28 February 2017

Dilution Analysis Alden 3-Jet Duckbill Diffuser Retrofit at Huntington Beach Desalination Facility (HBDF)

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Initial Dilution Results Using the 3-Jet Duckbill Diffuser Retrofit. The initial dilution analysis of the Alden-designed *3-Jet Duckbill Diffuser Retrofit* (Alden Diffuser) at the Huntington Beach Desalination Facility (Figures 1) was conducted using the EPA certified Visual Plumes models *COSMOS/ FLowWorks* computational fluid dynamics (CFD) model. The Alden Diffuser has three 36-in. duckbill check valves and one 4.5-ft. diameter port; the number and diameter were selected to produce an initial discharge velocity of about 10 ft./sec. The port will be operated only for higher flows and HBDF brine will not be discharged. As shown in Figure 1, the check valves are generally oriented to provide a net offshore momentum. The horizontal angles between the check valves is 45 degrees to provide adequate flow separation for entrainment of ambient ocean water into each discharge jet and to fit the pipes into the available space. Flow to the check valves would come from a new common plenum under the tower cap, which would otherwise be sealed. The plenum with imbedded pipes would sit on top of the existing tower after the existing grating and two tower riser rings are removed; all other existing elements of the tower and the 14-ft. diameter supply pipe would be used.

The Alden Diffuser in Figure 1 was transposed into a 3-D CAD model shown in Figure 2, using COSMOS/SolidWorks in order to exploit the CAD embedded Cartesian gridding capabilities of *COSMOS/ FLowWorks*. Two discharge scenarios were studied:

> **Worst-case #1**: Annual Average with Backwash discharge of 56.7 mgd with an end-of-pipe discharge salinity S_b = 63.1 ppt.
>
> **Worst-case #2:** Annual Average with Recycled Backwash of 50 MGD with an end-of-pipe discharge salinity S_b = 67 ppt.

For testing the dilution performance for these two discharge scenarios, the single 4.5-ft. diameter port was capped with a manhole cover plate. Because the open cross sectional area of the duckbill check valves changes with discharge rate, it was necessary to adjust the nozzle geometry of the duckbills in the CAD model according to an empirical relation between nozzle

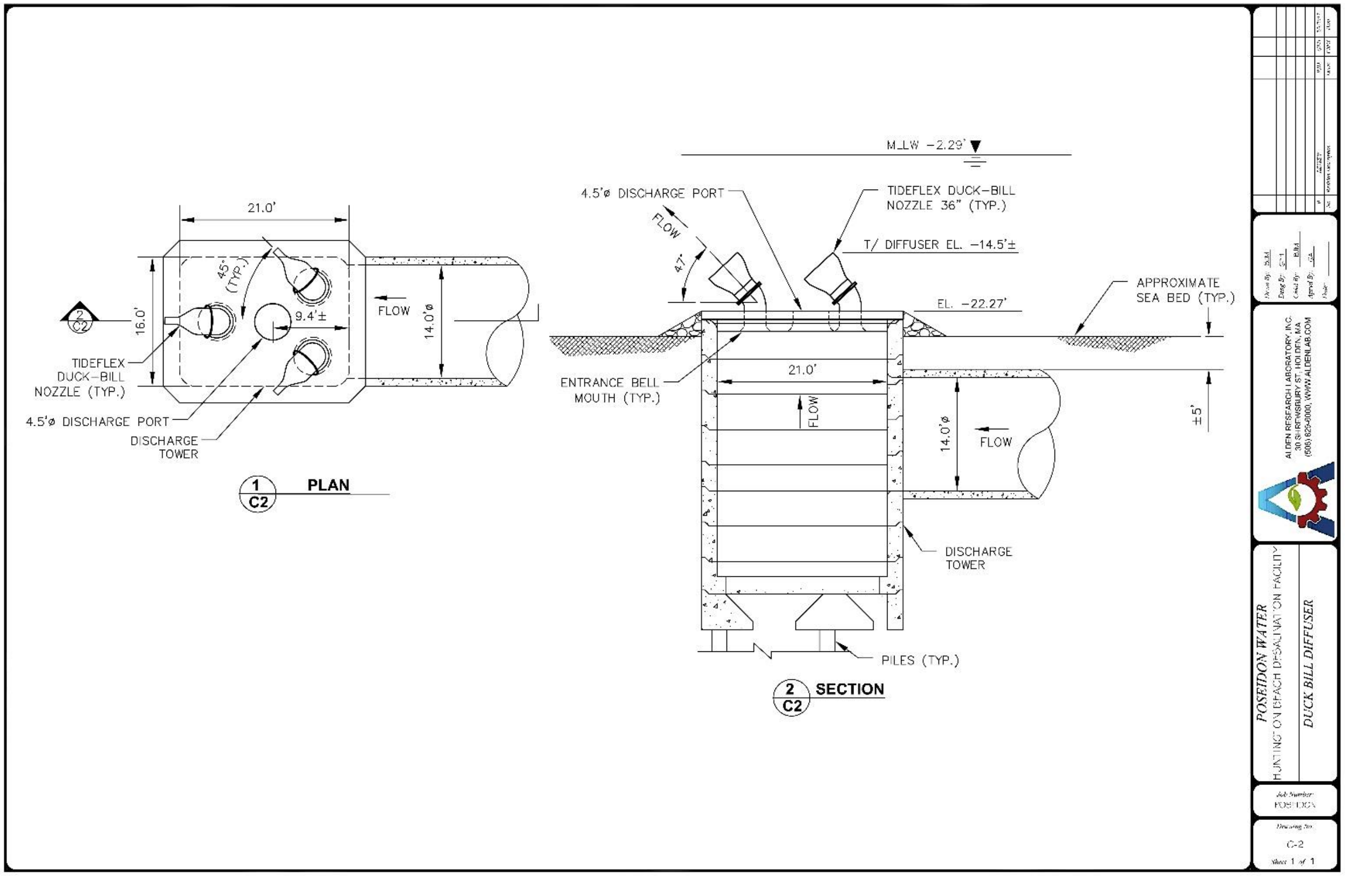


Figure 1: Design drawing for the second generation of HBDF diffuser design after Hecker and Allen, (2017)

