Technical Memorandum

PO Box 1678 • Tacoma, WA 98401-1678
711 Pacific Avenue • Tacoma, WA 98402
Phone (253) 272-7220 • Fax (253) 272-7250
bfox@cosmopolitaneng.com

TM TITLE:	**RIVPLUM5 Validation Study**
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TO:	John Lenth, Herrera Environmental
PREPARED BY:	Bill Fox, PE, Cosmopolitan Engineering Group Matt DeBoer, PE, Cosmopolitan Engineering Group
REVIEWED BY:	David McBride, PE, Cosmopolitan Engineering Group
PROJECT #:	HER001

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INTRODUCTION

RIVPLUM5.xls is an Excel spreadsheet model available from Ecology's website (http://www.ecy.wa.gov/programs/eap/pwspread/pwspread.html) that may be used to determine farfield dilution factors for discharges to surface waters. The model is based on the solution to the two-dimensional advection-dispersion equation as described in Fischer *et al* (1979) and cited in EPA's *Technical Support Document for Water Quality-based Toxics Control* (EPA, 1991) and Ecology's *Water Quality Program Permit Writer's Manual, Appendix 6* (Bailey, 1998).

PURPOSE AND SCOPE

The purpose of this Technical Memorandum (TM) is to compare the predictions of RIVPLUM5 to past dye tracer studies that have been conducted by staff of Cosmopolitan Engineering Group (CEG). This TM includes the following:

- Description of RIVPLUM5 model construct, limitations and variations

- Screening of dye tracer studies conducted by Cosmopolitan Engineering staff for the purpose of comparing to RIVPLUM5

- Detailed comparison of dye tracer study results to RIVPLUM5 predictions for six cases deemed applicable

- Conclusions and general discussion of RIVPLUM5 applicability and alternatives

RIVPLUM5 DESCRIPTION

RIVPLUM5 is an Excel spreadsheet adaptation by Ecology of a LOTUS 123 spreadsheet developed by the author (Bill Fox) in 1995 and applied originally to the City of Enumclaw Wastewater Treatment Plant (WWTP) outfall. The model is based on the following solution to the two-dimensional advection-dispersion equation, is presented in Equation 5.7 of Fischer *et al* (1979):

$$C = \frac{M}{ud\sqrt{4\pi\varepsilon_t \frac{x}{u}}} \exp\left\{\frac{-y^2 u}{4\varepsilon_t x}\right\}$$

Where:
C = Concentration of constituent at point of interest
M = Mass discharge rate
x = downstream distance
y = lateral, or cross-stream distance
u = current speed in x-direction
d = stream depth
ε_t = transverse dispersion coefficient

This equation can be transformed from units of mass discharge rate and concentration to units of effluent flow rate and dilution factor, as presented in the RIVPLUM5 documentation. The basic equation above is mass-based, and does not reflect or consider any nearfield mixing that occurs due to jet velocity or buoyancy effects of an effluent discharge. Nearfield models that consider these factors are described in Ecology guidance. The RIVPLUM5 model is correctly classified in the Ecology guidance document as a farfield model, subject to the following limitations (Ecology, 2008):

1. The discharge is a single point source, which is most appropriate for single-port or short diffusers, or for side-bank discharges.

2. The discharge is completely and rapidly mixed vertically, which usually only occurs in shallow rivers.

3. There is no significant transverse variation in the velocity field (*e.g.* gyres and eddies).

As a condition of accepting RIVPLUM5 model results, Ecology will typically require some verification that the second and third criteria above are met. While the point source limitation is inherent to RIVPLUM5, Cosmopolitan Engineering Group has developed hybrid spreadsheet models that use the same equations and the principal of superposition to assess farfield mixing from multiport diffusers. Additionally, discharges that are not vertically mixed can be simulated using the three-dimensional solution to the advection-dispersion equation. These options are evaluated separately in this TM, following the direct RIVPLUM5 comparison.

TRACER STUDY TEST CASES

Cosmopolitan Engineering Group staff have completed 40 dye tracer studies of NPDES-permitted discharges to surface waters in Washington and Oregon.

Six of these projects have been selected for the RIVPLUM5 comparison to tracer study results. The six discharges selected for this study are City of Arlington, City of Mount Vernon, City of Ridgefield, Portland Airport, City of Grants Pass, and City of Camas. The rationale for selecting these projects is summarized below:

- Studies that used a tracer other than Rhodamine WT dye were rejected because the results are not as precise.

- RIVPLUM5 is designed for single port discharges, so projects with multiport diffusers were rejected for direct comparison to the model.

- Discharges to salt water were rejected because RIVPLUM5 does not account for buoyant plume mixing, which is typically very significant.

- Discharges to deep water that were not completely mixed vertically at the point of the tracer study measurements were rejected.

- Discharges to steady-flowing ambient are preferred in order to avoid tidal variability.

- The most recent studies are preferred because of advances in fluorometric measuring equipment and data processing capabilities.

The Arlington and Mount Vernon are the most directly-applicable projects that meet all of the selection criteria. Ridgefield and the Portland Airport project also are appropriate comparisons, but these studies were conducted on simulated discharges rather than actual discharges. Grants Pass and Camas have multiport diffusers, and thus cannot be directly compared to RIVPLUM5. However, we have chosen to evaluate and present the tracer results for these projects to the custom 3-D spreadsheet models used by Cosmopolitan Engineering that are based on the same fundamental equations.

CASE 1 – CITY OF ARLINGTON

A dye tracer study of the City of Arlington WWTP discharge to the Stillaguamish River was performed August 22, 2006 and documented in a *Mixing Zone Study* report (CEG, November 2006, revised May 2007). The field study included injection of Rhodamine WT dye into the WWTP effluent at a known concentration; collection of bottled fluorescence samples from within the effluent plume; and measurement of river bathymetry, width, and current velocity.

DISCHARGE DESCRIPTION

Effluent from the Arlington WWTP is discharged to the mainstem of the Stillaguamish River at River Mile 17.7, approximately 500 feet below the confluence of the North and South Forks. At seasonal low flow conditions observed during the dye study, the river was approximately 121 feet wide with an average depth of 4 feet. Average current speeds, measured with a Swoffer meter, were 1.5 feet per second (fps). The river channel is relatively straight and uniform downstream of the outfall, and river cross-section bathymetry is similar at other locations up to 500 feet downstream of the outfall.

The outfall consists of a single port discharge (12-inch-diameter) discharging horizontally at the river bottom. The outfall discharge is located approximately 52 feet from the left (south) bank at an invert depth of 4.61 feet during low flow conditions. Appendix A contains plan and profile record drawings of the outfall. Effluent discharge flow through the outfall was 2.2 million gallons per day (mgd) during the study.

DYE TRACER STUDY RESULTS

Figure 1 shows the effluent volume fraction plume centerline profiles at distances of 30 feet, 50 feet, 100 feet, and 304 feet downstream of the outfall. Except for the 50-foot distance, centerline profiles were measured over two time periods to better represent the time varying nature of the plume.

The 30-foot centerline profile shows both the unsteady nature of the plume at the acute mixing zone boundary, and incomplete vertical mixing. Visual observation of the plume behavior confirms these results. The plume was observed to rise from the river bottom immediately following discharge to approximately river mid-depth, and was relatively unsteady with a billowing nature (wandering back and forth across river within a prescribed area).

At 50 feet from the outfall, the effluent volume fraction profile shows complete vertical mixing has still not occurred, as the plume centerline is still apparent near mid-depth. The plume has risen slightly higher, with greater effluent concentrations observed near the surface than river bottom.

Between 100 and 304 feet from the outfall, complete vertical mixing of the plume was visually observed to occur, and the billowing nature of the effluent plume was less apparent. These observations are confirmed in the effluent volume fraction profiles at the mixing zone boundary (304 feet downstream), where both time period results are nearly indistinguishable, and effluent concentrations are nearly uniform from the top to bottom of the water column.

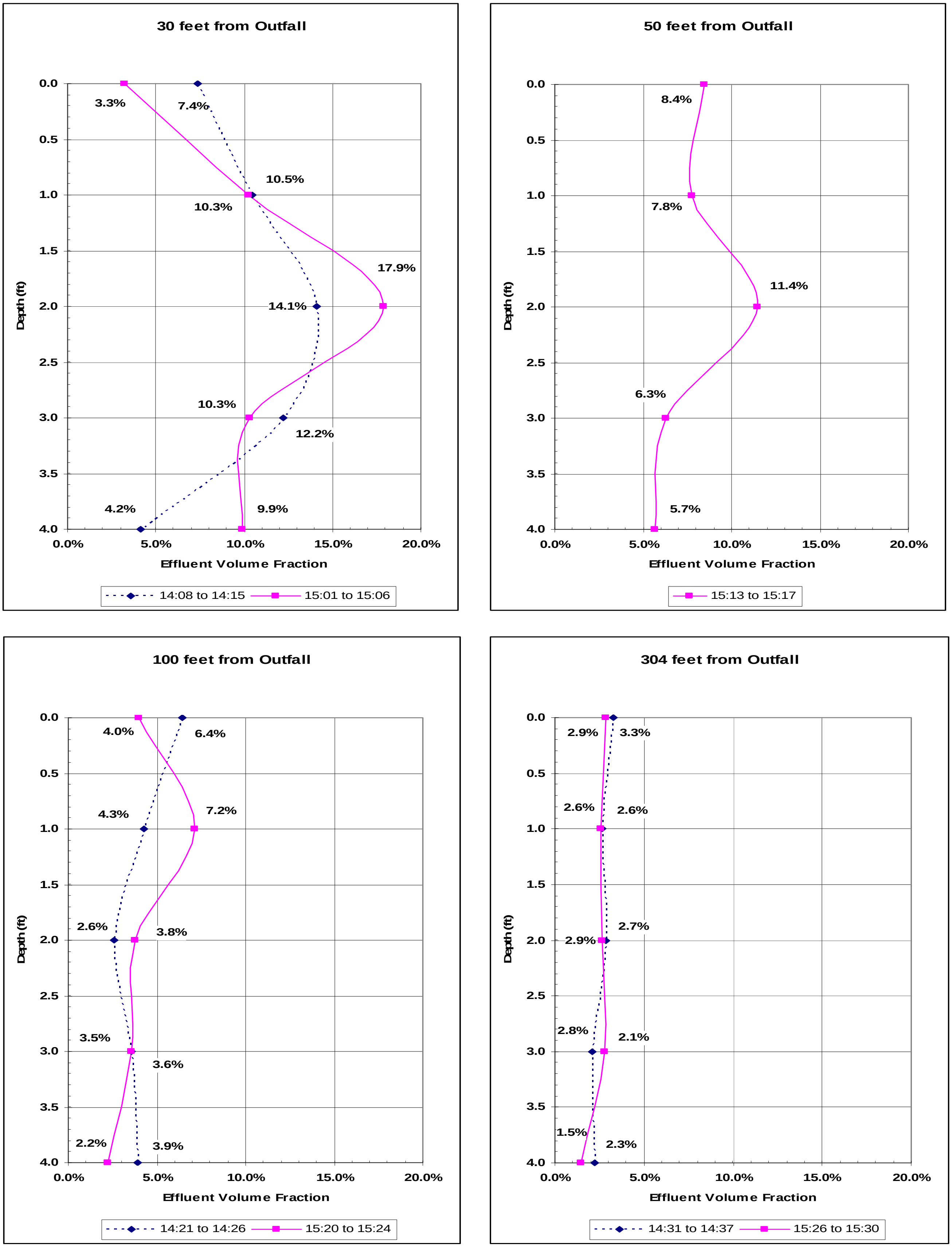


Figure 1 Effluent Volume Fraction Profiles at Plume Centerline

Figure 2 shows plume centerline dilution ratios versus distance from the outfall. Depth averaged dilution ratios are provided for each distance where profile data is available. Best fit lines are drawn to predict minimum dilution ratio versus distance from the outfall. Jet-momentum and buoyancy effects are believed to end from 50 to 60 feet from the outfall. This defines the near-field mixing region.

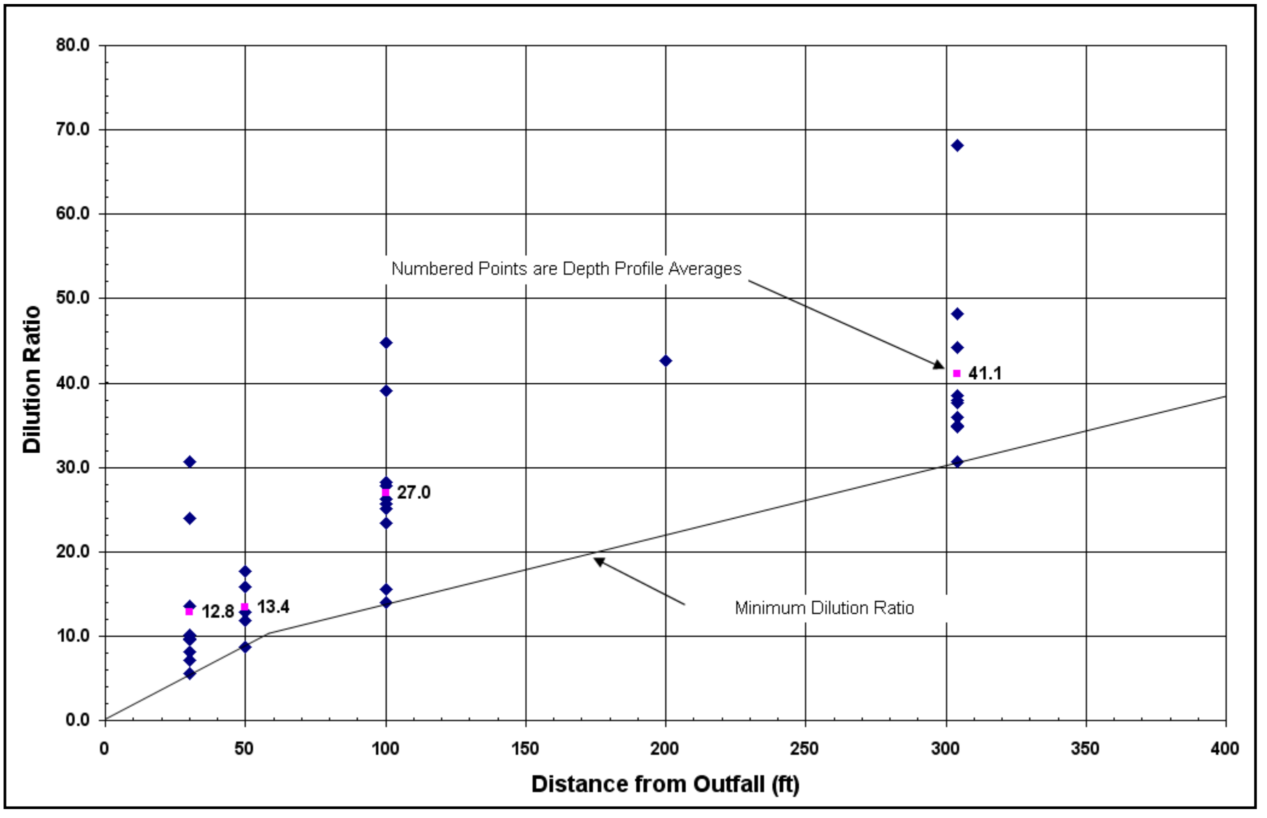


Figure 2 Dilution at Plume Centerline vs. Downstream Distance from Outfall

Dilution ratios shown in Figure 2 are summarized in Table 2. Plume widths observed during the study are also included in Table 1.

Table 1 Tracer Study Results

Distance from Outfall (ft)	Minimum Dilution Factor	Water Column Average Dilution Factor at Plume Centerline	Plume Width Range
30	5.6	12.8	4.4 ft to 6.0 ft
50	8.7	13.4	6.2 ft to 7.0 ft
100	14.0	27.0	13 ft to 15 ft
304	30.6	41.1	28 ft to 30 ft

RIVPLUM5 MODEL RESULTS

Table 2 compares RIVPLUM5 model results to the observed dye tracer study results. RIVPLUM5 model input and output are provided in Appendix B. Model runs were performed using the default Transverse Mixing Coefficient Constant (TMCC) equal to 0.6. As shown in Table 2, RIVPLUM5 model results slightly overpredict dilution observed in the intermediate field (30 to 50 feet downstream) because vertical mixing was incomplete, as stated earlier. In general, model predictions become more accurate with distance from the discharge, as the actual conditions more closely match RIVPLUM5 applicability criteria.

Table 2 RIVPLUM5 Model Results – City of Arlington Mixing Zone Study

Distance from Outfall (feet)	Field Study Dilution Results	RIVPLUM Dilution Predictions at Plume Centerline	
	Depth/Time Averaged Dilution Factor	Default TMCC (TMCC = 0.6)	Percent Difference
30	12.8	14.7	+ 14.8%
50	13.4	18.9	+ 41.0%
100	27.0	26.8	- 0.7%
304	41.1	46.7	+ 13.6%

CASE 2 – CITY OF MOUNT VERNON

A dye tracer study of the City of Mount Vernon WWTP discharge to the Skagit River was performed August 14, 2007 and documented in a *Mixing Zone Study* report (CEG, July 2008). The field study included injection of Rhodamine WT dye into the effluent, and collection of in-situ fluorescence concentrations, current velocity, and conductivity, temperature, and depth (CTD) profile data.

DISCHARGE DESCRIPTION

Effluent from the Mount Vernon WWTP is discharged to the Skagit River at River Mile 10.7. At seasonal low flow conditions observed during the dye study, the outfall discharge was at a depth of approximately 12.7 feet while the river was approximately 281 feet wide.

The outfall is a single port discharge, terminating in a 36-inch Tideflex® check valve located approximately 44 feet from the left (south) river bank at low flow conditions. The check valve is oriented 45 degrees downstream and approximately 22.5 degrees above horizontal to maximize initial mixing near the discharge point. Appendix A contains plan and profile design drawings of the outfall. Average effluent discharge flow through the outfall was 3.44 mgd during the study, with minimum and maximum values of 3.25 mgd and 3.68 mgd, respectively.

DYE TRACER STUDY RESULTS

In-situ fluorescence concentration measurements were collected from a boat piloted throughout the mixing zone. Sampling focused primarily at the chronic mixing zone boundary (313 feet downstream). Three sampling methods were used, described as follows:

- Horizontal transects were collected by towing the fluorometer laterally across the chronic mixing zone boundary at discrete depth ranges, bracketing and including the depth of maximum concentration. Edges of the plume were found and sampling continued until the riverbank was reached or background concentrations were observed.

- Vertical profiles were collected by raising and lowering the fluorometer through the water column while the sample boat was stationary.

- Time series measurements were made at discrete depth ranges by holding the fluorometer at the observed horizontal plume centerline location for several minutes.

Horizontal Transect Results

The effluent plume was observed to be spatially and temporally unsteady, with discrete "puffs" or "patches" of effluent at various sizes and concentration distributions migrating downstream. The unsteady nature of effluent plumes accounts for the high degree of effluent concentration fluctuation seen. In addition, the Skagit River is relatively deep and vertical mixing does not occur as rapidly as it would in a shallower river, such as in the Stillaguamish River (Case 1). The high degree of unsteadiness appeared at all transect depths.

Figure 3 presents data compiled from a combination of the measured transects at the chronic mixing zone boundary, and illustrates the discrete "patches" of dye measured throughout the study.

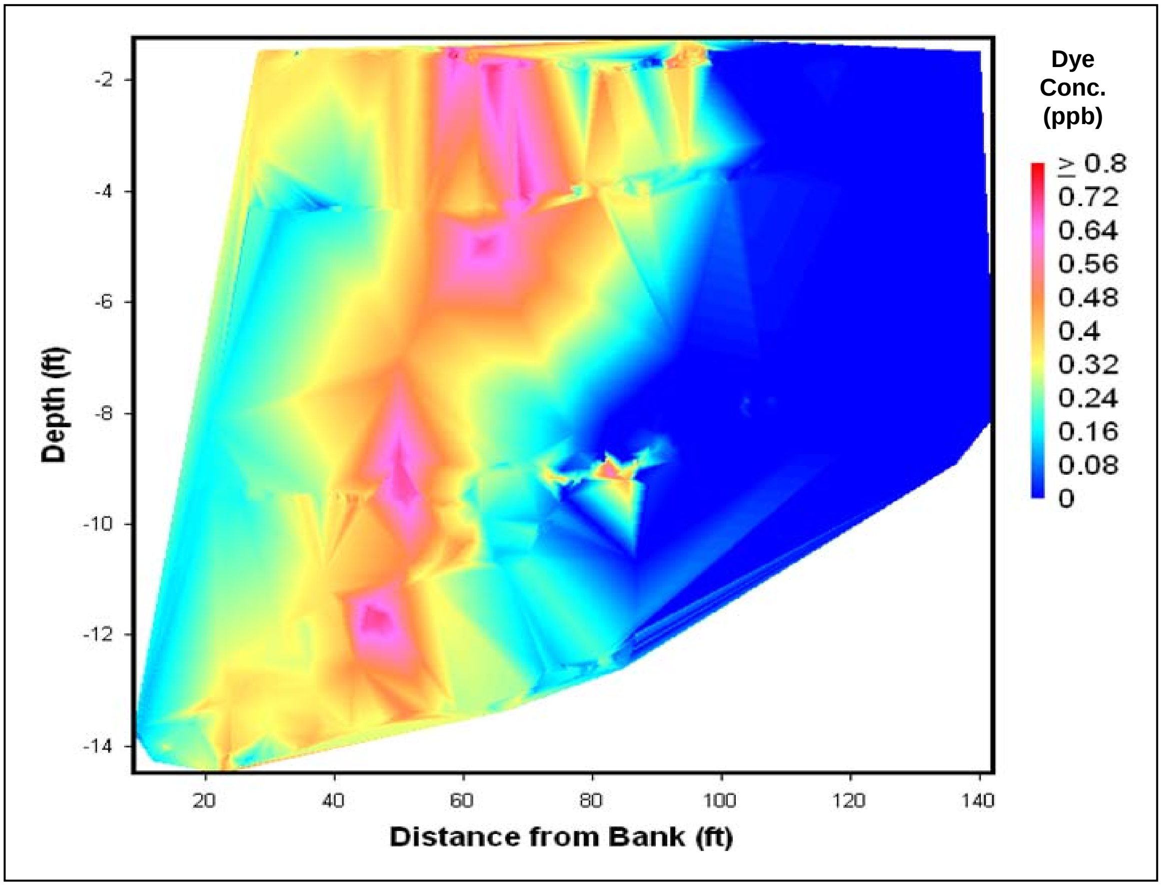


Figure 3 Cross-Section of the Chronic Mixing Zone Boundary

In order to establish appropriate centerline effluent concentrations, transect concentrations were determined using a Polynomial Trendline, which was fitted through the measured data points. Conservative estimates for transect effluent concentrations (at the horizontal plume centerline) were determined using the peak value on the Trendline. Table 3 shows the determined peak effluent concentrations at the chronic mixing zone boundary and the associated plume centerline.

