Spokane County
Public Works

August 1, 2023

Ms. Diana Washington, P.E.
Washington State Department of Ecology – ERO
4601 N. Monroe St
Spokane, WA 99205

Submitted via Water Quality Permitting Portal

RE: NPDES Permit No. WA-0093317; Spokane County Regional Water Reclamation Facility
Effluent Mixing and Dye Tracer Plan of Study

Dear Ms. Washington,

Spokane County is pleased to submit the attached Effluent Mixing and Dye Tracer Plan of Study as required by the subject National Pollutant Discharge Elimination System (NPDES) wastewater discharge permit Section S10.

Spokane County understands that activities planned in the study are to be jointly reviewed and agreed upon between Spokane County and the Department of Ecology.

Please contact me at 509-477-7521 or bbrattebo@spokanecounty.org if you have any questions or comments.

Sincerely,

Ben Brattebo, P.E.
Water Programs Manager

CC: File

Effluent Mixing and Dye Tracer Plan of Study

Spokane County Regional Water Reclamation Facility: Outfall 001

NPDES Permit WA0093317

Spokane County, Washington

July 2023

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Abbreviations

°C	degree(s) centigrade
AKART	all known available and reasonable treatment
cm	centimeter(s)
County	Spokane County
CSO	combined sewer overflow
CTD	conductivity, temperature, and depth
DGPS	Differential Global Positioning System
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
HDR	HDR Engineering, Inc.
m	meter(s)
MBR	membrane bioreactor
mgd	million gallons per day
min	minute(s)
mL	milliliter(s)
mS	microsiemens
NERL	National Exposure Research Laboratory
NPDES	National Pollutant Discharge Elimination System
ppb	part(s) per billion
QA	quality assurance
QC	quality control
SCRWRF	Spokane County Regional Water Reclamation Facility
sec	second(s)
USGS	United States Geological Survey
VP	Visual Plumes
WAC	Washington Administrative Code

Appendices

1 Introduction

This Effluent Mixing and Dye Tracer Plan of Study presents the specific approach for conducting an Effluent Mixing and Dye Tracer Study of the Spokane County Regional Water Reclamation Facility's (SCRWRF's) Outfall 001 in the Spokane River (Figure 1). This Effluent Mixing and Dye Tracer Plan of Study includes project background information, a detailed study approach, methodology for field measurements and dilution modeling, quality assurance and quality control (QA/QC) methods, and the plan for reporting.

Figure 1. Spokane County Regional Water Reclamation Facility and Outfall 001 site in Spokane River

1.1 Project Basis

Spokane County (County) operates the SCRWRF under its National Pollutant Discharge Elimination System (NPDES) Permit WA0093317, issued by the Washington State Department of Ecology (Ecology). Section S10 of the current NPDES Permit (issued June 13, 2022) includes requirements for this Effluent Mixing and Dye Tracer Plan of Study.

The NPDES Permit has the following requirements in Section S10.A (note: the permit language is provided in Appendix A to this Effluent Mixing and Dye Tracer Plan of Study):

1. Submit an Effluent Mixing and Dye Tracer Plan of Study to Ecology for review by August 1, 2023.
2. Meet with Ecology at least 60 days prior to initiation of the effluent mixing study.
3. The Effluent Mixing and Dye Tracer Plan of Study must include an evaluation of the possible overlap of mixing zones with the City of Spokane combined sewer overflows (CSOs); an estimate of the low flow, including the estimated groundwater contribution to flow, at the point of discharge; an evaluation of the physical features of the river bed upstream, downstream, and at the location of the diffuser; dye tracer results for the diffuser during a typical low-flow period for the river; and identification of any shoreline interactions and bottom attachments.
4. Use the “Guidance for Conducting Mixing Zone Analyses” (Appendix C of Ecology’s *Permit Writer’s Manual*, 2018) and the protocols identified in Section S10.C of the Permit.
5. Include the results of the effluent mixing study in the Effluent Mixing Report and submit it to Ecology for approval by August 1, 2026.

The SCRWRF’s NPDES Permit also defines the reporting requirements for the mixing zone study in Section S10.B as presented below:

- A confirmation that an all known available and reasonable treatment (AKART) analysis has been applied to the discharge
- A description of the size of the mixing zone allowed under Washington Administrative Code (WAC) Chapter 173-201A
- An analysis showing how bank outfall mixing zones have been minimized using the lowest dilution from hydraulic limitations, width limitations, distance limitations, and those predicted by the model
- A description of the critical conditions used for dilution factors
- Discharge information and characteristics as well as ambient water characteristics
- Model selection and results as well as summary tables of model results

This Effluent Mixing and Dye Tracer Plan of Study for Outfall 001 has been prepared and will be submitted to Ecology in accordance with the requirements of Section S10 of the SCRWRF NPDES Permit. Following review and approval of this Effluent Mixing and Dye

Tracer Plan of Study by Ecology, the SCRWRF will complete the field measurements under the appropriate river flow conditions, and then submit the study report by August 1, 2026.

1.2 Background on Discharge Characteristics and Mixing Zones

This section presents background on discharge characteristics and mixing zones, including outfall characteristics, mixing zones and dilution factors, and discharge site characteristics.

1.2.1 Outfall Characteristics

The SCRWRF is an advanced wastewater treatment plant owned by the County. It provides an initial 8 million gallons per day (mgd) of capacity with an ability to expand capacity in phases up to 24 mgd. The SCRWRF includes a treatment process incorporating a step-feed nitrification/denitrification membrane bioreactor (MBR) with the following key components: fine screening, grit removal, primary clarification, aeration basin, membranes, sodium hypochlorite disinfection, gravity-belt thickening for primary and waste activated sludge, anaerobic digestion, solid storage, centrifuge dewatering, and chemical feed systems. Other facilities include odor control, equalization tank, an administration building with a laboratory, a water resource center for public outreach, and a maintenance building.

The treated, disinfected, and dechlorinated effluent from Outfall 001 flows into the Spokane River through a 36-inch-diameter, duckbill-style Tideflex valve (single port). Outfall 001 extends north into the river about 75 feet beyond the ordinary high-water level on the south bank of the river (Figure 2). The top of the pipe is roughly 15 feet below the ordinary high-water level. At the outfall location the river width varies from about 150 to 200 feet depending on river flow.

