Mixing Zone Study Report
for the Proposed Spokane County Discharge to the Spokane River, Washington

Prepared for:

HDR Engineering, Inc.
Portland, OR

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Limno-Tech, Inc.
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1. INTRODUCTION

This report summarizes the methods and findings of a mixing zone study for the proposed Spokane County municipal wastewater discharge to the Spokane River in Spokane, Washington. Limno-Tech, Inc. (LTI) of Ann Arbor, Michigan, conducted this work under contract to HDR Engineering, Inc. (HDR) of Portland, Oregon. Background information, study objectives, and the assessment approach are presented below.

1.1 PROJECT BACKGROUND

This work is being conducted as part of the facilities planning process for the proposed Spokane County Regional Plant. The location of the proposed discharge to the Spokane River is east of the N. Hamilton Street Bridge, as shown in Figure 1.

1.2 STUDY OBJECTIVES

The primary objective of this study was to evaluate whether the proposed Spokane County Regional Plant discharge is likely to attain State of Washington water quality standards through use of a mixing zone. The applicable standards include acute and chronic numeric water quality criteria and narrative mixing zone standards for the protection of fish. The water quality constituents considered in this study were temperature, ammonia, and toxic metals including arsenic, copper, chromium, mercury, nickel, and silver.

1.3 APPROACH

This modeling study focused on predicting effluent dilution under critical receiving water conditions to establish technically defensible and regulatory-compliant mixing zone boundaries for acute and chronic water quality criteria. The mixing zone within which acute water quality criteria may be exceeded, but beyond which the acute criteria will be met, is referred to as the zone of initial dilution (ZID). The mixing zone within which chronic water quality criteria may be exceeded, but beyond which chronic criteria will be attained, is referred to as the chronic mixing zone (CMZ).

Critical receiving water conditions were evaluated for two seasons: summer (May through October) and winter (November through April). In the absence of a pre-specified ZID or CMZ, the spatial extent of the mixing zones were determined based on the modeling conducted in this study and evaluated by comparison to the mixing zone size restrictions promulgated in Washington regulations and Washington Department of Ecology (Ecology) guidance, as discussed below.

Washington regulations (WAC 173-201A-400) impose the following restrictions on mixing zones in rivers and streams:

- The downstream extent of the chronic mixing zone (CMZ) shall not exceed 300 feet plus the depth of water over the discharge port and the upstream extent shall not exceed 100 feet.

- The chronic mixing zone shall not utilize more than 25% of the flow of the river.

- The acute mixing zone (ZID) cannot utilize more than 2.5% of the river flow.

- Neither the chronic nor the acute mixing zones shall occupy more than 25% of the width of the river.

- The ZID may not extend beyond 10% of the distance towards the upstream and downstream CMZ boundaries.

The approach to this study was designed to be consistent with the project's scope of work (Dilks, 2003). The scenarios modeled and results presented in this mixing zone study report were selected to meet the objectives outlined in the workplan.

The following design scenarios were developed for both single-port and multi-port discharge structures:

Scenario 1: Maximum Daily Effluent Flow, 7Q20 Summer Ambient Flow
Scenario 2: Maximum Monthly Average Effluent Flow, 7Q20 Summer Ambient Flow
Scenario 3: Maximum Daily Effluent Flow, 7Q20 Winter Ambient Flow
Scenario 4: Maximum Monthly Average Effluent Flow, 7Q20 Winter Ambient Flow

Scenarios 1 and 3 were developed to evaluate attainment of acute water quality standards and scenarios 2 and 4 were developed to evaluate attainment of chronic water quality standards.

The basis for selecting the model scenarios is described in the following section.

2. MODEL INPUTS

The effluent, receiving water, and discharge structure must be qualitatively and quantitatively described, in order to estimate the dilution and trajectory of near-field discharges from the Spokane County Regional Plant outfall. Necessary model inputs are identified and described in the following sections.

2.1 DESCRIPTION OF PROPOSED DISCHARGE

The design of the discharge structure is important because it not only determines the location of the discharge with respect to receiving water boundaries (e.g. channel bottom), but the size of the discharge opening governs the momentum of the discharge for a given flowrate. In the absence of an existing outfall structure, three basic discharge structure configurations/locations were evaluated. These correspond to a single-port bank outfall, a single-port mid-channel outfall, and multi-port mid-channel diffuser. Each is described below.

2.1.1 Single-Port Bank Outfall

The first discharge configuration/location evaluated corresponded to a near-bank, single port outfall. Several parameters were considered in determining the configuration for the single-port outfall. Port diameter, outfall orientation, and outfall position all affect the dilution and trajectory of the discharge plume. Port diameters were selected based on velocity criteria. The target design discharge velocity of the single-port outfall was selected as 10 feet per second (fps), based on the following guidelines:

- Discharge velocities in excess of 10 fps should be avoided, to prevent erosion or interference with boat navigation (Metcalf & Eddy, 1991).

- Discharge velocities of 10 fps or greater are useful in reducing the risk of exposure of aquatic organisms to acutely toxic conditions (USEPA, 1991a).

For the single-port outfall, 12-, 18-, 24-, and 36-inch port diameters were evaluated with the model. The outfall was also modeled at three different horizontal orientations (perpendicular to ambient flow and angled 30 and 60 degrees in the direction of river current).

The single-port bank outfall alternatives were rejected as providing insufficient dilution, due to the shallow water depths in the vicinity of the shore.

2.1.2 Single-Port Mid-Channel Outfall

The second discharge configuration/location evaluated also corresponded to a single port outfall, but located in the deeper center portion of the stream channel. 18-, 24-, 27-, 30-, and 36-inch port diameters were evaluated with the model. The outfall was

also modeled at different horizontal orientations ranging from perpendicular to ambient flow to coflowing.

Based on these design variations, a preferred single-port outfall configuration was selected, involving a single 30-inche diameter discharge pipe positioned so that its opening lies approximately 1.5 feet above the channel bottom and is located approximately mid-channel at a distance of 174 feet from the left (south) channel bank. The outfall pipe is horizontal and is oriented downstream 25-degrees in the direction of the river current.

2.1.3 Multi-Port Mid-Channel Diffuser

Several parameters were also considered in determining the preferred configuration for the multi-port diffuser. Diffuser length, number of ports, and port diameter are important parameters to be evaluated for a multi-port diffuser. The effluent velocity guidelines for sizing the single port outfall diameters also apply to port diameters for multi-port diffusers. In addition, because multi-port diffusers are often buried in the channel bottom, the following criteria applies:

- Discharge velocities greater than 1.6 fps are recommended to prevent sediment accumulation in the ports (USEPA, 1991b).

From the above criterion, the discharge velocity range for the multi-port diffuser was specified as 1.6 fps and 10 fps.

The multi-port diffuser design configuration consists of a round pipe laid on the bottom of the river, with ten evenly spaced ports on top. The ports point straight upward, extending approximately one foot above the channel bed, and are oriented perpendicular to the ambient current. Each port has a diameter of eight inches. Two diffuser lengths (50 and 75 feet) were evaluated with a total of either 8 or 10 ports evenly spaced on the diffuser. The ports were configured to discharge horizontally in the direction of river flow or at a 30-degree angle from horizontal.

The multi-port mid-channel alternatives were rejected as providing insufficient dilution.

2.2 RECEIVING WATER CHARACTERISTICS

The receiving water characteristics necessary for this mixing zone assessment in the Spokane River include channel geometry, ambient velocity and ambient temperature. These characteristics are discussed below.

2.2.1 Channel Geometry

For purposes of estimating effluent mixing, the geometry of the receiving water channel is significant for several reasons. First, the relative proximity of the discharge structure to the banks or bottom of the channel may determine whether dilution of the

effluent plume is affected by impingement on these boundaries. Second, the depth of the channel at and downstream from the point of discharge will limit the vertical space available for buoyant rise of effluent plumes. Third, the channel cross-sectional area is necessary for calculating ambient velocity from flow data.

Channel cross-section data collected by David Evans and Associates, Inc. in March 2003 was used to define channel geometry for this study. Cross-sections at six locations in the vicinity of the proposed discharge were provided. From these, the cross-section that most typically represented the six locations was selected. A representation of the channel cross-section is shown in Figure 2. Channel roughness was defined using a value of 0.03 for the Manning's 'n' coefficient based on a QUAL-2e model for the Spokane River developed by Pelletier (Pelletier, 1997).

2.2.2 Ambient Velocity

Magnitude and direction of the receiving water velocity, relative to the effluent discharge, are important factors in determining the behavior of the effluent discharge. For this study, an average ambient velocity was determined by dividing the design flow rates by the cross-sectional area of the Spokane River at the discharge outfall. The velocities were calculated to be 0.30 fps and 0.51 fps for the 7Q20 summer and winter flows, respectively.

The proposed discharge site is located between the Hamilton and Trent Street Bridges on the Spokane River, downstream of the Upriver Dam and upstream of the USGS gaging station below Spokane Falls (USGS gage no. 12422500), as shown in Figure 3. Seasonal 7Q20 river flows for the proposed discharge site were determined from the interpolation between the seasonal 7Q20 flows presented by Pelletier for the Upriver Dam and the Spokane gage, as conducted in the LTI (2002) mixing zone assessment. This interpolation yielded 7Q20 values of 593 cubic feet per second (cfs) for summer and 1047 cfs for winter (Pelletier, 1997).

River stages for the 7Q20 flows were estimated at the proposed point of discharge by interpolation between known river stages at upstream and downstream locations. Upstream stage was estimated using a rating curve for a gage at Greene Street (former USGS gage no. 12422000; currently maintained by Spokane Community College), located approximately 1.7 miles upstream of the proposed discharge. The rating curve was developed using daily flow and water surface elevation data for the years 1999 to 2001, as provided by the County of Spokane. The downstream stage was estimated using standing pool elevation at Upper Falls Dam (Figure 4), located approximately 3.3 miles downstream of the discharge. The interpolated water surface elevations were calculated to be 1870.9 and 1871.1 ft (NAVD 88 datum), corresponding to stages of 11.5 and 11.7 ft for summer and winter 7Q20 flows, respectively. A schematic representation of the channel cross-section, including water elevation at the summer and winter 7Q20 flows is provided in Figure 5.

2.2.3 Ambient Temperature

Buoyancy effects caused by density differences between the effluent and the receiving water can be an important factor in near-field dilution of municipal wastewater discharges to rivers. Any differences in density between the Spokane County Regional Plant effluent and the Spokane River were assumed to be wholly due to temperature differences. In accordance with the Ecology guidance, the 90th percentile temperature values were calculated for both the summer and winter seasons using data from stations at Mission Street Bridge, Spokane City Dam, Greene Street Bridge, and Stateline Bridge. The 90th percentile temperatures for the Spokane River during summer and winter are 17.9 ^{o}C and 8.4 ^{o}C, respectively.

2.3 EFFLUENT CHARACTERISTICS

The effluent temperature and discharge velocity, relative to ambient conditions, are of primary importance in determining near-field trajectory and mixing. In addition, analysis of water quality standards attainment requires quantification of effluent quality. The characterization of these input parameters is the following sections.

2.3.1 Discharge Velocity

Effluent flowrate is significant both in comparison to receiving water flowrate and for establishing effluent momentum. In accordance to Ecology's *Guidance for Conducting Mixing Zone Analyses* (Ecology, 2001, Appendix VI), maximum daily flow was used for calculation of acute dilution and maximum monthly average flow was used for chronic dilution. In lieu of an operating history for the Spokane County facility, the expected maximum daily flow and maximum monthly average flow were used. This effluent does not contradict Ecology guidance and provides a reasonable extreme flow with which to evaluate attainment of water quality standards. A value of 21.4 MGD (33.1 cfs) was used for the acute dilution calculation and a value of 15.6 MGD (24.1 cfs) was used for the chronic dilution calculation.

Discharge velocities were calculated for the two design flows by dividing the design flowrate by the open port area of the discharge structure. For the single port design, the discharge velocities for a 30-inch diameter port corresponding to the maximum daily and maximum monthly average are 6.8 fps and 4.9 fps, respectively.

2.3.2 Effluent Temperature

Effluent temperature, relative to ambient receiving water temperature, is important in determining the relative buoyancy of the effluent and in evaluating attainment of receiving water temperature standards. As a surrogate for the proposed Spokane County facility, LTI analyzed a full year of daily effluent temperature data from the Spokane Advanced Wastewater Treatment Plant (SAWTP) for this study. The temperature data evaluated did exhibit seasonality, so the dataset was divided by

season and a 90th percentile high effluent temperature was calculated for each season. The 90th percentile temperatures for summer and winter are 21 ^{o}C and 17 ^{o}C, respectively.

3. MODEL SELECTION

The CORMIX mixing zone model was used in this study for the following reasons:

- CORMIX is one of the three mixing zone models currently supported by the USEPA.
- CORMIX is accepted by Ecology under appropriate circumstances, as indicated in Ecology guidance (Ecology, 2001).
- CORMIX has the capability to consider boundary constraints and effects.
- It is not necessary to incorporate tidal or stratification effects, which might require use of a different model.

Model selection for this study was also based on the objectives of the study, the availability and quality of input data, and the specific conditions of the discharge being modeled. The general approach used in evaluating effluent dilution included the following components:

- Defining input parameters representative of receiving water conditions, effluent conditions, and discharge structure;
- Reviewing applicability of selected model (CORMIX) based on these conditions;
- Making simplifying assumptions, as necessary;
- Conducting model runs;
- Comparing predicted plume geometry and dilution to mixing zone size and volumetric restrictions and estimated constituent concentrations and temperature at the mixing zone boundaries to the acute and chronic water quality criteria.

4. DILUTION MODELING RESULTS

As described in the previous sections of this report, dilution of the proposed Spokane County Regional Plant effluent in the Spokane River was predicted using the model CORMIX. Dilution was evaluated under two ambient flow conditions (summer and winter 7Q20 flows), two effluent flow conditions (maximum daily and maximum monthly average flows) and two temperature conditions (summer and winter seasons). Model inputs specific to each scenario are provided in Table 1. CORMIX model prediction files for each scenario are provided in the appendix. The following model results are given in Table 2:

- Distance to Maximum Allowable Dilution at Chronic Mixing Zone Boundary
- Maximum Allowable Dilution at Chronic Mixing Zone Boundary
- Distance to 10% of the Chronic Mixing Zone Boundary based on Maximum Allowable Chronic Dilution
- Centerline Dilution at 10% of the Chronic Mixing Zone Boundary based on Maximum Allowable Chronic Dilution
- Distance to Maximum Allowable Dilution at Acute Mixing Zone
- Maximum Allowable Dilution at Acute Mixing Zone
- Distance to 10x the Acute Mixing Zone Boundary based on Maximum Allowable Acute Dilution
- Centerline Dilution at 10x the Acute Mixing Zone Boundary based on Maximum Allowable Acute Dilution

In the absence of a pre-specified ZID or CMZ, the spatial extent of the mixing zones was determined based on the modeling conducted in this study.

4.1 DETERMINATION OF MIXING ZONE SIZE

As discussed in Section 1.3 of this report, Washington water quality regulations impose the following restrictions on the size of mixing zones:

- The downstream extent of the chronic mixing zone (CMZ) shall not exceed 300 feet plus the depth of water over the discharge port and the upstream extent shall not exceed 100 feet.

- The chronic mixing zone shall not utilize more than 25% of the flow of the river.

- The acute mixing zone shall not utilize more than 2.5% of the flow of the river.

- The acute mixing zone shall not extend more than 10% of the distance to the boundary of the chronic (regulatory) mixing zone.

- Neither the chronic nor the acute mixing zones shall occupy more than 25% of the width of the river.

The more restrictive of these limitations will govern the possible size of the chronic mixing zone. In the scenarios evaluated for this study, calculated dilution values at

the end of near-field mixing were all greater than the maximum allowable dilution based on the 25% flow limitation. Therefore, the approach taken to evaluate attainment of water quality standards within mixing zone restrictions was as follows:

1) Locate the downstream point where model predicted dilution is equal to the maximum allowable chronic dilution value (i.e., the dilution utilizing 25% of river flow).
2) Evaluate attainment of acute criteria at a point equal to 10% of this downstream distance. If acute criteria are met, this is the acute mixing zone boundary, and the chronic mixing zone boundary is defined by 1 above. If acute criteria are not met, proceed to 3 below.
3) If acute criteria are not met based on distance defined in 2 above, locate downstream point where model predicted dilution is equal to the maximum allowable acute dilution.
4) Evaluate attainment of chronic criteria at point equal to 10 times the distance identified in 3 above. If chronic criteria are met, this is the chronic mixing zone boundary, and the acute mixing zone boundary is defined by 3 above.

