508	0.505	0.514	0.497	0.501	0.511	15	0.510	0.007	0.007	0.051	PASS
Baseline Total Zinc	Median	0.051	0.049	0.050	0.049	0.048	0.049	0.050	0.052	0.049	0.051	0.051	0.051	0.048	0.048	0.050	15	0.050	0.001	0.001	0.005	PASS
Proposed Total Zinc	Median	0.025	0.024	0.023	0.023	0.024	0.024	0.024	0.023	0.024	0.024	0.024	0.023	0.023	0.023	0.024	15	0.024	0.001	0.001	0.002	PASS
Total Zinc	P (exceed)	0.240	0.237	0.217	0.228	0.228	0.230	0.218	0.198	0.212	0.191	0.225	0.208	0.228	0.225	0.212	15	0.220	0.014	0.014	0.022	PASS
Baseline Dissolved Zinc	Median	0.021	0.021	0.021	0.021	0.021	0.021	0.020	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	15	0.021	0.000	0.000	0.002	PASS
Proposed Dissolved Zinc	Median	0.016	0.016	0.016	0.016	0.017	0.015	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	15	0.016	0.000	0.000	0.002	PASS
Dissolved Zinc	P (exceed)	0.345	0.330	0.331	0.316	0.329	0.329	0.325	0.322	0.345	0.333	0.337	0.328	0.319	0.352	0.320	15	0.331	0.010	0.010	0.033	PASS

Annual Runoff Volume (cf)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Highway - Baseline	Average	3556988	3550668	3551346	3589955	3536825	3526075	3501946	3504521	3551881	3517379	3531075	3579971	3511967	3504411	3520147	15	3535677	27300	27631	353568	PASS
Highway - Proposed	Average	3844771	3929039	3828510	3892704	3865618	3867560	3862000	3868575	3896464	3837812	3880707	3906696	3900329	3880972	3882235	15	3876266	27057	27385	387627	PASS
BMP Outflow - Baseline	Average	3556988	3550668	3551346	3589955	3536825	3526075	3501946	3504521	3551881	3517379	3531075	3579971	3511967	3504411	3520147	15	3535677	27300	27631	353568	PASS
BMP Outflow - Proposed	Average	3523825	3598704	3502914	3570901	3540961	3539455	3537039	3546954	3575217	3516665	3559128	3582843	3575550	3548096	3558938	15	3551813	26292	26611	355181	PASS

Upstream Concentration (mg/L)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Dissolved Copper		0.00153	0.00153	0.00153	0.00153	0.00153	0.00153	0.00153	0.00153	0.00153	0.00153	0.00153	0.00153	0.00153	0.00153	0.00153	15	0.00153	0.00000	0.00000	0.00015	PASS
Dissolved Zinc		0.00450	0.00450	0.00450	0.00450	0.00450	0.00450	0.00450	0.00450	0.00450	0.00450	0.00450	0.00450	0.00450	0.00450	0.00450	15	0.00450	0.00000	0.00000	0.00045	PASS

TDA 2 Downstream Concentration (mg/L)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Baseline Dissolved Copper	Median	0.00168	0.00168	0.00167	0.00168	0.00168	0.00168	0.00168	0.00168	0.00167	0.00167	0.00167	0.00167	0.00167	0.00167	0.00167	15	0.00167	0.00001	0.00001	0.00017	PASS
Proposed Dissolved Copper	Median	0.00164	0.00164	0.00165	0.00165	0.00165	0.00165	0.00164	0.00164	0.00164	0.00165	0.00164	0.00165	0.00164	0.00164	0.00165	15	0.00165	0.00000	0.00000	0.00016	PASS
Baseline Dissolved Zinc	Median	0.00618	0.00608	0.00610	0.00614	0.00624	0.00604	0.00619	0.00616	0.00618	0.00604	0.00604	0.00613	0.00602	0.00623	0.00600	15	0.00612	0.00008	0.00008	0.00061	PASS
Proposed Dissolved Zinc	Median	0.00587	0.00587	0.00585	0.00596	0.00591	0.00591	0.00593	0.00583	0.00581	0.00584	0.00584	0.00590	0.00595	0.00585	0.00593	15	0.00588	0.00005	0.00005	0.00059	PASS

TDA 3 Downstream Concentration (mg/L)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Baseline Dissolved Copper	Median	0.00171	0.00170	0.00171	0.00170	0.00171	0.00170	0.00170	0.00170	0.00171	0.00171	0.00170	0.00170	0.00171	0.00171	0.00171	15	0.00171	0.00001	0.00001	0.00017	PASS
Proposed Dissolved Copper	Median	0.00164	0.00163	0.00163	0.00163	0.00163	0.00163	0.00163	0.00163	0.00163	0.00164	0.00163	0.00163	0.00163	0.00164	0.00163	15	0.00163	0.00000	0.00000	0.00016	PASS
Baseline Dissolved Zinc	Median	0.00652	0.00657	0.00660	0.00645	0.00662	0.00652	0.00644	0.00648	0.00651	0.00651	0.00647	0.00650	0.00651	0.00652	0.00639	15	0.00651	0.00006	0.00006	0.00065	PASS
Proposed Dissolved Zinc	Median	0.00582	0.00584	0.00586	0.00584	0.00587	0.00583	0.00587	0.00579	0.00585	0.00590	0.00594	0.00598	0.00586	0.00592	0.00589	15	0.00587	0.00005	0.00005	0.00059	PASS

Table 37: Case Study 2 (Salmon Creek) – SELDM Output Summary

Load (lbs)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Baseline TSS	Median	9360	10226	9099	10004	9567	9786	9134	10151	9534	9352	9596	9745	9488	9342	9137	15	9568	357	361	957	PASS
Proposed TSS	Median	6934	7237	7087	7524	7104	7197	7257	8024	7392	7679	7299	7086	7268	7079	7128	15	7286	278	281	729	PASS
TSS	P (exceed)	0.408	0.431	0.423	0.436	0.417	0.433	0.449	0.425	0.420	0.439	0.431	0.436	0.439	0.428	0.448	15	0.431	0.011	0.011	0.043	PASS
Baseline Total Copper	Median	1.983	2.090	2.018	2.030	2.063	1.992	2.001	2.063	2.036	1.992	1.959	1.988	1.979	2.029	2.014	15	2.016	0.036	0.037	0.202	PASS
Proposed Total Copper	Median	1.600	1.548	1.589	1.566	1.648	1.523	1.533	1.543	1.561	1.679	1.575	1.611	1.598	1.527	1.504	15	1.574	0.048	0.049	0.157	PASS
Total Copper	P (exceed)	0.431	0.427	0.422	0.426	0.427	0.406	0.412	0.427	0.412	0.431	0.419	0.431	0.437	0.410	0.421	15	0.423	0.009	0.009	0.042	PASS
Baseline Dissolved Copper	Median	0.498	0.494	0.493	0.512	0.511	0.528	0.493	0.490	0.517	0.523	0.504	0.480	0.487	0.487	0.492	15	0.501	0.015	0.015	0.050	PASS
Proposed Dissolved Copper	Median	0.420	0.424	0.414	0.434	0.438	0.436	0.431	0.428	0.440	0.423	0.431	0.436	0.427	0.445	0.422	15	0.430	0.008	0.009	0.043	PASS
Dissolved Copper	P (exceed)	0.417	0.427	0.429	0.424	0.449	0.419	0.432	0.418	0.436	0.437	0.422	0.436	0.438	0.435	0.439	15	0.431	0.009	0.009	0.043	PASS
Baseline Total Zinc	Median	13.120	12.203	12.899	11.953	12.237	12.415	12.035	12.317	12.906	12.290	13.309	12.520	12.313	12.304	12.690	15	12.501	0.399	0.404	1.250	PASS
Proposed Total Zinc	Median	9.469	9.658	9.726	9.284	9.650	9.613	9.775	9.437	9.390	9.393	9.754	9.367	9.591	9.580	9.470	15	9.544	0.154	0.156	0.954	PASS
Total Zinc	P (exceed)	0.405	0.437	0.426	0.420	0.421	0.417	0.436	0.419	0.416	0.406	0.409	0.414	0.420	0.424	0.438	15	0.421	0.010	0.011	0.042	PASS
Baseline Dissolved Zinc	Median	4.083	3.974	3.874	3.994	4.080	3.946	3.842	3.949	4.144	3.980	4.094	3.984	4.014	3.881	3.811	15	3.977	0.097	0.098	0.398	PASS
Proposed Dissolved Zinc	Median	3.305	3.422	3.292	3.351	3.255	3.352	3.320	3.335	3.213	3.284	3.455	3.446	3.408	3.180	3.254	15	3.325	0.083	0.084	0.332	PASS
Dissolved Zinc	P (exceed)	0.418	0.435	0.430	0.422	0.424	0.443	0.441	0.420	0.430	0.432	0.430	0.447	0.442	0.423	0.431	15	0.431	0.009	0.009	0.043	PASS

TDA 5 Concentration (mg/L)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Baseline TSS	Median	52.223	50.603	49.032	51.968	51.398	51.463	51.812	50.249	52.493	51.972	52.469	53.829	52.582	52.431	51.288	15	51.721	1.141	1.155	5.172	PASS
Proposed TSS	Median	26.931	27.953	28.449	27.344	26.981	28.990	28.898	28.738	27.953	29.160	27.787	27.938	28.754	28.411	29.397	15	28.246	0.771	0.780	2.825	PASS
TSS	P (exceed)	0.376	0.371	0.382	0.384	0.374	0.380	0.406	0.398	0.382	0.381	0.387	0.380	0.396	0.391	0.388	15	0.385	0.010	0.010	0.039	PASS
Baseline Total Copper	Median	0.014	0.014	0.014	0.014	0.015	0.014	0.015	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	15	0.014	0.000	0.000	0.001	PASS
Proposed Total Copper	Median	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.010	0.009	0.010	0.009	0.009	0.009	0.009	0.009	15	0.009	0.000	0.000	0.001	PASS
Total Copper	P (exceed)	0.379	0.399	0.399	0.388	0.382	0.376	0.372	0.394	0.385	0.397	0.386	0.382	0.390	0.386	0.371	15	0.386	0.009	0.009	0.039	PASS
Baseline Dissolved Copper	Median	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	15	0.004	0.000	0.000	0.000	PASS
Proposed Dissolved Copper	Median	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	15	0.003	0.000	0.000	0.000	PASS
Dissolved Copper	P (exceed)	0.474	0.479	0.476	0.493	0.491	0.481	0.488	0.491	0.480	0.481	0.473	0.488	0.490	0.487	0.496	15	0.484	0.007	0.007	0.048	PASS
Baseline Total Zinc	Median	0.087	0.077	0.082	0.076	0.082	0.083	0.080	0.083	0.081	0.082	0.083	0.081	0.082	0.080	0.079	15	0.081	0.003	0.003	0.008	PASS
Proposed Total Zinc	Median	0.050	0.050	0.051	0.050	0.053	0.052	0.054	0.049	0.050	0.048	0.050	0.050	0.051	0.051	0.051	15	0.051	0.001	0.001	0.005	PASS
Total Zinc	P (exceed)	0.365	0.386	0.377	0.369	0.386	0.385	0.391	0.366	0.385	0.381	0.365	0.376	0.382	0.374	0.391	15	0.379	0.009	0.009	0.038	PASS
Baseline Dissolved Zinc	Median	0.027	0.027	0.027	0.027	0.028	0.026	0.026	0.027	0.026	0.027	0.027	0.026	0.027	0.026	0.027	15	0.027	0.001	0.001	0.003	PASS
Proposed Dissolved Zinc	Median	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	15	0.021	0.000	0.000	0.002	PASS
Dissolved Zinc	P (exceed)	0.135	0.154	0.141	0.128	0.141	0.137	0.131	0.131	0.135	0.130	0.141	0.141	0.148	0.135	0.135	15	0.138	0.007	0.007	0.014	PASS

Table 37: Case Study 2 (Salmon Creek) – SELDM Output Summary (continued)