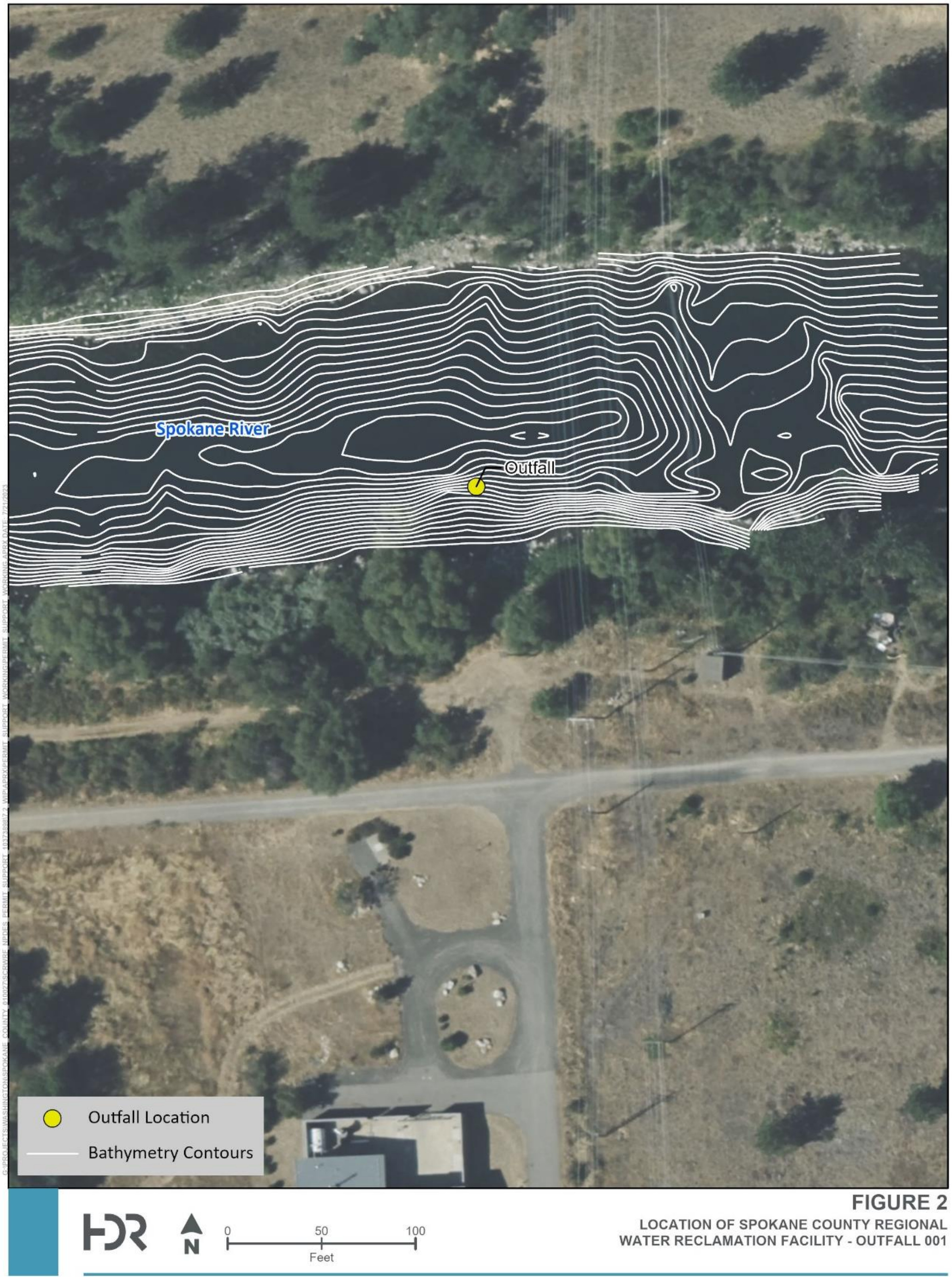

Figure 2. Location of Spokane County Regional Water Reclamation Facility: Outfall 001 (Bathymetry Data Collected by Gravity, June 14th, 2023)

1.2.2 Mixing Zones and Dilution Factors

The NPDES Permit defines the acute and chronic mixing zones for Outfall 001 in Section S1.B as follows:

S1.B. Mixing zone authorization

Mixing Zone for Outfall 001

The following paragraphs define flow-volume restriction of the mixing zones.

Acute Mixing Zone

The acute mixing zone must not use more than 2.5 percent of the flow in the receiving water. The width of the acute mixing zone is limited to a distance of 4 feet (1.2 meters) in any horizontal direction from the outfall. The length of the acute mixing zone extends 10 feet (3.0 meters) upstream and 30 feet (9.1 meters) downstream of the outfall. The acute mixing zone extends from the bottom to the top of the water column. The concentration of pollutants at the edge of the acute mixing zone must meet acute aquatic life criteria.

Chronic Mixing Zone

The chronic mixing zone must not use more than 25 percent of the flow in the receiving water. The width of the chronic mixing zone is limited to a distance of 40 feet (12.2 meters). The length of the chronic mixing zone extends 100 feet (30.5 meters) upstream and 300 feet (91.4 meters) downstream of the outfall. The chronic mixing zone extends from the bottom to the top of the water column. The concentration of pollutants at the edge of the chronic mixing zone must meet chronic aquatic life criteria and human-health criteria.

The NPDES Permit includes the applicable dilution factors for Outfall 001 in Section S1.B, as presented in Table 1 below.

Table 1. Effluent dilution factors

Parameter	Value
Acute Aquatic Life Criteria	2.0
Chronic Aquatic life criteria	15.7
Human Health Criteria: Carcinogen	47.8
Human-Health Criteria: Non-carcinogen	21.6

1.2.3 Discharge Site Characteristics

The SCRWRF Outfall 001 discharges to the Spokane River at river mile 78.9 (latitude 47°40' 34.2372", longitude 117°20' 48.678"). The outfall site is located between two active hydropower dams and this section of the river is relatively well hydrologically controlled. Extreme flood conditions appear to be rare and relatively well attenuated by these and other upstream dams. Other nearby point sources include City of Spokane CSO Outfalls 40, 39, and 38 downstream from the SCRWRF Outfall 001; City of

Spokane CSO 41, which is directly across the river from the SCRWRF Outfall 001; and the Inland Empire Paper outfall, which is roughly 4 miles upstream of SCWRF Outfall 001.

In the Spokane River, July to October represent low river flows, November and December represent average river flows, and January to June represent high river flows. Consequently, the dye tracer study will be performed in the July to October period as these are critical low-flow months. The overall methodology for conducting the effluent mixing and dye tracer study in the vicinity of Outfall 001 is presented in Section 2 of this Effluent Mixing and Dye Tracer Plan of Study.