If the plume width at the chronic mixing zone boundaries determined in 1 or 3 above is greater than 25% of the channel width (80 feet in this case), the steps to determine the mixing zone boundaries are as follows:

5) Locate the downstream point where the model predicted plume width is equal to the maximum allowable plume width (i.e., plume width less than 25% of the channel width). Evaluate attainment of chronic criteria.
6) Evaluate attainment of acute criteria at a point equal to 10% of the downstream distance determined in step 5. If acute criteria are met, this is the acute mixing zone boundary, and the chronic mixing zone boundary is defined by 5 above.

Maximum possible acute and chronic dilutions were calculated on a volumetric basis for both summer and winter seasons to evaluate attainment of acute and chronic water quality standards. Utilizing no more than 25% of the flow of the river, summer and winter maximum chronic dilutions were determined to be 7.2 and 12, respectively. Utilizing no more than 2.5% of the flow of the river, summer and winter maximum acute dilutions were determined to be 1.4 and 1.8, respectively.

4.2 SINGLE-PORT BANK DISCHARGE

All of the single-port bank discharge scenarios resulted in insufficient dilution to meet water quality standards, due to the shallow water depth in the vicinity of the stream bank.

4.3 SINGLE-PORT MID-CHANNEL OUTFALL

Based on the model predictions and the steps outline in Section 4.1, mixing zones for the single port discharge were determined as follows:

- For the summer season, the chronic mixing zone boundary was defined based on maximum allowable dilution and is located approximately 40 feet downstream from the discharge. The corresponding acute mixing zone boundary is 4.0 feet downstream from the discharge. The dilution values at these boundaries are predicted to be 7.2 for chronic exposure and 1.1 for acute exposure. The width of the plume at the chronic mixing zone boundary is 13 feet.

- For the winter season, the chronic mixing zone boundary was determined as 10 times the distance where maximum allowable dilution was achieved in acute conditions. The chronic mixing zone boundary for the winter season is approximately 88 downstream of the discharge, and the acute mixing zone boundary is 8.8 feet downstream of the discharge. The dilution values at those boundaries are predicted to be 9.6 for chronic exposure and 1.8 for acute exposure. The width of the plume at the chronic mixing zone boundary is 26 feet.

Table 3 provides a summary of the resulting mixing zone boundaries and predicted dilutions. Plan view, profile, and dilution values as a function of downstream distance for the chronic mixing zone is shown in Figure 6. Figure 7 displays plan view, profile, and dilution values for the acute mixing zone.

For both seasons, the spatial extent of the chronic and acute mixing zone boundaries established by the CORMIX model predictions for the single-port mid-channel outfall meet the regulatory size restrictions. The downstream extent of the predicted chronic mixing zone does not exceed 300 feet and the downstream extent of the predicted acute mixing zone does not extend beyond 10% of the distance towards the downstream chronic mixing zone boundary. The width of the mixing zone does not exceed 25% of the channel width (approximately 80 feet).

Using the approach outlined in Section 4.1, predicted dilution values implicitly fall within the range of allowable values based on ambient flow percentages.

4.4 MULTI-PORT MID-CHANNEL DIFFUSER

All of the evaluated multi-port mid-channel diffuser scenarios resulted in insufficient dilution to meet water quality standards.

5. CALCULATION OF REQUIRED DILUTION

The required dilution for each toxic constituent was estimated by comparing a maximum probable effluent concentration for each constituent to the respective water quality criterion, taking into account the background concentration in the river. The methodology and results are described below.

5.1 AMBIENT WATER QUALITY

The ambient water quality parameters considered in this study were temperature, ammonia, and toxic metals including arsenic, chromium, copper, mercury, nickel, and silver. Ambient water concentrations for arsenic, copper, mercury, silver, and ammonia were obtained from the Spokane AWTP discharge permit fact sheet. Chromium, nickel, and temperature data were obtained from the U.S. EPA STORET and Ecology databases. Temperature data were obtained from Spokane City Dam station, Mission Street Bridge station, the Greene Street Bridge, and the Stateline Bridge station. The stations used to obtain data are shown in Figure 3. The temperature data set for the four stations consists of 2,038 measurements between the years 1970 and 1999. A summary of the ambient temperature dataset used in this analysis is provided in Table 4.

The data for chromium were selected from the following stations located along the Spokane River: Mission Street Bridge, Spokane City Dam, Boat Launch at Sekani, Stateline Bridge. The chromium dataset for the four stations consists of 71 measurements between the years 1972-1973 and 1994-1999. Nickel data were available only at the Stateline Bridge station. There were 39 measurements at this station for the years 1994-1999. These stations are located in Figure 3. Total concentration values were used in this study as opposed to dissolved concentrations to conform to the approach prescribed by Ecology. Table 4 presents the 90th percentile ambient concentrations for the Spokane River.

5.2 EFFLUENT QUALITY

Mixing zone guidance from the State of Washington (Ecology, 2001, Chapter VI) recommends calculation of the maximum expected effluent concentration in accordance with USEPA guidance (USEPA, 1991a) for use in mixing zone studies, using the 95th percentile exceedance value for all parameters. Because the Spokane County Regional Plant does not yet exist, no effluent data are available. Data from the Spokane City AWTP were therefore used as a surrogate. Temperature, arsenic, copper, mercury, and silver data were provided to LTI in spreadsheet form by HDR. The arsenic, copper, mercury and silver data represent the results of low-level metals analyses collected between May 2000 and July 2002. Chromium and nickel data were taken from a report by CH2M-Hill (CH2M-Hill, 1997). Analysis of the data indicated that temperature exhibited seasonal variation. No seasonal trend was observed in any

metals data, therefore it was assumed that metals would not vary seasonally. The calculated 95th percentile maximum probable effluent concentrations are presented in Table 5.

The Spokane AWTP data were not used to specify the probable effluent concentration for ammonia, because it is expected that the Spokane County WWTP will have to perform nitrification in the summer to meet receiving water dissolved oxygen standards, but that nitrification will not be necessary in the winter. Therefore, treatment plant designers expect maximum ammonia concentrations to be approximately 3.0 mg/L in the summer and approximately 20 mg/L in the winter. These values are also included in Table 5.

5.3 WATER QUALITY STANDARDS

Water quality criteria were taken from Washington Water Quality Standards for Surface Waters of the State of Washington (WAC 173-201A). The following standards are specified for temperature in the Lower Spokane River (river miles 58.0 to 96.5):

- Temperature shall not exceed a one-day maximum of 20.0°C due to human activities.
- When natural conditions exceed a one-day maximum of 20.0°C, no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3°C; nor shall such temperature increases, at any time exceed t=34/(T+9).

Temperature criteria were evaluated based on predicted dilution as shown in Table 6. The point of compliance for temperature criteria is specified in the Water Quality Standards (WAC 173-201A-200 (1)(c)(ii)(A)) as the edge of a mixing zone boundary, so it is assumed that the temperature criteria must be met at the chronic mixing zone boundary.

The water quality standards specify the method of calculating chronic fresh water criteria for ammonia in the unionized form as a function of pH and temperature. For this analysis, blended ambient and effluent pH and temperature were used to calculate applicable ammonia criteria. Criteria were converted to total ammonia using standard equations (Chapra, 1997). Ambient pH data for 10 stations on the Spokane River in the vicinity of Spokane were evaluated. The data did not exhibit strong seasonal variation. A 90th percentile ambient pH value of 7.8 was calculated (Table 4). The maximum probable effluent pH of 7.4 was used (Table 5). Ambient temperatures used to calculate ammonia water quality criteria for summer and winter were 17.9^{o}C and 8.4^{o}C (Table 4), respectively. Effluent temperatures used in the calculations for summer and winter were 21°C and 17°C (Table 5), respectively. Ammonia criteria are also dependent on the presence of absence of salmonids. Based on the designated uses of the reach of the Lower Spokane River (river miles 58.0 to 96.5) corresponding to the proposed Spokane County Regional Plant outfall location, criteria were calculated for the presence of salmonids.

Criteria for copper, nickel, and silver are hardness-dependent. These criteria were calculated using a blended hardness determined from summer and winter ambient hardness values and an effluent hardness value developed by Ecology for the Spokane AWTP (145 mg/l as CaCO3). Ambient summer and winter hardness values of 95 and 74 mg/L as $CaCO_3$, respectively, were calculated from the flow-based regression developed by CH2M-Hill (CH2M-Hill, 1997): Hardness = 1518 $Q^{-0.4346}$. Table 6 presents both the acute and chronic water quality standards for the Spokane River near the discharge location.

5.4 DILUTION REQUIRED TO MEET ACUTE CRITERIA

Dilution required to meet acute water quality criteria were calculated as the ratio of the differences between each acute water quality criterion and the respective effluent concentration, and the ambient concentration and the criterion for each constituent:

$$S = (C_e - C_a)/(C_{wqs} - C_a)$$

Where:

S = dilution required

C_e = effluent concentration

C_a = ambient concentration

C_{wqs} = water quality standard

Table 6 presents the effluent dilution required to meet acute water quality criteria in the Spokane River. No dilution is necessary to meet acute water quality criteria for the parameters considered in this study, with the exceptions of ammonia and silver. Ammonia is expected to require a dilution factor of approximately 1.7 to attain the acute criterion in winter. No dilution is necessary to attain the acute summer criterion. To attain silver standards, dilution values of 4.7 and 4.8 in the summer and winter seasons, respectively, are needed.

A comparison of predicted mixed concentrations at the acute mixing zone boundary to corresponding acute criteria is provided in Table 7. Based on model predictions for the design scenarios, all acute water quality criteria are likely to be met, with the exception of silver. However, the effluent data set for silver contains an apparent outlier, which skews the maximum probable concentration upward. Without this apparent data outlier, it is likely that the acute criteria for silver will be easily met and no dilution will be necessary to achieve the acute silver criterion. This is discussed in more detail in Section 5.6.

5.5 DILUTION REQUIRED TO MEET CHRONIC CRITERIA

Dilution required to meet water quality criteria were calculated using the same equation presented in the previous section, substituting chronic criteria for acute criteria. Table 6 presents the results of these calculations. A comparison of predicted mixed concentrations at the chronic mixing zone boundary to corresponding chronic criteria is provided in Table 7.

These results indicate that no dilution is required to attain chronic water quality criteria, except for ammonia and mercury. To attain ammonia standards, a dilution value of 1.7 is needed in the summer and 9.3 is needed in the winter. To attain chronic mercury standards, dilution values of 32 and 36 are needed in the summer and winter, respectively.

Based on these results, attainment of chronic water quality criteria for all constituents is expected, with the exception of mercury, for which the required dilution exceeds the predicted dilution. However, the effluent data set for mercury contains two apparent outliers, which skew the maximum probable concentration upward. Without these apparent data outliers, it is likely that the chronic criteria for mercury will easily be met with lower required dilution values of 2.3 for summer and 2.5 for winter. This is discussed in more detail in Section 5.6.

Temperature results in Table 6 indicate that the proposed discharge is not expected to increase the receiving water temperature above 20°C at the edge of the chronic mixing zone boundary in summer or winter.

5.6 PROBABLE ATTAINMENT OF MERCURY AND SILVER CRITERA

As described in the preceding sections, the attainment analysis conducted using the Spokane AWTP effluent data indicates that the chronic criterion for mercury and the acute criterion for silver may not be attained through available mixing zone dilution. However, visual inspection of the mercury and silver data for the Spokane AWTP shows some anomalously high values for mercury and silver in the early part of the data set. The effluent data for mercury are graphically presented in Figure 8, and Figure 9 shows the time series of silver in the plant's effluent.

Two anomalously high data points are evident in the mercury data (0.13 ug/L on February 7, 2000 and 0.424 ug/L on February 21, 2000). Because these data points are drastically different than the rest of the data, they bear further examination. The coefficient of variation (CV), calculated as the standard deviation divided by the mean, is a common screening test for identification of data outliers; a CV greater than one generally indicates the presence of outliers in a dataset. The CV for the entire mercury time series is 3.01, while the CV for the time series without the two anomalously high data points is 0.43. This result indicates that the two data points in question are outliers and that they may upwardly bias the expected effluent concentration. It should be noted that if the two mercury outliers are eliminated from the calculation of the expected effluent concentration, effluent dilution values of 2.3

and 2.5 are required to meet the chronic mercury criterion for summer and winter, respectively. These values are within the range of available dilution, so the chronic criteria for mercury would likely be attained at the edge of the mixing zone.

Similarly, one anomalously high data point is evident in the silver data (16.58 ug/L on March 20, 2000). The coefficient of variation (CV) for the entire silver time series is 3.09, while the CV for the time series without the outlier is 0.71. For comparison, effluent datasets for arsenic and copper over the same time period used in the attainment analysis have CVs of 0.44 and 0.28, respectively. If the identified outlier is eliminated from the calculation of the expected effluent concentration, no dilution is required to meet the acute silver criterion for both seasons.

6. CONCLUSIONS

Based on results of this study as described in the preceding sections, the following conclusions can be made with respect to the Spokane County Regional Plant proposed discharge as a single-port outfall to the Spokane River:

- Under critical summer and winter receiving water conditions, attainment of acute and chronic water quality criteria is predicted within the mixing zone for all constituents except mercury and silver. However, anomalously high data values exist in the datasets used to calculate expected effluent concentrations for these constituents. If these apparent outliers are removed from the data sets, silver and mercury are predicted to attain water quality standards within the mixing zone.

- Ammonia is the most critical constituent with respect to attainment of acute water quality criteria in winter, in that it is the only constituent expected to require dilution (in winter only) to meet the criteria. No dilution is required to attain the acute criterion in summer.

- Ammonia and mercury are the critical constituents with respect to attainment of chronic water quality criteria in both summer and winter, in that they are the only constituents requiring dilution to meet their criteria.

- Dilution sufficient to attain acute and chronic water quality criteria in both summer and winter for the parameters evaluated in this study is expected to be achieved with a single-port outfall located mid-channel. The 30-inch horizontal outfall would be oriented 25 degrees downstream in the direction of the river current.