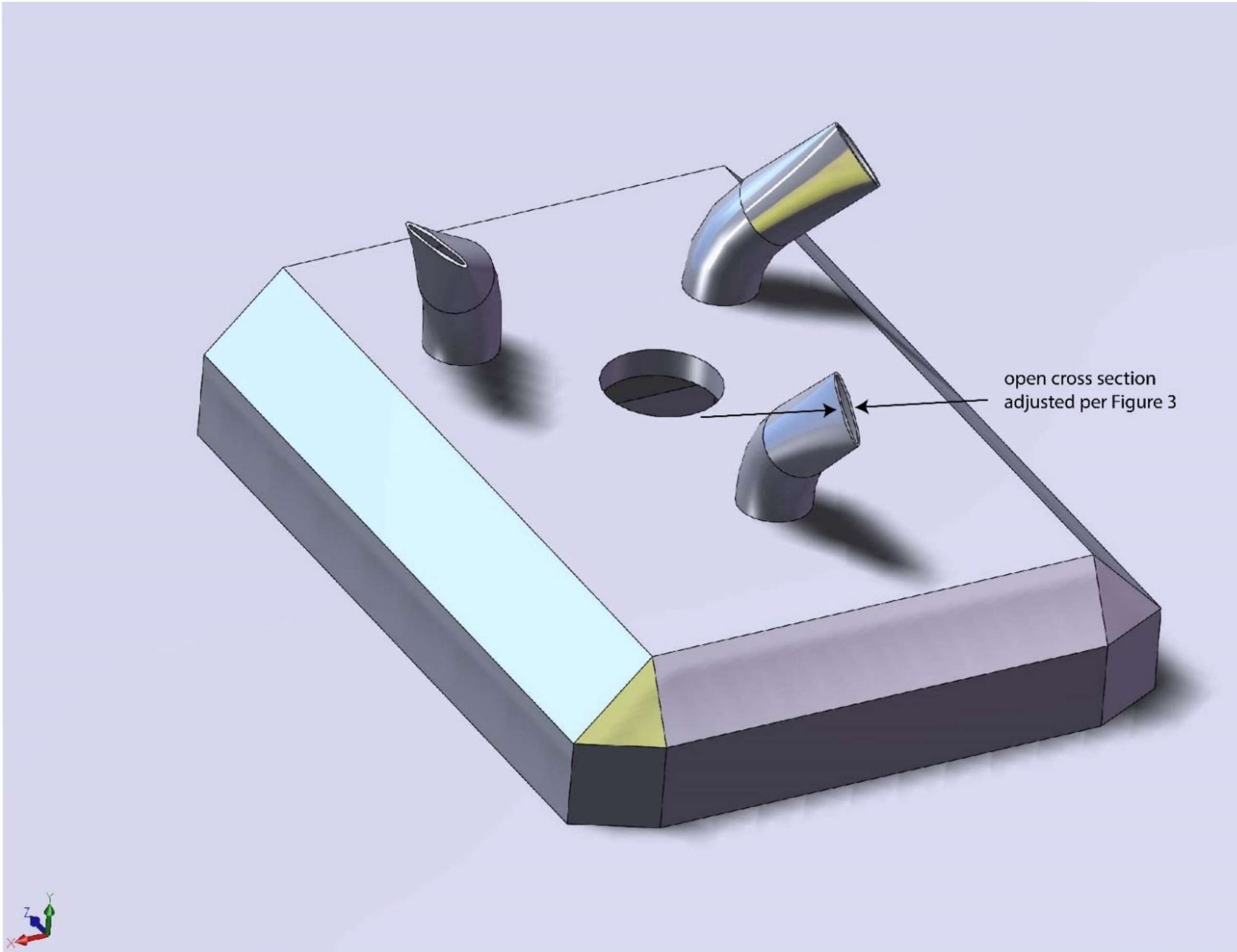


Figure 2: Three-dimensional CAD of the Alden-designed *3-Jet Duckbill Diffuser Retrofit* (cf. Figure 1) at the discharge tower site located at latitude 33º 38' 19'' N, longitude 117º 58' 57'' W, approximately 1,500 ft (457 m) offshore from the mean lower-low water tide line at a depth of 27.9 ft (8.5 m) below mean sea level. For the dilution analysis in this technical memorandum, the 4.5-ft. diameter port that appears in the center of the diffuser was capped with a circular cover plate as shown in Figures 4 & 8.

cross section and flow rate as shown in Figure 3. This relation was derived from manufacturer provided specifications for the duckbill check valves found in Appendix-A.

Figure 4 shows the CFD simulation of the discharge and entrainment streams from the Alden Diffuser operating in the *stand-alone* regime using three seaward facing 36-in. Tideflex duckbill check valves with the 4.5-ft. diameter port capped. The brine discharge in this simulation is Q = 56.7 mgd at 63.1 ppt, with ΔT = 0 ^{0}C. The densimetric Froude number is a robust $F_r = u\big/\sqrt{\Delta\rho g D/\rho}$ = 8.35, which is as improvement over the previous Alden design for stand–alone operation. Maximum discharge velocities from the duckbill check valves is u = 10.1 ft/s, with each valve providing A_i = 2.87 ft^2 of discharge cross sectional area. These CFD results support the Alden design expectations in Hecker and Allen, (2017). In the nearfield of the diffuser, the discharge streams from the three duckbill check valves are found in Figure 4 to produce organized entrainment streams several meters above the bottom which draw receiving water inward toward the diffuser and then merge with the upward trajectories of the discharge streams to provide initial dilution before the discharge streams merge and subside to the seabed under of the immersed weight of the negatively buoyant plume. The initial negative buoyancy of the discharge is $\Delta\rho/\rho$ = 2.37%.