1.3 Project Objectives

The project objectives of the Effluent Mixing and Dye Tracer Study for the SCRWRF Outfall 001 diffuser are to address all the requirements in Section S10.A of the NPDES Permit as presented below:

- Determining dilution factors under critical receiving water conditions, as defined in WAC 173-201A and Appendix C, "Guidance for Conducting Mixing Zone Analyses," in Ecology's *Permit Writer's Manual*
- Taking measurements of dilution factors in the field (dye tracer study) applying approved protocols (defined in Section S10.C or other approved methods) and per the guidelines provided in Section 12 of Appendix C, "Guidance for Conducting Mixing Zone Analyses," in Ecology's *Permit Writer's Manual*
- Dilution modeling consistent with Appendix C, "Guidance for Conducting Mixing Zone Analyses," in Ecology's *Permit Writer's Manual*
- Calibration of a selected model using field tracer study results (consistent with Appendix C, "Guidance for Conducting Mixing Zone Analyses," in Ecology's *Permit Writer's Manual*)
- Applying dilutions at the acute and chronic mixing zone boundaries in accordance with Ecology's *Permit Writer's Manual*

This study has been designed to provide the following information:

- Site-specific field measurements of the dilution performance of the SCRWRF Outfall 001 during low-flow critical conditions in the Spokane River
- Accurate field measurements of receiving water characteristics and dilutions that will be used to calibrate the dilution model
- Direct measurements of the plume mixing and location
- Dilution modeling results for receiving water and effluent conditions encountered during the field survey
- Dilution modeling results for the receiving water at low-flow critical conditions
- A study report that meets with Ecology's approval

The study will be conducted using well planned, designed, implemented, and documented procedures to produce a technically defensible study that documents the dilution performance of the SCRWRF's Outfall 001 and meets the requirements of Ecology's "Guidance for Conducting Mixing Zone Analyses," fulfills the specific requirement in Sections S10.A and S1.B of the SCRWRF's NPDES Permit, and achieves the objectives and activities defined in this Effluent Mixing and Dye Tracer Plan of Study (as approved by Ecology).

1.4 Study Approach

The study approach for this Effluent Mixing and Dye Tracer Plan of Study involves collecting site-specific measurements of river velocities, water temperature, and simultaneous measurements of diffuser dilutions using a dye tracer during low river flow conditions. These field-measured effluent dilutions and river data will be used to develop model predictions of discharge dilutions for the field-measured conditions and for other critical river conditions and effluent flows. The field-measured dilutions will also be used to compare and select the correct dilution model (Visual Plumes [VP] or CORMIX1 for application over a range of river flow and effluent discharge conditions.

Following approval of the Effluent Mixing and Dye Tracer Plan of Study by Ecology, HDR Engineering, Inc. (HDR) and SCRWRF personnel will complete preparations for and conduct the field study. The field study will be performed during the July to October critical low-flow period. Prior to the field study, an external inspection of the Outfall 001 diffuser will be completed to document the diffuser functional status, layout, and configuration. Alternatively, the most recent inspection conducted by the County may be used.

The field study will include measurements of river velocity, water depth, conductivity, and temperature at a location immediately downstream of Outfall 001. The field tracer study will consist of injecting a tracer dye into the effluent pipeline, and water column measurements of the injected tracer dye at multiple locations upstream and downstream from Outfall 001 in the river during low river flow conditions. Initial dye tracer measurements will also be collected downstream of the dye injection point in the effluent pipeline to record the dye concentration in the outfall prior to effluent reaching the diffuser and river.

Following the field studies, the dye tracer study data will be summarized and analyzed. Dilution modeling will be conducted using the collected receiving water data and effluent data. Dilution modeling analyses will first focus on the field tracer study conditions. The field-measured dilutions will be used to compare and select the correct dilution model (VP or CORMIX1) for application. Dilution modeling will be completed for the effluent and river conditions specified in Ecology's *Permit Writer's Manual* and according to the "Guidance for Conducting Mixing Zone Analyses."

A report will be prepared summarizing the outfall mixing zone study, including the field and modeling work, and supporting documentation, and the report will be submitted to Ecology.

2 Field Study Methods

The field dilution (mixing) study of the SCRWRF outfall diffuser will include site-specific river measurements, a dye tracer study, and field measurements documentation. The field study will be performed during a 1-day period during the July to October critical low river flow period.

2.1 Field Study Methodology

The field data collection will include recording measurements of ambient river velocity, temperature, conductivity, and depth at one site immediately upstream of Outfall 001. Multiple measurements of water velocity across the river, immediately upstream of Outfall 001, will be performed to identify any cross-sectional velocity gradients due to river bathymetric changes. Measurements of water velocity will also include measurements vertically over depth. Data collection will also include water column measurements of dye tracer concentrations, temperature, and conductivity over a range of depths and locations along the acute mixing zone boundary, the chronic mixing zone boundary currently specified in the SCRWRF NPDES Permit, and additional upstream and downstream locations. A CORMIX and/or VP model application will be preliminarily configured and run to represent the effluent and river conditions likely to be present during the dye tracer study once the sampling period is determined. These preliminary model predictions will help in identifying critical sampling locations considering the expected spatial extent of the effluent dye plume. An example of possible river monitoring locations is presented on Figure 3.

Field dye tracer, temperature, and conductivity measurements will be collected from two 10-foot work vessels, and field sampling site locations will be recorded using a Differential Global Positioning System (DGPS). Given the relatively high river velocities, even under low flow conditions, the dye measurement period will be approximately 1 to 2 hours.

Important elements that will be included in the dye tracer study are listed below:

- Vertical profile measurements of dye concentration with depth at pre-selected downstream and lateral distances from the outfall in the path of the effluent plume, including upstream background sampling
- Measurements of conductivity and temperature at the same locations as dye measurements, as well as upstream background measurements
- Velocity measurements near the outfall to assess near-field mixing and rate of travel downstream from the outfall location
- Velocity measurements conducted over depth and along the river cross section near the outfall
- Sampling position coordinates to be determined using DGPS logging
- Calibration of equipment before and, in the case of fluorometers, after field data collections

In coordination with the SCRWRF, a location within the Outfall 001 structure will be selected for the dye injection. This selected dye injection location should allow the dye to mix completely before the initial downstream sample point. At the initial downstream sampling point, dye measurements will be recorded with an instrument deployed in the outfall pipe downstream from the injection site to allow for complete mixing in the pipeline. The SCRWRF will record effluent flows during the dye injection period every 30 minutes.

Dye standards will be prepared with the dye used in the study, effluent from the SCRWRF, and background water. Water will be collected from the study site prior to the dye study, and fluorometers will be calibrated before going into the field. Immediately following the dye study, a second set of fluorometer calibration measurements will be recorded using effluent, dye, and background water.

A fluorescent, water-soluble, biodegradable dye (e.g., Rhodamine WT) will be used as the effluent tracer because it can be accurately measured to 0.5–1.0 part per billion (ppb). Based on the SCRWRF discharge flow, Rhodamine WT will be injected at a rate sufficient to produce a relatively steady target effluent concentration to be determined based on the preliminary CORMIX and/or VP model simulations. Having defined a target concentration and, in conjunction with the equipment practical dye detection limit above background, the field team will be able to accurately measure river dye concentrations and calculate effluent dilution at the acute and chronic mixing zone boundaries.