TDA 6 Concentration (mg/L)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Baseline TSS	Median	50.422	51.862	56.093	53.061	53.054	51.138	57.636	56.223	53.428	51.972	54.234	50.619	53.783	51.906	51.071	15	53.100	2.182	2.209	5.310	PASS
Proposed TSS	Median	49.636	49.132	52.833	51.450	49.998	51.219	53.229	50.681	50.955	50.813	52.650	49.185	50.997	49.484	49.468	15	50.782	1.337	1.353	5.078	PASS
TSS	P (exceed)	0.482	0.494	0.495	0.495	0.502	0.495	0.477	0.482	0.490	0.509	0.487	0.499	0.480	0.491	0.500	15	0.492	0.009	0.009	0.049	PASS
Baseline Total Copper	Median	0.015	0.014	0.015	0.014	0.015	0.015	0.015	0.014	0.014	0.014	0.014	0.014	0.014	0.015	0.015	15	0.015	0.000	0.000	0.001	PASS
Proposed Total Copper	Median	0.014	0.014	0.014	0.014	0.014	0.013	0.014	0.014	0.013	0.014	0.013	0.014	0.014	0.013	0.014	15	0.014	0.000	0.000	0.001	PASS
Total Copper	P (exceed)	0.479	0.501	0.468	0.485	0.470	0.468	0.476	0.489	0.492	0.490	0.498	0.480	0.506	0.462	0.491	15	0.484	0.013	0.013	0.048	PASS
Baseline Dissolved Copper	Median	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	15	0.004	0.000	0.000	0.000	PASS
Proposed Dissolved Copper	Median	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	15	0.004	0.000	0.000	0.000	PASS
Dissolved Copper	P (exceed)	0.498	0.501	0.509	0.517	0.498	0.484	0.506	0.496	0.513	0.497	0.506	0.509	0.512	0.494	0.499	15	0.503	0.009	0.009	0.050	PASS
Baseline Total Zinc	Median	0.088	0.082	0.082	0.081	0.081	0.084	0.080	0.079	0.084	0.083	0.083	0.083	0.082	0.081	0.083	15	0.082	0.002	0.002	0.008	PASS
Proposed Total Zinc	Median	0.078	0.081	0.080	0.081	0.077	0.077	0.082	0.079	0.081	0.073	0.080	0.080	0.082	0.078	0.080	15	0.079	0.002	0.002	0.008	PASS
Total Zinc	P (exceed)	0.469	0.507	0.500	0.496	0.491	0.479	0.497	0.495	0.501	0.475	0.490	0.481	0.503	0.495	0.487	15	0.491	0.011	0.011	0.049	PASS
Baseline Dissolved Zinc	Median	0.027	0.026	0.026	0.027	0.027	0.027	0.026	0.026	0.027	0.027	0.028	0.027	0.027	0.027	0.027	15	0.027	0.001	0.001	0.003	PASS
Proposed Dissolved Zinc	Median	0.026	0.027	0.026	0.026	0.026	0.026	0.026	0.025	0.026	0.026	0.026	0.027	0.027	0.026	0.026	15	0.026	0.000	0.000	0.003	PASS
Dissolved Zinc	P (exceed)	0.512	0.518	0.516	0.493	0.488	0.500	0.510	0.490	0.486	0.502	0.494	0.509	0.522	0.501	0.507	15	0.503	0.011	0.012	0.050	PASS

Annual Runoff Volume (cf)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Highway - Baseline	Average	1644550	1660810	1675021	1659800	1658268	1670311	1615073	1659251	1669452	1661164	1677546	1628146	1643886	1649961	1643570	15	1654454	17270	17480	165445	PASS
Highway - Proposed	Average	1831480	1813982	1838814	1836356	1856230	1843121	1849325	1827429	1851300	1830968	1849529	1836089	1827460	1833389	1817957	15	1836229	12163	12311	183623	PASS
BMP Outflow - Baseline	Average	1644550	1660810	1675021	1659800	1658268	1670311	1615073	1659251	1669452	1661164	1677546	1628146	1643886	1649961	1643570	15	1654454	17270	17480	165445	PASS
BMP Outflow - Proposed	Average	1487436	1470115	1489641	1490051	1502471	1492520	1500559	1485238	1497879	1482889	1504636	1491529	1480366	1487391	1469969	15	1488846	10379	10505	148885	PASS

Upstream Concentration (mg/L)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Dissolved Copper		0.00154	0.00154	0.00154	0.00154	0.00154	0.00154	0.00154	0.00154	0.00154	0.00154	0.00154	0.00154	0.00154	0.00154	0.00154	15	0.00154	0.00000	0.00000	0.00015	PASS
Dissolved Zinc		0.00450	0.00450	0.00450	0.00450	0.00450	0.00450	0.00450	0.00450	0.00450	0.00450	0.00450	0.00450	0.00450	0.00450	0.00450	15	0.00450	0.00000	0.00000	0.00045	PASS

TDA 5 Downstream Concentration (mg/L)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Baseline Dissolved Copper	Median	0.00155	0.00155	0.00155	0.00155	0.00155	0.00155	0.00155	0.00155	0.00155	0.00155	0.00155	0.00155	0.00155	0.00155	0.00155	15	0.00155	0.00000	0.00000	0.00015	PASS
Proposed Dissolved Copper	Median	0.00154	0.00154	0.00154	0.00154	0.00154	0.00154	0.00154	0.00154	0.00154	0.00154	0.00154	0.00154	0.00154	0.00154	0.00154	15	0.00154	0.00000	0.00000	0.00015	PASS
Baseline Dissolved Zinc	Median	0.00458	0.00458	0.00457	0.00457	0.00458	0.00458	0.00457	0.00458	0.00458	0.00458	0.00458	0.00457	0.00458	0.00458	0.00458	15	0.00458	0.00000	0.00000	0.00046	PASS
Proposed Dissolved Zinc	Median	0.00453	0.00453	0.00453	0.00453	0.00453	0.00453	0.00453	0.00453	0.00453	0.00453	0.00453	0.00453	0.00453	0.00453	0.00453	15	0.00453	0.00000	0.00000	0.00045	PASS

Table 38: Case Study 2 (Rockwell Creek) – SELDM Output Summary

Load (lbs)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Baseline TSS	Median	19335	18100	19078	18997	19223	20110	18474	18840	18520	19150	18480	18109	18109	18776	19350	15	18843	562	569	1884	PASS
Proposed TSS	Median	5541	6346	6072	6004	6062	6003	5886	5843	6111	5921	5659	6094	6094	6278	5621	15	5969	229	232	597	PASS
TSS	P (exceed)	0.225	0.225	0.219	0.228	0.237	0.224	0.213	0.217	0.216	0.201	0.220	0.224	0.224	0.222	0.212	15	0.220	0.008	0.008	0.022	PASS
Baseline Total Copper	Median	4.571	4.590	4.319	4.575	4.450	4.434	4.570	4.405	4.545	4.495	4.499	4.422	4.422	4.197	4.686	15	4.478	0.121	0.123	0.448	PASS
Proposed Total Copper	Median	2.291	2.340	2.264	2.223	2.285	2.318	2.252	2.147	2.284	2.240	2.305	2.284	2.284	2.332	2.371	15	2.281	0.054	0.054	0.228	PASS
Total Copper	P (exceed)	0.333	0.323	0.322	0.333	0.325	0.334	0.304	0.314	0.305	0.288	0.309	0.319	0.319	0.326	0.327	15	0.319	0.013	0.013	0.032	PASS
Baseline Dissolved Copper	Median	1.354	1.335	1.357	1.438	1.379	1.416	1.425	1.371	1.435	1.352	1.336	1.373	1.373	1.327	1.374	15	1.376	0.036	0.037	0.138	PASS
Proposed Dissolved Copper	Median	1.143	1.150	1.117	1.139	1.072	1.131	1.078	1.103	1.107	1.151	1.099	1.105	1.105	1.173	1.134	15	1.120	0.028	0.029	0.112	PASS
Dissolved Copper	P (exceed)	0.504	0.513	0.494	0.503	0.502	0.498	0.502	0.515	0.492	0.484	0.498	0.503	0.503	0.509	0.506	15	0.502	0.008	0.008	0.050	PASS
Baseline Total Zinc	Median	27.690	27.460	25.740	26.830	26.700	28.790	25.745	26.865	27.080	27.305	26.425	27.330	27.330	26.525	27.935	15	27.050	0.797	0.807	2.705	PASS
Proposed Total Zinc	Median	11.855	12.400	12.045	11.565	12.360	12.225	12.165	11.675	12.400	12.880	12.485	12.425	12.425	12.640	12.135	15	12.245	0.353	0.357	1.225	PASS
Total Zinc	P (exceed)	0.279	0.296	0.286	0.285	0.284	0.302	0.288	0.297	0.279	0.256	0.285	0.287	0.287	0.299	0.273	15	0.285	0.011	0.011	0.029	PASS
Baseline Dissolved Zinc	Median	10.082	10.040	10.255	9.955	9.664	10.047	9.714	10.299	10.570	10.304	9.921	10.220	10.220	9.877	9.742	15	10.060	0.255	0.258	1.006	PASS
Proposed Dissolved Zinc	Median	6.773	7.367	6.825	7.035	7.204	6.606	6.926	7.250	7.423	6.852	6.973	7.068	7.068	7.409	7.143	15	7.061	0.243	0.246	0.706	PASS
Dissolved Zinc	P (exceed)	0.434	0.435	0.432	0.451	0.443	0.434	0.436	0.438	0.436	0.405	0.442	0.443	0.443	0.449	0.467	15	0.439	0.013	0.013	0.044	PASS

TDA 4 Concentration (mg/L)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Baseline TSS	Median	39.580	39.528	39.750	39.913	38.931	41.606	38.314	42.153	41.864	37.917	39.830	41.185	41.185	41.456	41.662	15	40.325	1.353	1.369	4.033	PASS
Proposed TSS	Median	11.911	12.492	12.861	12.199	12.753	12.208	11.912	12.434	12.087	11.936	11.637	12.145	12.145	12.547	12.178	15	12.230	0.334	0.338	1.223	PASS
TSS	P (exceed)	0.250	0.250	0.249	0.244	0.247	0.256	0.263	0.241	0.251	0.209	0.242	0.243	0.243	0.243	0.239	15	0.245	0.012	0.012	0.024	PASS
Baseline Total Copper	Median	0.011	0.012	0.011	0.011	0.011	0.011	0.012	0.012	0.012	0.011	0.012	0.012	0.012	0.012	0.011	15	0.011	0.000	0.000	0.001	PASS
Proposed Total Copper	Median	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	15	0.006	0.000	0.000	0.001	PASS
Total Copper	P (exceed)	0.291	0.280	0.276	0.275	0.286	0.292	0.256	0.263	0.264	0.197	0.272	0.284	0.284	0.273	0.280	15	0.272	0.023	0.023	0.027	PASS
Baseline Dissolved Copper	Median	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	15	0.003	0.000	0.000	0.000	PASS
Proposed Dissolved Copper	Median	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	15	0.003	0.000	0.000	0.000	PASS
Dissolved Copper	P (exceed)	0.433	0.429	0.443	0.433	0.439	0.435	0.453	0.434	0.426	0.378	0.438	0.428	0.428	0.442	0.455	15	0.433	0.017	0.018	0.043	PASS
Baseline Total Zinc	Median	0.065	0.064	0.064	0.064	0.064	0.063	0.065	0.064	0.069	0.065	0.064	0.066	0.066	0.065	0.066	15	0.065	0.002	0.002	0.007	PASS
Proposed Total Zinc	Median	0.030	0.029	0.029	0.029	0.029	0.030	0.030	0.030	0.029	0.030	0.030	0.029	0.029	0.029	0.029	15	0.029	0.000	0.000	0.003	PASS
Total Zinc	P (exceed)	0.247	0.266	0.261	0.249	0.238	0.268	0.248	0.279	0.235	0.212	0.256	0.243	0.243	0.253	0.260	15	0.250	0.016	0.016	0.025	PASS
Baseline Dissolved Zinc	Median	0.024	0.025	0.024	0.024	0.023	0.024	0.024	0.024	0.024	0.023	0.023	0.023	0.023	0.023	0.023	15	0.024	0.000	0.000	0.002	PASS
Proposed Dissolved Zinc	Median	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.018	0.017	0.017	0.017	0.017	0.017	0.017	15	0.017	0.000	0.000	0.002	PASS
Dissolved Zinc	P (exceed)	0.380	0.368	0.373	0.390	0.376	0.378	0.373	0.368	0.383	0.291	0.391	0.370	0.370	0.399	0.392	15	0.373	0.025	0.025	0.037	PASS

Table 38: Case Study 2 (Rockwell Creek) – SELDM Output Summary (continued)

