Application of Mixing Zone Modeling in Decision Making for CSO Tunnel Construction Water Discharge

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Stantec

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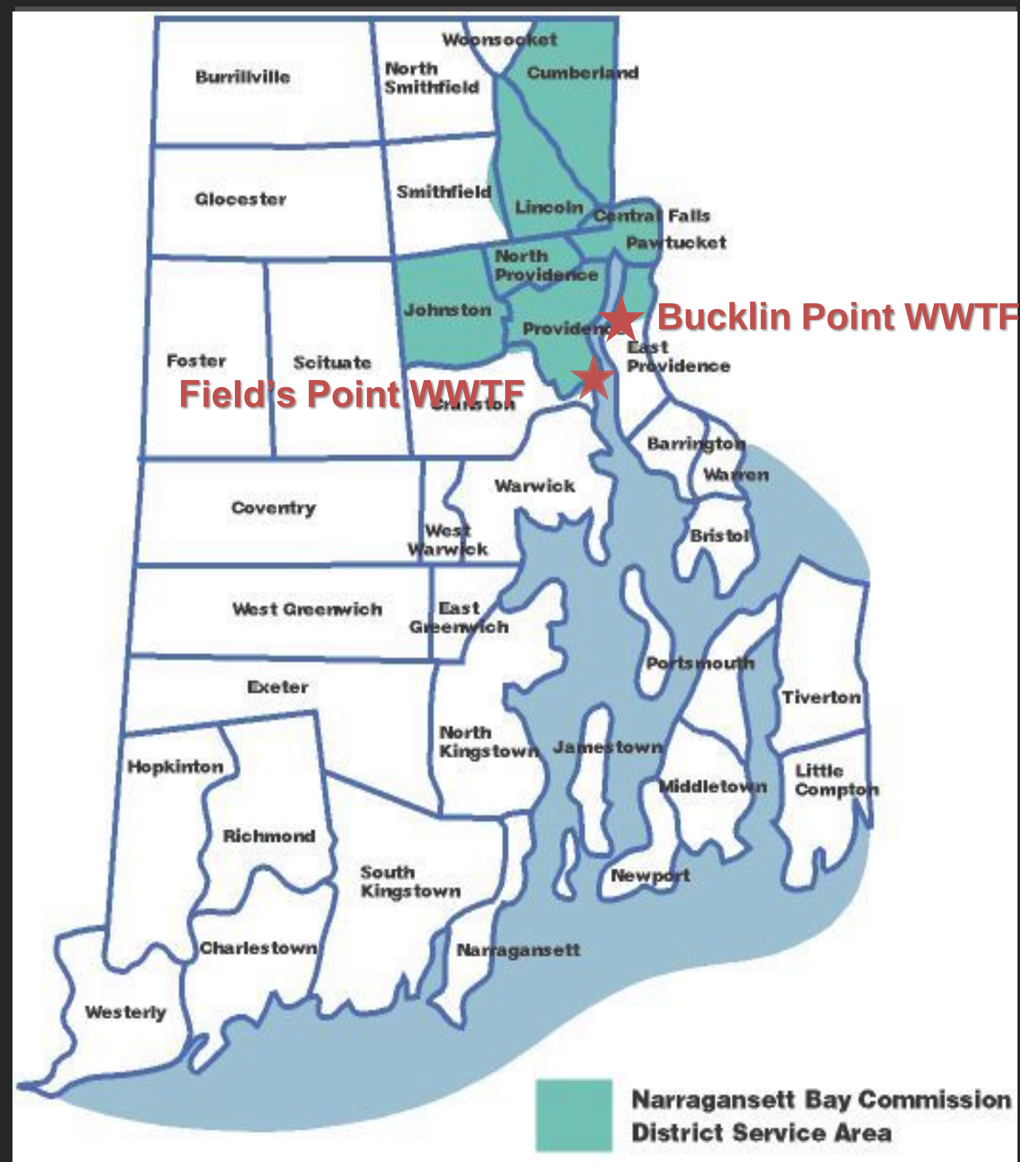
Narragansett Bay Commission (NBC), Rhode Island

- Two WWTFs
- 110 Miles of Interceptors
- 64 CSO Outfalls
- 3-mile CSO Tunnel
- 6 Pump Stations
- 10 Communities

  (70,000 Customers)



NBC CSO Program

1992: Consent Agreement with RIDEM for CSO Controls

1996-1998: Program Reevaluation with Stakeholders Group Input

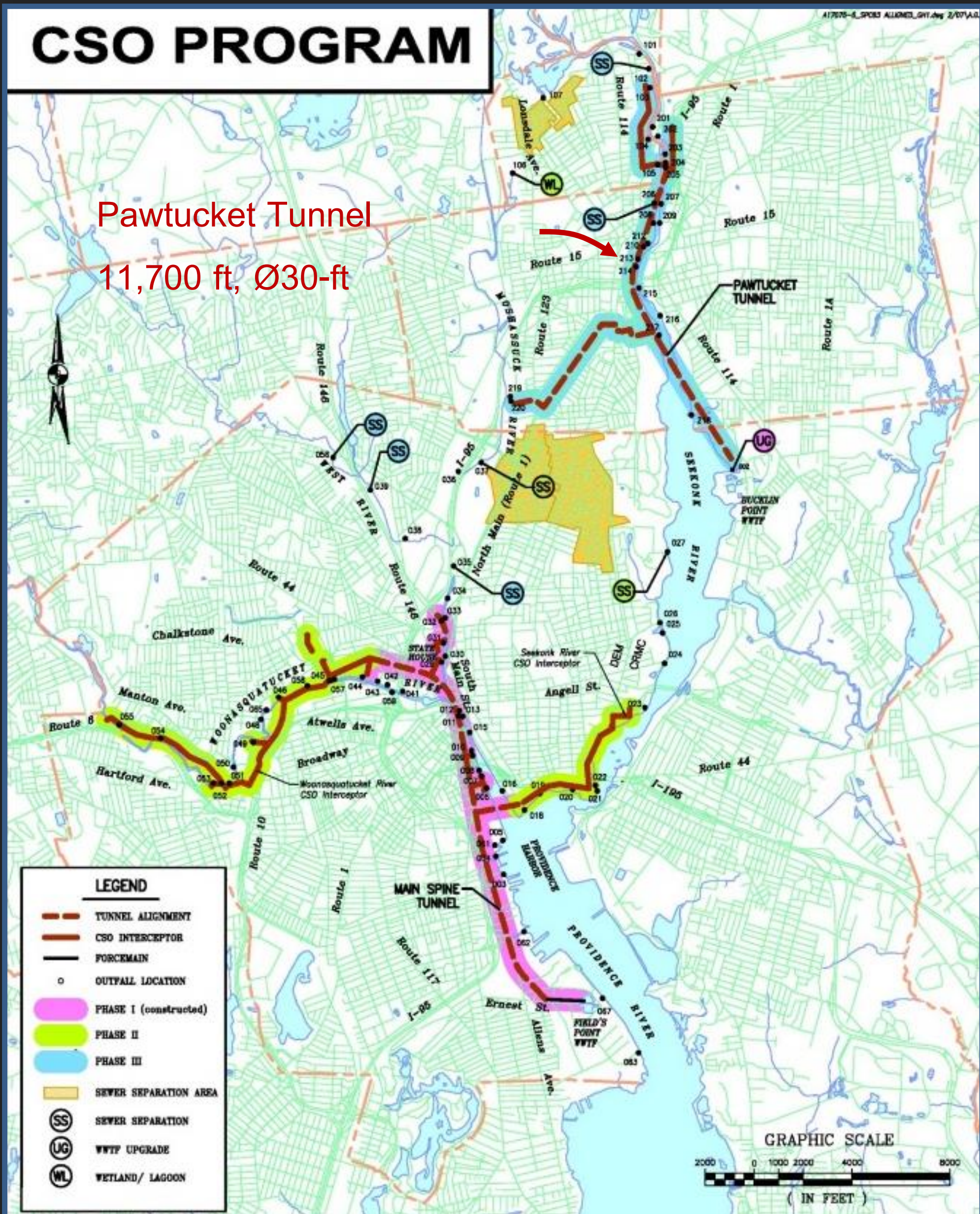
- 1994 EPA CSO Policy Change - Provide more flexibility
- Cost (capital and rate increase)
- Technical Concerns

1998: Defined a three-phase CSO Control Program

Program Goals:

- 98% reduction annual CSO volume
- 80% reduction in shellfish bed closures
- < 4 overflows per year

NBC CSO Program



Phase I: 2001-2008 — $360M

- Providence Tunnel (63 MG, Ø26-ft, 3-mile)
- Addresses 40% CSO Volume

Phase II: 2011-2015 — $197M

- CSO Interceptors
- Sewer Separation
- Storage/Wetlands Facility

Phase III: 2021-2041 — $1B

- **Pawtucket Tunnel** (58.5 MG, Ø30-ft, 2.2-mile)
- Bucklin Points WWTF Upgrades
- Targeted Sewer Separation
- Green Stormwater Infrastructure

What do we do

with the construction water during

tunnel mining?

Discharge Alternative & Summary

Alternative	Feasibility	Comments
1. No Build	Not feasible	• NBC would violate the CA with RIDEM
2. Seekonk River In-channel Discharge	F F	…ce …o greatest extent possible through design
3. Seekonk River Off-channel Discharge	N	…alternative viable. This degree of dredging is …edule constraints
4. Subsurface Dispersal	N	…us of project site …ot be constructible within allowable project schedule
5. Discharge to Bucklin Brook	N	
6. Discharge to Bucklin Point WWTF	N	…l sludge management …harge permit
7. Discharge to Ten Mile River	Not feasible	• Challenging within allowable project schedule • Technical constraints, such as crossing railroads and greenway/bike path • Insufficient mixing and dilution

2. Seekonk River In-channel Discharge
3. Seekonk River Off-channel Discharge

Seekonk River Discharge

- The Seekonk River has been identified as a Class SB receiving water by the Rhode Island Department of Environmental Management (RIDEM)

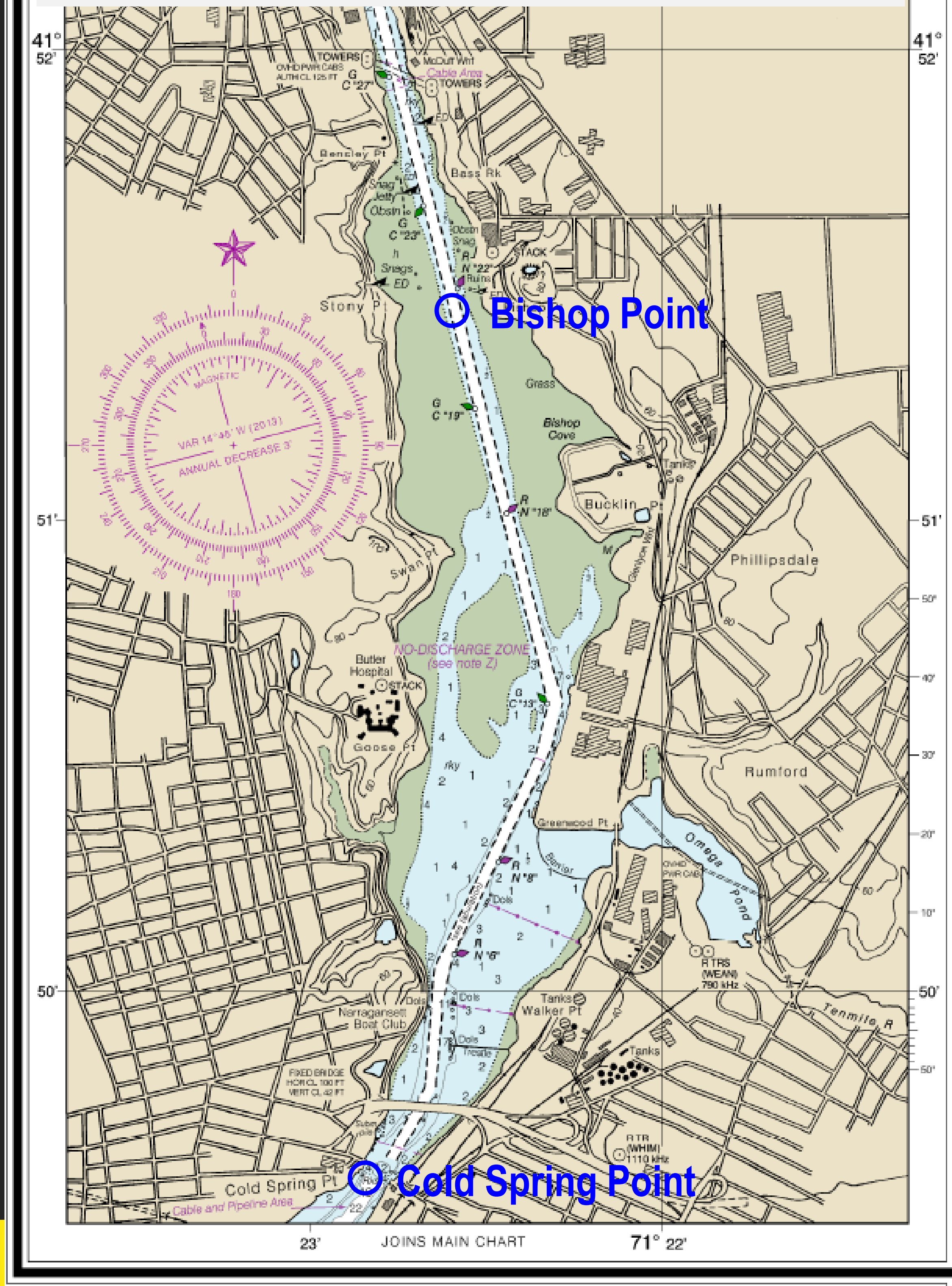
Permit Requirements

- Permits from RIDEM
- Permit from Rhode Island Coastal Resources Management Council (CRMC)
- Authorization from US Army Corps of Engineers (USACE)

Seekonk River Navigation Channel

- 3.4 mile-long
- 16 feet deep
- 100-230 feet wide (narrows to 60 feet upstream to the Division Street Bridge)