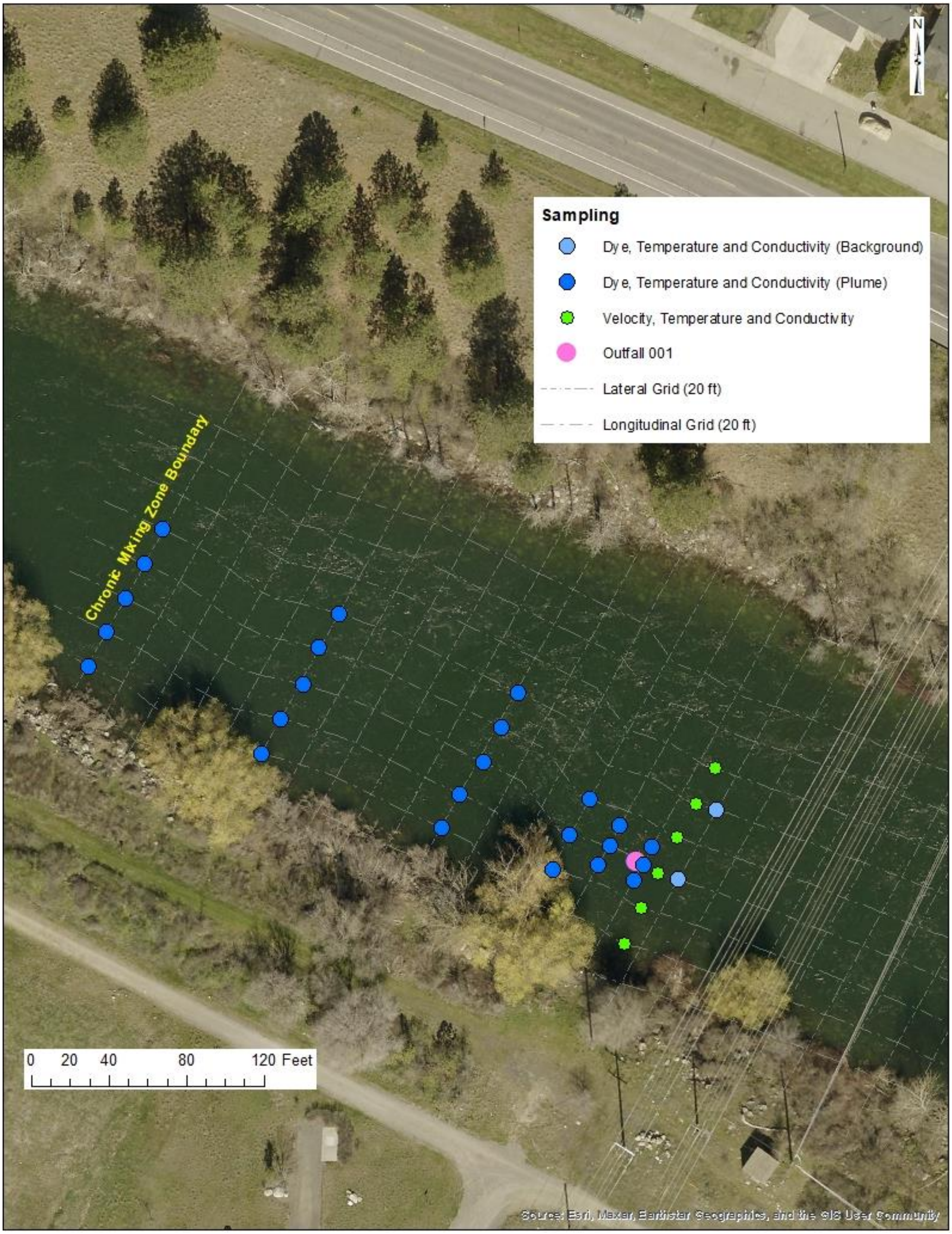

Figure 3. Example of possible river monitoring locations

2.2 Instrumentation

Field instruments for the dilution study, including backup units, are listed in Table 2. The final equipment brand and unit count will be decided once the location and number of monitoring locations is confirmed.

Table 2. Field equipment for outfall mixing zone study

Equipment item	Purpose	No. of units	Accuracy standard
EXO1s multiparameter sonde (or comparable unit)	Fluorescent dye measurements	3–4	Detection to 0.5 ppb
C3 submersible fluorometer	Fluorescent dye measurements	1 (if needed)	Detection to 0.5 ppb
EXO1s multiparameter sonde (or comparable unit)	Conductivity, temperature, and depth measurements	1–2	Conductivity ±0.001 mS/m Temperature ±0.01°C Depth = 0.5% of full scale
GPS unit	Survey positioning measurements	3	Submeter
MasterFlex peristaltic pump (or comparable unit)	Used for dye injection into effluent	1	0.2 mL/min
Positive-displacement or peristaltic pump	Pump receiving water thru fluorometer (if needed)	2	1 mL/min; minimum delivery rate of 3 L/min
InterOcean S4 current meter (or comparable unit)	Measures in situ current speed	3	Speed = ±0.2 cm/sec
	Measures conductivity		Conductivity ±0.001 mS/m
	Measures temperature		Temperature ±0.01°C
	Measures water depth		Depth = ±0.2 cm

2.3 Quality Assurance/Quality Control

The QA/QC objective for the field study is to collect measurements of effluent dilution and river conditions that are of known and acceptable quality. The following requirements will be followed to achieve these objectives:

- Provide verifiable dye injection rates and initial dye concentrations
- Provide verifiable equipment calibration with pre- and post-study calibrations of the fluorometer instruments
- Provide verifiable laboratory QA/QC documentation
- Maintain accurate positioning for measurements
- Provide equipment redundancy (backup equipment)
- Examine dye injection site and downstream sample collection site to verify complete mixing in the pipeline before river samples are collected

- Pre-study planning and organization to clarify site-specific conditions and plan for efficient and uninterrupted field work

This Effluent Mixing and Dye Tracer Plan of Study has been developed as the basic element of QA/QC activities for the field study. A field operations memorandum will also be developed and discussed with the SCRWRF personnel prior to the field study to define the detailed study schedule, communications, personnel assignments, and field safety procedures. Project-specific field safety instructions will be prepared by HDR and reviewed by SCRWRF personnel.

2.3.1 Equipment Calibration

All equipment will be obtained prior to the beginning of the dye study. Each instrument will be checked and calibrated upon its arrival to confirm that it is in working condition. Each instrument will also be calibrated immediately prior to the beginning of the dye study and, when appropriate, following the study. Calibration methods for each instrument are described below:

- **Current meters** will be calibrated by the equipment providers according to their specifications. Calibration results will be used during data reduction and the calibration history will be incorporated for the units used.
- **Dye pumps** will be calibrated at the location where they will be used during the dye study. The pumps will be equipped with a micrometer control to accurately determine pumping rate. The flow rate scale will be calibrated with the dye at ambient temperature by repeatedly discharging dye into a graduated cylinder for a fixed period at various flow rate scale settings. According to the manufacturer, reproducible metering accuracy of greater than 1 percent can be expected when handling medium-viscosity fluids if fluid differential pressure, fluid viscosity, and electric line voltage remain constant. To verify that none of these factors is affecting expected dye flow rates during dye injection, dye flow rates will be verified and logged prior to the start of dye injection and at 15-minute intervals during injection.
- **Fluorometers** will be calibrated according to the manufacturer's specifications such that they measure total dye concentration in the appropriate range for their use (receiving water and effluent initial dye measurements). Standards will be prepared with the dye used in the study, effluent from the SCRWRF, and background river water. Water will be collected from the study site prior to the dye study, and fluorometers will be calibrated before going into the field. Immediately following the dye study, a second set of fluorometer calibration measurements will be recorded using effluent, dye, and background water. This second set of calibration measurements will be compared to the pre-study calibration data, after correction for temperature. Both calibration curves will be used to correct or adjust the observed dye concentration and dilution.
- **Conductivity, temperature, and depth (CTD) units** will be calibrated to the manufacturer's specifications before conducting the dye study. Calibration results will be used during data reduction and calculation of the water column density structure. Calibration history will be incorporated for the unit that will be used.