TDA CC6 Concentration (mg/L)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Baseline TSS	Median	57.300	58.500	57.550	57.650	58.000	62.050	60.300	60.100	58.500	60.400	59.500	56.800	56.800	57.100	58.600	15	58.610	1.556	1.575	5.861	PASS
Proposed TSS	Median	6.950	7.190	7.265	7.290	7.280	7.410	7.500	6.930	7.550	7.255	7.270	7.045	7.045	7.630	7.380	15	7.266	0.210	0.213	0.727	PASS
TSS	P (exceed)	0.116	0.127	0.120	0.115	0.119	0.116	0.127	0.118	0.127	0.131	0.127	0.126	0.126	0.128	0.132	15	0.124	0.006	0.006	0.012	PASS
Baseline Total Copper	Median	0.016	0.016	0.015	0.016	0.015	0.016	0.016	0.016	0.015	0.016	0.016	0.016	0.016	0.016	0.016	15	0.016	0.000	0.000	0.002	PASS
Proposed Total Copper	Median	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	15	0.005	0.000	0.000	0.000	PASS
Total Copper	P (exceed)	0.187	0.185	0.192	0.191	0.203	0.194	0.189	0.192	0.179	0.181	0.189	0.177	0.177	0.197	0.184	15	0.188	0.007	0.007	0.019	PASS
Baseline Dissolved Copper	Median	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	15	0.004	0.000	0.000	0.000	PASS
Proposed Dissolved Copper	Median	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	15	0.003	0.000	0.000	0.000	PASS
Dissolved Copper	P (exceed)	0.391	0.395	0.385	0.378	0.376	0.387	0.385	0.391	0.394	0.384	0.394	0.397	0.397	0.396	0.385	15	0.389	0.007	0.007	0.039	PASS
Baseline Total Zinc	Median	0.090	0.092	0.090	0.091	0.088	0.090	0.090	0.092	0.091	0.091	0.091	0.089	0.089	0.089	0.092	15	0.090	0.001	0.001	0.009	PASS
Proposed Total Zinc	Median	0.023	0.025	0.023	0.023	0.024	0.024	0.023	0.023	0.023	0.024	0.024	0.024	0.024	0.024	0.024	15	0.024	0.001	0.001	0.002	PASS
Total Zinc	P (exceed)	0.156	0.168	0.157	0.160	0.160	0.163	0.150	0.152	0.156	0.163	0.161	0.159	0.159	0.161	0.143	15	0.158	0.006	0.006	0.016	PASS
Baseline Dissolved Zinc	Median	0.028	0.028	0.028	0.029	0.028	0.029	0.029	0.030	0.029	0.029	0.029	0.029	0.029	0.029	0.028	15	0.028	0.001	0.001	0.003	PASS
Proposed Dissolved Zinc	Median	0.015	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.017	0.017	0.016	0.016	15	0.016	0.000	0.000	0.002	PASS
Dissolved Zinc	P (exceed)	0.285	0.293	0.294	0.301	0.309	0.291	0.280	0.293	0.286	0.279	0.310	0.306	0.306	0.301	0.301	15	0.296	0.010	0.010	0.030	PASS

TDA CC7 Concentration (mg/L)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Baseline TSS	Median	43.327	42.080	41.325	43.613	42.218	41.942	41.994	40.277	39.874	38.545	42.266	40.300	40.300	42.690	42.898	15	41.577	1.433	1.450	4.158	PASS
Proposed TSS	Median	7.400	6.940	7.220	7.590	8.110	7.620	7.230	7.270	7.250	7.115	7.350	7.655	7.655	7.560	7.410	15	7.425	0.284	0.288	0.743	PASS
TSS	P (exceed)	0.127	0.123	0.124	0.129	0.125	0.138	0.139	0.118	0.134	0.140	0.118	0.147	0.147	0.130	0.133	15	0.131	0.009	0.010	0.013	PASS
Baseline Total Copper	Median	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.011	0.012	0.012	0.012	0.012	0.012	0.013	0.012	15	0.012	0.000	0.000	0.001	PASS
Proposed Total Copper	Median	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	15	0.005	0.000	0.000	0.000	PASS
Total Copper	P (exceed)	0.201	0.207	0.203	0.218	0.202	0.211	0.213	0.205	0.192	0.203	0.212	0.199	0.199	0.213	0.207	15	0.206	0.007	0.007	0.021	PASS
Baseline Dissolved Copper	Median	0.003	0.004	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.004	0.003	0.003	0.003	0.004	0.003	15	0.003	0.000	0.000	0.000	PASS
Proposed Dissolved Copper	Median	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	15	0.003	0.000	0.000	0.000	PASS
Dissolved Copper	P (exceed)	0.382	0.369	0.384	0.374	0.369	0.374	0.373	0.361	0.358	0.372	0.371	0.367	0.367	0.371	0.368	15	0.371	0.007	0.007	0.037	PASS
Baseline Total Zinc	Median	0.066	0.067	0.067	0.068	0.070	0.071	0.067	0.068	0.067	0.066	0.067	0.068	0.068	0.068	0.070	15	0.068	0.001	0.001	0.007	PASS
Proposed Total Zinc	Median	0.024	0.024	0.023	0.024	0.024	0.023	0.024	0.023	0.024	0.022	0.023	0.024	0.024	0.024	0.023	15	0.023	0.000	0.000	0.002	PASS
Total Zinc	P (exceed)	0.168	0.174	0.172	0.176	0.168	0.168	0.168	0.166	0.182	0.172	0.181	0.187	0.187	0.158	0.183	15	0.174	0.008	0.008	0.017	PASS
Baseline Dissolved Zinc	Median	0.024	0.024	0.024	0.024	0.024	0.024	0.025	0.024	0.024	0.024	0.024	0.024	0.024	0.025	0.024	15	0.024	0.000	0.000	0.002	PASS
Proposed Dissolved Zinc	Median	0.016	0.016	0.016	0.017	0.016	0.016	0.015	0.016	0.016	0.017	0.016	0.017	0.017	0.016	0.016	15	0.016	0.000	0.000	0.002	PASS
Dissolved Zinc	P (exceed)	0.291	0.301	0.272	0.294	0.292	0.279	0.289	0.293	0.314	0.306	0.289	0.301	0.301	0.296	0.310	15	0.295	0.011	0.011	0.030	PASS

Annual Runoff Volume (cf)		Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Number of Runs	Mean	STD	95% conf. interval spread	10% of mean	Sample Size Test
Highway - Baseline	Median	3919710	3935607	3928899	3909516	3914964	3970393	3974929	3963750	4003987	3924857	3932821	3954628	3954628	3885839	3956560	15	3942073	30195	30562	394207	PASS
Highway - Proposed	Median	5277250	5429143	5330357	5382679	5349964	5353329	5317500	5297073	5375893	5431745	5303214	5370214	5370214	5383393	5437276	15	5360616	49482	50083	536062	PASS
BMP Outflow - Baseline	Median	3919710	3935607	3928899	3909516	3914964	3970393	3974929	3963750	4003987	3924857	3932821	3954628	3954628	3885839	3956560	15	3942073	30195	30562	394207	PASS
BMP Outflow - Propsed	Median	4512286	4636321	4552071	4600000	4590179	4565008	4544857	4504184	4579893	4658745	4520286	4596571	4596571	4605071	4652455	15	4580967	48128	48713	458097	PASS

Appendix K: Pre-processing of Data for Populating SELDM

Pre-processing of the data set used for the determination of HI-RUN parameter statistics was completed in order to determine the statistical characteristics necessary for input to SELDM. The data set was provided by WSDOT for the purpose of customizing SELDM for use in this comparison study. This data set, titled "Hi-Run WSDOT BMP Data Summary," consists of a total of 415 observations. Each observation contains data for a storm event from a total of 13 separate sites. 210 of the observations are coded "pavement" and represent untreated highway runoff. 205 of the observations are coded "basic" or "enhanced" and represent treated BMP outflow. The current version of HI-RUN provides the option to select a basic or enhanced BMP, but because of data set limitations the observations for basic and enhanced were combined and HI-RUN uses one BMP characterization. In addition to event information, such as storm duration and depth, event mean concentration (EMC) values are provided for DCu, TCu, DZn, TZn, and TSS for the majority of observations. The total number of EMC values for each water quality parameter is, respectively, 391, 391, 415, 415, and 414. The data set was first analyzed in Excel. Further analysis with Stata, a statistical software package, was completed to substantiate the results from Excel.

Prior to processing to determine the necessary values for SELDM, it was confirmed that the data set was the same as used in the current version of HI-RUN. This was accomplished by the calculation of the mean and standard deviation of the EMC values for each water quality parameter for untreated and treated. These values are provided in Table 39. The values were then compared to Table 4 (Table 40 in this report) from the HI-RUN model documentation which provides the mean and standard deviation as calculated for use in HI-RUN. HI-RUN has several "hidden" Excel sheets which are used in computations. The values listed on the hidden sheet titled "Water Quality" are the same as the concentration values provided in Table 40. In general the values calculated from the data set matched the HI-RUN values with some small discrepancies; i.e. a difference of 0.0003 between the means for untreated TZn and 0.0006 between the standard deviations. The greatest difference was between the means and standard deviations for treated TSS; 0.36 and 1.81 respectively. This difference was not considered to be significant enough to warrant further investigation and the comparison was accepted as confirmation that this was the data set utilized for HI-RUN.

Table 35: Mean and Standard Deviation Values from "Hi-Run WSDOT BMP Data Summary"

	Untreated Runoff (mg/L)	Treated Runoff (mg/L)
Total Suspended Solids		
Mean	106.3	12.16
Standard Deviation	147.5	19.89
Total Copper		
Mean	0.0219	0.0057
Standard Deviation	0.0215	0.0035
Dissolved Copper		
Mean	0.0051	0.0036
Standard Deviation	0.0049	0.0024
Total Zinc		
Mean	0.1351	0.0279
Standard Deviation	0.1347	0.0192
Dissolved Zinc		
Mean	0.0423	0.0193
Standard Deviation	0.0494	0.0138

Table 40: Table 4 from HI-RUN Model Documentation (Herrera, 2008)

	Untreated Runoff (mg/L)	Treated Runoff (mg/L)
Total Suspended Solids		
Mean	106.4	11.8
Standard Deviation	149.8	21.7
Total Copper		
Mean	0.0219	0.0057
Standard Deviation	0.0216	0.0035
Dissolved Copper		
Mean	0.0051	0.0036
Standard Deviation	0.0050	0.0025
Total Zinc		
Mean	0.1348	0.0283
Standard Deviation	0.1353	0.0196
Dissolved Zinc		
Mean	0.0423	0.0193
Standard Deviation	0.0507	0.0139

As stated in the methods section of this report, the random option for generating water quality data was selected for use in SELDM. This option uses sample statistics from monitoring studies, which is also the method used in HI-RUN. For this method three values are required to characterize a water quality parameter; average, standard deviation, and skew coefficient. In addition a corresponding transformation factor of “Untransformed”, “Base 10 Log”, or “Natural Log” must be selected. According to the HI-RUN Model Documentation, it was determined that “a lognormal distribution provides the best fit for the majority of parameters in treated and untreated runoff” (p. 10, Herrera, 2008). Therefore the “Base 10 Log” transformation factor was used. This required the determination of statistics of the log of each parameter for treated and untreated. A transformed data set was created, which was the log 10 of each entry value, and the average, standard deviation, and skew coefficient of the transformed data was calculated for each water quality parameter, treated and untreated. The resulting values are provided in Table 41.

In order to characterize BMPs in SELDM, the ratio of the inflow concentrations to outflow concentrations are required. This ratio can be modeled in SELDM as a uniform distribution, a trapezoidal distribution, or a triangular distribution. In order to most closely replicate the HI-RUN method, which uses the statistical distribution of EMC values for BMP outflow, a uniform distribution was used. As stated previously, all parameters have been found to fit a lognormal distribution. Therefore the ratio of the median values was used (the median best represents the central tendency of a lognormal data set). The minimum irreducible concentration, which is a required value in SELDM, was found from the data set. The SELDM required value for rank correlation to inflow concentration was set to 0 because there was not sufficient data to suggest a positive or negative correlation. The ratio, minimum concentration, and correlation values are provided in Table 42. HI-RUN includes five different BMP types that provide volume reduction through infiltration. The five options include 0, 20, 40, 60, and 80% volume reduction. In SELDM five BMPs were created using the uniform distribution with the same volume reduction percentages as HI-RUN.

Table 41: Mean, Standard Deviation, and Skew Coefficient of the Transformed Data Set

	Untreated Runoff	Treated Runoff
Total Suspended Solids		
Mean	1.7302	0.8893
Standard Deviation	0.5529	0.3761
Skew Coefficient	-0.4373	0.5126
Total Copper		
Mean	1.1666	0.6869
Standard Deviation	0.4091	0.2518
Skew Coefficient	-0.3983	-0.1219
Dissolved Copper		
Mean	0.5915	0.4873
Standard Deviation	0.3067	0.2520
Skew Coefficient	0.2545	0.0263
Total Zinc		
Mean	1.9491	1.3447
Standard Deviation	0.4065	0.3113
Skew Coefficient	-0.0680	-0.3222
Dissolved Zinc		
Mean	1.4787	1.1922
Standard Deviation	0.3345	0.2857
Skew Coefficient	0.4771	0.0950

Table 42: Mean and Median Ratios for Each Water Quality Parameter

	Untreated Runoff (mg/L)	Treated Runoff (mg/L)	Ratio	Minimum Irreducible Concentration	Rank Correlation to Inflow Conc.
Total Suspended Solids					
Mean	106.3	12.16			
Median	60	7.4	0.1233	0.8	0
Total Copper					
Mean	0.0219	0.0057			
Median	0.0158	0.0050	0.3139	0.001	0
Dissolved Copper					
Mean	0.0051	0.0036			
Median	0.0041	0.0031	0.7552	0.001	0
Total Zinc					
Mean	0.1351	0.0279			
Median	0.0880	0.0230	0.2614	0.005	0
Dissolved Zinc					
Mean	0.0423	0.0193			
Median	0.0282	0.0158	0.5613	0.005	0

Multiple trial runs of SELDM were completed after input of the calculated statistics. One possible variation in method that was closely investigated was the option of setting the skew value to zero (see Table 41 for skew values determined and entered in SELDM). Per SELDM documentation when a skew value is specified the statistical distribution modeled is a log Pearson Type III. When the skew value is set to zero a lognormal distribution is modeled. In comparing the output it was found that using the log Pearson Type III distribution (skew values not set to zero) provided comparable output to HI-RUN and to the original HI-RUN WSDOT data set. It was also confirmed through the trial runs that a uniform distribution of the ratios of median values provided output comparable to that provided by HI-RUN. This is seen in the comparison of proposed (treated) concentrations which were again found to be comparable with output from HI-RUN and the original HI-RUN WSDOT data set. Table 43 summarizes the results of five trial runs in HI-RUN and five trial runs of two different formulations of SELDM. The average of the median concentrations is provided for comparison with median concentrations from the WSDOT data set.