The EPA-certified Visual Plumes (UM3) model was used to determine compliance with brine discharge limits set under the newly amended California Ocean Plan (Appendix-A, SWRCB, 2015) which requires that brine discharge salinity declines to within 2 ppt over natural background salinity within a brine mixing zone (BMZ) measuring 100 m (328 ft) from the point of discharge. Natural background salinity at Huntington Beach is S_0 = 33.52 ppt. The Visual Plumes dilution results are shown in Figure 5 for the Alden duckbill diffuser operating in the *stand-alone mode* using 3 ea. 36-in. diameter Tideflex duckbill check valves with the 4.5-ft. diameter port capped, per Figure 4. The solutions in Figure 5 are based on quiescent ocean conditions (no waves, currents or tides) with worst month temperature/salinity profiles in the water column per Figures 6 and 7. The brine discharge is modeled assuming brine discharges having a ΔT = 0 ^{0}C. The ΔT = 0 ^{0}C assumption represents worst-case initial dilution because the mass diffusivity of NaCl in water (a proxy for sea salts) increases moderately with increasing temperature, and higher ΔT causes higher mixing rates. The results in Figure 5 are based on vertical scans of the Visual Plumes solution space in order to find the maximum salinity $S_{\max}(x)$, at any given distance, x, as measured from the point of discharge. This representation is used because the new Ocean Plan brine discharge standard has no vertical dimension. In addition, The Ocean Plan defines dilution factor, *Dm*, as parts receiving water per parts effluent; and consequently the minimum initial dilution is calculated from the modeled results for $S_{\max}(x)$ according to:

$$\text{Dm} = \frac{S_b - S_{\max}(x)}{S_{\max}(x) - S_0} \qquad (1)$$

Upon inspection of Figure 5, we find that the Alden Diffuser dilutes the brine to within 2 ppt of natural background at 24.3 m (79.7 ft) from the point of discharge and is therefore fully compliant with the new Ocean Plan brine discharge limits in all quadrants around the HBDF discharge site. The dilution factor at the edge of the BMZ at 24.3 m (79.7 ft) from the discharge is Dm = 13.9, and reaches a Dm = 61 at 100 m (328 ft) from the point of discharge.

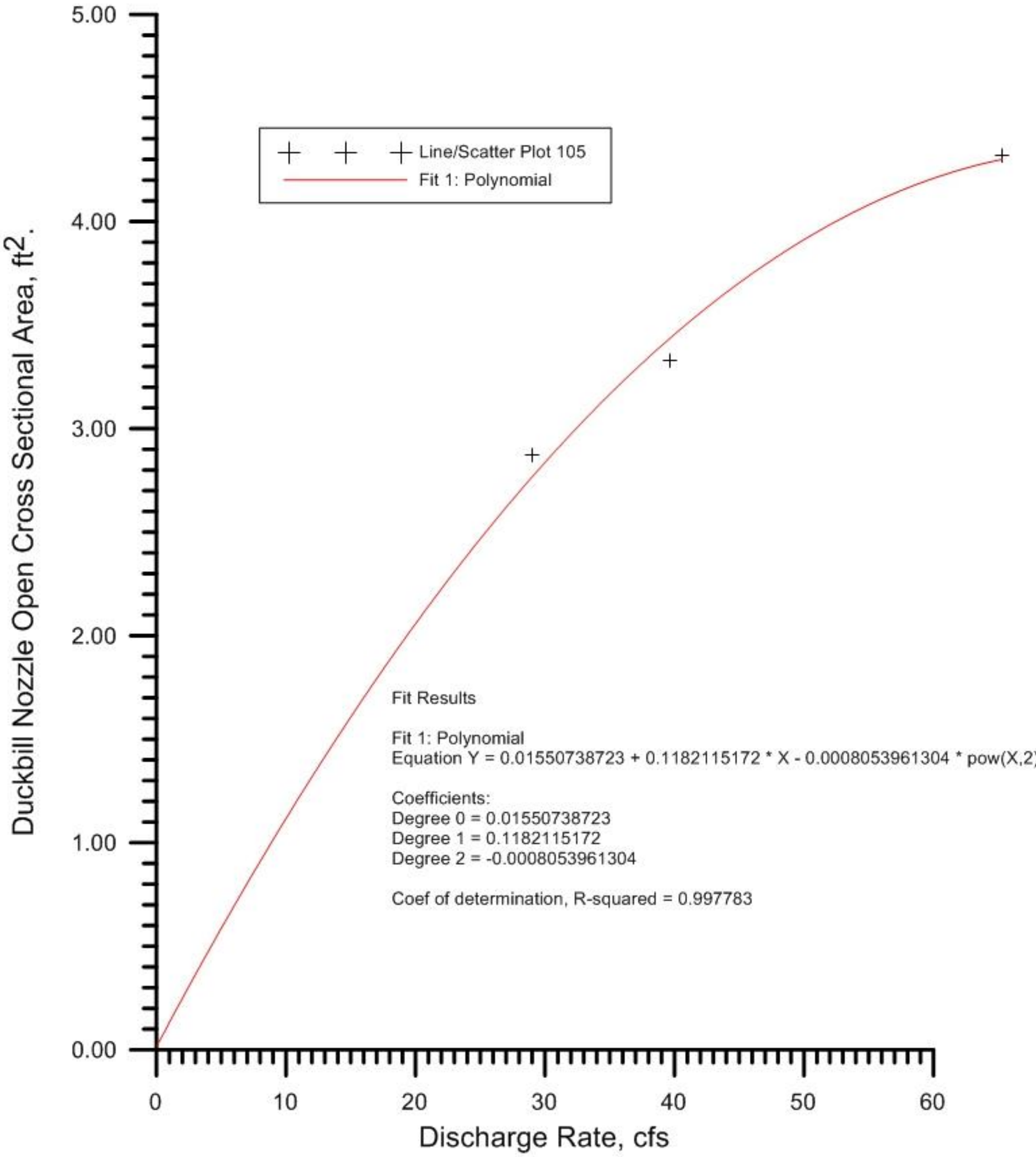


Figure 3: Sensitivity of open cross sectional area of individual Tideflex duckbill nozzles as a function of discharge rate through each nozzle