7. REFERENCES

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FIGURES

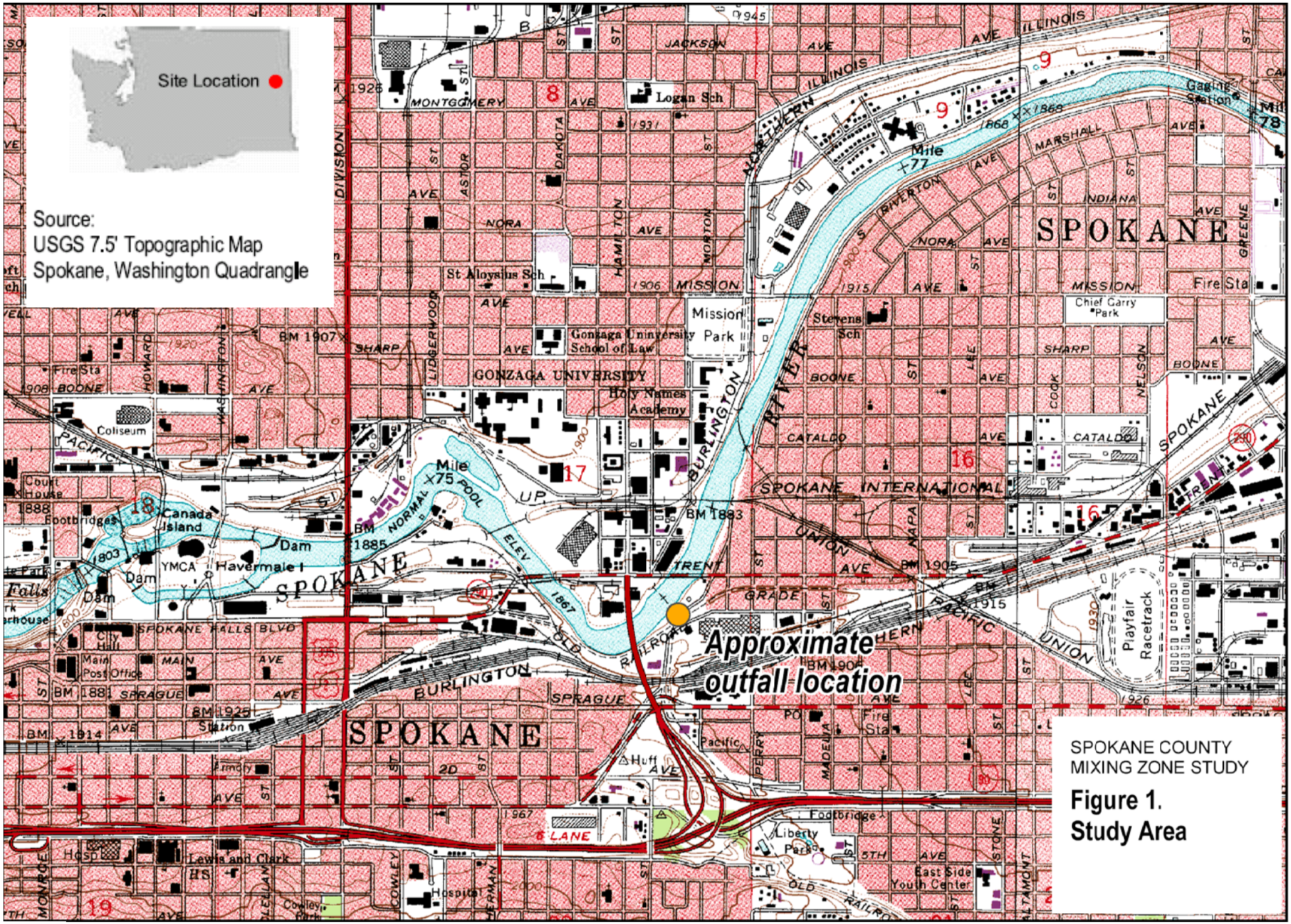
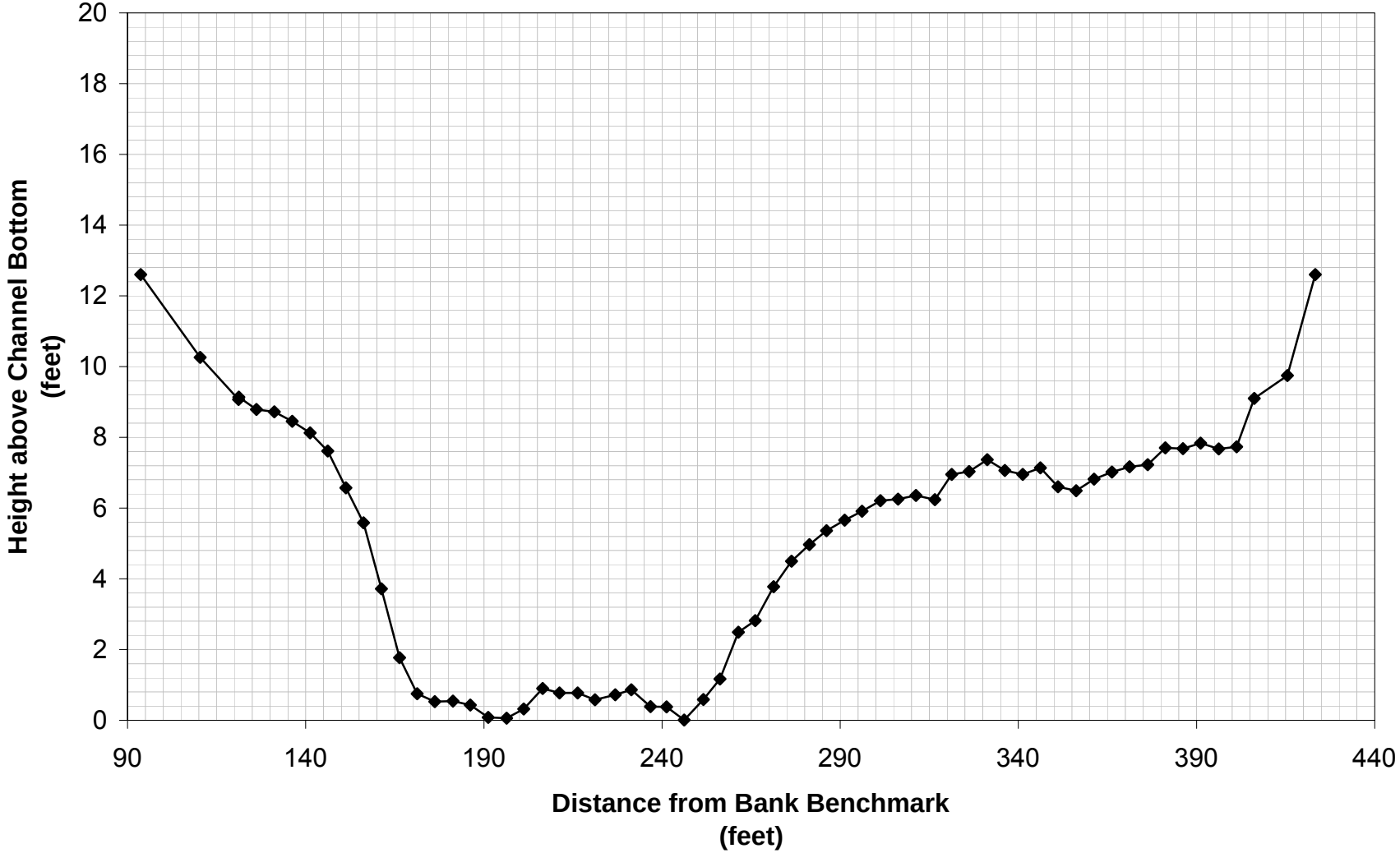

Site Location
Source:
USGS 7.5' Topographic Map
Spokane, Washington Quadrangle
Approximate outfall location
SPOKANE
SPOKANE COUNTY
MIXING ZONE STUDY
Figure 1.
Study Area

Figure 2: Cross-Section of Spokane River near Hamilton Street (looking upstream)



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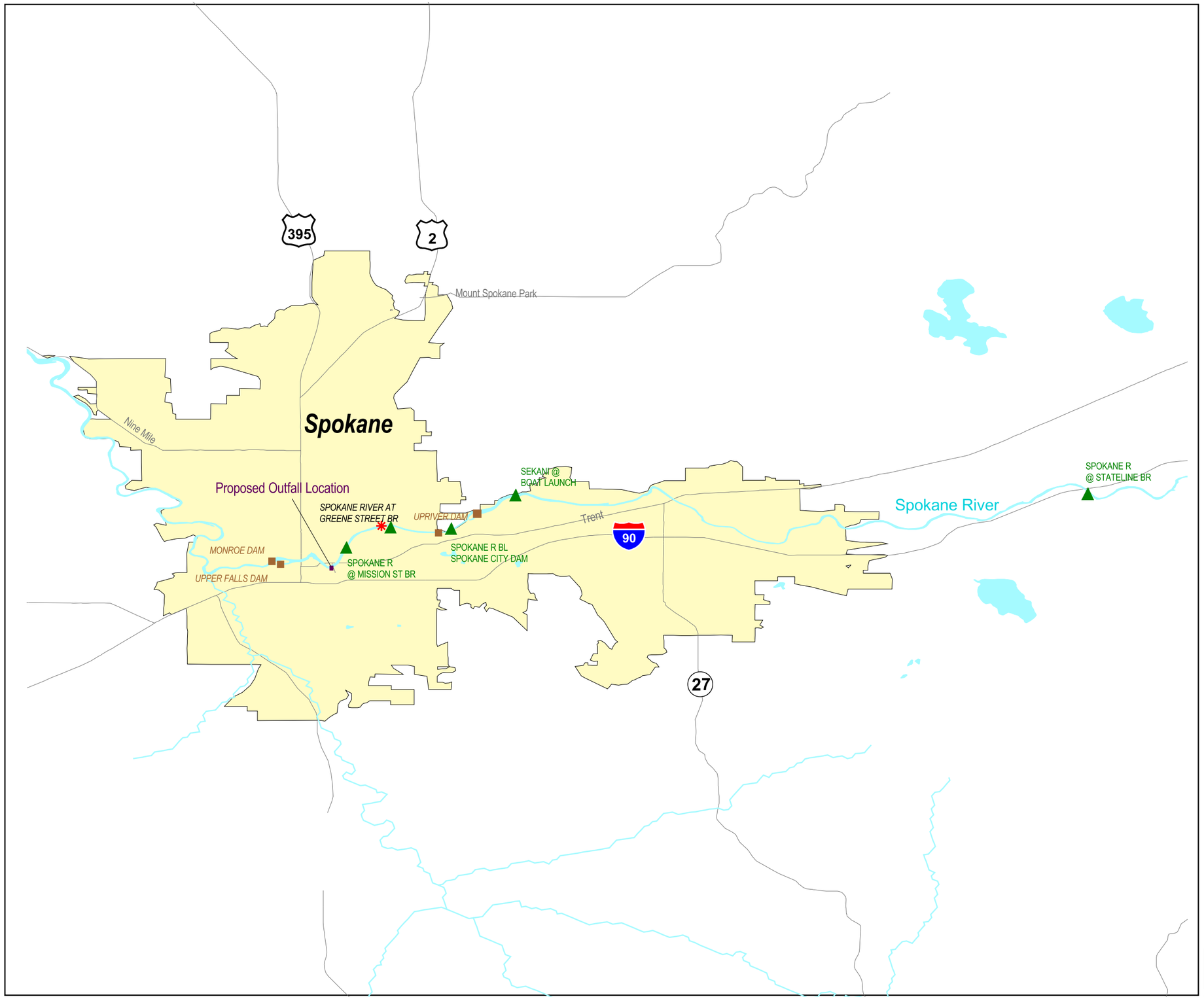


N

2 0 2 4 6 Miles

Legend

- Sampling Station
- Flow Gage
- Dam
- Water body
- Spokane

Figure 3
Flow Gage and
Sampling Station Locations

Spokane County Mixing Zone Study

LTI - Limno-Tech, Inc.
Excellence in Environmental Solutions Since 1975
501 Avis Drive. Ann Arbor, MI 48108

Figure 4: Rating Curve for Spokane River at Green Street Gage (1999-2001)

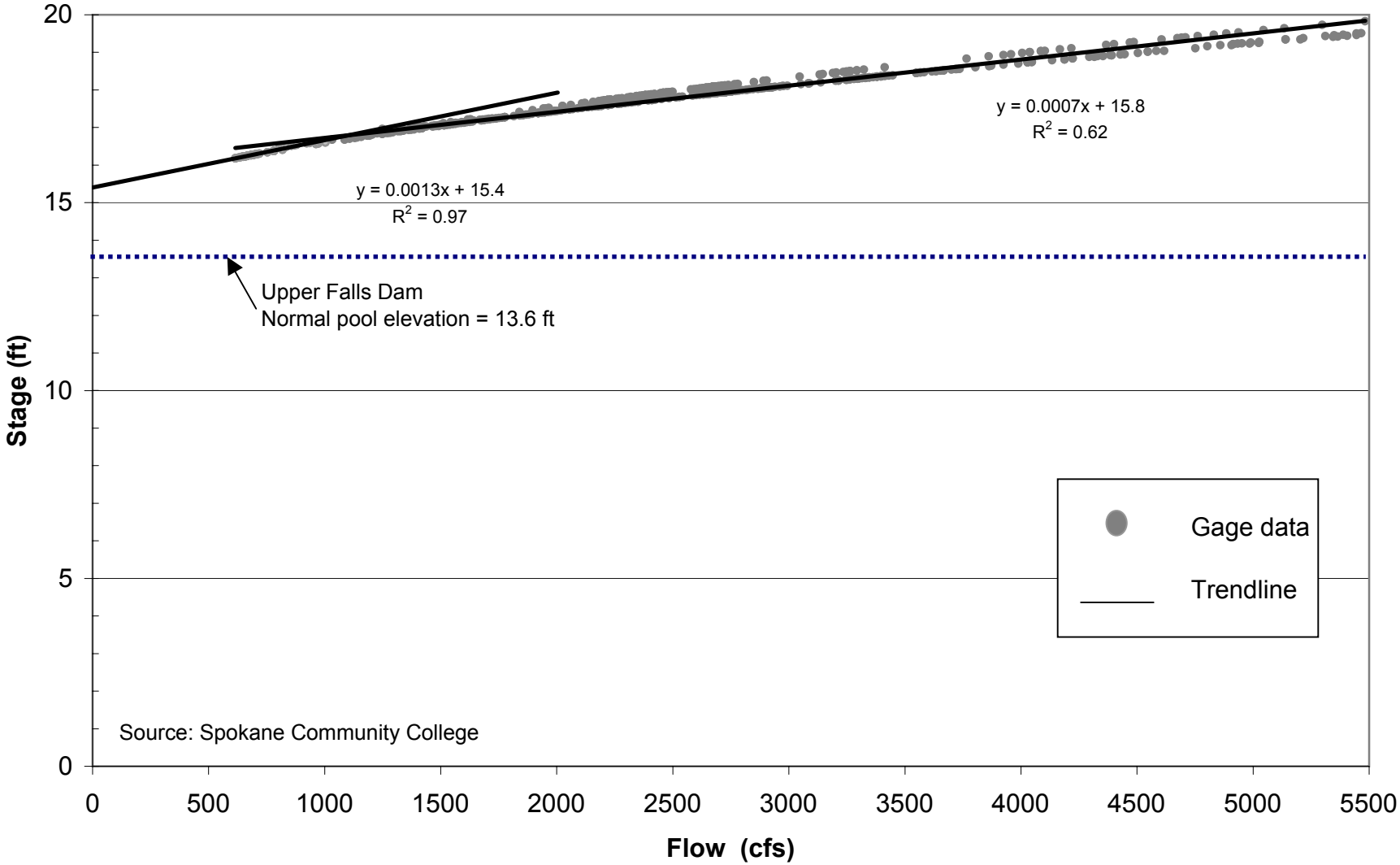
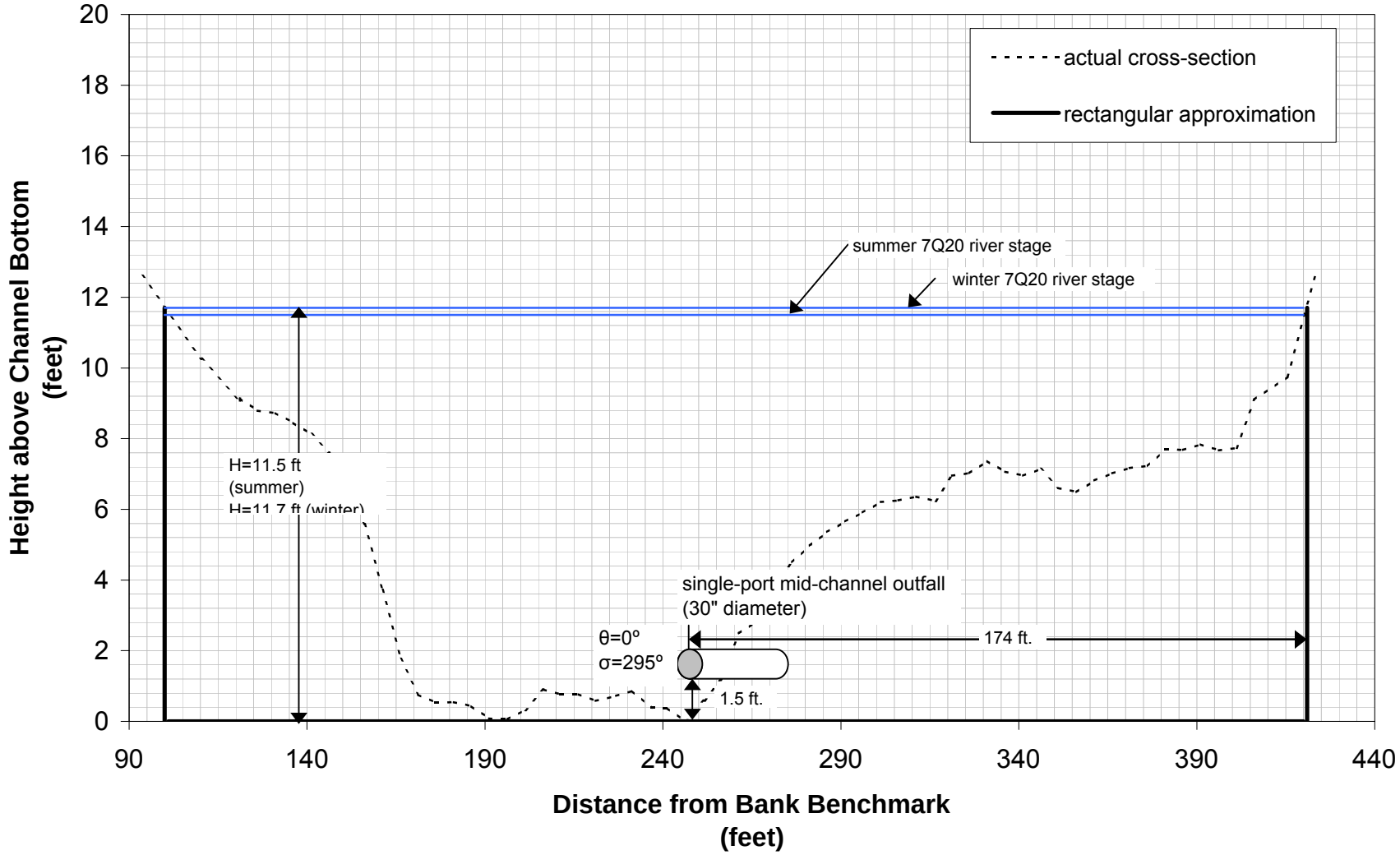
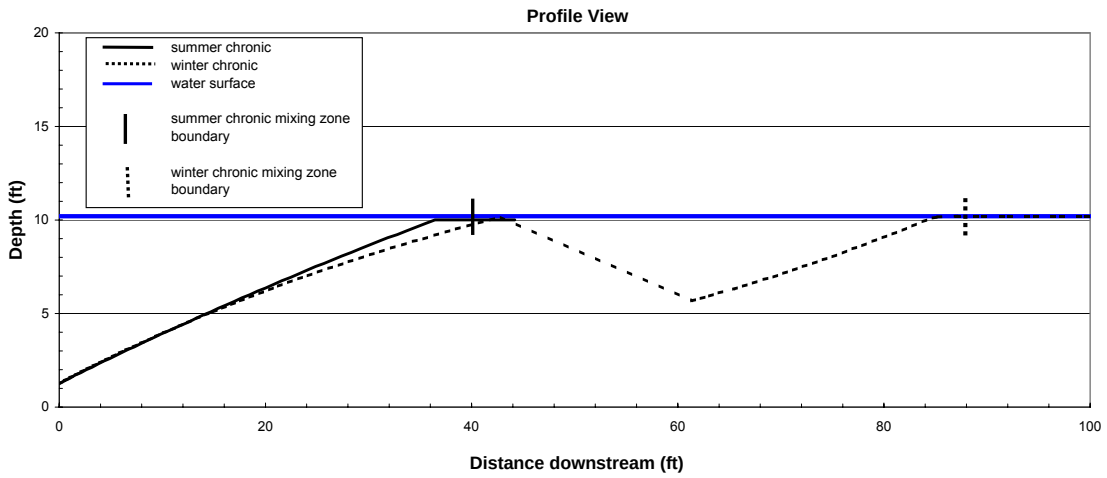