2.4 Organization

Key personnel for the mixing zone study and field data collection efforts will be the project manager and technical team leader. The project manager is responsible for accomplishing the scope of work; assigning resources, communications, and schedules; and reviewing deliverables. All work will be performed by experienced personnel. Specific people for each project role will be determined once the Effluent Mixing and Dye Tracer Plan of Study is approved. Table 3 lists key roles that will be involved in the project.

Table 3. Key roles for the outfall mixing zone study

Role	Assigned Personnel
SCRWRF Manager	Hannah Thomascall Spokane County hthomascall@spokanecounty.org
Project manager	Tyson Schlect HDR Tyson.schlect@hdrinc.com
Technical leader	Cindy Helmericks HDR Cynthia.Helmericks@hdrinc.com
Modeler and scientist	Michael Kasch HDR Michael.kasch@hdrinc.com
Field scientist	TBD
Senior field lead	TBD
Vessel operators	Gravity Marine shawn@gravitymarine.com

When QA problems or deficiencies requiring special action arise in the field, the technical and senior field leaders will identify the appropriate corrective action to be initiated and implemented. Problems will be documented in writing, along with the corrective action taken.

3 Dilution Modeling

Dilution modeling will be conducted using the collected receiving water and effluent data. Dilution modeling analyses will first focus on the dye measurements and calculated effluent dilution obtained during the field tracer study. Dilutions and plume behavior observed and calculated will be used to compare and select the appropriate dilution model (CORMIX1 or VP) for application to Outfall 001. Sensitivity model runs will be performed to select the most representative model, and the remaining modeling will be conducted using that selected model.

3.1 Model Selection

Based on evaluations of available dilution models, the following models will be considered for use in modeling the SCRWRF Outfall 001: (1) Visual Plumes, a model interface and file manager that includes both plume models DKHW and UM3 (Frick et al. 2000), and (2) CORMIX1 (Jirka et al. 1996). The dilution model selection and approach will be developed through screening model runs and reviews with a senior reviewer and modeler. One of these dilution models will be applied (depending upon which was shown to best represent measured dye concentrations and calculated dilutions) to simulate the discharge and effluent plume behavior (plume dimensions and effluent dilution). These models are discussed in more detail below.

3.1.1 Visual Plumes

Visual Plumes is an update of the PLUMES modeling system developed by the National Exposure Research Laboratory (NERL) of the U.S. Environmental Protection Agency (EPA) (Baumgartner et al. 1994). VP is a Windows-based computer application that supersedes the DOS PLUMES (Baumgartner et al. 1994) mixing zone modeling system. VP simulates single and merging multiple submerged plumes in arbitrarily stratified ambient flow and buoyant surface discharges. VP includes the DKHW model, which is based on UDKHDEN (Muellenhoff et al. 1985), the surface discharge model PDS, the three-dimensional UM3 model based on UM, and the NRFIELD model based on RSB. The Brooks equations (Brooks 1960) are retained to simulate far-field plume behavior.

The time-series file-linking capability provides a way to simulate outfall performance over long periods. Most effluent and ambient variables can be input from files that store data that change with time. This is the heart of the pollutant-buildup capability, designed for one-dimensional tidal rivers or estuaries to estimate background pollution from the source in question. The time-series file linking capability is served by “summary graphics” (i.e., graphics that focus on overall performance indicators, like mixing zone dilutions or concentrations).

The following briefly describes the capabilities of the individual models contained within the VP model interface.

3.1.2 DKHW

DKHW is a three-dimensional hydrodynamic model that considers variable ambient receiving water current and density profiles with depth. DKHW uses a fourth-order integration routine along the centerline of the effluent plume to trace its position and average dilution over time. The model calculates the average dilution, plume trajectory, and trapping level for submerged, buoyant plumes from a single diffuser or single row of multiple diffuser ports in either stagnant or flowing environments. DKHW is sensitive to water column density gradients and ambient velocities. Jet-integral plumes models such as DKHW provide relatively conservative dilution estimates (i.e., they predict lower dilutions than are actually achieved), which are based on comparisons of field and dilution modeling results.

The model output of each DKHW run provides sequential calculation of both dilution and plume distance from the port until initial dilution is completed, and this output can be used to summarize the dilutions and plume depth at the acute mixing zone boundary and at the completion of initial dilution. The method of Brooks is used to develop dilution predictions in the far field, typically at the chronic mixing zone boundary. These equations are retained in VP to simulate far-field behavior.

3.1.3 UM3

UM3 calculates the flux-average dilution, plume trajectory, and trapping level for submerged, buoyant plumes from a single diffuser or single row of multiple diffuser ports in either stagnant or flowing environments. UM3 is a two-dimensional mathematical model that analyzes effluent discharges by tracing the position of the plume through its trajectory path. The model approximates the plume development by using single, one-step integrations over discrete time increments.

The output of each UM3 model run provides sequential calculation of both dilution and plume distance from the port until initial dilution is completed, and the outputs are used to predict the dilutions and plume depth at the completion of initial dilution and at various distances downstream of the outfall. As stated previously, the VP interface contains far-field dilution algorithms based on equations developed by Brooks. The far-field estimates will be used to develop predicted dilutions at the chronic mixing zone boundary.

3.1.4 CORMIX

The CORMIX modeling system, developed for EPA at Cornell University and currently maintained at Portland State University, is a rule-based system that classifies the interaction of discharges and the receiving water (Jirka et al. 1996). The program makes many of the decisions for the model user based on the input parameters that are provided. The system was designed for the non-specialist model user, in order that plume predictions could be made without having prior knowledge about dilution modeling and mixing processes. The CORMIX models use empirically derived curve fit equations to make dilution predictions. These equations are selected from length scales that are determined from parameters input by the user.

CORMIX1 predicts the geometry and dilution characteristics of the effluent flow resulting from a single-port discharge. The effluent can be of arbitrary density (positively, neutrally, or negatively buoyant relative to the ambient), location, and geometry, into an ambient receiving water body. The ambient receiving water body may be stagnant or flowing and have ambient density stratification of different types. The single-port outfall can be deeply submerged or be a near-surface or above-surface discharge.