Table 3 Summary of Measured Transect Effluent Concentrations at the Mixing Zone Boundary

Transect	Plume Centerline (distance from bank, feet)	Trendline Peak Effluent Concentration
Transect #1	38	0.36%
Transect #2	68	0.41%
Transect #3	47	0.35%
Transect #4	40	0.52%
Transect #5	62	0.61%
Transect #6	62	0.40%
Transect #7	53	0.45%
Transect #8	49	0.48%
Average Effluent Concentration at Plume Centerline		**0.45%**

Vertical Profile Results

Profile data show the same high degree of plume concentration unsteadiness as observed along the horizontal transects. As a result, profile measurements were averaged to determine a representative effluent concentration at the mixing zone boundaries. Table 4 presents the mean effluent concentration, the 95th percentile concentration, and mean dilution (inverse of mean effluent concentration) at the acute and chronic mixing zone boundaries.

Because the horizontal plume centerline was not easily determined from the data presented in Table 4, the centerline effluent concentration for the measured profiles was determined from the two profiles that had the highest mean effluent concentration (shaded data). The average effluent concentration at the horizontal plume centerline of the chronic mixing zone boundary is 0.44 percent.

Table 4 Mixing Zone Boundary Profile Dilution Analysis Summary

Chronic Mixing Zone Boundary				Acute Mixing Zone Boundary	
Distance from Shore (ft)	**Mean Effluent Conc.**	**95th Percentile Eff. Conc.**	**Mean Dilution**	**Mean Effluent Conc.**	**95th Percentile Eff. Conc.**
3	0.212%	0.468%	749	1.140%	3.815%
21	0.364%	0.495%	293		
34	0.424%	0.647%	270		
52	0.288%	0.600%	423		
58	0.454%	0.642%	233		
71	0.304%	0.645%	557		
82	0.0008%	0.003%	>10,000		
Horizontal Plume Centerline Average(1)		**0.44%**			

(1) The plume centerline average was determined averaging the two highest mean effluent concentrations of 0.424% and 0.454% (shaded data).

Despite the unsteady nature of the effluent plume, the profile data indicates that, in general, the plume was relatively well mixed vertically at the chronic mixing zone boundary. Complete vertical mixing was detected 1 mile downstream from the outfall, where measurements were collected on the North and South Fork of the Skagit River in the apparent horizontal plume centerline.

Time Series Results

Temporal variations were most extreme at the acute mixing zone boundary, where effluent concentrations ranged from 0 to 7.5 percent (average = 1.6 percent). Temporal fluctuations were less significant at the chronic mixing zone boundary, with an effluent concentration range of 0.25 percent to 0.62 percent (average = 0.40 percent). The time series data best portrays the “puff” like nature of the effluent plume.

Results Summary

Table 5 presents a summary of the dye tracer study results, including the effluent concentration for each sampling method.

Table 5 Dye Tracer Study Results Summary

Method of Fluorometric Analysis	Effluent Concentration @ Chronic Mixing Zone Boundary	Effluent Concentration @ Acute Mixing Zone Boundary
Horizontal Transect Average	0.45%	
Vertical Profile Average	0.44%	1.14%
Time Series Average	0.40%	1.60%
Average Concentration	**0.43%**	**1.37%**
Average Dilution Factor	**232**	**73**

RIVPLUM5 MODEL RESULTS

Table 6 compares RIVPLUM5 model results to the observed dye tracer study results. RIVPLUM5 model input and output are provided in Appendix B. Model runs were performed using the default TMCC equal to 0.6. As shown in Table 6, RIVPLUM5 model results slightly overpredict dilution. Similar to the City of Arlington test case, the model results are generally appropriate as the actual conditions closely match RIVPLUM5 applicability criteria.

Table 6 RIVPLUM5 Model Results – City of Mount Vernon Mixing Zone Study

Distance from Outfall (feet)	Field Study Dilution Results	RIVPLUM Dilution Predictions	
	Depth/Time Averaged Dilution Factor	Default TMCC (TMCC = 0.6)	Percent Difference
31.3	73	88.4	+ 21.1%
313	232	279.5	+ 20.5%

CASE 3 – CITY OF RIDGEFIELD

A dye tracer study of the City of Ridgefield WWTP discharge to Lake River was performed over a period of two weeks in September 2004 and documented in a *Mixing Zone Study* report (CEG, January 2005). The field study included collection of both in-situ fluorescence concentrations and bottled fluorescence samples, measurement of the river cross-section and current velocity, and collection of conductivity, temperature, and depth (CTD) profile data.

DISCHARGE DESCRIPTION

Lake River is a branch channel of the lower Columbia River, which experiences twice-daily flow reversal during flood tides. Effluent is discharged along the eastern shoreline of Lake River, approximately 10,000 feet upstream of its confluence with the Columbia River main channel. To simulate a proposed extension of the City's outfall, fluorescent dye was injected into the receiving water via plastic tubing during the dye study. A cross-section of the river at the existing outfall, including the dye injection point, is shown in Figure 4.

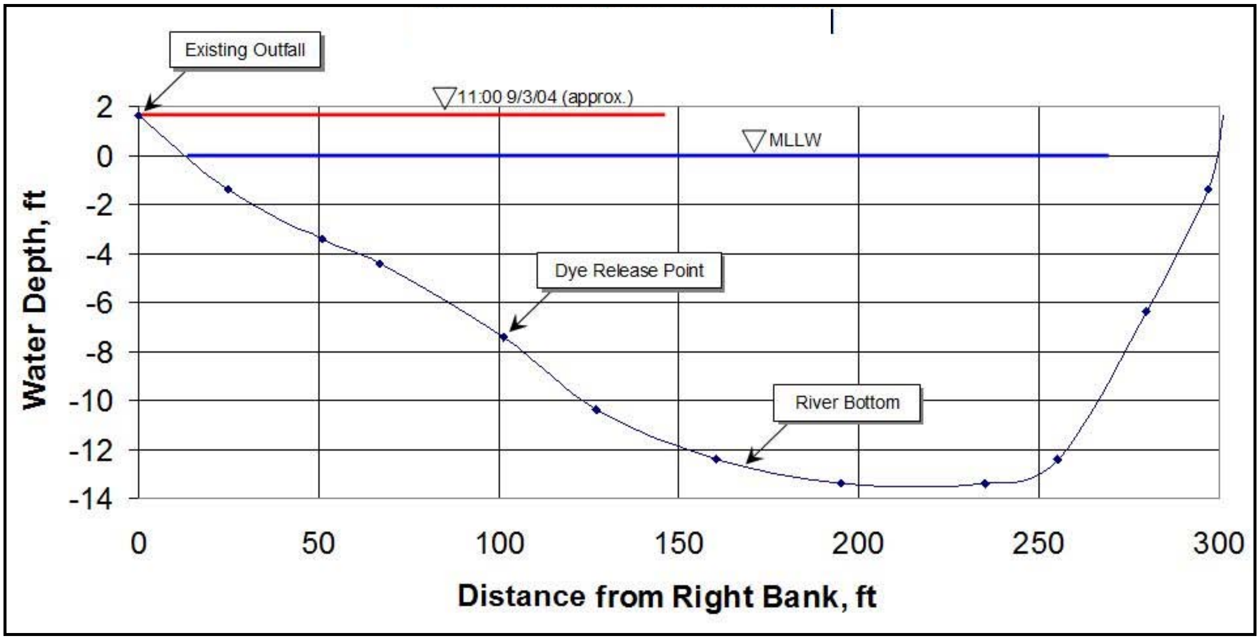


Figure 4 Lake River Cross-Section Near the Ridgefield Outfall

CTD profiles collected during the study show no salinity stratification and minimal temperature stratification. The CTD profiles were consistent with historic Columbia River measurements that indicate the salt wedge does not intrude past Longview, Washington. Average current speed and direction at varying tidal stages, measured using a Swoffer meter, is summarized in Table 7.

Table 7 Field Study Current Speed Data

Tidal Stage	Current Speed (fps)	Direction
¾ Flood	0.9	Upstream
High Slack	0.6[(1)]	Variable[(1)]
¼ Ebb	1.0	Downstream
Mid-Ebb	1.6	Downstream
¾ Ebb	1.2	Downstream

(1) Ambient flow broke into visible small-scale eddies with variable upstream net velocity near high slack water. Speed estimated based upon model calibration to field study results.

DYE TRACER STUDY RESULTS

Dye concentration was measured at the down-current chronic mixing zone boundary (200 feet) at five tidal stages (see Table 8 above). Dye measurements consisted of (1) horizontal transects through the plume at several depths, (2) vertical profiles at the horizontal centerline of the plume as determined during the transects, and (3) stationary time series holding the sampler at the horizontal and vertical position of maximum concentration. Results for all sampling methods during each tidal stage condition are as shown in Figures 5 through 8. Note also that plume concentration predictions using CEG's 2-D model equivalent to RIVPLUM5 are also shown.

Plume width, peak concentration, depth- or time-averaged concentration, and the calculated dilution are summarized in Table 8.

Table 8 Dye Tracer Study Results Summary – Chronic Mixing Zone Boundary

Tidal Stage	Plume Width (feet)	Peak Dye Concentration (ppb)	Averaged Dye Concentration (ppb)	Calculated Dilution
¾ Flood	30	6.5	5.2	258
High Slack	50	4.5	3.4	394
¼ Ebb	25	11	5	268
Mid-Ebb	20	8	3.5	383
¾ Ebb	25	6.2	3.2	419

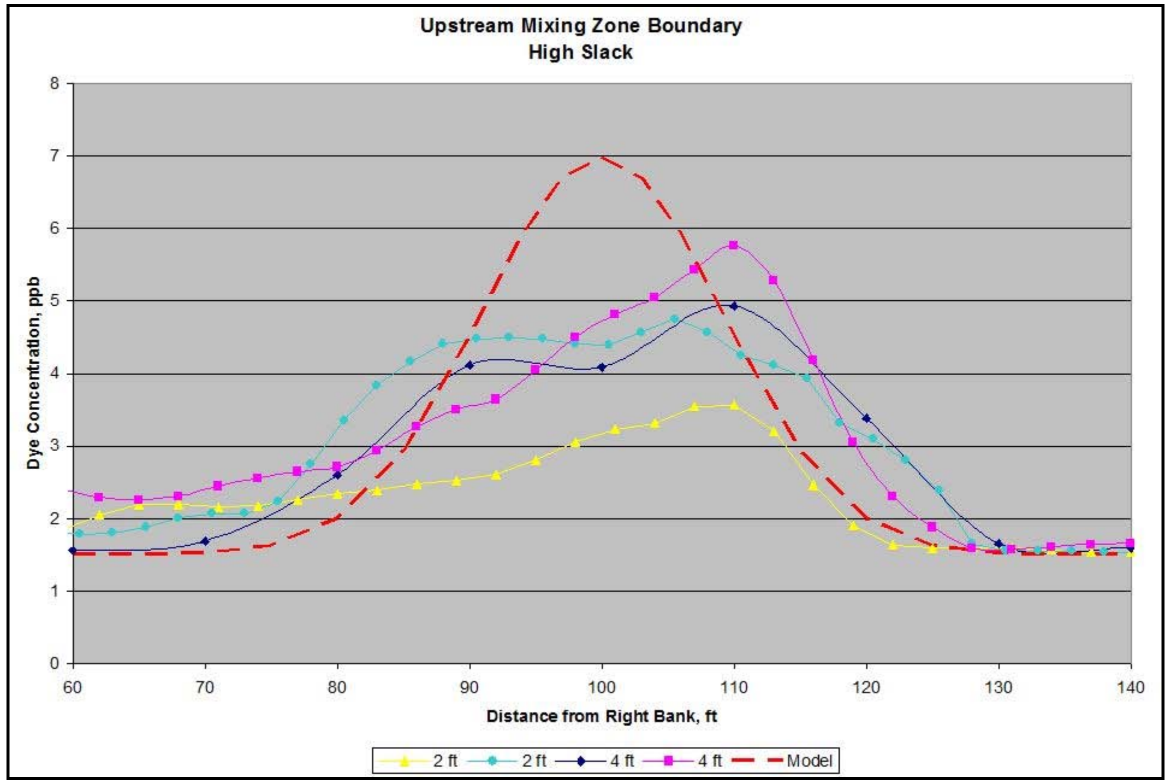


Figure 5 Dye Transect – High Slack Tide

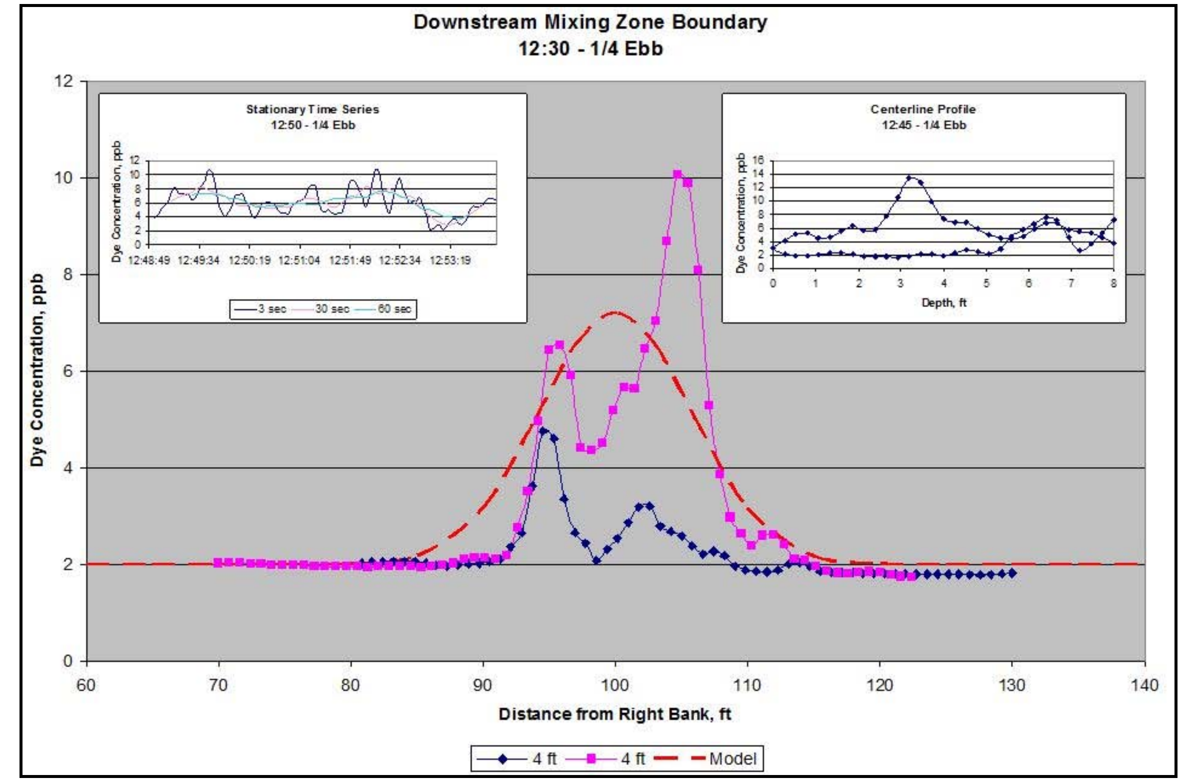


Figure 6 Dye Transect, Profile, and Stationary Time Series – 1/4 Ebb Tide

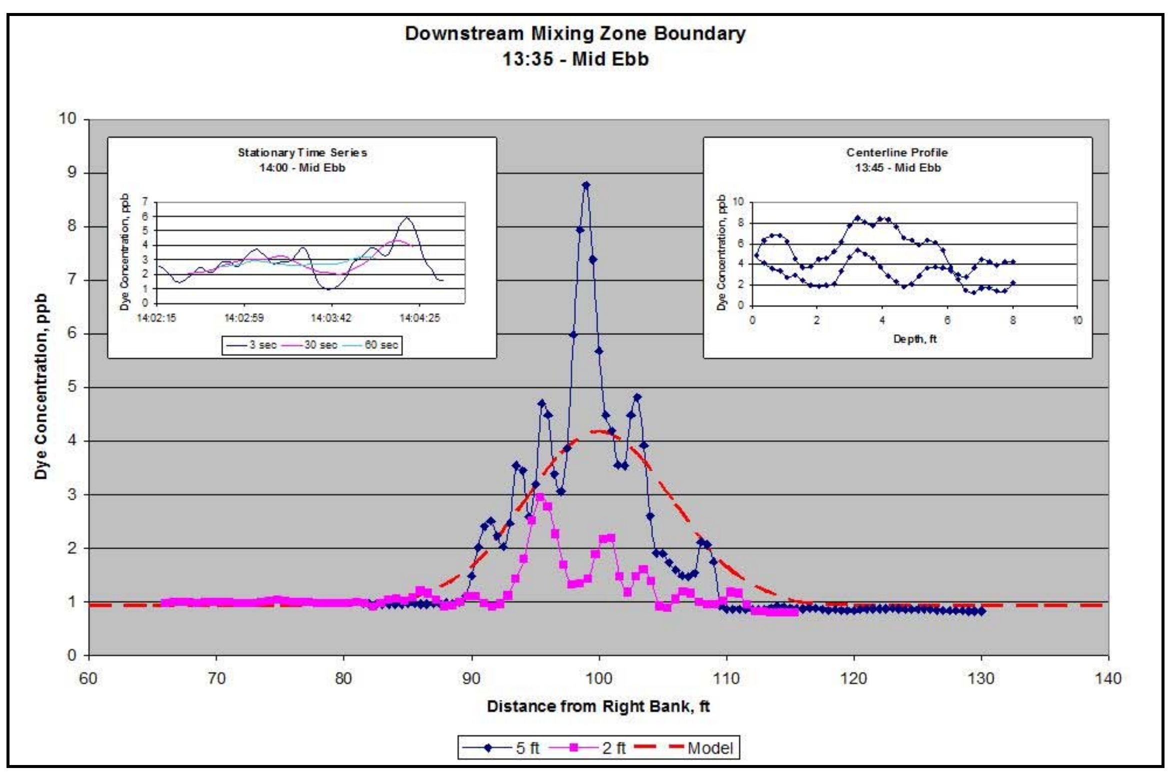


Figure 7 Dye Transect, Profile, and Stationary Time Series – Mid Ebb Tide

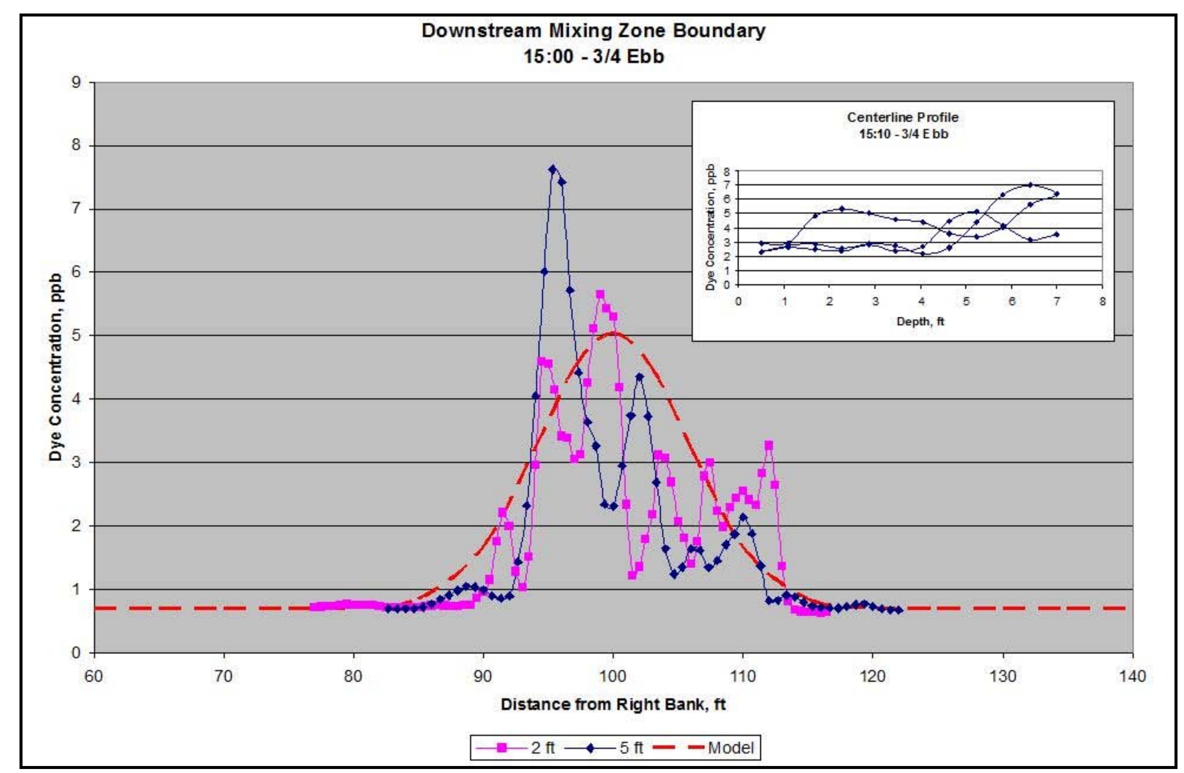


Figure 8 Dye Transect and Profile – 3/4 Ebb Tide

RIVPLUM5 MODEL RESULTS

Table 9 compares RIVPLUM5 model results to the observed dye tracer study results. RIVPLUM5 model input and output are provided in Appendix B. Model runs were performed using the default TMCC equal to 0.6. As shown in Table 9, RIVPLUM5 model results significantly overpredict dilution. The default RIVPLUM5 settings are not applicable due to the tidally influenced nature of the receiving water. The default values for the TMCC and shear velocity presented by Fischer, *et al* (1979) are not applicable, which will be discussed later.