Table 43: Summary of Trial Runs in HI-RUN and SELDM

	HI-RUN	SELDM (log Pearson Type III)	SELDM (lognormal)	WSDOT Data Set
Baseline (untreated)	Median (mg/L)	Median (mg/L)	Median (mg/L)	Median (mg/L)
TSS	61.352	57.87	52.100	60.000
TCu	0.016	0.016	0.015	0.016
DCu	0.004	0.004	0.004	0.004
TZn	0.095	0.088	0.091	0.088
DZn	0.027	0.028	0.030	0.028
Proposed (treated)	Median (mg/L)	Median (mg/L)	Median (mg/L)	Median (mg/L)
TSS	5.663	7.277	6.524	7.400
TCu	0.005	0.005	0.005	0.005
DCu	0.003	0.003	0.003	0.003
TZn	0.023	0.022	0.024	0.023
DZn	0.016	0.016	0.017	0.016

Appendix L: Example of Completed F-test Forms

Case Study 1
Baseline
Concentration
TSS

	HI-RUN	SELDM
Number of Runs	15	15
Mean	61.3282	57.77667
Standard Deviation	0.195666	1.88877
Variance	0.038285	3.567452

F-TEST	
F	93.1807
df_1	14
df_2	14
F Upper Bound	2.463
F Lower Bound	0.406
Result	Fail

Case Study 1
Baseline
Concentration
TCu

	HI-RUN	SELDM
Number of Runs	15	15
Mean	0.016	0.01566
Standard Deviation	7.18E-18	0.000495
Variance	5.16E-35	2.45E-07

F-TEST	
F	4.75E+27
df_1	14
df_2	14
F Upper Bound	2.463
F Lower Bound	0.406
Result	Fail

Case Study 1
Baseline
Concentration
DCu

	HI-RUN	SELDM
Number of Runs	15	15
Mean	0.004	0.003783
Standard Deviation	1.8E-18	5.28E-05
Variance	3.22E-36	2.79E-09

F-TEST	
F	8.65E+26
df_1	14
df_2	14
F Upper Bound	2.463
F Lower Bound	0.406
Result	Fail

Appendix M: Example of Completed t-test Forms

Case Study 2, TDA 6
Baseline
Concentration
TSS

	HI-RUN	SELDM
Number of Runs	15	15
Mean	61.53493	58.61
Standard Deviation	0.2071	1.556002
Variance	0.04289	2.421143

T-TEST	
s_p^2	1.232017
t_c	7.216695
df_1	14
df_2	14
t	2.145
Result	Unequal

Case Study 2, TDA 6
Baseline
Concentration
Total Copper

	HI-RUN	SELDM
Number of Runs	15	15
Mean	0.016	0.016
Standard Deviation	0.00106	0.000214
Variance	1.12E-06	4.6E-08

T-TEST	
s_p^2	5.85E-07
t_c	0.167107
df_1	14
df_2	14
t	2.145
Result	Equal

Case Study 2, TDA 6
Baseline
Concentration
Dissolved Copper

	HI-RUN	SELDM
Number of Runs	15	15
Mean	0.004	0.003782
Standard Deviation	1.8E-18	3.91E-05
Variance	3.22E-36	1.53E-09

T-TEST	
s_p^2	7.64E-10
t_c	21.56564
df_1	14
df_2	14
t	2.145
Result	Unequal

Appendix N: Example Output Results from t-tests in Stata

Baseline TSS Concentration

```
Two-sample t test with unequal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
   HIRUN |      15     61.3282    .0505208    .1956663    61.21984    61.43656
   SELDM |      15    57.77667    .4876783     1.88877     56.7307    58.82263
---------+--------------------------------------------------------------------
combined |      30    59.55243    .4083619     2.23669    58.71724    60.38763
---------+--------------------------------------------------------------------
    diff |            3.551533    .4902882                2.502039    4.601028
------------------------------------------------------------------------------
    diff = mean(HIRUN) - mean(SELDM)                              t =   7.2438
Ho: diff = 0                     Satterthwaite's degrees of freedom =  14.3005

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 1.0000         Pr(|T| > |t|) = 0.0000          Pr(T > t) = 0.0000
```

Proposed TCu Concentration

```
Two-sample t test with unequal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
   HIRUN |      15        .005           0           0        .005        .005
   SELDM |      15    .0049443    .0000204    .0000789    .0049006     .004988
---------+--------------------------------------------------------------------
combined |      30    .0049722    .0000113    .0000617    .0049491    .0049952
---------+--------------------------------------------------------------------
    diff |            .0000557    .0000204                 .000012    .0000994
------------------------------------------------------------------------------
    diff = mean(HIRUN) - mean(SELDM)                              t =   2.7311
Ho: diff = 0                     Satterthwaite's degrees of freedom =       14

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.9919         Pr(|T| > |t|) = 0.0162          Pr(T > t) = 0.0081
```

ProposedDZn Concentration

```
Two-sample t test with unequal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
   HIRUN |      15        .016           0           0        .016        .016
   SELDM |      15      .01607    .0000842    .0003261    .0158894    .0162506
---------+--------------------------------------------------------------------
combined |      30     .016035    .0000419    .0002294    .0159494    .0161206
---------+--------------------------------------------------------------------
    diff |             -.00007    .0000842               -.0002506    .0001106
------------------------------------------------------------------------------
    diff = mean(HIRUN) - mean(SELDM)                              t =  -0.8313
Ho: diff = 0                     Satterthwaite's degrees of freedom =       14

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.2099         Pr(|T| > |t|) = 0.4198          Pr(T > t) = 0.7901
```

Appendix O: Summary of p-values from t-tests in Stata

	Concentration									
	Baseline TSS	Proposed TSS	Baseline TCu	Proposed TCu	Baseline DCu	Proposed DCu	Baseline TZn	Proposed TZn	Baseline DZn	Proposed DZn
Case Study 1										
Bender Road	0	0	0.0187	0	0	0	0	0	0	0
Depot Road	0.0010	0	0	0	0	0	0	0	0	0
Case Study 2										
Rockwell Creek TDA4	0	0	0	0	0	0	0	0	0	0
Rockwell Creek TDA CC6	0	0	0.8695	0.0162	0	0	0	0.0001	0	0.4198
Rockwell Creek TDA CC7	0	0	0.4669	0.1811	0	0	0	0.0014	0	0.7419
Salmon Creek TDA 5	0	0	0.0023	0	0	0	0	0	0.0002	0
Salmon Creek TDA 6	0.0001	0	0.3848	0.0245	0	0	0	0	0.0001	0.0840
Whipple Creek TDA 1	0	0.0001	0.0038	0.0216	0	0	0	0	0	0
Whipple Creek TDA 2	0	0	0.0258	0	0	0	0	0	0	0.0032
Whipple Creek TDA 3	0.0001	0	0.2525	0	0	0	0	0	0	0
Whipple Creek TDA CC5	0	0	0	0.0003	0	0	0	0.0010	0	0.5486

	Load									
	Baseline TSS	Proposed TSS	Baseline TCu	Proposed TCu	Baseline DCu	Proposed DCu	Baseline TZn	Proposed DZn	Baseline DZn	Proposed DZn
Case Study 1										
Bender Road	0	0	0	0	0	0	0	0	0	0
Depot Road	0	0	0	0	0	0	0	0	0	0
Case Study 2										
Rockwell Creek	0	0	0	0	0	0	0	0	0	0
Salmon Creek	0	0	0	0	0	0	0	0	0	0
Whipple Creek	0	0	0	0	0	0	0	0	0	0

Appendix P: Example Output Results from Wilcoxon rank-sum tests in Stata

Baseline TSS Concentration

```
Two-sample Wilcoxon rank-sum (Mann-Whitney) test

       Model |      obs    rank sum    expected
-------------+---------------------------------
       HIRUN |       15         330       232.5
       SELDM |       15         135       232.5
-------------+---------------------------------
    combined |       30         465         465

unadjusted variance      581.25
adjustment for ties       -0.65
                     ----------
adjusted variance        580.60

Ho: Baseli~S(Model==HIRUN) = Baseli~S(Model==SELDM)
             z =   4.046
    Prob > |z| =   0.0001
```

Baseline TCu Concentration

```
Two-sample Wilcoxon rank-sum (Mann-Whitney) test

       Model |      obs    rank sum    expected
-------------+---------------------------------
       HIRUN |       15       307.5       232.5
       SELDM |       15       157.5       232.5
-------------+---------------------------------
    combined |       30         465         465

unadjusted variance      581.25
adjustment for ties      -89.74
                     ----------
adjusted variance        491.51

Ho: Base~Tcu(Model==HIRUN) = Base~Tcu(Model==SELDM)
             z =   3.383
    Prob > |z| =   0.0007
```

ProposedTCu Concentration

```
Two-sample Wilcoxon rank-sum (Mann-Whitney) test

       Model |      obs    rank sum    expected
-------------+---------------------------------
       HIRUN |       15         270       232.5
       SELDM |       15         195       232.5
-------------+---------------------------------
    combined |       30         465         465

unadjusted variance      581.25
adjustment for ties      -72.80
                     ----------
adjusted variance        508.45

Ho: Prop~Tcu(Model==HIRUN) = Prop~Tcu(Model==SELDM)
             z =   1.663
    Prob > |z| =   0.0963
```

Appendix Q: Summary of p-values from Wilcoxon rank-sum tests in Stata

	Concentration									
	Baseline TSS	Proposed TSS	Baseline TCu	Proposed TCu	Baseline DCu	Proposed DCu	Baseline TZn	Proposed TZn	Baseline DZn	Proposed DZn
Case Study 1										
Bender Road	0.0001	0	0.0007	0	0	0	0	0	0	0
Depot Road	0.0004	0	0	0	0	0	0	0	0	0
Case Study 2										
Rockwell Creek TDA4	0	0	0	0	0	0	0	0	0	0
Rockwell Creek TDA CC6	0.0001	0	0.0761	0.0963	0	0	0	0	0	0.3020
Rockwell Creek TDA CC7	0	0	0.3184	0.0964	0	0	0	0.4991	0	0
Salmon Creek TDA 5	0	0	0.0199	0	0	0	0	0	0.0003	0
Salmon Creek TDA 6	0.0004	0	0.4585	0.0199	0	0	0	0	0.0001	0.0964
Whipple Creek TDA 1	0	0.0001	0.0002	0.0114	0	0	0	0	0	0
Whipple Creek TDA 2	0.0001	0	0.0251	0	0	0	0	0	0	0.0003
Whipple Creek TDA 3	0.0001	0	0.0555	0	0	0	0	0	0	0
Whipple Creek TDA CC5	0	0	0	0.0001	0	0	0	0.0001	0	0.7394

	Load									
	Baseline TSS	Proposed TSS	Baseline TCu	Proposed TCu	Baseline DCu	Proposed DCu	Baseline TZn	Proposed DZn	Baseline DZn	Proposed DZn
Case Study 1										
Bender Road	0	0	0	0	0	0	0	0	0	0
Depot Road	0	0	0	0	0	0	0	0	0	0
Case Study 2										
Rockwell Creek	0	0	0	0	0	0	0	0	0	0
Salmon Creek	0	0	0	0	0	0	0	0	0	0
Whipple Creek	0	0	0	0	0	0	0	0	0	0

Appendix R: HI-RUN Training Materials

WSDOT Biological Assessment Guidance Home Page
http://www.wsdot.wa.gov/Environment/Biology/BA/BAguidance.htm

HI-RUN Questions & Answers
http://www.wsdot.wa.gov/NR/rdonlyres/5362821F-24A4-4FF9-80EE-7378273176CE/0/HRM_FAQsTroubleGuide.pdf

HI-RUN Model User's Guide
http://www.wsdot.wa.gov/NR/rdonlyres/85B43C71-DEBE-478C-A468-C6BF64D86B64/0/BA_HIRUNUsersGuide.pdf

HI-RUN User's Input/Output Guide
http://www.wsdot.wa.gov/NR/rdonlyres/A67BE8AA-8FA7-4F59-B636-8CD8CC190945/0/BA_UserInputGuide.pdf

Appendix S: Task 2 Scenario Description

An existing intersection on state route 506 in Vader, WA is being upgraded for safety reasons. The improvements at the site will increase impervious roadway surface by 0.4 acres. Stormwater runoff at the site is discharged to Olequa Creek. Ditches on both sides of state route 506 discharge to the creek through a single outfall. Currently there are no stormwater controls at the intersection. Two vegetated filter strips, with incidental infiltration of 20%, are proposed for water quality improvement. To meet WSDOT flow control requirements a detention basin will be constructed at the site. Olequa Creek discharges to the Cowlitz River. There are two ESA listed fish species in the Cowlitz River: Chinook Salmon and Steelhead Trout. Analysis is required to determine if there is any potentially negative water quality effects associated with this planned upgrade. This analysis includes determining the runoff concentration and load before and after the planned improvements for five water quality parameters; total suspended solids (TSS), total zinc (TZn), dissolved zinc (DZn), total copper (TCu), and dissolved copper (DCu). The analysis should also include determination of downstream effects on Olequa Creek for all months of the year.