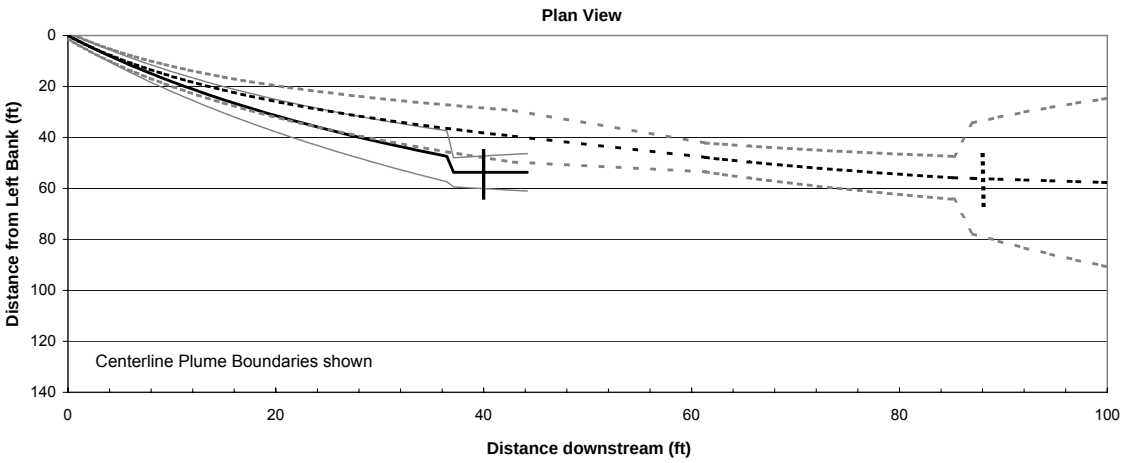
Figure 5: Schematized Cross-Section of Spokane River near Hamilton Street (looking upstream)



Limno-Tech, Inc.

Figure 6: Centerline Trajectory and Dilution for Chronic Mixing Zone - Single-Port, Mid-Channel Discharge
Spokane County Proposed Discharge





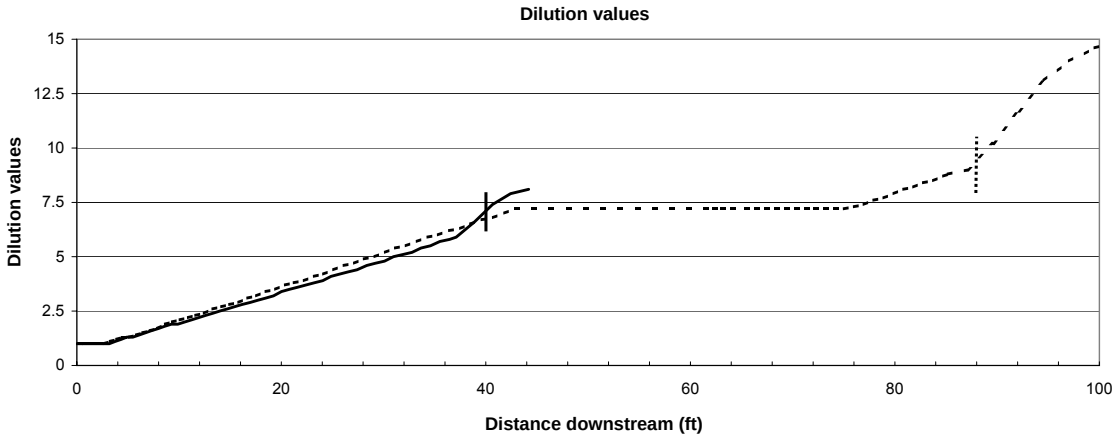
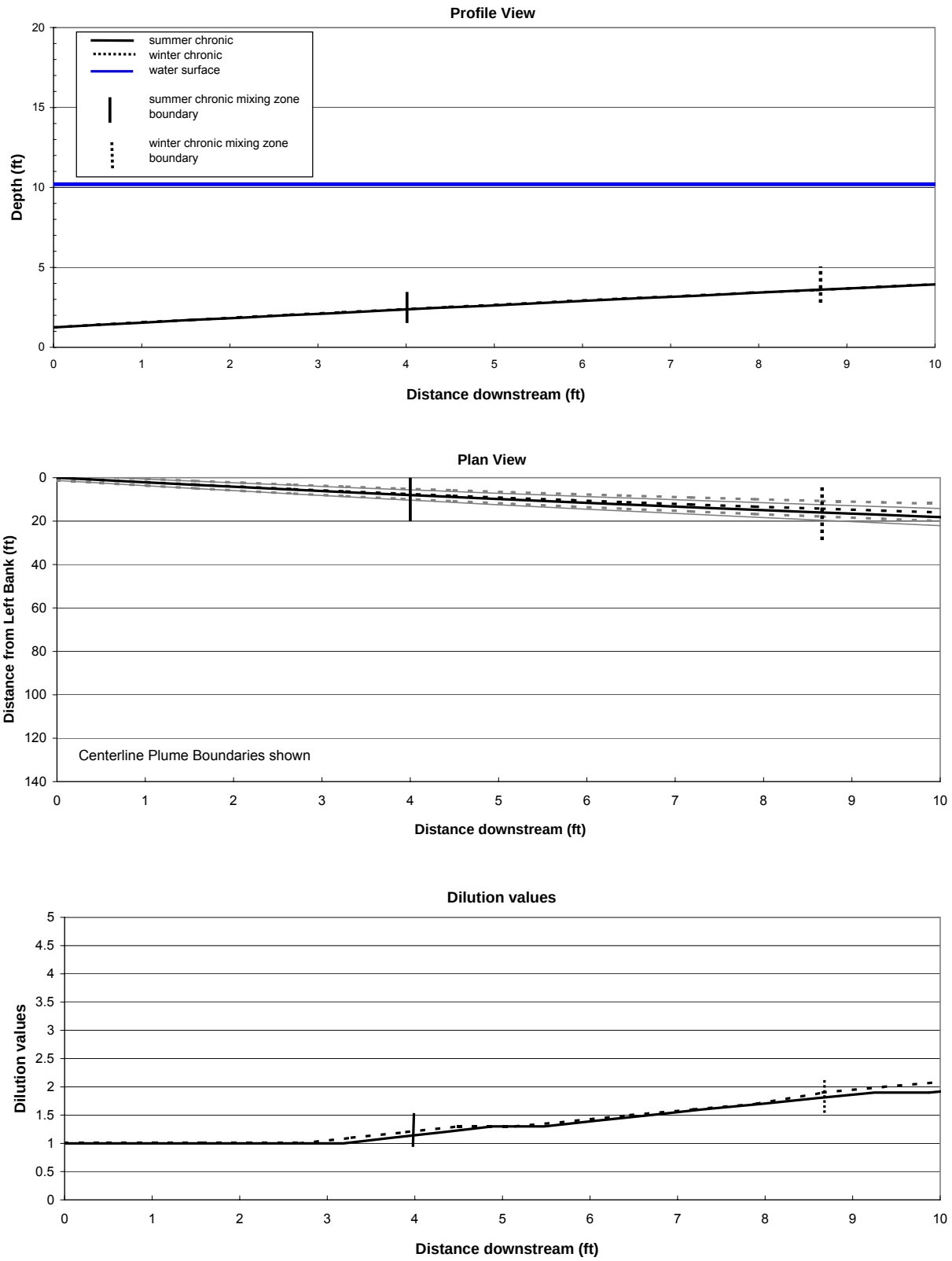


Figure 7: Centerline Trajectory and Dilution for Acute Mixing Zone - Single-Port, Mid-Channel Discharge
Spokane County Proposed Discharge



TABLES

Table 1: Model Inputs

Spokane County Proposed Discharge

			Receiving Water Conditions								Discharge Structure Configuration						Effluent Conditions	
Description	Scenario Number	File	water depth maximum (ft)	water depth average (ft)	depth of discharge calculated (ft)	ambient velocity (ft/s)	bounded width (ft)	Manning's "n"	wind speed (ft/s)	ambient temperature (°C)	discharge structure configuration	port diameter (ft)	horizontal angle* (degrees)	vertical angle	nearest bank	port height above bottom (ft)	effluent flow (MGD)	effluent temperature (°C)
Single-Port Mid-Channel Design Scenarios																		
Summer	Scenario 1	summer_acute	11.5	6.6	10	0.300	320	0.03	2	17.9	single port	2.5	295	0	right	1.5	21.4	21
	Scenario 2	summer_chronic	11.5	6.6	10	0.300	320	0.03	2	17.9	single port	2.5	295	0	right	1.5	15.6	21
Winter	Scenario 3	winter_acute	11.7	6.8	10.2	0.512	320	0.03	2	8.4	single port	2.5	295	0	right	1.5	21.4	17
	Scenario 4	winter_chronic	11.7	6.8	10.2	0.512	320	0.03	2	8.4	single port	2.5	295	0	right	1.5	15.6	17

*Horizontal angle of 295 degrees corresponds to the discharge oriented 30 degrees in the direction of river flow.

Table 2: Model Results

Spokane County Proposed Discharge

			Model Results							
Description	Scenario Number	Scenario	Distance to Maximum Allowable Dilution at Chronic Mixing Zone Boundary (ft)	Maximum Allowable Dilution at Chronic Mixing Zone Boundary[b]	Distance to 10% of the Chronic Mixing Zone Boundary based on Maximum Allowable Chronic Dilution (ft)	Centerline Dilution at 10% of the Chronic Mixing Zone Boundary based on Maximum Allowable Chronic Dilution	Distance to Maximum Allowable Dilution at Acute Mixing Zone (ft)	Maximum Allowable Dilution at Acute Mixing Zone[c]	Distance to 10 x the Acute Mixing Zone Boundary based on Maximum Allowable Acute Dilution (ft)	Centerline Dilution at 10 x the Acute Mixing Zone Boundary based on Maximum Allowable Acute Dilution
Single-Port Mid-Channel Design Scenarios										
Summer	Scenario 1	acute	40	7.2	**4.0**	**1.1**	-	-	-	-
	Scenario 2	chronic	**40**	**7.2**	4.0	1.1	-	-	-	-
Winter	Scenario 3	acute	NA[c]	11.9	-	-	**8.8**	**1.8**	-	-
	Scenario 4	chronic	93	11.9	9.3	1.9	8.8	1.8	**88**	**9.6**

BOLD text indicates the dilution and distance selected to define the mixing zone for the scenario.

[a] Chronic mixing zone can not ultilize more than 25% of the river flow at the mixing zone boundary

[b] Acute mixing zone can not ultilize more than 2.5% of the river flow at 10% of the chronic mixing zone boundary

[c] CORMIX prediction did not extend to far field mixing zone for this scenario

[d] CORMIX prediction did not extend to 10 x the distance to acutte mixing zone boundary. Value shown is maximum predicted dilution

Table 3: Predicted Mixing Zone Lengths, Associated Dilution Values, and Plume Widths

Spokane County Proposed Discharge

Season	Distance to Mixing Zone Boundary		Dilution at Mixing Zone Boundary		Plume Width at Chronic Mixing Zone Boundary (ft)
	Acute (ft)	Chronic (ft)	Acute	Chronic	
Summer	4	40	1.1	7.2	13
Winter	8.8	88	1.8	9.6	26

Table 4: Ambient Water Conditions
Spokane County Proposed Discharge

Constituent	90%-ile Concentration Summer	90%-ile Concentration Winter	Source	Stations	# of Data Points	Years
Arsenic	0 ug/l	0 ug/l	Spokane AWTP discharge permit fact sheet			
Chromium	4.2 ug/l	1.9 ug/l	U.S. EPA STORET and Ecology databases	Mission Street Bridge, Spokane City Dam Boat launch at Sekani, Stateline Bridge	45 (summer) 26 (winter)	1972-1973, 1994-1999
Copper	0.372 ug/l	0.372 ug/l	Spokane AWTP discharge permit fact sheet			
Mercury	0.0013 ug/l	0.0031 ug/l	Spokane AWTP discharge permit fact sheet			
Nickel	0.76 ug/l	1.1 ug/l	U.S. EPA STORET and Ecology databases	Stateline Bridge	20 (summer) 19 (winter)	1994-1999
Silver	0.0204 ug/l	0.048 ug/l	Spokane AWTP discharge permit fact sheet			
Ammonia	0.22 mg/l	0.3 mg/l	Spokane AWTP discharge permit fact sheet			
pH	7.8	7.8	U.S. EPA STORET and Ecology databases	Monroe Street Bridge, Washington Street Bridge, Cochran Street Gage, Ft. Wright Bridge, Mission Street Bridge, Below Spokane City Dam, Above Washington Street Bridge, Spokane, Spokane at USGS Gage, Stateline Bridge	451	1959-1965, 1968-1973, 1979-1980, 1990-2001
Temperature	17.9°C	8.4°C	U.S. EPA STORET and Ecology databases	Mission Street Bridge, Greene Street Bridge, Spokane City Dam, Stateline Bridge	1928 (summer) 110 (winter)	1970-1973, 1979-1980, 1991-2000

Table 5: Effluent Conditions

Spokane County Proposed Discharge

Constituent	Units	Maximum Probable Effluent Concentrations
Arsenic	ug/l	3.6
Chromium	ug/l	14
Copper	ug/l	16
Mercury	ug/l	0.34
Nickel	ug/l	61
Silver	ug/l	13.1
Ammonia	mg/l	3.0 (summer) 20 (winter)
pH	-	7.4
Temperature	^{o}C	21 (summer) 17 (winter)

Table 6: Dilution Required for Water Quality Standards Attainment

Spokane County Proposed Discharge

						Temperature (°C)		Ammonia (mg/l)		Arsenic (ug/l)		Chromium (ug/l)		Copper (ug/l)		Mercury (ug/l)		Nickel (ug/l)		Silver (ug/l)	
Description	**Scenario**	**Exposure**	**Predicted Dilution (from Table 3)**	**Blended Hardness (mg/l)**	**Blended pH**	**Mixed Temperature at Chronic Mixing Zone (°C)**	**Change in Ambient Temperature (°C)**	**Water Quality Criteria**	**Dilution required to meet Criteria**	**Water Quality Criteria**	**Dilution required to meet Criteria**	**Water Quality Criteria**	**Dilution required to meet Criteria**	**Water Quality Criteria**	**Dilution required to meet Criteria**	**Water Quality Criteria**	**Dilution required to meet Criteria**	**Water Quality Criteria**	**Dilution required to meet Criteria**	**Water Quality Criteria**	**Dilution required to meet Criteria**
Single-Port Mid-Channel Design Scenarios																					
Summer	Scenario 1	acute	1.1	140	7.4	---	---	15	0	360	0	725	0	23	0	2.1	0	1886	0	6.2	4.7
	Scenario 2	chronic	7.2	102	7.7	18.3	0.4	1.9	1.7	190	0	180	0	12	0	0.012	32	159	0	---	---
Winter	Scenario 3	acute	1.8	116	7.6	---	---	12	1.7	360	0	619	0	20	0	2.1	0	1602	0	4.4	4.8
	Scenario 4	chronic	9.6	81	7.8	9.2	0.8	2.5	9.3	190	0	149	0	9.5	0	0.012	38	131	0	---	---

*Data outliers exist for both mercury and silver. See discussion in Section 5.6. Without these outliers, lower dilution values are required to meet water quality criteria for mercury and no dilution is necessary to meet criteria for silver.