Table 9 RIVPLUM5 Model Results – City of Ridgefield Mixing Zone Study

Distance from Outfall (feet)	Field Study Dilution Results	RIVPLUM Dilution Predictions	
	Depth/Time Averaged Dilution Factor	Default TMCC (TMCC = 0.6)	Percent Difference
200 (3/4 Flood)	258	1,416	+ 449%
200 (High Slack)	394	989	+ 151%
200 (1/4 Ebb)	268	1,603	+ 498%
200 (Mid-Ebb)	383	2,399	+ 526%
200 (3/4 Ebb)	419	1,712	+ 309%

CASE 4 – PORTLAND INTERNATIONAL AIRPORT (PDX) DEICING DISCHARGE

A dye tracer study of three proposed outfall locations within the mainstem Columbia River for the PDX deicing runoff treatment system was performed January 17-19, 2008 and documented in a *Columbia River Discharge Schematic Design Technical Report* (CEG, January 2009). The field study included injection of a fixed rate of Rhodamine WT dye to simulate an effluent outfall, and collection of fluorescence concentration data along horizontal transects and fixed stations, current velocity data, and conductivity, temperature, and depth (CTD) profile data.

The dye tracer study was designed to validate or calibrate farfield mixing for dissolved oxygen models, and show the location in the water column downstream that the plume is anticipated to occupy. Therefore, sample collection transects and fixed stations were located much farther downstream than would be selected for a typical mixing zone study. Discharge locations and sampling locations are as shown in Figure 9.

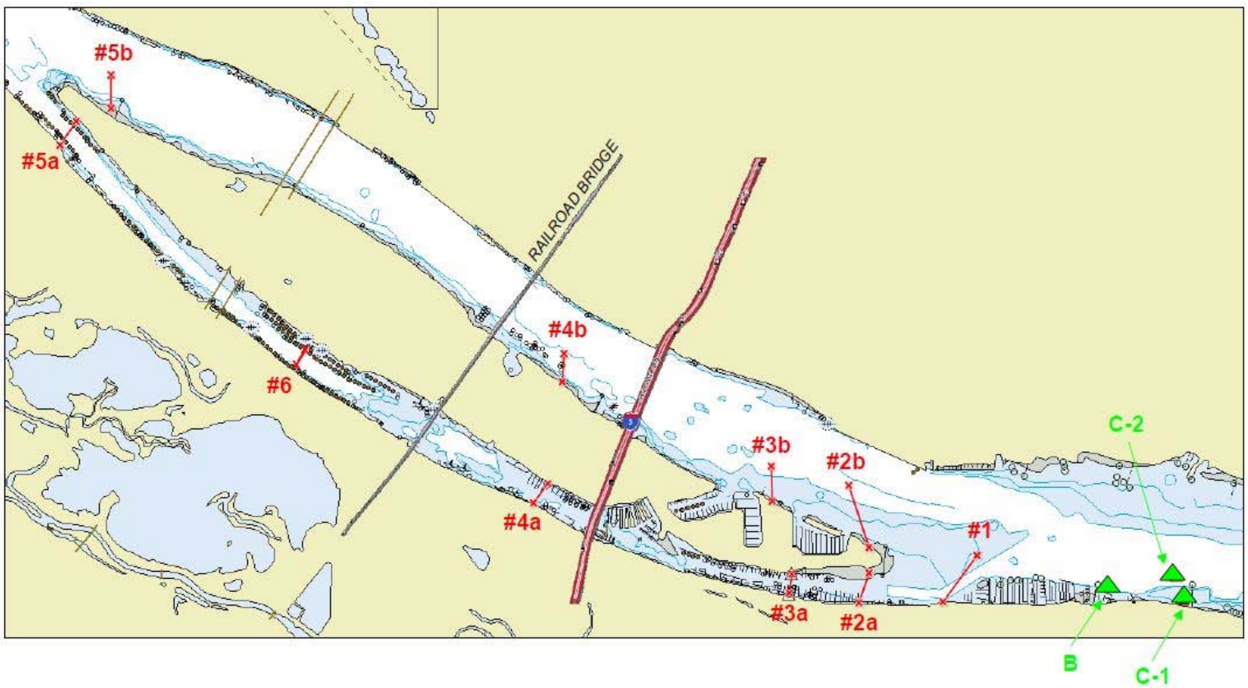


Figure 9 Dye Study Transect Locations

DISCHARGE DESCRIPTION

Three field study sites were selected to cover a range of water depths and distances offshore. Field study sites were located at natural breaks in bathymetry conducive to placement of the outfall discharge. Approximate water depth and distance offshore of the three field study sites are summarized below:

- Site C1 – Water Depth 13 feet, Distance Offshore 350 feet
- Site C2 – Water Depth 42 feet, Distance Offshore 750 feet
- Site B – Water Depth 26 feet, Distance Offshore 950 feet

The proposed outfall location near River Mile 110 is tidally influenced. The study was scheduled to capture critical river conditions, including extreme high tides, which could potentially result in reversal of river flow. Although the river current slowed during high tide, no reversal was observed during the field study.

The Columbia River is approximately 4,000 feet wide and up to 45 feet deep at the potential outfall locations. Current speed data were collected for one week (January 16-23, 2008) by Acoustic Doppler Current Profilers (ADCP) moored at each of the potential outfall locations. The mean velocity for Sites B, C1, and C2 were 0.45, 0.21, and 0.70 meters per second (m/s), respectively. The CTD profiles collected during the study indicated no significant density stratification within the river.

DYE TRACER STUDY RESULTS

The measured fluorescence concentration data were contoured and presented graphically using the program DPlot within Microsoft Excel. Figures 10 and 11 show the cross-sections at two downstream locations.

The relevant qualitative observations from these data include:

- All of the dye transects demonstrated that complete vertical mixing occurs. Therefore, a vertically-averaged two dimensional farfield model is appropriate for the farfield stations of interest in this study.

- Site C-2 provides the most rapid dilution of the plume, and C-1 the lowest.

- Tomahawk Island bifurcates the plume from site C-2. Approximately half the tracer mass went north of Tomahawk/Hayden Islands, and half entered the Portland Channel south of Hayden Island.

- The plume from sites B and C-1 stay entirely within the Portland Channel south of Hayden Island.

- The plume from site C-1 quickly attached to the near bank, somewhere within the marinas just downstream of Broughton Beach and the boat launch. The highest concentrations from site C-1 were observed at the shoreline.

- The plume from site B had the least contact with adjacent shorelines. The plume traveled approximately down the middle of the Portland Slough and did not appear to have significant shoreline contact at any point.

Observed dilution factors at several downstream distances based upon field study data are summarized in Table 10.

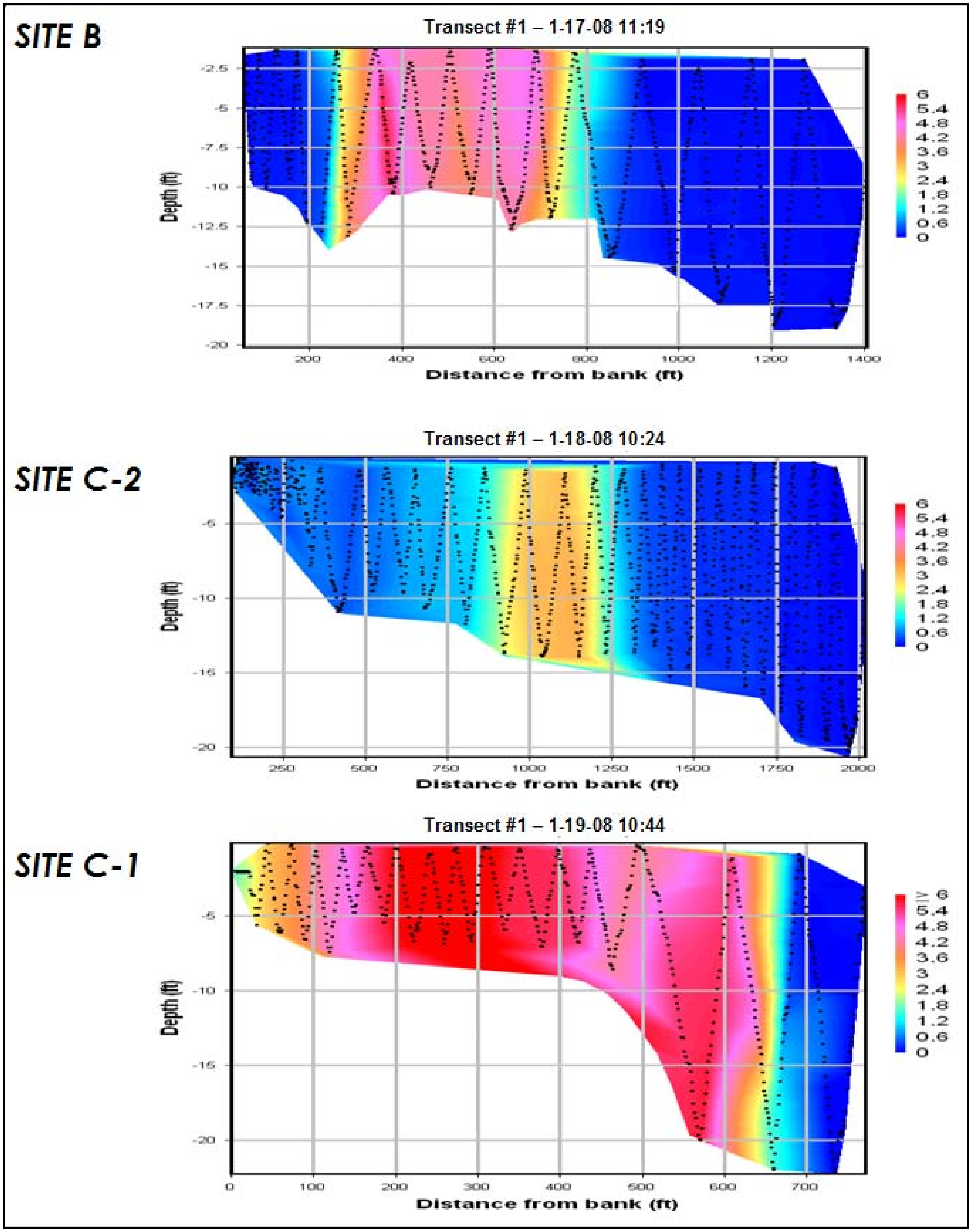


Figure 10 Plume Cross-Section Data at Transect 1

NOTE:
Concentration data are for 1 gram/second normalized dye discharge. Units are ppb.

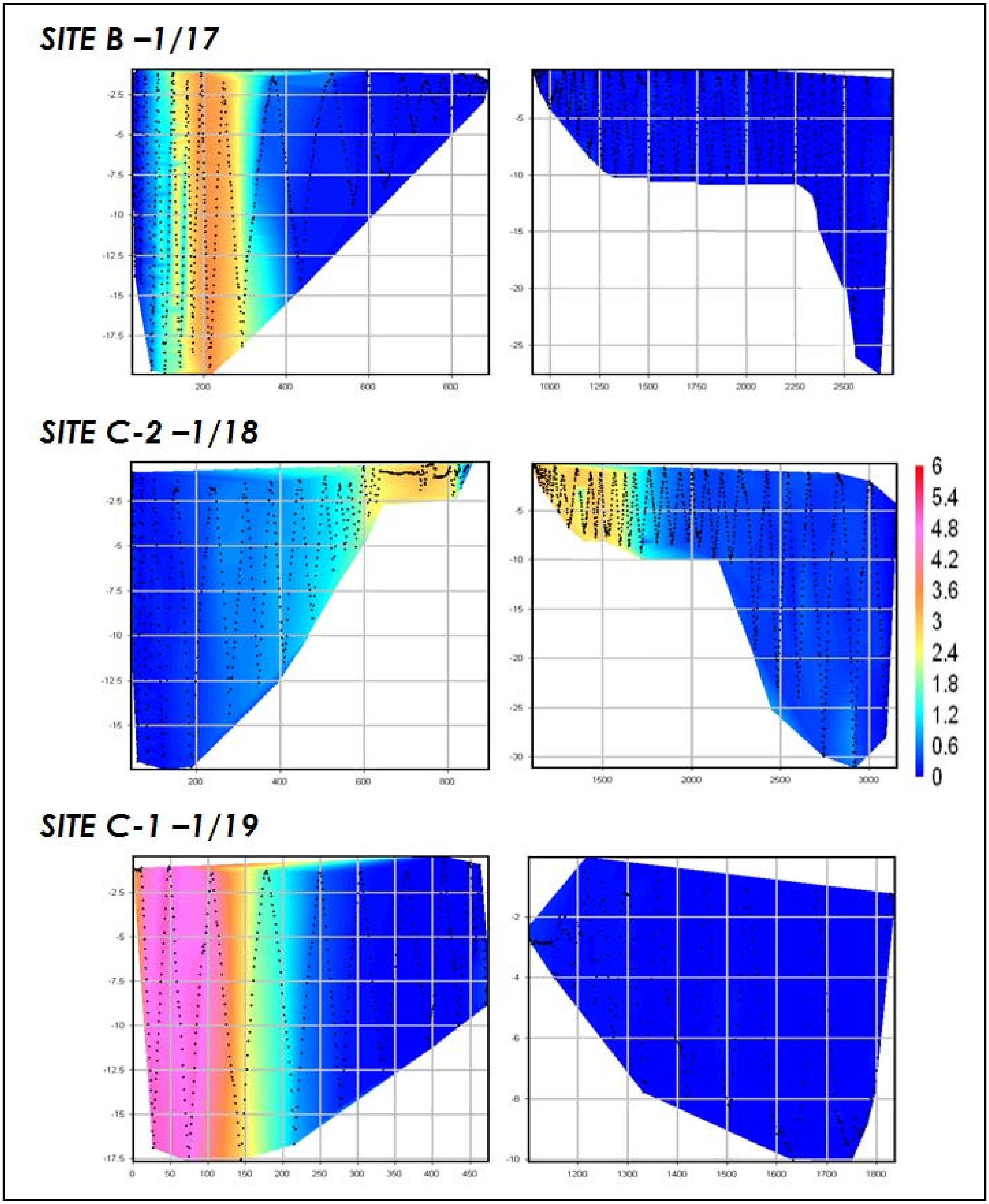


Figure 11 Plume Cross-Section Data at Transect 2

NOTE:
Concentration data are for 1 gram/second normalized dye discharge. Units are ppb.

Table 10 Observed Dilution Factors

Transect	Downstream Distance (meters)	Observed Dilution
SITE B		
1	1,100	1,400
3	2,900	2,000
4	5,000	4,300
6	8,000	6,600
SITE C2		
1	1,800	3,100
2	2,850	3,400
3	3,600	5,200
4	5,750	6,200

TWO-DIMENSIONAL MODEL

AD2D (Advection-Dispersion, Two Dimensions) is a custom model developed by Cosmopolitan Engineering Group. The model is an algorithm based on the two-dimensional advection-diffuser equation (same as RIVPLUM5) with use of images for lateral boundaries. AD2D was calibrated to the 1 gram/second tracer discharge at Site B on January 17, 2008. The AD2D model results are compared to the observed data in Figure 12. The advantage of the AD2D model is that each application may be highly customized to fit observed data, hence the close fit between model and observed.

RIVPLUM5 MODEL RESULTS

Table 11 compares RIVPLUM5 model results to the observed dye tracer study results. RIVPLUM5 model input and output are provided in Appendix B. Model runs were performed using the default TMCC equal to 0.6. As shown in Table 11, RIVPLUM5 model results underpredict dilution for Site B and overpredict dilution for Site C2.

Table 11 RIVPLUM5 Model Results – PDX Mixing Zone Study (Site B)

Distance from Outfall (feet)	Field Study Dilution Results	RIVPLUM Dilution Predictions	
	Depth/Time Averaged Dilution Factor	Default TMCC (TMCC = 0.6)	Percent Difference
SITE B			
1,100	1,400	943	- 32.6%
2,900	2,000	1,530	- 23.5%
5,000	4,300	2,009	- 53.3%
8,000	6,600	2,542	- 61.5%
SITE C2			
1,800	3,100	3,647	+ 17.6%
2,850	3,400	4,589	+ 35.0%
3,600	5,200	5,158	- 0.8%
5,750	6,200	6,518	+ 5.1%

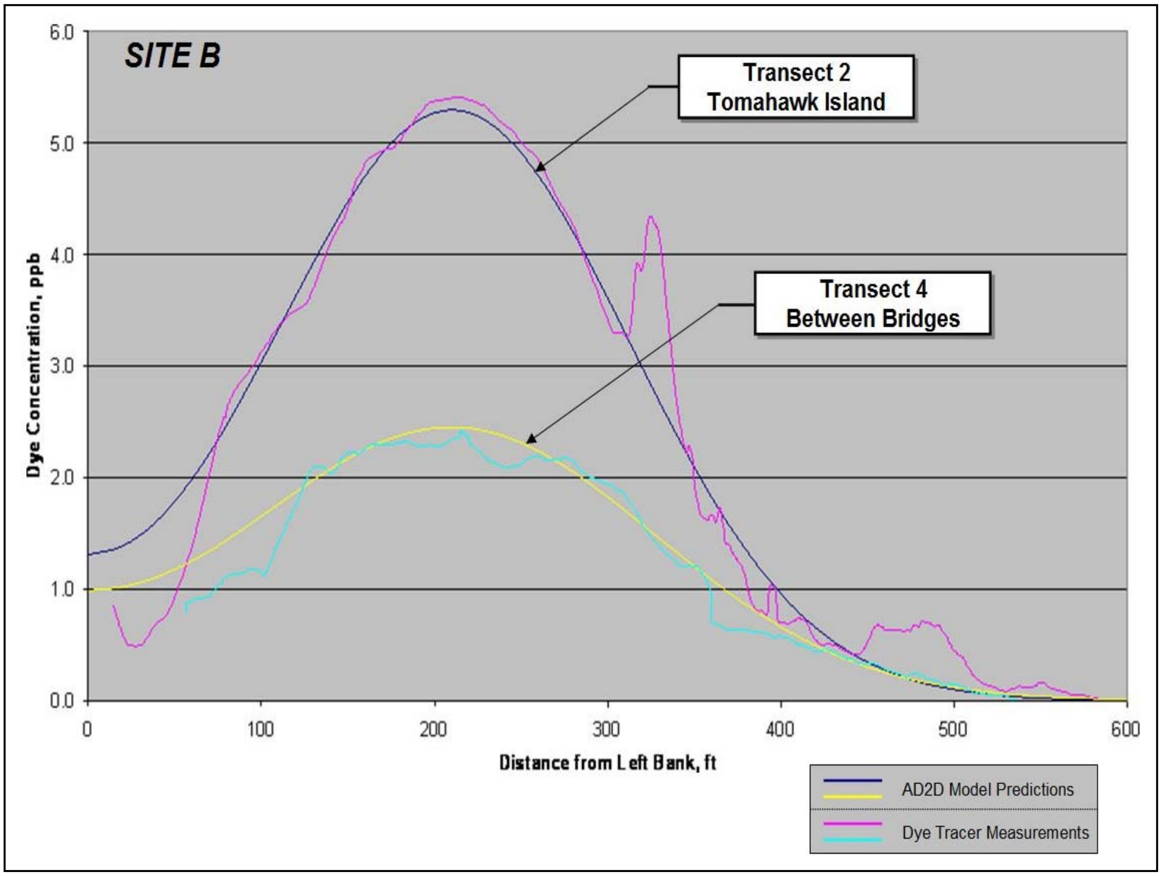


Figure 12 Dye vs. AD2D Model

CASE 5 – CITY OF GRANTS PASS

A dye tracer study of the City of Grants Pass WWTP discharge to the Rouge River was performed on September 28 and 29, 2004, and documented in a *Mixing Zone Dye Tracer Study* report (Parametrix, December 2004). The field study included injection of Rhodamine WT dye, and collection of dye concentration samples within the mixing zone and investigation of the physical characteristics (width, depth, current speed, and temperature) of the Rogue River upstream of the outfall and within the mixing zone.