Reference: NOAA Chart of Providence River and Head of Narragansett Bay

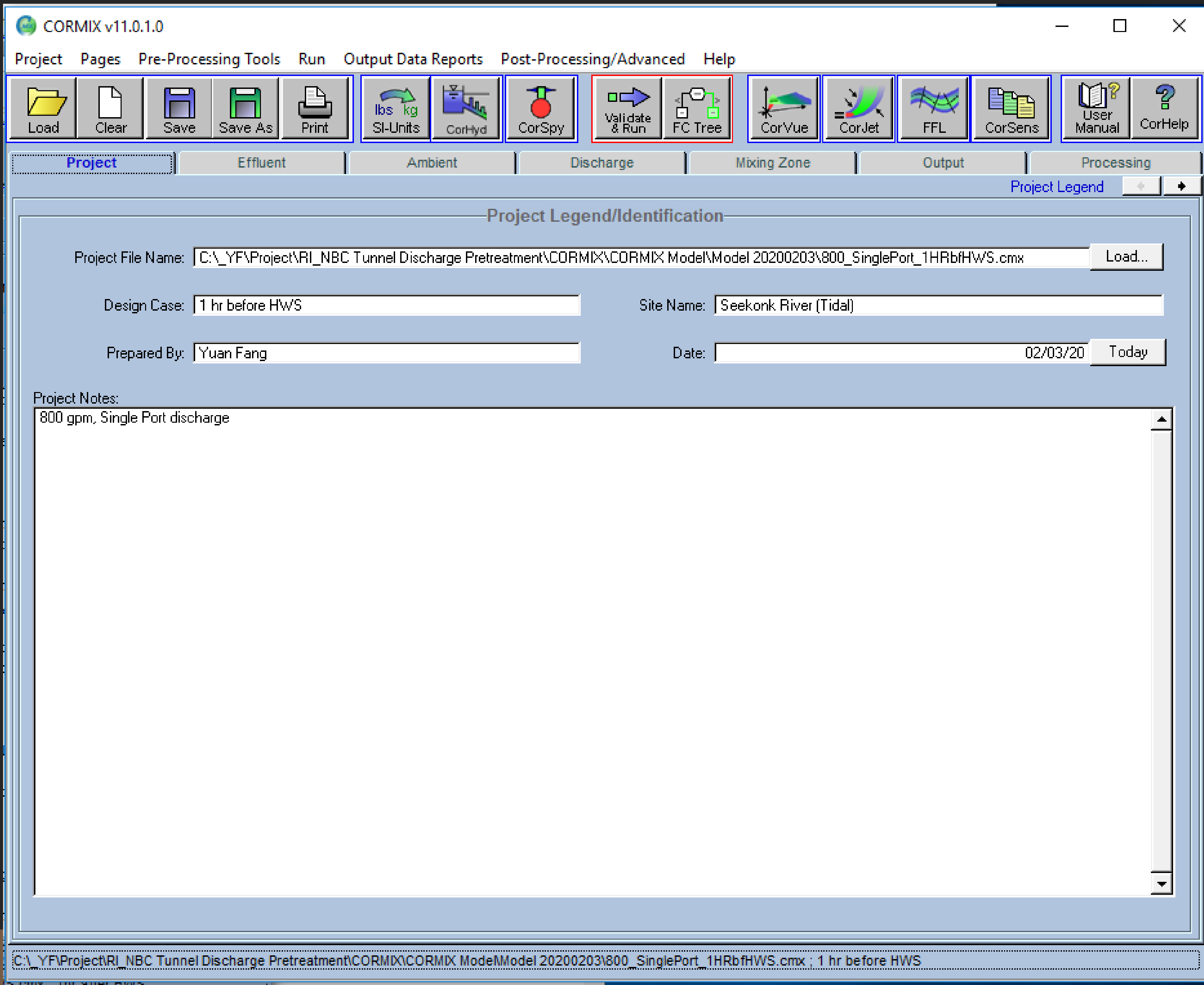


CORMIX Model

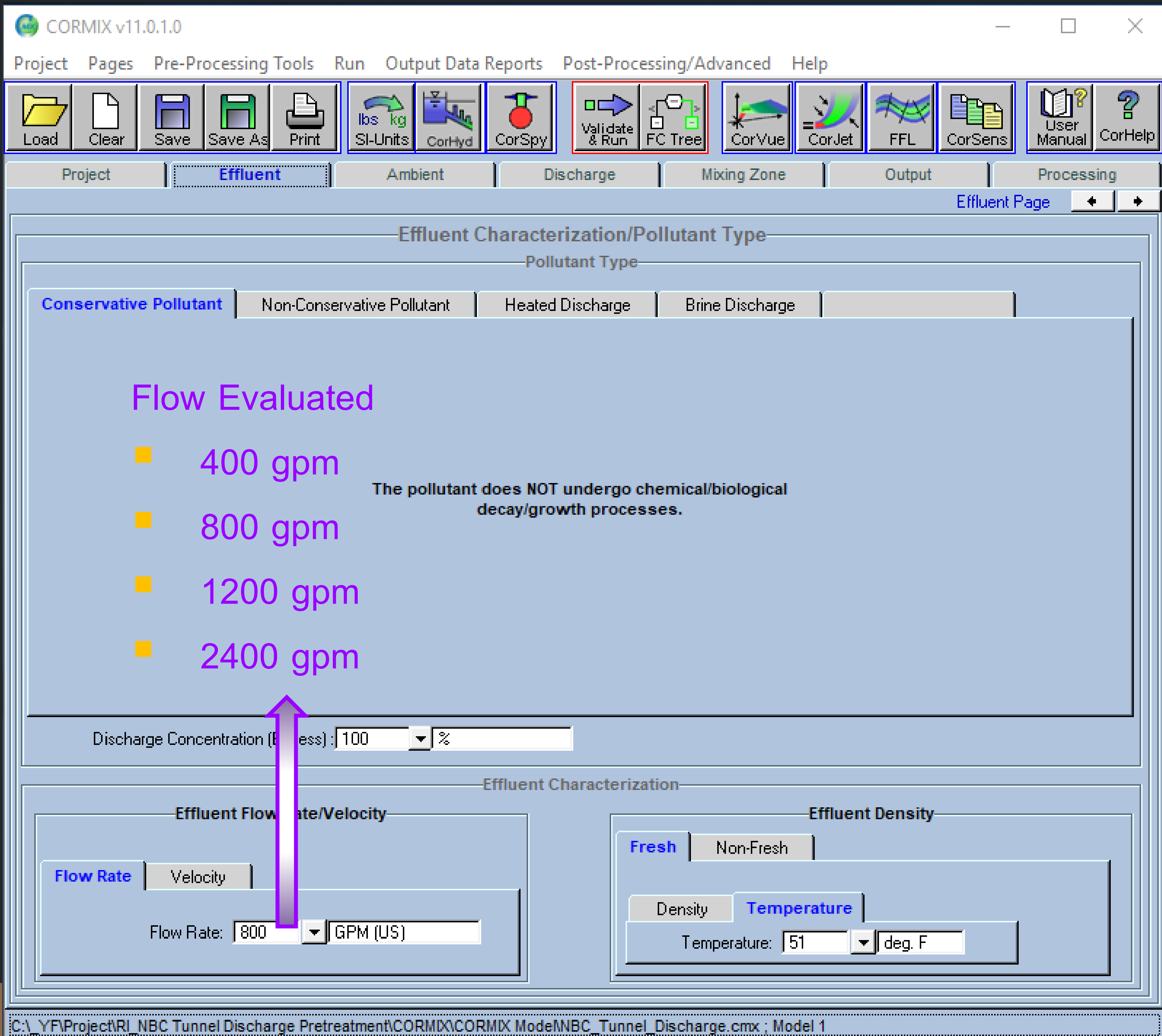
- CORMIX is a USEPA-supported mixing zone model
- Decision support system for environmental impact assessment of mixing zones resulting from continuous point source discharges.
- The system emphasizes the role of boundary interaction to predict steady-state mixing behavior and plume geometry.
- The CORMIX methodology contains systems to model single-port, multiport diffuser discharges and surface discharge sources.

CORMIX model was used in this study to simulate mixing zone in the Seekonk River for estimating dilution factors.