Table 7: Water Quality Standards Attainment for Design Scenarios

Spokane County Proposed Discharge

		Concentration at Mixing Zone Boundary*		Water Quality Criteria	
Constituent	**Season**	**Chronic**	**Acute**	**Chronic**	**Acute**
Arsenic	summer	0.5	3.3	190	360
(ug/l)	winter	0.3	2.1	190	360
Chromium	summer	5.6	13	180	725
(ug/l)	winter	3.1	9.0	149	619
Copper	summer	2.5	15	12	23
(ug/l)	winter	1.9	9.5	9.5	20
Mercury	summer	**0.048***	0.309	0.012	2.1
(ug/l)	winter	**0.035***	0.201	0.012	2.1
Nickel	summer	9.1	56	159	1886
(ug/l)	winter	6.8	36	131	1602
Silver	summer	1.8	**11.9***	---	6.2
(ug/l)	winter	1.3	**7.7***	---	4.4
Ammonia	summer	0.6	2.7	1.9	15
(mg/l)	winter	2.2	12	2.5	12
Temperature	summer	18.3	---	<20	---
(^oC)	winter	9.2	---	<20	---

Bold values exceed applicable criteria.

*Data outliers exist for both mercury and silver. See discussion in Section 5.6. Without these outliers, water quality standards are attained for both parameters.

APPENDIX

ACUTE SUMMER

```
CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111111
                       CORNELL MIXING ZONE EXPERT SYSTEM
             Subsystem CORMIX1:  Submerged Single Port Discharges
 CORMIX-GI Version 4.1GT
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:   SPOCFP New Location (12+00)
 Design case:       Summer Acute
 FILE NAME:         I:\...5 degrees_deisgn_scenarios\Acute_Summer_Run02.prd
 Time stamp:        Fri Apr  9 15:52:49 2004

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =     97.54  AS    =    341.88  QA    =     31.26  ICHREG= 1
 HA    =      3.51  HD    =      3.05
 UA    =      0.091 F     =      0.047 USTAR =0.6971E-02
 UW    =      2.000 UWSTAR=0.2198E-02
 Uniform density environment
 STRCND=  U         RHOAM =  998.6151

DISCHARGE PARAMETERS (metric units)
 BANK  =  RIGHT     DISTB =     44.81
 D0    =      0.762 A0    =      0.456 H0    =      0.84
 THETA =      0.00  SIGMA =    295.00
 U0    =      2.056 Q0    =      0.938       =0.9376E+00
 RHO0  =  997.9934  DRHO0 =0.6217E+00  GP0   =0.6105E-02
 C0    = 0.1000E+03 CUNITS=  mg/l
 IPOLL =  1         KS    =0.0000E+00  KD    =0.0000E+00

FLUX VARIABLES (metric units)
 Q0    =0.9376E+00  M0    =0.1928E+01  J0    =0.5724E-02  SIGNJ0=      1.0
 Associated length scales (meters)
 LQ    =      0.68  LM    =     21.62  Lm    =     15.18  Lb    =      7.49
                                       Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     30.14  R     =     22.48

FLOW CLASSIFICATION
 111111111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    H5-90  1
 1  Applicable layer depth HS =     3.05  1
 111111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    = 0.1000E+03 CUNITS=  mg/l
 NTOX  =  0
 NSTD  =  0
 REGMZ =  0
 XINT  =    975.36  XMAX  =    975.36

X-Y-Z COORDINATE SYSTEM:
```

```
    ORIGIN is located at the bottom and below the center of the port:
        44.81 m  from the RIGHT bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

 COANDA ATTACHMENT immediately following the discharge.

       X        Y       Z        S       C       B
      0.00     0.00    0.00     1.0 0.100E+03   0.54

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Bottom-attached jet motion.

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
            Half wall jet, attached to bottom.
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y       Z        S       C       B
      0.00     0.00    0.00     1.0 0.100E+03   0.38
      0.16    -0.33    0.00     1.0 0.100E+03   0.43
      0.33    -0.69    0.00     1.0 0.100E+03   0.47
      0.50    -1.05    0.00     1.0 0.100E+03   0.52
      0.66    -1.37    0.00     1.0 0.100E+03   0.56
      0.83    -1.73    0.00     1.0 0.100E+03   0.61
      1.01    -2.08    0.00     1.0 0.964E+02   0.66
      1.18    -2.41    0.00     1.1 0.902E+02   0.70
      1.36    -2.76    0.00     1.2 0.842E+02   0.75
      1.55    -3.11    0.00     1.3 0.789E+02   0.80
      1.72    -3.43    0.00     1.3 0.745E+02   0.85
      1.91    -3.78    0.00     1.4 0.702E+02   0.90
      2.10    -4.13    0.00     1.5 0.664E+02   0.95
      2.27    -4.45    0.00     1.6 0.632E+02   0.99
      2.47    -4.79    0.00     1.7 0.600E+02   1.04
      2.67    -5.14    0.00     1.8 0.570E+02   1.10
      2.87    -5.48    0.00     1.8 0.543E+02   1.15
      3.05    -5.80    0.00     1.9 0.521E+02   1.19
      3.26    -6.14    0.00     2.0 0.498E+02   1.25
      3.46    -6.47    0.00     2.1 0.476E+02   1.30
      3.65    -6.79    0.00     2.2 0.458E+02   1.35
      3.86    -7.12    0.00     2.3 0.440E+02   1.40
      4.08    -7.46    0.00     2.4 0.422E+02   1.45
      4.27    -7.76    0.00     2.5 0.407E+02   1.50
      4.49    -8.10    0.00     2.6 0.392E+02   1.56
      4.71    -8.43    0.00     2.6 0.378E+02   1.61
      4.91    -8.73    0.00     2.7 0.365E+02   1.66
      5.14    -9.06    0.00     2.8 0.352E+02   1.72
      5.36    -9.38    0.00     2.9 0.340E+02   1.78
      5.59    -9.71    0.00     3.0 0.329E+02   1.83
```

5.81	-10.00	0.00	3.1	0.319E+02	1.88
6.04	-10.32	0.00	3.2	0.309E+02	1.94
6.27	-10.64	0.00	3.3	0.299E+02	2.00
6.49	-10.94	0.00	3.4	0.290E+02	2.05
6.73	-11.25	0.00	3.6	0.282E+02	2.11
6.97	-11.56	0.00	3.7	0.273E+02	2.17
7.20	-11.85	0.00	3.8	0.266E+02	2.22
7.45	-12.16	0.00	3.9	0.258E+02	2.28
7.69	-12.47	0.00	4.0	0.251E+02	2.34
7.93	-12.75	0.00	4.1	0.244E+02	2.39
8.18	-13.06	0.00	4.2	0.237E+02	2.45
8.43	-13.36	0.00	4.3	0.231E+02	2.51
8.69	-13.66	0.00	4.4	0.225E+02	2.57
8.93	-13.94	0.00	4.6	0.219E+02	2.63
9.19	-14.24	0.00	4.7	0.214E+02	2.69
9.46	-14.53	0.00	4.8	0.208E+02	2.75
9.70	-14.80	0.00	4.9	0.203E+02	2.81
9.97	-15.09	0.00	5.0	0.198E+02	2.87
10.24	-15.38	0.00	5.2	0.193E+02	2.93
10.49	-15.65	0.00	5.3	0.189E+02	2.99
10.77	-15.93	0.00	5.4	0.184E+02	3.05

Cumulative travel time = 21. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

BEGIN MOD133: LAYER BOUNDARY IMPINGEMENT/FULL VERTICAL MIXING

Control volume inflow:

X	Y	Z	S	C	B
10.77	-15.93	0.00	5.4	0.184E+02	3.05

Profile definitions:

BV = layer depth (vertically mixed)
BH = top-hat half-width, in horizontal plane normal to trajectory
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
7.72	-18.12	3.05	5.4	0.184E+02	0.00	0.00	3.05	3.05
8.24	-18.12	3.05	5.4	0.184E+02	3.05	0.76	3.05	0.00
8.75	-18.12	3.05	5.4	0.184E+02	3.05	1.07	3.05	0.00
9.27	-18.12	3.05	5.4	0.184E+02	3.05	1.31	3.05	0.00
9.79	-18.12	3.05	5.4	0.184E+02	3.05	1.51	3.05	0.00
10.31	-18.12	3.05	5.4	0.184E+02	3.05	1.69	3.05	0.00
10.82	-18.12	3.05	5.4	0.184E+02	3.05	1.85	3.05	0.00
11.34	-18.12	3.05	6.0	0.168E+02	3.05	2.00	3.05	0.00
11.86	-18.12	3.05	6.8	0.146E+02	3.05	2.14	3.05	0.00
12.37	-18.12	3.05	7.4	0.136E+02	3.05	2.27	3.05	0.00
12.89	-18.12	3.05	7.6	0.132E+02	3.05	2.39	3.05	0.00

Cumulative travel time = 38. sec

END OF MOD133: LAYER BOUNDARY IMPINGEMENT/FULL VERTICAL MIXING

BEGIN MOD154: VERTICALLY MIXED PLUME IN WEAK CROSS-FLOW

Phase 1: Vertically mixed, Phase 2: Re-stratified

Phase 1: The plume is VERTICALLY FULLY MIXED over the entire layer depth.
Profile definitions:
BV = layer depth (vertically mixed)
BH = Gaussian 1/e (37%) half-width in horizontal plane normal to trajectory
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic centerline dilution
C = centerline concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
12.89	-18.12	3.05	7.6	0.132E+02	3.05	2.07	3.05	0.00
12.97	-18.18	3.05	7.6	0.132E+02	3.05	2.08	3.05	0.00
13.04	-18.24	3.05	7.6	0.131E+02	3.05	2.08	3.05	0.00
13.12	-18.30	3.05	7.6	0.131E+02	3.05	2.09	3.05	0.00
13.19	-18.36	3.05	7.6	0.131E+02	3.05	2.09	3.05	0.00
13.27	-18.42	3.05	7.6	0.131E+02	3.05	2.10	3.05	0.00
13.34	-18.48	3.05	7.6	0.131E+02	3.05	2.10	3.05	0.00
13.42	-18.54	3.05	7.7	0.131E+02	3.05	2.11	3.05	0.00
13.49	-18.59	3.05	7.7	0.131E+02	3.05	2.11	3.05	0.00
13.57	-18.65	3.05	7.7	0.130E+02	3.05	2.12	3.05	0.00
13.64	-18.71	3.05	7.7	0.130E+02	3.05	2.12	3.05	0.00
13.72	-18.77	3.05	7.7	0.130E+02	3.05	2.13	3.05	0.00
13.80	-18.83	3.05	7.7	0.130E+02	3.05	2.13	3.05	0.00
13.87	-18.89	3.05	7.7	0.130E+02	3.05	2.13	3.05	0.00
13.95	-18.95	3.05	7.7	0.130E+02	3.05	2.14	3.05	0.00
14.02	-19.01	3.05	7.7	0.129E+02	3.05	2.14	3.05	0.00
14.10	-19.06	3.05	7.7	0.129E+02	3.05	2.15	3.05	0.00
14.18	-19.12	3.05	7.7	0.129E+02	3.05	2.15	3.05	0.00
14.25	-19.18	3.05	7.8	0.129E+02	3.05	2.16	3.05	0.00
14.33	-19.24	3.05	7.8	0.129E+02	3.05	2.16	3.05	0.00
14.41	-19.30	3.05	7.8	0.129E+02	3.05	2.17	3.05	0.00
14.48	-19.36	3.05	7.8	0.129E+02	3.05	2.17	3.05	0.00
14.56	-19.42	3.05	7.8	0.128E+02	3.05	2.18	3.05	0.00
14.63	-19.48	3.05	7.8	0.128E+02	3.05	2.18	3.05	0.00
14.71	-19.54	3.05	7.8	0.128E+02	3.05	2.19	3.05	0.00
14.79	-19.59	3.05	7.8	0.128E+02	3.05	2.19	3.05	0.00
14.86	-19.65	3.05	7.8	0.128E+02	3.05	2.19	3.05	0.00
14.94	-19.71	3.05	7.8	0.128E+02	3.05	2.20	3.05	0.00
15.02	-19.77	3.05	7.8	0.128E+02	3.05	2.20	3.05	0.00
15.09	-19.83	3.05	7.8	0.127E+02	3.05	2.21	3.05	0.00
15.17	-19.89	3.05	7.9	0.127E+02	3.05	2.21	3.05	0.00
15.25	-19.95	3.05	7.9	0.127E+02	3.05	2.22	3.05	0.00
15.32	-20.01	3.05	7.9	0.127E+02	3.05	2.22	3.05	0.00
15.40	-20.06	3.05	7.9	0.127E+02	3.05	2.23	3.05	0.00
15.48	-20.12	3.05	7.9	0.127E+02	3.05	2.23	3.05	0.00
15.56	-20.18	3.05	7.9	0.127E+02	3.05	2.24	3.05	0.00
15.63	-20.24	3.05	7.9	0.126E+02	3.05	2.24	3.05	0.00
15.71	-20.30	3.05	7.9	0.126E+02	3.05	2.24	3.05	0.00
15.79	-20.36	3.05	7.9	0.126E+02	3.05	2.25	3.05	0.00
15.87	-20.42	3.05	7.9	0.126E+02	3.05	2.25	3.05	0.00
15.94	-20.48	3.05	7.9	0.126E+02	3.05	2.26	3.05	0.00
16.02	-20.53	3.05	8.0	0.126E+02	3.05	2.26	3.05	0.00
16.10	-20.59	3.05	8.0	0.126E+02	3.05	2.27	3.05	0.00

```
     16.18   -20.65    3.05     8.0 0.125E+02   3.05     2.27    3.05    0.00
     16.25   -20.71    3.05     8.0 0.125E+02   3.05     2.28    3.05    0.00
     16.33   -20.77    3.05     8.0 0.125E+02   3.05     2.28    3.05    0.00
     16.41   -20.83    3.05     8.0 0.125E+02   3.05     2.29    3.05    0.00
     16.49   -20.89    3.05     8.0 0.125E+02   3.05     2.29    3.05    0.00
     16.56   -20.95    3.05     8.0 0.125E+02   3.05     2.30    3.05    0.00
     16.64   -21.01    3.05     8.0 0.125E+02   3.05     2.30    3.05    0.00
     16.72   -21.06    3.05     8.0 0.124E+02   3.05     2.30    3.05    0.00
 Cumulative travel time =          78. sec

 Entire region is occupied by Phase 1.
   Plume does not re-stratify in this flow region.

END OF MOD154: VERTICALLY MIXED PLUME IN WEAK CROSS-FLOW
-------------------------------------------------------------------------------
** End of NEAR-FIELD REGION (NFR) **

 The initial plume WIDTH values in the next far-field module will be
  CORRECTED by a factor  5.69 to conserve the mass flux in the far-field!
 The correction factor is quite large because of the small ambient velocity
   relative to the strong mixing characteristics of the discharge!
   This indicates localized RECIRCULATION REGIONS and internal hydraulic JUMPS.
 Flow appears highly UNSTEADY and prediction results are UNRELIABLE!
   SIMULATION STOPS!
-------------------------------------------------------------------------------
CORMIX1: Submerged Single Port Discharges              End of Prediction File
1111111111111111111111111111111111111111111111111111111111111111111111111111111
```

ACUTE WINTER

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CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111111
                       CORNELL MIXING ZONE EXPERT SYSTEM
             Subsystem CORMIX1:  Submerged Single Port Discharges
 CORMIX-GI Version 4.1GT
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:   SPOCFP New Location (12+00)
 Design case:       Winter Acute
 FILE NAME:         I:\...5 degrees_deisgn_scenarios\Acute_Winter_Run02.prd
 Time stamp:        Fri Apr  9 15:53:19 2004

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =     97.54  AS    =    347.83  QA    =     54.28  ICHREG= 1
 HA    =      3.57  HD    =      3.11
 UA    =      0.156 F     =      0.046 USTAR =0.1186E-01
 UW    =      2.000 UWSTAR=0.2198E-02
 Uniform density environment
 STRCND=  U         RHOAM =  999.8255

DISCHARGE PARAMETERS (metric units)
 BANK  =  RIGHT     DISTB =     44.81
 D0    =      0.762 A0    =      0.456 H0    =      0.84
 THETA =      0.00  SIGMA =    295.00
 U0    =      2.056 Q0    =      0.938       =0.9376E+00
 RHO0  =  998.7761  DRHO0 =0.1049E+01  GP0   =0.1029E-01
 C0    = 0.1000E+03 CUNITS=  mg/l
 IPOLL =  1         KS    =0.0000E+00  KD    =0.0000E+00

FLUX VARIABLES (metric units)
 Q0    =0.9376E+00  M0    =0.1928E+01  J0    =0.9650E-02  SIGNJ0=      1.0
 Associated length scales (meters)
 LQ    =      0.68  LM    =     16.65  Lm    =      8.90  Lb    =      2.54
                                       Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     23.22  R     =     13.17

FLOW CLASSIFICATION
 111111111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    H5-90  1
 1  Applicable layer depth HS =     3.11  1
 111111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    = 0.1000E+03 CUNITS=  mg/l
 NTOX  =  0
 NSTD  =  0
 REGMZ =  0
 XINT  =    975.36  XMAX  =    975.36

X-Y-Z COORDINATE SYSTEM:
```

```
    ORIGIN is located at the bottom and below the center of the port:
        44.81 m  from the RIGHT bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

 COANDA ATTACHMENT immediately following the discharge.