DISCHARGE DESCRIPTION

Effluent from the Grants Pass WWTP is discharged to the Rogue River at River Mile 100.9. At seasonal low flow conditions observed during the dye study, the river was approximately 225 feet wide with an average depth of 2.5 feet. Average current speeds, measured with a Swoffer meter, were 1.7 fps at the outfall location, increasing to 2.8 fps at the chronic mixing zone boundary 300 feet downstream. A conservatively low value of 1.8 fps was selected for analysis to better represent current speeds in the nearfield region where most of the mixing occurs.

The 42-inch diameter outfall extends approximately 70 feet from the right (north) bank. The final 36-foot segment of the outfall consists of a diffuser with 12 diffuser port risers with integral Tideflex® check valves. The outfall and diffuser segment are buried, with only the diffuser port check valves extending through the riverbed. Appendix A contains plan and profile design drawings of the outfall (Parametrix, 2002). Average effluent discharge flow through the outfall was 5.7 mgd during the study, with minimum and maximum values of 4.9 mgd and 6.5 mgd, respectively.

DYE TRACER STUDY RESULTS

Fluorescence samples were collected along five downriver transects selected to encompass the effluent plume (determined visually by observed color of the fluorescent dye). The five downriver transects were facilitated by tying the metered rope to a diffuser discharge port and allowing the rope to extend downstream.

Mixing Zone Dye Concentration and Dilution

Average centerline dilution at several downstream distances for samples collected at the water surface, mid-depth, and river bottom is as shown in Figure 13. Average data were used to represent dilution along the observed plume centerline because effluent flow from the diffuser ports is not constant. Rather than discharging at a steady pace, effluent is discharged in "pulses" as hydraulic head (pressure) builds up in the outfall and diffuser pipeline. This phenomenon was observed in the field.

Up to 100 feet downstream of the diffuser, only mid-depth sample results are shown to represent the plume centerline, since the dye plume had not yet mixed over the entire water depth and width. For these distances, average dilution was calculated as the average of results from each of the five perpendicular transects. Beyond 100 feet downstream, average dilution was calculated as the average of results from several transects.

Data points for surface, mid-depth, and bottom samples at the 200, 300, and 400 feet downstream locations overlap, indicating that the plume is well mixed over the river depth. The "best-fit" curve shown in Figure 13 represents the overall average calculated centerline dilution with distance from the diffuser axis.

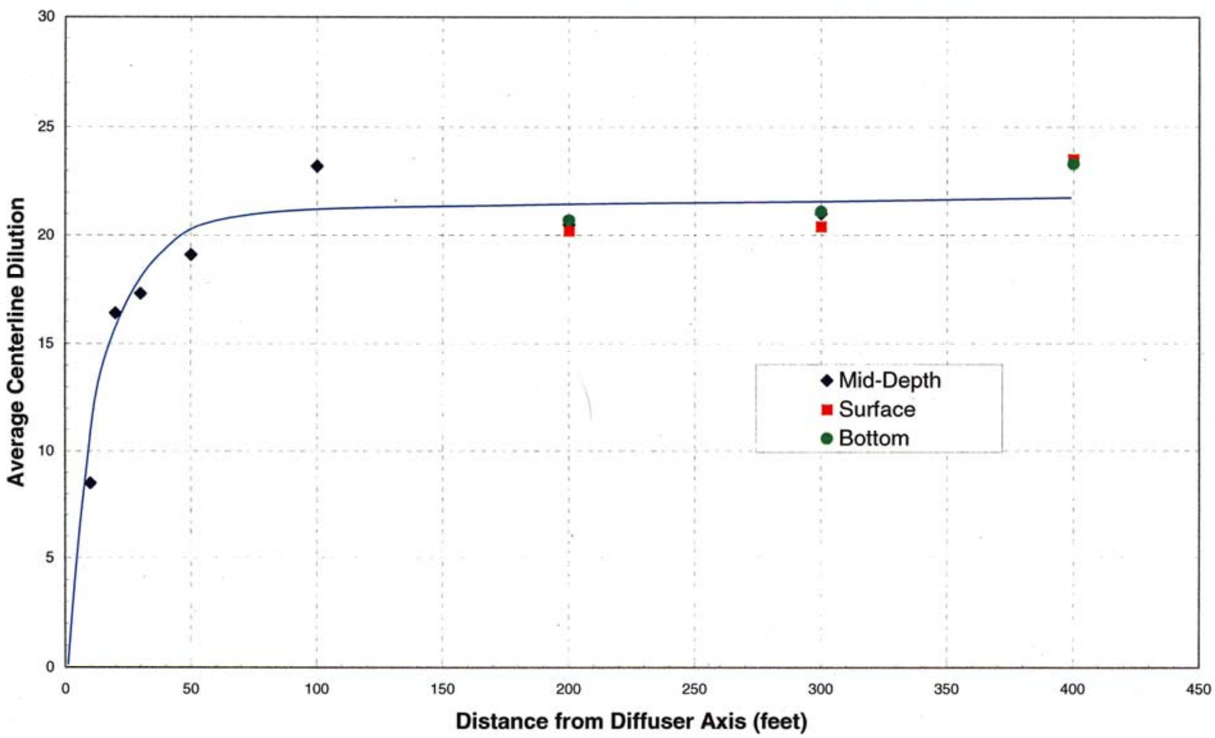


Figure 13 Average Centerline Dilution vs. Distance from Diffuser Axis

Plume Width

Plume width 300 feet downstream of the diffuser was estimated based upon measured dye concentration in bottled samples collected from each of the five transects. Figure 14 presents dye concentration data versus distance of the sample point from the north riverbank. Calculated dilution for each sample is also presented in Figure 14. The calculated dilution accounts for varying sample times and effluent dye concentration.

THREE-DIMENSIONAL MODEL RESULTS

Table 12 compares results of the 3-D Advection-Dispersion (3DAD) equation to the observed dye tracer study results. 3DAD input and output are provided in Appendix C. The 3DAD equation input data was set so that a calculated TMCC was equal to 0.6, the same as for RIVPLUM5 model runs. As shown in Table 12, the 3DAD results underpredict dilution. Model predictions become more accurate with distance from the discharge, as the presumption of complete vertical mixing becomes more accurate.

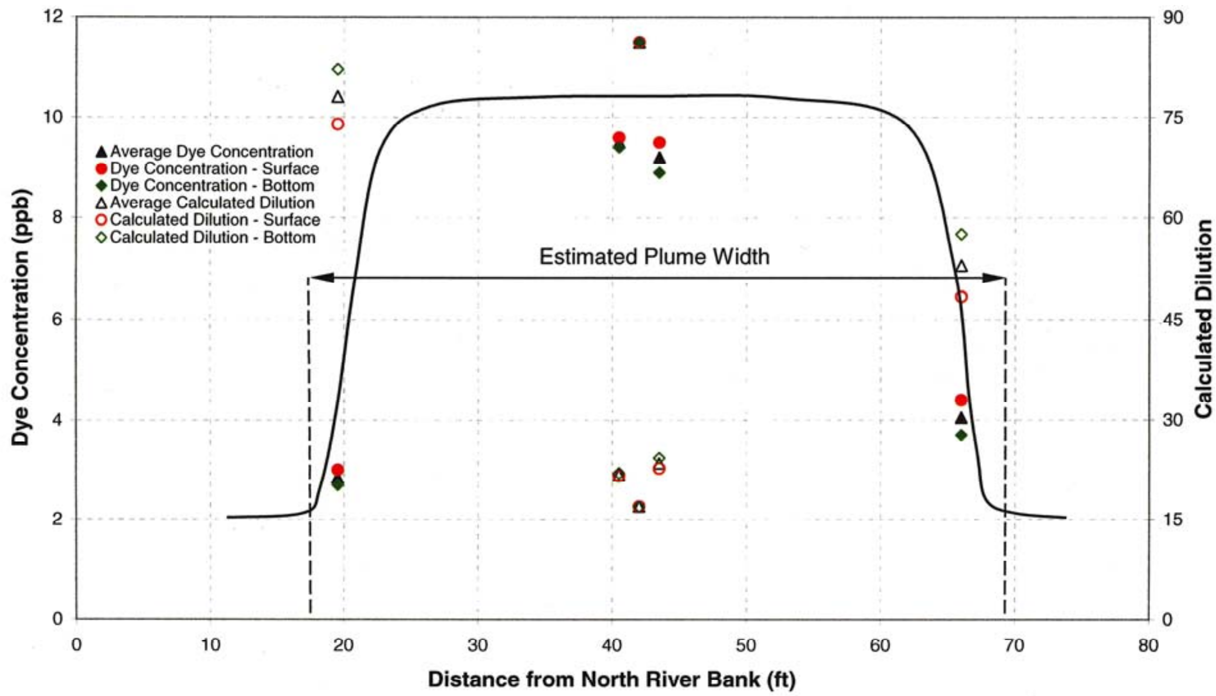


Figure 14 Dye Concentration/Calculated Dilution vs. Distance from North Riverbank at 300-Foot Downstream Transect at 300-Foot Downstream Distance

Table 12 Three-Dimensional Model Results – City of Grants Pass Mixing Zone Study

Distance from Outfall (feet)	Field Study Dilution Results	Default TMCC	Percent Difference
	Depth/Time Averaged Dilution Factor	(TMCC = 0.6)	
30	18	8.7	- 51.7%
50	20.5	11.2	- 45.4%
100	21.5	15.4	- 28.4%
300	22	19.4	- 11.8%

CASE 6 – CITY OF CAMAS

Dye tracer studies of the City of Camas WWTP discharge to the Columbia River were performed in February and October 2005 to evaluate critical winter and late summer conditions, respectively. Both studies and subsequent model analyses were documented in a *Final Dye Tracer and Mixing Zone Study* report (CEG, December 2006, updated June 2007). Field studies included collection of in-situ fluorescence concentrations, current velocity, and conductivity, temperature, and depth (CTD) profile data. Additional model analysis using the 3-D advection dispersion equation was documented in a *Supplemental Modeling for Camas* Technical Memorandum (CEG, September 2007). The supplemental memorandum evaluated the critical low flow (summer) conditions.

DISCHARGE DESCRIPTION

River flow at Camas varies as a function of river discharge, which is controlled by the Bonneville Dam, and tidal influence. Field studies were scheduled to capture critical river conditions, including high tides that could potentially result in reversal of river flow. Although the river current slowed during high tide, no reversal was observed during the field study. Average low and high current speeds, as measured by an ADCP moored upstream of the outfall, were 0.21 meters per second (m/s) and 0.50 m/s, respectively. The CTD profiles collected during the study indicated no significant density stratification within the river.

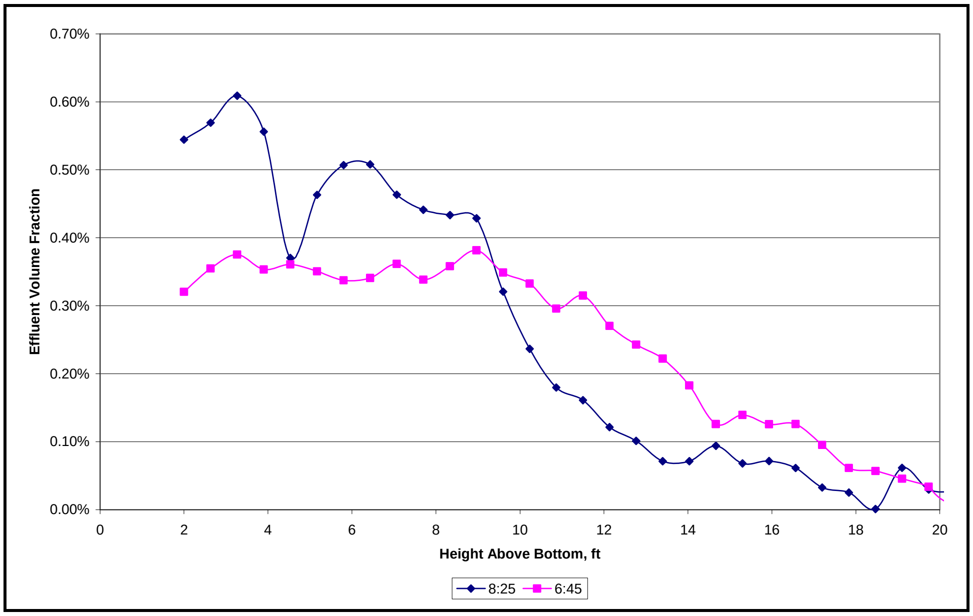
The outfall extends approximately 850 feet from the river bank to a depth of approximately 22 feet at seasonal low flow conditions. The outfall terminates in a 150-foot diffuser section consisting of sixteen 6-inch-diameter ports. The ports extend vertically from the diffuser and include 90-degree bends pointing horizontally downstream. The first eight ports are currently capped. Appendix A contains plan and profile design drawings of the outfall. Average effluent discharge flow through the outfall was 2.53 mgd during slack tide.

DYE TRACER STUDY RESULTS

Figure 15 provides the best three-dimensional data of plume concentration during the critical ambient conditions at slack water (minimum current speed). These data were combined and extrapolated to simulate the comprehensive distribution of effluent concentration at the chronic mixing zone boundary. The 95th percentile of all non-zero concentrations was selected for the peak time averaged plume concentration. The 95th percentile concentration is 0.48 percent effluent or a dilution factor of 210.

THREE-DIMENSIONAL MODEL RESULTS

Table 13 compares results of the 3DAD equation to the observed dye tracer study results. 3DAD input and output are provided in Appendix C. The 3DAD equation input data was set so that a calculated TMCC was equal to 0.6, the same as for RIVPLUM5 model runs. As shown in Table 13, the 3DAD results are nearly identical to the field results at the chronic mixing zone boundary 321 feet downstream of the discharge.



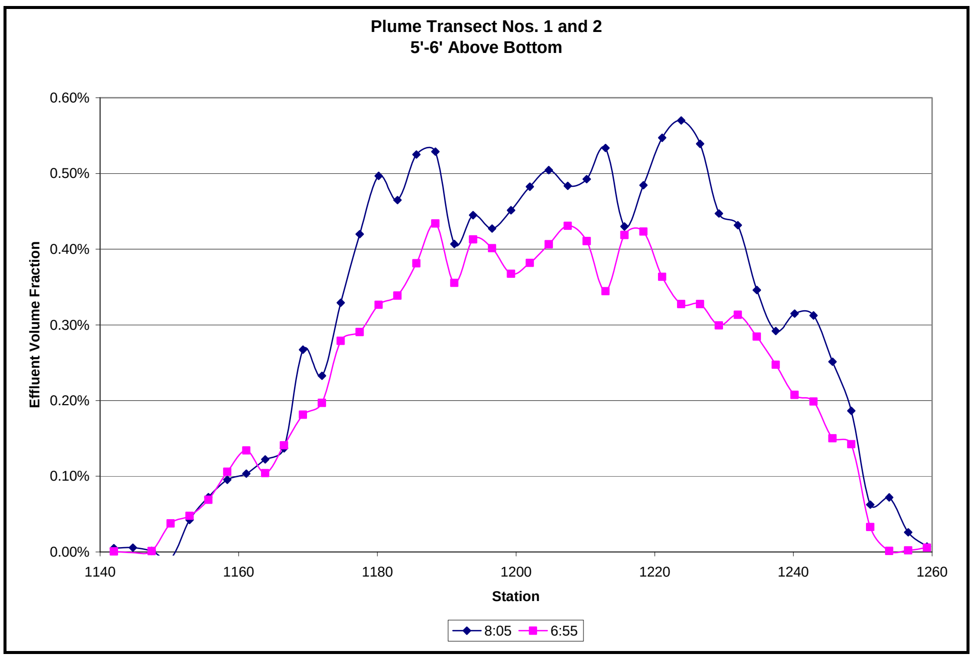


Figure 15 Slack Tide Profiles and Transects

Table 13 Three-Dimensional Model Results – City of Camas Mixing Zone Study

Distance from Outfall (feet)	Field Study Dilution Results Depth/Time Averaged Dilution Factor	Default TMCC (TMCC = 0.6)	Percent Difference
321	210	204	- %2.9

COMPARISON TO LITERATURE VALUES

Table 14 presents a summary of discharge data and the calibrated transverse mixing coefficient constants (TMCC) for the six test cases presented in this report, plus five test cases presented in Fischer *et al* (1979). The test cases for this study were within the ranges of river width, depth, and velocity of the historical data, which provide the basis for the default TMCC in RIVPLUM5. The TMCC values calibrated to the six test cases also fall within the range of the historical observations from Fischer.

Table 14 Comparison of RIVPLUM5 Test Case Data to Historical Data from Fischer, *et al* (1979)

Receiving Water	Channel Width (W) (meters)	Mean Depth of Flow (d) (meters)	Mean Velocity (u) (meters/sec)	TMCC
Experimental data from CEG tracer studies:				
Stillaguamish River (Arlington, WA)	36.9	1.22	0.46	0.4
Skagit River (Mount Vernon, WA)	85.6	3.9	0.7	0.4
Lake River (Ridgefield, WA)	91.4	4.5	0.18-0.49	0.08-0.13
Columbia River (Portland, OR)	1,220	7.9-12.8	0.45-0.70	0.5-1.8
Rouge River (Grants Pass, OR)	68.6	0.76	0.55	1.15
Columbia River (Camas, WA)	1,000	6.7	0.21	0.63
Experimental Data from Table 5.2 in Fischer, *et al* (1979):				
Missouri River	200	2.7	1.75	0.6
Ijssel River	69.5	4	0.96	0.51
Mackenzie River	1,240	6.7	1.77	0.66
Missouri River	210-270	4	5.4	3.4
Potomac River	350	0.73-1.74	0.29-0.58	0.52-0.65

SUMMARY AND CONCLUSIONS

We have drawn several conclusions from the comparison of RIVPLUM5 model predictions to results of six tracer studies conducted by Cosmopolitan Engineering staff. Our conclusions include the suitability of RIVPLUM5 for selected discharge environments, and the use of the default calibration coefficients.

GENERAL

- RIVPLUM5 is a spreadsheet model of the solution to the two-dimensional advection dispersion equation. Therefore, it may only be applied at a farfield distance where the plume is completely or nearly-completely vertically mixed.
- RIVPLUM5 is a mass-based model that is driven only by ambient-induced mixing. Nearfield mixing driven by jet velocity or buoyancy of the discharge is neglected. Therefore, the model conservatively underestimates mixing that occurs in the nearfield if the plume is vertically mixed.

- RIVPLUM5 should not be used for discharges to marine waters because of the buoyancy of the effluent and the unsteady (tidal) ambient velocity field.

- RIVPLUM5 is confirmed as a valid hydrodynamic mixing zone model for discharges to rivers or creeks, subject to the applicability stipulations described above.

- Calibration of RIVPLUM5 to the tracer study results produced transverse mixing coefficient constants (TMCC) that were within the range of experiments reported by Fischer *et al* (1979), from which RIVPLUM5 was developed.

SPECIFIC CASES

- The City of Arlington WWTP discharge is the best test case of those presented in this TM, because it most closely meets the criteria for its applicability (single port discharge, straight river, uniform velocity field, shallow stream with relatively rapid compete vertical mixing). Accordingly, the calibrated TMCC is also close to default RIVPLUM5 parameters.

- The City of Mount Vernon WWTP study is the second best test case, because it generally meets the stipulations for RIVPLUM5 applicability, except the velocity field is less uniform than for Arlington, and the distance to complete vertical mixing is greater. The calibrated TMCC is also close to the default value for RIVPLUM5.

- The City of Ridgefield WWTP is an appropriate discharge for RIVPLUM5 to be applied. However, the ambient environment is not steady (*i.e.,* tidally-influenced), and therefore the default multipliers for shear velocity and TMCC are not applicable. Direct measurement of the shear velocity using current profilers would likely be necessary to apply RIVPLUM5 in cases like Ridgefield where the ambient velocity field is unsteady.

- The Portland Airport deicing discharge tracer study is a good test for RIVPLUM5 application in the greater farfield (*i.e.,* one kilometer and up). Calibrated TMCC values were within the observe range from Fischer, *et al* (1979). We were unable to test RIVPLUM5 at closer distances because the river is relatively deep and the distance to complete vertical mixing was great.

- The Rouge River and City of Camas WWTP tracer studies are not applicable for comparison to RIVPLUM5 because they have multi-port diffusers. However, they are valid test cases for comparison to three-dimensional models created by Cosmopolitan Engineering based on the same fundamental equations as RIVPLUM5. Calibrated TMCC values were within the observe range from Fischer, *et al* (1979).

REFERENCES

Bailey, G, 2008, *Water Quality Program Permit Writer's Manual*, Washington State Department of Ecology, Water Quality Program, Publication Number 92-109, Revised July 2008.

Parametrix, December 2004. *Mixing Zone Dye Tracer Study*. Prepared for the City of Grants Pass, Oregon.

Cosmopolitan Engineering Group (CEG), December 2005. *Mixing Zone Study Part II – Future Discharge Alternatives.* Prepared for the City of Ridgefield, Washington.