Appendix T: Instructions & Introduction for Student Modelers

The Washington State Department of Transportation (WSDOT) needs to determine the cost and benefits of two different stormwater models, the Highway Runoff Dilution and Loading Model (HI-RUN) and the Stochastic Empirical Loading and Dilution Model (SELDM), for use in BAs. This is the goal of the Stormwater Model Comparison project. To this end tasks are being performed by University of Utah Department of Civil and Environmental Engineering (UU) research staff in order to assist WSDOT in this determination.

The purpose of the task in which you are participating is to evaluate the usability of HI-RUN and SELDM. To accomplish this task the UU research team has employed you to model a theoretical scenario. Your results, including the model output, the time required for completing the overall task and time to complete sub-tasks, and comments regarding each model and modeling process, will be used by the UU research team in this evaluation.

You have been provided with a USB flash drive in addition to this information packet. This drive contains both models, the user's manuals and related reference materials for each model, and digital copies of all paper documents in this information packet. Included on the drive and in this packet is a document titled "Scenario Description." This provides a description of the scenario to be modeled. Also a completed Stormwater Design Checklist is included for both models. The Stormwater Design Checklist is a WSDOT form used to convey project details from the project designer to the person responsible for modeling.

Three forms are included in this information packet. As you are modeling the scenario, the time to complete sub-tasks must be recorded on Form 1. In addition notes regarding each sub-task should be kept on this same form. Summary output information obtained from each model is to be recorded on Form 2. Form 3 should be filled out once all modeling is complete. All forms must be turned in when finished.

Appendix U: Task 2 Scenario Details

HI-RUN Scenario Details

Project Name: Stormwater Model Comparison Project - Usability Scenario

Project Location: State Route 506 & Annonen Road, Vader, WA (Lewis County)

Baseline (i.e., Pre-Project) Stormwater Facilities

Treatment Type	***Level of Infiltration[a]***	***Subbasin 1 Impervious Area (acres)***	***Subbasin 2 Impervious Area (acres)***	***Subbasin 3 Impervious Area (acres)***	***Subbasin 4 Impervious Area (acres)***	***Subbasin 5 Impervious Area (acres)***
☐ **Basic OR**	0%					
☐ **Phosphorus**	20%					
(Check one)	40%					
	60%					
	80%					
Enhanced	0%					
	20%					
	40%					
	60%					
	80%					
None		0.6	0.8			
Infiltration BMP	100%					

Proposed (i.e., Post Project) Stormwater Facilities

Treatment Type	***Level of Infiltration[a]***	***Subbasin 1 Impervious Area (acres)***	***Subbasin 2 Impervious Area (acres)***	***Subbasin 3 Impervious Area (acres)***	***Subbasin 4 Impervious Area (acres)***	***Subbasin 5 Impervious Area (acres)***
☐ **Basic OR**	0%					
☐ **Phosphorus**	20%	0.4	0.4			
(Check one)	40%					
	60%					
	80%					
Enhanced	0%					
	20%					
	40%					
	60%					
	80%					
None		0.4	0.6			
Infiltration BMP	100%					

Inputs for HI-RUN Model Receiving Water Dilution Subroutine

Stormwater Parameter	Background Concentration (mg/L)
Total Suspended Solids	
Copper – Total	
Copper – Dissolved	0.001
Zinc – Total	
Zinc – Dissolved	0.003

Drainage Subbasin #__1___

Receiving Water Characteristics Downstream from Discharge	Month											
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept	Oct.	Nov.	Dec.
Stream depth (ft)	0.7	0.65	0.6	0.55	0.5	0.5	0.45	0.4	0.45	0.5	0.6	0.65
Stream velocity (fps)	5.5	5.2	5.0	4.8	4.6	4.4	4.2	4.0	4.2	4.6	5.0	5.2
Channel width (ft)	10	10	10	10	10	10	10	10	10	10	10	10
Manning’s roughness “n”	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012
Discharge distance into receiving waterbody from nearest shoreline	0	0	0	0	0	0	0	0	0	0	0	0

Drainage Subbasin #__2___

Receiving Water Characteristics Downstream from Discharge	Month											
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept	Oct.	Nov.	Dec.
Stream depth (ft)	0.7	0.65	0.6	0.55	0.5	0.5	0.45	0.4	0.45	0.5	0.6	0.65
Stream velocity (fps)	5.5	5.2	5.0	4.8	4.6	4.4	4.2	4.0	4.2	4.6	5.0	5.2
Channel width (ft)	10	10	10	10	10	10	10	10	10	10	10	10
Manning’s roughness “n”	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012
Discharge distance into receiving waterbody from nearest shoreline	0	0	0	0	0	0	0	0	0	0	0	0

See HI-RUN Users Guide for instructions on completing these tables

SELDM Scenario Details

Project Name: Stormwater Model Comparison Project - Usability Scenario

Project Location: State Route 506 & Annonen Road, Vader, WA (Lewis County)
46.401944 N -122.962778 W

Baseline (i.e., Pre-Project) Site Characteristics

	Drainage Area (acres / square miles)	*Drainage Length (feet)*	*Mean Basin Slope (feet per mile)*	*Impervious Fraction*	*Basin Development Factor*	
Highway Site	1.4	800	10	1	6	
Upstream Basin	55	56000	120	0.05	3	

Baseline (i.e., Pre-Project) Stormwater Facilities

BMP Type	*Area Treated (acres)*	*Level of Infiltration*				
None	1.4	N.A.				

Proposed (i.e., Post Project) Site Characteristics

	Drainage Area (acres / square miles)	*Drainage Length (feet)*	*Mean Basin Slope (feet per mile)*	*Impervious Fraction*	*Basin Development Factor*	
Highway Site	1.8	800	10	1	6	
Upstream Basin	55	56000	120	0.05	3	

Proposed (i.e., Post Project) Stormwater Facilities

BMP Type	*Area Treated (acres)*	*Level of Infiltration*				
Vegetated Filter Strips	0.8	20%				
None	1.0	N.A.				

Receiving Water Characteristics

Stormwater Parameter	*Background Concentration (mg/L)*
Copper – Dissolved	0.001
Zinc – Dissolved	0.003

Appendix V: Student Modelers – Form 1

Table 44: Blank Version of Form 1

Student Name		
Model Name		

Tasks	Time Required	Comments
Review Scenario Details		
Enter Scenario Details In Model		
Run Model		
Review Output		
Summarize Output (Form 2)		

Table 45: Completed Form 1 for HI-RUN - Student 1

Student Name	*Zach Magdol*	
Model Name	*HI-RUN*	

Tasks	Time Required	Comments
Review Scenario Details	***2 min***	***Lacks detail but ok since parameters were given in separate document***
Enter Scenario Details In Model	***15 min***	***Difficult to see map. Not sure which subbasin will have detention - I chose 2.***
Run Model	***> 5 min***	***Very slow***
Review Output	***2 min***	***Concise tables!***
Summarize Output (Form 2)	***2 min***	***Again; results are concise and easy to follow.***

Table 46: Completed Form 1 for HI-RUN – Student 2

Student Name	*Duncan Smith*	
Model Name	*HI-RUN*	

Tasks	Time Required	Comments
Review Scenario Details	*4 min*	
Enter Scenario Details In Model	*~ 15 min*	*The map is a pain. With Google maps it's still hard to tell with region. Then the isopluvial lines are not very clear. Wasn't quite sure how to do the detention when asked - for subbasin 1 or 2, in the loading run.*
Run Model	*10 min*	
Review Output	*0 min*	
Summarize Output (Form 2)	*15 min*	*The output is in a convenient format with summary & detailed sheets.*

Table 47: Completed Form 1 for HI-RUN – Student 3

Student Name	*Travis Christensen*	
Model Name	*HI-RUN*	

Tasks	Time Required	Comments
Review Scenario Details	*1 min*	
Enter Scenario Details In Model	*16 min (load) 5 min (dilution)* *21 min total*	*Map was difficult to use. It would be more helpful with a scale bar. It seems to be easier to input data into this model.*
Run Model	*5 min (load) 8 min (dilution) 8 min (dilution 2)* *21 min total*	*The run time seems a lot longer when compared to SELDM.*
Review Output	*1 min (load) 1 min (dilution)* *2 min total*	
Summarize Output (Form 2)	*5 min (load) 4 min (dilution)* *9 min total*	*Tables are easy to read.*

Table 48: Completed Form 1 for HI-RUN – Student 4

Student Name	***Peter Bergeson***	
Model Name	***HI-RUN***	

Tasks	Time Required	Comments
Review Scenario Details	***1 min***	***Well laid-out, easy to read and understand.***
Enter Scenario Details In Model	***5 min***	***Slightly tedious, but excel makes it go faster with copy/paste functions.***
Run Model	***3 min (each dilution) 1.5 min (loading)***	***Runs relatively quickly. Would be more tedious with more subbasins.***
Review Output	***1 min***	***Easy to review.***
Summarize Output (Form 2)	***2 min***	***Not bad at all.***

Table 49: Completed Form 1 for SELDM - Student 1

Student Name	*Zach Magdol*	
Model Name	*SELDM*	

Tasks	Time Required	Comments
Review Scenario Details	***5 min***	***Should order info on form as order entered in model.***
Enter Scenario Details In Model	***15 min***	***I don't like how you enter a different "analysis" for different BMPs. Should be one analysis for all runs at same highway site.***
Run Model	***3 min***	
Review Output	***10 min***	
Summarize Output (Form 2)	***7 min***	

Table 50: Completed Form 1 for SELDM – Student 2

Student Name	*Duncan Smith*	
Model Name	*SELDM*	

Tasks	Time Required	Comments
Review Scenario Details	*1 min*	
Enter Scenario Details In Model	*5 min + 5 min + 5 min*	*After doing the example, this part is really easy. Lacking that training, it would be very slow deciding what is and isn't important among the many options.*
Run Model	*10 sec + 15 sec + 15 sec*	*Quick!*
Review Output	*1 min*	*Getting the output into excel is a bit cumbersome. Using one macro to read in data and analyze would be nice.*
Summarize Output (Form 2)	*5 min*	

Table 51: Completed Form 1 for SELDM – Student 3

Student Name	*Travis Christensen*	
Model Name	*SELDM*	

Tasks	Time Required	Comments
Review Scenario Details	*1 min*	
Enter Scenario Details In Model	*15 min*	*From the training it was easy to go through this example.*
Run Model	*45 sec each - ~ 3 min total*	*Quick and easy to run.*
Review Output	*5 min*	
Summarize Output (Form 2)	*5 min*	*Easy once you gave us your spreadsheet. There was no proposed upstream concentration listed in the Excel output.*

Table 52: Completed Form 1 for SELDM – Student 4

Student Name	***Peter Bergeson***	
Model Name	***SELDM***	

Tasks	Time Required	Comments
Review Scenario Details	***3 min***	
Enter Scenario Details In Model	***5 min***	
Run Model	***30 sec***	
Review Output	***1 min***	
Summarize Output (Form 2)	***2 min***	***Messing with the .txt files and converting to Excel was a bit cumbersome.***

Appendix W: Student Modelers – Form 2

Table 53: Blank Version of Form 2 for HI-RUN

Student Name	
Model Name	HI-RUN

Water Quality Parameter	Baseline Load (Median)	Proposed Load (Median)	Percent Exceed
TSS			
TCu			
DCu			
TZn			
DZn			

Water Quality Parameter	Baseline Concentration (Median)	Proposed Concentration (Median)	Percent Exceed
TSS			
TCu			
DCu			
TZn			
DZn			