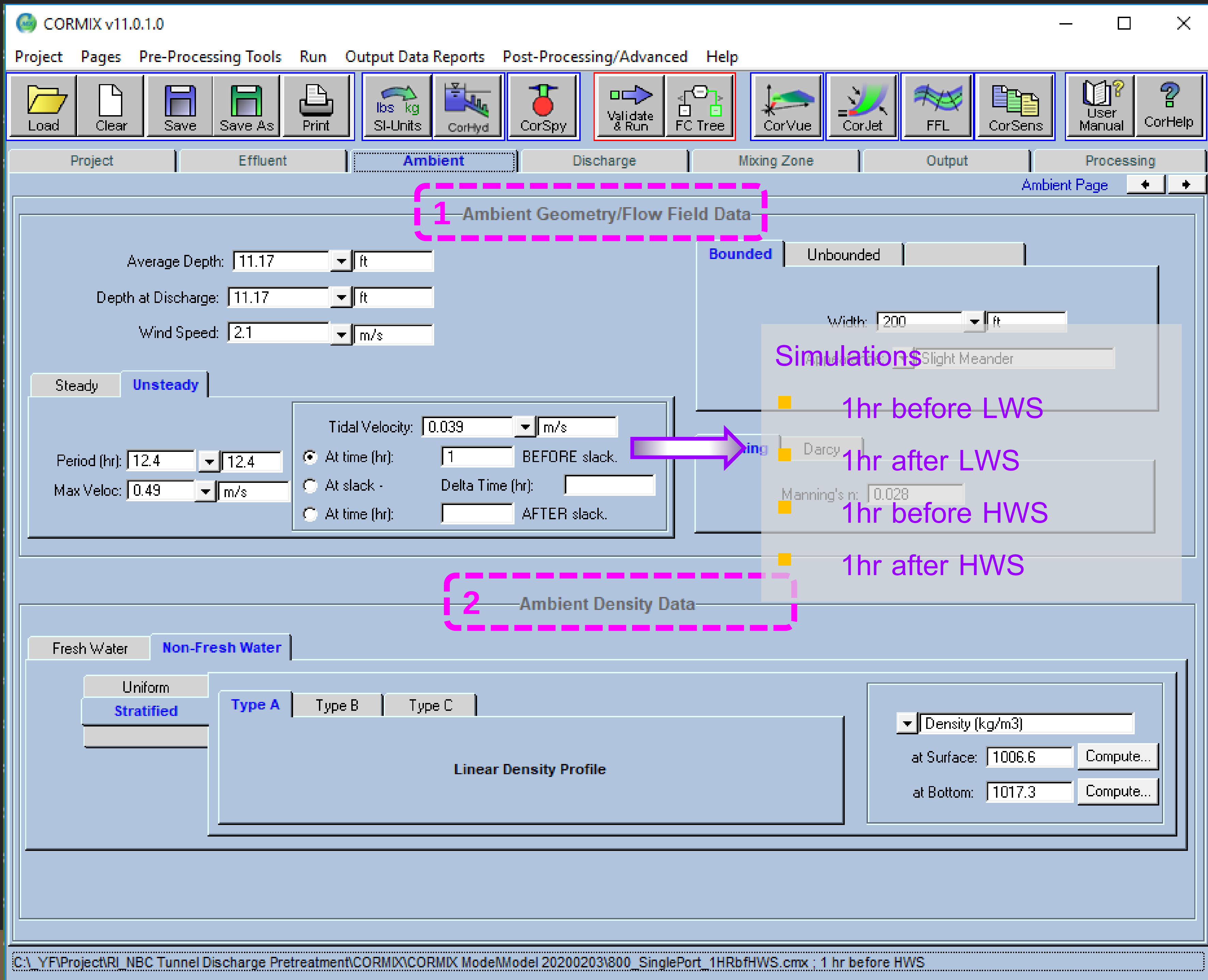
CORMIX Input 1. Project Information



CORMIX Input 2. Effluent Properties

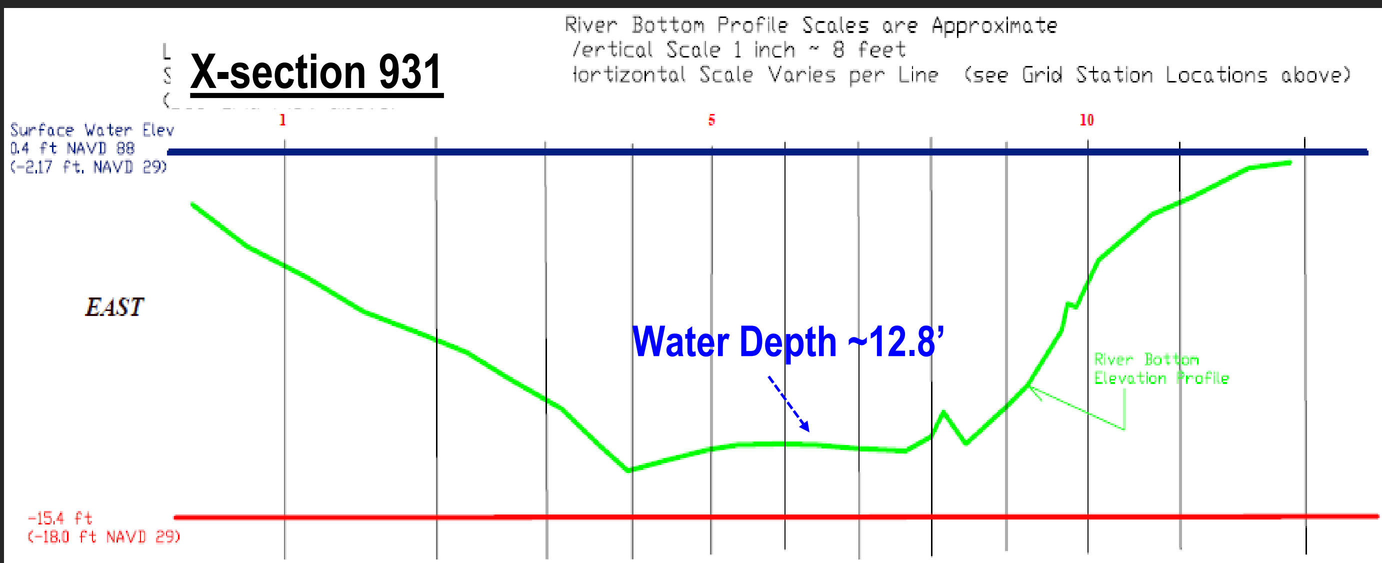


CORMIX Input 3. Ambient Condition

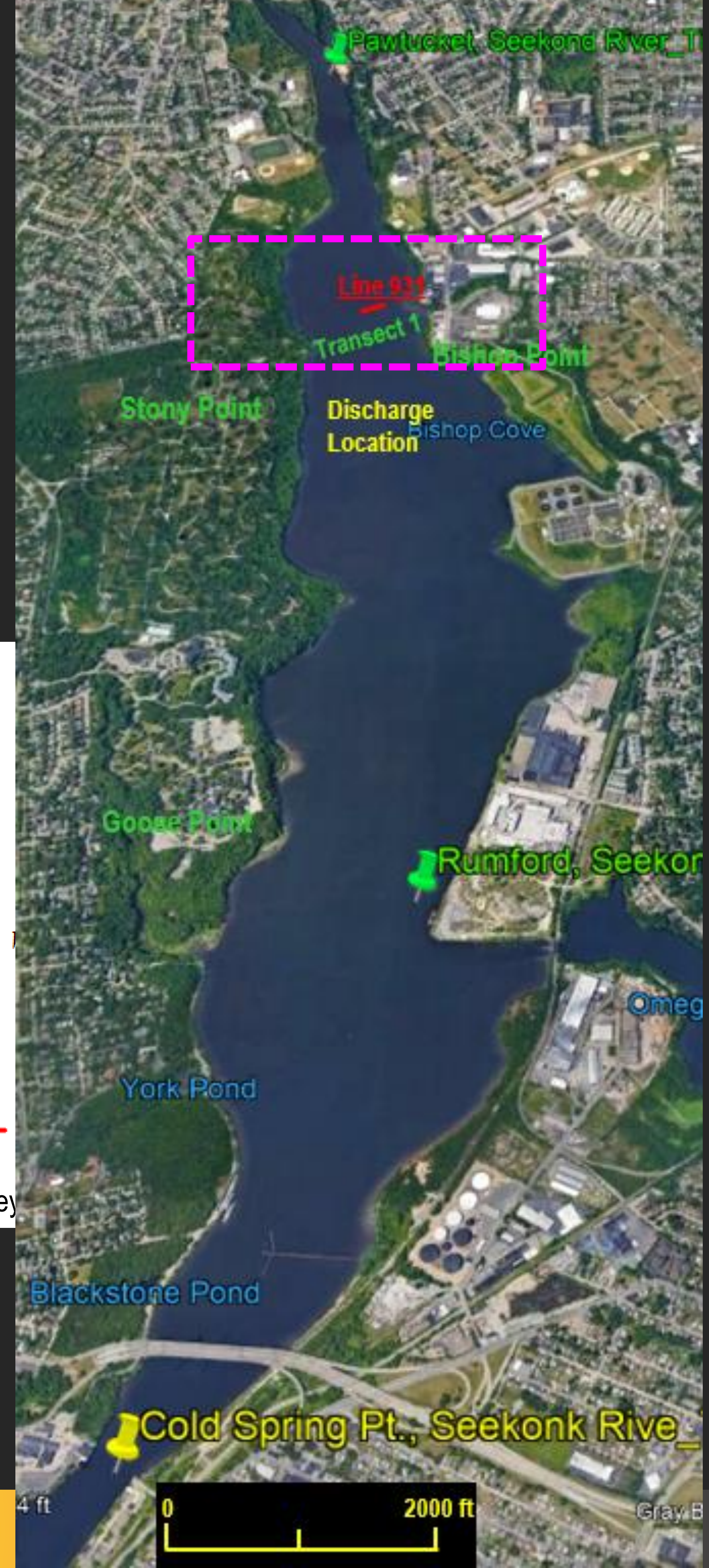


Reference 1: Pawtucket Geophysical Survey Profile

Seekonk River Channel Cross Section Profile

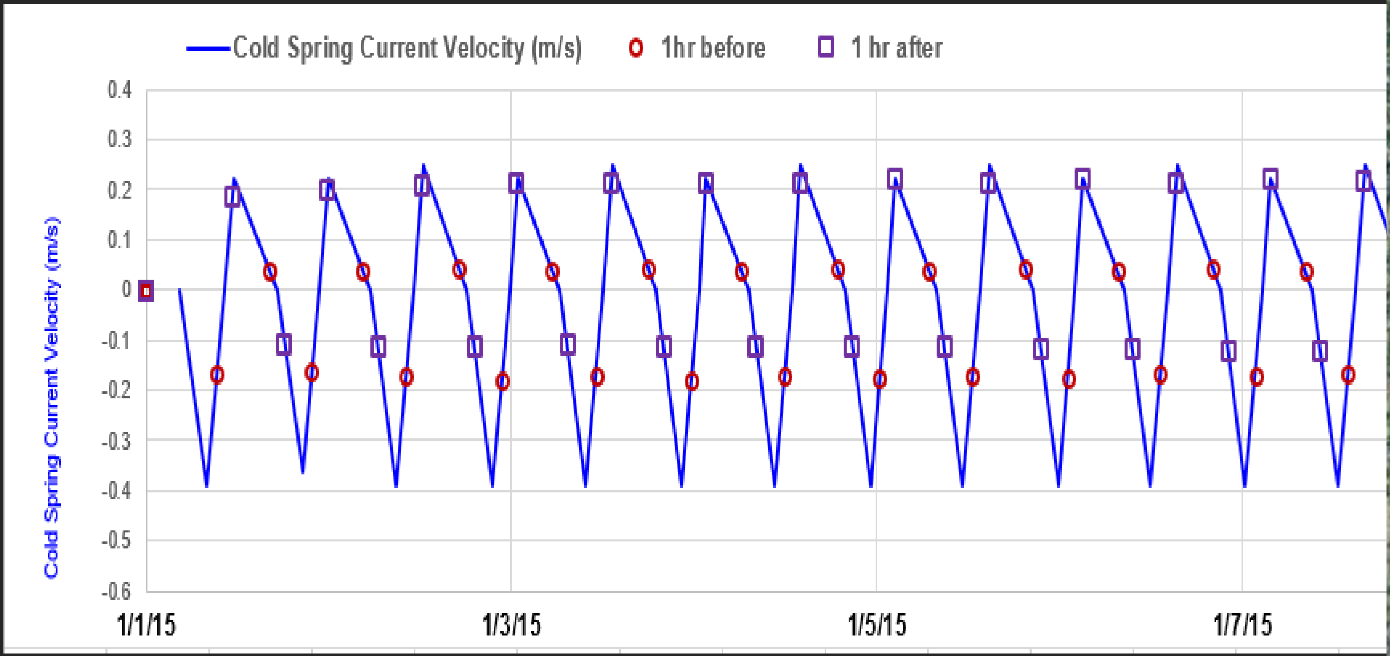


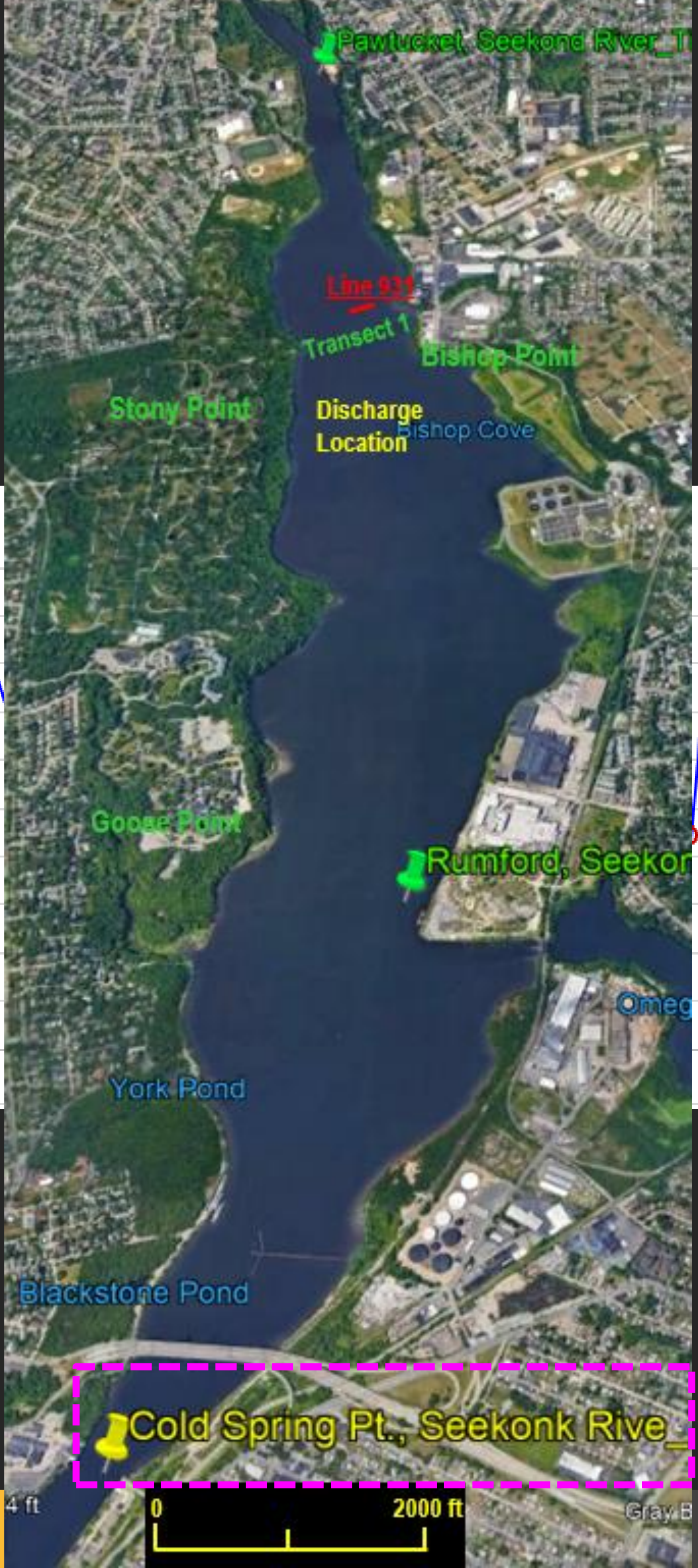
Note: The distance between two adjoining stations is 25ft based on survey document - Pawtucket Geophysical Survey Report, December 2017.



Reference 2: Narragansett Bay Tidal Current

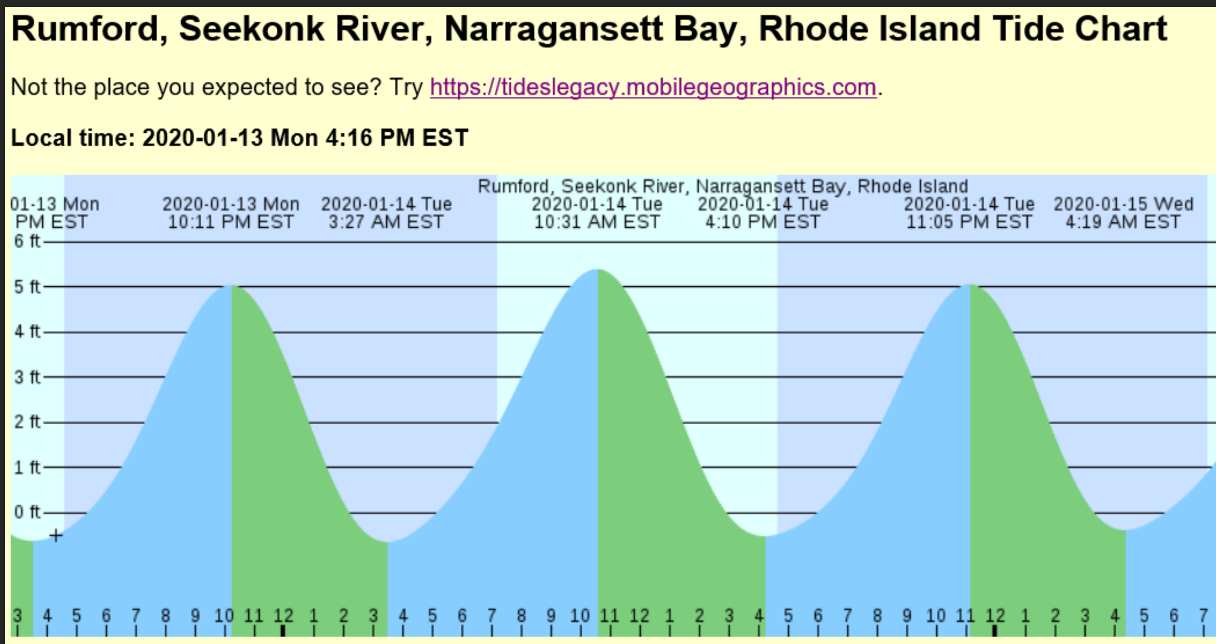
Cold Spring Pt., 2015 Tidal Current Predictions