Cosmopolitan Engineering Group (CEG), November 2006. *Mixing Zone Study.* Prepared for the City of Arlington, Washington and Kennedy Jenks Consultants, Revised May 2007.

Cosmopolitan Engineering Group (CEG), December 2006. *Final Dye Tracer and Mixing Zone Study*. Prepared for the City of Camas, Washington, Updated June 2007.

Cosmopolitan Engineering Group (CEG), July 2008. *Mixing Zone Study*. Prepared for the City of Mount Vernon, Washington.

Cosmopolitan Engineering Group (CEG), January 2009. *Columbia River Discharge Schematic Design.* Prepared for the Portland International Airport Deicing Collection and Treatment System Enhancement Project.

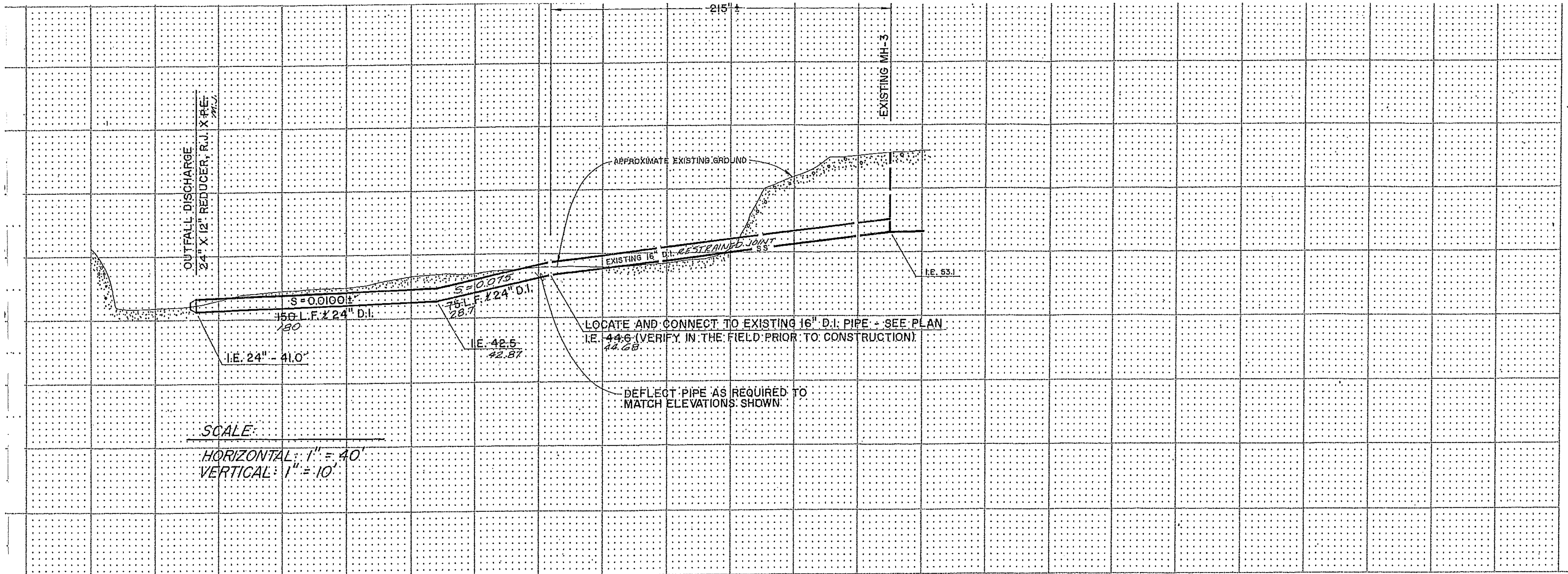
EPA, 1991, *Technical Support Document for Water Quality-based Toxics Control*, United States Environmental Protection Agency, Office of Water, Publication No. EPA/505/2-90-001.

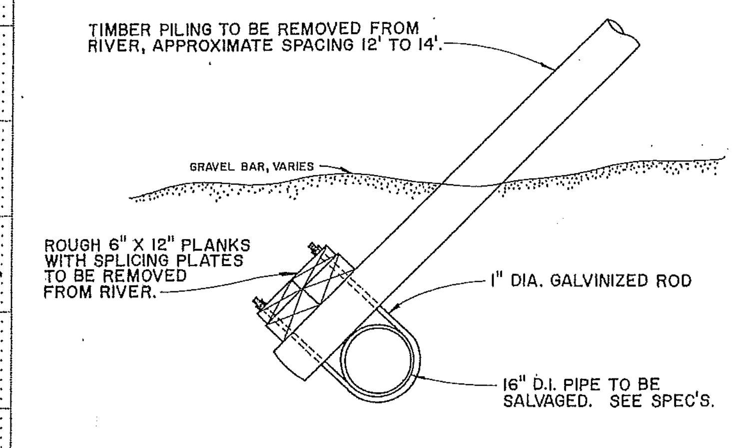
Fischer, H.B., E.J. List, R.C.Y. Koh, J. Imberger and N.H. Brooks, 1979, *Mixing in Inland and Coastal Waters*, Academic Press, New York.

Appendix A

Outfall Drawings:

City of Arlington (1 sheet)
City of Mount Vernon (2 sheets)
City of Grants Pass (3 sheets)
City of Camas (2 sheets)





EXISTING PIPE AND PILING

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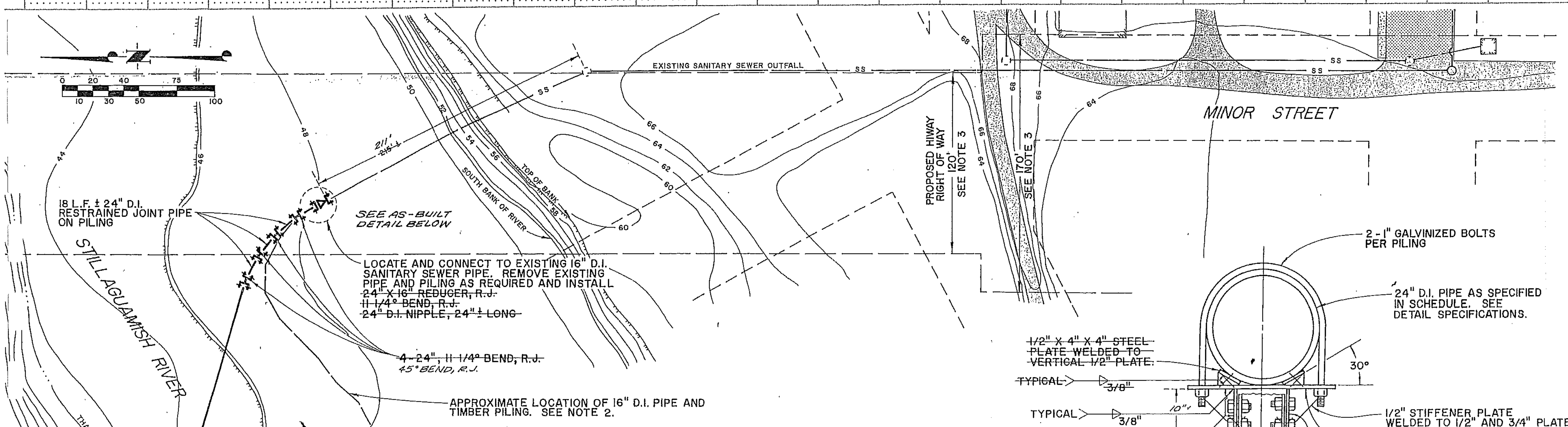
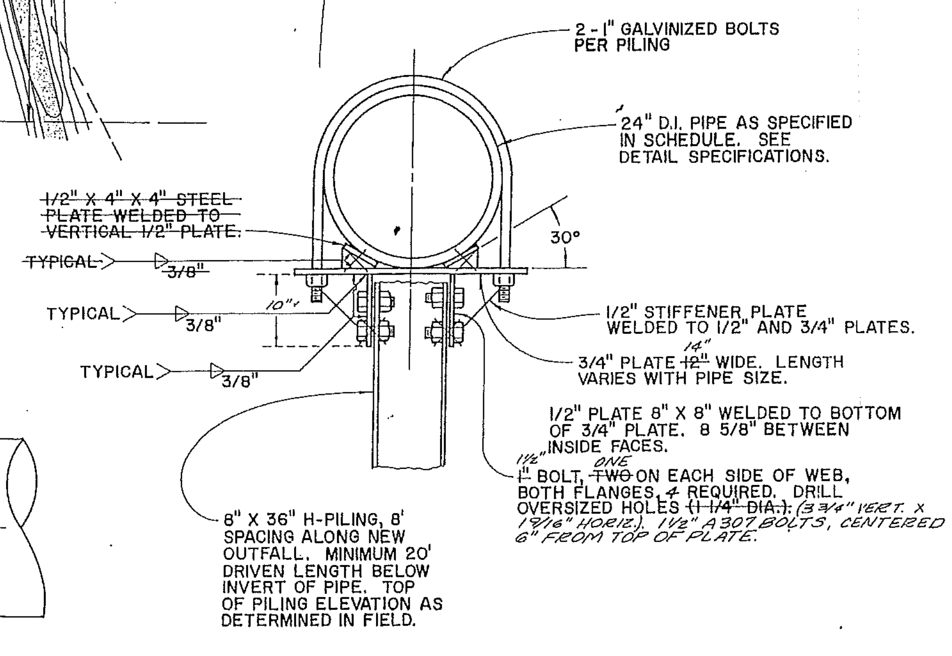


NOTES:

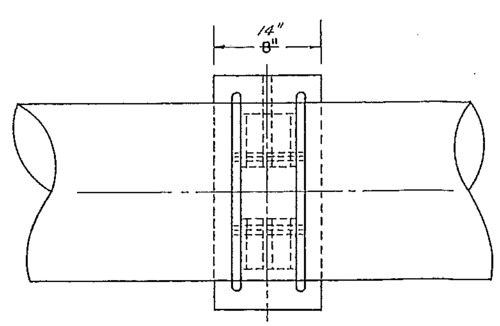
1. Pipe shall be Ductile Iron, CL 50, Cement Lined. Pipe and Fittings shall be Restrained Joints, according to the Specifications.
2. Contractor shall Remove and Salvage Existing 16" D.I. Pipe as Directed.
3. Location of Proposed Highway Right of Way is Approximate only. Exact Width to be Determined by Washington D.O.T.



ELEVATION
OUTFALL PIPE ATTACHMENT

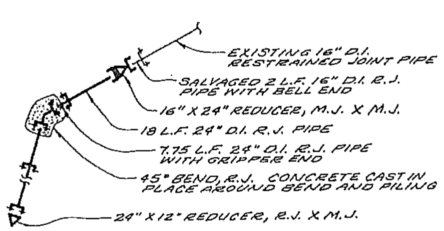
NOT TO SCALE

REVISED TO CONFORM TO CONSTRUCTION RECORDS
[signature] 10/31/91
DATE



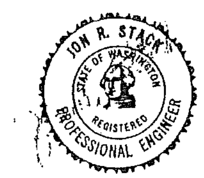
PLAN
OUTFALL PIPE ATTACHMENT

NOT TO SCALE



AS-BUILT DETAIL

NOT TO SCALE



LS	AS-BUILT	OCT. 1991	[initials]
DRAWN BY	REVISIONS	DATE	APPROVAL

ST ENGINEERING INC., P.S.
MUNICIPAL ENGINEERING CONSULTANT
1501 PARKER WAY, SUITE 4
MOUNT VERNON, WA 98221
PHONE: (206) 428-5933

CITY OF ARLINGTON

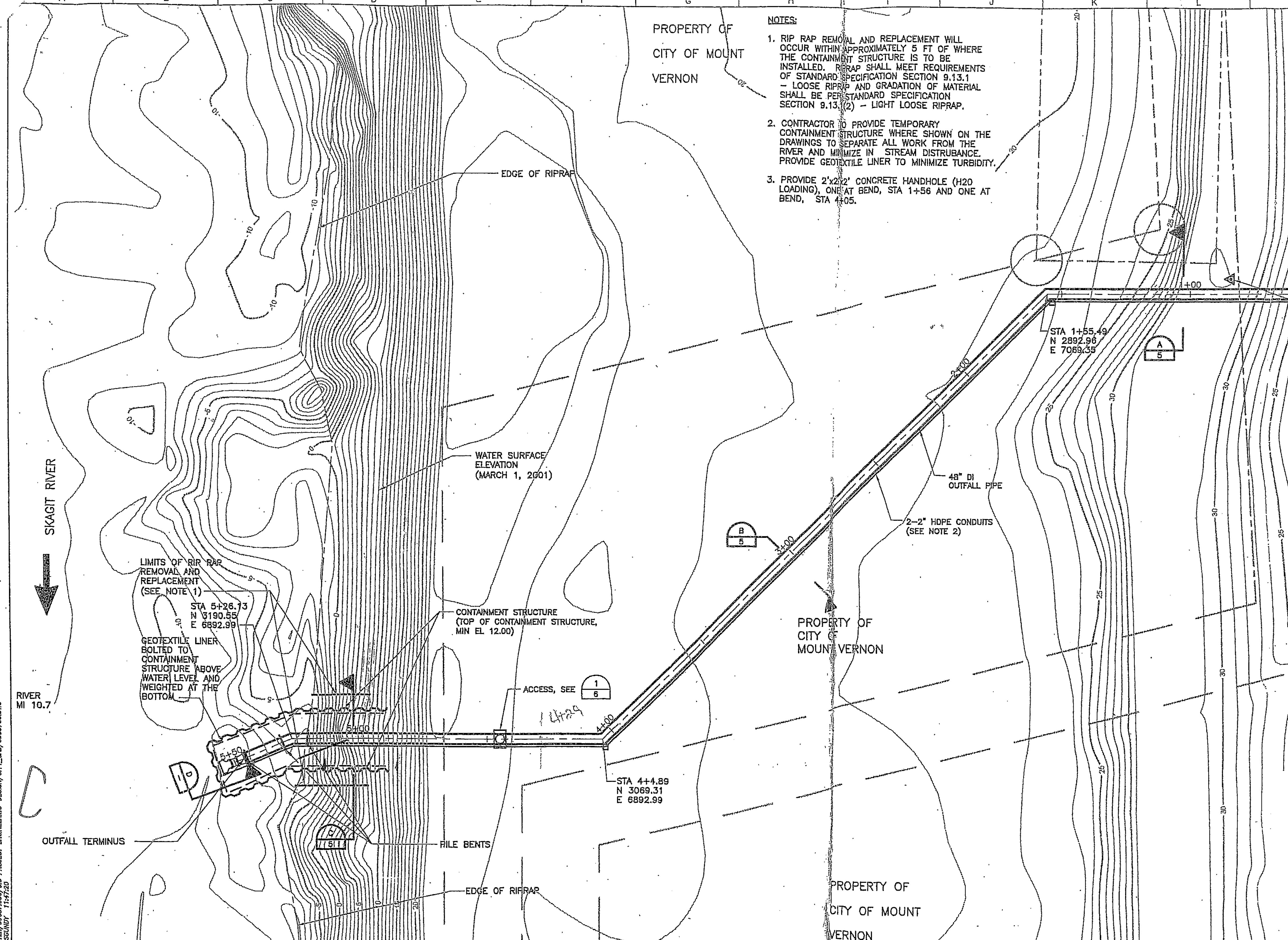
RECONSTRUCTION OF SEWER OUTFALL

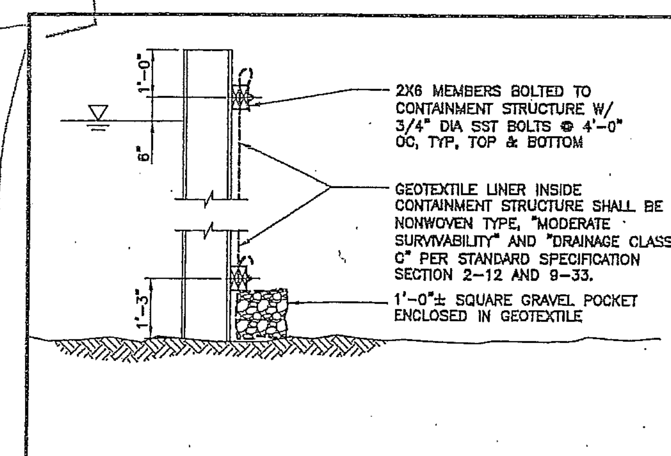
FIELD BOOK NO
PAGE NO.
JOB NO. 104.03-5
DATE JULY, 1991
SCALE 1" = 40'
DRAWING BY LS
DESIGNED BY DS
APPROVED

SHEET 1
OF 1

NOTES:

1. RIP RAP REMOVAL AND REPLACEMENT WILL OCCUR WITHIN APPROXIMATELY 5 FT OF WHERE THE CONTAINMENT STRUCTURE IS TO BE INSTALLED. RIPRAP SHALL MEET REQUIREMENTS OF STANDARD SPECIFICATION SECTION 9.13.1 – LOOSE RIPRAP AND GRADATION OF MATERIAL SHALL BE PER STANDARD SPECIFICATION SECTION 9.13.1(2) – LIGHT LOOSE RIPRAP.
2. CONTRACTOR TO PROVIDE TEMPORARY CONTAINMENT STRUCTURE WHERE SHOWN ON THE DRAWINGS TO SEPARATE ALL WORK FROM THE RIVER AND MINIMIZE IN STREAM DISTRUBANCE. PROVIDE GEOTEXTILE LINER TO MINIMIZE TURBIDITY.
3. PROVIDE 2'x2'x2' CONCRETE HANDHOLE (H20 LOADING), ONE AT BEND, STA 1+56 AND ONE AT BEND, STA 4+05.





SECTION D
1/2" = 1'-0"

HDR Engineering, Inc.

Project Manager	D OLSON
Designed	K HUI
Checked	R MARTIN
Drawn	S GUNDY

EXPIRES 12/25/04

City of Mount Vernon

CITY OF MOUNT VERNON OUT FALL IMPROVEMENTS

OUTFALL PLAN

Date	Project No.	Drawing No.	Issue
MARCH 2003	09637-006-002	3	1
Scale 1" = 20"	File Name 09637C3.DWG		

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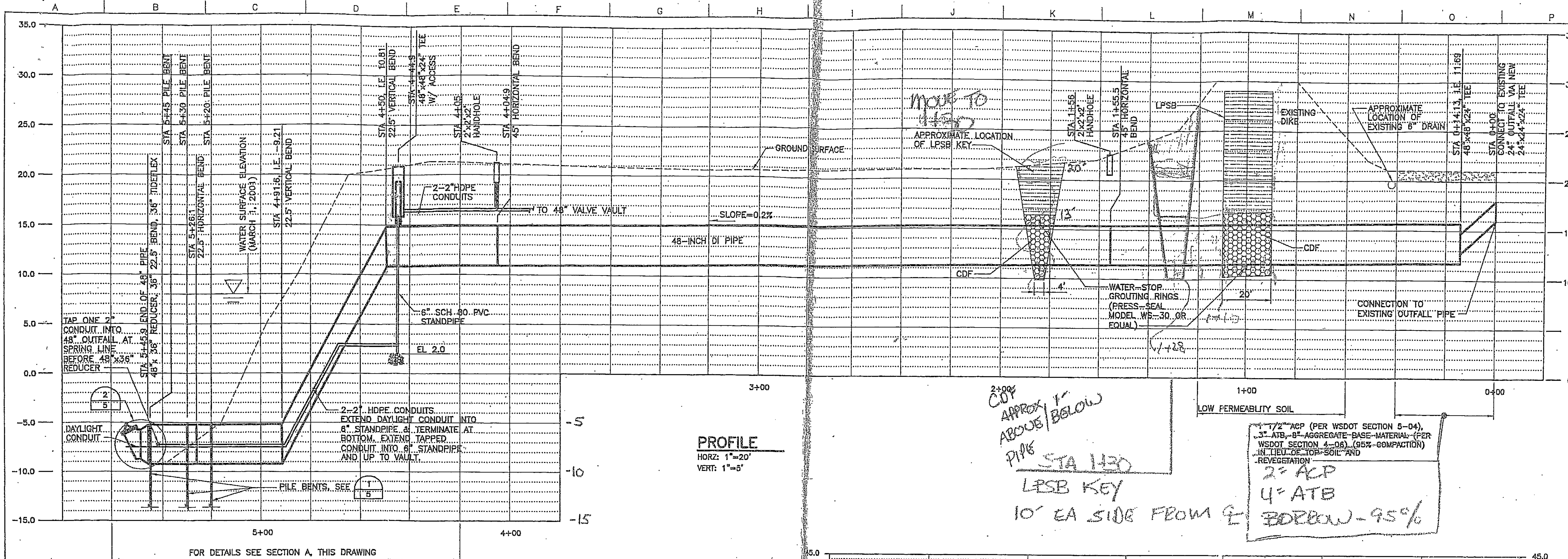

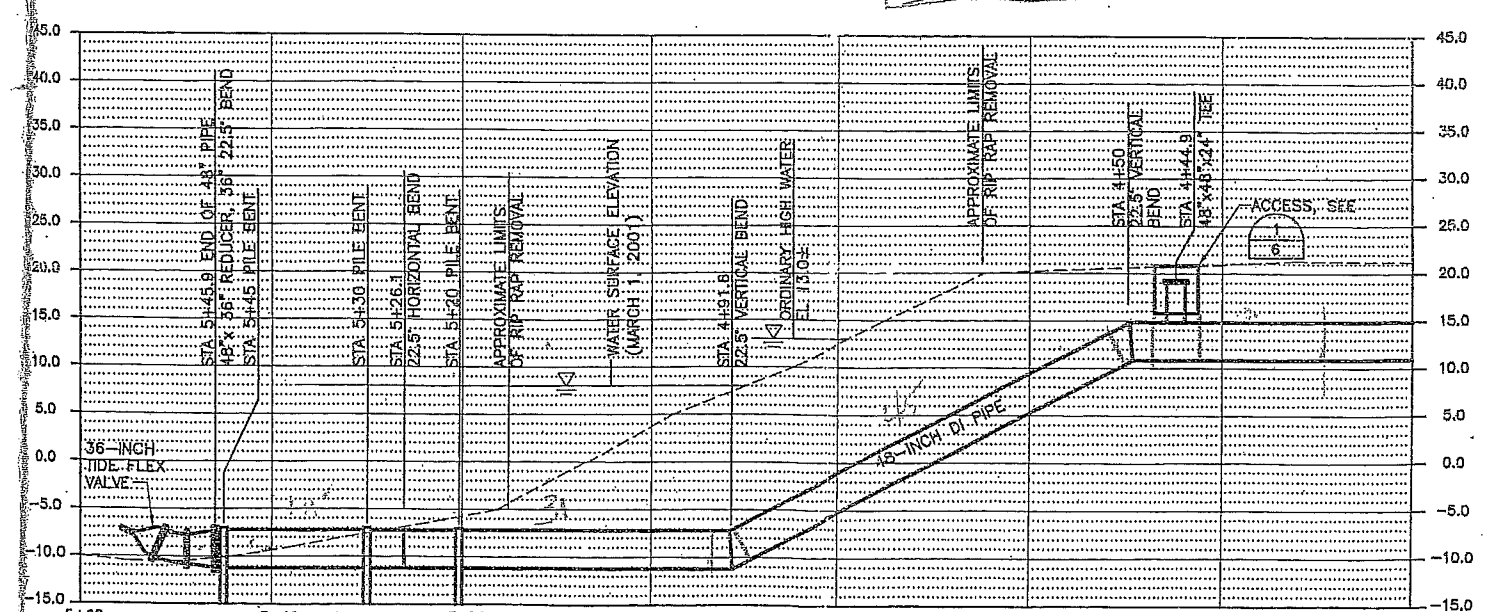

NOTE:

HDPE CONDUITS AND PVC STAND PIPE ARE NOT SHOWN FOR CLARITY.