       X        Y       Z        S       C       B
      0.00     0.00    0.00     1.0 0.100E+03   0.54

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Bottom-attached jet motion.

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
            Half wall jet, attached to bottom.
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y       Z        S       C       B
      0.00     0.00    0.00     1.0 0.100E+03   0.38
      0.15    -0.31    0.00     1.0 0.100E+03   0.43
      0.31    -0.65    0.00     1.0 0.100E+03   0.47
      0.47    -0.98    0.00     1.0 0.100E+03   0.52
      0.64    -1.31    0.00     1.0 0.100E+03   0.57
      0.80    -1.62    0.00     1.0 0.100E+03   0.61
      0.98    -1.94    0.00     1.0 0.958E+02   0.66
      1.16    -2.27    0.00     1.1 0.888E+02   0.71
      1.34    -2.60    0.00     1.2 0.828E+02   0.75
      1.53    -2.92    0.00     1.3 0.773E+02   0.80
      1.70    -3.21    0.00     1.4 0.729E+02   0.85
      1.89    -3.53    0.00     1.5 0.685E+02   0.90
      2.09    -3.85    0.00     1.5 0.645E+02   0.95
      2.29    -4.16    0.00     1.6 0.609E+02   1.00
      2.49    -4.48    0.00     1.7 0.576E+02   1.06
      2.69    -4.76    0.00     1.8 0.549E+02   1.11
      2.90    -5.07    0.00     1.9 0.521E+02   1.16
      3.11    -5.37    0.00     2.0 0.495E+02   1.21
      3.33    -5.67    0.00     2.1 0.471E+02   1.27
      3.54    -5.95    0.00     2.2 0.451E+02   1.32
      3.76    -6.25    0.00     2.3 0.431E+02   1.37
      3.99    -6.54    0.00     2.4 0.411E+02   1.43
      4.22    -6.83    0.00     2.5 0.394E+02   1.49
      4.46    -7.12    0.00     2.7 0.377E+02   1.54
      4.68    -7.38    0.00     2.8 0.363E+02   1.60
      4.93    -7.66    0.00     2.9 0.348E+02   1.66
      5.17    -7.94    0.00     3.0 0.334E+02   1.71
      5.42    -8.22    0.00     3.1 0.321E+02   1.77
      5.68    -8.49    0.00     3.2 0.309E+02   1.83
      5.91    -8.74    0.00     3.4 0.298E+02   1.89
```

6.18	-9.01	0.00	3.5	0.287E+02	1.94
6.44	-9.27	0.00	3.6	0.277E+02	2.00
6.71	-9.53	0.00	3.7	0.267E+02	2.06
6.98	-9.79	0.00	3.9	0.258E+02	2.12
7.23	-10.02	0.00	4.0	0.250E+02	2.18
7.50	-10.27	0.00	4.1	0.242E+02	2.24
7.78	-10.52	0.00	4.3	0.234E+02	2.30
8.06	-10.76	0.00	4.4	0.226E+02	2.36
8.33	-10.98	0.00	4.6	0.220E+02	2.41
8.61	-11.22	0.00	4.7	0.213E+02	2.47
8.90	-11.46	0.00	4.8	0.207E+02	2.53
9.20	-11.69	0.00	5.0	0.200E+02	2.59
9.49	-11.92	0.00	5.1	0.195E+02	2.65
9.76	-12.12	0.00	5.3	0.189E+02	2.71
10.06	-12.34	0.00	5.4	0.184E+02	2.77
10.36	-12.56	0.00	5.6	0.179E+02	2.83
10.67	-12.78	0.00	5.7	0.174E+02	2.88
10.98	-12.99	0.00	5.9	0.170E+02	2.94
11.26	-13.18	0.00	6.0	0.166E+02	3.00
11.57	-13.39	0.00	6.2	0.161E+02	3.05
11.88	-13.60	0.00	6.4	0.157E+02	3.11

Cumulative travel time = 21. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

BEGIN MOD133: LAYER BOUNDARY IMPINGEMENT/FULL VERTICAL MIXING

Control volume inflow:

X	Y	Z	S	C	B
11.88	-13.60	0.00	6.4	0.157E+02	3.11

Profile definitions:

BV = layer depth (vertically mixed)
BH = top-hat half-width, in horizontal plane normal to trajectory
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
8.77	-15.29	3.11	6.4	0.157E+02	0.00	0.00	3.11	3.11
9.34	-15.29	3.11	6.4	0.157E+02	3.11	0.68	3.11	0.00
9.92	-15.29	3.11	6.4	0.157E+02	3.11	0.96	3.11	0.00
10.49	-15.29	3.11	6.4	0.157E+02	3.11	1.18	3.11	0.00
11.06	-15.29	3.11	6.4	0.157E+02	3.11	1.36	3.11	0.00
11.63	-15.29	3.11	6.4	0.157E+02	3.11	1.52	3.11	0.00
12.20	-15.29	3.11	6.5	0.154E+02	3.11	1.67	3.11	0.00
12.77	-15.29	3.11	7.3	0.137E+02	3.11	1.80	3.11	0.00
13.35	-15.29	3.11	8.2	0.122E+02	3.11	1.93	3.11	0.00
13.92	-15.29	3.11	8.7	0.115E+02	3.11	2.05	3.11	0.00
14.49	-15.29	3.11	8.9	0.112E+02	3.11	2.16	3.11	0.00

Cumulative travel time = 36. sec

END OF MOD133: LAYER BOUNDARY IMPINGEMENT/FULL VERTICAL MIXING

```
BEGIN MOD154: VERTICALLY MIXED PLUME IN WEAK CROSS-FLOW

 Phase 1: Vertically mixed, Phase 2: Re-stratified

 Phase 1: The plume is VERTICALLY FULLY MIXED over the entire layer depth.
 This flow region is INSIGNIFICANT in spatial extent and will be by-passed.

-------------------------------------------------------------------------------
 Phase 2: The flow has RESTRATIFIED at the beginning of this zone.

 This flow region is INSIGNIFICANT in spatial extent and will be by-passed.

END OF MOD154: VERTICALLY MIXED PLUME IN WEAK CROSS-FLOW
-------------------------------------------------------------------------------
** End of NEAR-FIELD REGION (NFR) **

 The initial plume WIDTH values in the next far-field module will be
  CORRECTED by a factor  3.92 to conserve the mass flux in the far-field!
 The correction factor is quite large because of the small ambient velocity
   relative to the strong mixing characteristics of the discharge!
   This indicates localized RECIRCULATION REGIONS and internal hydraulic JUMPS.
 Flow appears highly UNSTEADY and prediction results are UNRELIABLE!
   SIMULATION STOPS!
-------------------------------------------------------------------------------
CORMIX1: Submerged Single Port Discharges              End of Prediction File
1111111111111111111111111111111111111111111111111111111111111111111111111111111
```

CHRONIC SUMMER

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CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111111
                       CORNELL MIXING ZONE EXPERT SYSTEM
             Subsystem CORMIX1:  Submerged Single Port Discharges
 CORMIX-GI Version 4.1GT
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:   SPOCFP New Location (12+00)
 Design case:       Summer Chronic
 FILE NAME:         I:\...degrees_deisgn_scenarios\Chronic_Summer_Run02.prd
 Time stamp:        Fri Apr  9 15:53:33 2004

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =     97.54  AS    =    341.88  QA    =     31.26  ICHREG= 1
 HA    =      3.51  HD    =      3.05
 UA    =      0.091 F     =      0.047 USTAR =0.6971E-02
 UW    =      2.000 UWSTAR=0.2198E-02
 Uniform density environment
 STRCND=  U         RHOAM =  998.6151

DISCHARGE PARAMETERS (metric units)
 BANK  =  RIGHT     DISTB =     44.81
 D0    =      0.762 A0    =      0.456 H0    =      0.84
 THETA =      0.00  SIGMA =    295.00
 U0    =      1.499 Q0    =      0.683       =0.6835E+00
 RHO0  =  997.9934  DRHO0 =0.6217E+00  GP0   =0.6105E-02
 C0    = 0.1000E+03 CUNITS=  mg/l
 IPOLL =  1         KS    =0.0000E+00  KD    =0.0000E+00

FLUX VARIABLES (metric units)
 Q0    =0.6835E+00  M0    =0.1024E+01  J0    =0.4173E-02  SIGNJ0=      1.0
 Associated length scales (meters)
 LQ    =      0.68  LM    =     15.76  Lm    =     11.07  Lb    =      5.46
                                       Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     21.97  R     =     16.39

FLOW CLASSIFICATION
 111111111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    H5-90  1
 1  Applicable layer depth HS =     3.05  1
 111111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    = 0.1000E+03 CUNITS=  mg/l
 NTOX  =  0
 NSTD  =  0
 REGMZ =  0
 XINT  =    975.36  XMAX  =    975.36

X-Y-Z COORDINATE SYSTEM:
```

```
    ORIGIN is located at the bottom and below the center of the port:
        44.81 m  from the RIGHT bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

 COANDA ATTACHMENT immediately following the discharge.

       X        Y       Z        S       C       B
      0.00     0.00    0.00     1.0 0.100E+03   0.54

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Bottom-attached jet motion.

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
            Half wall jet, attached to bottom.
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y       Z        S       C       B
      0.00     0.00    0.00     1.0 0.100E+03   0.38
      0.16    -0.33    0.00     1.0 0.100E+03   0.43
      0.31    -0.66    0.00     1.0 0.100E+03   0.47
      0.47    -0.99    0.00     1.0 0.100E+03   0.52
      0.64    -1.32    0.00     1.0 0.100E+03   0.56
      0.80    -1.64    0.00     1.0 0.100E+03   0.61
      0.97    -1.97    0.00     1.0 0.970E+02   0.65
      1.14    -2.29    0.00     1.1 0.903E+02   0.70
      1.32    -2.61    0.00     1.2 0.845E+02   0.75
      1.49    -2.93    0.00     1.3 0.792E+02   0.79
      1.67    -3.25    0.00     1.3 0.745E+02   0.84
      1.85    -3.57    0.00     1.4 0.703E+02   0.89
      2.04    -3.89    0.00     1.5 0.665E+02   0.94
      2.22    -4.20    0.00     1.6 0.630E+02   0.98
      2.43    -4.54    0.00     1.7 0.596E+02   1.04
      2.62    -4.85    0.00     1.8 0.567E+02   1.09
      2.82    -5.16    0.00     1.9 0.540E+02   1.14
      3.01    -5.47    0.00     1.9 0.515E+02   1.19
      3.22    -5.77    0.00     2.0 0.492E+02   1.24
      3.42    -6.08    0.00     2.1 0.471E+02   1.29
      3.63    -6.38    0.00     2.2 0.451E+02   1.34
      3.84    -6.68    0.00     2.3 0.433E+02   1.39
      4.05    -6.98    0.00     2.4 0.415E+02   1.45
      4.26    -7.27    0.00     2.5 0.399E+02   1.50
      4.48    -7.57    0.00     2.6 0.384E+02   1.55
      4.70    -7.86    0.00     2.7 0.369E+02   1.61
      4.92    -8.15    0.00     2.8 0.356E+02   1.66
      5.17    -8.46    0.00     2.9 0.342E+02   1.72
      5.40    -8.74    0.00     3.0 0.330E+02   1.78
      5.63    -9.03    0.00     3.1 0.319E+02   1.83
```

5.86	-9.31	0.00	3.2	0.308E+02	1.89
6.10	-9.59	0.00	3.4	0.298E+02	1.94
6.34	-9.86	0.00	3.5	0.288E+02	2.00
6.58	-10.14	0.00	3.6	0.279E+02	2.06
6.83	-10.41	0.00	3.7	0.270E+02	2.11
7.08	-10.68	0.00	3.8	0.262E+02	2.17
7.33	-10.94	0.00	3.9	0.254E+02	2.23
7.58	-11.21	0.00	4.1	0.246E+02	2.29
7.83	-11.47	0.00	4.2	0.239E+02	2.34
8.09	-11.73	0.00	4.3	0.232E+02	2.40
8.35	-11.99	0.00	4.4	0.225E+02	2.46
8.64	-12.26	0.00	4.6	0.218E+02	2.52
8.90	-12.51	0.00	4.7	0.212E+02	2.58
9.17	-12.76	0.00	4.8	0.207E+02	2.64
9.44	-13.01	0.00	5.0	0.201E+02	2.70
9.71	-13.25	0.00	5.1	0.196E+02	2.76
9.99	-13.49	0.00	5.2	0.191E+02	2.81
10.26	-13.73	0.00	5.4	0.186E+02	2.87
10.54	-13.97	0.00	5.5	0.181E+02	2.93
10.82	-14.20	0.00	5.7	0.177E+02	2.99
11.11	-14.44	0.00	5.8	0.172E+02	3.05

Cumulative travel time = 27. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

BEGIN MOD133: LAYER BOUNDARY IMPINGEMENT/FULL VERTICAL MIXING

Control volume inflow:

X	Y	Z	S	C	B
11.11	-14.44	0.00	5.8	0.172E+02	3.05

Profile definitions:

BV = layer depth (vertically mixed)
BH = top-hat half-width, in horizontal plane normal to trajectory
ZU = upper plume boundary (Z-coordinate)
ZL = lower plume boundary (Z-coordinate)
S = hydrodynamic average (bulk) dilution
C = average (bulk) concentration (includes reaction effects, if any)

X	Y	Z	S	C	BV	BH	ZU	ZL
8.06	-16.36	3.05	5.8	0.172E+02	0.00	0.00	3.05	3.05
8.60	-16.36	3.05	5.8	0.172E+02	3.05	0.71	3.05	0.00
9.14	-16.36	3.05	5.8	0.172E+02	3.05	1.00	3.05	0.00
9.68	-16.36	3.05	5.8	0.172E+02	3.05	1.23	3.05	0.00
10.23	-16.36	3.05	5.8	0.172E+02	3.05	1.42	3.05	0.00
10.77	-16.36	3.05	5.8	0.172E+02	3.05	1.58	3.05	0.00
11.31	-16.36	3.05	5.9	0.171E+02	3.05	1.74	3.05	0.00
11.85	-16.36	3.05	6.6	0.153E+02	3.05	1.87	3.05	0.00
12.39	-16.36	3.05	7.4	0.135E+02	3.05	2.00	3.05	0.00
12.93	-16.36	3.05	7.9	0.127E+02	3.05	2.13	3.05	0.00
13.47	-16.36	3.05	8.1	0.123E+02	3.05	2.24	3.05	0.00