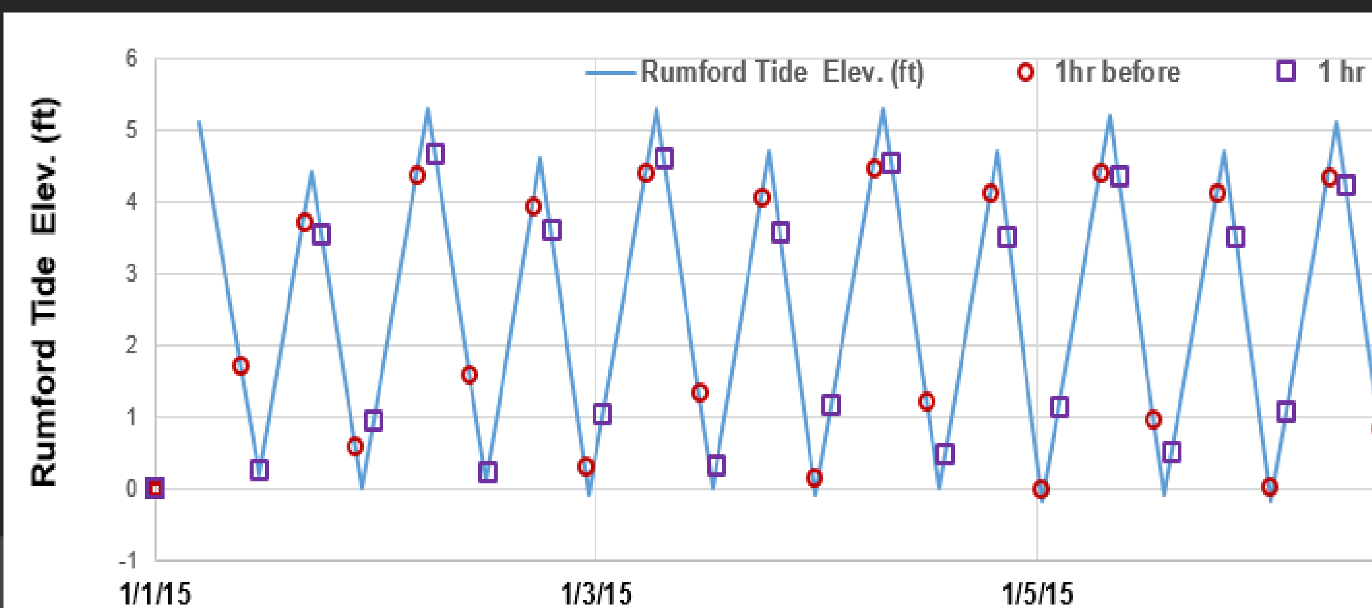


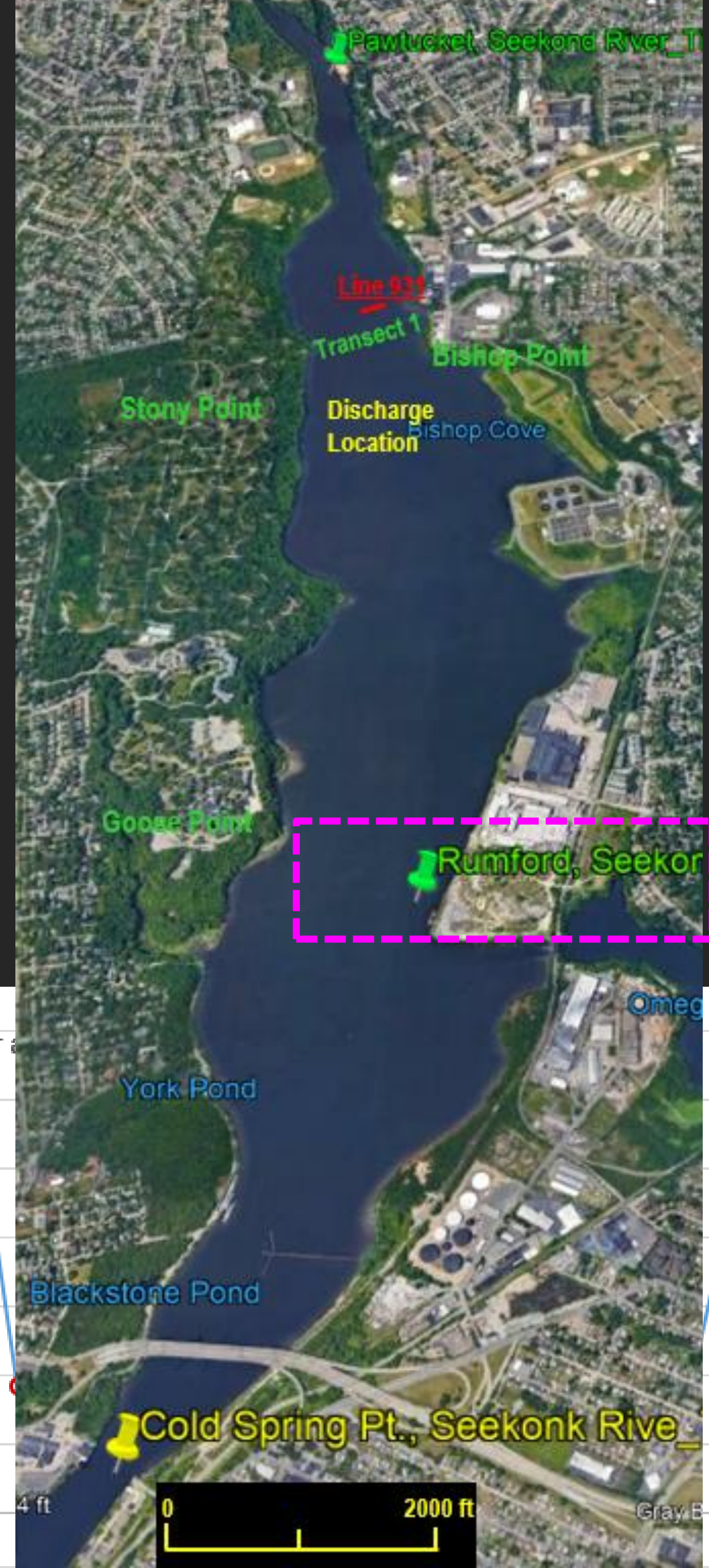


Reference 3: Narragansett Bay Tidal Chart

Rumford, Seekonk River Tidal Chart, 2015

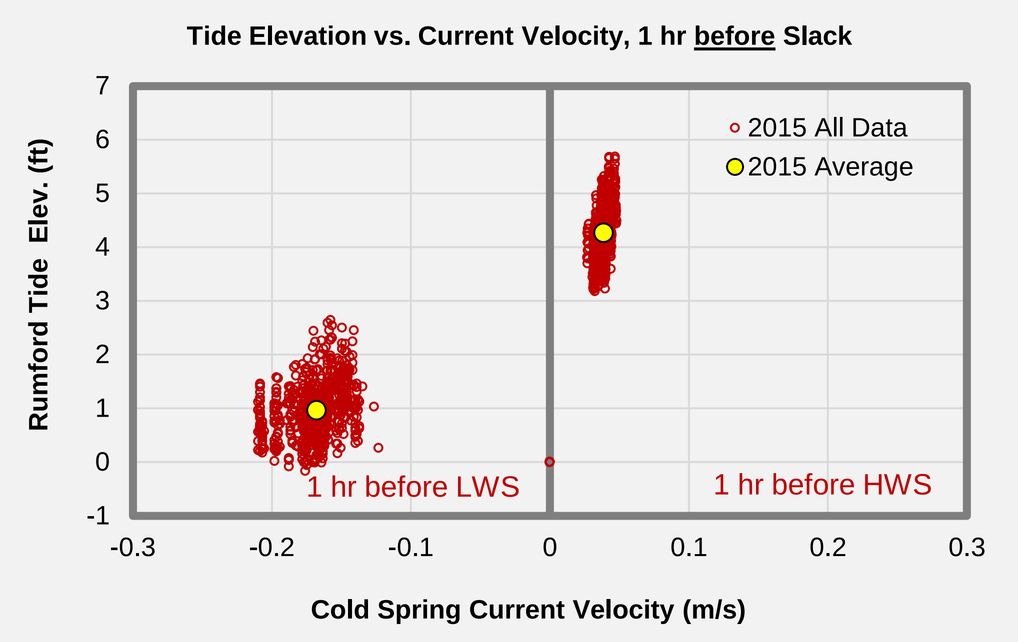


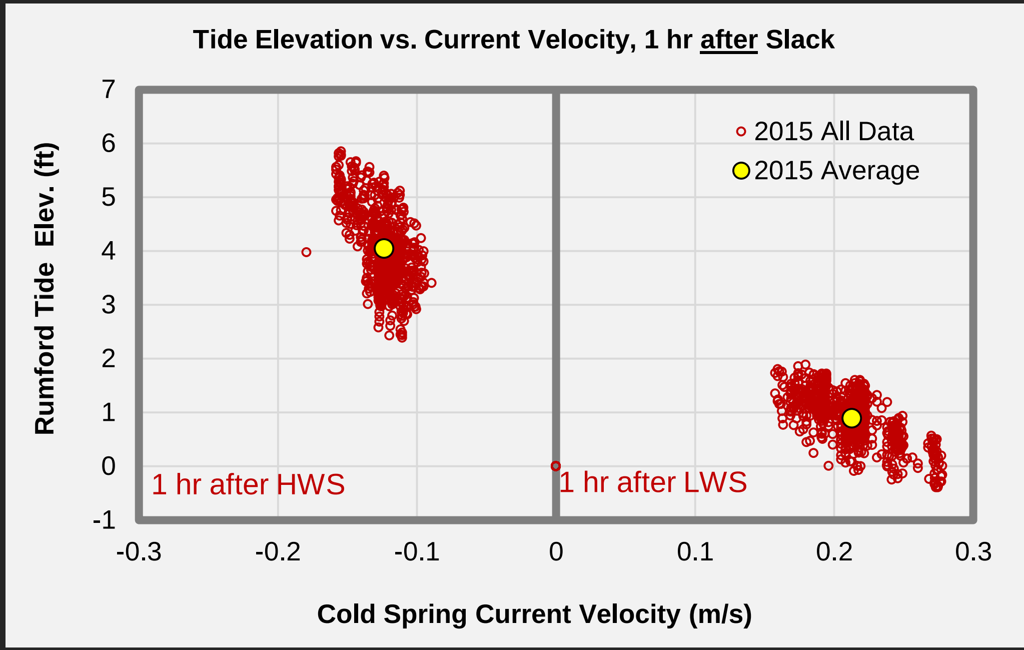


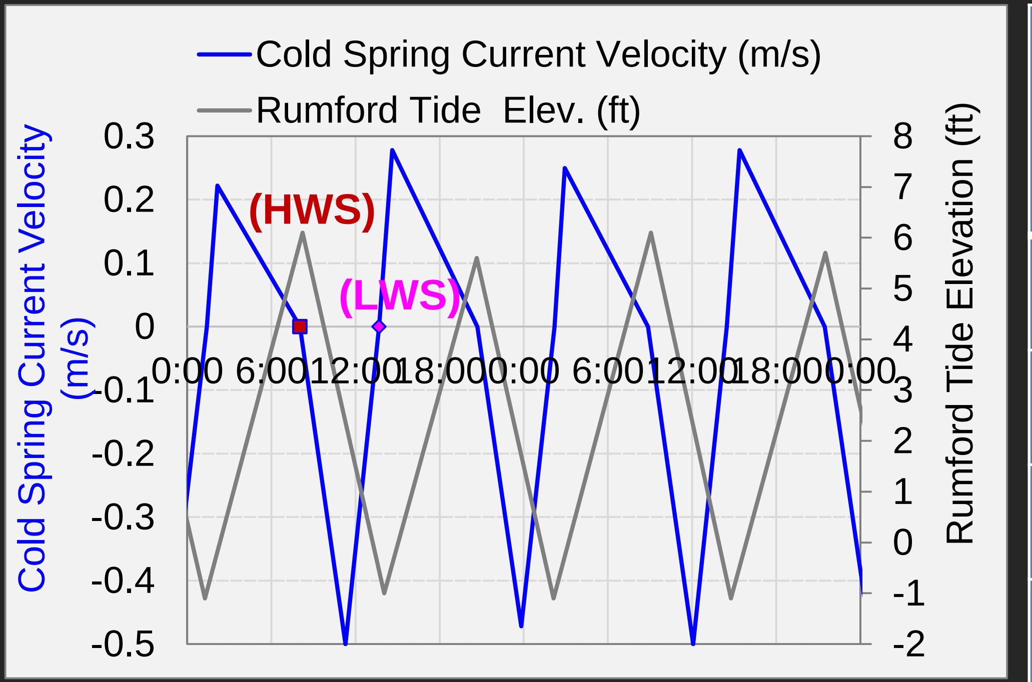


Reference 2 & 3: Narragansett Bay Tidal Data Analysis

Tide Elevation vs. Current Velocity at Four Tidal Intervals



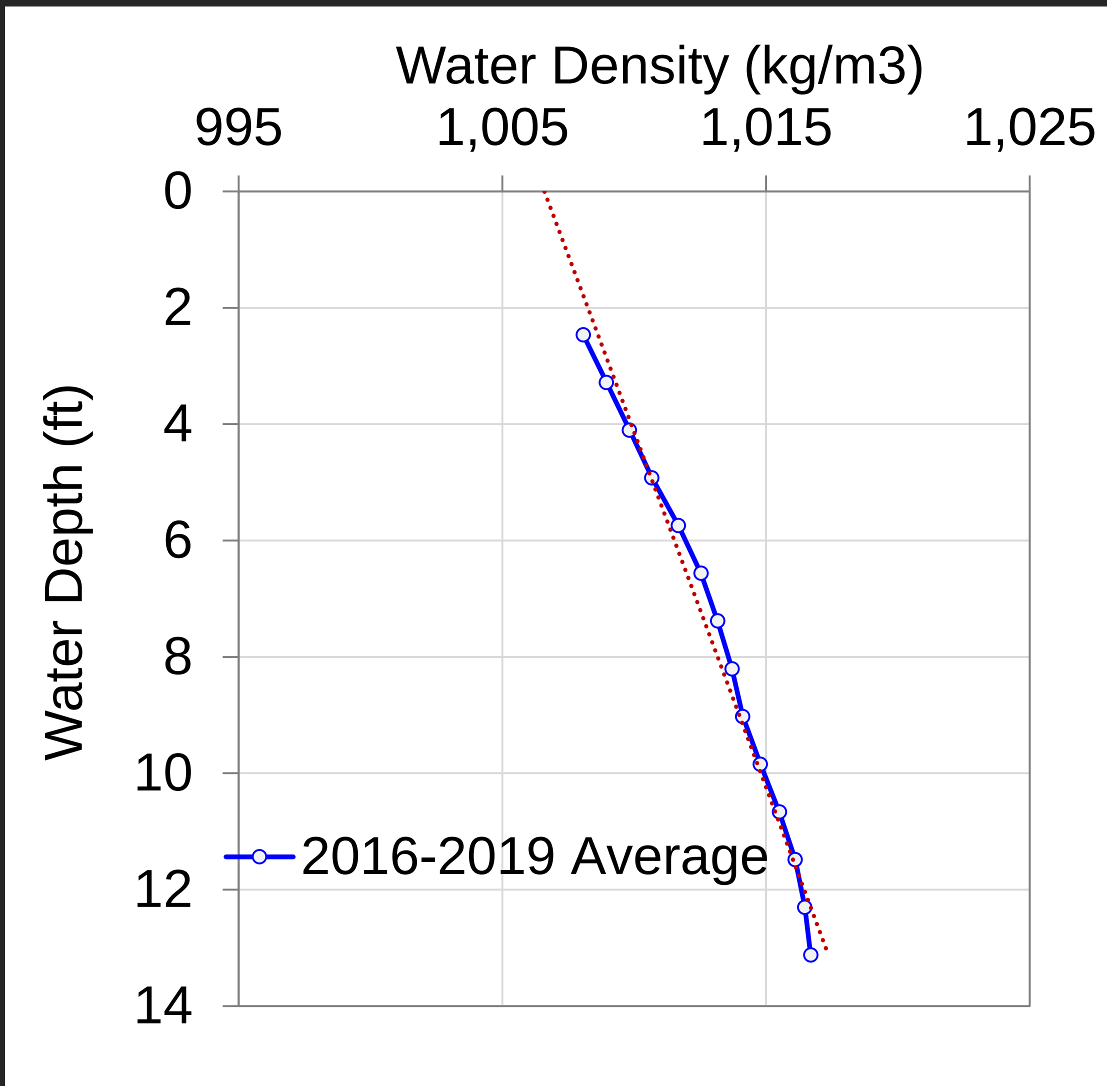




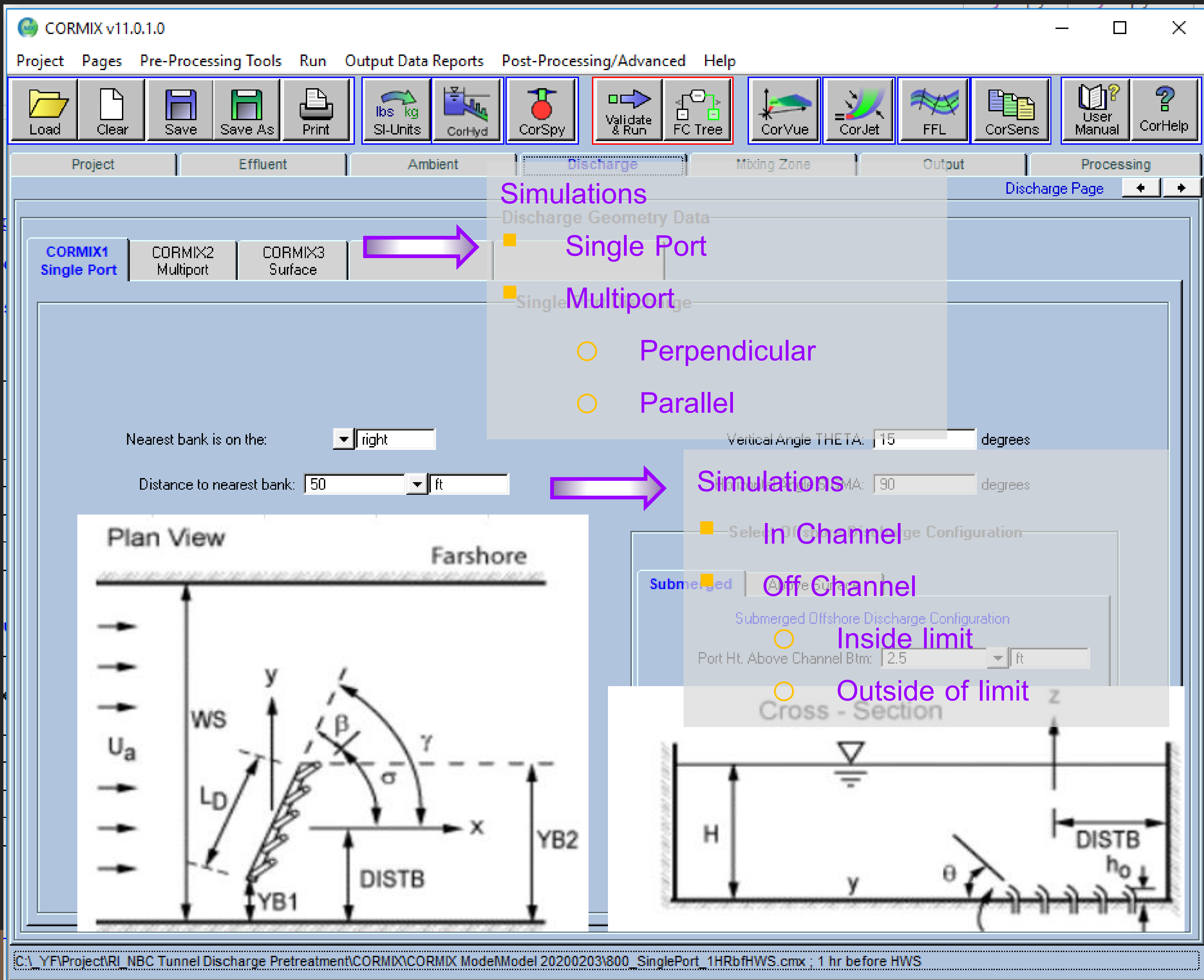
Simulation Time	Current Velocity (m/s)	Tide Elevation (ft)	Average Depth at Discharge (ft)
1hr before LWS	-0.168	0.97	8.38
1hr after LWS	0.213	0.90	8.38
1hr before HWS	0.039	4.27	11.17
1hr after HWS	-0.124	4.05	11.57