SECTION A

HORIZ: 1"=10'
VERT: 1"=10'

Issue No.	Description	Date	Drwn.	Chkd.	Resp. Engr.	Proj. Mgr.

KENNETH C. Y. HUI, STATE OF WASHINGTON, 36575, REGISTERED PROFESSIONAL ENGINEER, EXPIRES: 12/25/04, 3/19/03

HDR Engineering, Inc.

Project Manager: D OLSON
Designed: K HUI
Designed:
Checked: R MARTIN
Drawn: S GUNDY

City of Mount Vernon

CITY OF MOUNT VERNON
OUT FALL IMPROVEMENTS

OUTFALL PROFILE AND SECTION

Date	Project No.	Drawing No.	Issue
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Scale: AS SHOWN	File Name: 09637C4.DWG		

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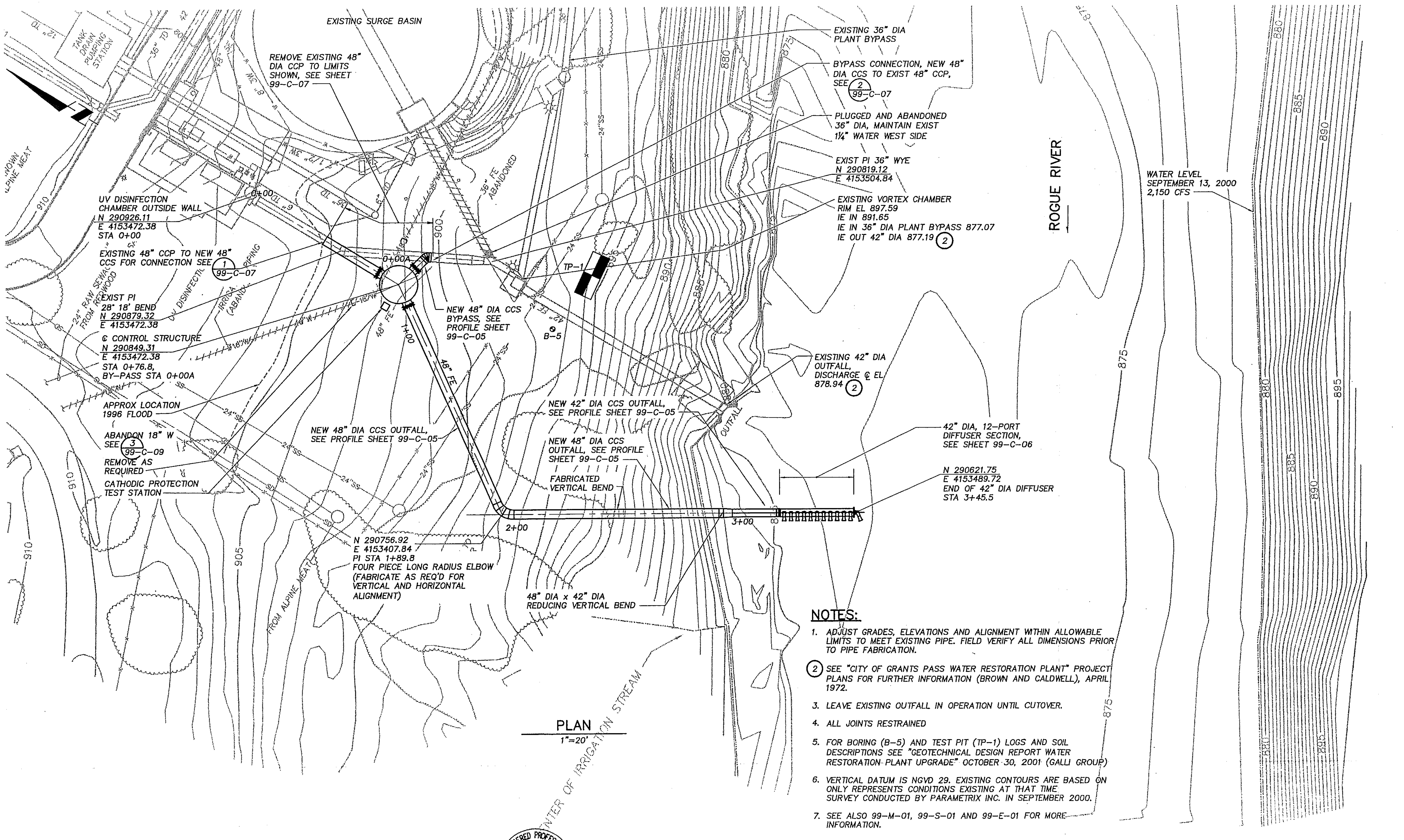


NOTES:

1. ADJUST GRADES, ELEVATIONS AND ALIGNMENT WITHIN ALLOWABLE LIMITS TO MEET EXISTING PIPE. FIELD VERIFY ALL DIMENSIONS PRIOR TO PIPE FABRICATION.
2. SEE "CITY OF GRANTS PASS WATER RESTORATION PLANT" PROJECT PLANS FOR FURTHER INFORMATION (BROWN AND CALDWELL), APRIL 1972.
3. LEAVE EXISTING OUTFALL IN OPERATION UNTIL CUTOVER.
4. ALL JOINTS RESTRAINED
5. FOR BORING (B-5) AND TEST PIT (TP-1) LOGS AND SOIL DESCRIPTIONS SEE "GEOTECHNICAL DESIGN REPORT WATER RESTORATION PLANT UPGRADE" OCTOBER 30, 2001 (GALLI GROUP)
6. VERTICAL DATUM IS NGVD 29. EXISTING CONTOURS ARE BASED ON ONLY REPRESENTS CONDITIONS EXISTING AT THAT TIME SURVEY CONDUCTED BY PARAMETRIX INC. IN SEPTEMBER 2000.
7. SEE ALSO 99-M-01, 99-S-01 AND 99-E-01 FOR MORE INFORMATION.

DATE: 06/19/02 IMAGES: XREF'S: PI S341619B62 S341619DE RVH_OREGON

NO.	REVISIONS	DATE	BY

DESIGNED D. MCBRIDE
DRAWN E. HARRIS
CHECKED M. Odo
APPROVED D. Bender

TWO INCHES AT FULL SCALE IF NOT SCALE ACCORDINGLY
SCALE 1"=20'
DATE JUNE 2002

REGISTERED PROFESSIONAL ENGINEER 7860 OREGON RICKI V. HERMES 9/23/02 Exp. 6/30/03

Parametrix, Inc. "Quality Service Through Employee Ownership"
1231 Fryar Avenue Sumner, WA 98390 Ph: (253) 863-5128 Fax: (253) 863-0946 http://www.parametrix.com
WASHINGTON Sumner Bremerton Kirkland
OREGON Portland

PROJECT NAME: CITY OF GRANTS PASS WATER RESTORATION PLANT UPGRADE PHASE 1 GRANTS PASS, OREGON

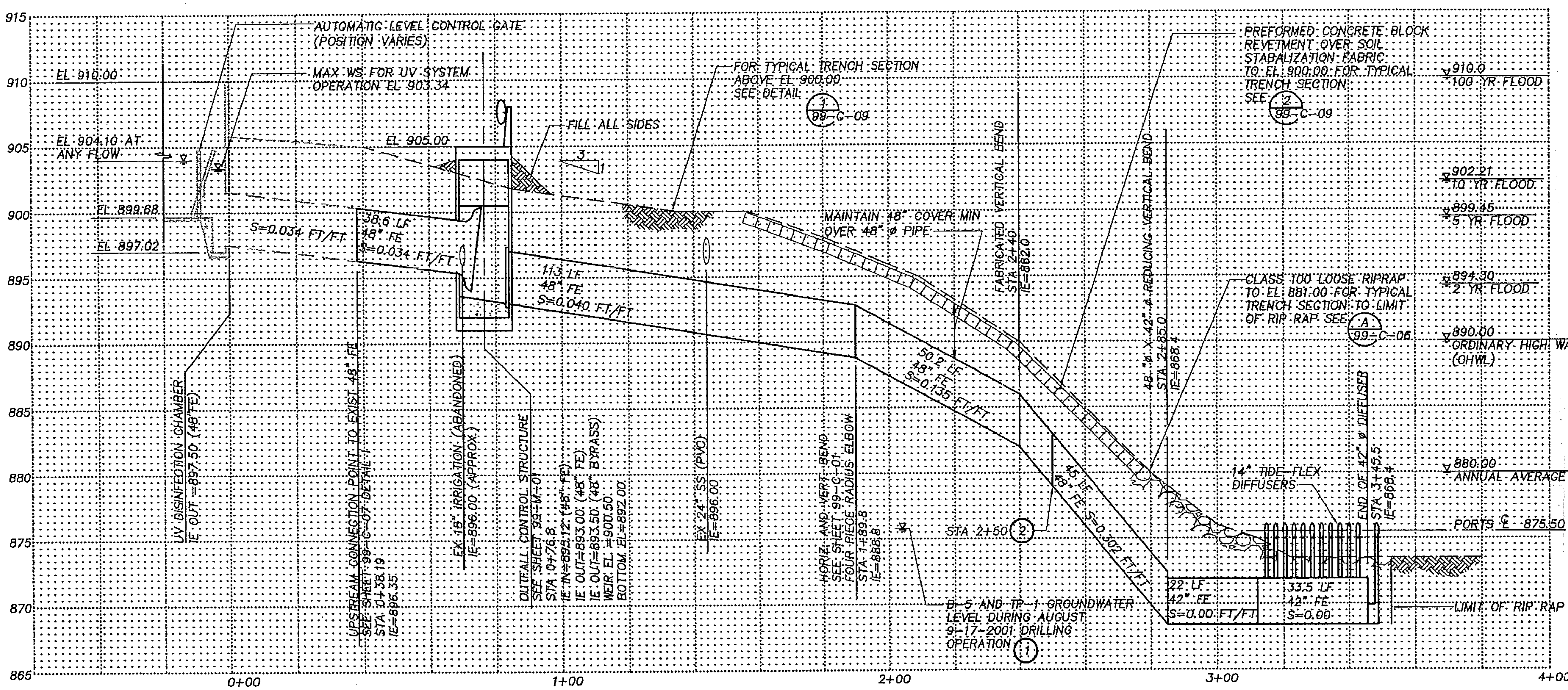
JOB NO. 216-3416-019 FILE NAME: S341619C010

AREA 3 OUTFALL PIPING PLAN

SHEET NO. 99-C-01

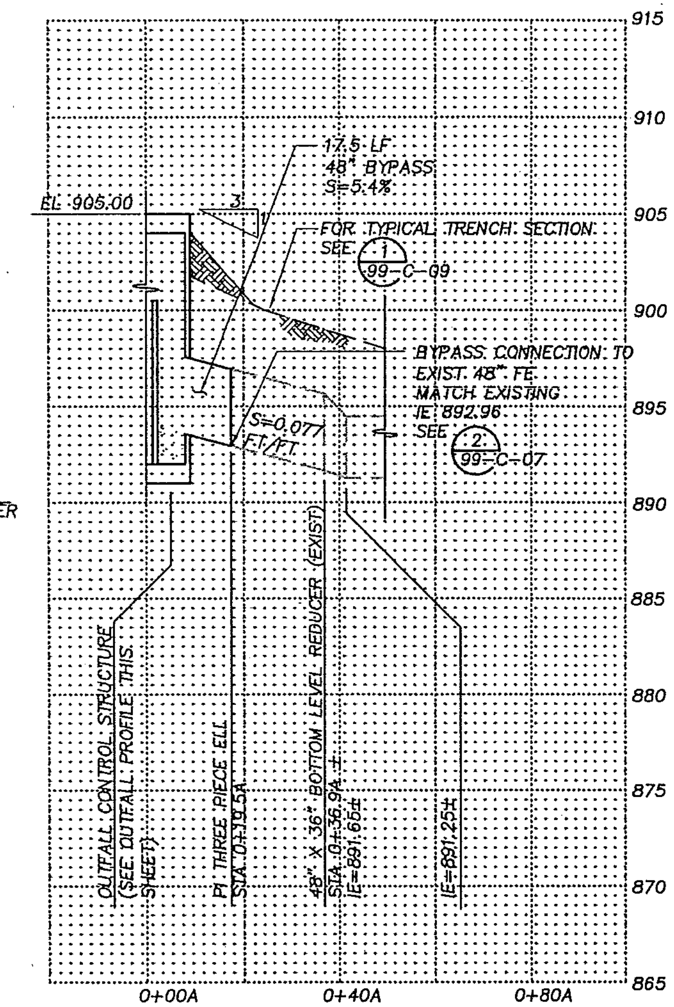
54 / 275

ISSUED FOR CONSTRUCTION



OUTFALL PROFILE

HORIZ: 1"=20'
VERT: 1"=5'



BYPASS PROFILE

HORIZ: 1"=20'
VERT: 1"=5'

NOTES:

1. GROUNDWATER LEVELS FLUCTUATE SEASONALLY DUE TO RAINFALL, IRRIGATION, AND WATER LEVEL IN THE ROGUE RIVER. SEEPAGE MAY BE ENCOUNTERED IN EXCAVATIONS ABOVE GROUNDWATER LEVEL DUE TO "PERCHED" AQUIFERS ON TOP OF CEMENTED/CLAYED ZONES. SEE "GEOTECHNICAL DESIGN REPORT WATER RESTORATION PLANT UPGRADE" OCTOBER 30 2001 (GALLI GROUP)
2. INSTALL 48" DIA BLIND FLANGE BETWEEN TWO FLANGE FACES. AFTER HYDROSTATIC TESTING REMOVE BLIND FLANGE AND REPLACE WITH 48" DIA SPACER FLANGE WITH 48" ORIFICE.

IMAGES:
XREFS: PI RVH_OREGON
DATE: 06/19/02

NO.	REVISIONS	DATE	BY

DESIGNED D. MC BRIDE
DRAWN E. HARRIS
CHECKED M. Ado
APPROVED D. Bresdian

TWO INCHES AT FULL SCALE IF NOT SCALE ACCORDINGLY
SCALE AS SHOWN
DATE JUNE 2002

REGISTERED PROFESSIONAL ENGINEER 18660 OREGON JAN. 30, 1973 VICKI V. HERMES
Exp. 6/30/03
9/23/02

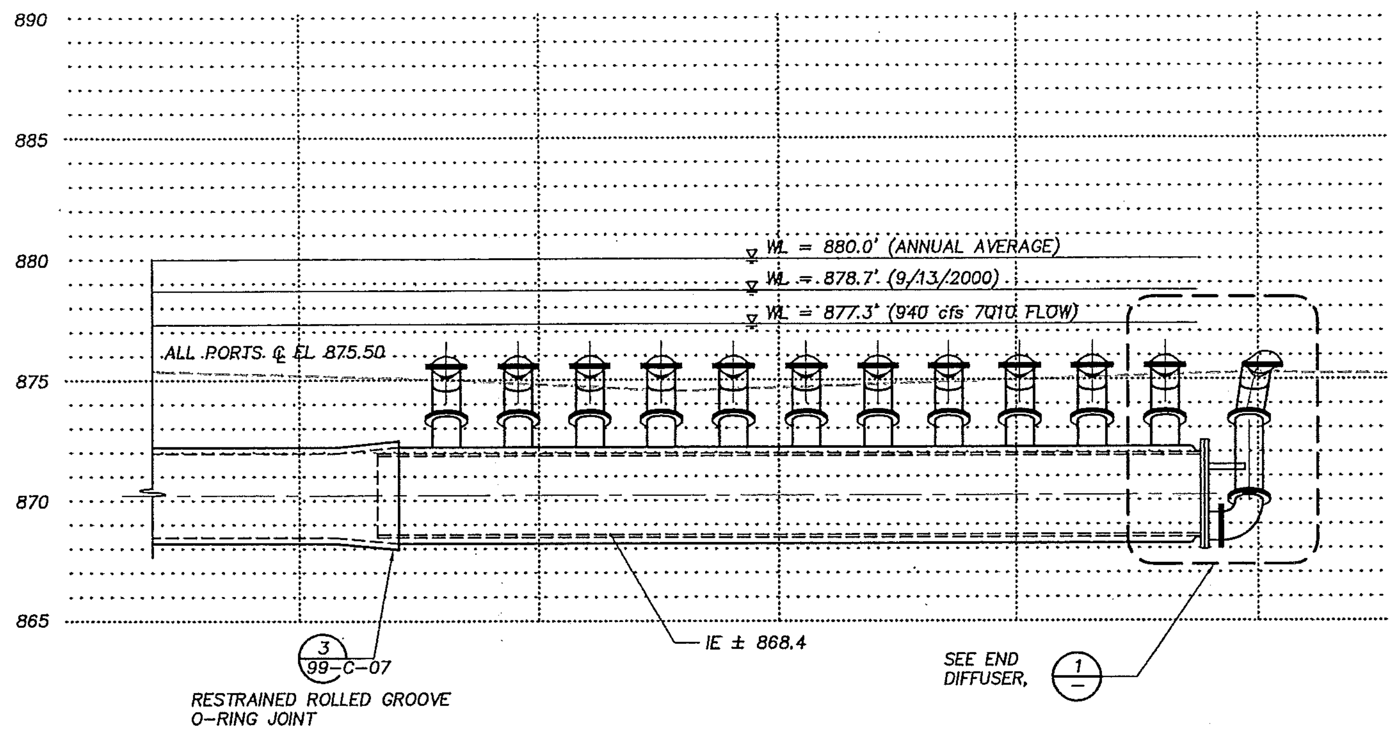
Parametrix, Inc. "Quality Service Through Employee Ownership"
1231 Fryar Avenue Sumner, WA 98390
Ph: (253) 863-5128
Fax: (253) 863-0946
http://www.parametrix.com
WASHINGTON Sumner Bremerton Kirkland
OREGON Portland

PROJECT NAME CITY OF GRANTS PASS WATER RESTORATION PLANT UPGRADE PHASE 1
GRANTS PASS, OREGON
JOB NO. 216-3416-019 FILE NAME: S341619C012