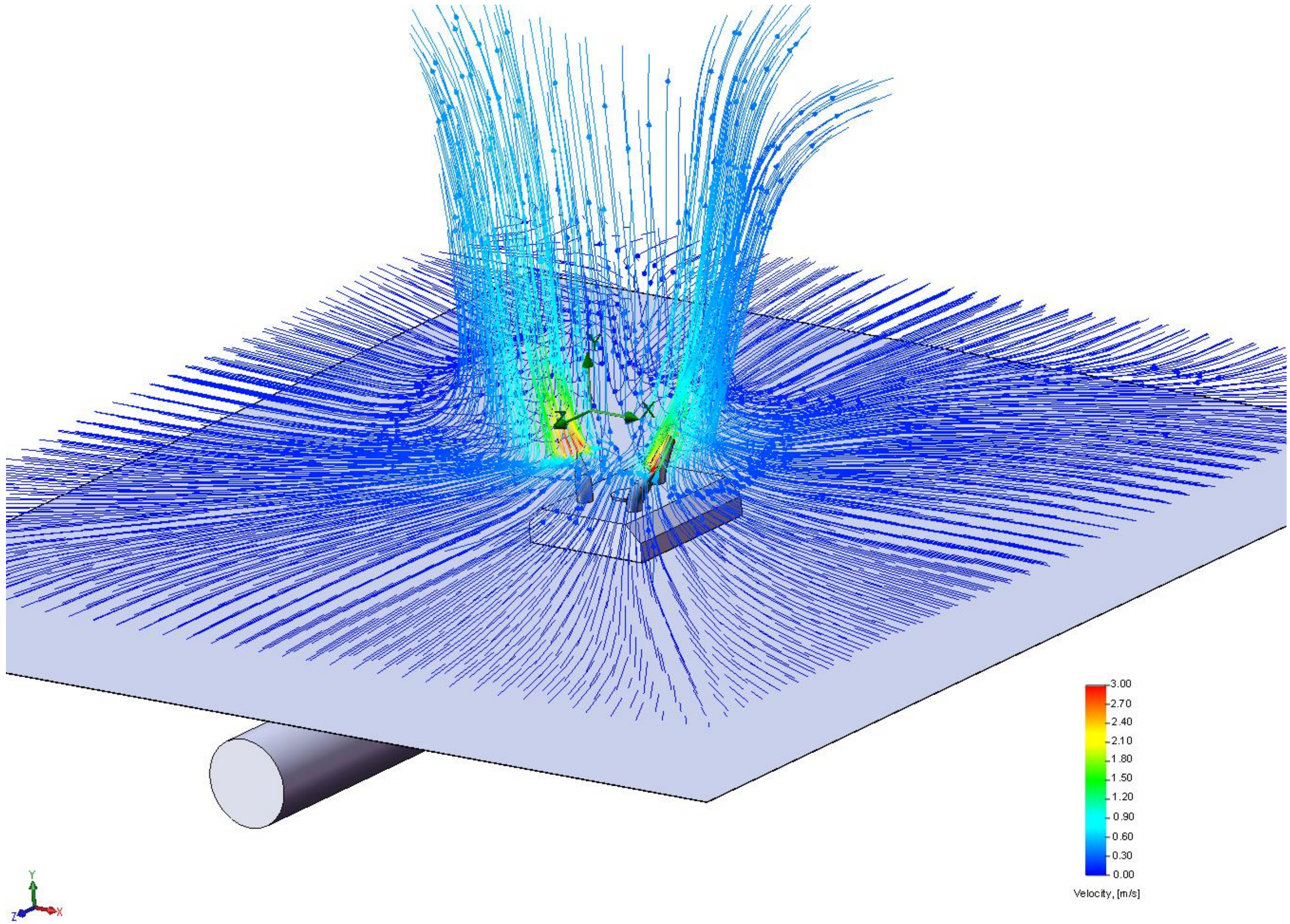


Figure 4: Matched Visual Plumes (UM3) and *COSMOS/ FLowWorks* solutions of the discharge and entrainment streams from Alden Duckbill diffuser operating in the *stand-alone* regime using three seaward facing 36-in. Tideflex duckbill check valves with the 4.5-ft. diameter port capped. Brine discharge = 56.7 mgd at 63.1 ppt, with $\Delta T = 0\ ^0C$. Densimetric Froude number $F_r = u/\sqrt{\Delta\rho g D/\rho}$ = 8.35.

Figure 8 shows a matched Visual Plumes (UM3) and *COSMOS/ FLowWorks* solution of the other potential worst-case *stand-alone* case, when the Alden Duckbill diffuser is using its three seaward-facing 36-in. Tideflex duckbill check valves with the 4.5-ft. diameter port capped. In this case, the brine discharge is reduced to Q = 50.0 mgd at 67.0 ppt, with $\Delta T = 0\ ^0C$. The densimetric Froude number remains very good at $F_r = u \big/ \sqrt{\Delta\rho g D / \rho}$ = 8.70 due to the Tideflex duckbill check valves contracting their exit areas to A_i = 2.53 ft^2 each, producing a discharge velocity of u = 10.1 ft/s. The structure of the nearfield entrainment streams in Figure 8 remain very similar to that in Figure 4 (that were produced at a higher stand-alone discharge rate), with vigorous inflow a few meters above the bottom that merge with the discharge streams to produce rapid initial dilution. This rapid initial dilution is evident in the Visual Plumes (UM3) solution in Figure 9, where dilution performance remains excellent despite a higher end-of-pipe salinity. Compliance with the new Ocean Plan discharge limit (2 ppt above natural background) is obtained within 30.0 m (98.4 ft). from the point of discharge. The dilution factor at the edge of the BMZ is Dm = 15.9.