Reference 6: NBC Water Quality Monitoring

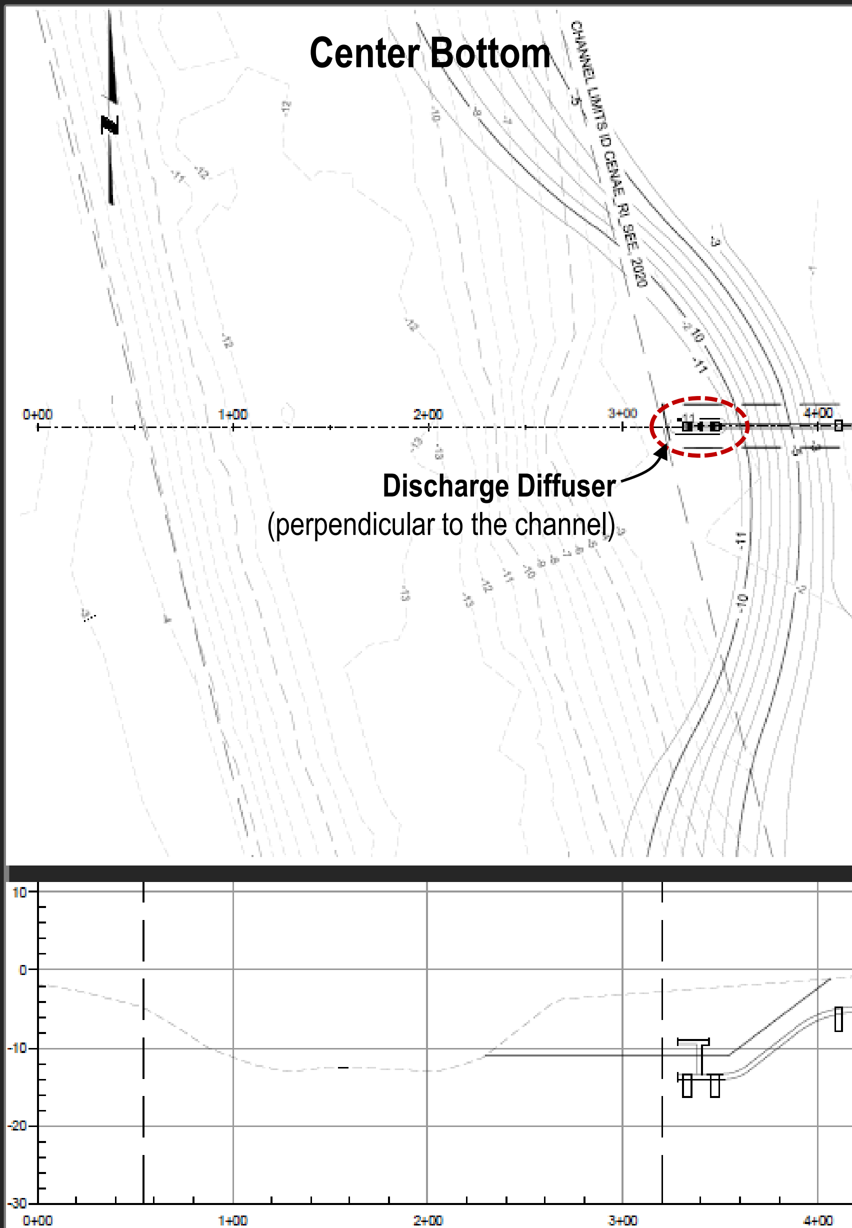
Water Column Profile Data 2016-2019

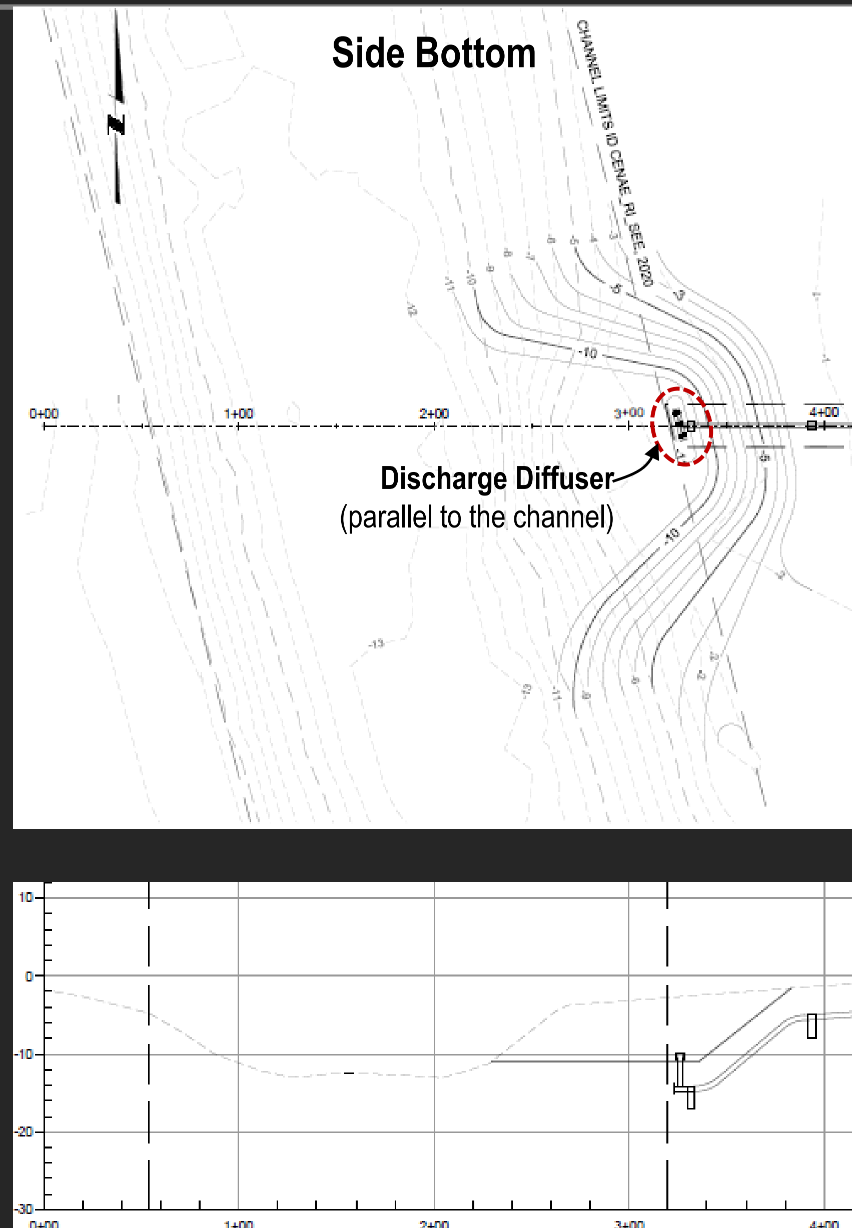


CORMIX Input 4. Discharge Properties



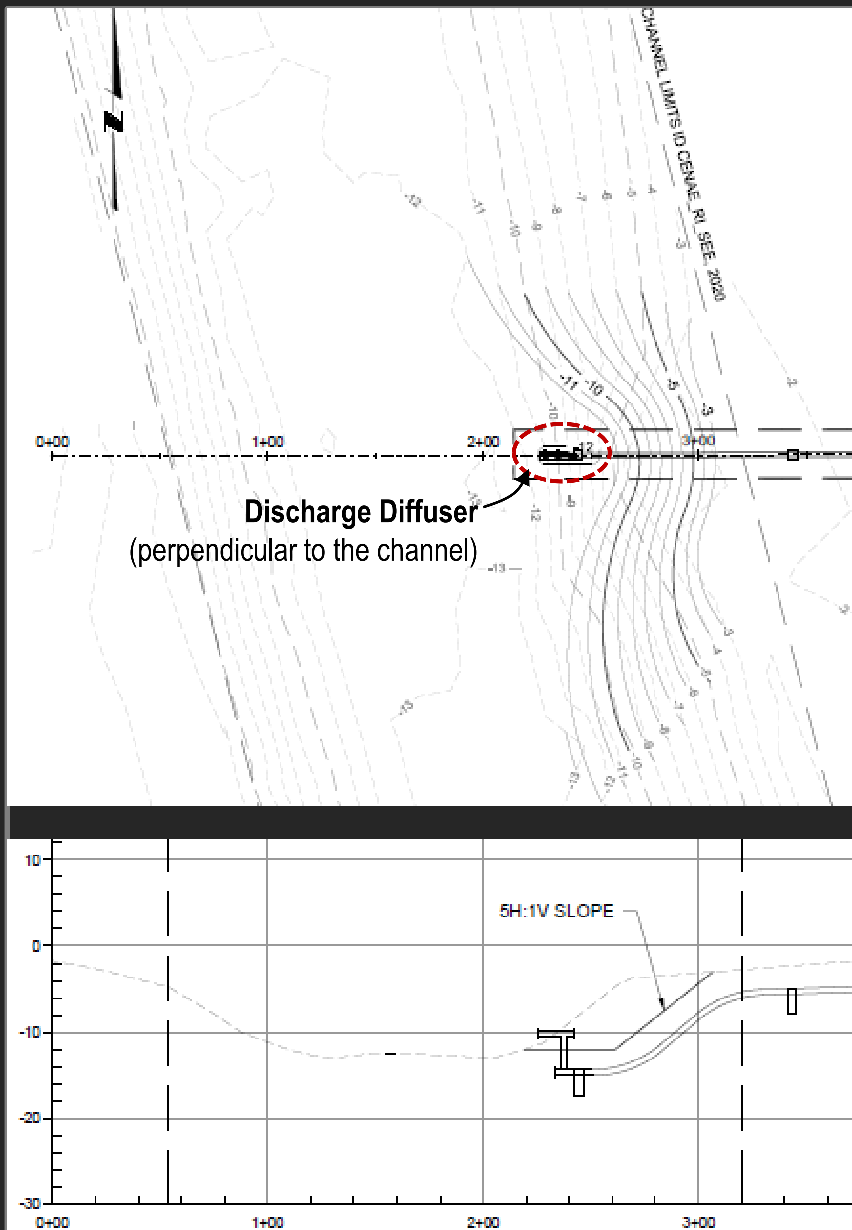
Tunnel Construction Water Discharge Options Diffuser located outside of the Federal Channel Limits

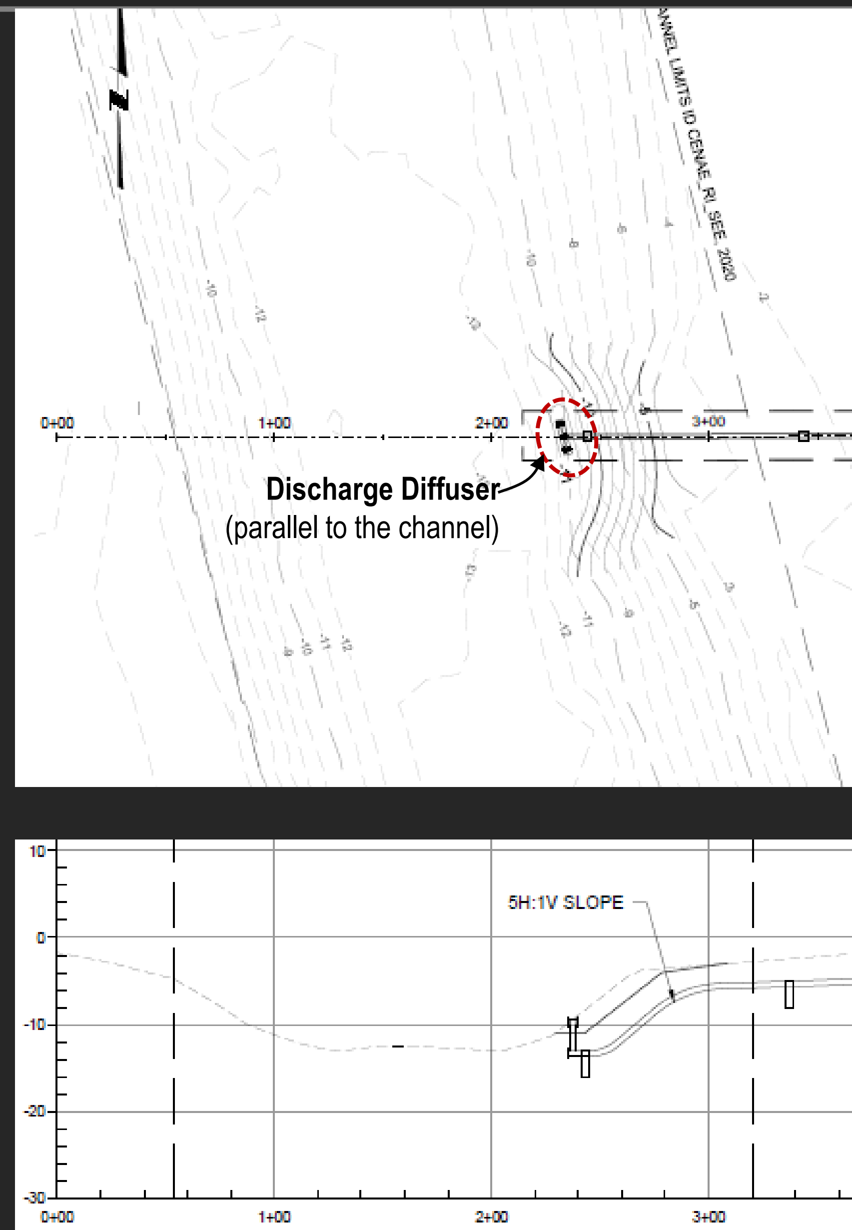




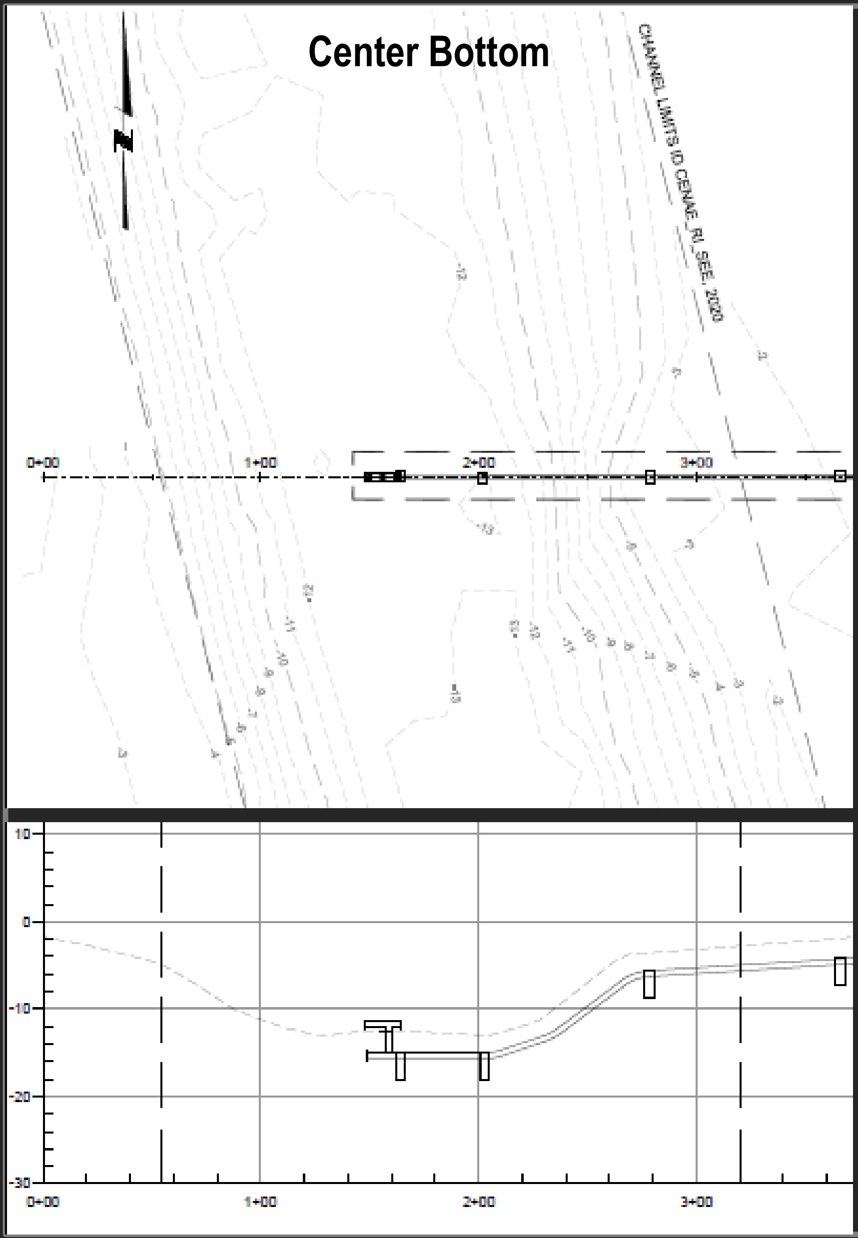
Tunnel Construction Water Discharge Options

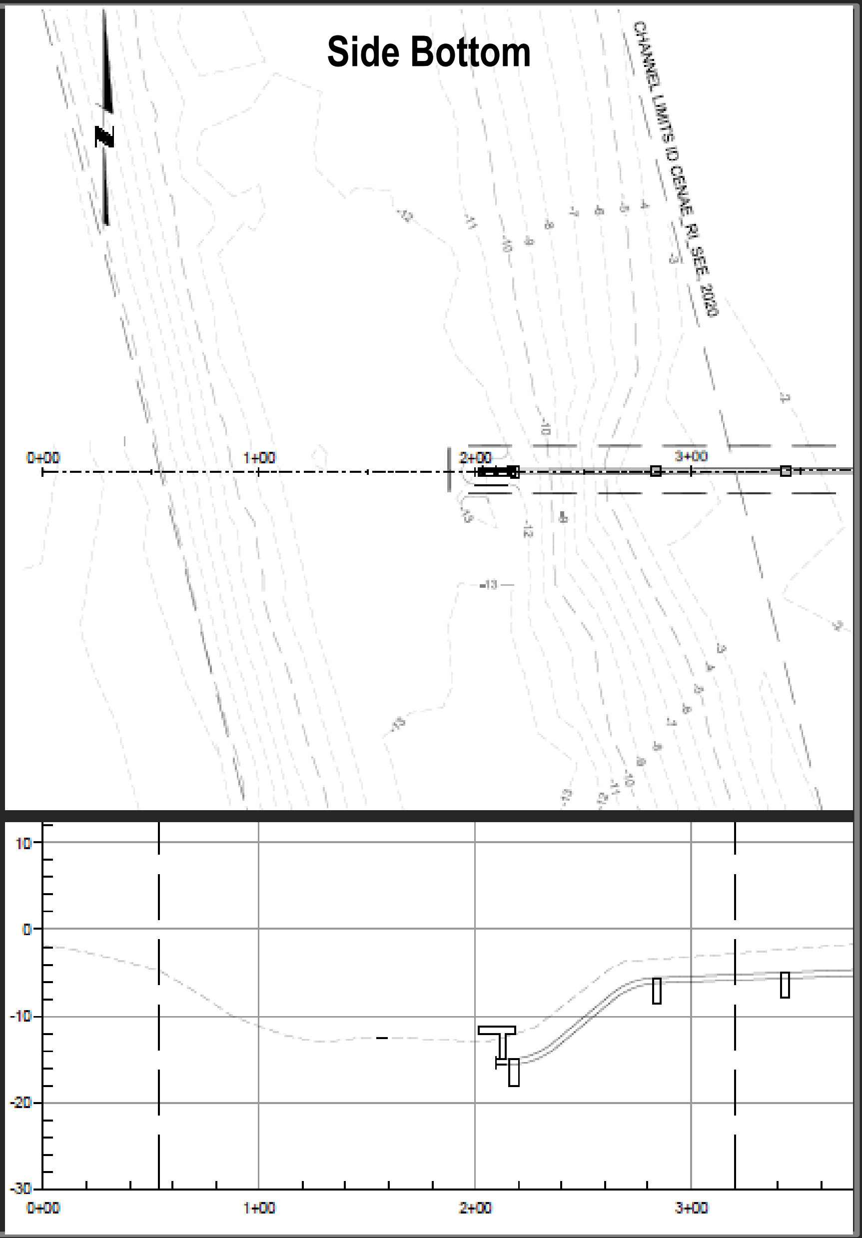
Inside of the Federal Channel Limits but outside of the deep channel