Cumulative travel time = 50. sec

END OF MOD133: LAYER BOUNDARY IMPINGEMENT/FULL VERTICAL MIXING

```
BEGIN MOD154: VERTICALLY MIXED PLUME IN WEAK CROSS-FLOW

 Phase 1: Vertically mixed, Phase 2: Re-stratified

 Phase 1: The plume is VERTICALLY FULLY MIXED over the entire layer depth.
 This flow region is INSIGNIFICANT in spatial extent and will be by-passed.

-------------------------------------------------------------------------------
 Phase 2: The flow has RESTRATIFIED at the beginning of this zone.

 This flow region is INSIGNIFICANT in spatial extent and will be by-passed.

END OF MOD154: VERTICALLY MIXED PLUME IN WEAK CROSS-FLOW
-------------------------------------------------------------------------------
** End of NEAR-FIELD REGION (NFR) **

 The initial plume WIDTH values in the next far-field module will be
  CORRECTED by a factor  4.35 to conserve the mass flux in the far-field!
 The correction factor is quite large because of the small ambient velocity
   relative to the strong mixing characteristics of the discharge!
   This indicates localized RECIRCULATION REGIONS and internal hydraulic JUMPS.
 Flow appears highly UNSTEADY and prediction results are UNRELIABLE!
   SIMULATION STOPS!
-------------------------------------------------------------------------------
CORMIX1: Submerged Single Port Discharges              End of Prediction File
11111111111111111111111111111111111111111111111111111111111111111111111111111
```

CHRONIC WINTER

```
CORMIX1 PREDICTION FILE:
1111111111111111111111111111111111111111111111111111111111111111111111111111111
                       CORNELL MIXING ZONE EXPERT SYSTEM
             Subsystem CORMIX1:  Submerged Single Port Discharges
 CORMIX-GI Version 4.1GT
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
CASE DESCRIPTION
 Site name/label:   SPOCFP New Location (12+00)
 Design case:       Winter Chronic
 FILE NAME:         I:\...degrees_deisgn_scenarios\Chronic_Winter_Run02.prd
 Time stamp:        Fri Apr  9 15:53:45 2004

ENVIRONMENT PARAMETERS (metric units)
 Bounded section
 BS    =     97.54  AS    =    347.83  QA    =     54.28  ICHREG= 1
 HA    =      3.57  HD    =      3.11
 UA    =      0.156 F     =      0.046 USTAR =0.1186E-01
 UW    =      2.000 UWSTAR=0.2198E-02
 Uniform density environment
 STRCND=  U         RHOAM =  999.8255

DISCHARGE PARAMETERS (metric units)
 BANK  =  RIGHT     DISTB =     44.81
 D0    =      0.762 A0    =      0.456 H0    =      0.84
 THETA =      0.00  SIGMA =    295.00
 U0    =      1.499 Q0    =      0.683       =0.6835E+00
 RHO0  =  998.7761  DRHO0 =0.1049E+01  GP0   =0.1029E-01
 C0    = 0.1000E+03 CUNITS=  mg/l
 IPOLL =  1         KS    =0.0000E+00  KD    =0.0000E+00

FLUX VARIABLES (metric units)
 Q0    =0.6835E+00  M0    =0.1024E+01  J0    =0.7035E-02  SIGNJ0=      1.0
 Associated length scales (meters)
 LQ    =      0.68  LM    =     12.14  Lm    =      6.49  Lb    =      1.85
                                       Lmp   =  99999.00  Lbp   =  99999.00

NON-DIMENSIONAL PARAMETERS
 FR0   =     16.92  R     =      9.60

FLOW CLASSIFICATION
 111111111111111111111111111111111111111111
 1  Flow class (CORMIX1)      =    H4-90A31
 1  Applicable layer depth HS =     3.11  1
 111111111111111111111111111111111111111111

MIXING ZONE / TOXIC DILUTION / REGION OF INTEREST PARAMETERS
 C0    = 0.1000E+03 CUNITS=  mg/l
 NTOX  =  0
 NSTD  =  0
 REGMZ =  1
 REGSPC=  2         XREG  =      0.00  WREG  =     24.38  AREG  =      0.00
 XINT  =    975.36  XMAX  =    975.36
```

```
X-Y-Z COORDINATE SYSTEM:
    ORIGIN is located at the bottom and below the center of the port:
        44.81 m  from the RIGHT bank/shore.
    X-axis points downstream, Y-axis points to left, Z-axis points upward.
NSTEP = 50 display intervals per module
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD101: DISCHARGE MODULE

 COANDA ATTACHMENT immediately following the discharge.

       X        Y       Z        S       C       B
      0.00     0.00    0.00     1.0 0.100E+03   0.54

END OF MOD101: DISCHARGE MODULE
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in weak crossflow.
 Bottom-attached jet motion.

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
            Half wall jet, attached to bottom.
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

       X        Y       Z        S       C       B
      0.00     0.00    0.00     1.0 0.100E+03   0.38
      0.15    -0.31    0.00     1.0 0.100E+03   0.43
      0.31    -0.64    0.00     1.0 0.100E+03   0.48
      0.48    -0.98    0.00     1.0 0.100E+03   0.52
      0.64    -1.28    0.00     1.0 0.100E+03   0.57
      0.82    -1.61    0.00     1.0 0.100E+03   0.62
      1.00    -1.93    0.00     1.1 0.928E+02   0.67
      1.19    -2.25    0.00     1.2 0.856E+02   0.72
      1.37    -2.54    0.00     1.3 0.799E+02   0.77
      1.57    -2.86    0.00     1.3 0.742E+02   0.82
      1.78    -3.17    0.00     1.4 0.692E+02   0.88
      1.97    -3.45    0.00     1.5 0.651E+02   0.93
      2.19    -3.76    0.00     1.6 0.610E+02   0.98
      2.41    -4.06    0.00     1.7 0.573E+02   1.04
      2.64    -4.35    0.00     1.9 0.539E+02   1.09
      2.85    -4.62    0.00     2.0 0.511E+02   1.15
      3.08    -4.91    0.00     2.1 0.482E+02   1.21
      3.33    -5.19    0.00     2.2 0.456E+02   1.26
      3.55    -5.45    0.00     2.3 0.434E+02   1.32
      3.80    -5.73    0.00     2.4 0.412E+02   1.38
      4.06    -6.00    0.00     2.6 0.391E+02   1.44
      4.32    -6.26    0.00     2.7 0.372E+02   1.50
      4.56    -6.51    0.00     2.8 0.356E+02   1.55
      4.83    -6.76    0.00     2.9 0.340E+02   1.61
      5.10    -7.02    0.00     3.1 0.324E+02   1.67
      5.36    -7.25    0.00     3.2 0.311E+02   1.73
      5.64    -7.49    0.00     3.4 0.298E+02   1.79
      5.93    -7.73    0.00     3.5 0.285E+02   1.85
```

```
      6.22    -7.97    0.00     3.7 0.274E+02   1.91
      6.48    -8.18    0.00     3.8 0.264E+02   1.97
      6.78    -8.40    0.00     3.9 0.253E+02   2.03
      7.08    -8.63    0.00     4.1 0.244E+02   2.09
      7.36    -8.83    0.00     4.2 0.236E+02   2.14
      7.66    -9.04    0.00     4.4 0.227E+02   2.20
      7.97    -9.25    0.00     4.6 0.219E+02   2.26
      8.28    -9.46    0.00     4.7 0.212E+02   2.31
      8.57    -9.64    0.00     4.9 0.205E+02   2.37
      8.89    -9.84    0.00     5.0 0.199E+02   2.42
      9.20   -10.03    0.00     5.2 0.192E+02   2.48
      9.50   -10.21    0.00     5.4 0.187E+02   2.53
      9.82   -10.39    0.00     5.5 0.181E+02   2.59
     10.15   -10.58    0.00     5.7 0.176E+02   2.64
     10.47   -10.76    0.00     5.9 0.171E+02   2.70
     10.78   -10.92    0.00     6.0 0.166E+02   2.74
     11.11   -11.09    0.00     6.2 0.162E+02   2.80
     11.44   -11.26    0.00     6.3 0.158E+02   2.85
     11.74   -11.41    0.00     6.5 0.154E+02   2.90
     12.08   -11.58    0.00     6.7 0.150E+02   2.95
     12.42   -11.74    0.00     6.8 0.146E+02   3.00
     12.76   -11.89    0.00     7.0 0.143E+02   3.05
     13.07   -12.04    0.00     7.2 0.140E+02   3.09
 Cumulative travel time =          29. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD152: LIFT OFF/FALL DOWN

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
   C = centerline concentration (includes reaction effects, if any)

  Inflow (attached) and outflow (free) conditions:
       X        Y       Z        S       C       B
     13.07   -12.04    0.00     7.2 0.140E+02   3.09
     18.70   -14.58    0.00     7.2 0.140E+02   2.18
 Cumulative travel time =          65. sec

END OF MOD152: LIFT OFF/FALL DOWN
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

 Jet/plume transition motion in weak crossflow.
 Plume-like motion after lift off/fall down.

 The WIDTH PREDICTION B in the first entry below may exhibit some mismatch
   (up to a factor of 1.5) relative to the last entry of the previous module.
   This is unavoidable due to differences in the width definitions.
   The actual physical transition will be smoothed out.

 Profile definitions:
   B = Gaussian 1/e (37%) half-width, normal to trajectory
   S = hydrodynamic centerline dilution
```

C = centerline concentration (includes reaction effects, if any)

X	Y	Z	S	C	B
18.70	-14.58	0.00	7.2	0.140E+02	1.73
18.80	-14.63	0.00	7.2	0.140E+02	1.75
18.98	-14.71	0.00	7.2	0.140E+02	1.77
19.12	-14.77	0.00	7.2	0.140E+02	1.79
19.23	-14.81	0.00	7.2	0.140E+02	1.81
19.37	-14.87	0.01	7.2	0.140E+02	1.83
19.51	-14.93	0.01	7.2	0.140E+02	1.85
19.66	-14.99	0.01	7.2	0.140E+02	1.87
19.80	-15.05	0.02	7.2	0.140E+02	1.88
19.94	-15.11	0.02	7.2	0.140E+02	1.90
20.08	-15.16	0.02	7.2	0.140E+02	1.92
20.23	-15.22	0.03	7.2	0.140E+02	1.94
20.37	-15.28	0.04	7.2	0.140E+02	1.96
20.52	-15.33	0.04	7.2	0.140E+02	1.98
20.66	-15.39	0.05	7.2	0.140E+02	1.99
20.84	-15.45	0.06	7.2	0.140E+02	2.02
20.99	-15.51	0.06	7.2	0.140E+02	2.04
21.13	-15.56	0.07	7.2	0.140E+02	2.05
21.28	-15.61	0.08	7.2	0.140E+02	2.07
21.42	-15.66	0.09	7.2	0.140E+02	2.09
21.57	-15.71	0.10	7.2	0.140E+02	2.10
21.71	-15.76	0.11	7.2	0.140E+02	2.12
21.86	-15.81	0.12	7.2	0.140E+02	2.14
22.00	-15.86	0.13	7.2	0.140E+02	2.16
22.15	-15.91	0.14	7.2	0.140E+02	2.17
22.30	-15.96	0.15	7.2	0.140E+02	2.19
22.44	-16.00	0.16	7.2	0.140E+02	2.20
22.59	-16.05	0.18	7.2	0.140E+02	2.22
22.74	-16.10	0.19	7.2	0.140E+02	2.24
22.88	-16.14	0.20	7.2	0.140E+02	2.25
23.03	-16.19	0.21	7.2	0.139E+02	2.27
23.18	-16.23	0.23	7.3	0.138E+02	2.28
23.32	-16.28	0.24	7.3	0.136E+02	2.30
23.47	-16.32	0.26	7.4	0.135E+02	2.32
23.62	-16.37	0.27	7.5	0.133E+02	2.33
23.76	-16.41	0.28	7.6	0.132E+02	2.35
23.91	-16.45	0.30	7.7	0.131E+02	2.36
24.06	-16.50	0.32	7.7	0.129E+02	2.38
24.21	-16.54	0.33	7.8	0.128E+02	2.39
24.36	-16.58	0.35	7.9	0.127E+02	2.41
24.50	-16.62	0.36	8.0	0.125E+02	2.42
24.65	-16.66	0.38	8.1	0.124E+02	2.44
24.80	-16.70	0.40	8.1	0.123E+02	2.45
24.95	-16.74	0.41	8.2	0.122E+02	2.47
25.09	-16.78	0.43	8.3	0.120E+02	2.48
25.24	-16.82	0.45	8.4	0.119E+02	2.50
25.39	-16.86	0.47	8.5	0.118E+02	2.51
25.54	-16.90	0.49	8.5	0.117E+02	2.53
25.69	-16.94	0.51	8.6	0.116E+02	2.54
25.84	-16.98	0.53	8.7	0.115E+02	2.55
25.98	-17.01	0.54	8.8	0.114E+02	2.56

Cumulative travel time = 90. sec

END OF CORJET (MOD110): JET/PLUME NEAR-FIELD MIXING REGION

```
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
BEGIN MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH

  Control volume inflow:
       X        Y       Z        S       C       B
     25.98   -17.01    0.54     8.8 0.114E+02   2.56

 Profile definitions:
   BV = top-hat thickness, measured vertically
   BH = top-hat half-width, measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
   S  = hydrodynamic average (bulk) dilution
   C  = average (bulk) concentration (includes reaction effects, if any)

       X        Y       Z        S       C       BV       BH      ZU      ZL
     23.50   -16.70    3.11     8.8 0.114E+02   0.00     0.00    3.11    3.11
     24.26   -16.80    3.11     8.8 0.114E+02   1.96     3.32    3.11    1.15
     25.02   -16.89    3.11     8.8 0.114E+02   2.32     4.69    3.11    0.79
     25.78   -16.99    3.11     8.8 0.114E+02   2.55     5.75    3.11    0.56
     26.54   -17.08    3.11     9.0 0.111E+02   2.72     6.64    3.11    0.39
     27.31   -17.18    3.11    10.2 0.981E+01   2.85     7.42    3.11    0.26
     28.07   -17.28    3.11    11.7 0.853E+01   2.95     8.13    3.11    0.16
     28.83   -17.37    3.11    13.1 0.763E+01   3.02     8.78    3.11    0.09
     29.59   -17.47    3.11    14.0 0.712E+01   3.07     9.39    3.11    0.04
     30.35   -17.56    3.11    14.6 0.687E+01   3.10     9.95    3.11    0.01
     31.11   -17.66    3.11    14.9 0.671E+01   3.11    10.49    3.11    0.00
 Cumulative travel time =         123. sec

END OF MOD131: LAYER BOUNDARY/TERMINAL LAYER APPROACH
-------------------------------------------------------------------------------
** End of NEAR-FIELD REGION (NFR) **
-------------------------------------------------------------------------------
BEGIN MOD141: BUOYANT AMBIENT SPREADING

 Profile definitions:
   BV = top-hat thickness, measured vertically
   BH = top-hat half-width, measured horizontally in Y-direction
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
   S  = hydrodynamic average (bulk) dilution
   C  = average (bulk) concentration (includes reaction effects, if any)

 Plume Stage 1 (not bank attached):
       X        Y       Z        S       C       BV       BH      ZU      ZL
     31.11   -17.66    3.11    14.9 0.671E+01   3.11    10.49    3.11    0.00
     33.25   -17.66    3.11    15.1 0.664E+01   3.02    10.93    3.11    0.09
     35.40   -17.66    3.11    15.2 0.657E+01   2.93    11.36    3.11    0.18
     37.54   -17.66    3.11    15.4 0.650E+01   2.86    11.78    3.11    0.25
 ** REGULATORY MIXING ZONE BOUNDARY **
 In this prediction interval the TOTAL plume width meets or exceeds
   the regulatory value =    24.38 m.
 This is the extent of the REGULATORY MIXING ZONE.
     39.68   -17.66    3.11    15.5 0.644E+01   2.79    12.20    3.11    0.32
     41.82   -17.66    3.11    15.7 0.638E+01   2.72    12.61    3.11    0.39
     43.96   -17.66    3.11    15.8 0.632E+01   2.66    13.01    3.11    0.45
```