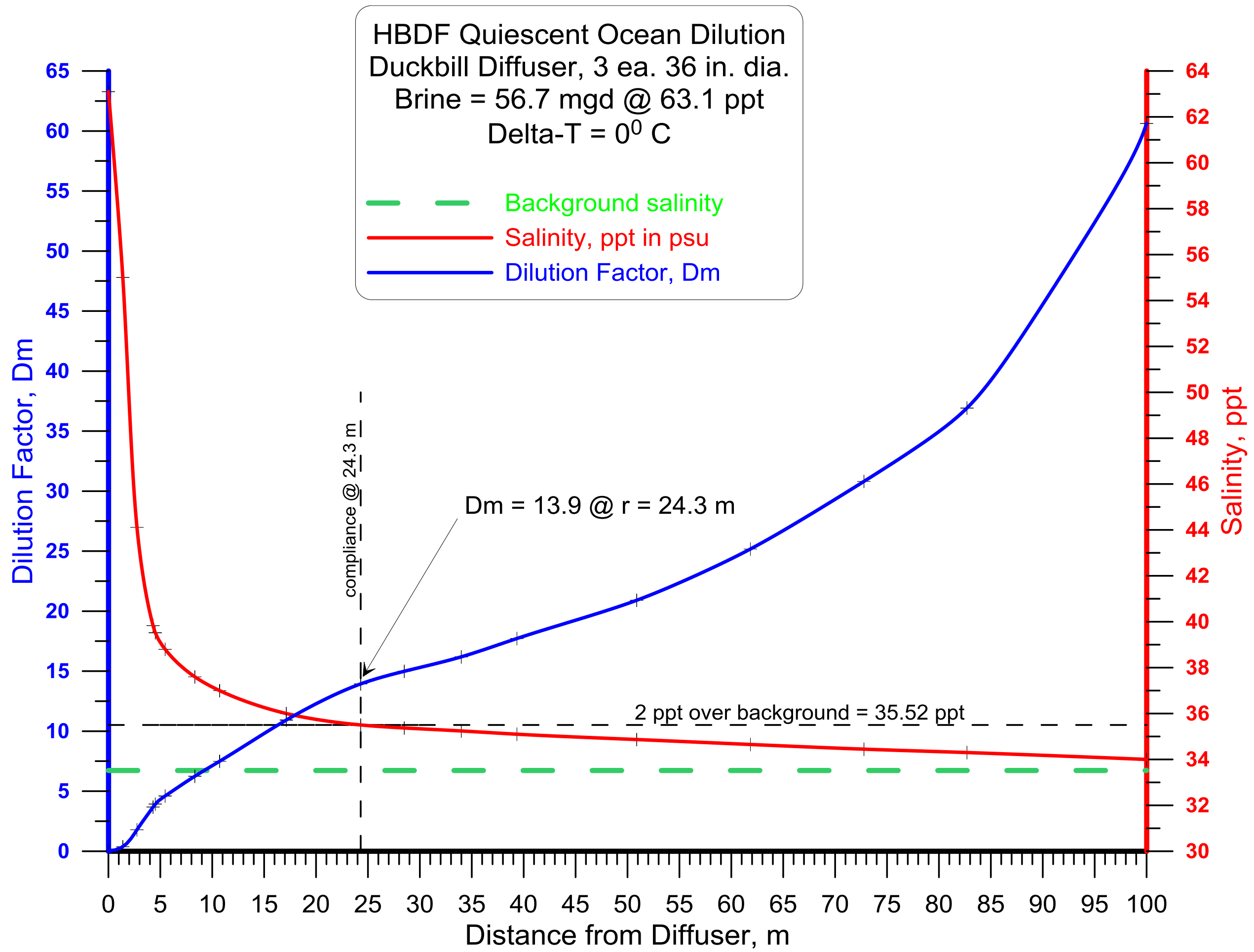
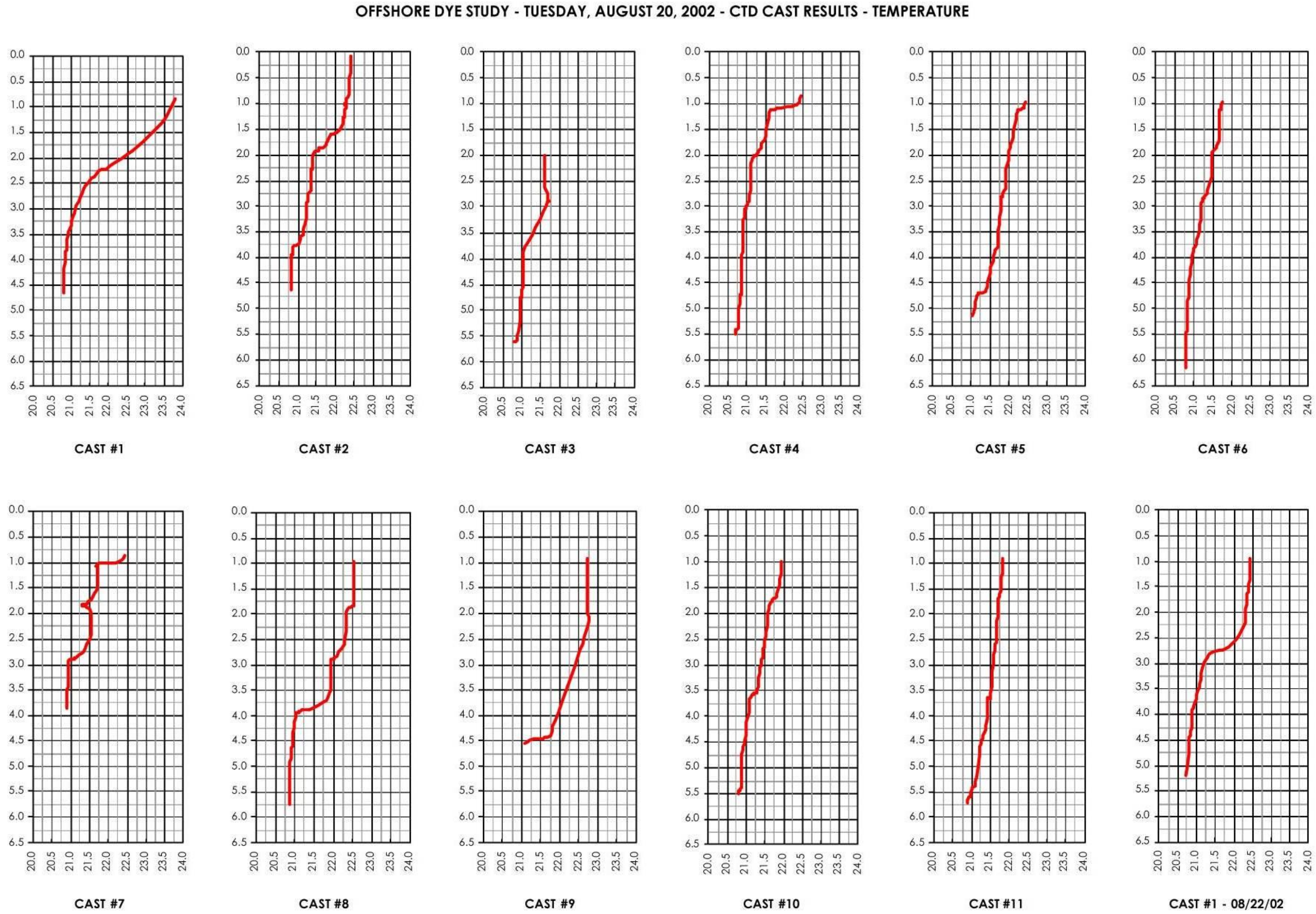