Tunnel Construction Water Discharge Options In Channel Discharge



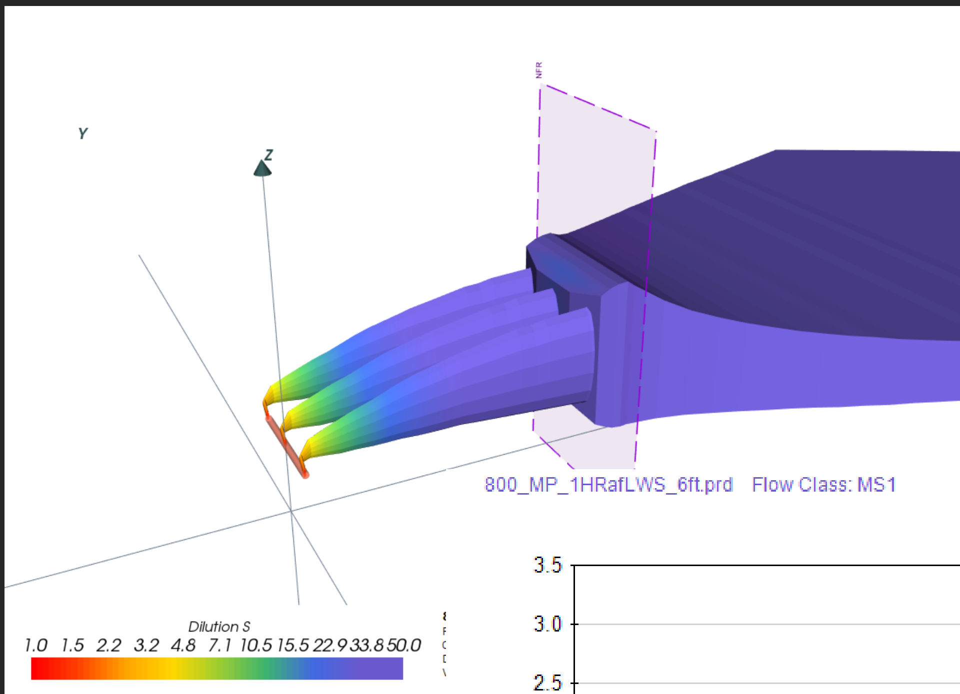


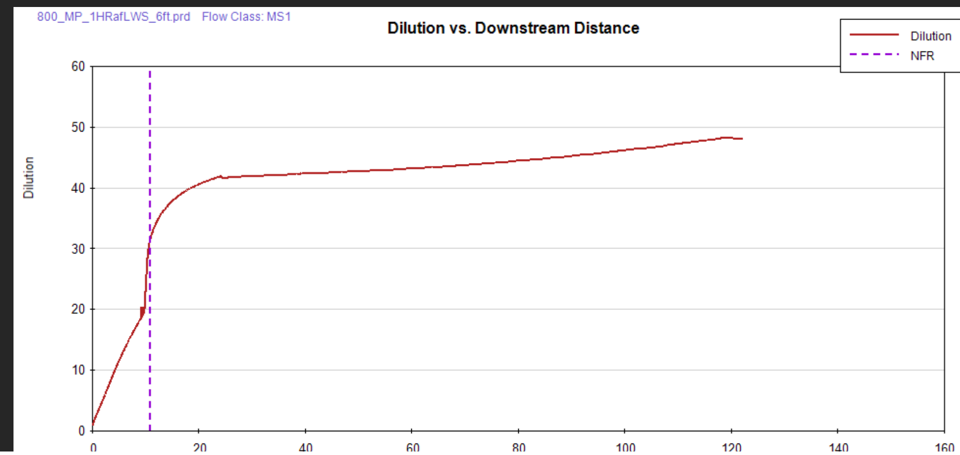
CORMIX Model Scenario Examples

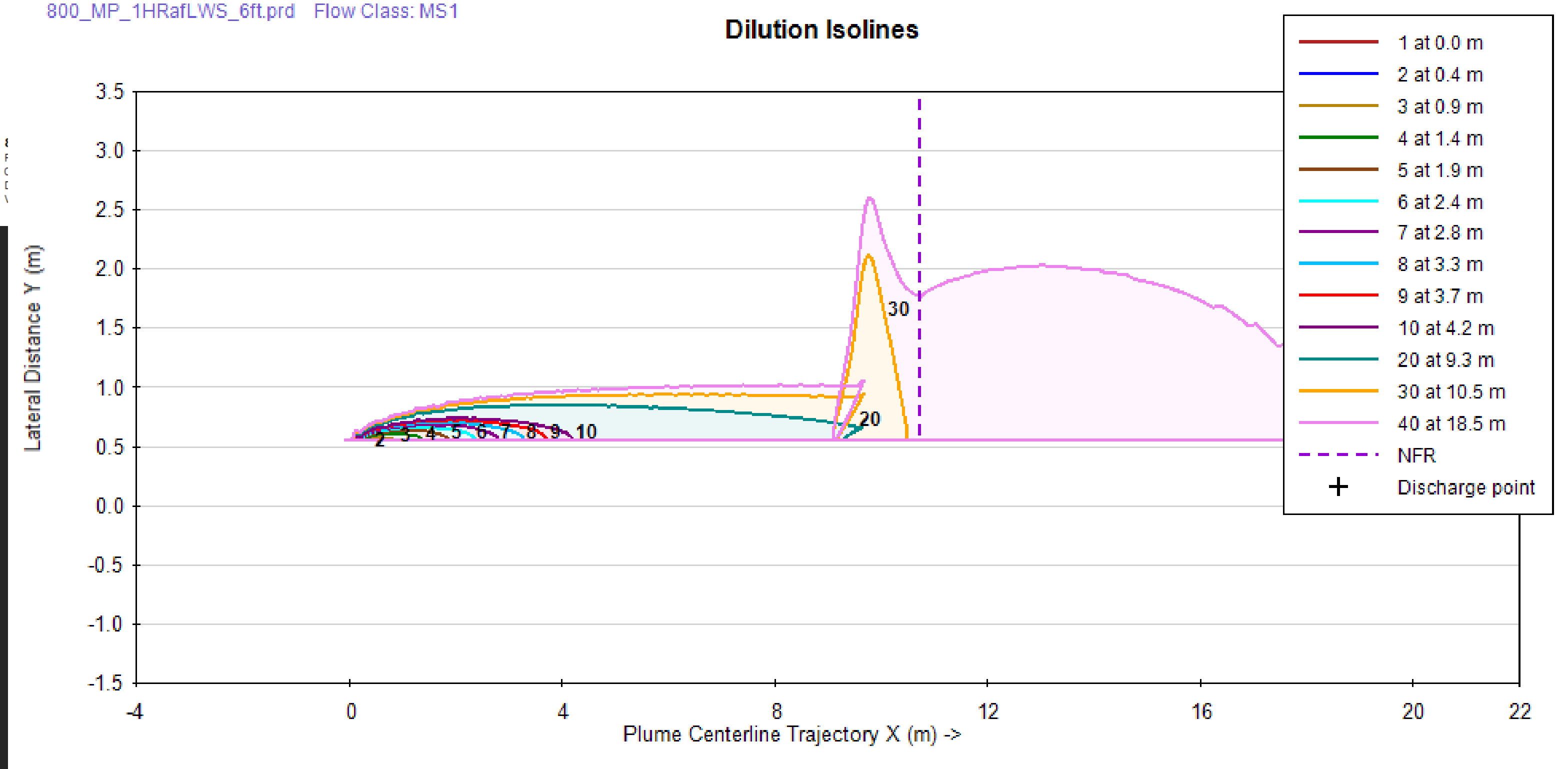
Modeling Scenario	Discharge Flow (GPM)	Simulation Time	Single / Multiple Port
400_SinglePort_1HRbfLWS	400	1hr before LWS	Single Port
400_SinglePort_1HRafLWS	400	1hr after LWS	
400_SinglePort_1HRbfHWS	400	1hr before HWS	
400_SinglePort_1HRafHWS	400	1hr after HWS	
800_SinglePort_1HRbfLWS	800	1hr before LWS	Single Port
800_SinglePort_1HRafLWS	800	1hr after LWS	
800_SinglePort_1HRbfHWS	800	1hr before HWS	
800_SinglePort_1HRafHWS	800	1hr after HWS	
1200_SinglePort_1HRbfLWS	1200	1hr before LWS	Single Port
1200_SinglePort_1HRafLWS	1200	1hr after LWS	
1200_SinglePort_1HRbfHWS	1200	1hr before HWS	
1200_SinglePort_1HRafHWS	1200	1hr after HWS	
1200_MultiPort_1HRbfLWS	1200	1hr before LWS	Multiple Port
1200_MultiPort_1HRafLWS	1200	1hr after LWS	
1200_MultiPort_1HRbfHWS	1200	1hr before HWS	
1200_MultiPort_1HRafHWS	1200	1hr after HWS	
2400_MultiPort_1HRbfLWS	2400	1hr before LWS	Multiple Port
2400_MultiPort_1HRafLWS	2400	1hr after LWS	
2400_MultiPort_1HRbfHWS	2400	1hr before HWS	
2400_MultiPort_1HRafHWS	2400	1hr after HWS	