Water Quality Parameter	Upstream (Background) Concentration
DCu	
DZn	

Month/Parameter	DCu Baseline Distance Downstream	DCu Proposed Distance Downstream	DZn Baseline Distance Downstream	DZn Proposed Distance Downstream
January				
February				
March				
April				
May				
June				
July				
August				
September				
October				
November				
December				

Table 54: Completed Form 2 for HI-RUN – Student 1

Student Name	*Zach Magdol*
Model Name	*HI-RUN*

Water Quality Parameter	Baseline Load (Median)	Proposed Load (Median)	Percent Exceed
TSS	*861*	*686*	*0.439*
TCu	*0.22*	*0.19*	*0.452*
DCu	*0.051*	*0.056*	*0.543*
TZn	*1.34*	*1.1*	*0.441*
DZn	*0.38*	*0.38*	*0.509*

Water Quality Parameter	Baseline Concentration (Median)	Proposed Concentration (Median)	Percent Exceed
TSS	*61.39 / 61.372*	*40.002 / 44.709*	*0.383 / 0.414*
TCu	*0.016 / 0.016*	*0.011 / 0.012*	*0.388 / 0.42*
DCu	*0.004 / 0.004*	*0.004 / 0.004*	*0.515 / 0.514*
TZn	*0.095 / 0.095*	*0.066 / 0.072*	*0.373 / 0.406*
DZn	*0.027 / 0.027*	*0.024 / 0.025*	*0.466 / 0.477*

Water Quality Parameter	Upstream (Background) Concentration
DCu	*0.001*
DZn	*0.003*

Month/Parameter	DCu Baseline Distance Downstream	DCu Proposed Distance Downstream	DZn Baseline Distance Downstream	DZn Proposed Distance Downstream
January	< 1	< 1	< 1	< 1
February	< 1	< 1	< 1	< 1
March	< 1	< 1	< 1	< 1
April	< 1	< 1	< 1	< 1
May	< 1	< 1	< 1	< 1
June	< 1	< 1	< 1	< 1
July	< 1	< 1	< 1	< 1
August	< 1	< 1	< 1	< 1
September	< 1	< 1	< 1	< 1
October	< 1	< 1	< 1	< 1
November	< 1	< 1	< 1	< 1
December	< 1	< 1	< 1	< 1

Table 55: Completed Form 2 for HI-RUN – Student 2

Student Name	*Duncan Smith*
Model Name	*HI-RUN*

Water Quality Parameter	Baseline Load (Median)	Proposed Load (Median)	Percent Exceed
TSS	*708*	*564*	*0.44*
TCu	*0.182*	*0.16*	*0.455*
DCu	*0.042*	*0.047*	*0.543*
TZn	*1.1*	*0.91*	*0.441*
DZn	*0.331*	*0.31*	*0.511*

Water Quality Parameter	Baseline Concentration (Median)	Proposed Concentration (Median)	Percent Exceed
TSS	*61.382 / 61.361*	*40.019 / 44.738*	*0.384 / 0.414*
TCu	*0.016 / 0.015*	*0.011 / 0.012*	*0.388 / 0.42*
DCu	*0.004 / 0.004*	*0.004 / 0.004*	*0.515 / 0.514*
TZn	*0.095 / 0.095*	*0.066 / 0.072*	*0.373 / 0.406*
DZn	*0.027 / 0.027*	*0.024 / 0.025*	*0.466 / 0.477*

Water Quality Parameter	Upstream (Background) Concentration
DCu	*0.001*
DZn	*0.003*

Month/Parameter	DCu Baseline Distance Downstream	DCu Proposed Distance Downstream	DZn Baseline Distance Downstream	DZn Proposed Distance Downstream
January	*<1*	*<1*	*<1*	*<1*
February	*4 / 8*	*3 / 5*	*48 / 82*	*24 / 48*
March	*<1*	*<1*	*<1*	*<1*
April	*<1*	*<1*	*<1*	*<1*
May	*<1*	*<1*	*<1*	*<1*
June	*<1*	*<1*	*<1*	*<1*
July	*<1*	*<1*	*<1*	*<1*
August	*<1*	*<1*	*<1*	*<1*
September	*<1*	*<1*	*<1*	*<1*
October	*<1*	*<1*	*<1*	*<1*
November	*<1*	*<1*	*<1*	*<1*
December	*<1*	*<1*	*<1*	*<1*

Table 56: Completed Form 2 for HI-RUN – Student 3

Student Name	*Travis Christensen*
Model Name	*HI-RUN*

Water Quality Parameter	Baseline Load (Median)	Proposed Load (Median)	Percent Exceed
TSS	*862*	*686*	*0.442*
TCu	*0.219*	*0.19*	*0.453*
DCu	*0.051*	*0.057*	*0.544*
TZn	*1.34*	*1.1*	*0.442*
DZn	*0.383*	*0.38*	*0.506*

Water Quality Parameter	Baseline Concentration (Median)	Proposed Concentration (Median)	Percent Exceed
TSS	*61.276 / 61.754*	*39.85 / 44.722*	*0.383 / 0.412*
TCu	*0.016 / 0.016*	*0.011 / 0.012*	*0.389 / 0.419*
DCu	*0.004 / 0.004*	*0.004 / 0.004*	*0.514 / 0.512*
TZn	*0.095 / 0.095*	*0.066 / 0.072*	*0.375 / 0.407*
DZn	*0.027 / 0.027*	*0.024 / 0.025*	*0.468 / 0.48*

Water Quality Parameter	Upstream (Background) Concentration
DCu	*0.001*
DZn	*0.003*

Month/Parameter	DCu Baseline Distance Downstream	DCu Proposed Distance Downstream	DZn Baseline Distance Downstream	DZn Proposed Distance Downstream
January	< 1	< 1	< 1	< 1
February	< 1	< 1	< 1	< 1
March	< 1	< 1	< 1	< 1
April	< 1	< 1	< 1	< 1
May	< 1	< 1	< 1	< 1
June	< 1	< 1	< 1	< 1
July	< 1	< 1	< 1	< 1
August	< 1	< 1	< 1	< 1
September	< 1	< 1	< 1	< 1
October	< 1	< 1	< 1	< 1
November	< 1	< 1	< 1	< 1
December	< 1	< 1	< 1	< 1

Table 57: Completed Form 2 for HI-RUN – Student 4

Student Name	*Peter Bergeson*
Model Name	*HI-RUN*

Water Quality Parameter	Baseline Load (Median)	Proposed Load (Median)	Percent Exceed
TSS	*1093*	*710*	*0.388*
TCu	*0.278*	*0.2*	*0.395*
DCu	*0.064*	*0.063*	*0.495*
TZn	*1.7*	*1.2*	*0.385*
DZn	*0.486*	*0.42*	*0.461*

Water Quality Parameter	Baseline Concentration (Median)	Proposed Concentration (Median)	Percent Exceed
TSS	*61.75 / 61.389*	*39.87 / 39.798*	*0.383 / 0.381*
TCu	*0.016 / 0.016*	*0.011 / 0.011*	*0.387 / 0.39*
DCu	*0.004 / 0.004*	*0.004 / 0.004*	*0.51 / 0.515*
TZn	*0.095 / 0.095*	*0.066 / 0.066*	*0.375 / 0.376*
DZn	*0.027 / 0.027*	*0.024 / 0.024*	*0.469 / 0.467*

Water Quality Parameter	Upstream (Background) Concentration
DCu	*0.001*
DZn	*0.003*

Month/Parameter	DCu Baseline Distance Downstream	DCu Proposed Distance Downstream	DZn Baseline Distance Downstream	DZn Proposed Distance Downstream
January	< 1	< 1	< 1	< 1
February	48 /< 1	10 / < 1	160 / < 1	84 / < 1
March	< 1	< 1	< 1	< 1
April	< 1	< 1	< 1	< 1
May	< 1	< 1	< 1	< 1
June	< 1	< 1	< 1	< 1
July	< 1	< 1	< 1	< 1
August	< 1	< 1	< 1	< 1
September	< 1	< 1	< 1	< 1
October	< 1	< 1	< 1	< 1
November	< 1	< 1	< 1	< 1
December	< 1	< 1	< 1	< 1

Table 58: Blank Version of Form 2 for SELDM

Student Name	
Model Name	SELDM

Water Quality Parameter	Baseline Load (Median)	Proposed Load (Median)	Percent Exceed
TSS			
TCu			
DCu			
TZn			
DZn			

Water Quality Parameter	Baseline Concentration (Median)	Proposed Concentration (Median)	Percent Exceed
TSS			
TCu			
DCu			
TZn			
DZn			

Water Quality Parameter	Baseline Upstream Concentration	Baseline Downstream Concentration	Proposed Upstream Concentration	Proposed Downstream Concentration
DCu				
DZn				

Table 59: Completed Form 2 for SELDM – Student 1

Student Name	*Zach Magdol*
Model Name	*SELDM*

Water Quality Parameter	Baseline Load (Median)	Proposed Load (Median)	Percent Exceed
TSS	*1030*	*1208.5*	*0.59*
TCu	*0.211*	*0.234*	*0.608*
DCu	*0.045*	*0.058*	*0.619*
TZn	*1.27*	*1.596*	*0.626*
DZn	*0.379*	*0.466*	*0.624*

Water Quality Parameter	Baseline Concentration (Median)	Proposed Concentration (Median)	Percent Exceed
TSS	*63.05*	*60.294*	*0.543*
TCu	*0.016*	*0.015*	*0.54*
DCu	*0.004*	*0.004*	*0.563*
TZn	*0.089*	*0.089*	*0.569*
DZn	*0.029*	*0.029*	*0.569*

Water Quality Parameter	Baseline Upstream Concentration	Baseline Downstream Concentration	Proposed Upstream Concentration	Proposed Downstream Concentration
DCu	*0.001*	*0.001*	*N.A.*	*0.001*
DZn	*0.003*	*0.003*	*N.A.*	*0.003*

Table 60: Completed Form 2 for SELDM – Student 2

Student Name	*Duncan Smith*
Model Name	*SELDM*

Water Quality Parameter	Baseline Load (Median)	Proposed Load (Median)	Percent Exceed
TSS	*1120*	*800.1*	*0.477*
TCu	*0.208*	*0.169*	*0.536*
DCu	*0.047*	*0.050*	*0.589*
TZn	*1.345*	*1.089*	*0.489*
DZn	*0.352*	*0.383*	*0.563*

Water Quality Parameter	Baseline Concentration (Median)	Proposed Concentration (Median)	Percent Exceed
TSS	*61.30*	*36.971*	*0.422*
TCu	*0.016*	*0.011*	*0.424*
DCu	*0.004*	*0.003*	*0.516*
TZn	*0.091*	*0.060*	*0.402*
DZn	*0.027*	*0.023*	*0.481*

Water Quality Parameter	Baseline Upstream Concentration	Baseline Downstream Concentration	Proposed Upstream Concentration	Proposed Downstream Concentration
DCu	*0.001*	*0.002*	*0.001*	*0.002*
DZn	*0.003*	*0.003*	*0.003*	*0.003*

Table 61: Completed Form 2 for SELDM – Student 3

Student Name	*Travis Christensen*
Model Name	*SELDM*

Water Quality Parameter	Baseline Load (Median)	Proposed Load (Median)	Percent Exceed
TSS	*1030.000*	*739.800*	*0.474*
TCu	*0.215*	*0.185*	*0.509*
DCu	*0.048*	*0.051*	*0.592*
TZn	*1.390*	*1.068*	*0.486*
DZn	*0.378*	*0.391*	*0.556*

Water Quality Parameter	Baseline Concentration (Median)	Proposed Concentration (Median)	Percent Exceed
TSS	*60.000*	*36.922*	*0.405*
TCu	*0.016*	*0.011*	*0.407*
DCu	*0.004*	*0.003*	*0.514*
TZn	*0.092*	*0.060*	*0.398*
DZn	*0.029*	*0.023*	*0.464*

Water Quality Parameter	Baseline Upstream Concentration	Baseline Downstream Concentration	Proposed Upstream Concentration	Proposed Downstream Concentration
DCu	*0.001*	*0.001*	*N.A.*	*0.001*
DZn	*0.003*	*0.003*	*N.A.*	*0.003*

Table 62: Completed Form 2 for SELDM – Student 4

Student Name	*Peter Bergeson*
Model Name	*SELDM*

Water Quality Parameter	Baseline Load (Median)	Proposed Load (Median)	Percent Exceed
TSS	*975.000*	*781.100*	*0.464*
TCu	*0.210*	*0.183*	*0.509*
DCu	*0.010*	*0.010*	*0.570*
TZn	*1.255*	*1.069*	*0.499*
DZn	*0.029*	*0.028*	*0.528*