OUTFALL PROFILES

SHEET NO. 99-C-05
58/275

ISSUED FOR CONSTRUCTION



DIFFUSER
SECTION
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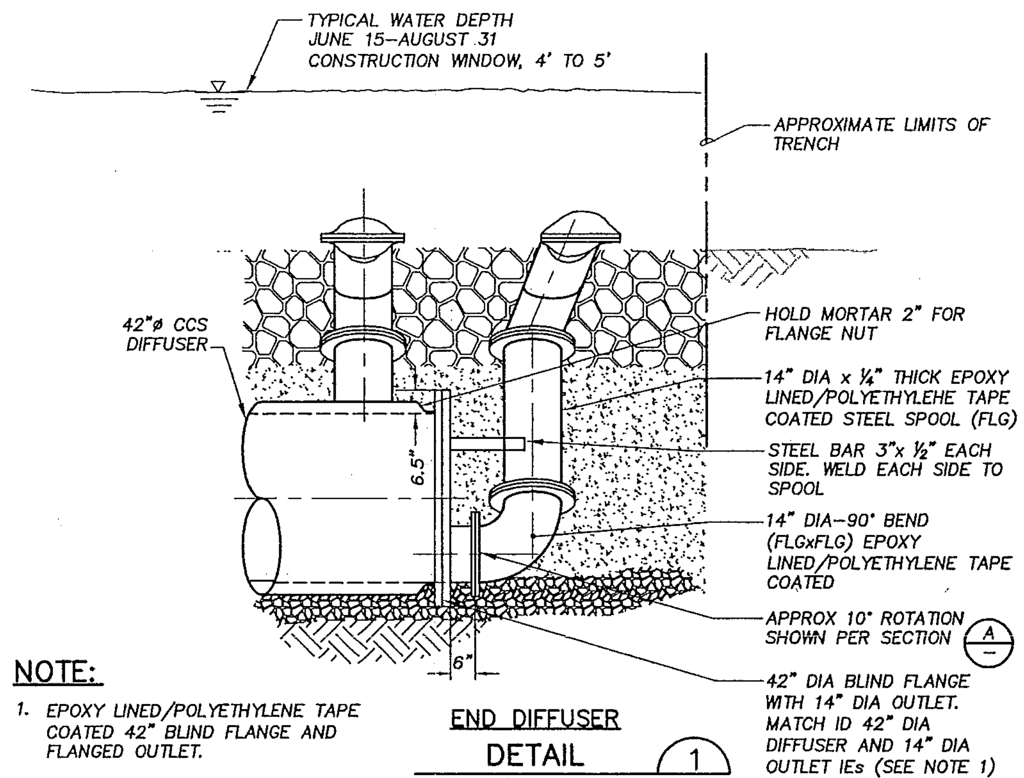
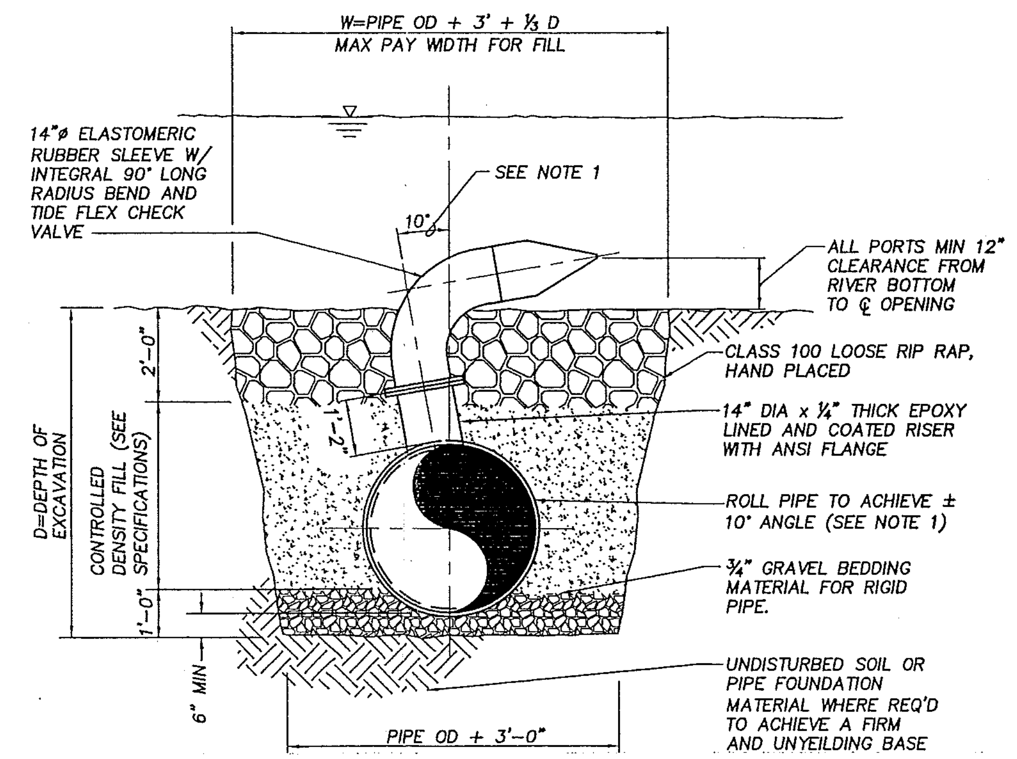


NOTE:

1. EPOXY LINED/POLYETHYLENE TAPE COATED 42" BLIND FLANGE AND FLANGED OUTLET.
2. ALL FLANGE BOLTS AND NUTS 304SST.

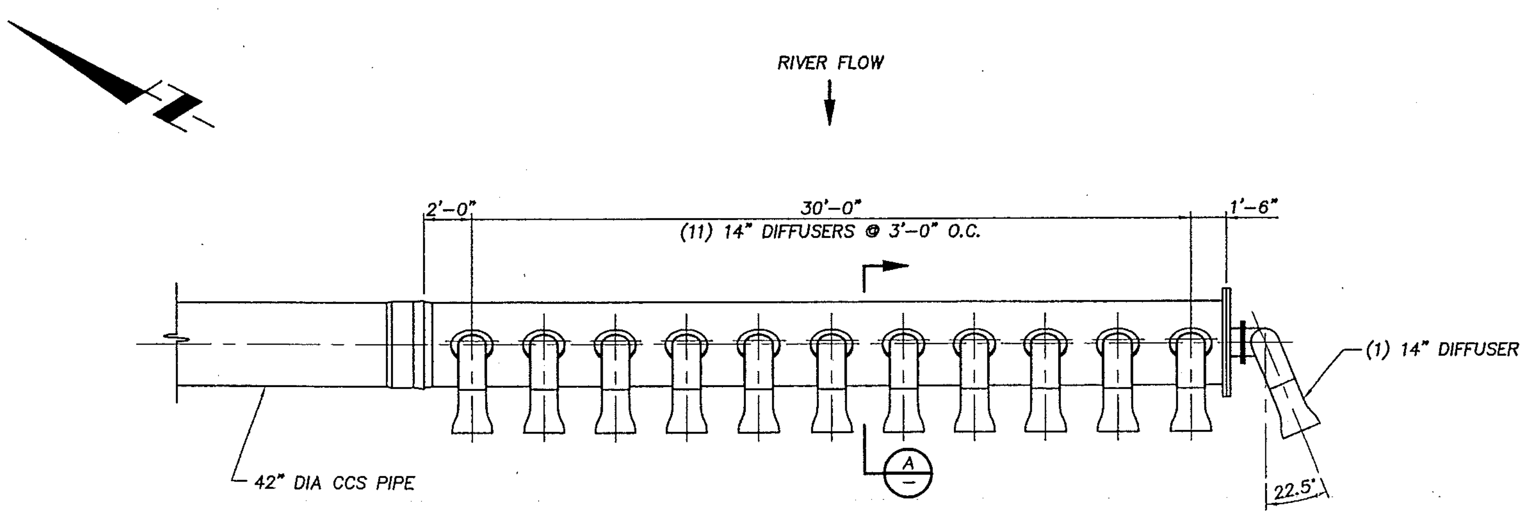
END DIFFUSER
DETAIL 1
1/2"=1'-0"



14" DIFFUSER AND
IN-RIVER TRENCH SECTION
SECTION A
1/2"=1'-0"

NOTE:

1. ENGINEER SHALL APPROVE ANGLE OF ROTATION PRIOR TO BACKFILL. LESSER OR GREATER ANGLE MAY BE REQUIRED TO ACHIEVE DESIRED PORT CLEARANCE FROM RIVER BOTTOM.



DIFFUSER
PLAN
1/4"=1'-0"

IMAGES:
XREF'S: S341619PI RVH_OREGON
DATE: 06/19/02

NO.	REVISIONS	DATE	BY

DESIGNED D. MCBRIDE
DRAWN PMX
CHECKED [signature]
APPROVED [signature]

TWO INCHES AT FULL SCALE IF NOT SCALE ACCORDINGLY
SCALE AS SHOWN
DATE JUNE 2002

REGISTERED PROFESSIONAL ENGINEER 17660 OREGON JAN. 30, 1976 RICKI V. HERMES
Exp. 6/30/03
9/23/02

Parametrix, Inc. "Quality Service Through Employee Ownership"
1231 Fryar Avenue
Sumner, WA 98390
Ph: (253) 863-5128
Fax: (253) 863-0946
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OREGON Portland

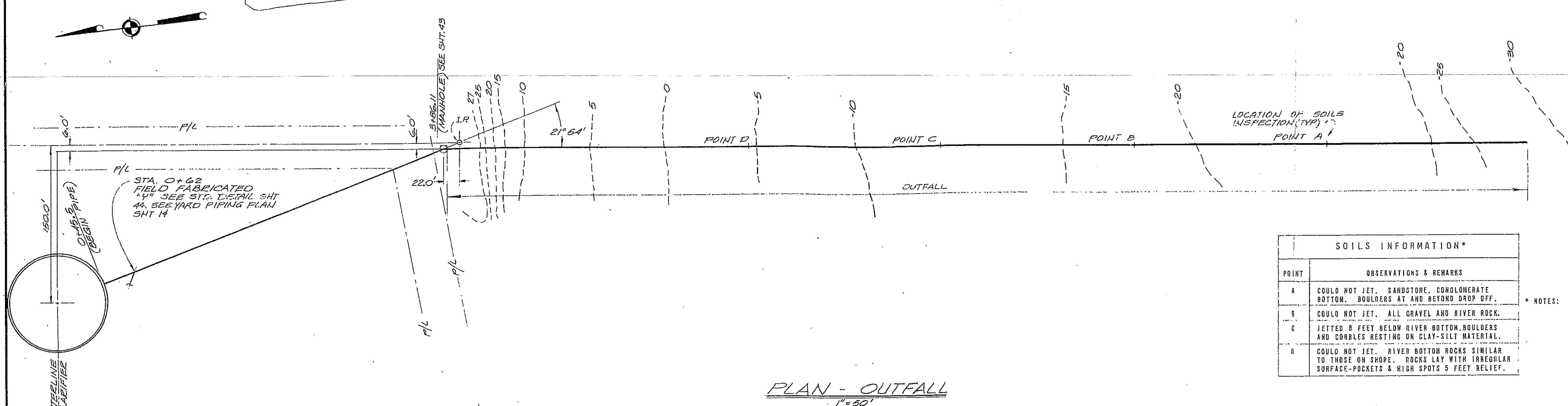
PROJECT NAME
CITY OF GRANTS PASS
WATER RESTORATION PLANT UPGRADE
PHASE 1
GRANTS PASS, OREGON
JOB NO. 216-3416-019 FILE NAME: S341619C013

DIFFUSER PLAN, SECTIONS, AND DETAILS

SHEET NO. 99-C-06
59 / 275

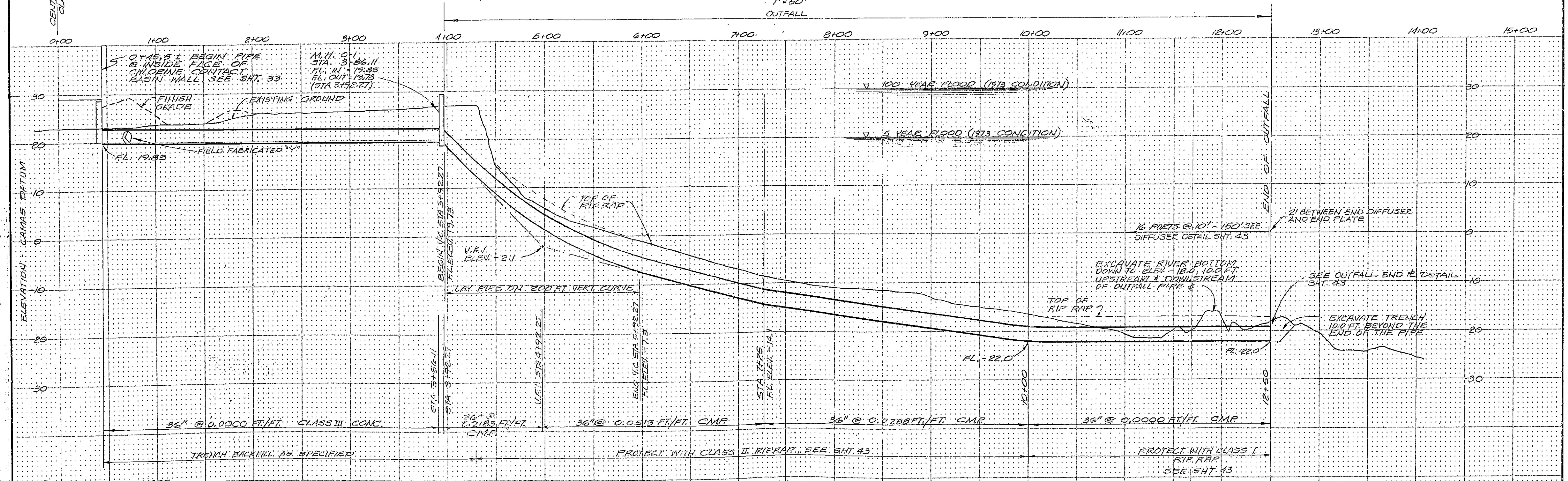
ISSUED FOR CONSTRUCTION

BRG 353



PLAN - OUTFALL

1"=50'



NOTE:
CAMAS DATUM MINUS 1.0 FT.
EQUALS COLUMBIA RIVER
DATUM ELEVATION

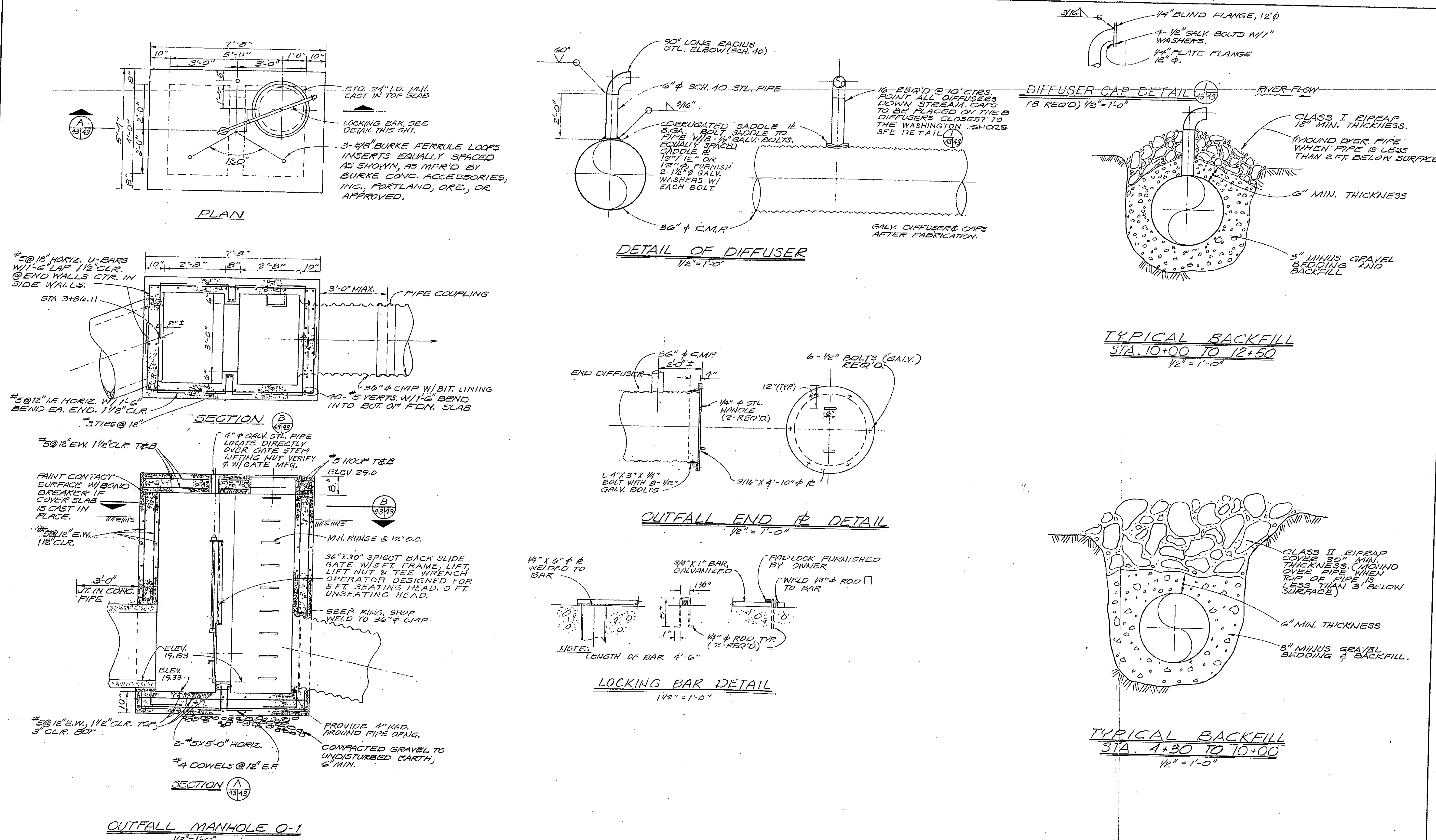
SOILS INFORMATION*	
POINT	OBSERVATIONS & REMARKS
A	COULD NOT JET. SANDSTONE, CONGLOMERATE BOTTOM. BOULDERS AT AND BEYOND DROP OFF.
B	COULD NOT JET. ALL GRAVEL AND RIVER ROCK.
C	JETTED 8 FEET BELOW RIVER BOTTOM. BOULDERS AND COBBLES RESTING ON CLAY-SILT MATERIAL.
D	COULD NOT JET. RIVER BOTTOM ROCKS SIMILAR TO THOSE ON SHORE. ROCKS LAY WITH IRREGULAR SURFACE-POCKETS & HIGH SPOTS 5 FEET RELIEF.

* NOTES:
1. SOILS INFORMATION WAS OBTAINED FROM A DIVER, WHO INSPECTED THE RIVER BOTTOM ON 28 DEC. 1970. A 1½" JET PIPE WAS USED BY THE DIVER TO JET HOLES INTO RIVER BED.
2. SEE NOTE UNDER TEST LOGS SHEET 6

CORNELL, HOWLAND, HAYES & MERRYFIELD
CH2M
ENGINEERS
PLANNERS
ECONOMISTS

CITY OF CAMAS, WASHINGTON
SEWERAGE SYSTEM ADDITIONS
SCHEDULE T
OUTFALL -
PLAN & PROFILE

DES	SHEET 42 OF 53
DR	
CK	DATE FEB. 1971
RN P5924.1 P6270.1	SCALE AS SHOWN
DWG 5924-1	



CORNELL, HOWLAND, HAYES & MERRYFIELD
ENGINEERS PLANNERS ECONOMISTS
CH2M

CITY OF CAMAS, WASHINGTON
SEWERAGE SYSTEM ADDITIONS
SCHEDULE T

OUTFALL - DETAILS

DES RWL	SHEET 43
DR RJK	OF 53
CK RSR	DATE FEB. 1971
EN P6024.1 P6270.1	SCALE AS SHOWN

Appendix B

RIVPLUM5 Model Input/Output

RIVPLUM ANALYSIS

based upon the method of Fischer et al. (1979) with correction for the effective origin of effluent.