CORMIX Model Result Examples

800gpm, 1HR after LWS, multiport

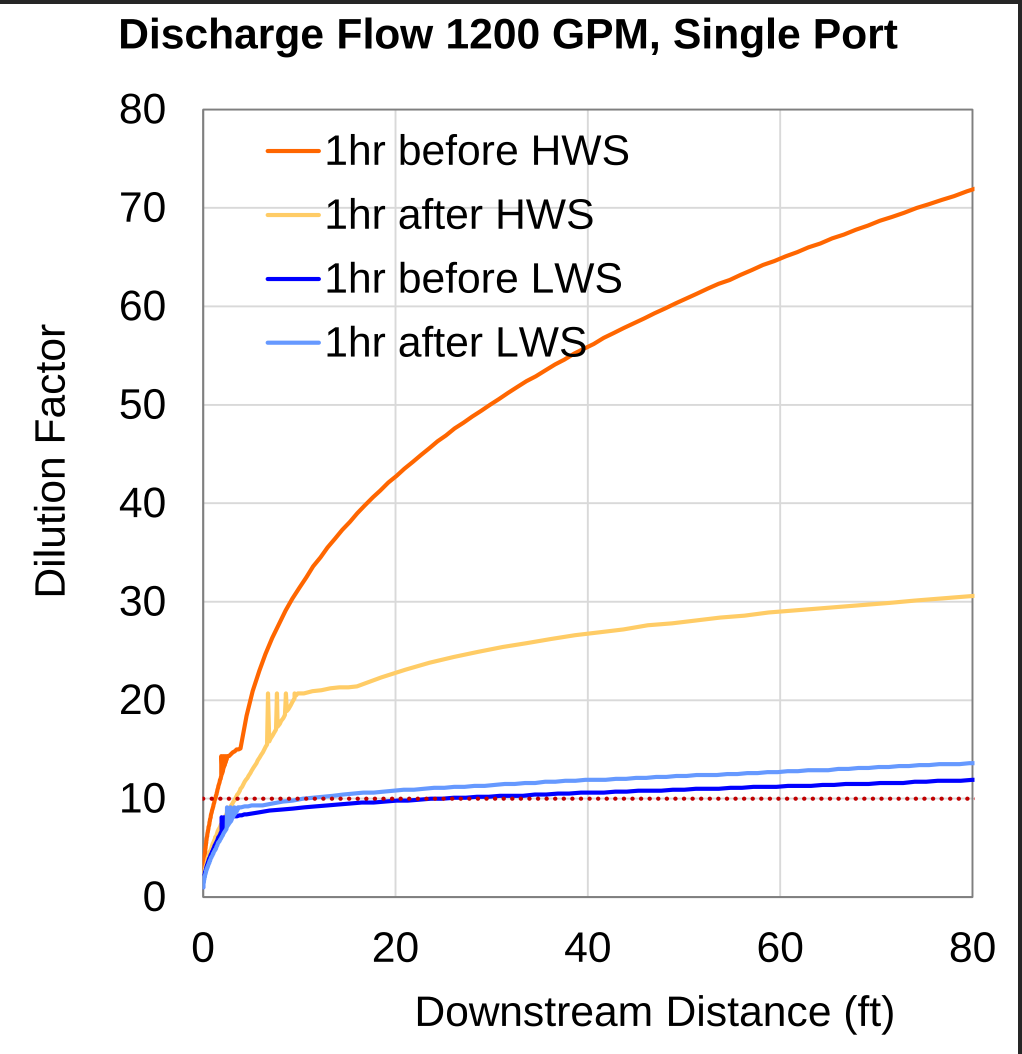


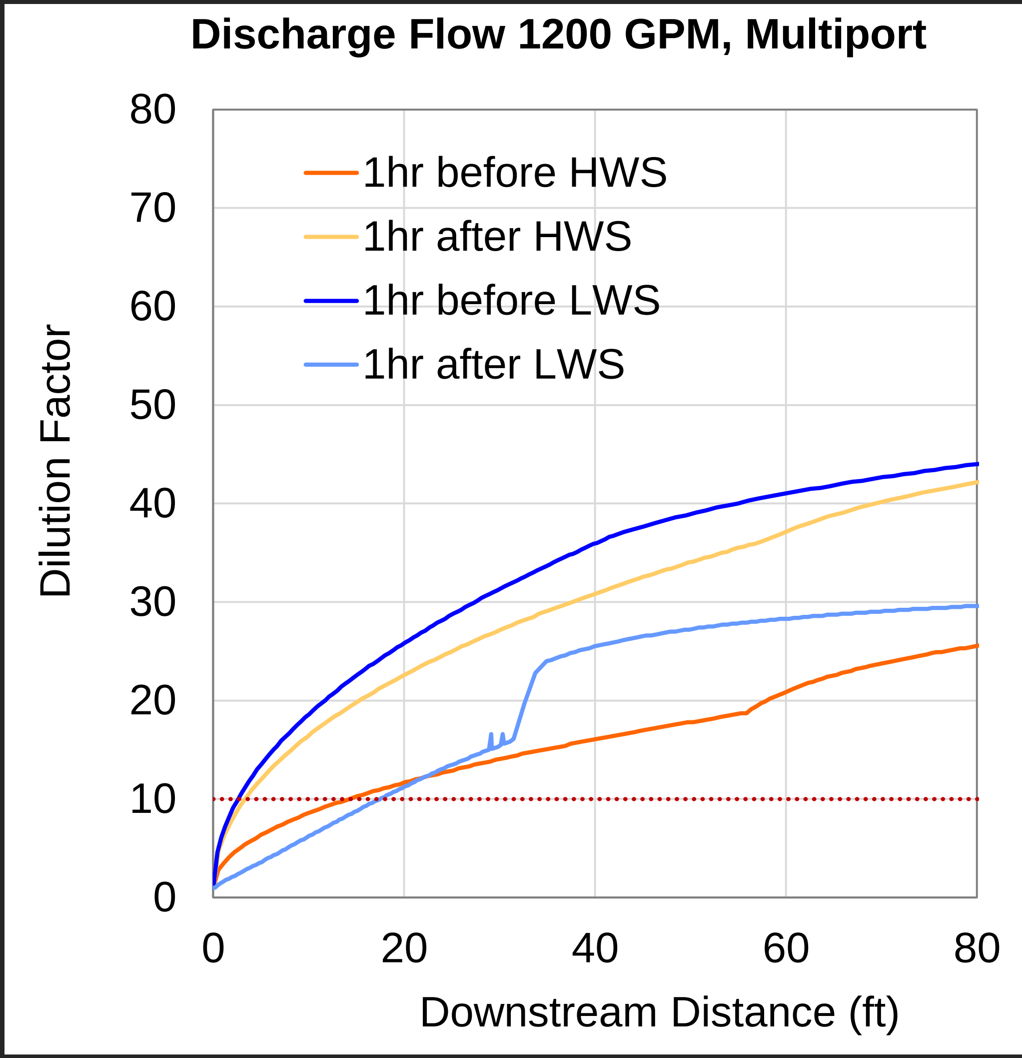




CORMIX Model Result Examples

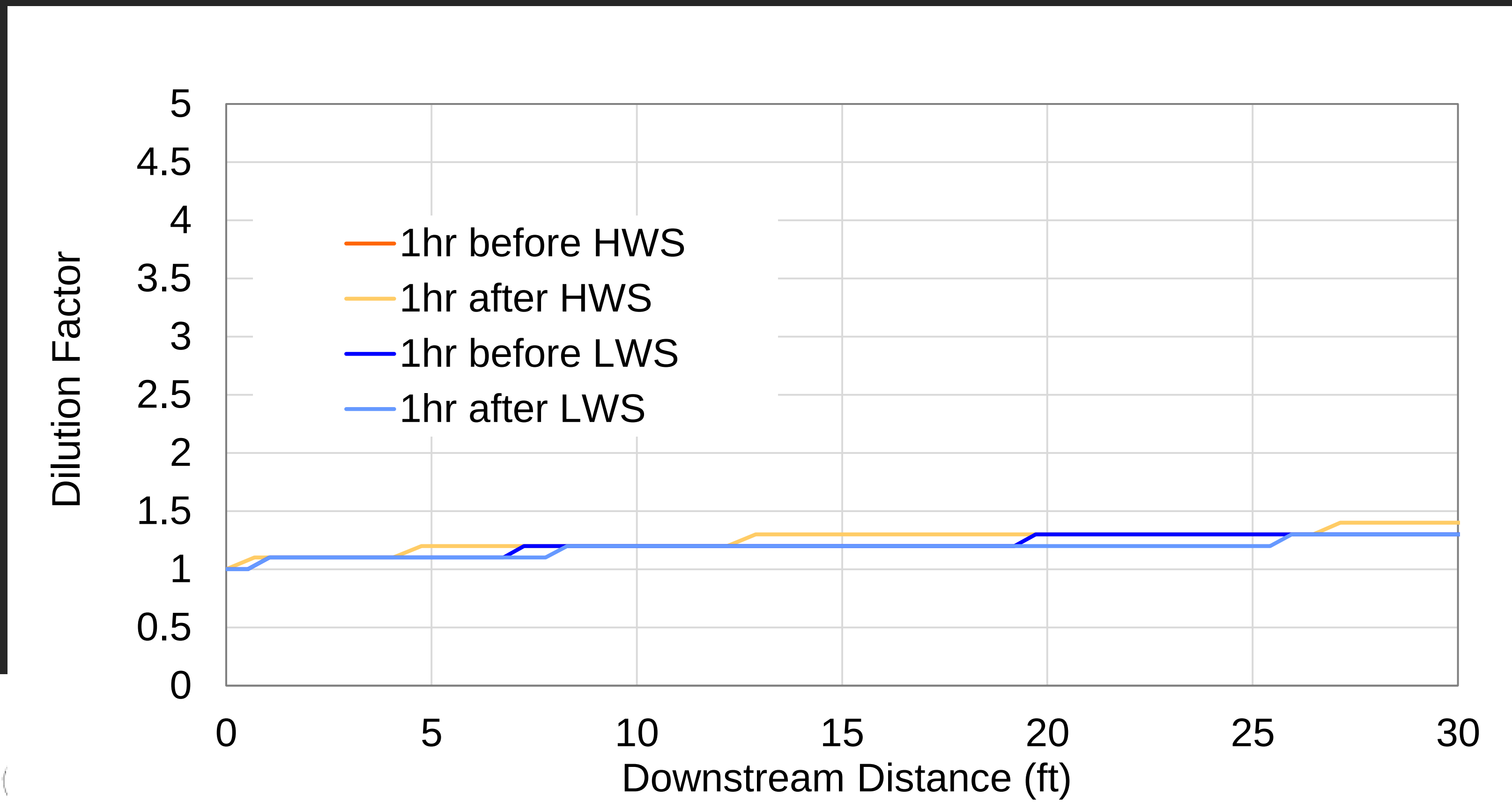
1200gpm, Single Port vs. Multiport

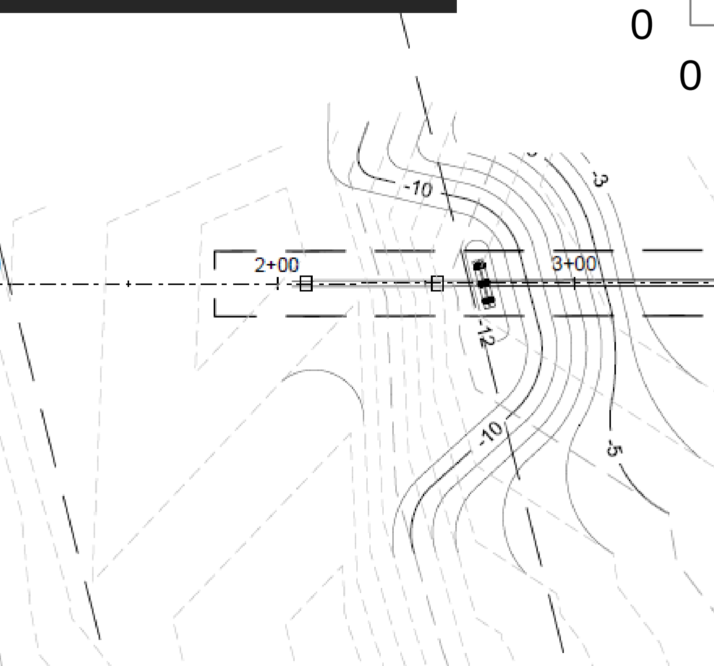




CORMIX Model Result Examples

2400gpm, Multiport Diffuser Parallel to Flow

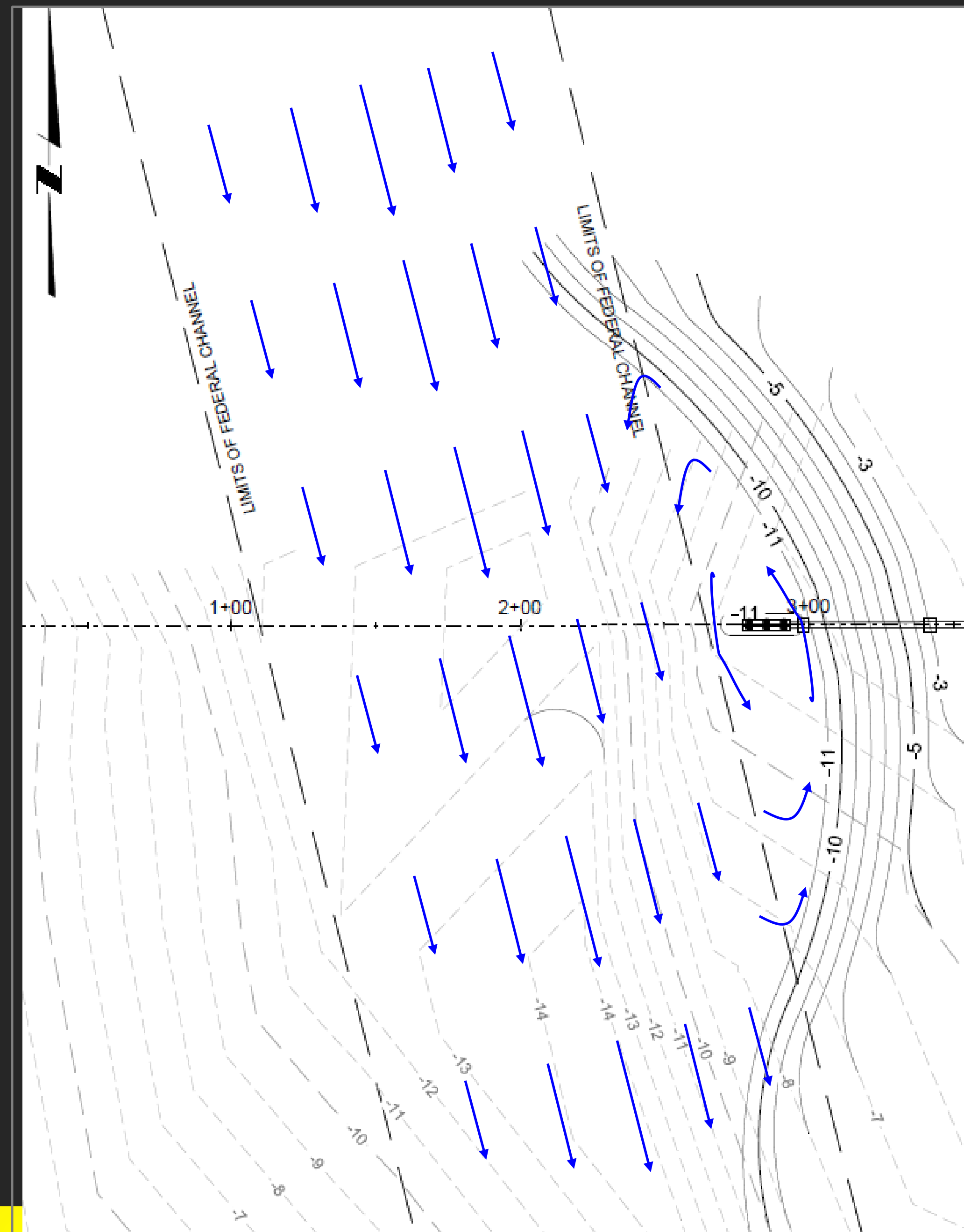




CORMIX Model Result Examples

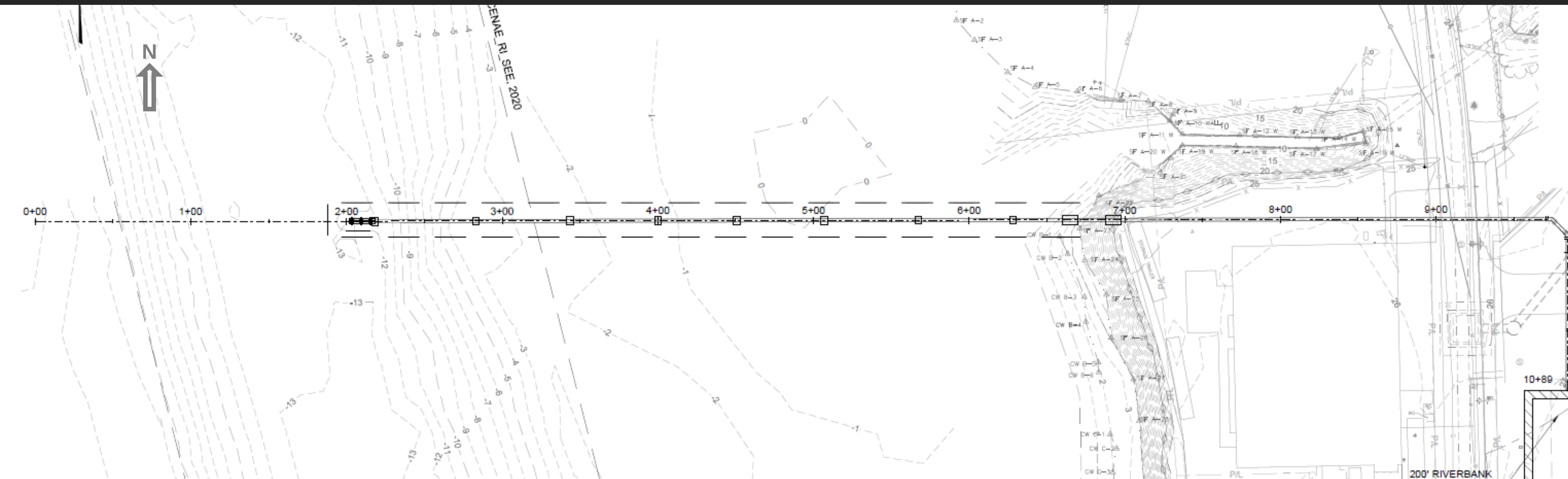
Multiport Diffuser off Channel Limit

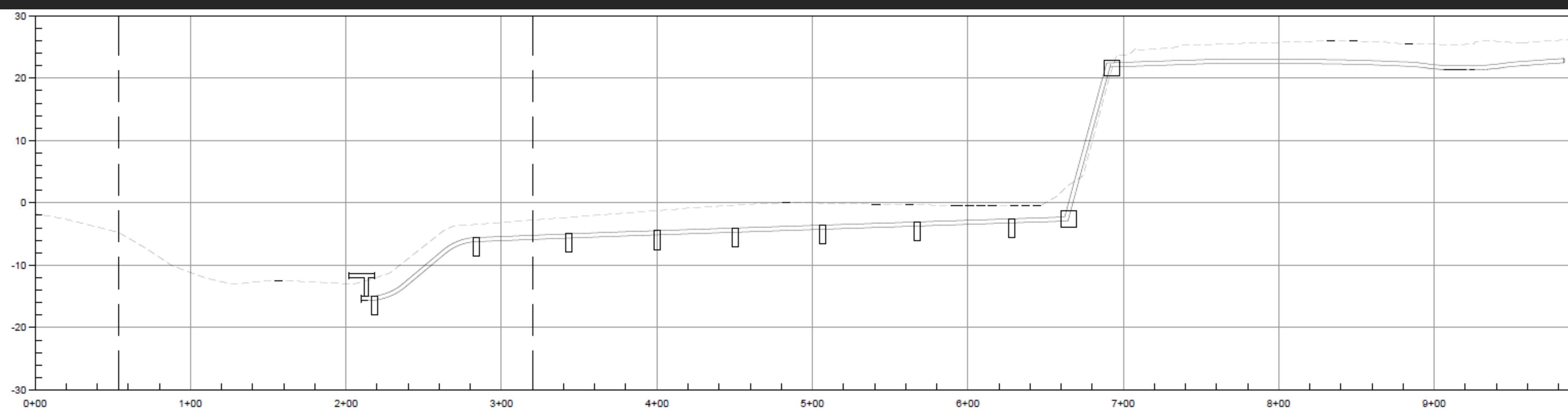
- Depending on bank curvature, surface roughness and flow regime, **flow detachment and eddy** may form within the dredged section outside of the channel
- Discharge in the curved section **will not have sufficient ambient flow** and velocity to for effective mixing
- In long term, the pollutant from the discharge will accumulate in the curved section to **high concentration levels**



Pawtucket Tunnel Construction Water Effluent Pipe and Discharge Diffuser

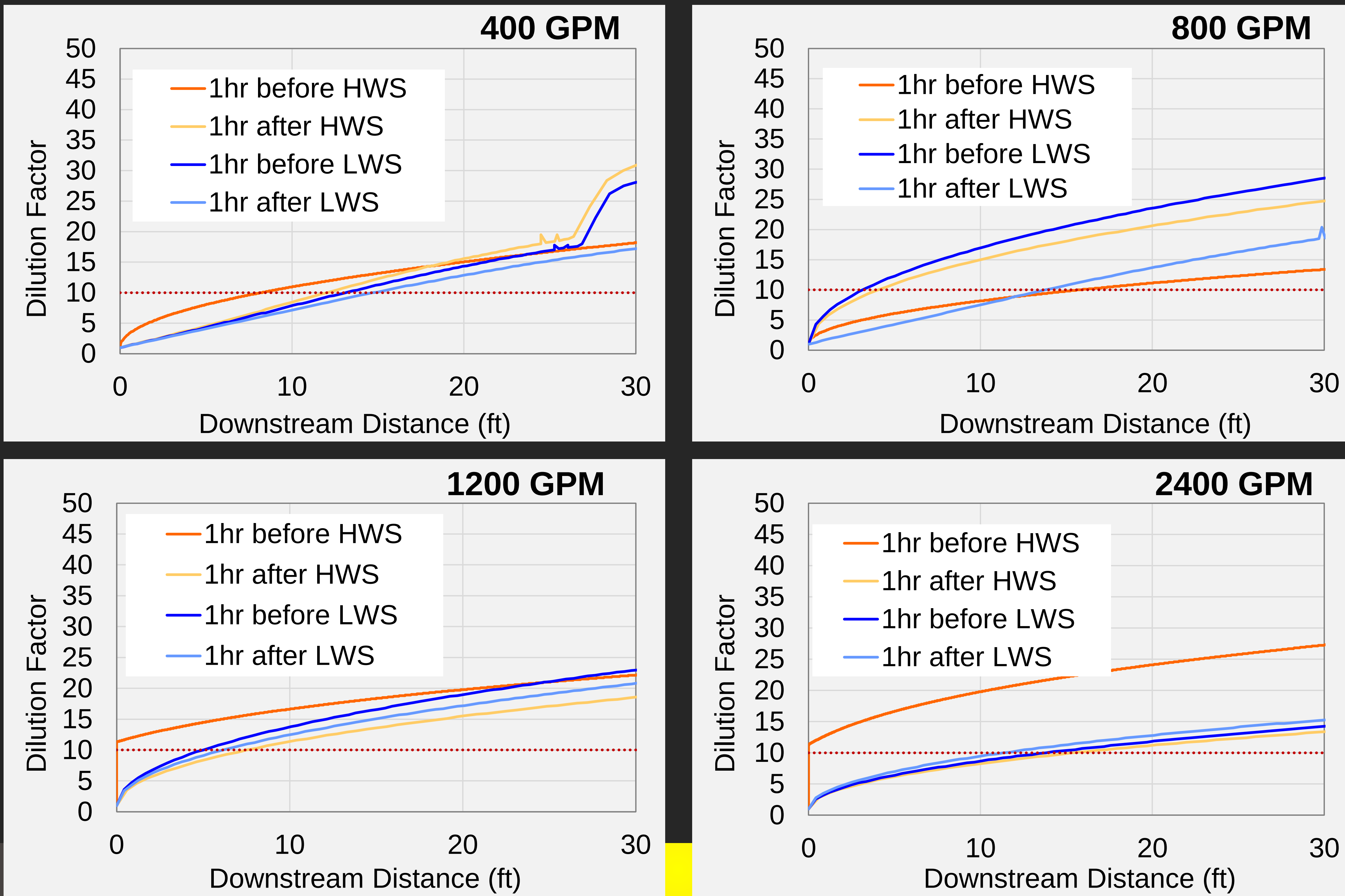
Proposed Plan and Profile View





CORMIX Model Result Examples

Multiport Diffuser, three 4” ports @6ft apart



Take-away Message

- CORMIX Modeling is a useful tool to simulate mixing zone around the discharge to estimate dilution factors
- Dredging and expanding river channel for an off-channel discharge would not provide sufficient ambient flow to mix and dilute the discharged stream.
- Positioning multiport diffuser parallel to the channel will reduce intrusion to the channel, however, it would provide insufficient dilution.
- Recommended Alternative: multiport diffuser in the channel perpendicular to the flow. Achieve a dilution factor of 10 within 20 feet downstream of the discharging point.

Happy New Year of the Rabbit!

Construction Pictures

Construction Pictures

Construction Pictures

Construction Pictures

Construction Pictures

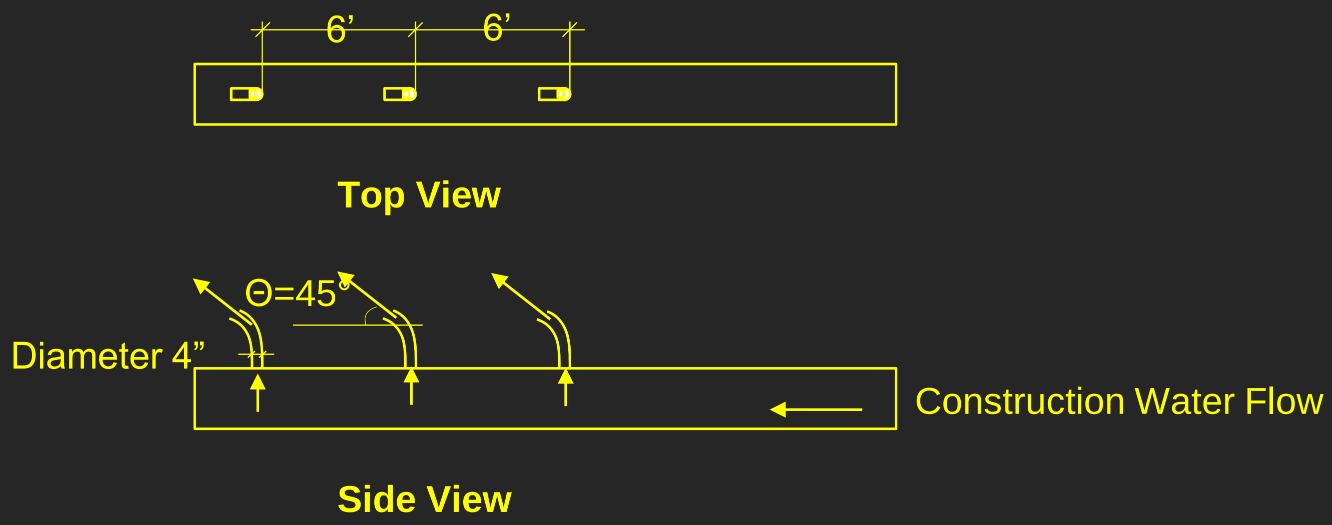
Construction Pictures

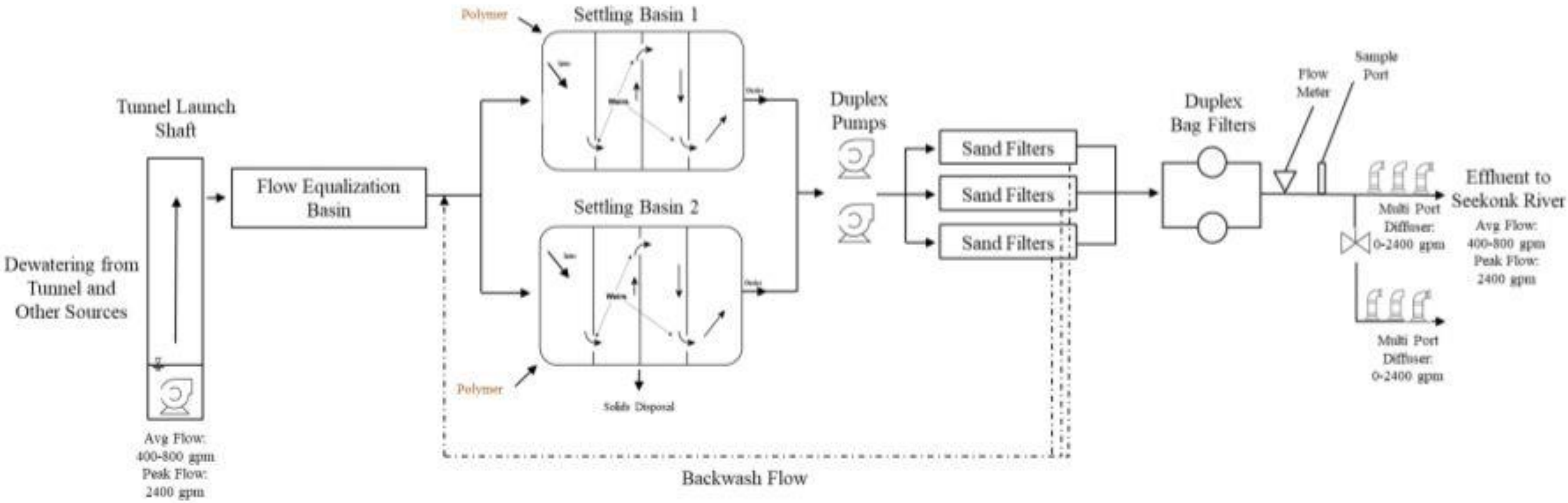
Construction Pictures

Construction Pictures

Multiport Diffuser Simulated in the Model

- Port Number: 3
- Port Diameter: 4 inch
- Distance between continuous port: minimum 6 ft
- Orientation of Nozzles
    - Vertical: 45 degrees
    - Horizontal: parallel to the diffuser (length)