3.2 Modeling Objectives and Approach

Dilution modeling will be used to predict effluent dilutions based upon the field study results as well as effluent and receiving water conditions (e.g., flow and temperature) during the dye study period. The field-measured dye concentrations and calculated dilutions will be used for direct comparisons to dilution model results using VP (DKHW and UM3) and CORMIX1. The basis for model selection will be carefully documented. After model selection, measured receiving water and effluent conditions will be used to accurately test the model predictions. The model testing using the field tracer study data will be consistent with the "Guidance for Conducting Mixing Zone Analyses" in Ecology's *Permit Writer's Manual*.

Using the calibrated dilution model, dilution modeling analyses will be developed for the applicable effluent and receiving water conditions as specified in Ecology's *Permit Writer's Manual* and consistent with the "Guidance for Conducting Mixing Zone Analyses" in Ecology's *Permit Writer's Manual*. In performing the dilution modeling analyses, emphasis will be given to address all the requirements specified in Section S10.A of the SCRWRF NPDES Permit.

The results of the dilution modeling will include a comparison of model-predicted versus field-measured dye concentrations and calculated effluent dilution (for the dye data collection period), model-predicted dilutions at the current acute and chronic mixing zones boundaries, model-predicted extent of the plume (horizontally and vertically), and model-predicted dilution at other relevant locations (if necessary). The dilution model output will be included with the Outfall Mixing Zone Study Report.

4 Data Analysis and Modeling Study Report

The field data collected during the dye tracer study, supporting data (e.g., United States Geological Survey [USGS] river flows and bathymetric data), and effluent data will be analyzed for the development and calibration of the SCRWRF Outfall 001 dilution model. A draft Outfall Mixing Zone Study Report will be prepared that summarizes the results of the field data collection, data analyses, dilution modeling, and the evaluation of effluent dilution and the acute and chronic mixing zone boundaries. The draft Outfall Mixing Zone Study Report will be submitted to the SCRWRF for review approximately three months after the field studies. Following review and completion, a final Outfall Mixing Zone Study Report will be submitted to the SCRWRF for submission to Ecology in accordance with the NPDES Permit timeline.

5 References

Baumgartner, D.J., Frick, W.E., & Roberts, P.J.W. (1994). *Dilution Models for Effluent Discharges (Second Edition)*. U.S. EPA Publication No. EPA 600/R-94/086.

Brooks, N.H., (1960). Diffusion of sewage effluent in an ocean current. pp 246-267. *Proceedings of the First Conference on Waste Disposal in the Marine Environment*. Ed. E.A. Pearson. Pergamon Press. New York. 569 pp.

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Environmental Research Division, NERL, ORD. U.S. Environmental Protection Agency.

Jirka, G.H., Doneker , R.L., & Hinton, S.W. (1996). *User's Manual for CORMIX: A Hydrodynamic Mixing Zone Model and Decision Support System for Pollutant Discharges Into Surface Waters*. Office of Science and Technology, U.S. Environmental Protection Agency. Cooperative Agreement No. CX824847-01-0.

Muellenhoff, W.P., et al. (1985). *Initial Mixing Characteristics of Municipal Ocean Discharges. Volume I, Procedures and Applications*. EPA 600/3-85-073a. U.S. Environmental Protection Agency, Office of Research and Development.

Appendix A. NPDES Permit Section S10

S10. Effluent Mixing and Dye Tracer Study

S10.A. General Requirements

The Permittee must:

1. Submit a Plan of Study to Ecology for review by August 1, 2023. Additionally, MEET WITH ECOLOGY at least 60 days prior to initiation of the effluent mixing study. The dye study should be the primary tool. The most appropriate model should be the one that best validates against the dye results.

   In addition to information typically identify using a dye tracer and mixing study, the study must include:

   - An evaluation of the possible overlap of mixing zone with the City of Spokane CSOs
   - An estimate of the low flow, including the estimated groundwater contribution to flow, at the point of discharge
   - An accurate evaluation of the physical features of the river bed upstream, downstream and at the location of the diffuser
   - Dye tracer results for the diffuser during typical low flow period for the river.
   - Identification any shoreline interactions and bottom attachments.
2. Use the Guidance for Conducting Mixing Zone Analyses (Appendix C of Ecology's Permit Writer's Manual; 2018) and the protocols identified in S10.C.
3. Include the results of the effluent mixing study in the Effluent Mixing Report and submit it to Ecology for approval by August 1, 2026.
4. If the results of the mixing study, toxicity tests, and chemical analysis indicate that the concentration of any pollutant(s) exceeds or has a reasonable potential to exceed the state water quality standards, chapter 173-201A WAC, Ecology may issue an administrative order to require a reduction of pollutants or modify this permit to impose effluent limits to meet the water quality standards.

S10.B. Reporting Requirements

The mixing zone study must include:

1. A statement confirming that AKART has been applied to the discharge.
2. A description of the size of the mixing zone allowed under chapter 173-201A WAC.
3. An analysis showing how bank outfall mixing zones have been minimized using the lowest dilution from hydraulic limitations, width limitations, distance limitations and those predicted by the model.

4. A clear description of the critical conditions used for dilution factors:
    i. For ambient freshwater (unidirectional flow) use 7Q10 flows for acute, chronic and non-carcinogenic pollutants, and harmonic flow for carcinogens.
    ii. Use density profile that gives the lowest dilution. Evaluate both maximum and minimum stratification. For human health, use average density profiles to estimate dilution.
    iii. For unidirectional flow use centerline dilution factor for acute and chronic conditions, while flux average for human health dilution factors.
5. Discharge information:
    i. Location, orientation, description and dimensions of outfall.
    ii. Plan view maps showing the mixing zone size and dimensions in relation to the bank outfall.
    iii. Schematic of waterbody cross-section, showing channel width, depth, and bank outfall.
6. Discharge characteristics:
    i. Existing and projected maximum daily, maximum monthly average, and annual average flows.
    ii. Discharge density (temperature and salinity).
7. Ambient water characteristics:
    i. Critical stream flow statistics (7Q10, 30Q5, harmonic flow).
    ii. Velocity profile upstream, at the outfall, and downstream of the outfall.
    iii. Temporal density (temperature and salinity) profiles near the outfall. Include seasonal variability.
    iv. Manning’s roughness coefficient, if used.
    v. Available information regarding background concentrations of chemical substances in the receiving water for which there are criteria in chapter 173-201A WAC.
8. Model selection and results:
    i. Model selection and application discussion. Consider model applicability to bank discharge and potential plume attachment to boundaries.
    ii. Description of mixing and plume dynamics (near-field, far-field).
    iii. Sensitivity analysis.
    iv. Calibration to empirical data (tracer studies), if applicable.
    v. Provide model output and summary table of results.

S10.C. Protocols

The Permittee must determine the dilution ratio using protocols outlined in the following references, approved modifications thereof, or by another method approved by Ecology:

Doneker, R.L. and G.H. Jirka, CORMIX User Manual: A Hydrodynamic Mixing Zone Model and Decision Support System for Pollutant Discharges into Surface Waters, EPA-823-K- 07-001, Dec. 2007. (http://www.mixzon.com/downloads/).