Water Quality Parameter	Baseline Concentration (Median)	Proposed Concentration (Median)	Percent Exceed
TSS	*59.500*	*33.662*	*0.405*
TCu	*0.016*	*0.011*	*0.413*
DCu	*0.001*	*0.001*	*0.000*
TZn	*0.090*	*0.061*	*0.427*
DZn	*0.003*	*0.002*	*0.000*

Water Quality Parameter	Baseline Upstream Concentration	Baseline Downstream Concentration	Proposed Upstream Concentration	Proposed Downstream Concentration
DCu	*0.001*	*0.002*	*0.001*	*0.002*
DZn	*0.003*	*0.003*	*0.003*	*0.003*

Appendix X: Student Modelers – Form 3

Table 63: Blank Version of Form 3

System Usability Scale

	Strongly disagree				Strongly agree
	1	2	3	4	5
1. I think that I would like to use this system frequently					
2. I found the system unnecessarily complex					
3. I thought the system was easy to use					
4. I think that I would need the support of a technical person to be able to use this system					
5. I found the various functions in this system were well integrated					
6. I thought there was too much inconsistency in this system					
7. I would imagine that most people would learn to use this system very quickly					
8. I found the system very cumbersome to use					
9. I felt very confident using the system					
10. I needed to learn a lot of things before I could get going with this system					

Table 64: Completed Form 3 for HI-RUN – Student 1

System Usability Scale

	Strongly disagree				Strongly agree
	1	2	3	4	5
1. I think that I would like to use this system frequently				X	
2. I found the system unnecessarily complex			X		
3. I thought the system was easy to use				X	
4. I think that I would need the support of a technical person to be able to use this system	X				
5. I found the various functions in this system were well integrated			X		
6. I thought there was too much inconsistency in this system		X			
7. I would imagine that most people would learn to use this system very quickly				X	
8. I found the system very cumbersome to use			X		
9. I felt very confident using the system				X	
10. I needed to learn a lot of things before I could get going with this system		X			

Table 65: Completed Form 3 for HI-RUN – Student 2

System Usability Scale

	1 Strongly disagree	2	3	4	5 Strongly agree
1. I think that I would like to use this system frequently			X		
2. I found the system unnecessarily complex		X			
3. I thought the system was easy to use				X	
4. I think that I would need the support of a technical person to be able to use this system		X			
5. I found the various functions in this system were well integrated				X	
6. I thought there was too much inconsistency in this system		X			
7. I would imagine that most people would learn to use this system very quickly				X	
8. I found the system very cumbersome to use			X		
9. I felt very confident using the system			X		
10. I needed to learn a lot of things before I could get going with this system		X			

Table 66: Completed Form 3 for HI-RUN – Student 3

System Usability Scale

	Strongly disagree 1	2	3	4	Strongly agree 5
1. I think that I would like to use this system frequently				X	
2. I found the system unnecessarily complex		X			
3. I thought the system was easy to use			X		
4. I think that I would need the support of a technical person to be able to use this system		X			
5. I found the various functions in this system were well integrated				X	
6. I thought there was too much inconsistency in this system		X			
7. I would imagine that most people would learn to use this system very quickly				X	
8. I found the system very cumbersome to use			X		
9. I felt very confident using the system				X	
10. I needed to learn a lot of things before I could get going with this system	X				

Table 67: Completed Form 3 for HI-RUN – Student 4

System Usability Scale

	Strongly disagree 1	2	3	4	Strongly agree 5
1. I think that I would like to use this system frequently				X	
2. I found the system unnecessarily complex		X			
3. I thought the system was easy to use			X		
4. I think that I would need the support of a technical person to be able to use this system		X			
5. I found the various functions in this system were well integrated			X		
6. I thought there was too much inconsistency in this system		X			
7. I would imagine that most people would learn to use this system very quickly				X	
8. I found the system very cumbersome to use		X			
9. I felt very confident using the system			X		
10. I needed to learn a lot of things before I could get going with this system			X		

Table 68: Completed Form 3 for SELDM – Student 1

System Usability Scale

	Strongly disagree				Strongly agree
	1	2	3	4	5
1. I think that I would like to use this system frequently		X			
2. I found the system unnecessarily complex				X	
3. I thought the system was easy to use			X		
4. I think that I would need the support of a technical person to be able to use this system			X		
5. I found the various functions in this system were well integrated		X			
6. I thought there was too much inconsistency in this system		X			
7. I would imagine that most people would learn to use this system very quickly		X			
8. I found the system very cumbersome to use				X	
9. I felt very confident using the system			X		
10. I needed to learn a lot of things before I could get going with this system		X			

Table 69: Completed Form 3 for SELDM – Student 2

System Usability Scale

	Strongly disagree 1	2	3	4	Strongly agree 5
1. I think that I would like to use this system frequently			X		
2. I found the system unnecessarily complex				X	
3. I thought the system was easy to use				X	
4. I think that I would need the support of a technical person to be able to use this system		X			
5. I found the various functions in this system were well integrated				X	
6. I thought there was too much inconsistency in this system		X			
7. I would imagine that most people would learn to use this system very quickly		X			
8. I found the system very cumbersome to use			X		
9. I felt very confident using the system				X	
10. I needed to learn a lot of things before I could get going with this system				X	

Table 70: Completed Form 3 for SELDM – Student 3

System Usability Scale

	Strongly disagree 1	2	3	4	Strongly agree 5
1. I think that I would like to use this system frequently				X	
2. I found the system unnecessarily complex		X			
3. I thought the system was easy to use				X	
4. I think that I would need the support of a technical person to be able to use this system	X				
5. I found the various functions in this system were well integrated				X	
6. I thought there was too much inconsistency in this system		X			
7. I would imagine that most people would learn to use this system very quickly				X	
8. I found the system very cumbersome to use		X			
9. I felt very confident using the system					X
10. I needed to learn a lot of things before I could get going with this system	X				

Table 71: Completed Form 3 for SELDM – Student 4

System Usability Scale

Statement	1 (Strongly disagree)	2	3	4	5 (Strongly agree)
1. I think that I would like to use this system frequently				X	
2. I found the system unnecessarily complex		X			
3. I thought the system was easy to use			X		
4. I think that I would need the support of a technical person to be able to use this system				X	
5. I found the various functions in this system were well integrated				X	
6. I thought there was too much inconsistency in this system			X		
7. I would imagine that most people would learn to use this system very quickly			X		
8. I found the system very cumbersome to use		X			
9. I felt very confident using the system			X		
10. I needed to learn a lot of things before I could get going with this system				X	

Appendix Y: Analysis of Form 2 and Control Set Output

Table 72: HI-RUN Control Set and Analysis

	Student 1	Student 2	Student 3	Student 4	Control 1	Control 2	Control 3	Control 4	Control 5	Control 6	Control 7	Control 8	Control 9	Control 10	Mean	Minimum	Maximum
Baseline Load																	
TSS	861 RIGHT	708 WRONG	862 RIGHT	1093 WRONG	861	866	869	865	869	862	870	872	868	865	866.7	861	872
TCu	0.22 RIGHT	0.182 WRONG	0.219 RIGHT	0.278 WRONG	0.22	0.219	0.22	0.219	0.22	0.219	0.218	0.218	0.219	0.219	0.2191	0.218	0.22
DCu	0.051 RIGHT	0.042 WRONG	0.051 RIGHT	0.064 WRONG	0.051	0.052	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.0511	0.051	0.052
TZn	1.34 RIGHT	1.1 WRONG	1.34 RIGHT	1.7 WRONG	1.34	1.34	1.34	1.34	1.35	1.34	1.34	1.34	1.34	1.34	1.341	1.34	1.35
DZn	0.38 RIGHT	0.331 WRONG	0.383 RIGHT	0.486 WRONG	0.38	0.382	0.383	0.384	0.381	0.383	0.382	0.382	0.382	0.381	0.382	0.38	0.384
Proposed Load																	
TSS	686 RIGHT	564 WRONG	686 RIGHT	710 WRONG	686	687	686	685	685	687	685	686	691	681	685.9	681	691
TCu	0.19 RIGHT	0.16 WRONG	0.19 RIGHT	0.2 WRONG	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
DCu	0.056 RIGHT	0.047 WRONG	0.057 RIGHT	0.063 WRONG	0.056	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.0569	0.056	0.057
TZn	1.1 RIGHT	0.91 WRONG	1.1 RIGHT	1.2 WRONG	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
DZn	0.38 RIGHT	0.31 WRONG	0.38 RIGHT	0.42 WRONG	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
Load - Percent Exceed																	
TSS	0.439 RIGHT	0.44 RIGHT	0.442 RIGHT	0.388 WRONG	0.439	0.442	0.44	0.438	0.438	0.44	0.438	0.438	0.44	0.438	0.4391	0.438	0.442
TCu	0.452 RIGHT	0.455 RIGHT	0.453 RIGHT	0.395 WRONG	0.452	0.453	0.452	0.454	0.45	0.452	0.456	0.454	0.449	0.453	0.4525	0.449	0.456
DCu	0.543 RIGHT	0.543 RIGHT	0.544 RIGHT	0.495 WRONG	0.543	0.543	0.545	0.546	0.544	0.544	0.545	0.542	0.545	0.546	0.5443	0.542	0.546
TZn	0.441 RIGHT	0.441 RIGHT	0.442 RIGHT	0.385 WRONG	0.441	0.442	0.442	0.443	0.441	0.44	0.443	0.441	0.44	0.438	0.4411	0.438	0.443
DZn	0.509 RIGHT	0.511 RIGHT	0.506 RIGHT	0.461 WRONG	0.509	0.505	0.506	0.509	0.506	0.506	0.508	0.508	0.508	0.507	0.5072	0.505	0.509
TDA 1 Baseline Concentration																	
TSS	61.39 RIGHT	61.382 RIGHT	61.276 RIGHT	61.75 RIGHT	61.39	61.672	61.374	61.8447	61.151	62.139	61.714	61.958	61.647	61.292	61.61817	61.151	62.139
TCu	0.016 RIGHT	0.016 RIGHT	0.016 RIGHT	0.016 RIGHT	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016
DCu	0.004 RIGHT	0.004 RIGHT	0.004 RIGHT	0.004 RIGHT	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
TZn	0.095 RIGHT	0.095 RIGHT	0.095 RIGHT	0.095 RIGHT	0.095	0.096	0.095	0.096	0.095	0.095	0.095	0.095	0.095	0.095	0.0952	0.095	0.096
DZn	0.027 RIGHT	0.027 RIGHT	0.027 RIGHT	0.027 RIGHT	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027
TDA 1 Proposed Concentration																	
TSS	40.002 RIGHT	40.019 RIGHT	39.85 RIGHT	39.87 RIGHT	40.019	39.667	39.799	39.726	39.693	39.702	39.586	39.402	39.797	39.836	39.7227	39.402	40.019
TCu	0.011 RIGHT	0.011 RIGHT	0.011 RIGHT	0.011 RIGHT	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
DCu	0.004 RIGHT	0.004 RIGHT	0.004 RIGHT	0.004 RIGHT	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
TZn	0.066 RIGHT	0.066 RIGHT	0.066 RIGHT	0.066 RIGHT	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066
DZn	0.024 RIGHT	0.024 RIGHT	0.024 RIGHT	0.024 RIGHT	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024
TDA 1 Concentration - Percent Exceed																	
TSS	0.383 RIGHT	0.384 RIGHT	0.383 RIGHT	0.383 RIGHT	0.384	0.382	0.381	0.38	0.381	0.38	0.381	0.38	0.382	0.383	0.3814	0.38	0.384
TCu	0.388 RIGHT	0.388 RIGHT	0.389 RIGHT	0.387 RIGHT	0.388	0.387	0.389	0.389	0.393	0.389	0.39	0.388	0.388	0.391	0.3892	0.387	0.393
DCu	0.515 RIGHT	0.515 RIGHT	0.514 RIGHT	0.51 RIGHT	0.515	0.515	0.513	0.514	0.513	0.512	0.514	0.513	0.51	0.51	0.5129	0.51	0.515
TZn	0.373 RIGHT	0.373 RIGHT	0.375 RIGHT	0.375 RIGHT	0.373	0.375	0.376	0.376	0.376	0.374	0.373	0.373	0.376	0.376	0.3748	0.373	0.376
DZn	0.466 RIGHT	0.466 RIGHT	0.468 RIGHT	0.469 RIGHT	0.466	0.468	0.47	0.469	0.467	0.472	0.468	0.468	0.469	0.469	0.4686	0.466	0.472
TDA 2 Baseline Concentration																	
TSS	61.372 RIGHT	61.381 RIGHT	61.754 RIGHT	61.389 RIGHT	61.372	61.848	61.347	61.095	62.001	61.402	61.529	61.649	61.37	61.531	61.5144	61.095	62.001
TCu	0.016 RIGHT	0.015 RIGHT	0.016 RIGHT	0.016 RIGHT	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016
DCu	0.004 RIGHT	0.004 RIGHT	0.004 RIGHT	0.004 RIGHT	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
TZn	0.095 RIGHT	0.095 RIGHT	0.095 RIGHT	0.095 RIGHT	0.095	0.095	0.095	0.095	0.095	0.095	0.096	0.096	0.095	0.095	0.0952	0.095	0.096
DZn	0.027 RIGHT	0.027 RIGHT	0.027 RIGHT	0.027 RIGHT	0.027	0.027	0.027	0.027	0.27	0.027	0.027	0.027	0.027	0.027	0.0513	0.027	0.27
TDA 2 Proposed Concentration																	
TSS	44.709 RIGHT	44.738 RIGHT	44.722 RIGHT	39.798 WRONG	44.709	44.585	44.785	44.617	44.638	44.393	44.346	44.317	44.613	44.512	44.5515	44.317	44.785
TCu	0.012 RIGHT	0.012 RIGHT	0.012 RIGHT	0.011 WRONG	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012
DCu	0.004 RIGHT	0.004 RIGHT	0.004 RIGHT	0.004 RIGHT	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
TZn	0.072 RIGHT	0.072 RIGHT	0.072 RIGHT	0.066 WRONG	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.072	0.073	0.0721	0.072	0.073
DZn	0.025 RIGHT	0.025 RIGHT	0.025 RIGHT	0.024 WRONG	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
TDA 2 Concentration - Percent Exceed																	
TSS	0.414 RIGHT	0.414 RIGHT	0.412 RIGHT	0.381 WRONG	0.414	0.412	0.416	0.416	0.412	0.413	0.412	0.411	0.415	0.413	0.4134	0.411	0.416
TCu	0.42 RIGHT	0.42 RIGHT	0.419 RIGHT	0.39 WRONG	0.42	0.417	0.418	0.417	0.418	0.42	0.417	0.418	0.418	0.418	0.4181	0.417	0.42
DCu	0.514 RIGHT	0.514 RIGHT	0.512 RIGHT	0.515 RIGHT	0.514	0.516	0.514	0.516	0.515	0.512	0.512	0.515	0.514	0.511	0.5139	0.511	0.516
TZn	0.406 RIGHT	0.406 RIGHT	0.407 RIGHT	0.376 WRONG	0.406	0.408	0.407	0.405	0.407	0.409	0.404	0.407	0.405	0.409	0.4067	0.404	0.409
DZn	0.477 RIGHT	0.477 RIGHT	0.48 RIGHT	0.467 WRONG	0.477	0.482	0.48	0.48	0.478	0.479	0.48	0.481	0.481	0.481	0.4799	0.477	0.482