Tunnel Launch Shaft
Dewatering from Tunnel and Other Sources
Avg Flow: 400-800 gpm
Peak Flow: 2400 gpm
Flow Equalization Basin
Polymer
Settling Basin 1
Settling Basin 2
Polymer
Solids Disposal
Duplex Pumps
Sand Filters
Sand Filters
Sand Filters
Backwash Flow
Duplex Bag Filters
Flow Meter
Sample Port
Multi Port Diffuser: 0-2400 gpm
Multi Port Diffuser: 0-2400 gpm
Effluent to Seekonk River
Avg Flow: 400-800 gpm
Peak Flow: 2400 gpm

CALCULATION OF WATER QUALITY BASED SALTWATER DISCHARGE LIMITS

FACILITY NAME: NBC Pawtucket Tunnel Construction Dewatering (DF=10) RIPDES PERMIT #:

CHEMICAL NAME	CAS#	DAILY MAX LIMIT (ug/L)	MONTHLY AVE LIMIT (ug/L)
PRIORITY POLLUTANTS:			
TOXIC METALS AND CYANIDE			
ANTIMONY	7440360	No Criteria	5120.00
ARSENIC, TOTAL	7440382	611.64	3.24
ASBESTOS	1332214	No Criteria	No Criteria
BERYLLIUM	7440417	No Criteria	No Criteria
CADMIUM, TOTAL	7440439	377.82	82.86
CHROMIUM III, TOTAL	16065831	No Criteria	No Criteria
CHROMIUM VI, TOTAL	18540299	9967.32	450.71
COPPER, TOTAL	7440508	59.31	36.47
CYANIDE	57125	8.00	8.00
LEAD, TOTAL	7439921	13690.50	523.11
MERCURY, TOTAL	7439976	19.05	1.34
NICKEL, TOTAL	7440020	698.76	73.42
SELENIUM, TOTAL	7782492	2614.60	639.65
SILVER, TOTAL	7440224	34.55	No Criteria
THALLIUM	7440280	No Criteria	3.76
ZINC, TOTAL	7440666	843.58	757.96
VOLATILE ORGANIC COMPOUNDS			
ACROLEIN	107028	No Criteria	2320.00
ACRYLONITRILE	107131	No Criteria	20.00
BENZENE	71432	No Criteria	4080.00
BROMOFORM	75252	No Criteria	11200.00
CARBON TETRACHLORIDE	56235	No Criteria	128.00
CHLOROBENZENE	108907	No Criteria	12800.00
CHLORODIBROMOMETHANE	124481	No Criteria	1040.00
CHLOROFORM	67663	No Criteria	37600.00
DICHLOROBROMOMETHANE	75274	No Criteria	1360.00
1,2DICHLOROETHANE	107062	No Criteria	2960.00
1,1DICHLOROETHYLENE	75354	No Criteria	56800.00
1,2DICHLOROPROPANE	78875	No Criteria	1200.00
1,3DICHLOROPROPYLENE	542756	No Criteria	168.00
ETHYLBENZENE	100414	No Criteria	16800.00
BROMOMETHANE (methyl bromide)	74839	No Criteria	12000.00
CHLOROMETHANE (methyl chloride)	74873	No Criteria	No Criteria

CHEMICAL NAME	CAS#	DAILY MAX LIMIT (ug/L)	MONTHLY AVE LIMIT (ug/L)
TETRACHLOROETHYLENE	127184	No Criteria	264.00
TOLUENE	108883	No Criteria	120000.00
1,2TRANSDICHLOROETHYLENE	156605	No Criteria	80000.00
1,1,1TRICHLOROETHANE	71556	No Criteria	No Criteria
1,1,2TRICHLOROETHANE	79005	No Criteria	1280.00
TRICHLOROETHYLENE	79016	No Criteria	2400.00
VINYL CHLORIDE	75014	No Criteria	19.20
ACID ORGANIC COMPOUNDS			
2CHLOROPHENOL	95578	No Criteria	1200.00
2,4DICHLOROPHENOL	120832	No Criteria	2320.00
2,4DIMETHYLPHENOL	105679	No Criteria	6800.00
4,6DINITRO2METHYL PHENOL	534521	No Criteria	2240.00
2,4DINITROPHENOL	51285	No Criteria	42400.00
4NITROPHENOL	88755	No Criteria	No Criteria
PENTACHLOROPHENOL	87865	104.00	63.20
PHENOL	108952	No Criteria	13600000.00
2,4,6TRICHLOROPHENOL	88062	No Criteria	192.00
BASE NEUTRAL COMPUNDS			
ACENAPHTHENE	83329	No Criteria	7920.00
ANTHRACENE	120127	No Criteria	320000.00
BENZIDINE	92875	No Criteria	0.02
PAHs		No Criteria	1.44
BIS(2CHLOROETHYL)ETHER	111444	No Criteria	42.40
	108601	No Criteria	520000.00
BIS(2ETHYLHEXYL)PHTHALATE	117817	No Criteria	176.00
BUTYL BENZYL PHTHALATE	85687	No Criteria	15200.00
2CHLORONAPHTHALENE	91587	No Criteria	12800.00
1,2DICHLOROBENZENE	95501	No Criteria	10400.00
1,3DICHLOROBENZENE	541731	No Criteria	7680.00
1,4DICHLOROBENZENE	106467	No Criteria	1520.00
3,3DICHLOROBENZIDENE	91941	No Criteria	2.24
DIETHYL PHTHALATE	84662	No Criteria	352000.00
DIMETHYL PHTHALATE	131113	No Criteria	8800000.00
DI-n-BUTYL PHTHALATE	84742	No Criteria	36000.00
2,4DINITROTOLUENE	121142	No Criteria	272.00

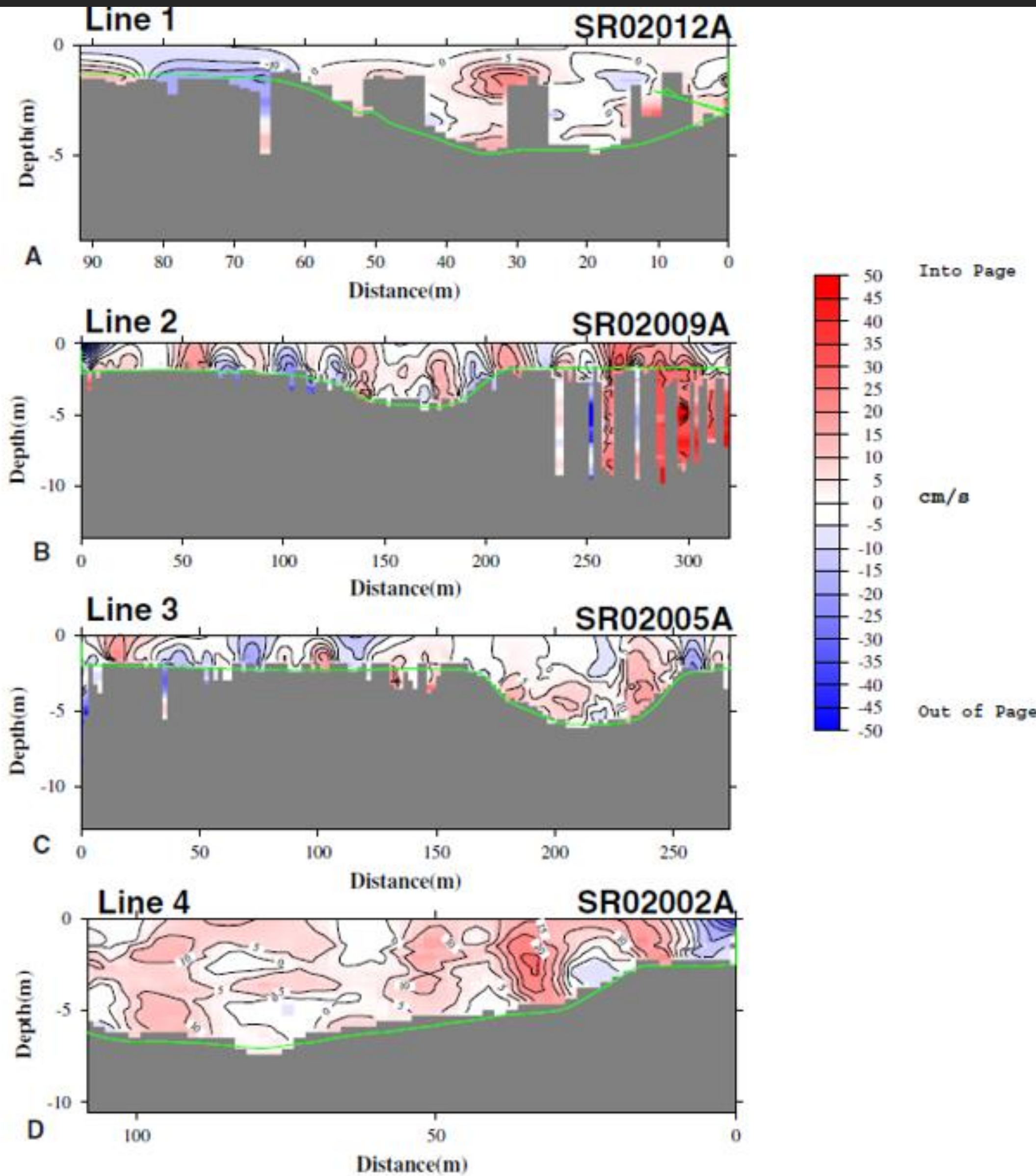
Parameter	Unit	South Hartford Conveyance Tunnel Construction Dewatering Samples[1]								RIPDES GP G DF=10 [3]	
		INF 1	INF 3	INF 4	INF 6	Influent Average	EFF 3	EFF 6	Effluent Average	Maximum Daily	Average Monthly
Antimony	µg/L	ND	ND	ND	ND	**ND**	ND	ND	**ND**	56	56
Arsenic	µg/L	6	4	ND	ND	**3.5**	ND	ND	**ND**	552	11
Cadmium	µg/L	1	1	ND	ND	**1**	ND	ND	**ND**	102	71
Chromium	µg/L	29	40	16	21	**26.5**	9	7	**8**	3,230	1,000
Copper	µg/L	19.5	22.5	6.5	6.4	**13.7**	3.1	2.7	**2.9**	46	30
Cyanide	µg/L	ND	ND	ND	ND	**ND**	ND	ND	**ND**	8	8
Lead	µg/L	13	17	4	10	**11**	ND	ND	**ND**	1,600	68
Mercury	µg/L	ND	ND	ND	ND	**ND**	ND	ND	**ND**	17	1
Nickel	µg/L	31	36	11	16	**23.5**	3	3	**3**	598	66
pH (S.U.)		9.65	11.09	10.63	10.62	**10.5**	7.51	6.71	**7.1**		
Selenium	µg/L	ND	ND	ND	ND	**ND**	ND	ND	**ND**	2,325	569
Silver	µg/L	ND	ND	ND	ND	**ND**	ND	ND	**ND**	18	18
Zinc	µg/L	136	194	43	89	**115.5**	15	16	**15.5**	761	685
TSS	mg/L	280	970	6300	1200	**860**[2]	75	77	**104**[2]	300	
Iron	mg/L	29.6	33.6	11.3	14.5	**22.3**	2.59	2.82	**2.7**	10	

Parameter	Unit	South Hartford Conveyance Tunnel Construction Dewatering Samples[1]								RIPDES GP G No Dilution (DF=1)	
		INF 1	INF 3	INF 4	INF 6	Influent Average	EFF 3	EFF 6	Effluent Average	Maximum Daily	Average Monthly
Antimony	µg/L	ND	ND	ND	ND	**ND**	ND	ND	**ND**	5.6	5.6
Arsenic	µg/L	6	4	ND	ND	**3.5**	ND	ND	**ND**	55.2	1.12
Cadmium	µg/L	1	1	ND	ND	**1**	ND	ND	**ND**	10.2	7.08
Chromium	µg/L	29	40	16	21	**26.5**	9	7	**8**	323	100
Copper	µg/L	19.5	22.5	6.5	6.4	**13.7**	3.1	2.7	**2.9**	4.62	2.98
Cyanide	µg/L	ND	ND	ND	ND	**ND**	ND	ND	**ND**	0.8	0.8
Lead	µg/L	13	17	4	10	**11**	ND	ND	**ND**	160	6.81
Mercury	µg/L	ND	ND	ND	ND	**ND**	ND	ND	**ND**	1.69	0.12
Nickel	µg/L	31	36	11	16	**23.5**	3	3	**3**	59.79	6.62
pH (S.U.)		9.6	11.1	10.6	10.6	**10.5**	7.5	6.7	**7.1**	5.0-11.0	
Selenium	µg/L	ND	ND	ND	ND	**ND**	ND	ND	**ND**	232.46	56.91
Silver	µg/L	ND	ND	ND	ND	**ND**	ND	ND	**ND**	1.78	1.78
Zinc	µg/L	136	194	43	89	**116**	15	16	**15.5**	76.11	68.5
TSS	mg/L	280	970	6300	1200	**860** [2]	75	77	**104** [2]	30	
Iron	mg/L	29.6	33.6	11.3	14.5	**22.3**	2.59	2.82	**2.7**	1	

Parameter [1]	Unit	Providence Tunnel		Foundry		Seekonk CSO Interceptor		RIPDES GP G DF=10 [2]	
		Mean	95% CI	Mean	95% CI	Mean	95% CI	Maximum Daily	Average Monthly
Antimony	µg/L	1	NA	NA	NA	NA	NA	56	56
Arsenic	µg/L	NA	NA	NA	NA	NA	NA	552	11
Cadmium	µg/L	6.2	14	8.5	41.9	5.5	18.8	102	71
Chromium	µg/L	27.9	67	31.6	60	11.9	75	3,230	1,000
Copper	µg/L	36.8	50	41.5	50	21.5	40	46	30
Cyanide	µg/L	NA	NA	NA	NA	NA	NA	8	8
Lead	µg/L	41.9	80	43.3	87	10.9	63.5	1,600	68
Mercury	µg/L	NA	NA	NA	NA	NA	NA	17	1
Nickel	µg/L	25.3	50	23	58	8.5	44	598	66
pH (S.U.)		NA	NA	NA	NA	NA	NA		
Selenium	µg/L	NA	NA	NA	NA	NA	NA	2,325	569
Silver	µg/L	19.4	20	19.6	20	7.4	23.8	18	18
Zinc	µg/L	57.7	150	51	91	23.8	60	761	685
TSS	mg/L	NA	NA	NA	NA	NA	NA	300	
Iron	mg/L	NA	NA	NA	NA	NA	NA	10	

Reference 4: Hydrographic Surveys on the Providence and Seekonk Rivers, December 2001

Circuit 2 & Circuit 3 (mid & late ebb) velocity contours



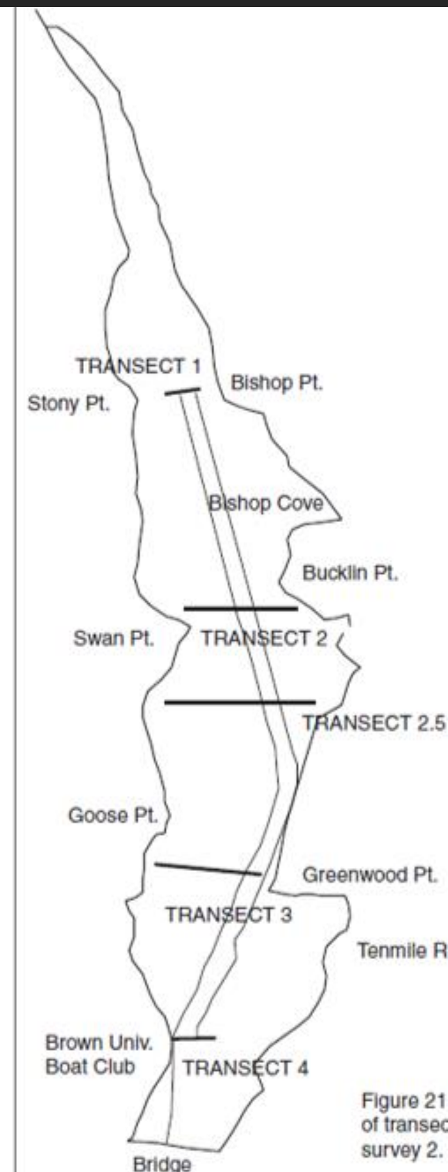


Figure 21
of transec
survey 2.