A complete list of general reference for CORMIX (http://www.cormix.info/references.php).

Frick, W.E., Roberts, P.J.W., Davis, L.R., Keyes, D.J., Baumgartner, George, K.P. 2003. Dilution Models for Effluent Discharges, 4th Edition (Visual Plumes). Ecosystems Research Div., USEPA, Athens, GA, USA. (https://www.epa.gov/sites/default/files/documents/VP-Manual.pdf)

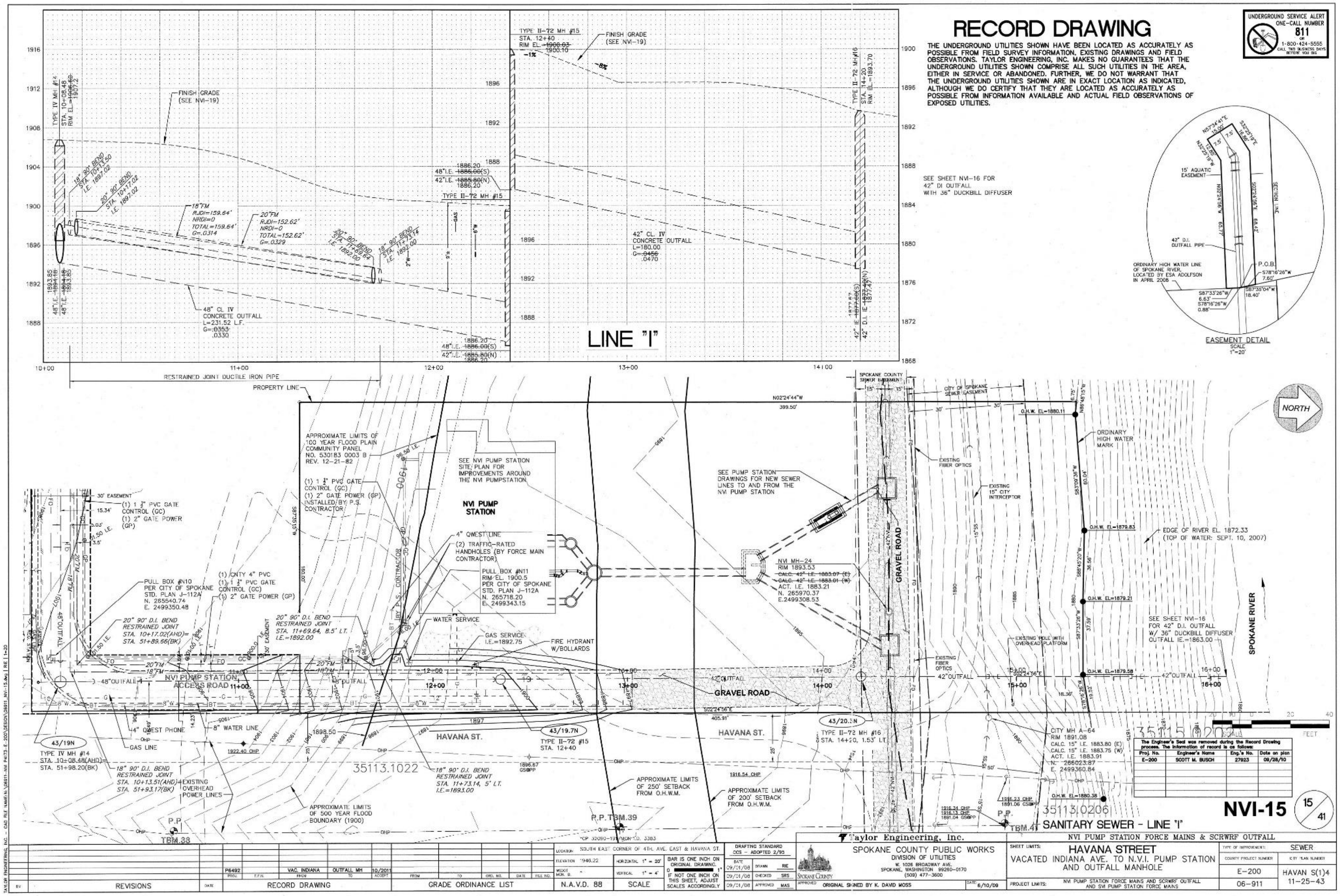
Ecology, Water Quality Program, Permit Writer's Manual.2018. Washington State Department of Ecology. Publication No. 92-109, Revised July 2018. (https://apps.ecology.wa.gov/publications/documents/92109.pdf).

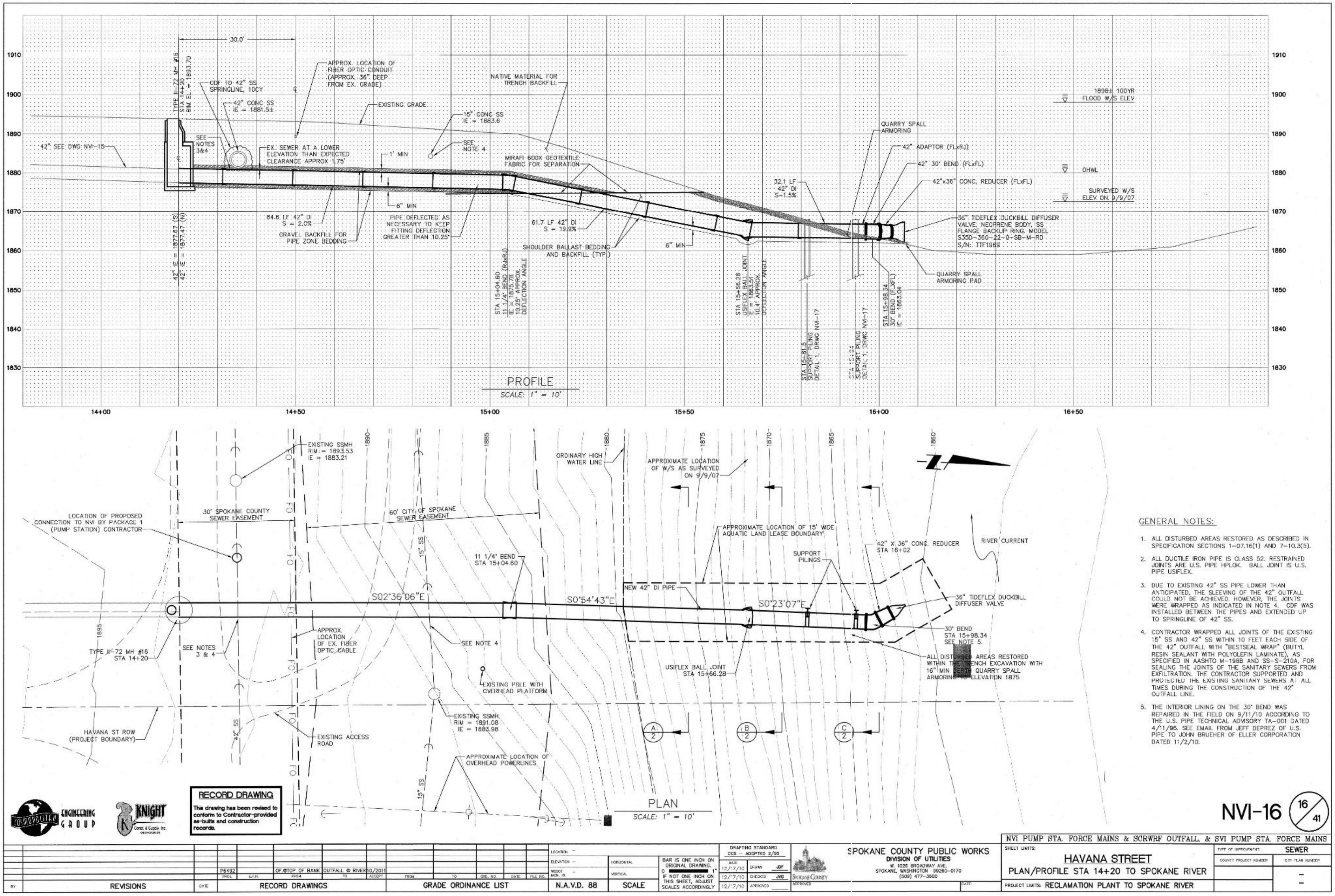
Ecology, Guidance for conducting mixing zone analysis Appendix C, Water Quality Program, Permit Writer's Manual. 2015 (https://apps.ecology.wa.gov/ecy/publications/parts/92109part1.pdf).