NOTE: Shading indicates values manually re-catergorized as "Right".

Table 72: HI-RUN Control Set and Analysis, continued

	Student 1	Student 2	Student 3	Student 4	Control 1	Control 2	Control 3	Control 4	Control 5	Control 6	Control 7	Control 8	Control 9	Control 10	Mean	Minimum	Maximum
TDA 1 - Baseline DCu																	
January	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
February	1 RIGHT	4 WRONG	1 RIGHT	48 WRONG	1	1	1	1	1	1	1	1	1	1	1	1	1
March	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
April	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
May	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
June	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
July	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
August	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
September	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
October	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
November	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
December	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
TDA 1 - Proposed DCu																	
January	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
February	1 RIGHT	3 WRONG	1 RIGHT	10 WRONG	1	1	1	1	1	1	1	1	1	1	1	1	1
March	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
April	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
May	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
June	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
July	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
August	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
September	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
October	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
November	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
December	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
TDA 2 - Baseline DCu																	
January	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
February	1 RIGHT	8 WRONG	1 RIGHT	160 WRONG	1	1	1	1	1	1	1	1	1	1	1	1	1
March	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
April	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
May	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
June	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
July	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
August	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
September	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
October	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
November	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
December	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
TDA 2 - Proposed DCu																	
January	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
February	1 RIGHT	5 WRONG	1 RIGHT	84 WRONG	1	1	1	1	1	1	1	1	1	1	1	1	1
March	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
April	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
May	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
June	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
July	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
August	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
September	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
October	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
November	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
December	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1

NOTE: Shading indicates values manually re-catergorized as "Right".

Table 72: HI-RUN Control Set and Analysis, continued

	Student 1	Student 2	Student 3	Student 4	Control 1	Control 2	Control 3	Control 4	Control 5	Control 6	Control 7	Control 8	Control 9	Control 10	Mean	Minimum	Maximum
TDA 1 - Baseline DZn																	
January	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
February	1 RIGHT	48 WRONG	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
March	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
April	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
May	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
June	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
July	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
August	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
September	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
October	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
November	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
December	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
TDA 1 - Proposed DZn																	
January	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
February	1 RIGHT	82 WRONG	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
March	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
April	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
May	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
June	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
July	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
August	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
September	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
October	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
November	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
December	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
TDA 2 - Baseline DZn																	
January	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
February	1 RIGHT	24 WRONG	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
March	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
April	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
May	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
June	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
July	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
August	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
September	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
October	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
November	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
December	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
TDA 2 - Proposed DZn																	
January	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
February	1 RIGHT	48 WRONG	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
March	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
April	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
May	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
June	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
July	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
August	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
September	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
October	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
November	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1
December	1 RIGHT	1 RIGHT	1 RIGHT	1 RIGHT	1	1	1	1	1	1	1	1	1	1	1	1	1

NOTE: Shading indicates values manually re-catergorized as "Right".

Table 73: SELDM Control Set and Analysis

	Student 1	Student 2	Student 3	Student 4	Control 1	Control 2	Control 3	Control 4	Control 5	Control 6	Control 7	Control 8	Control 9	Control 10	Mean	Minimum	Maximum
Baseline Load																	
TSS	1030 RIGHT	1120 RIGHT	1030 RIGHT	975 RIGHT	1170	1100	991.5	1060	983	980	1020	949	1025	1000	1027.85	949	1170
TCu	0.211 RIGHT	0.208 RIGHT	0.215 RIGHT	0.21 RIGHT	0.221	0.212	0.22	0.2	0.207	0.201	0.213	0.209	0.21	0.203	0.2096	0.2	0.221
DCu	0.045 RIGHT	0.047 RIGHT	0.048 RIGHT	0.01 WRONG	0.053	0.051	0.047	0.048	0.048	0.046	0.048	0.048	0.05	0.045	0.0484	0.045	0.053
TZn	1.27 RIGHT	1.345 RIGHT	1.39 RIGHT	1.255 RIGHT	1.315	1.245	1.21	1.275	1.27	1.33	1.265	1.295	1.3	1.25	1.2755	1.21	1.33
DZn	0.379 RIGHT	0.352 RIGHT	0.378 RIGHT	0.029 WRONG	0.41	0.385	0.412	0.433	0.39	0.378	0.383	0.382	0.383	0.389	0.3945	0.378	0.433
Proposed Load																	
TSS	1208.5 WRONG	800.1 RIGHT	739.8 RIGHT	781.1 RIGHT	690.3	754.75	768.7	820.85	786.3	781	722.15	803.3	738.05	814.55	767.995	690.3	820.85
TCu	0.234 WRONG	0.169 RIGHT	0.185 RIGHT	0.183 RIGHT	0.181	0.168	0.17	0.181	0.176	0.172	0.172	0.18	0.173	0.183	0.1756	0.168	0.183
DCu	0.058 WRONG	0.05 RIGHT	0.051 RIGHT	0.01 WRONG	0.052	0.051	0.052	0.051	0.051	0.054	0.049	0.055	0.053	0.053	0.0521	0.049	0.055
TZn	1.596 WRONG	1.089 RIGHT	1.068 RIGHT	1.069 RIGHT	1.087	1.043	1.089	1.121	1.068	1.141	1.071	1.041	1.122	1.012	1.0795	1.012	1.141
DZn	0.466 WRONG	0.383 RIGHT	0.391 RIGHT	0.028 WRONG	0.397	0.374	0.375	0.392	0.405	0.38	0.382	0.372	0.388	0.386	0.3851	0.372	0.405
Load - Percent Exceed																	
TSS	0.59 WRONG	0.477 RIGHT	0.474 RIGHT	0.464 RIGHT	0.446	0.479	0.498	0.463	0.477	0.461	0.471	0.484	0.49	0.489	0.4758	0.446	0.498
TCu	0.608 WRONG	0.536 RIGHT	0.509 RIGHT	0.509 RIGHT	0.508	0.523	0.514	0.491	0.508	0.516	0.509	0.523	0.526	0.526	0.5144	0.491	0.526
DCu	0.619 WRONG	0.589 RIGHT	0.592 RIGHT	0.57 RIGHT	0.57	0.572	0.574	0.551	0.578	0.571	0.568	0.567	0.583	0.59	0.5724	0.551	0.59
TZn	0.626 WRONG	0.489 RIGHT	0.486 RIGHT	0.499 RIGHT	0.471	0.499	0.485	0.48	0.504	0.511	0.499	0.511	0.498	0.503	0.4961	0.471	0.511
DZn	0.624 WRONG	0.563 RIGHT	0.556 RIGHT	0.528 RIGHT	0.544	0.555	0.546	0.538	0.548	0.535	0.547	0.556	0.561	0.557	0.5487	0.535	0.561
Baseline Concentration																	
TSS	63.05 RIGHT	61.3 RIGHT	60 RIGHT	59.5 RIGHT	58.9	58.9	57.9	63.3	58.6	64.55	58.9	57.5	57.7	57.45	59.37	57.45	64.55
TCu	0.016 RIGHT	0.016 RIGHT	0.016 RIGHT	0.016 RIGHT	0.016	0.016	0.015	0.015	0.016	0.016	0.016	0.016	0.016	0.016	0.0158	0.015	0.016
DCu	0.004 RIGHT	0.004 RIGHT	0.004 RIGHT	0.001 WRONG	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
TZn	0.089 RIGHT	0.091 RIGHT	0.092 RIGHT	0.09 RIGHT	0.088	0.087	0.091	0.086	0.093	0.091	0.09	0.089	0.093	0.09	0.0898	0.086	0.093
DZn	0.029 RIGHT	0.027 RIGHT	0.029 RIGHT	0.003 WRONG	0.028	0.029	0.027	0.029	0.028	0.029	0.029	0.028	0.028	0.029	0.0284	0.027	0.029
Proposed Concentration																	
TSS	60.294 WRONG	36.971 RIGHT	36.922 RIGHT	33.662 RIGHT	34.693	37.693	36.381	34.987	37.316	37.463	34.838	37.022	34.842	34.376	35.9611	34.376	37.693
TCu	0.015 WRONG	0.011 RIGHT	0.011 RIGHT	0.011 RIGHT	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
DCu	0.004 WRONG	0.003 RIGHT	0.003 RIGHT	0.001 WRONG	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
TZn	0.089 WRONG	0.06 RIGHT	0.06 RIGHT	0.061 RIGHT	0.062	0.061	0.058	0.06	0.061	0.061	0.062	0.059	0.063	0.062	0.0609	0.058	0.063
DZn	0.029 WRONG	0.023 RIGHT	0.023 RIGHT	0.002 WRONG	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023
Concentration - Percent Exceed																	
TSS	0.543 WRONG	0.422 RIGHT	0.405 RIGHT	0.405 RIGHT	0.389	0.41	0.424	0.392	0.388	0.398	0.386	0.408	0.407	0.41	0.4012	0.386	0.424
TCu	0.54 WRONG	0.424 RIGHT	0.407 RIGHT	0.413 RIGHT	0.421	0.433	0.419	0.407	0.418	0.424	0.401	0.442	0.417	0.413	0.4195	0.401	0.442
DCu	0.563 WRONG	0.516 RIGHT	0.514 RIGHT	0 WRONG	0.487	0.517	0.501	0.486	0.494	0.501	0.494	0.492	0.509	0.484	0.4965	0.484	0.517
TZn	0.569 WRONG	0.402 RIGHT	0.398 RIGHT	0.427 RIGHT	0.418	0.417	0.403	0.4	0.413	0.419	0.414	0.42	0.405	0.404	0.4113	0.4	0.42
DZn	0.569 WRONG	0.481 RIGHT	0.464 RIGHT	0 WRONG	0.459	0.459	0.472	0.445	0.477	0.469	0.459	0.482	0.485	0.456	0.4663	0.445	0.485
Downstream Concentration																	
Baseline DCu	0.001 RIGHT	0.002 WRONG	0.001 RIGHT	0.002 WRONG	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Proposed DCu	0.001 RIGHT	0.002 WRONG	0.001 RIGHT	0.002 WRONG	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Baseline DZn	0.003 RIGHT	0.003 RIGHT	0.003 RIGHT	0.003 RIGHT	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Proposed DZn	0.003 RIGHT	0.003 RIGHT	0.003 RIGHT	0.003 RIGHT	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003

NOTE: Shading indicates values manually re-catergorized as "Right".