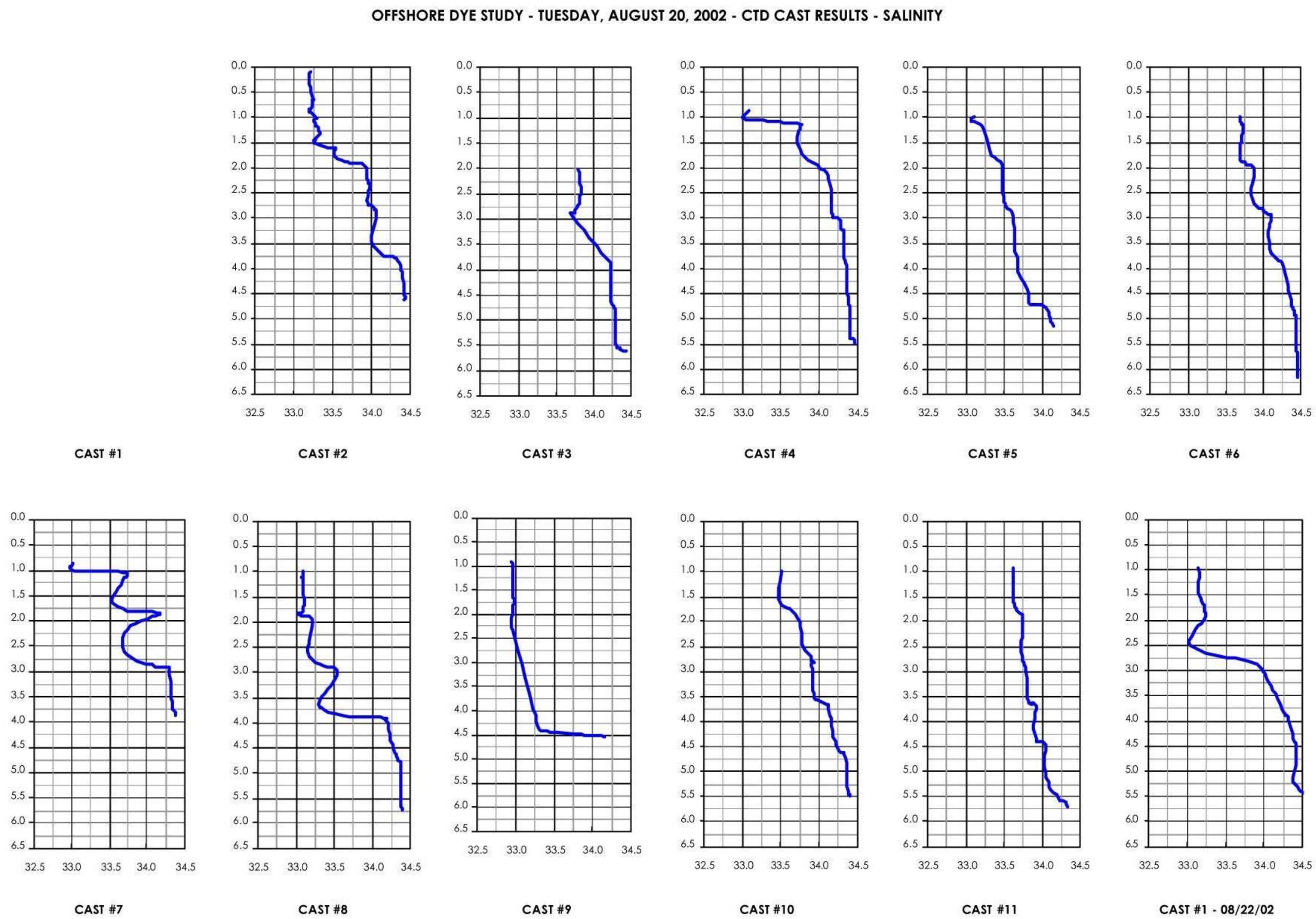