46.10	-17.66	3.11	15.9	0.627E+01	2.61	13.40	3.11	0.50
48.24	-17.66	3.11	16.1	0.622E+01	2.55	13.79	3.11	0.56
50.38	-17.66	3.11	16.2	0.617E+01	2.50	14.18	3.11	0.60
52.53	-17.66	3.11	16.3	0.612E+01	2.46	14.56	3.11	0.65
54.67	-17.66	3.11	16.5	0.607E+01	2.42	14.93	3.11	0.69
56.81	-17.66	3.11	16.6	0.603E+01	2.38	15.30	3.11	0.73
58.95	-17.66	3.11	16.7	0.598E+01	2.34	15.66	3.11	0.77
61.09	-17.66	3.11	16.8	0.594E+01	2.30	16.02	3.11	0.81
63.23	-17.66	3.11	17.0	0.589E+01	2.27	16.38	3.11	0.84
65.37	-17.66	3.11	17.1	0.585E+01	2.24	16.73	3.11	0.87
67.52	-17.66	3.11	17.2	0.581E+01	2.21	17.08	3.11	0.90
69.66	-17.66	3.11	17.3	0.577E+01	2.18	17.43	3.11	0.93
71.80	-17.66	3.11	17.4	0.573E+01	2.15	17.77	3.11	0.96
73.94	-17.66	3.11	17.6	0.570E+01	2.12	18.11	3.11	0.99
76.08	-17.66	3.11	17.7	0.566E+01	2.10	18.44	3.11	1.01
78.22	-17.66	3.11	17.8	0.562E+01	2.07	18.78	3.11	1.03
80.36	-17.66	3.11	17.9	0.559E+01	2.05	19.11	3.11	1.06
82.50	-17.66	3.11	18.0	0.555E+01	2.03	19.43	3.11	1.08
84.65	-17.66	3.11	18.1	0.551E+01	2.01	19.76	3.11	1.10
86.79	-17.66	3.11	18.3	0.548E+01	1.99	20.08	3.11	1.12
88.93	-17.66	3.11	18.4	0.544E+01	1.97	20.40	3.11	1.14
91.07	-17.66	3.11	18.5	0.541E+01	1.95	20.71	3.11	1.15
93.21	-17.66	3.11	18.6	0.538E+01	1.94	21.03	3.11	1.17
95.35	-17.66	3.11	18.7	0.534E+01	1.92	21.34	3.11	1.19
97.49	-17.66	3.11	18.8	0.531E+01	1.91	21.65	3.11	1.20
99.64	-17.66	3.11	18.9	0.528E+01	1.89	21.95	3.11	1.22
101.78	-17.66	3.11	19.1	0.524E+01	1.88	22.26	3.11	1.23
103.92	-17.66	3.11	19.2	0.521E+01	1.86	22.56	3.11	1.25
106.06	-17.66	3.11	19.3	0.518E+01	1.85	22.86	3.11	1.26
108.20	-17.66	3.11	19.4	0.515E+01	1.84	23.16	3.11	1.27
110.34	-17.66	3.11	19.5	0.512E+01	1.82	23.46	3.11	1.28
112.48	-17.66	3.11	19.7	0.509E+01	1.81	23.75	3.11	1.30
114.62	-17.66	3.11	19.8	0.505E+01	1.80	24.05	3.11	1.31
116.77	-17.66	3.11	19.9	0.502E+01	1.79	24.34	3.11	1.32
118.91	-17.66	3.11	20.0	0.499E+01	1.78	24.63	3.11	1.33
121.05	-17.66	3.11	20.2	0.496E+01	1.77	24.91	3.11	1.34
123.19	-17.66	3.11	20.3	0.493E+01	1.76	25.20	3.11	1.35
125.33	-17.66	3.11	20.4	0.490E+01	1.75	25.48	3.11	1.36
127.47	-17.66	3.11	20.5	0.487E+01	1.74	25.77	3.11	1.36
129.61	-17.66	3.11	20.7	0.484E+01	1.74	26.05	3.11	1.37
131.76	-17.66	3.11	20.8	0.481E+01	1.73	26.33	3.11	1.38
133.90	-17.66	3.11	20.9	0.478E+01	1.72	26.61	3.11	1.39
136.04	-17.66	3.11	21.0	0.475E+01	1.71	26.88	3.11	1.39
138.18	-17.66	3.11	21.2	0.472E+01	1.71	27.16	3.11	1.40

Cumulative travel time = 800. sec

Plume is ATTACHED to RIGHT bank/shore.
Plume width is now determined from RIGHT bank/shore.

Plume Stage 2 (bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
138.18	-44.81	3.11	21.2	0.472E+01	1.71	54.29	3.11	1.40
146.19	-44.81	3.11	21.6	0.463E+01	1.71	55.31	3.11	1.40
154.20	-44.81	3.11	22.0	0.455E+01	1.71	56.31	3.11	1.40
162.20	-44.81	3.11	22.4	0.446E+01	1.71	57.31	3.11	1.40
170.21	-44.81	3.11	22.8	0.438E+01	1.71	58.30	3.11	1.39

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   178.22   -44.81    3.11    23.3 0.430E+01   1.72    59.28    3.11    1.39
   186.23   -44.81    3.11    23.7 0.421E+01   1.72    60.25    3.11    1.39
   194.24   -44.81    3.11    24.2 0.413E+01   1.73    61.22    3.11    1.38
   202.25   -44.81    3.11    24.7 0.405E+01   1.74    62.18    3.11    1.37
   210.25   -44.81    3.11    25.1 0.398E+01   1.74    63.13    3.11    1.36
   218.26   -44.81    3.11    25.6 0.390E+01   1.75    64.07    3.11    1.36
   226.27   -44.81    3.11    26.2 0.382E+01   1.76    65.00    3.11    1.35
   234.28   -44.81    3.11    26.7 0.375E+01   1.77    65.93    3.11    1.34
   242.29   -44.81    3.11    27.2 0.368E+01   1.78    66.85    3.11    1.33
   250.29   -44.81    3.11    27.8 0.360E+01   1.79    67.77    3.11    1.32
   258.30   -44.81    3.11    28.3 0.353E+01   1.80    68.68    3.11    1.30
   266.31   -44.81    3.11    28.9 0.346E+01   1.82    69.58    3.11    1.29
   274.32   -44.81    3.11    29.5 0.339E+01   1.83    70.48    3.11    1.28
   282.33   -44.81    3.11    30.1 0.333E+01   1.84    71.37    3.11    1.27
   290.34   -44.81    3.11    30.7 0.326E+01   1.86    72.26    3.11    1.25
   298.34   -44.81    3.11    31.3 0.320E+01   1.87    73.14    3.11    1.24
   306.35   -44.81    3.11    31.9 0.313E+01   1.89    74.02    3.11    1.22
   314.36   -44.81    3.11    32.6 0.307E+01   1.90    74.89    3.11    1.21
   322.37   -44.81    3.11    33.2 0.301E+01   1.92    75.75    3.11    1.19
   330.38   -44.81    3.11    33.9 0.295E+01   1.94    76.61    3.11    1.17
   338.39   -44.81    3.11    34.6 0.289E+01   1.95    77.47    3.11    1.15
   346.39   -44.81    3.11    35.3 0.283E+01   1.97    78.32    3.11    1.14
   354.40   -44.81    3.11    36.0 0.278E+01   1.99    79.16    3.11    1.12
   362.41   -44.81    3.11    36.7 0.272E+01   2.01    80.00    3.11    1.10
   370.42   -44.81    3.11    37.5 0.267E+01   2.03    80.84    3.11    1.08
   378.43   -44.81    3.11    38.2 0.262E+01   2.05    81.67    3.11    1.06
   386.44   -44.81    3.11    39.0 0.257E+01   2.07    82.50    3.11    1.04
   394.44   -44.81    3.11    39.8 0.251E+01   2.09    83.33    3.11    1.02
   402.45   -44.81    3.11    40.6 0.247E+01   2.11    84.15    3.11    1.00
   410.46   -44.81    3.11    41.4 0.242E+01   2.13    84.96    3.11    0.98
   418.47   -44.81    3.11    42.2 0.237E+01   2.15    85.78    3.11    0.96
   426.48   -44.81    3.11    43.0 0.232E+01   2.18    86.59    3.11    0.93
   434.48   -44.81    3.11    43.9 0.228E+01   2.20    87.39    3.11    0.91
   442.49   -44.81    3.11    44.8 0.223E+01   2.22    88.19    3.11    0.89
   450.50   -44.81    3.11    45.6 0.219E+01   2.25    88.99    3.11    0.86
   458.51   -44.81    3.11    46.5 0.215E+01   2.27    89.78    3.11    0.84
   466.52   -44.81    3.11    47.5 0.211E+01   2.29    90.57    3.11    0.82
   474.53   -44.81    3.11    48.4 0.207E+01   2.32    91.36    3.11    0.79
   482.53   -44.81    3.11    49.3 0.203E+01   2.34    92.15    3.11    0.77
   490.54   -44.81    3.11    50.3 0.199E+01   2.37    92.93    3.11    0.74
   498.55   -44.81    3.11    51.3 0.195E+01   2.39    93.70    3.11    0.71
   506.56   -44.81    3.11    52.2 0.191E+01   2.42    94.48    3.11    0.69
   514.57   -44.81    3.11    53.2 0.188E+01   2.45    95.25    3.11    0.66
   522.58   -44.81    3.11    54.3 0.184E+01   2.47    96.02    3.11    0.63
   530.58   -44.81    3.11    55.3 0.181E+01   2.50    96.78    3.11    0.61
   538.59   -44.81    3.11    56.3 0.177E+01   2.53    97.54    3.11    0.58
 Cumulative travel time =        3334. sec
 Plume is LATERALLY FULLY MIXED at the end of the buoyant spreading regime.

END OF MOD141: BUOYANT AMBIENT SPREADING
-------------------------------------------------------------------------------
 Bottom coordinate for FAR-FIELD is determined by average depth, ZFB = -0.46m
-------------------------------------------------------------------------------
BEGIN MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT

  Vertical diffusivity (initial value)   = 0.740E-02 m^2/s
  Horizontal diffusivity (initial value) = 0.924E-02 m^2/s
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Profile definitions:
  BV = Gaussian s.d.*sqrt(pi/2) (46%) thickness, measured vertically
     = or equal to layer depth, if fully mixed
  BH = Gaussian s.d.*sqrt(pi/2) (46%) half-width,
       measured horizontally in Y-direction
  ZU = upper plume boundary (Z-coordinate)
  ZL = lower plume boundary (Z-coordinate)
  S  = hydrodynamic centerline dilution
  C  = centerline concentration (includes reaction effects, if any)

Plume Stage 2 (bank attached):
      X        Y       Z        S       C       BV       BH      ZU      ZL
   538.59   -44.81    3.11    56.3 0.177E+01   2.53    97.54    3.11    0.58
   547.33   -44.81    3.11    57.0 0.176E+01   2.56    97.54    3.11    0.55
   556.06   -44.81    3.11    57.6 0.174E+01   2.58    97.54    3.11    0.53
   564.80   -44.81    3.11    58.2 0.172E+01   2.61    97.54    3.11    0.50
   573.53   -44.81    3.11    58.8 0.170E+01   2.64    97.54    3.11    0.47
   582.27   -44.81    3.11    59.5 0.168E+01   2.67    97.54    3.11    0.44
   591.00   -44.81    3.11    60.1 0.166E+01   2.70    97.54    3.11    0.41
   599.74   -44.81    3.11    60.8 0.165E+01   2.73    97.54    3.11    0.38
   608.47   -44.81    3.11    61.4 0.163E+01   2.76    97.54    3.11    0.35
   617.21   -44.81    3.11    62.1 0.161E+01   2.79    97.54    3.11    0.32
   625.95   -44.81    3.11    62.8 0.159E+01   2.82    97.54    3.11    0.29
   634.68   -44.81    3.11    63.5 0.158E+01   2.85    97.54    3.11    0.26
   643.42   -44.81    3.11    64.2 0.156E+01   2.88    97.54    3.11    0.23
   652.15   -44.81    3.11    64.9 0.154E+01   2.91    97.54    3.11    0.20
   660.89   -44.81    3.11    65.6 0.152E+01   2.95    97.54    3.11    0.16
   669.62   -44.81    3.11    66.4 0.151E+01   2.98    97.54    3.11    0.13
   678.36   -44.81    3.11    67.1 0.149E+01   3.01    97.54    3.11    0.10
   687.09   -44.81    3.11    67.8 0.147E+01   3.04    97.54    3.11    0.06
   695.83   -44.81    3.11    68.6 0.146E+01   3.08    97.54    3.11    0.03
   704.56   -44.81    3.11    69.4 0.144E+01   3.11    97.54    3.11    0.00
   713.30   -44.81    3.11    70.2 0.143E+01   3.15    97.54    3.11   -0.04
   722.03   -44.81    3.11    70.9 0.141E+01   3.18    97.54    3.11   -0.07
   730.77   -44.81    3.11    71.7 0.139E+01   3.22    97.54    3.11   -0.11
   739.50   -44.81    3.11    72.5 0.138E+01   3.26    97.54    3.11   -0.15
   748.24   -44.81    3.11    73.4 0.136E+01   3.29    97.54    3.11   -0.18
   756.98   -44.81    3.11    74.2 0.135E+01   3.33    97.54    3.11   -0.22
   765.71   -44.81    3.11    75.0 0.133E+01   3.37    97.54    3.11   -0.26
   774.45   -44.81    3.11    75.9 0.132E+01   3.40    97.54    3.11   -0.30
   783.18   -44.81    3.11    76.7 0.130E+01   3.44    97.54    3.11   -0.33
   791.92   -44.81    3.11    77.6 0.129E+01   3.48    97.54    3.11   -0.37
   800.65   -44.81    3.11    78.4 0.127E+01   3.52    97.54    3.11   -0.41
   809.39   -44.81    3.11    79.3 0.126E+01   3.56    97.54    3.11   -0.45
Plume interacts with BOTTOM.
The passive diffusion plume becomes VERTICALLY FULLY MIXED within this
  prediction interval.
   818.12   -44.81    3.11    79.5 0.126E+01   3.57    97.54    3.11   -0.46
Effluent is FULLY MIXED over the entire channel cross-section.
Except for possible far-field decay or reaction processes, there are
    NO FURTHER CHANGES with downstream direction.
   826.86   -44.81    3.11    79.5 0.126E+01   3.57    97.54    3.11   -0.46
   835.59   -44.81    3.11    79.5 0.126E+01   3.57    97.54    3.11   -0.46
   844.33   -44.81    3.11    79.5 0.126E+01   3.57    97.54    3.11   -0.46
   853.06   -44.81    3.11    79.5 0.126E+01   3.57    97.54    3.11   -0.46
   861.80   -44.81    3.11    79.5 0.126E+01   3.57    97.54    3.11   -0.46
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    870.53   -44.81    3.11    79.5 0.126E+01   3.57    97.54    3.11   -0.46
    879.27   -44.81    3.11    79.5 0.126E+01   3.57    97.54    3.11   -0.46
    888.01   -44.81    3.11    79.5 0.126E+01   3.57    97.54    3.11   -0.46
    896.74   -44.81    3.11    79.5 0.126E+01   3.57    97.54    3.11   -0.46
    905.48   -44.81    3.11    79.5 0.126E+01   3.57    97.54    3.11   -0.46
    914.21   -44.81    3.11    79.5 0.126E+01   3.57    97.54    3.11   -0.46
    922.95   -44.81    3.11    79.5 0.126E+01   3.57    97.54    3.11   -0.46
    931.68   -44.81    3.11    79.5 0.126E+01   3.57    97.54    3.11   -0.46
    940.42   -44.81    3.11    79.5 0.126E+01   3.57    97.54    3.11   -0.46
    949.15   -44.81    3.11    79.5 0.126E+01   3.57    97.54    3.11   -0.46
    957.89   -44.81    3.11    79.5 0.126E+01   3.57    97.54    3.11   -0.46
    966.62   -44.81    3.11    79.5 0.126E+01   3.57    97.54    3.11   -0.46
    975.36   -44.81    3.11    79.5 0.126E+01   3.57    97.54    3.11   -0.46
 Cumulative travel time =        6098. sec

 Simulation limit based on maximum specified distance =    975.36 m.
   This is the REGION OF INTEREST limitation.

END OF MOD161: PASSIVE AMBIENT MIXING IN UNIFORM AMBIENT
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-------------------------------------------------------------------------------
CORMIX1: Submerged Single Port Discharges              End of Prediction File
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