Revised 17-Oct-2007

	City of Arlington		City of Mount Vernon		City of Ridgefield										PDX - Site B		PDX - Site C2	
INPUT	**Default TMCC**	**Calibrated TMCC**	**Default TMCC**	**Calibrated TMCC**	**Default TMCC 3/4 Flood**	**Default TMCC High Slack**	**Default TMCC 1/4 Ebb**	**Default TMCC Mid-Ebb**	**Default TMCC 3/4 Ebb**	**Calibrated TMCC 3/4 Flood**	**Calibrated TMCC High Slack**	**Calibrated TMCC 1/4 Ebb**	**Calibrated TMCC Mid-Ebb**	**Calibrated TMCC 3/4 Ebb**	**Default TMCC**	**Calibrated TMCC**	**Default TMCC**	**Calibrated TMCC**
1. Effluent Discharge Rate (MGD):	2.20	2.20	3.44	3.44	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	3.20	3.20	3.20	3.20
1. Effluent Discharge Rate (cfs):	3.40	3.40	5.32	5.32	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	4.95	4.95	4.95	4.95
2. Receiving Water Characteristics Downstream From Waste Input																		
Stream Depth (ft):	4.00	4.00	12.70	12.70	15.00	15.50	15.20	14.50	14.00	15.00	15.50	15.20	14.50	14.00	26.00	26.00	42.00	42.00
Stream Velocity (fps):	1.51	1.51	2.29	2.29	0.90	0.60	1.00	1.60	1.20	0.90	0.60	1.00	1.60	1.20	1.50	1.50	2.30	2.30
Channel Width (ft):	121.0	121.0	281.0	281.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	4000.0	4000.0	4000.0	4000.0
Stream Slope (ft/ft) or Manning roughness "n":	0.025	0.025	0.035	0.035	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
0 if slope or 1 if Manning "n" in previous cell:	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3. Discharge Distance From Nearest Shoreline (ft):	52	52	44	44	100	100	100	100	100	100	100	100	100	100	950	950	750	750
4. Location of Point of Interest to Estimate Dilution																		
Distance Downstream to Point of Interest (ft):	304	304	313	313	200	200	200	200	200	200	200	200	200	200	8000	8000	5750	5750
Distance From Nearest Shoreline (ft):	52	52	44	44	100	100	100	100	100	100	100	100	100	100	950	950	750	750
5. Transverse Mixing Coefficient Constant (usually 0.6):	0.6	0.4	0.6	0.4	0.6	0.6	0.6	0.6	0.6	0.09	0.13	0.08	0.13	0.1	0.6	1.8	0.6	0.5
6. Original Fischer Method (0) or *Effective Origin* Modification (1)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OUTPUT																		
1. Source Conservative Mass Input Rate																		
Concentration of Conservative Substance (%):	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Source Conservative Mass Input Rate (cfs*%):	340	340	532	532	39	39	39	39	39	39	39	39	39	39	495	495	495	495
2. Shear Velocity																		
Shear Velocity based on slope (ft/sec):	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Shear Velocity based on Manning "n":																		
using Prasuhn equations 8-26 and 8-54 assuming																		
hydraulic radius equals depth for wide channel																		
Darcy-Weisbach friction factor "f" (ft/sec):	0.046	0.046	0.061	0.061	0.042	0.042	0.042	0.043	0.043	0.042	0.042	0.042	0.043	0.043	0.035	0.035	0.030	0.030
Shear Velocity from Darcy-Weisbach "f" (ft/sec):	0.114	0.114	0.200	0.200	0.065	0.043	0.073	0.117	0.088	0.065	0.043	0.073	0.117	0.088	0.100	0.100	0.141	0.141
Selected Shear Velocity for next step (ft/sec):	0.114	0.114	0.200	0.200	0.065	0.043	0.073	0.117	0.088	0.065	0.043	0.073	0.117	0.088	0.100	0.100	0.141	0.141
3. Transverse Mixing Coefficient (ft2/sec):	0.274	0.183	1.523	1.015	0.589	0.404	0.662	1.018	0.742	0.088	0.087	0.088	0.221	0.124	1.553	4.660	3.552	2.960
4. Plume Characteristics Accounting for Shoreline Effect (Fischer 1979)																		
Co	0.466	0.466	0.065	0.065	0.010	0.014	0.008	0.006	0.008	0.010	0.014	0.008	0.006	0.008	0.003	0.003	0.001	0.001
x'	0.003766	0.002511	0.002636	0.001757	0.001455	0.001495	0.001471	0.001415	0.001374	0.000218	0.000324	0.000196	0.000306	0.000229	0.000518	0.001553	0.000555	0.000462
y'o	0.42975	0.42975	0.15658	0.15658	0.33333	0.33333	0.33333	0.33333	0.33333	0.33333	0.33333	0.33333	0.33333	0.33333	0.23750	0.23750	0.18750	0.18750
y' at point of interest	0.42975	0.42975	0.15658	0.15658	0.33333	0.33333	0.33333	0.33333	0.33333	0.33333	0.33333	0.33333	0.33333	0.33333	0.23750	0.23750	0.18750	0.18750
Solution using superposition equation (Fischer eqn 5.9)																		
Term for n= -2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Term for n= -1	4.71E-116	1.021E-173	1.73E-165	7.2118E-248	3.357E-299	3.726E-291	6.34E-296	9.406E-308	0	0	0	0	0	0	0	2.5221E-280	0	0
Term for n= 0	1.00000	1.00000	1.00009	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
Term for n= 1	3.145E-38	5.5766E-57	6.26E-118	1.5678E-176	2.212E-133	8.328E-130	6.32E-132	3.497E-137	3.12E-141	0	0	0	0	0	0	2.7532E-163	0	0
Term for n= 2	4.37E-285	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upstream Distance from Outfall to *Effective Origin* of Effluent Source (ft)	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Effective Distance Downstream from Effluent to Point of Interest (ft)	304.000	304.000	313.000	313.000	200.000	200.000	200.000	200.000	200.000	200.000	200.000	200.000	200.000	200.000	8000.000	8000.000	5750.000	5750.000
x' Adjusted for *Effective Origin*	0.003766	0.002511	0.002636	0.001757	0.001455	0.001495	0.001471	0.001415	0.001374	0.000218	0.000324	0.000196	0.000306	0.000229	0.000518	0.001553	0.000555	0.000462
C/Co (dimensionless)	4.597	5.630	5.495	6.729	7.395	7.295	7.355	7.501	7.611	19.095	15.672	20.141	16.114	18.643	12.397	7.158	11.975	13.117
Effluent Concentration at Point of Interest (Fischer Eqn 5.9)	2.141	2.622	0.358	0.438	0.071	0.101	0.062	0.042	0.058	0.182	0.217	0.171	0.090	0.143	0.039	0.023	0.015	0.017
Unbounded Plume Width at Point of Interest (ft)	42.004	34.296	81.610	66.635	64.734	65.625	65.093	63.826	62.900	25.072	30.547	23.768	29.710	25.679	514.872	891.785	533.052	486.608
Unbounded Plume half-width (ft)	21.002	17.148	40.805	33.317	32.367	32.812	32.546	31.913	31.450	12.536	15.273	11.884	14.855	12.839	257.436	445.892	266.526	243.304
Distance from near shore to discharge point (ft)	52	52	44	44	100	100	100	100	100	100	100	100	100	100	950	950	750	750
Distance from far shore to discharge point (ft)	69	69	237	237	200	200	200	200	200	200	200	200	200	200	3050	3050	3250	3250
Plume width bounded by shoreline (ft)	42.00	34.30	81.61	66.63	64.73	65.62	65.09	63.83	62.90	25.07	30.55	23.77	29.71	25.68	514.87	891.78	533.05	486.61
Approximate Downstream Distance to Complete Mix (ft):	10,500	15,751	33,788	50,682	24,436	23,777	24,168	25,136	25,882	162,907	109,741	181,258	116,013	155,292	3,593,363	1,197,788	2,735,929	3,283,115
Theoretical Dilution Factor at Complete Mix:	214.7	214.7	1,535.7	1,535.7	10,471.9	7,214.0	11,790.6	17,996.1	13,031.7	10,471.9	7,214.0	11,790.6	17,996.1	13,031.7	31,512.6	31,512.6	78,054.3	78,054.3
Calculated Flux-Average Dilution Factor Across Entire Plume Width:	74.5	60.9	446.0	364.2	2,259.6	1,578.1	2,558.3	3,828.8	2,732.3	875.2	734.5	934.1	1,782.2	1,115.5	4,056.2	7,025.6	10,401.8	9,495.5
Calculated Dilution Factor at Point of Interest:	46.7	38.1	279.5	228.2	1,416.0	988.9	1,603.2	2,399.3	1,712.2	548.4	460.3	585.4	1,116.8	699.0	2,541.9	4,402.7	6,518.3	5,950.4

NOTES

Arlington

1) "n" value calculated in City of Arlington Mixing Zone Study Report based upon average rock diameter observed at site
2) Calibrated TMCC = 0.4 selected in Mixing Zone Study Report to match field observed dilution and plume width

Mount Vernon

1) "n" value selected for RIVPLUM analysis presented in the City of Mount Vernon Mixing Zone Study Report
2) Calibrated TMCC = 0.4 selected in Mixing Zone Study Report to match field observed dilution and plume width

Ridgefield

1) "n" value selected for RIVPLUM analysis presented in the City of Ridgefield Mixing Zone Study Report
2) Calibrated TMCC values selected in Mixing Zone Study Report to match field observed dilution and plume width

PDX

1) "n" value selected for RIVPLUM analysis typical of a "clean and straight natural river."
2) Calibrated TMCC values selected for this Technical Memorandum to match field observed dilution

Appendix C

3DAD Equation Input/Output

City of Grants Pass - 3DAD Equation
Calibrated TMCC

Parameter	Symbol	Value	Units		
Effluent Flow	Qe	0.250	m^3/s	5.7	mgd
Number Ports	#	12			
Port Flow	qe	0.0208	m^3/s		
Current Speed	u	0.549	m/s	1.8	ft/s
Port Spacing	Pspace	0.914	m	3	feet
Water Depth	d	0.762	m	2.5	feet
Port Elev	h	0	m	0	feet
Shear Velocity	u*	0.054864	m/s	Assumed	
Lateral Disp Coeff	Ey	0.048	m^2/s	Assumed	
Vertical Disp Coeff	Ez	0.0048	m^2/s	Assumed	
	Ey/du*	1.15		Calculated	

Point of Interest	X	91.44	m	300	feet
	Y	5.0292	m	16.5	feet
	Z	0	m	0	feet

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	Units
Station (from end)	0	0.9144	1.8288	2.7432	3.6576	4.572	5.4864	6.4008	7.3152	8.2296	9.144	10.0584	m
y	-5.0292	-4.1148	-3.2004	-2.286	-1.3716	-0.4572	0.4572	1.3716	2.286	3.2004	4.1148	5.0292	m
z1 (port)	0	0	0	0	0	0	0	0	0	0	0	0	m
z2 (image 1)	1.524	1.524	1.524	1.524	1.524	1.524	1.524	1.524	1.524	1.524	1.524	1.524	m
z3 (image 2)	3.048	3.048	3.048	3.048	3.048	3.048	3.048	3.048	3.048	3.048	3.048	3.048	m
z4 (image 3)	4.572	4.572	4.572	4.572	4.572	4.572	4.572	4.572	4.572	4.572	4.572	4.572	m
z5 (image -1)	-1.524	-1.524	-1.524	-1.524	-1.524	-1.524	-1.524	-1.524	-1.524	-1.524	-1.524	-1.524	m
z6 (image -2)	-3.048	-3.048	-3.048	-3.048	-3.048	-3.048	-3.048	-3.048	-3.048	-3.048	-3.048	-3.048	m
z7 (image -3)	-4.572	-4.572	-4.572	-4.572	-4.572	-4.572	-4.572	-4.572	-4.572	-4.572	-4.572	-4.572	m

2*qe/[4*pi*x*sqrt(EyEz)]	0.00239	0.00239	0.00239	0.00239	0.00239	0.00239	0.00239	0.00239	0.00239	0.00239	0.00239	0.00239	
u/4x	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	s^-1
y^2/Ey+z1^2/Ez (port)	526.93	352.74	213.39	108.87	39.19	4.35	4.35	39.19	108.87	213.39	352.74	526.93	s
y^2/Ey+z2^2/Ez (image 1)	1010.80	836.61	697.26	592.74	523.06	488.22	488.22	523.06	592.74	697.26	836.61	1010.80	s
y^2/Ey+z3^2/Ez (image 2)	2462.41	2288.22	2148.87	2044.35	1974.67	1939.83	1939.83	1974.67	2044.35	2148.87	2288.22	2462.41	s
y^2/Ey+z4^2/Ez (image 3)	4881.76	4707.57	4568.22	4463.70	4394.02	4359.18	4359.18	4394.02	4463.70	4568.22	4707.57	4881.76	s
y^2/Ey+z5^2/Ez (image -1)	1010.80	836.61	697.26	592.74	523.06	488.22	488.22	523.06	592.74	697.26	836.61	1010.80	s
y^2/Ey+z6^2/Ez (image -2)	2462.41	2288.22	2148.87	2044.35	1974.67	1939.83	1939.83	1974.67	2044.35	2148.87	2288.22	2462.41	s
y^2/Ey+z7^2/Ez (image -3)	4881.76	4707.57	4568.22	4463.70	4394.02	4359.18	4359.18	4394.02	4463.70	4568.22	4707.57	4881.76	s

Term multiplied by two to account for images resulting from a discharge located at the river bed

exp -{ } (port)	0.45366	0.58913	0.72609	0.84933	0.94290	0.99349	0.99349	0.94290	0.84933	0.72609	0.58913	0.45366
exp -{ } (image 1)	0.21954	0.28510	0.35138	0.41102	0.45630	0.48078	0.48078	0.45630	0.41102	0.35138	0.28510	0.21954
exp -{ } (image 2)	0.02488	0.03231	0.03982	0.04658	0.05171	0.05449	0.05449	0.05171	0.04658	0.03982	0.03231	0.02488
exp -{ } (image 3)	0.00066	0.00086	0.00106	0.00124	0.00137	0.00145	0.00145	0.00137	0.00124	0.00106	0.00086	0.00066
exp -{ } (image -1)	0.21954	0.28510	0.35138	0.41102	0.45630	0.48078	0.48078	0.45630	0.41102	0.35138	0.28510	0.21954
exp -{ } (image -2)	0.02488	0.03231	0.03982	0.04658	0.05171	0.05449	0.05449	0.05171	0.04658	0.03982	0.03231	0.02488
exp -{ } (image -3)	0.00066	0.00086	0.00106	0.00124	0.00137	0.00145	0.00145	0.00137	0.00124	0.00106	0.00086	0.00066

Sum (all ports)	9.10921
Sum (all images)	9.84227
Sum (ports and images)	18.95148
Effluent Fraction (f)	**0.045273**
Centerline Dilution (S)	**22.1**

City of Grants Pass - 3DAD Equation
Default TMCC

Parameter	Symbol	Value	Units		
Effluent Flow	Qe	0.250	m^3/s	5.7	mgd
Number Ports	#	12			
Port Flow	qe	0.0208	m^3/s		
Current Speed	u	0.549	m/s	1.8	ft/s
Port Spacing	Pspace	0.914	m	3	feet
Water Depth	d	0.762	m	2.5	feet
Port Elev	h	0	m	0	feet
Shear Velocity	u*	0.054864	m/s	Assumed	
Lateral Disp Coeff	Ey	0.025	m^2/s	Assumed	
Vertical Disp Coeff	Ez	0.0025	m^2/s	Assumed	
	Ey/du*	0.60		Calculated	
Point of Interest	X	91.44	m	300	feet
	Y	5.0292	m	16.5	feet
	Z	0	m	0	feet

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	Units
Station (from end)	0	0.9144	1.8288	2.7432	3.6576	4.572	5.4864	6.4008	7.3152	8.2296	9.144	10.0584	m
y	-5.0292	-4.1148	-3.2004	-2.286	-1.3716	-0.4572	0.4572	1.3716	2.286	3.2004	4.1148	5.0292	m
z1 (port)	0	0	0	0	0	0	0	0	0	0	0	0	m
z2 (image 1)	1.524	1.524	1.524	1.524	1.524	1.524	1.524	1.524	1.524	1.524	1.524	1.524	m
z3 (image 2)	3.048	3.048	3.048	3.048	3.048	3.048	3.048	3.048	3.048	3.048	3.048	3.048	m
z4 (image 3)	4.572	4.572	4.572	4.572	4.572	4.572	4.572	4.572	4.572	4.572	4.572	4.572	m
z5 (image -1)	-1.524	-1.524	-1.524	-1.524	-1.524	-1.524	-1.524	-1.524	-1.524	-1.524	-1.524	-1.524	m
z6 (image -2)	-3.048	-3.048	-3.048	-3.048	-3.048	-3.048	-3.048	-3.048	-3.048	-3.048	-3.048	-3.048	m
z7 (image -3)	-4.572	-4.572	-4.572	-4.572	-4.572	-4.572	-4.572	-4.572	-4.572	-4.572	-4.572	-4.572	m
2*qe/[4*pi*x*sqrt(EyEz)]	0.00459	0.00459	0.00459	0.00459	0.00459	0.00459	0.00459	0.00459	0.00459	0.00459	0.00459	0.00459	
u/4x	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	0.0015	s^-1
y^2/Ey+z1^2/Ez (port)	1011.71	677.26	409.70	209.03	75.25	8.36	8.36	75.25	209.03	409.70	677.26	1011.71	s
y^2/Ey+z2^2/Ez (image 1)	1940.74	1606.29	1338.73	1138.06	1004.28	937.39	937.39	1004.28	1138.06	1338.73	1606.29	1940.74	s
y^2/Ey+z3^2/Ez (image 2)	4727.84	4393.38	4125.82	3925.15	3791.37	3724.48	3724.48	3791.37	3925.15	4125.82	4393.38	4727.84	s
y^2/Ey+z4^2/Ez (image 3)	9372.99	9038.54	8770.98	8570.31	8436.53	8369.63	8369.63	8436.53	8570.31	8770.98	9038.54	9372.99	s
y^2/Ey+z5^2/Ez (image -1)	1940.74	1606.29	1338.73	1138.06	1004.28	937.39	937.39	1004.28	1138.06	1338.73	1606.29	1940.74	s
y^2/Ey+z6^2/Ez (image -2)	4727.84	4393.38	4125.82	3925.15	3791.37	3724.48	3724.48	3791.37	3925.15	4125.82	4393.38	4727.84	s
y^2/Ey+z7^2/Ez (image -3)	9372.99	9038.54	8770.98	8570.31	8436.53	8369.63	8369.63	8436.53	8570.31	8770.98	9038.54	9372.99	s
exp -{ } (port)	0.21924	0.36208	0.54088	0.73085	0.89326	0.98754	0.98754	0.89326	0.73085	0.54088	0.36208	0.21924	
exp -{ } (image 1)	0.05441	0.08987	0.13424	0.18139	0.22170	0.24510	0.24510	0.22170	0.18139	0.13424	0.08987	0.05441	
exp -{ } (image 2)	0.00083	0.00137	0.00205	0.00277	0.00339	0.00375	0.00375	0.00339	0.00277	0.00205	0.00137	0.00083	
exp -{ } (image 3)	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	
exp -{ } (image -1)	0.05441	0.08987	0.13424	0.18139	0.22170	0.24510	0.24510	0.22170	0.18139	0.13424	0.08987	0.05441	
exp -{ } (image -2)	0.00083	0.00137	0.00205	0.00277	0.00339	0.00375	0.00375	0.00339	0.00277	0.00205	0.00137	0.00083	
exp -{ } (image -3)	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	

Term multiplied by two to account for images resulting from a discharge located at the river bed

Sum (all ports)	7.46770
Sum (all images)	3.76360
Sum (ports and images)	11.23130
Effluent Fraction (f)	**0.051515**
Centerline Dilution (S)	**19.4**

City of Camas - 3DAD Equation
Calibrated TMCC

Parameter	Symbol	Value	Units		
Effluent Flow	Qe	0.111	m^3/s	2.53	mgd
Number Ports	#	8			
Port Flow	qe	0.0139	m^3/s		
Current Speed	u	0.21	m/s		
Port Spacing	Pspace	3.05	m		
Water Depth	d	6.7	m		
Port Elev	h	0.8	m		
Shear Velocity	u*	0.021	m/s	Assumed	
Lateral Disp Coeff	Ey	0.089	m^2/s	Assumed	
Vertical Disp Coeff	Ez	0.0089	m^2/s	Assumed	
	Ey/du*	0.63		Calculated	
Point of Interest	X	98	m		
	Y	10.675	m		
	Z	0	m		

	P1	P2	P3	P4	P5	P6	P7	P8	Units
Station (from end)	0	3.05	6.1	9.15	12.2	15.25	18.3	21.35	m
y	-10.675	-7.625	-4.575	-1.525	1.525	4.575	7.625	10.675	m
z1 (port)	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	m
z2 (image)	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	m
qe/[4*pi*x*sqrt(EyEz)]	0.00040	0.00040	0.00040	0.00040	0.00040	0.00040	0.00040	0.00040	
u/4x	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	s^-1
y^2/Ey+z1^2/Ez (port)	1352.31	725.18	307.09	98.04	98.04	307.09	725.18	1352.31	s
y^2/Ey+z2^2/Ez (image)	1352.31	725.18	307.09	98.04	98.04	307.09	725.18	1352.31	s
exp -{ } (port)	0.48459	0.67808	0.84831	0.94883	0.94883	0.84831	0.67808	0.48459	
exp -{ } (image)	0.48459	0.67808	0.84831	0.94883	0.94883	0.84831	0.67808	0.48459	
Sum (all ports)	5.91963								
Sum (all images)	5.91963								
Sum (ports and images)	11.83926								
Effluent Fraction (f)	**0.004738**								
Dilution (S)	**211**								

City of Camas - 3DAD Equation
Default TMCC

Parameter	Symbol	Value	Units		
Effluent Flow	Qe	0.111	m^3/s	2.53	mgd
Number Ports	#	8			
Port Flow	qe	0.0139	m^3/s		
Current Speed	u	0.21	m/s		
Port Spacing	Pspace	3.05	m		
Water Depth	d	6.7	m		
Port Elev	h	0.8	m		
Shear Velocity	u*	0.021	m/s	Assumed	
Lateral Disp Coeff	Ey	0.085	m^2/s	Assumed	
Vertical Disp Coeff	Ez	0.0085	m^2/s	Assumed	
	Ey/du*	0.60		Calculated	
Point of Interest	X	98	m		
	Y	10.675	m		
	Z	0	m		

	P1	P2	P3	P4	P5	P6	P7	P8	Units
Station (from end)	0	3.05	6.1	9.15	12.2	15.25	18.3	21.35	m
y	-10.675	-7.625	-4.575	-1.525	1.525	4.575	7.625	10.675	m
z1 (port)	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	m
z2 (image)	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	m
qe/[4*pi*x*sqrt(EyEz)]	0.00042	0.00042	0.00042	0.00042	0.00042	0.00042	0.00042	0.00042	
u/4x	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	s^-1
y^2/Ey+z1^2/Ez (port)	1415.95	759.30	321.54	102.65	102.65	321.54	759.30	1415.95	s
y^2/Ey+z2^2/Ez (image)	1415.95	759.30	321.54	102.65	102.65	321.54	759.30	1415.95	s
exp -{ } (port)	0.46835	0.66580	0.84177	0.94649	0.94649	0.84177	0.66580	0.46835	
exp -{ } (image)	0.46835	0.66580	0.84177	0.94649	0.94649	0.84177	0.66580	0.46835	
Sum (all ports)	5.84481								
Sum (all images)	5.84481								
Sum (ports and images)	11.68962								
Effluent Fraction (f)	**0.004898**								
Dilution (S)	**204**								