Figure 5: Visual Plumes (UM3) simulation of dilution of brine discharged from the Alden designed duckbill diffuser with 47^0 jet inclination angles. Discharge salinity (red curve per right hand axis) is plotted as a function of radial distance from the point of discharge based on vertical scans of the model solution space in all quadrants to insure discovery of maximum salinity, $S_{max}(x)$, at any given distance from the point of discharge. Dilution factor (blue curve per left hand axis) is based on $S_{max}(x)$ per equation (1). The 4.5 ft. discharge port is capped per Figure 4. Total discharge = 56.7 mgd of brine at salinity S_b = 63.1 ppt. Densimetric Froude number = 8.35 for 3 ea. 36. diameter Tideflex duckbill check valves.



Depths (shown along the vertical axis in each graph) are in meters.
Temperatures (shown along the horizontal axis in each graph) are in degrees Centigrade

Figure 6: Temperature – depth profiles around the HBDF discharge tower during worst-case month, August 2002. Data from KOMEX (2003).



Depths (shown along the vertical axis in each graph) are in meters.
Salinities (shown along the horizontal axis in each graph) are in p.p.t.

Figure 7. Salinity – depth profiles around the HBDF discharge tower during worst-case month, August 2002. Data from KOMEX (2003).

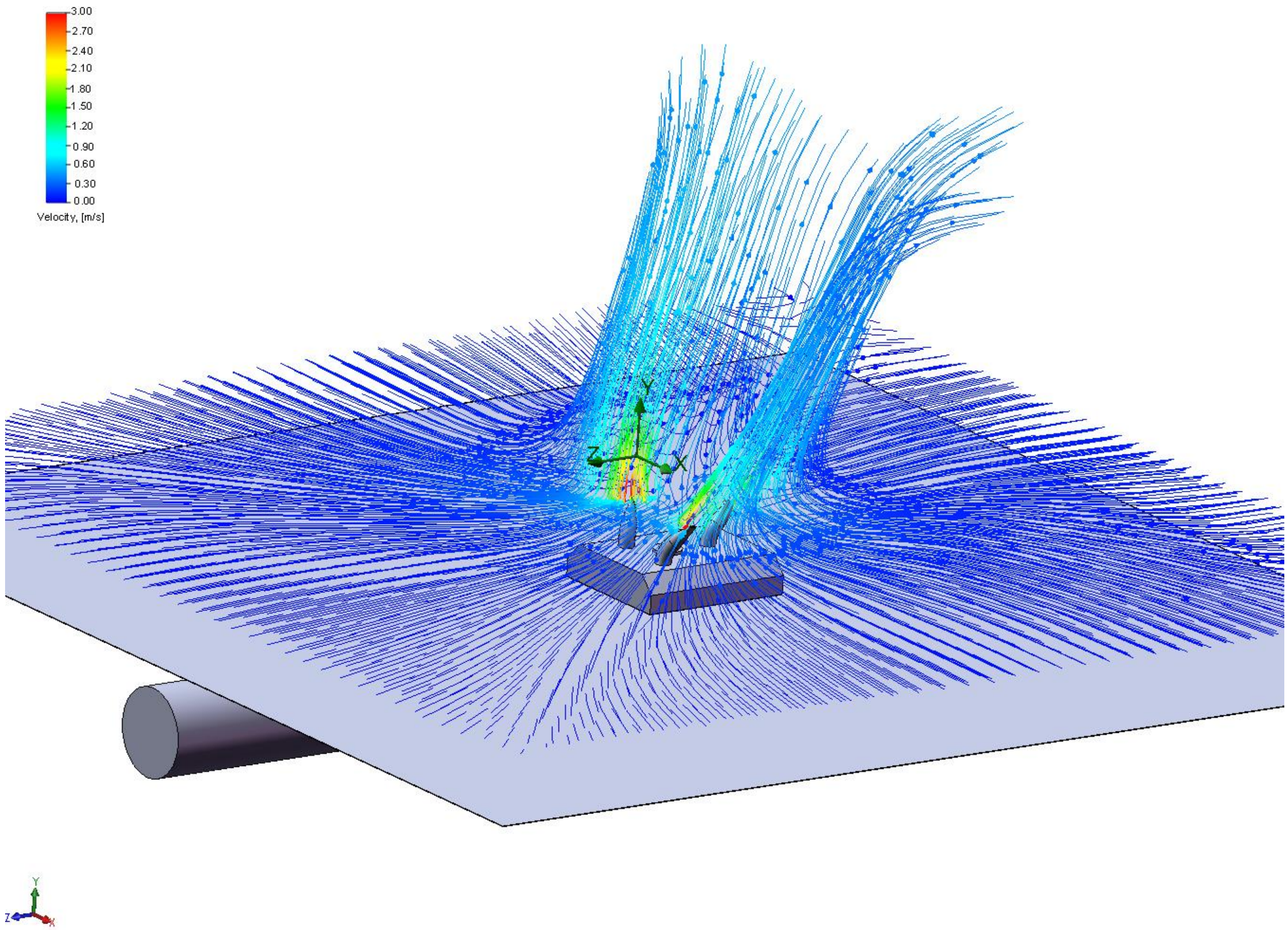


Figure 8: Matched Visual Plumes (UM3) and *COSMOS/ FLowWorks* solutions of the discharge and entrainment streams from Alden Duckbill diffuser operating in the *stand-alone* regime using three seaward facing 36-in. Tideflex duck bill check valves with the 4.5-ft. diameter port capped. Brine discharge = 50.0 mgd at 67.0 ppt, with $\Delta T = 0\ ^0C$. Densimetric Froude number $F_r = u\big/\sqrt{\Delta\rho g D/\rho}$ = 8.70.