Kilpatrick, F.A., and E.D. Cobb, Measurement of Discharge Using Tracers, Chapter A16, Techniques of Water-Resources Investigations of the USGS, Book 3, Application of Hydraulics, USGS, U.S. Department of the Interior, Reston, VA, 1985. (https://pubs.usgs.gov/twri/twri3-a16/pdf/TWRI_3-A16.pdf).

Wilson, J.F., E.D. Cobb, and F.A. Kilpatrick, Fluorometric Procedures for Dye Tracing, Chapter A12. Techniques of Water-Resources Investigations of the USGS, Book 3, Application of Hydraulics, USGS, U.S. Department of the Interior, Reston, VA, 1986. https://pubs.usgs.gov/twri/twri3-a12/pdf/TWRI_3-A12.pdf).

Appendix B. Outfall 001 Drawings


RECORD DRAWING
THE UNDERGROUND UTILITIES SHOWN HAVE BEEN LOCATED AS ACCURATELY AS POSSIBLE FROM FIELD SURVEY INFORMATION, EXISTING DRAWINGS AND FIELD OBSERVATIONS. TAYLOR ENGINEERING, INC. MAKES NO GUARANTEES THAT THE UNDERGROUND UTILITIES SHOWN COMPRISE ALL SUCH UTILITIES IN THE AREA, EITHER IN SERVICE OR ABANDONED. FURTHER, WE DO NOT WARRANT THAT THE UNDERGROUND UTILITIES SHOWN ARE IN EXACT LOCATION AS INDICATED, ALTHOUGH WE DO CERTIFY THAT THEY ARE LOCATED AS ACCURATELY AS POSSIBLE FROM INFORMATION AVAILABLE AND ACTUAL FIELD OBSERVATIONS OF EXPOSED UTILITIES.
UNDERGROUND SERVICE ALERT
ONE-CALL NUMBER
811
1-800-424-5555
LINE "I"
EASEMENT DETAIL
NORTH
NVI PUMP STATION
GRAVEL ROAD
HAVANA ST.
SPOKANE RIVER
SEE SHEET NVI-16 FOR 42" DI OUTFALL WITH 36" DUCKBILL DIFFUSER
Taylor Engineering, Inc.
SPOKANE COUNTY PUBLIC WORKS
DIVISION OF UTILITIES
HAVANA STREET
VACATED INDIANA AVE. TO N.V.I. PUMP STATION AND OUTFALL MANHOLE
NVI PUMP STATION FORCE MAINS & SCRWRF OUTFALL
SANITARY SEWER - LINE 'I'
NVI-15
15/41
REVISIONS
RECORD DRAWING
GRADE ORDINANCE LIST
N.A.V.D. 88
SCALE


PROFILE
SCALE: 1" = 10'
PLAN
SCALE: 1" = 10'
RECORD DRAWING
This drawing has been revised to conform to Contractor-provided as-builts and construction records.
GENERAL NOTES:
1. ALL DISTURBED AREAS RESTORED AS DESCRIBED IN SPECIFICATION SECTIONS 1-07.16(1) AND 7-10.3(5).
2. ALL DUCTILE IRON PIPE IS CLASS 52. RESTRAINED JOINTS ARE U.S. PIPE HPLOK. BALL JOINT IS U.S. PIPE USIFLEX.
3. DUE TO EXISTING 42" SS PIPE LOWER THAN ANTICIPATED, THE SLEEVING OF THE 42" OUTFALL COULD NOT BE ACHIEVED. HOWEVER, THE JOINTS WERE WRAPPED AS INDICATED IN NOTE 4. CDF WAS INSTALLED BETWEEN THE PIPES AND EXTENDED UP TO SPRINGLINE OF 42" SS.
4. CONTRACTOR WRAPPED ALL JOINTS OF THE EXISTING 15" SS AND 42" SS WITHIN 10 FEET EACH SIDE OF THE 42" OUTFALL WITH "BESTSEAL WRAP" (BUTYL RESIN SEALANT WITH POLYOLEFIN LAMINATE), AS SPECIFIED IN AASHTO M-198B AND SS-S-210A, FOR SEALING THE JOINTS OF THE SANITARY SEWERS FROM EXFILTRATION. THE CONTRACTOR SUPPORTED AND PROTECTED THE EXISTING SANITARY SEWERS AT ALL TIMES DURING THE CONSTRUCTION OF THE 42" OUTFALL LINE.
5. THE INTERIOR LINING ON THE 30" BEND WAS REPAIRED IN THE FIELD ON 9/11/10 ACCORDING TO THE U.S. PIPE TECHNICAL ADVISORY TA-001 DATED 4/11/96. SEE EMAIL FROM JEFF DEPREZ OF U.S. PIPE TO JOHN BRUEHER OF ELLER CORPORATION DATED 11/2/10.
NVI-16
16/41
NVI PUMP STA. FORCE MAINS & SCRWRF OUTFALL, & SVI PUMP STA. FORCE MAINS
SHEET LIMITS:
HAVANA STREET
PLAN/PROFILE STA 14+20 TO SPOKANE RIVER
PROJECT LIMITS: RECLAMATION PLANT TO SPOKANE RIVER
TYPE OF IMPROVEMENT: SEWER
SPOKANE COUNTY PUBLIC WORKS
DIVISION OF UTILITIES
REVISIONS
RECORD DRAWINGS
GRADE ORDINANCE LIST
N.A.V.D. 88
SCALE