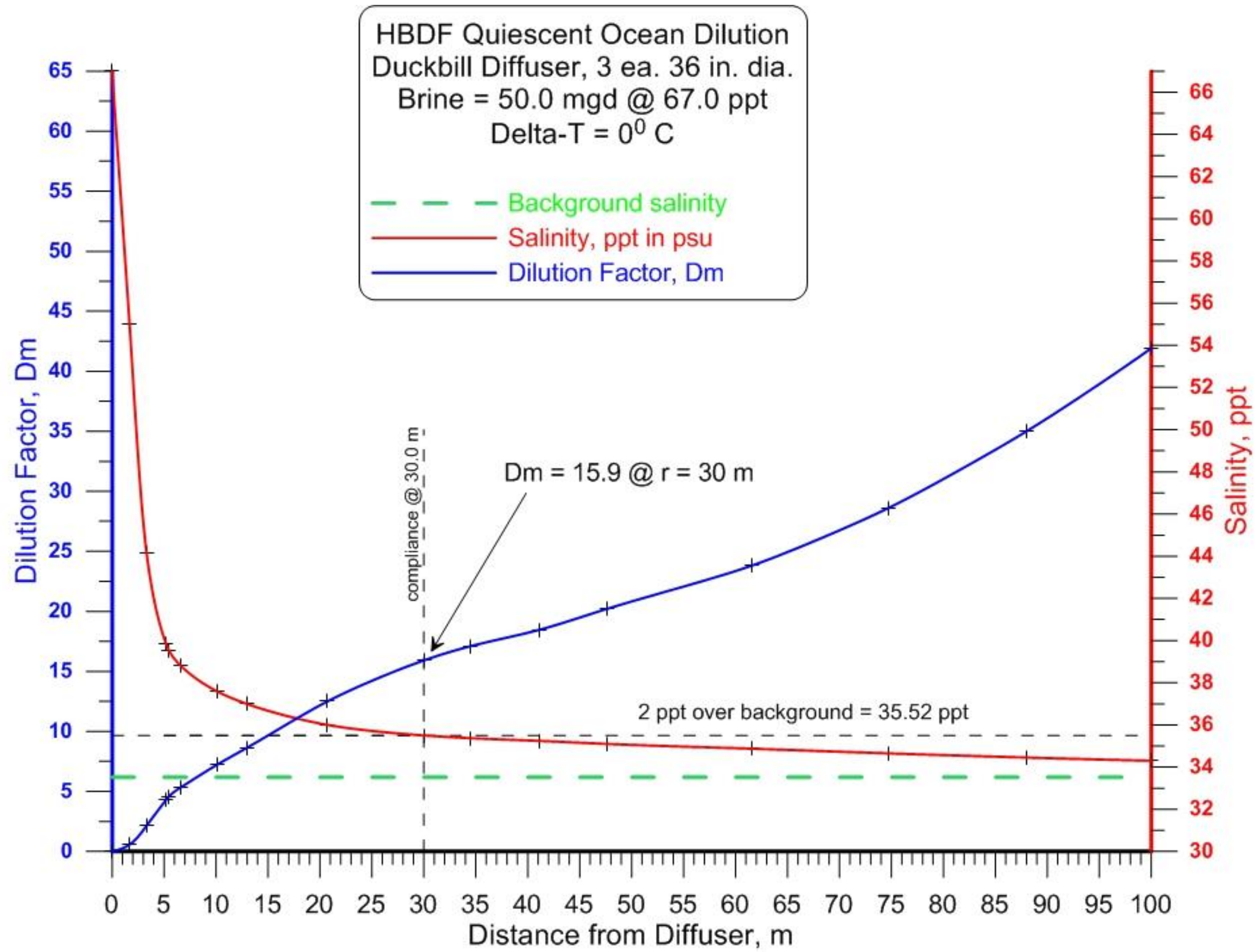


Figure 9: Visual Plumes (UM3) simulation of dilution of brine discharged from the Alden designed duckbill diffuser with 47^0 jet inclination angles. Discharge salinity (red curve per right hand axis) is plotted as a function of radial distance from the point of discharge based on vertical scans of the model solution space in all quadrants to insure discovery of maximum salinity, $S_{\max}(x)$, at any given distance from the point of discharge. Dilution factor (blue curve per left hand axis) is based on $S_{\max}(x)$ per equation (1). The 4.5 ft. discharge port is capped per Figure 4. Total discharge = 50.0 mgd of brine at salinity S_b = 67.0 ppt. Densimetric Froude number = 8.70 for 3 ea. 36. diameter Tideflex duckbill check valves.

References:

Hecker, G. and G. Allen, 2017, " HUNTINGTON BEACH DESALINATION FACILITY Technical Note, ALDEN RESEARCH LABORATORY, INC. submitted to Poseidon Resources, 10 pp.

SEIR, 2010, "Subsequent Environmental Impact Report Sea Water Desalination Project at Huntington Beach," #2001051092, City of Huntington Beach, prepared by Dudek Consulting, May, 2010, 9 sections + append.

SWRCB, 2015, Amendment to the Water Quality Control Plan For Ocean Waters of California Addressing: "DESALINATION FACILITY INTAKES, BRINE DISCHARGES, AND THE INCORPORATION OF OTHER NON-SUBSTANTIVE CHANGES", cf. Appendix-A: "Ocean Plan with the May 6, 2015 Final Desalination Amendment", 1303 pp.

APPENDIX-A

TIDEFLEX DIFFUSER (TFD) SYSTEM DATA ANALYSIS

MEDIA: Effluent

Density or ______ lb/ft^3

Spec. Gravity 1

FLOW RANGE:

56.7	MGD	=	39375	gpm
100	MGD	=	69444	gpm
120	MGD	=	83333	gpm

AVAILABLE HEADLOSS@ DIFFUSER:

Minimum		feet
Design		feet
Maximum		feet

MAX. BACKPRESSURE: ______ feet

TFD SIZE (IN)	HYDRAULIC CODE
36	**10165**

DATE: 02-Feb-2017

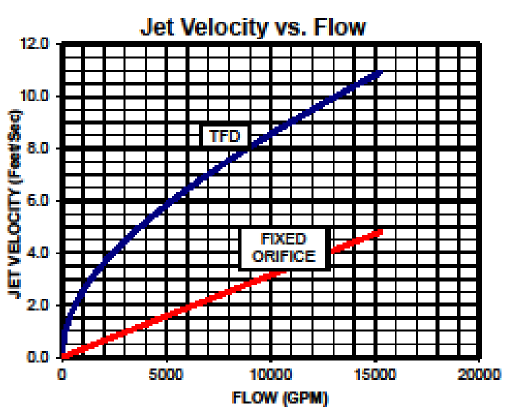
CLIENT:
CONTACT:

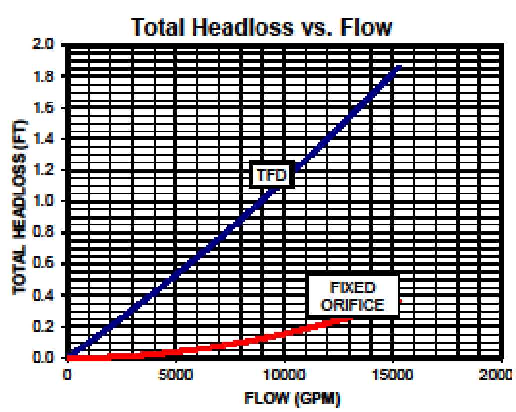
ENGINEER: ALDEN
CONTACT: Brian McMahon

PROJECT: Unknown Pacific Ocean Outfall Diffuser

REP:
CONTACT:

		PER TIDEFLEX DIFFUSER (TFD)				
	*** TOTAL QUANTITY**	TOTAL FLOW (gpm)	FLOW (gpm)	**JET VELOCITY (fps)**	**HEADLOSS (feet)**	EFFECTIVE DIAMETER (in)
	6	39374.748	6562.46	6.77	0.71	19.89
		69444	11574.00	9.30	1.35	22.53
		83332.8	13888.80	10.34	1.66	23.41
FIXED ORIFICE DIA.	* Cd = 1		*PER FIXED ORIFICE*			
36.00	**6**	39374.748	6562.46	**2.07**	**0.07**	36.00
		69444	11574.00	**3.64**	**0.21**	36.00
		83332.8	13888.80	**4.37**	**0.30**	36.00





TIDEFLEX TECHNOLOGIES, 600 NORTH BELL AVE., CARNEGIE, PA 15106, (412) 279-0044 phone (412) 279-5410 fax